LUCAS FABIAN OLIVERO

Hybrid Immersive Art through Handmade Spherical Perspectives

Doutoramento em Média-Arte Digital
especialidade em Computação, Tecnologia e Arte

PhD program in Digital Media Art
(Computing, Technology and Art)

Supervisor: Doutor António Manuel Bandeira Barata Alves de Araújo

University of Algarve | Universidade Aberta

Faculty of Human and Social Sciences | Department of Science and Technology

2026

Hybrid Immersive Art
through Handmade Spherical Perspectives

Declaração de autoria de trabalho

Declaro ser o(a) autor(a) deste trabalho, que é original e inédito. Autores e trabalhos consultados estão devidamente citados no texto e constam da listagem de referências incluída.

Declaration of authorship

I declare that I am the author of this work, which is original and unpublished. Authors and works consulted are duly cited in the text and are included in the list of references.

Lucas Fabian Olivero

Lucas Fabian Olivero

There are too many good people in this world that I won’t dare to count them.
To those alive,
to those who are not here anymore,
to those who will come,
just thanks,
eternal,
grateful,
deep,
simple,
and sincere,
thanks…

Lucas

ABSTRACT

The Handmade Immersive Art (HIA) research focuses on the creation of virtual reality environments using spherical perspectives drawings. Spherical perspective methods represent one of the latest advancements on the traditional discipline of drawing, an extension from the classical conical projections onto a plane to either a sphere or a cube. This change, facilitated by current digital technology, puts together the traditional procedures developed during the last 500 years with edge-cutting immersive experiences in VR, through the slow, line-by-line construction of a drawing, a human experience, the quintessence for those creative minds that express themselves through graphical and complex art manifestations. This intersection is not casual: a previous investigation called "Hybrid Immersive Models" (2017-2021) had per subject the merging of physical and digital media resulting from a given cubical perspective drawing, with applications in engineering, architecture and design. However, a straightforward migration of HIMs into the world of digital arts was simply not possible. In fact, the state of the art here developed reveals several six technical, methodological, applicative and dissemination gaps when considering the application of Hybrid Immersive Models within the realm of digital arts: 1, the lack of an art-practice-based research methodology; 2, the current limitations on the spreading and application of cubical perspective; 3, the lack of applications and the low diffusion of these techniques among artists; 4, the software limitations for the conversion between the flat drawing and the VR environment; 5, the low dissemination among regular drawing courses; and 6, the lack of a comprehensive software for drawing spherical perspectives. To these gaps, the HIA research responded with a robust body of new original developments: **the HIA-HIM methodology**, an art-practice-based methodology; **the A-Construction**, a shortcut for easing the application of cubical perspective; four versions of **IMWYM and Spheri**, software/installations facilitating the flat drawing/VR interaction using body tracking, machine learning and hand gestures; four editions (with three more expected within 2025) of **[IN]Musicality and Spheritivity**, exhibitions showcasing handmade immersive artworks and a collection of more than 40 artworks; and eight **international workshops and lessons** for improving the dissemination and integration of spherical perspectives' concepts. Most of these products were explored and gathered in at least eight peer-reviewed publications and participations in congresses (with three more expected within 2025), two publications in international indexed journals and the edition of four proceedings books (also with two more expected for 2025). These answers and research products materialise not only the efforts on the development of new methods and the diffusion of the advantages and endless possibilities that spherical perspectives might give for the creation of art; but also, some considerable improvements for transforming what once was a niche virtuoso application into an open, transmissible and expanding contemporary knowledge.

Keywords: Immersive Art, Virtual Reality, Spherical Perspectives, Cubical Perspective, Handmade Drawing

RESUMO (PORTUGUÊS)

Esta investigação centra-se na criação de ambientes de realidade virtual utilizando desenhos em perspetiva esférica. Os métodos de perspetiva esférica representam um dos mais recentes avanços na disciplina tradicional do desenho, uma transição das projeções cónicas clássicas de um plano para uma esfera ou um cubo. Na verdade, os artistas podem representar todo o campo visual à sua volta utilizando perspetivas esféricas, enquanto a perspetiva clássica limita o desenho a uma pequena parte do campo visual, uma pequena janela criada há séculos e da qual nos estamos a afastar agora. Esta mudança, facilitada pela tecnologia digital atual, reúne os procedimentos tradicionais desenvolvidos durante os últimos quinhentos anos com experiências imersivas de ponta em RV, através da construção lenta, linha por linha, de um desenho, uma experiência humana, a quintessência para aquelas mentes criativas que se expressam através de manifestações artísticas gráficas e complexas.

A interseção não é casual: uma investigação anterior chamada "Modelos Imersivos Híbridos" (2017-2021) tinha como tema a fusão de meios físicos e digitais resultantes de um determinado desenho em perspetiva cúbica. Em outras palavras, um HIM relaciona produtos e meios artísticos: começa com um desenho "especial" (uma perspetiva esférica feita à mão) que pode então ser convertido em um ambiente de RV e/ou em produtos físicos, como esferas, cubos ou outros objetos poliédricos. A investigação inicial sobre Modelos Imersivos Híbridos foi desenvolvida dentro de uma faculdade de Engenharia e teve como resultados os primeiros desenvolvimentos sistemáticos de métodos e aplicações de perspetiva cúbica dentro da engenharia, arquitetura, design, design industrial, design de produto, design de moda e artes. Depois disso, seguiu-se um segundo programa de investigação (aquele que este texto espera encerrar), focando uma aplicação pouco entusiasta sugerida no primeiro programa: artes e, particularmente, artes digitais.

Assim, esta investigação, doravante designada por «Arte Imersiva Artesanal» ou HIA (*Handmade Immersive Art*), por sua sigla em inglês, amplia a investigação anterior, fundamentando os Modelos Imersivos Híbridos nas definições vagas de arte, expondo por que razão uma obra de arte imersiva artesanal não é uma prática comum entre os artistas contemporâneos, apesar do seu potencial, das limitações e dos problemas atuais; e, finalmente, explorando e desenvolvendo soluções para esses problemas que possam ajudar a facilitar a integração da HIA/artes digitais, incluindo exposições, instalações, software, coleções de obras de arte e novas estratégias para o ensino de perspetivas esféricas. Além disso, a investigação procura compreender, comprovar e melhorar a conexão entre HIMs,

artes e artes digitais, explorando a sua dinâmica híbrida física/digital: veremos como um artista pode expressar e mostrar coisas diferentes através dos HIMs, seja com meios tradicionais ou digitais, mas necessariamente compreendendo ambos. De facto, o desenho "especial" inicial pretende ser feito à mão, ou seja, construído elemento por elemento através de uma compreensão consciente dos elementos representados no espaço. No entanto, isso não implica nenhuma tecnologia específica, e assim a obra de arte pode ser feita com meios tradicionais ou digitais, mas o ambiente de RV relacionado está inequivocamente relacionado ao mundo digital. Essa conjunção de uma construção metódica e um produto digital força o artista — intelectualmente falando — a compreender como e por que ambas as aplicações são realizadas.

Além dos extensos desenvolvimentos da primeira investigação, uma migração direta dos HIMs para o mundo das artes digitais simplesmente não era possível. Na verdade, o estado da arte aqui desenvolvido revela várias lacunas técnicas, metodológicas, aplicativas e de divulgação quando se considera a aplicação de Modelos Imersivos Híbridos no âmbito das artes digitais:

1. A falta de uma metodologia de investigação baseada na prática artística.
2. As limitações atuais na divulgação e aplicação da perspetiva cúbica.
3. A falta de aplicações e a baixa difusão destas técnicas entre os artistas.
4. Várias limitações de software para a conversão entre o desenho plano e o ambiente de RV.
5. A baixa divulgação entre os cursos regulares de desenho, muitas vezes devido à falta de tempo e espaço, o que limita a disseminação do conhecimento, dada a complexidade do assunto.
6. A falta de um software para desenhar uma perspetiva cúbica e um software abrangente para desenhar perspetivas esféricas que possa incluir outros programas existentes.

Para colmatar estas lacunas, a investigação da HIA responde com um conjunto robusto de novos desenvolvimentos originais: **a metodologia HIA-HIM**, uma metodologia baseada na prática artística que entrelaça definições matemáticas e de código com a sua prática e aplicação em criações artísticas e exposições; a ***A-Construction***, um atalho para facilitar a aplicação da perspetiva cúbica; quatro versões do **IMWYM e Spheri**, software/instalações que facilitam a interação entre desenho plano e RV através do uso de rastreamento corporal, *machine learning* e gestos com as mãos; quatro edições (com mais três previstas até 2025) de **[IN]Musicality e Spheritivity**, exposições que apresentam obras de arte imersivas feitas à mão e uma coleção de quase 40 obras de arte; e oito **workshops e aulas**

internacionais para melhorar a divulgação e integração dos conceitos de perspetivas esféricas. Além disso, a maioria destes produtos foi explorada e reunida em pelo menos oito publicações revisadas por pares e participações em congressos (com mais três previstas até 2025), duas publicações em revistas internacionais indexadas e a edição de quatro livros de atas (também com mais dois previstos para 2025).

O trabalho está estruturado em:

- **PARTE I - DEFINIÇÕES:** desenvolve parâmetros de referência e o quadro teórico.
- **PARTE II - ESTADO DA ARTE:** inclui uma visão histórica das projeções cónicas e anamorfos, métodos de desenho, software atual para criar, interagir e converter perspetivas esféricas e um bestiário de aplicações.
- **PARTE III - ESTADO DOS PROBLEMAS:** afirma de forma concisa o que falta e o que está errado.
- **PARTE IV - SOLUÇÃO PARA OS PROBLEMAS - NOVOS DESENVOLVIMENTOS:** desenvolve e propõe soluções para os problemas, incluindo a metodologia baseada na prática artística HIA-HIM, os novos desenvolvimentos para a perspetiva cúbica, as exposições e instalações artísticas, o desenvolvimento de software, uma coleção de obras de arte imersivas feitas à mão e workshops de transferibilidade.

Através destes desenvolvimentos, estudaremos as aplicações artísticas dos HIMs nas artes, as suas vantagens e desvantagens, o impacto no campo, as possibilidades, os resultados concretos e os desenvolvimentos futuros. Estas respostas e produtos de investigação materializam estratégias e soluções concretas para enfrentar os problemas atuais durante a criação de arte imersiva artesanal, tais como ligações em falta entre o desenho inicial e os seus produtos associados, falta de fluidez na sua criação e utilização, complicações no seu ensino e divulgação, falta de integração em cursos permanentes de desenho, etc. Desta forma, os desenvolvimentos da investigação tornam reais não só os esforços no desenvolvimento de novos métodos e na difusão das vantagens e possibilidades infinitas que as perspetivas esféricas podem oferecer para a criação de arte; mas também algumas melhorias consideráveis para transformar o que antes era uma aplicação virtuosa de nicho num conhecimento contemporâneo aberto, transmissível e em expansão, bem como aplicações futuras e lacunas ainda em aberto no campo e, em particular, na indústria de software, oportunidades que podem abrir as portas a outros investigadores para ampliar e melhorar estes desenvolvimentos.

Palavras-chave: Arte imersiva, Realidade virtual, Perspectivas esféricas, Perspectiva cúbica, Desenho feito à mão

TABLE OF CONTENTS

ABSTRACT ix
RESUMO (PORTUGUÊS) xi
INTRODUCTION 1
PART I – DEFINITIONS 5

I - Hybrid Immersive Models (HIM) 7

I.1 - Models 7
I.2 - Immersive Models 7
I.3 - Hybrid Immersive Model 8
I.4 - Methods for creating Immersive Perspectives 9
I.5 - M1 - Introduction to Spherical Perspectives 10
I.6 - M2 - The spherical perspective on a digital surface 14
I.7 - M3 - The spherical perspective on a physical surface 15

II - From Hybrid Immersive Models to Handmade Immersive Art 17

II.1 - Drawing, as a way of thinking art 17
II.2 - Perspective, as a way of expanding skills 18
II.3 - The centred experience 20
II.4 - The medium's influence 22
II.5 - Digital technology, as a way of enhancing art 24
II.6 - Handmade Immersive Art (HIA) 26

PART II - STATE OF THE ART 29

I - Conical projections 31

II - Radial occlusion and Anamorphs 31

III - Historical overview 34

IV - The elements of conical projections 42

IV.1 - Projecting onto a single plane 42
IV.2 - Projecting onto several planes and/or irregular surfaces 48
IV.2 - Projecting onto regular surrounding surfaces 49
IV.3 - Interaction with physical anamorphs 52
IV.4 - Interaction with digital anamorphs 56

V - Methods for creating anamorphs 59

V.1 - Linear perspective 59
V.2 - Anamorphs of Anamorphs 62
V.3 - The M1 component: spherical perspectives 65
V.3.1 - Equirectangular perspective 65
V.3.2 - Azimuthal-equidistant perspective (fisheye) 72
V.3.3 - Cubical perspective 82
The cubical-spherical perspective 90

VI - Software for creating HIA 95

VI.1 - Software for drawing immersive perspectives (Task 1) 96
VI.1.1 - Photoshop Panorama Tools (deprecated) 96
VI.1.2 - Oniride 3D Art (deprecated) 97

VI.1.3 - Harmony 98
VI.1.4 - Sketch 360 100
VI.1.5 - Eq A Sketch 360 100
VI.1.6 - Azimuthal-equidistant GeoGebra Script 102
VI.1.7 - Recap 105
VI.2 - Software for converting/switching spherical maps (Task 2) 105
VI.3 - Software for creating/navigating the VR environment (Task 3) 113
VI.4 - Software for enhancing and sharing the experience (Task 4) 114
VII - Applications 120
VII.1 - Recap 136
PART III - STATE OF THE PROBLEMS 139
I - PROBLEMS 141
II - HYPOTHESIS 143
PART IV - THESIS - NEW DEVELOPMENTS 145
I - SOLVING PROBLEM 1: the HIA-HIM methodology 147
I.1 - In search of an art-practice-based research methodology 147
I.1.1 - A/r/tography and A/r/cography 148
I.1.2 - Rhizomatic schemes 149
I.2 - Further components 150
I.3 - The HIA-HIM methodology 151
II - SOLVING PROBLEM 2: a shortcut for cubical perspective drawing 152
II.1 - Context of the developments 153
II.2 - Notation and problem 155
II.2.1 - The problem 156
II.3 - The new A-Construction 158
II.4 - Comparison of methods 159
II.5 - Applications 162
II.6 - Section's highlights 164
III - SOLVING PROBLEM 3 AND 4: Installations and exhibitions 166
III.1 - Installation I: IMWYM v1 166
III.1.1 - Summary of current software options 166
III.1.2 - Components, interaction and functionality 167
III.1.3 - Novelties 173
III.2 - Exhibition I: I'm watching you/me (Braga, Portugal) 174
III.2.1 - Users' experience 175
III.2.2 - Necessary improvements 178
III.2.3 - Evaluation of IMWYM v1 179
III.3 - Installation II: IMWYM v2 182
III.3.1 - Addressing issue 1: missing art concept 182
III.3.2 - Addressing issues 3 and 4: front-end interface and dependence on the artist's presence 186
III.3.3 - Addressing issue 4: dependence on the artist's presence 187
III.3.4 - Addressing issues 12 and 13: inconveniences on the spatial setup (ideal solution) 188
III.3.5 - Components, interaction and functionality 188

III.4 - Exhibition II: [IN]Tangibilidades Digitais (Loulé, Portugal) 192
III.4.1 - Addressing issue 2: missing narrative 193
III.4.2 - Addressing issues 12 and 13: inconveniences on the spatial setup (real possibilities at the venue) 194
III.4.3 - Development and feedback 195
III.4.4 - Evaluation of IMWYM v2 196
III.5 - Installation III: IMWYM v3 198
III.5.1 - Addressing issue 20: automatic start 199
III.5.2 - Addressing issues 5 (fixed FOV), 7 (navigation glitch), 8 (phone constantly on), 16 (complex UI), and 17 (low engagement due to shared physical devices) 199
III.5.3 - Addressing issues 14 (concept), 18 (insufficient data) and 19 (complex UX) 200
III.5.4 - Addressing issue 9: cubical perspective input 201
III.6 - Exhibition III: [IN]Musicality at the CLB Space (Berlin, Germany) 201
III.7 - Exhibition IV: [IN]Musicality at ArtsIT (Faro, Portugal) 205
III.7.1 - Evaluation of IMWYM v3 206
III.8 - Installation IV: Spheri 209
III.8.1 - Addressing issue 6: independent code 209
III.8.2 - Addressing the complexity of the experience (issues 19, 16, 21, 22, 23, 25): the new navigation system and the simplification of the experience 210
III.8.3 - Expanding functionalities 215
III.8.4 - Future improvements 215
III.9 - Collection I: Spheritivity 216
III.9.1 - Inspirations for Spheritivity: perspectives not perspectives 217
III.9.2 - Concept (artistic statement without a scientific proof) 224
III.9.3 - The collection 225
Parallel perspectives on a plane 226
Conical linear perspectives on a plane 230
Cubical perspectives (Handmade Immersive Artworks) 237
Equirectangular perspectives (Handmade Immersive Artworks) 238
Free mixed-up perspective systems 243
III.10 - Exhibitions V, VI, VII and VIII: Spheritivity at A Hidden Variable, KUI 2025, BAAM 3 and Artech 2025 252
III.10.1 - Components, interaction and functionality 252
III.10.2 - After interaction survey 253
IV - SOLVING PROBLEM 5: Low dissemination 255
IV.1 - Methodological and technological challenges and proposed solutions 256
IV.2 - Conducted workshops 257
IV.3 - Long courses and short workshops 259
IV.3.1 - The experience in Finland 263
IV.3.2 - The experience in Portugal 267
IV.4 - Reference exercises 271
IV.5 - Section's highlights 277
V - SOLVING PROBLEM 6: Lack of drawing software (or suites) for spherical perspectives 280
CONCLUSIONS **281**
ACKNOWLEDGEMENTS **284**
REFERENCES **284**

INTRODUCTION

Hybrid Immersive Model (HIM) is a term coined during a research program developed between 2017 and 2021 (Olivero, 2021). A HIM relates artistic products and media: it starts with a “special” drawing (a handmade spherical perspective) which can be converted either into a VR environment and/or into physical products such as spheres, cubes, or other polyhedral objects. That initial research (developed in a faculty of Engineering), produced the first systematic developments of cubical perspective methods, with applications in engineering, architecture, design, industrial design, product design, fashion design and arts (Olivero et al., 2020; Olivero & Sucurado, 2019; A. Rossi et al., 2021a).

This second research then focuses on one application that was lukewarmly suggested within the first program: the arts and, particularly, digital arts. This manuscript examines, substantiates and advances the connection between HIMs, arts and digital arts by exploring their hybrid physical-digital dynamic. The thesis shows how artists can express ideas through HIMs, either with traditional or digital means but necessarily understanding both. Indeed, the initial “special” drawing is intended to be handmade, i.e., constructed element by element through a conscious understanding of the represented elements in space. However, this does not imply any particular technology, and so the artwork can be made either with traditional or digital means, yet the related VR environment is unequivocally related to the digital world. This conjunction of a methodical construction and a digital product forces the artist - intellectually speaking - to understand how and why both applications are carried out.

This investigation, hereafter referred to as “Handmade Immersive Art” (HIA), extends the previous research by grounding the Hybrid Immersive Models in the swampy definitions of art, exposing why the HIA is not a common practice among digital artists despite their potential, its current limitations and problems (such as missing links between the initial drawing and their associated products, lack of fluidity for their creation and use, complications in their teaching and dissemination, lack of integration in permanent drawing courses, etc.); and finally, exploring and developing solutions for such problems that might help smoothing the integration HIA/digital arts, including several exhibitions, installations, software, a collection of artworks, and strategies for the teaching of spherical perspectives.

The work is structured in:

- **PART I - DEFINITIONS** develops parameters of reference and the theoretical framework.
- **PART II - STATE OF THE ART** includes a historical overview of conical projections and anamorphs, methods for drawing, current software for creating, interacting and converting spherical perspectives, and a bestiary of applications.
- **PART III - STATE OF THE PROBLEMS** states concisely what is missing and what is wrong.
- **PART IV - SOLUTION TO THE PROBLEMS - NEW DEVELOPMENTS**: developing the proposed solutions for the problems, including an art-practice-based methodology, new developments for cubical perspective, art exhibitions and installations, software development, a collection of Handmade Immersive Artworks and transferability workshops.

The developments study the artistic applications of HIMs, their advantages and disadvantages, their impact in the field, possibilities, concrete results, and future developments.

PART I – DEFINITIONS

I - Hybrid Immersive Models (HIM)

I.1 - Models

One of the purposes of a model is to show how a project will (or might) look like after its construction, before the materialisation of a certain design. For example, within architects, a physical model or *maquette* describes the technological components of a design, verifies its static behaviour, its formal, structural and functional hypotheses, and helps to pre-visualise the designed space (Gaiani, 2018, p. 23; Polato, 1991). Certain drawings also follow this same purpose of emulation. However, in this case their similarity regarding the final project depends on and gets affected by the conventions related to the kind of projections used for creating it (e.g., parallel, conical projections, etc.) (Gaiani, 2018, p. 23). In arts, the design is never intended to leave the canvas, but it still is a re-presentation of the imagery that artists have in their mind.

Models can be classified according to their similarity with the physical or mental project: a **homologue** model has the same structure but different shape and function; an **analogue** model the same structure and function but different shape; and finally an **isomorphic** model the same structure and shape while the function can either be the same or not (Gaiani, 2018, p. 24; Maldonado, 1987). So, *maquettes* and drawing models are iconic models representing an isomorphic reality, a mathematical model is a non-iconic model analogue to the final model, and 3D digital models are all three homologue, analogue and isomorphic at the same time with both iconic and non-iconic functionalities (Gaiani, 2018, p. 24).

I.2 - Immersive Models

Drawings, photography and computer graphics have travelled through history from partial to full immersive graphic scenes, first projecting onto immense buildings and creating physical augmented realities (e.g., the fresco of *Sant'Ignazio di Loyola* at Rome), up to the current moment in which almost every physical limitation has been removed: the entire observation field is covered in fully immersive virtual environments, and the interactive experience is dominated by Virtual Reality tools (Grau, 2003, Chapters 4, 5; 2016; Jerald, 2015, Chapter 2). The latest digital immersive models respond to the user interaction basically in two ways: either by displaying in the screen a linear perspective which is a portion of a unique image, or by computing a new perspective on-the-fly for every new position within a digital space. I will refer the first group as "Immersive

Perspectives" and the latter as the "Interactive and Dynamic Perspectives" (as defined by Migliari (2008)). On the one hand, an **Immersive Perspective** is a graphical map that gathers all the visual information that can be seen by an observer from one single spot P, and it can be made either with physical or digital means. On the other hand, an **Interactive and Dynamic Perspective** allows us to explore infinite points of view by rendering a flat perspective on screen from a previously created 3D model but, precisely to that end, it requires the full numerical definitions structuring relations, proportions and disposition among the different elements of the project, before the start of any interaction, which necessarily implies the use of digital technology (Migliari, 2008, pp. 6, 7).

I.3 - Hybrid Immersive Model

A Hybrid Immersive Model (Figure 1) consists of:

- M1 - An Immersive Perspective.
- M2 - A VR panorama (i.e., the wrapping of the M1 illustration on a **digital** surface).
- M3 - Design/artistic objects (i.e., the wrapping of the M1 illustration on a **physical** surface).

Figure 1: A Hybrid Immersive Model.[1]

According to the classifications seen above, a Hybrid Immersive Model is an iconic, isomorphic and immersive model. Since the M1 artwork is an immersive perspective, the immersion covers the entire visual field around one single spot. Furthermore, the visualisation ranges from VR headsets placed in front the eyes of the user, a screen, or a scene projected on a wall.

All three media, drawing (M1), VR environment (M2) and physical objects (M3), share the same visual data, but each of them show it in a different way, which gives a wide range of possibilities to explore and compare one same artwork from inside/outside and/or in a material/immaterial way. Hence, the research dives into the three individual

[1] All images are by the author, if not specified otherwise.

products and their connection, their utility to create art, and the possibilities they open as both physical and digital artistic tools.

I.4 - Methods for creating Immersive Perspectives

There are several ways to create an Immersive Perspective (M1), including **automated** and **non-automated** methods. Automated methods include: 2D photographic stitching (many individual shots with a limited field of view are "glued together" using software processing into a complete panoramic photograph); 2D panoramas rendered from point clouds, 3D models, 3D sketches, and lately 2D panoramas and 3D models created with artificial intelligence. These automated methods create the image through algorithms, mainly unknown to the user, and use brute-force rendering to visualise them. Non-automatised methods include 2D immersive drawings such as spherical perspectives (equirectangular, azimuthal-equidistant or fisheye, cubical).

Some methods such as photography and laser scanning are limited by the material reality, i.e. they can only represent a physical, existing reality. In contrast, media like 3D models, 3D sketches and regular 2D drawings can show something that does not exist yet. Particularly, the computer can render as many panoramas as we want in a very short time and for every different position using 3D models and 3D sketches (both Dynamic and Interactive Perspectives). However, this requires - precisely - the 3D model or the 3D sketch, which generally involves a great deal of time and unnecessary beforehand definition in the first case, and a very specific and (yet) not so open technology in the second case. A 3D model is our best option for changing perspectives dynamically once the artwork is already defined, and 3D digital sketching is definitively a very interesting option for directly thinking and materialising in space. The Hybrid Immersive Models that I propose here are drawings limited to one single spot, but that use the simplest possible technology (drawing and pencil) and focus on the early stages of thinking an artwork or understanding the immaterial components of an existing geometry before their full definition (project) or after their materialisation (survey).

The M1 component will be limited to handmade drawings and in particular to spherical perspective methods. The following sections show how handmade spherical perspective methods contribute to a new developments in digital arts, and their state of the art is in PART II. Regardless the election of these specific drawing methods, there is no limitation neither in the medium nor in mixing them. In fact, the M1 component can be done either with simple **physical tools** (such as pencil, ruler, compass); with **digital**

techniques (e.g., using Eq A Sketch 360 (Araújo, 2019b), or Microsoft's Sketch 360 App (Scherotter, 2018)), or **collaging several media** (as some students did during workshops for immersive drawings, see PART IV – Chapter IV.5). This versatility is an advantage over 3D models and spatial 3D drawing, it enhances the creative process and opens a range of possibilities only limited by creativity.

I.5 - M1 - Introduction to Spherical Perspectives

The M1 component will be created using spherical perspectives. A spherical perspective is a map done methodically, line by line, and following a systematic method for rendering lines according to the way the map is created. Maps and cartography have been present since the classical antiquity. For many centuries their elaboration represented big challenges, but this is no longer the case:

> "today, the planimetric construction of world maps using projections is neither a mathematical nor a technical challenge. Standard cartographic works describe projections, their derivation, their intended use and their characteristic properties. Cylindrical, spherical or azimuthal projections and their mathematical rules as well as the corresponding distortion properties such as length, area or angular distortions are described and, as the basic material of projection theory, are decisive for the definition of conventions" (Stirnemann, 2018, p. 145).

In other words, if we want to draw a spherical perspective, we have to learn about the way maps treat information: what and how do they distort, what is preserved and what is not, etc. Because of this, a spherical perspective is a human construction where the person behind it needs to necessarily understand the logical implications of the method to get accurate results. Furthermore, and because of this "humanity", it is also a slow process, limited in time, which forces an on-the-fly analysis and a critical selection of the elements to be represented. The map contains all the visual information that an observer can see around one unique point: if you consider an observer O, place a virtual sphere S centred on O, radially project the surrounding environment, and flatten the sphere, then you get a spherical perspective. Araújo (2018a) formalises more elegantly this definition by setting up a general scheme from which every spherical perspective is the result of a two-step process: first, an ***anamorphosis*** onto the sphere (unique and mimetic), followed by the flattening of the sphere (neither unique nor mimetic). Hence, consider an

anamorphosis as the environment radially projected onto a sphere, and a **spherical perspective** as the flattening of such a projection. As for the flattening, there are many ways of flattening a sphere and hence of spherical perspectives:

> "(spherical) perspective is to anamorphosis what a world map is to the globe, its purpose is to store visual information conveniently on the flat surface and, like in cartography, no flattening is perfect – each being merely convenient for some purposes" (Olivero et al., 2025, p. 4).

Nevertheless, each of these possible flattened maps are equivalent among them since they all come from the same anamorphic projection on the sphere. This equivalence is well-known in photography, where each projection can be easily converted into another (Figure 2, 3). Currently, some of the full methods for drawing immersive perspectives are: cubical perspective (Figure 4) (Araújo et al., 2020) (**linear method**), equirectangular perspective (Figure 5) (Araújo, 2018a) and azimuthal equidistant perspective (Figure 6) (Araújo, 2018c) (**curvilinear methods**). Notice, that the spatial understanding of the flattening gives the artist such a creative-intellectual freedom up to the extent that one could play with different variables and create their own method. An example of this is the full spherical representation by Barre & Flocon (1967) studied and decoded by Santoyo & Santoyo (2021) as the result of mixing azimuthal-equidistant and Mollweide projections.

Figure 2: Equirectangular projection. Castle of Gruyere, Switzerland © Lufo Art (Lucas Fabian Olivero), 2020.

Figure 3: Different ways of flattening the same spherical anamorphosis: azimuthal-equidistant (top), cylindrical Mercator (down left), and cubic (down right). Castle of Gruyere, Switzerland © Lufo Art (Lucas Fabian Olivero), 2020.

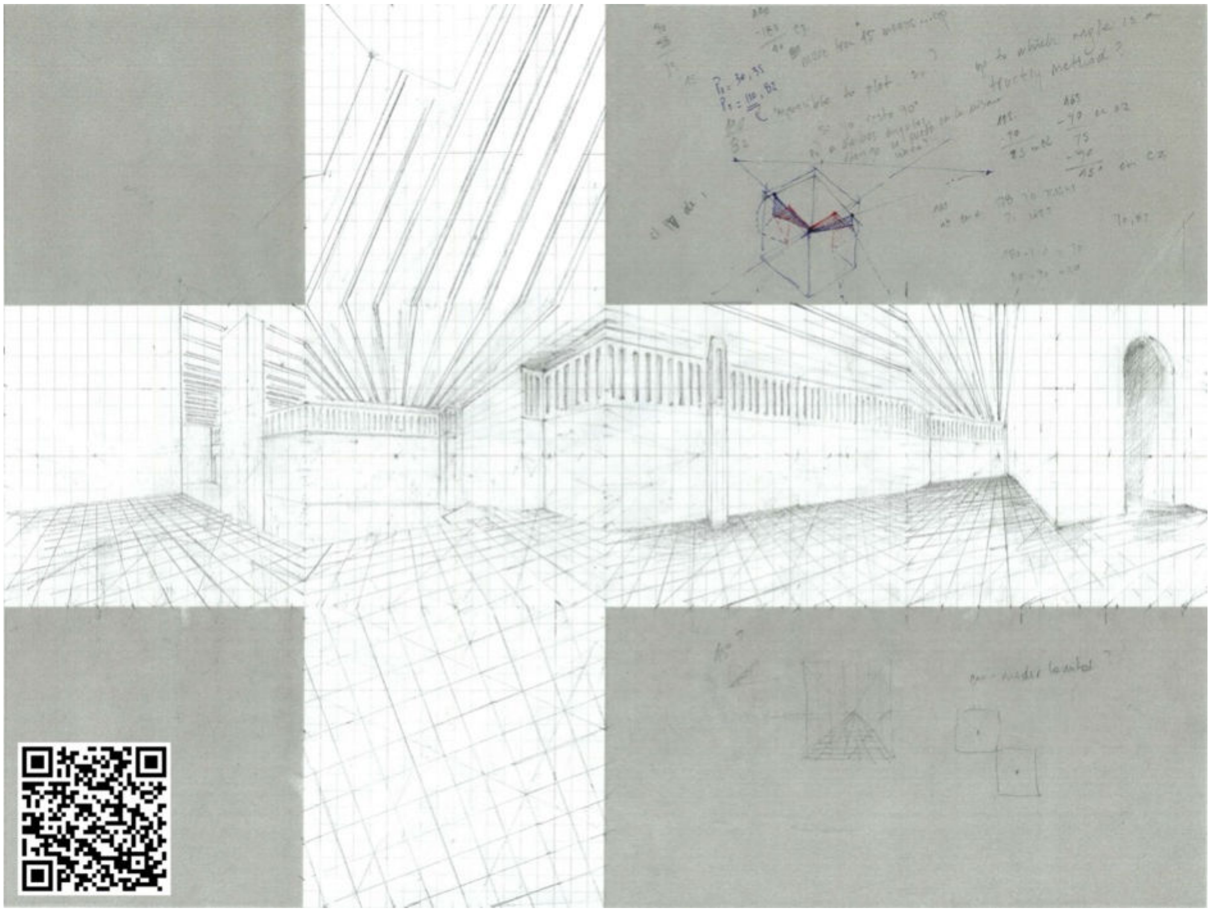


Figure 4: “Un Jardín de Arena”, urban sketch in cubical perspective. Scan the QR code to view the VR environment. Lisbon, Portugal © Lufo Art (Lucas Fabian Olivero), 2018.

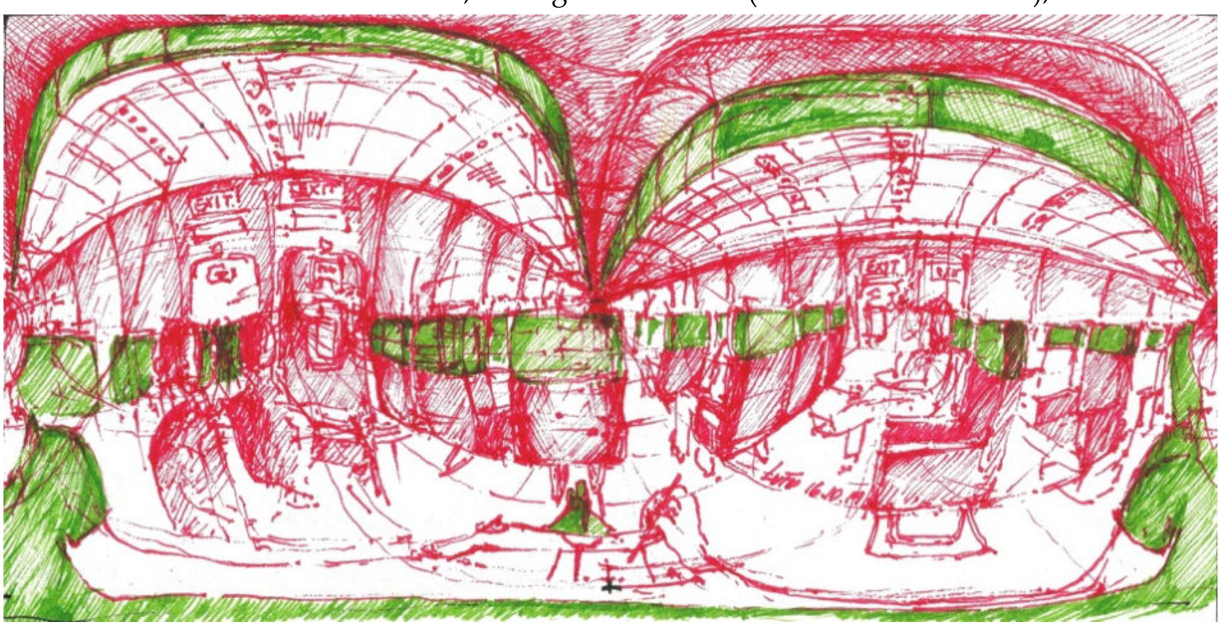


Figure 5: “Salida de Emergencia”. Cabin of an aircraft in equirectangular perspective. Colour pens on paper © Lufo Art (Lucas Fabian Olivero), 2019.

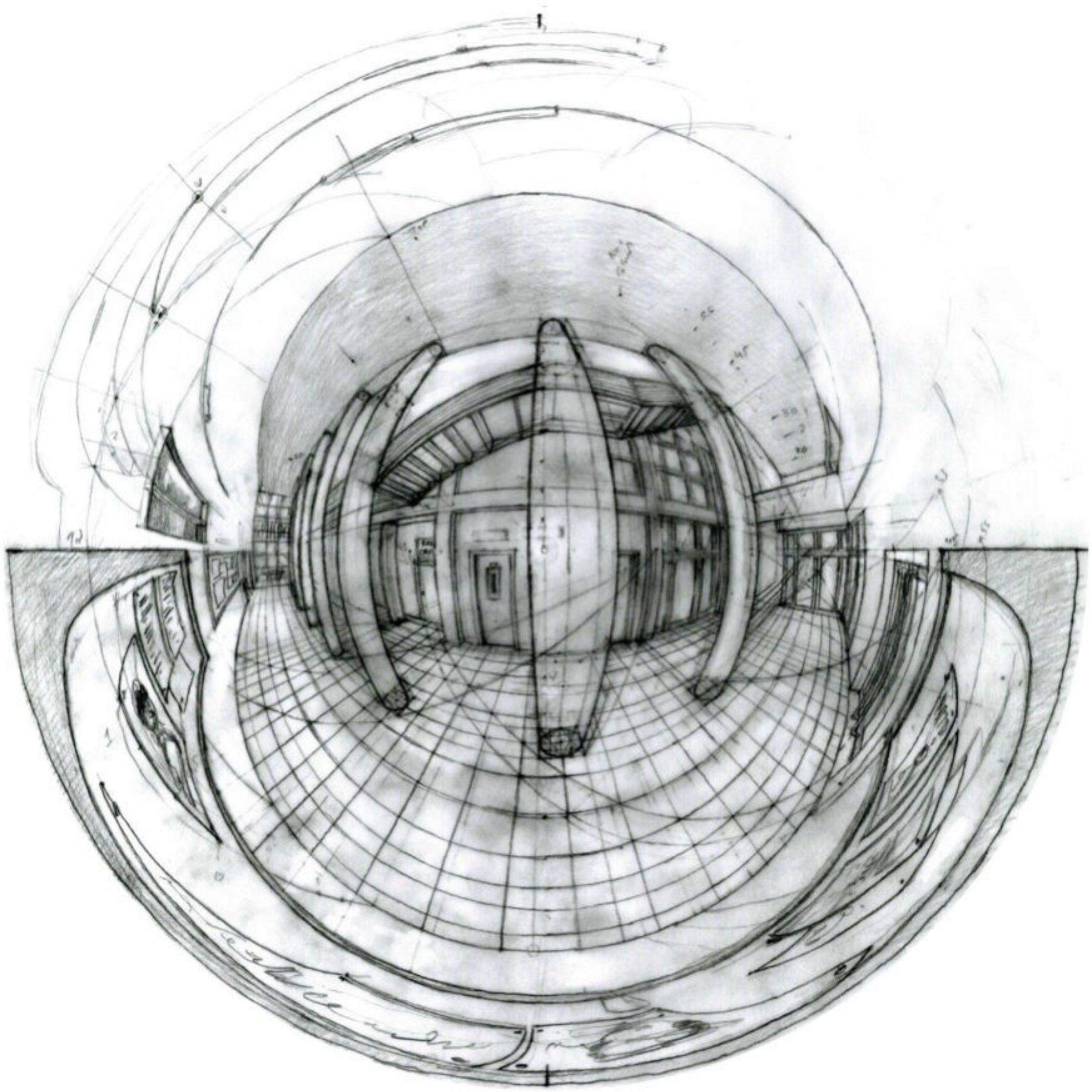


Figure 6: Azimuthal equidistant perspective © António Bandeira Araújo, 2018.

I.6 - M2 - The spherical perspective on a digital surface

We mentioned above that a spherical perspective gathers all the visual information that an observer standing at one unique point can see. In practice, a VR panorama is the *digital* wrapping of the spherical map onto a *virtual* surface. Computationally speaking, there is a setup composed by a surface S (generally, a sphere, a cube or a regular polyhedra) centred at O; and a camera C with a determined field of view FOV (e.g., 90°) and centred at O. This creates an immersive and interactive visualisation, in which the visitor sees only a portion of S on the screen, delimited by the FOV of C. The spherical map is wrapped onto S, which means that S has to be a map adapted to the chosen surface. Every time the user/visitor modifies the orientation within the 3D system of reference, C pivots around *O* and points towards the same direction, showing a new portion of the drawing/photography. With each interaction, the displayed portion changes, giving us the sensation of moving our head to look around. In this way, a spherical perspective can be explored in Virtual Reality and/or used in Augmented, Extended and Mixed Reality modalities. Consequently, the digital product is a fundamental part of a Hybrid Immersive Model, regardless the means used for creating the M1 component.

However, could an immersive model also be made with physical technology? The short answer is yes, or at least, more or less. In fact, in the State of the Art we shall see how Panoramas were the physical precursors of full immersive installations. However, Panoramas had limitations for the field of view in the upper and the bottom parts and, besides they were meant to be mainly a business, they were certainly not something easy to carry, mount and "share". Still, they were a very interesting example of how architecture accompanied the materialisation of a virtual landscape, and how the immersive art helped to materialise commemorative scenes of history. In comparison to physical technologies, the current availability of digital resources (through our smartphone and digital devices) places a fuller and more interactive immersive experience right in our hands, allowing the exploration of spherical perspective from within to whoever is interested (Araújo et al., 2019; Olivero, 2021). Furthermore, digital technology enables the creation, visualisation, and interaction with the virtual environment, as well as the manipulation of the M1 component for creating the M3 physical objects or, in other words, it is a way of enhancing the potential of an immersive drawing. In fact, the digital model can be also considered the base component for an informative and collaborative platform, through which we enrich the visiting experience adding multimedia assets such as documents, audio, videos, etc. Overall, a HIM is a physical and a digital product at the same time.

I.7 - M3 - The spherical perspective on a physical surface

The third component of a HIM consists of physical objects created from the spherical perspective. These objects use the *physical* folding of M1 onto a *physical*, tangible surface, such as a sphere or a cube. In other words, it is possible to manipulate a spherical perspective so to create physical craft anamorphoses. Some practical applications of these physical anamorphoses were explored through half-spheres used to let the user play with their position regarding the centre of the sphere and the perception of the content (Figure 7) (Abreu et al., 2025, p. 112; Masiero Sgrinzatto, 2024b; Masiero Sgrinzatto & Araújo,

2024) or by artists like Dick Termes (D. Termes, 1998; D. A. Termes, 1991) who have created an identity as artists by using spherical objects to portrait both real and imaginary scenes. These objects show the result of the re-shaping of the spherical map, meaning that one can compare the flat map with the physical object and see how a specific map manages to reduce a 3D environment into a 2D representation.

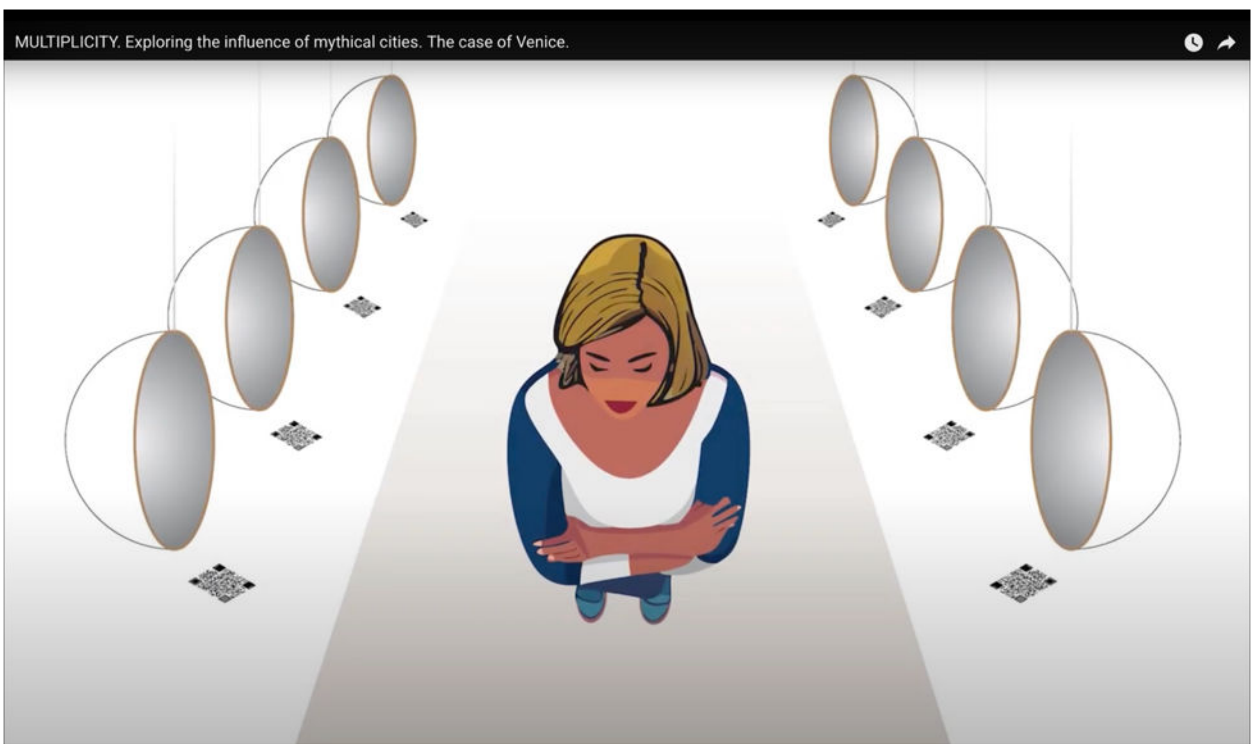


Figure 7: The exposition “Multiplicity” exploring the interaction with physical spherical anamorphoses © Chiara Masiero Sgrinzatto, 2024.

II - From Hybrid Immersive Models to Handmade Immersive Art

This chapter will explore how a Hybrid Immersive Models fits within the field of digital arts. Some key points of this connection are the relation handmade drawing/art, how perspective expands the skills of the artist through rational thinking, what is the influence of the medium, and how digital technology enhances the uniqueness of a physical/digital product.

II.1 - Drawing, as a way of thinking art

The connection between a HIM and the artistic practice is clear thanks to the fact that the Immersive Perspective M1 is intended to be a handmade, line-by-line built illustration. Indeed, drawing and the use of traditional tools (like a simple pencil) bring us very close to the artistic expression. Of course, not every drawing is art and not every piece of art is a drawing, but because of its simplicity, spontaneity and immediacy, a pencil is a direct tool for exteriorising thoughts and feelings: one takes a pencil and draws, that's all. A traditional pencil also avoids practical obstacles (nowadays "bureaucracy") such as battery dependence; the endless process of constantly learning new software tools (programmed by who knows and for a program that might disappear in a couple of years); the distraction given by the many notifications telling us the latest news of the program; and so on and so forth. A pencil is a software and hardware free tool which **forces the artist to learn** about spherical perspectives. This knowledge, far from being related to a specific software, is linked to a spatial thinking that can be then emulated with almost any drawing software, something not always possible the other way around since digital interfaces give one more level of virtuality altering the relation between reality and imagination, i.e., a brain/software/hand flow (Gaiani, 2018, p. 29). In other words, handmade physical drawing enhances the **brain/hand** flow by connecting thoughts and schemes with the simplest interface in between (Arnheim, 1954; Gaiani, 2018, p. 28). Nevertheless, just because it is simpler it does not mean a HIM has to be made exclusively and necessarily with a graphite pencil. In fact, our digital devices have many advantages, and it is only a matter of time until the limitations get solved (see PART I – Chapter II.4: The medium's influence).

Regardless of the technology, what I would most like to rescue from this well-known dynamic pencil/drawing is something else: this pair has been a protagonist in the history of art not because their technology but because of what is implied behind the act of drawing itself, meaning, **the process of thinking the artwork and the externalisation**

of a self-communication process which is "an essential practice in all creative and artistic processes" (Boddien et al., 2017, p. 101). The simplicity behind the pair drawing/pencil makes it suitable and versatile for a wide range of possibilities, from the fast burning and spontaneous traces of expressive drawings up to the slow, careful and meditative processes needed for more meticulous illustrations, such as scientific illustrations. Indeed, the gesticulation of the hand guides the tracing of layouts and organises signs that help to render visible concepts and non-material images (Purini, 1996, p. 39). The basic setup drawing/pencil can prove essential for the deep understanding of an existing reality (e.g., a city, a body) or for bringing to life an immaterial image, living only inside the artist's mind. Drawing helps materialising these things through the understanding of proportions and ratios among elements or, in other words, through structural and visual information, something invisible to the sensor of a camera but visible to the human intellect, immaterial relations and schemes that are neither digital nor physical but mental models that help us to think and support conceptual explorations (Arnheim, 1954, p. 47; Tran Luciani, 2019). The elements of a conceptual model are selected by the artist accordingly to what they have understood about a certain reality: the drawing process materialises the individual interpretation of reality (Arnheim, 1954, pp. 2, 171). And indeed, drawing has largely proved to be a way of thinking through experimentation, an organic way of organising ideas, shaping projects and guidelines, and creating artworks (García-García et al., 2016, p. 1040; Israel et al., 2009, p. 1; Schön, 2017, p. 159; Tran Luciani, 2019, p. 1491).

II.2 - Perspective, as a way of expanding skills

The simplicity behind a pencil leaves us more space for thinking the artwork but sadly no pencil includes the knowledge of how to represent a geometry in space (for now). So, if an artist wants to build an image composed by certain geometries distributed in space, place people and depict body expressions with some accuracy, create optical paradoxes and play with perception, etc., then the knowledge about perspective is a must. Knowing about perspective is far from being a restriction to creativity, on the contrary, it gives artists the freedom to manipulate and create environments and situations, architectonic atmospheres and proportionated spaces, materialise geometries and situations that never existed before, etc. In fact, a perspective drawing can be the flat equivalent of an environment before its construction, which implies that we could use a spherical perspective to draw a new environment in a small drawing, magnify it - using digital technology, and have a first-person experience (Maschietto, 2005, p. 2).

If we analyse how different professionals express graphically, we can say that mathematicians do not need any canvas at all, as they think in terms of logic and their constructions are purely mental; architects, designers and engineers need a canvas, but they have to think in construction protocols for the further materialisation of those geometries, and hence they are limited by statics; artists do not have to leave the canvas but they do need one, hence they are freer than architects but more limited than mathematicians (Ferrero et al., 2009, p. 306). If we consider mathematicians as the "freer builders", then artists could get one more degree of freedom and enhance their constructions using the tools of logic and abstract thinking, as mathematicians do (e.g., M. C. Escher, see Part IV, Chapter II.9.1). This provides the artist with a further, embracing structure of the mere visual expression, and leaves space to visitors for building the logic in their mind if they understand the structure behind. Philosophy and social sciences provide meta structures as well, yet through humanistic tools such as political and/or deep emotional messages or experiences, social behaviour, etc. The management of these embracing structures allow artists to manipulate the composition of an artwork to a deeper level and the flexibility of creating less complex compositions if wanted, which leaves the aesthetic experience accordingly to the complexity of the observer's mind (Wagensberg, 2003).

As a practical example of this, an observer who knows about linear perspective will see behind "The Flagellation of Christ" by Piero della Francesca not only the people's behaviour within a social situation, but also the technical particularities of how Piero della Francesca used vanishing points, diagonals for creating modules of equal size in the floor, and how he purposefully played with the position of the different elements in space so to create a particular focus and atmosphere or, in other words, how he used his technical skills to master the narrative of his painting. Such technical details will hardly be noticed accidentally by someone who does not know how a linear perspective works, in fact, the perspective connoisseur sees this and can also explain how the painting was made, why the perspective works as such, can replicate the construction or pull back with some accuracy how the geometry is distributed in the 3D space[2]. Furthermore, the artist who knows about perspective can choose to create an artwork that does not follow these principles (who knows the rules, can break them), but hardly the other way around. We can analyse the example of Jan Van Eyck (see Part IV - Chapter III.9.1) and see that he reached a certain degree of accuracy for creating linear perspectives, yet in an *ad-hoc* manner for every painting, following a very good intuition but an approximated approach accentuated with the use of lights and shadows (Elkins, 1991).

Creating handmade Immersive Art is, therefore, the intellectual exercise of understanding spherical perspectives in the abstract space and within the canvas, a reciprocal process of thinking and materialising with and from each new stroke. Understanding such principles give the artists also the freedom of composing their own system by breaking, distorting and mixing rules, with linear and curvilinear systems, with Euclidian and non-Euclidian geometries (Masetti, 2014). Consequently, rather than limiting, structures like perspective enhance the artists' skills and the complexity of the artwork, without taking away from them the possibility of escaping towards pseudo random expressions.

II.3 - The centred experience

Another aspect to consider is how handmade spherical perspectives facilitate a human-centred experience for both the artist and the public. As noted above, the visual sphere is centred on the user, which can be used by the artist to purposefully put the visitor right in their point of view, and not metaphorically but also literally. Figure 8 shows urban sketchers made using spherical and cubical perspectives that recreate not only the general atmosphere of the place in which the artworks were made but also the experience of interacting with the place by turning the view all around.

The human-centred positioning within the artwork was a key aspect for the Humanism during the Renaissance, and the experience was technically possible thanks to the use of linear perspective. Using a user-centred drawing marked the importance of moving the knowledge towards the manipulation of the point of view, which can be deduced from the painting itself. This is, for certain authors, an emancipation from the

[2] Actually, the complete accuracy of the 2D to 3D pull back passage depends on making certain assumptions due to radial occlusion. Strictly speaking, it is not possible to have the exact position of a point in space without a double projection.

mere image towards the elaboration of a representation system (Damisch, 1987, pp. 89–98; Damisch & Leal, 2007). Nowadays, within the Digital Humanism, spherical perspectives emerge as linear perspective's equal but enlarging the experience thanks to something that was not possible without digital technology, i.e., the representation of the full visual sphere around the observer (Masiero Sgrinzatto & Zilio, 2024).

Figure 8: Surveying existing spaces with HIM and including the draughtsman. Cubical perspective (up and bottom left) © Lufo Art (Lucas Fabian Olivero), 2017, 2018. Azimuthal equidistant perspective (bottom right) @ António Bandeira Araújo, 2019.

II.4 - The medium's influence

This section examines the active role that a certain technology has within the creation of an artwork, and how this conditions the drawing methods too. The discussion does not address the topic in ethical terms. Instead, it outlines some relevant facts about the impact of the medium with the purpose of raising awareness about such influence, leaving the artists to question and evaluate accordingly to their own parameters of reference.

There are some historical examples of how the medium influences the outcome, such as the connection of paper and linear perspective. For instance, for certain authors the methods for drawing linear perspectives adapted to the medium in vogue by the time (the paper) and they consider Alberti's window as a convenient analogy to the paper's rectangle, a shape that favours straight and orthogonal lines, parallels to the margins (Ackerman & Slosburg-Ackerman, 2002, pp. 294–295). Nowadays, the innovation and influence of paper has been compared to the one introduced by digital technology, a certainly not neutral influence (Ackerman & Slosburg-Ackerman, 2002, p. 305). Indeed, where before we had only one instrument (i.e., the pencil) we now have software as an intermediary which, on the one hand, limits our actions (we need to give several instructions before and during the drawing, such as kind of pencil, colour, thickness, layer, saving the file, etc.) but, on the other hand, it introduces new tools and ways of assistance (we only need one pencil and one software to access to a full variety of tools including colour pencils, watercolour brushes, acrylic-like strokes, etc.) (Gaiani, 2018, p. 28). However, it is only a matter of time before a digital pencil will become as simple as a graphite pencil and as powerful as the most powerful drawing software. Indeed, the simplicity behind a graphite pencil lies in the absence of technicalities and hence of problems, but the advancements on the many functionalities behind digital devices is going faster and faster and probably in just a couple of years their state of the art will be such that their issues will be at the level of sharpening the graphite. Nevertheless, it is fundamental to understand the role of software as something in between, so to avoid mixing up the learning of "what is, and how to draw a spherical perspective", with the learning of "how to use a drawing software". While the former remains among our skills and gives results only limited by our creativity, the latter changes with every program and/or update and gives results limited by tools programmed by someone else. This also implies that once we have the knowledge of what is and how to draw a spherical perspective, then we can use any software we like because the understanding of perspective is not software dependent. However, this does not verify the other way around, as digital tools are software dependent, and learning a drawing software does not always imply learning a drawing method.

Self-experience might be the best way to find an answer to which medium should be used and its influence in the creative process. But the workshops for teaching Handmade Immersive Art helped to find constants and a general view on how the technology can be more profitable when it goes according to the potential of every stage and scenario:

- For example, during the first stage for creating Handmade Immersive Art, the drawing of the spherical perspective (M1 component) happens right after or in parallel to theoretical lessons on spatial thinking, spherical anamorphoses, notions of geodesics, etc. These topics are most of the time entirely unknown to the attendants (even for artist that have notions of linear perspective), which can turn the first part of the workshop into something complex to assimilate. In terms of medium, there are no limitations for drawing either with a digital or with a graphite pencil, but the simplest tool/interface is more likely to leave more space for focusing on learning the concepts and assimilating the complexity of the subject. In practice, the simplest is the tool, the more freedom one has for using the brain to do and understand without further disturbances. Nowadays, the simplest technology is a graphite pencil and paper because working within a digital environment implies having notifications, software updates, battery levels, learning how the software and its digital tools work, incompatibility problems due to the operating system, etc. In other words, during the theoretical teaching of spherical perspectives, there is neither time nor mental space for learning about software, and learning about spherical perspectives is where our focus should be. Software knowledge can come after, when the students are more advanced and they are more familiarised with the basic concepts. Nevertheless, a graphite pencil might not be the most suited option for online lessons, as the contrast between the grey colour of graphite and the paper might not be entirely visible, the resolution of the camera recording might not be enough, or the visual might not be the best as the hand interposes between the drawing and the camera, covering the process. All these issues can be easily solved by using a digital pencil and almost any drawing software, showing the process in higher resolution, with perfect contrast, and without visual blocks, which will be of better guidance to students. This might also be the case for students familiarised with a certain software and hardware, because they will not need to learn any new software and they will feel more comfortable with their usual tools.
- During further stages, such as the creation of the VR environment (M2 component), the remapping of a spherical perspective for the physical anamorphoses (M3 component), digital tools have no equal. In fact, these tasks are more mechanic and can be assimilated more easily and digital tools provide powerful, interactive and very dynamic tools. Furthermore, these tasks are either

> almost impossible to complete with physical tools or extremely expensive in terms of time, space and resources.

Within this research, physical and digital techniques should be seen as complementary, with no point in comparing them, but rather in understanding what can be done best with each. This helps artists to keep their minds open to experiment and choose what is better or, in other words, by doing their own art-practice based research. In fact, creating immersive drawings is not a mere game of playing with technology, but rather another way of thinking and perceiving shapes in space, a way connected and dominated by the technology of our times. Indeed, perception and representation are two parts of the same process in which the representation of a space matches with the research of the medium for doing such representation (De Rosa & Giordano, 2018, p. 13; Sgrosso, 1969).

II.5 - Digital technology, as a way of enhancing art

Digital techniques have less history than physical techniques, but since their appearance they have occupied almost entirely our daily tasks in a very few decades, outdating traditional techniques that lasted hundreds of years, but also bringing many new and potent tools, discoveries, possibilities and extending the limits of our perception, etc. Among these developments there is the unprecedented expansion of Virtual (VR), Augmented (AR), Mixed (MR) and Extended (XR) Realities into our daily life, ways of interaction that nowadays are so natural to us that we hardly feel estranged from any of them anymore. Their integration has reached almost every field of human development, from engineering applications to medicine, from games to art, from cultural research to customer experiences, from cultural heritage revival to cinema, and of course, from regular to 3D drawing (Fangi et al., 2011; Jerald, 2015; Keefe et al., 2001, 2007; Kwiatek, 2005; Kwiatek, 2012; Machuca et al., 2024; Mekni & Lemieux, 2014; A. Rossi, 2017; Stark et al., 2022).

A Virtual Reality is a model in which we give in to our reasoning and let ourselves be carried away by the idea of wanting to believe that such a world exists, or in other words, the so-called "suspension of disbelief". This term, coined in 1817 (Chandler & Munday, 2011, p. 281; R. Oxford, n.d.) was defined within the virtual reality field as "the ability to give in to a simulation, to ignore its medium" (Cruz-Neira et al., 1992, p. 65). In other words, it is the same goal pursued by full immersive drawings, i.e., the perception of a continuous space without any interference of the medium:

> "(…) immersion arises when the artwork and technical apparatus, the message and medium of perception, converge into an inseparable whole" (Grau, 2003, p. 348).

The previous research on Hybrid Immersive Models used Virtual Reality as a way of providing an early representation of what an architectural, engineering or design project would look like, i.e. providing a tool through drawing where a 3D model was not yet needed (Olivero, 2021, p. 91). For this research instead, Virtual Reality is a way of enhancing the artwork by showing a further dimension of it, a content unknown to those who do not "read" the language of spherical maps, hidden details through spherical anamorphoses that reveal themselves only with the interaction during the VR navigation. For this, and the suspension of disbelief to happen, the content has to be coherent to the rules of spherical perspective, and as seamless as possible in the discontinuities of the chosen spherical map. Consequently, understanding the spherical perspective to create accurate content is of vital importance during the creation of Handmade Immersive Art, as they provide the logic rules for knowing how shapes are going to look like within the VR environment before its creation.

Digital technology also offers us another additional way of enhancing art, a more (digital) humanistic one: when we draw digitally, we can create as many replicas as we want, identical to the first digital drawing. This enhances HIA as follows: there is little difference (if any) between an initial drawing made with a digital pencil on a drawing pad and the subsequent digital copies, all of them preserving the same information, except when the file is purposefully altered and compressed. The structure of a digital drawing (either raster or vector based) created by a human hand is unique, yet it can be multiplied with complete accuracy through digital techniques and, paradoxically, it cannot be replicated with the same degree of exactness by a human hand. Hence, we do not have an original drawing as we traditionally understand (i.e., the unique, initial and unrepeatable physical version), but we can neither say that the digital artwork is a copy or an emulation of something else. Consequently, a digital original is a unique set of instructions that can be digitally reproduced countless times, giving always the same graphic output. The repeatability (or better, the lack of) is central to our definition of cultural heritage as we perceive it now (Muñoz Viñas, 2004; Osorio García, 2012; Wagensberg, 2003) and, in fact, we have spent millions and millions preserving unique, physical originals or every kind, from paintings to buildings, from jewels to music scores. Hence: how should we deal as a society with digital originals? How should we preserve our digital heritage? Should we? These questions might help us to look further to deal with a different, extended idea of heritage, considering that digital techniques are increasingly growing in our present and will dominate the future of handmade human artworks creation and that these concerns not only focus on the storing of files but also on ensuring long-term accessibility, preventing obsolesce and keeping integrity (Grau, 2007, 2017; P. A. da Veiga, 2020). Hence, the idea of an original human handmade digital artwork behind HIA, makes us re-think our traditional values as a society, stimulating the reflexion while doing.

II.6 - Handmade Immersive Art (HIA)

Hence, Handmade Immersive Art is the technique, the procedure and the way of thinking in space through the use of Hybrid Immersive Models and spherical perspectives. It is immersive art by:

> "(…) media that are the means whereby the eye is addressed with a totality of images […] art that concentrate on immersive image spaces" (Grau, 2003, p. 6).

Furthermore, it offers a versatile alternative for creating compact drawings that get interactive and magnified through digital technology. The proposed model seeks for the best way of using physical and digital means by proposing an exercise of self-reflection and thinking art in an affordable, free, and technologically simple way of creating a fully immersive representation. Using Hybrid Immersive Models for creating Handmade Immersive Art provides artists with an intellectual tool for rethinking physical, virtual, mixed, augmented, extended realities and all their possible combinations, leaving the knowledge within the mind of the artist and not related to any specific software or hardware. The use of drawing, as complementary to photography, laser scanner, artificial intelligence and other ways of capturing and creating images, focuses on the creation of conceptual models made of immaterial aspects such as ratios, proportions, geometric relations, etc. selected by the artist during a conscious process of critical analysis and therefore in an individual, personal and different way, feeding the artist's style and vision of the world. In other words, the Handmade Immersive Art:

- is a physical and digital product at the same time,
- extends the potential of a physical artwork (M1) by using digital tools to create a Virtual Environment (M2) and physical anamorphoses (M3),
- promotes art thinking through the reflective action of drawing,
- promotes art-practice-based research,

- produces pieces of complex visual art,
- explores a new boundary of digital and physical products,
- pushes the boundaries of physical artistic practices to understand the complexity of digital products,
- is a tool for materialising and expressing thoughts, messages, concepts, non-materialised projects, intellectual models, etc.
- feeds the intellect of the artist by providing an abstract structure related to geometry in space.

Therefore, a Hybrid Immersive Model has all the potential to be formalised within the field of digital art, and it is feasible to propose the Handmade Immersive Art research. However, the research will need an adaptable, flexible and art-based methodology to study the topic from both hard and soft approaches and subsequently offer coherent results.

PART II - STATE OF THE ART

This section explores basic concepts, historical background and methods for drawing immersive spherical perspectives (M1), the creation of the virtual environment (M2), the physical anamorphoses (M3), and the existing level of adaptation of Hybrid Immersive Models.

I - Conical projections

A spherical perspective gathers the whole visual field around the observer. This gathering, however, makes full practical sense once visualised interactively, meaning, while exploring the visual sphere. During such a visualisation, the computer shows a portion of the sphere on the screen, with a limited field of view (generally between 60° and 90°). Each of these visualisations is nothing but a classical perspective, and so we can say that a spherical perspective is the "handy gathering" (on paper) of multiple linear perspectives (displayed on a screen). Anamorphoses, spherical and linear perspectives are defined by common principles: they are all conical projections following the principle of radial occlusion. They also have different elements, like the surface in which they project, and the field of view. Understanding these concepts is essential to the artist for comprehending and creating Handmade Immersive Art, and to this thesis for understanding where the developments are positioned. Hence, let us explore these shared and non-shared concepts, to understand and relate better anamorphosis, linear and spherical perspectives. The following section summarises essential elements and state of the art of conical projections, linear perspective, anamorphosis and spherical perspectives.

II - Radial occlusion and Anamorphs

If we consider an object in space, project each of its points radially towards an observer, and intersect any surface in between, then the sum up of the points intersecting the surface defines an anamorph. This means that, under certain experimental conditions, anamorphs will look the same when seen from O, something referred as the principle of radial occlusion (Araújo, 2021a). In other words: Let ß be a plane in space. Let O be a point such that $O \notin$ ß. Let Obj be an object to be represented such that O and Obj are on the same side with regards to ß. Let A be a point such that $A \in Obj$. Let $X \in \overrightarrow{OA}$. Then, we say that X and A are anamorphs (Figure 9).

Both X and A project radially the same within any surface intersecting $\overrightarrow{OA}$ and therefore an observer standing in O should notice no differences between them as any point along $\overrightarrow{OA}$ will occlude A (Dixon, 1991, p. 79). It follows that an anamorphosis is defined as follows (Figure 10):

> "If we accept the principle of radial occlusion, then it follows that many different 3D objects will look the same from O. The points of an object define a cone of rays from the observer O, the visual cone. If two objects define the same cone of rays, they should look the same. Such objects we will call anamorphs of each other relative to O" (Araújo, 2021a).

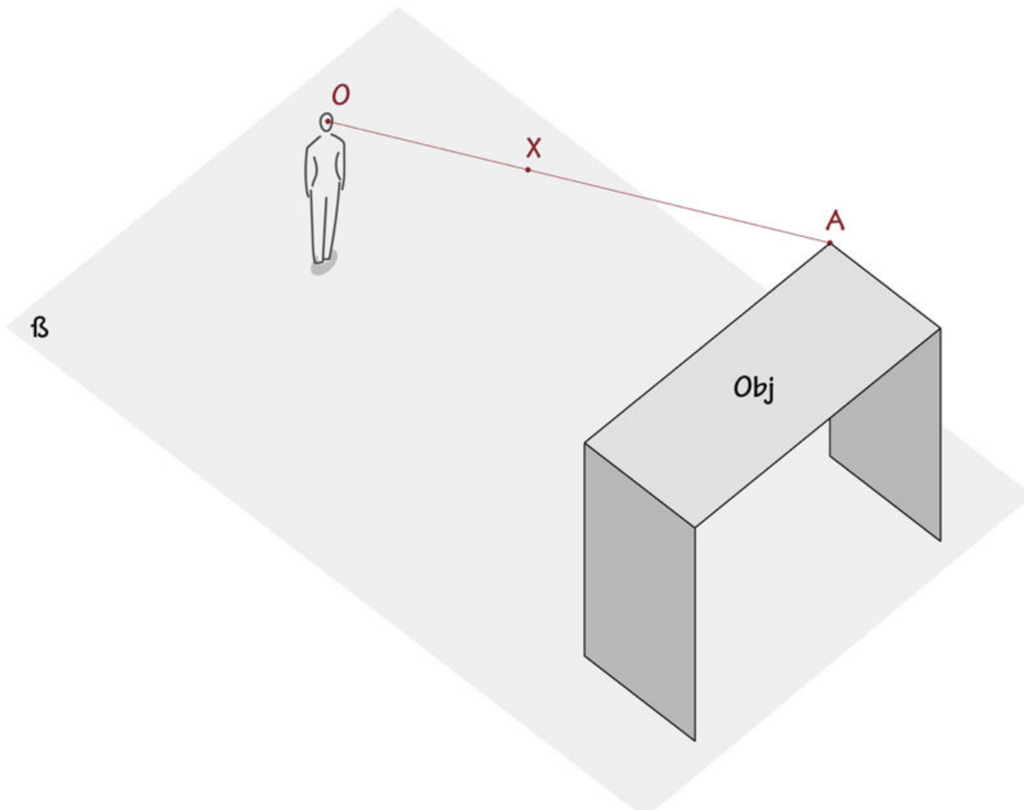


Figure 9: Radial occlusion.

This principle has application in conical perspectives and other anamorphoses. In fact, conical projections seek to create mimesis by composing an image equivalent to the represented object through different combinations of point images. Note, that the occlusion does not rely on any particular surface. In fact, we can project points from Obj to O and find their images on a plane π, on a sphere λ, or a composition of different surfaces, etc. Still, **they all radially project the same within every other surface, meaning that every image looks the same when seen from** O (Figure 10). In other words, every different surface (linear perspective uses a plane, spherical perspective uses a sphere, cubical perspective a cube…) gives us a different *anamorph* of the represented object, there is an infinite number of possible *anamorphs*, and what we know as a linear perspective is just one more of them (Araújo, 2021a, p. 10).

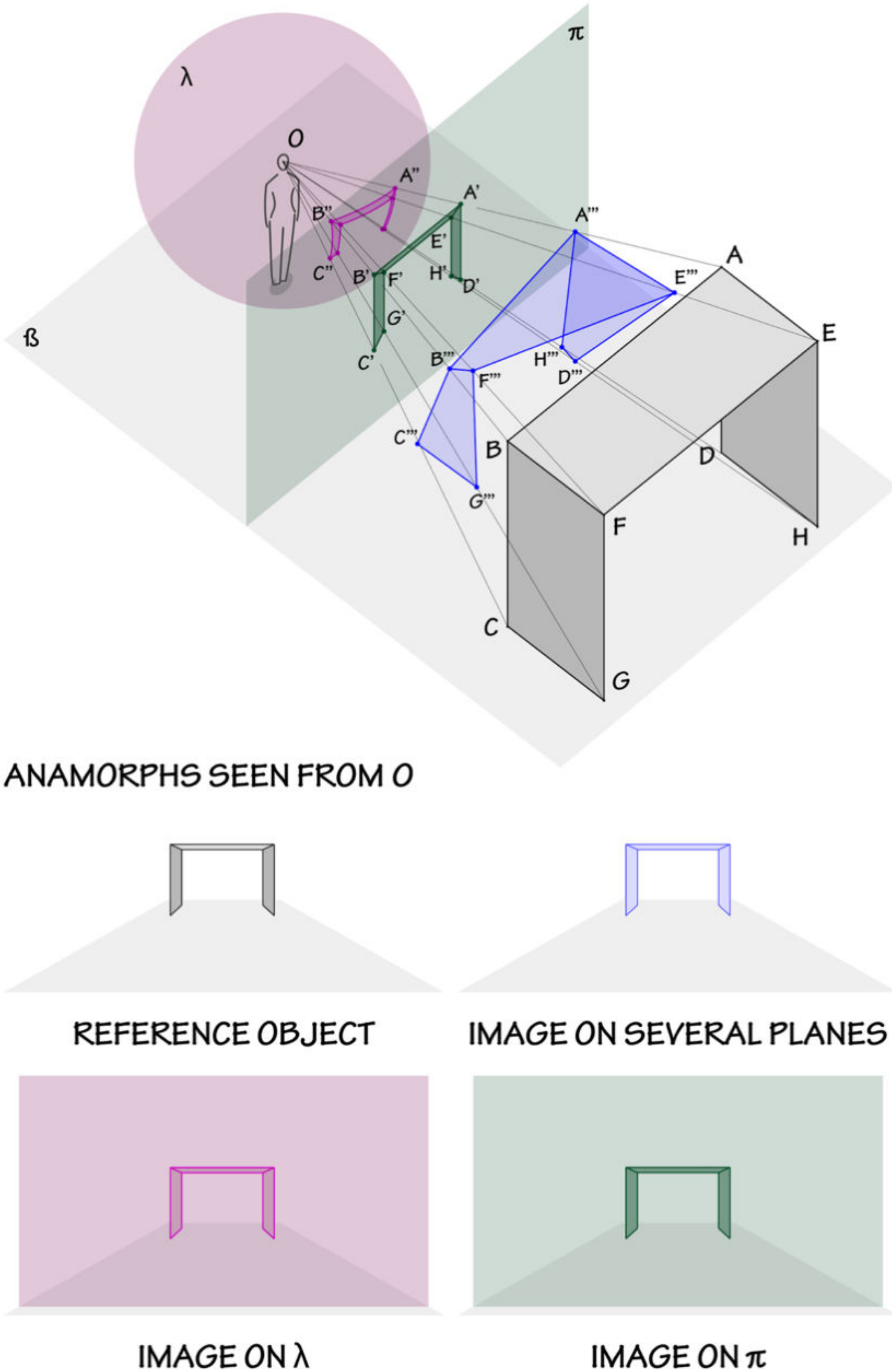


Figure 10: Every anamorph of Obj look the same when seen from O, even if their image points are in a sphere λ (pink), a plane π (green) or in an irregular surface (blue).

As can be seen in Figure 10, the projecting surface limits the quantity of content that can be gathered: in a plane we could grab the half-space in front of the observer, at least hypothetically and with many complications as we would need an infinite plane. Let's call this a **partially immersive drawing**. On the other hand, in the sphere one can grab the whole field of view around the observer easily and then flatten the sphere so to handle a plane drawing instead of a spherical one. Let's call this a **fully immersive drawing**. The limitations of the surface and radial occlusion are neither hard to understand nor complicated to explain in the theory but how do we build an anamorph in practice? Do we have to project every point from O to Obj, intersect the surface of choice, and create the image line by line? If we choose the sphere, do we have to have a spherical canvas? We could. But a better answer is to flatten the surface (if it is not a plane) and then use geometric constants and properties that help us to compose an internally consistent image of Obj from only a few translated points. These logical deductions are normally gathered in drawing methods that change according to the projecting surface, although sometimes one can cross-use methods as we will see further on.

III - Historical overview

Hence in our path from partially to fully immersive drawings, the very first methods for creating systematically conical anamorphs were those of **linear perspective**. These methods considered a plane right in front of the observer as a projecting surface and limited the drawing within a field of view determined by a cone of (normally) around 60° (Figure 11).

Perspective, *to see through* from the Latin *perspicere*, finds its origins in the studies of optics and Euclid's geometry applications: "Perspective is the application of Euclid's visual cone to a glass plane intersecting it" (Wade, 2017, p. 6). Linear perspective has been largely studied by architects, engineers, philosophers, art historians, mathematicians, etc., who have dealt with its origins, historical antecedents from the Roman Empire and the Medieval Age (Figure 12), the first codifications during the Renaissance, definitions and characteristics; and who have looked at these arguments from different and many times opposite points of view, yet considering it "a major event in the history of mankind" for the way it changed our way of thinking (Andersen, 2007, p. 2; Damisch, 1987; Della Francesca, 2016; Katinsky, 2000; Kemp, 1992, 2000; Migliari, 2018; Nicéron, 1638, 1638; Panofsky, 1991; Romor, n.d.; Talbot, 2003; B. Taylor, 1715). Perspective's purpose is to depict a 3D scene in a 2D plane:

> "(…) we are meant to believe we are looking through this window into a space" (Panofsky, 1991, p. 27);
> "(the) painting should give the impression of a window through which we look out into a section of the visible world" (Da Vinci, 2008, p. 107).

However, the difference with other representation systems that also recreate 3D geometry in a 2D plane (e.g. Monge, isometric representations) is that linear perspective is a conical projection following the principle of radial occlusion, which means that a person standing at the observation point O and looking at the drawing should see an anamorph equivalent of the 3D scene and, as such, notice no difference between them (Figure 10, green image):

> "Linear Perspective is the art of describing exactly, on paper, canvas, or any surface, the representations of any given objects as they would appear from any given point" (B. Taylor, 1715, p. 1).

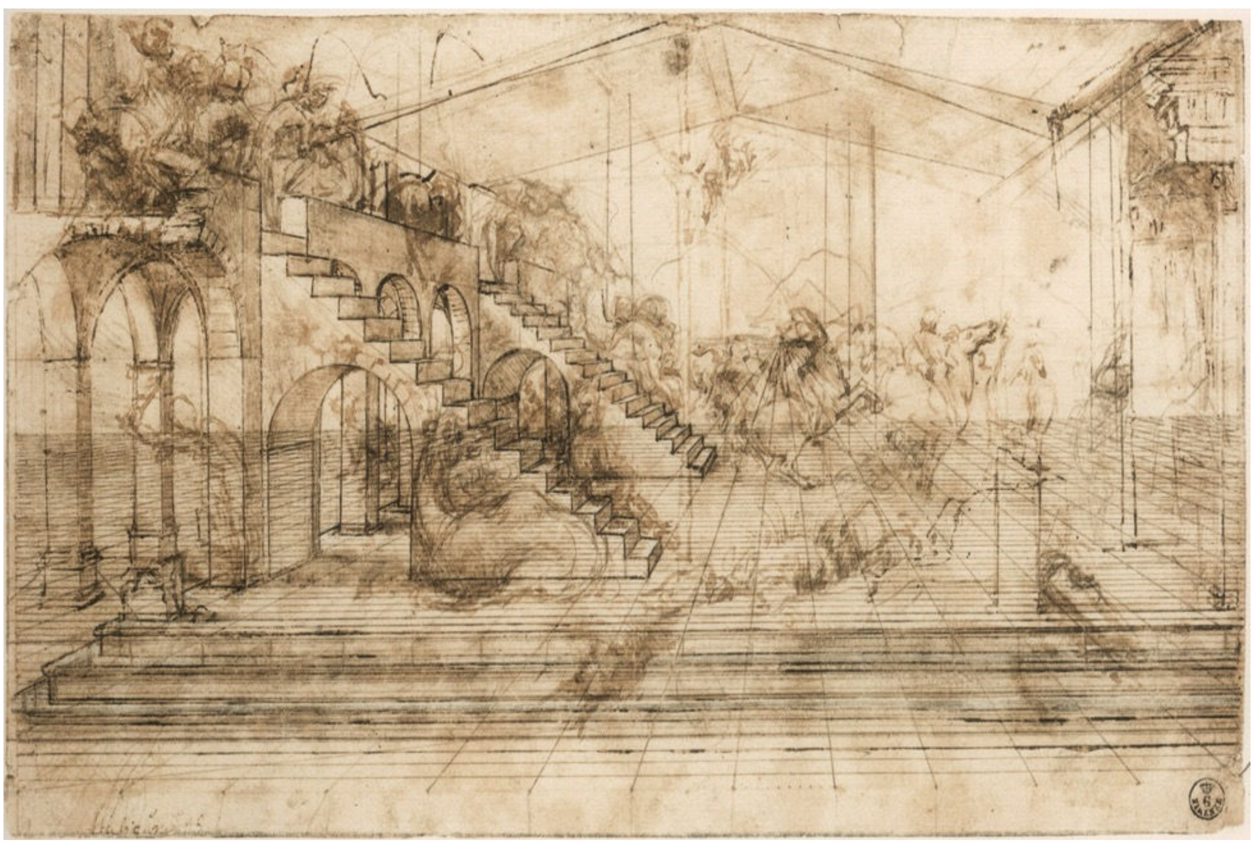


Figure 11: Linear perspective study for "The Adoration of the Magi" by Leonardo da Vinci, c. 1481. Source/Photographer: Bortolon, The Life and Times of Leonardo, Paul Hamlyn. Picture and drawing shared under the public domain and PDArt permission.

Figure 12: 1^{st} century wall fresco in Villa Poppea, Torre Annunziata, Italy. The image looks very close to a linear perspective, yet the set of rules that painters followed for establishing spatial relationships back then were not based on any scientifically proven method (Rehkämper, 2002, p. 27). Drawing by unknown author, no date. Orthophoto by Paolo Alfonso, Julieta Alaniz, Maria Victoria Cetti, Salvatore Falcone, Saverio Saviello and Maria Vicidomini, work conducted by Salvatore Barba, Laboratorio Modelli, University of Salerno, 2014.

Subsequently, the practices of creating anamorphs using any surface other than the classical plane were gathered under the general term **anamorphosis**. In fact, an anamorphosis has neither standard drawing surface nor determined field of view: there are flat anamorphoses (i.e., the projection onto a plane with a certain inclination regarding the observer), catoptric anamorphoses (i.e., grand angular compositions that shape back by means of mirrors), anamorphoses onto a several surfaces (e.g., the walls and the ceiling of a building), and the ones that we are studying here, spherical anamorphoses, which use surfaces such as the sphere or the cube to gather the full visual field around the observer (Araújo, 2017a, 2020c; Cabezos Bernal & Manuel, 2015;

Damisch, 1987, p. 217). The fact that linear perspective was the first method and the base drawing for some anamorphoses, created some misunderstandings still latent today, such as that a linear perspective is not an anamorphosis, that a linear perspective is an undistorted drawing and that an anamorphosis is a distorted drawing, and so an anamorphosis has been reduced to a

> "(…) distorted drawing that makes sense just when is viewed from the correct point of view" (Damisch, 1987; Dictionaries, 2019; Maschietto, 2005, p. 3; Migliari, 2005, p. 34; L. Oxford, 2019; RAE, 2019).

Maybe because of the Greek root (*ana-*, meaning "back" or "again", and *morphe*, meaning "shape" or "form") an anamorphosis is commonly associated to a drawing that has to be first trans-formed (hence it is de-formed) so as to show the correct image, which puts it for some authors as an ugly and bizarre sibling of linear perspective, a game or an aberrant practice of it (Cabezos Bernal et al., 2014, p. 137; Maschietto, 2005, p. 3; Migliari, 2005, p. 34). Nevertheless, the current adoption of the term anamorphosis is so broad and generic that mislead that both linear perspectives and all the ensemble called anamorphoses are the same, i.e, conical projections following the principle of radial occlusion to create mimesis or, in other words, anamorphoses also aim to compose a scene that looks as a real geometry the same way linear perspective does it (Brisbin, 2007, p. 2; Grau, 2003, p. 15). And indeed, there are anamorphoses that do not need to be "shaped back" at all, we only have to know where the observation point is and the whole composition will make perfect sense, as it happens with Andrea Pozzo's work at *Sant'Ignazio di Loyola* in Rome, where the observation points are materialised with two marble spots in the floor, one for the flat anamorph of the fake dome and one for the multi-surface main fresco anamorph Gloria di Sant'Ignazio (Figure 13).

Anamorphoses have been largely used by artists for creating immersive experiences through basically two ways: either through big paintings exhibited within large buildings, hence having the observer inside the installation such as the **Panoramas**; or by using smaller artifacts with peepholes through which visitors can have an immersive experience by putting the device in front of their eyes, such as the **Perspective Boxes** and the current **digital VR glasses** (Grau, 2003, p. 349).

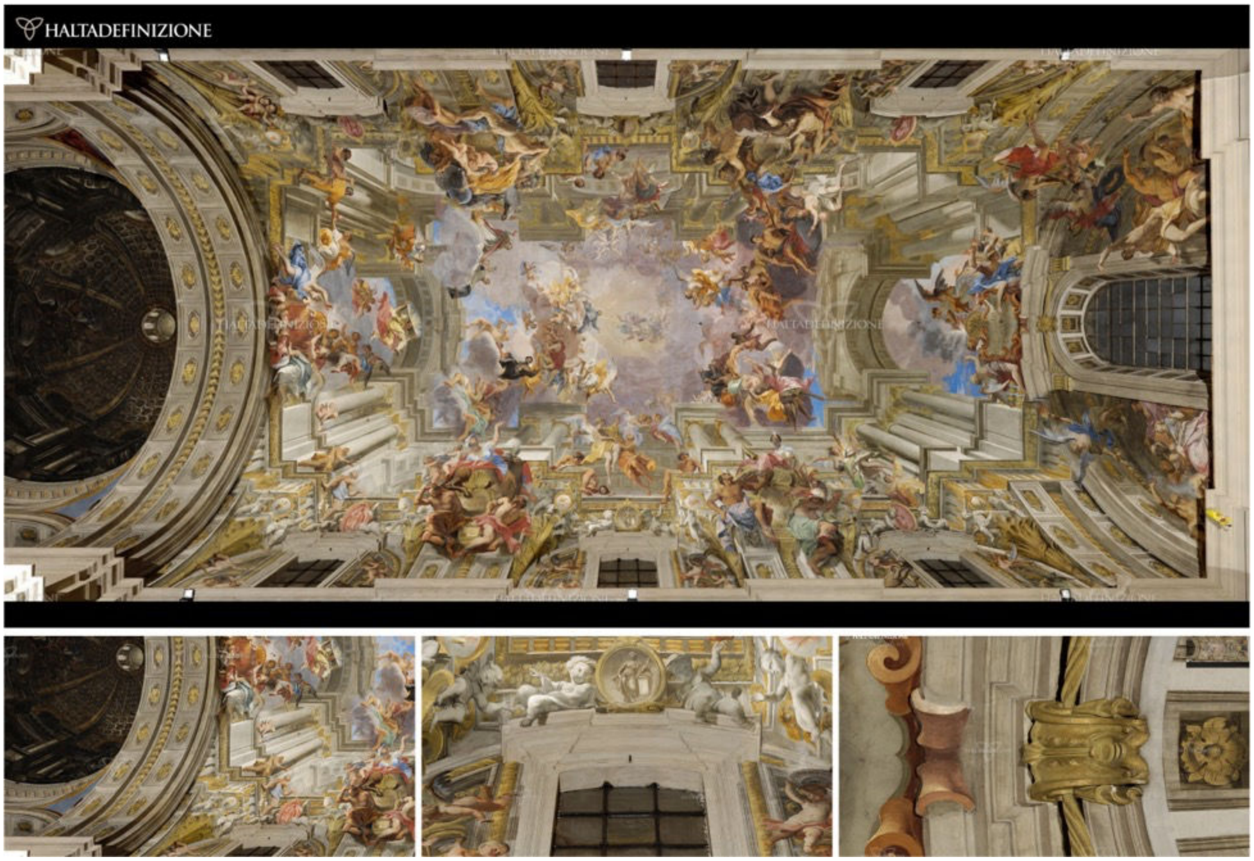


Figure 13: Gloria di Sant'Ignazio (1691-94) by Andrea Pozzo. Screenshots (2021) from Haltadefinizione's website (authorised free use for didactic non-profit purposes) (Pozzo & Panini Editore SpA, 1691).

On the side of the big installations, the Cycloramas (building) and **Panoramas** (drawing) brought immersion nearer to a full physical embodiment experience. This ensemble was patented in 1787 by Robert Barker and it consisted of an immense building in which observers will walk-in the point of observation and an anamorph on a cylindrical surface which was named named "Panorama" (from the Greek "an all-embracing view") (Figure 14) (Barker, 1796; Bigg, 2007, p. 73; Markman, 2008, p. 134). Barker not only registered the building and the cylindrical painting, but also many further ways to enhance the physical experience of being immersed somewhere else, such as *faux terrain* and lighting effects:

> "(…) the Panorama developed into a presentation apparatus that shut out the outside world completely and made the image absolute" (Barker, 1796, pp. 165–167; Grau, 2003, p. 59).

On the side of the small installations in front of the eyes, the **Perspective Boxes** were devices created by Dutch artists during the 17th century (later also expanded to the

Italian, Danish and Japanese cultures) and they used anamorphs onto several planes to illustrate scenes and architecture within wooden boxes (Fukuoka, 2005; Gay & Cazzaro, 2018; Koslow, 1967, p. 35; Spencer, 2018; Verweij, 2010). These devices reduce drastically the size of the immersive experience when compared to the massive frescoes in churches or the Panoramas since they can "make a figure the size of your finger appear to be life-size" (Hoogstraten, 1969; Spencer, 2018, p. 4). Back in the 17^{th} century, Dutch artists used these boxes for representing their daily life (Figure 15), looking for a connection between figures and environments, seeking the realistic representation of their churches, landscapes, fields, towns and houses and matching the iconicity of the represented objects with the representation of the activity itself (Koslow, 1967, p. 35). A recent remake of these boxes extended their use to design and architecture (Gay & Cazzaro, 2018).

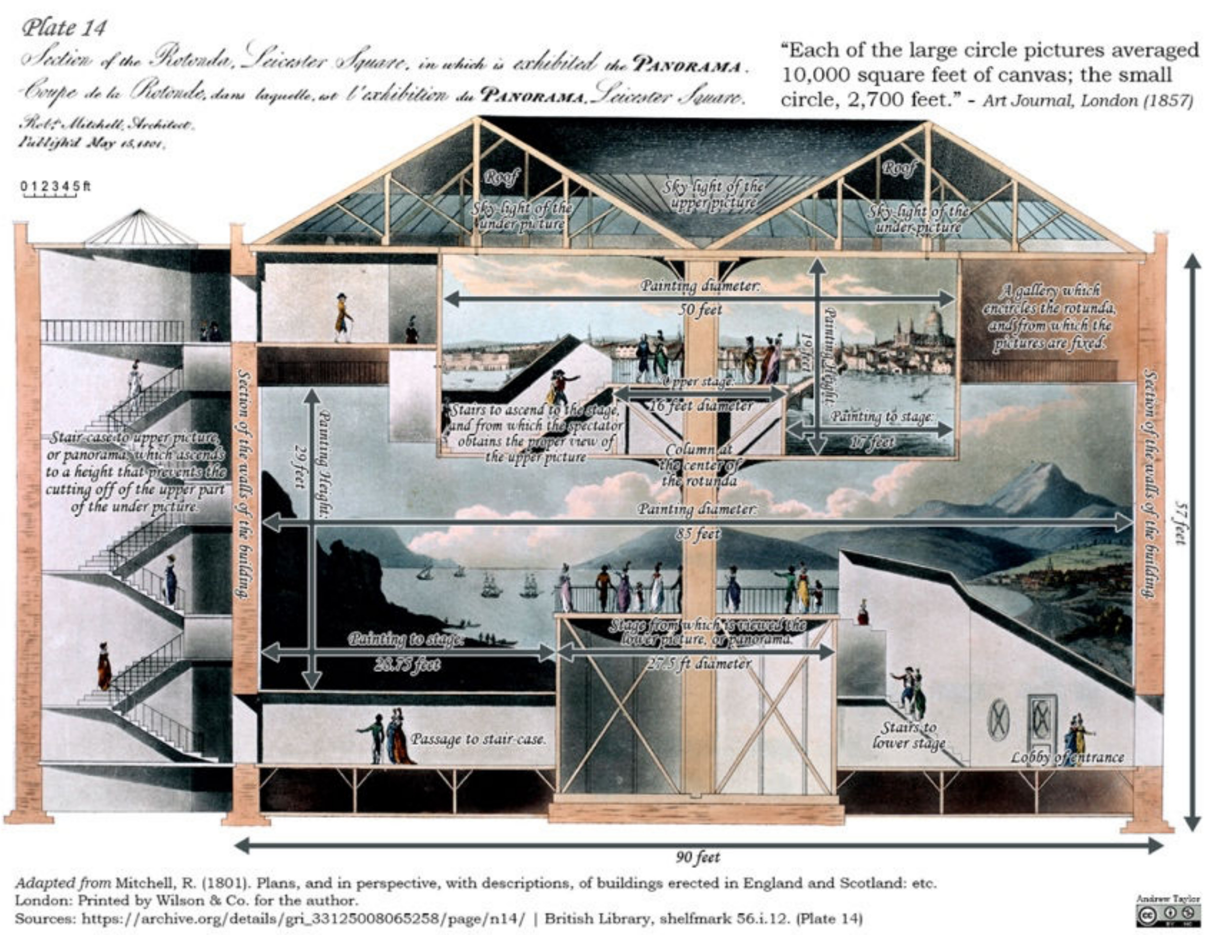


Figure 14: Section of the Rotunda designed by Robert Mitchell (1801) under Barker's indications (p. 58). Image edited by Andrew A. Taylor (2019) and shared under Creative Commons License.

Figure 15: A Perspective Box: Views of the Interior of a Dutch House (1663) © National Gallery, London (Nakamura, 2020; L. The National Gallery, n.d.; L. (photograph). The National Gallery & Hoogstraten, 1655).

Most of these anamorphoses had the same limitations than the classical linear perspectives simply because they were composed by first creating a linear perspective through the known and codified methods and then using a re-projection of that drawing either through grids of other physical mechanisms (see XXX Part II, Chapter V.2). However, some artists experimented parallel methods trying to push the limitations of linear perspective away, and so they explored wider fields of view through curvilinear reflections, which eventually led to the development of systematic ways for creating fully immersive drawings. Some historical examples of these explorations are The Arnolfini Portrait (1434) by Jan Van Eyck (Figure 16), Parmigianino's Self-portrait in a Convex Mirror (1524), and Hand with Reflecting Sphere (1935) by Maurits Cornelis Escher, instances that show how artists represented reflections on spherical mirrors as an early way of wide-angle images (Elkins, 1991; Escher & Vermeulen, 1989; Eyck, 2020; Mazzola (Parmigianino), 2020). From the mid 20th century on, spherical drawings attracted a great deal of interest leading towards new and deeper studies on the subject (Hansen, 1973; Luhmann, 2004; Macnair, 1957; United States. War Dept. Division of Military Aeronautics, 1918) and particularly to the first systematic methods for drawing not spherical reflections anymore (i.e., with the observer placed outside the sphere), but **spherical perspectives** (i.e., with the observer placed right in the centre of the sphere) using descriptive geometry and simple tools such as ruler, protractor and compass (Araújo, 2015, 2018c, 2018a; Casas, 1983; Catalano, 1986; Chelsea, 2011; Masetti, 2014; Michel, 2013). Not all these methods were full systematic methods, but they certainly pushed the field of spherical drawing towards a new state of the art.

Figure 16: Portrait of Giovanni Arnolfini and his Wife (1434) by Jan Van Eyck. Photography (2017) by Saiko. Image distributed under Creative Common Licence (Eyck & Sailko, 1434).

The latest developments of digital environments pushed these explorations even further. In fact, digital technology made full immersion technically possible, removing the limitations of the Cyclorama/Panorama apparatus: the observer can now be placed exactly within the very centre of the sphere; there can be content on the top and on the bottom of the visual field; there is no need for a special and bulky building; and diffuse lighting is not an issue anymore. Digital environments were quickly and widely adapted for the creation of immersive experiences, first using the sphere as a projecting surface, then the cube (Greene, 1986) and further on to other surfaces as well (Praun & Hoppe, 2003). Just a few years ago, the utility of the cubical environmental map was questioned during an academic research as a something more than the only support for computer rendered environments given its features (i.e., better and more efficient performance than the sphere (Wikipedia, 2018a)), and hypothesised as a medium for developing new perspective drawing methods, i.e., a **cubical perspective** (Olivero et al., 2019; Olivero, 2021; Olivero & Sucurado, 2019). That led first to the development of partially systematic methods (Olivero et al., 2019, 2020) and to a fully systematic method that treats cubical perspective as a special case of spherical perspective (Araújo et al., 2020).

IV - The elements of conical projections

Piero della Francesca describes the relation between an observer and a conical image through five elements (Figure 17): the **eye**, the **shape of the object** to be represented, the **distance** among them, the **rays** joining the extremes of the geometry, and the **projection support** (Della Francesca, 2016, p. 81; Romor, 2015, p. 4).[3] Further explorations of these elements over the following centuries developed the current methods for **central**, **parallel** and **double orthogonal projections**, from which we get **conical**, **axonometric** and **orthogonal** drawing respectively. Hence, within a conical projection, the image of a certain object depends on its position regarding the observer, it is related to the surface between them, and it is the result of projecting and intersecting using straight rays (Romor, 2015, pp. 2–4). Let us explore these elements to see how they contribute to the definition of the different conical projections.

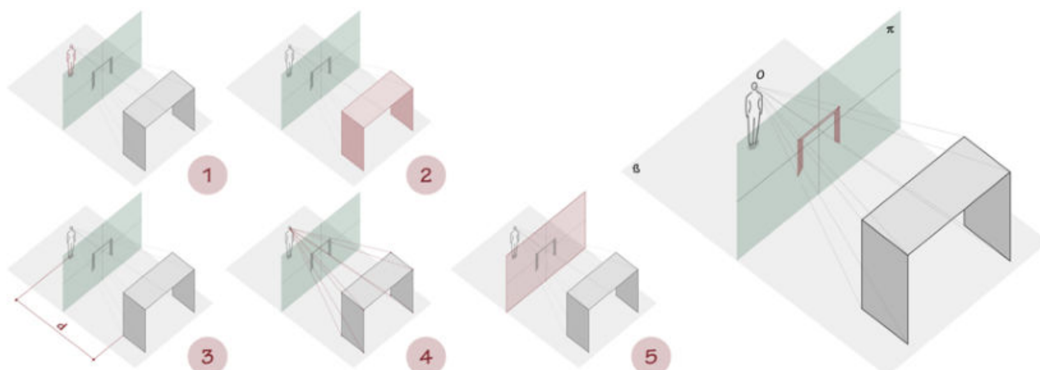


Figure 17: Five key elements to better understand the relation between observer and image in a classical perspective: 1, the observer O; 2, the object to be represented Obj; 3, the distance between them $d(O, Obj)$; 4, the rays $\overrightarrow{OObj}$; and 5, the projecting support or surface π.

IV.1 - Projecting onto a single plane

The most classical configuration for creating an anamorph is using a plane between the observer and the scene to be represented as the projection surface S, which is the case of linear perspective (Figure 18). The simplicity behind this projection facilitated the creation of general methods, where geometrical constants can be found through logical deductions and the scene can be reconstructed from the spatial understanding of the objects in space.

[3] Original quote: *"La prima è il vedere, cioè l'ochio, seconda è la forma de la cosa veduta, la terça è la distantia da l'ochio a la cosa veduta, la quarta è le linee che se partano da l'estremità de la cosa e vanno a l'ochio, la quinta è il termine che è intra l'ochio e la cosa veduta dove se intende ponere le cose"* (Della Francesca, 2016, p. 81).

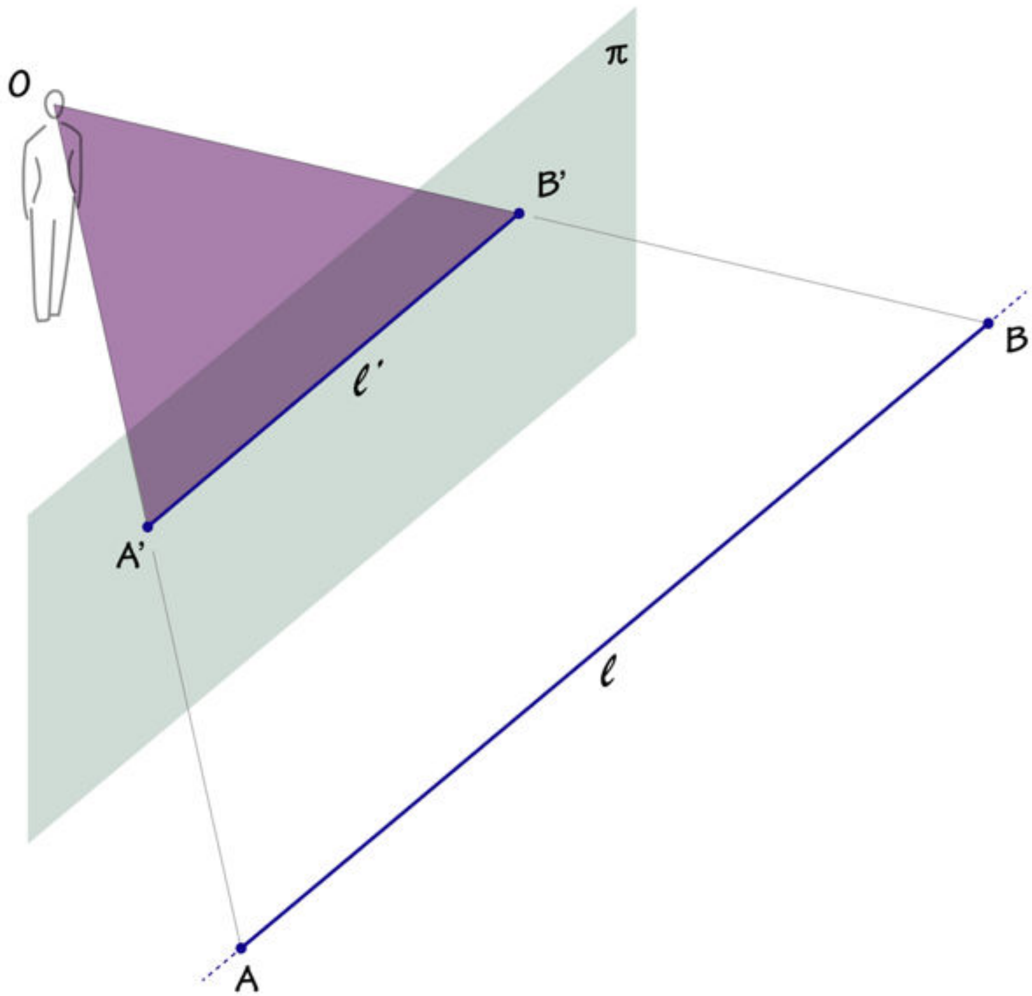


Figure 18: Projections onto a single plane are quite straightforward, which simplifies the creation of general methods.

Some optical effects were noticed using this setup: if we consider a very simple scene composed by two geometrically identical objects placed one behind the other and see to the anamorph on the right, we can see that the red parallelepiped looks effectively behind and farer than the blue one (Figure 19). Notice that, although by definition $AB = CD = EF$, they result $AB < CD < EF$ in π. These properties were defined for linear perspective methods as:

- **Convergence**, which "refers to the apparent movement of parallel lines toward a common vanishing point as they recede",

- **Diminution of size**, i.e., "converging sight lines reduce the size of distant objects, making them appear smaller than identical objects closer to the picture plane",
- **Foreshortening**, which "refers to the apparent compression in size or length when a facet of an object rotates away from the picture plane (and) when a facet of an object perpendicular or oblique to the picture plane moves laterally or vertically with respect to the central axis of vision",
- **Overlapping of shapes**, which is "an essential visual cue to spatial depth" (Ching, 2015, p. 114; D'Amelio, 2004, pp. 21–22; Da Vinci, 2008, p. 120).

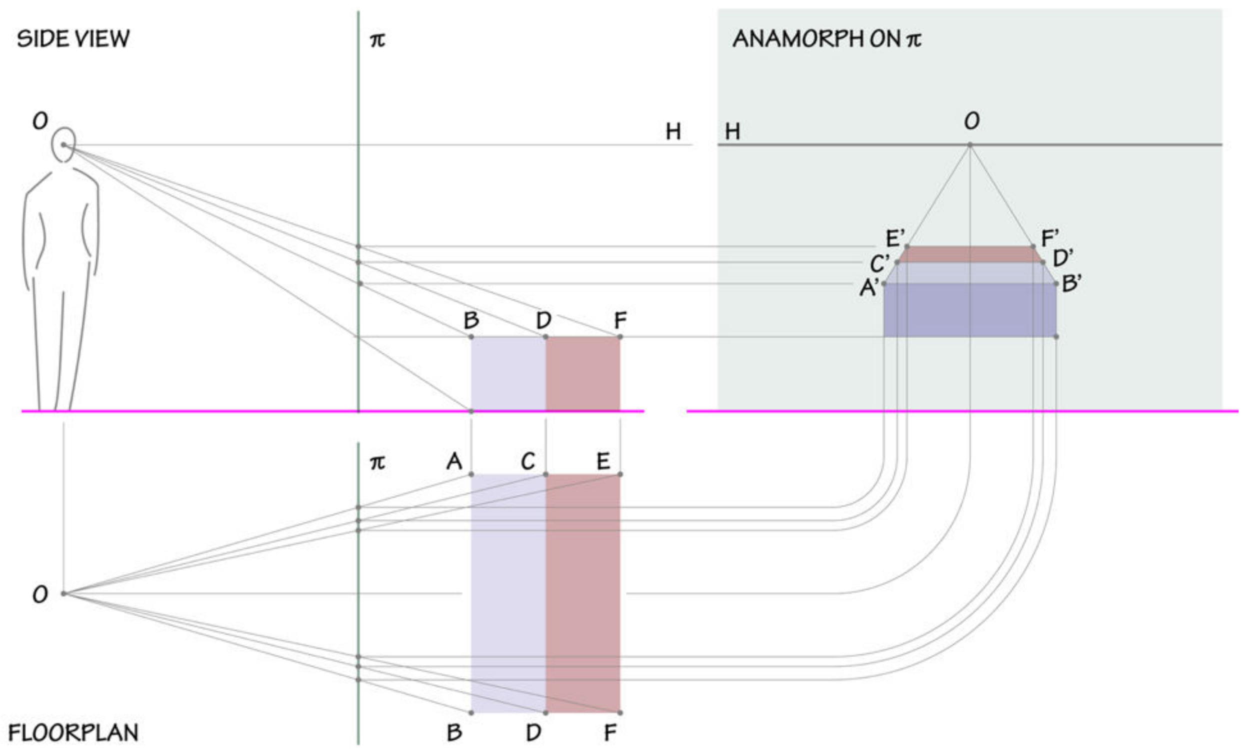


Figure 19: Creation of an anamorph by using conical projections onto a plane.

However, if we want to represent objects that have the same size but are parallel to the drawing plane (Figure 20), we will notice that their image looks bigger and bigger the farer they go, breaking the rules of the diminution of size (Andersen, 2007, p. 106; Dane, 2011, p. 148; Dixon, 1991, p. 83).

These anomalies were qualified as "lateral distortions", and the paradox was noted by both Piero della Francesca and Leonardo da Vinci and in particular Della Francesca proposed a fairly simple solution: to ignore what the projected image looks like, and to force the projections of objects of the same size to be the same size in the drawing (Dane, 2011, pp. 147–155). As a consequence of this paradox and in addition to Della Francesca's solution, the cone of view was introduced so as to keep the content within safe limits and avoid such "anomalies" (Della Francesca, 2016). Some scholars consider a cone of up to 60° for a "normal view", up to 90° for background and peripheral elements, and up to 30° to "minimise the distortion of objects like circles or circular shapes" (Ching, 2015, p. 111; D'Amelio, 2004, p. 18). And so finally, with the plane as projecting surface, and the cone of view limiting the image, we have the most classical setup of linear perspective (Figure 21).

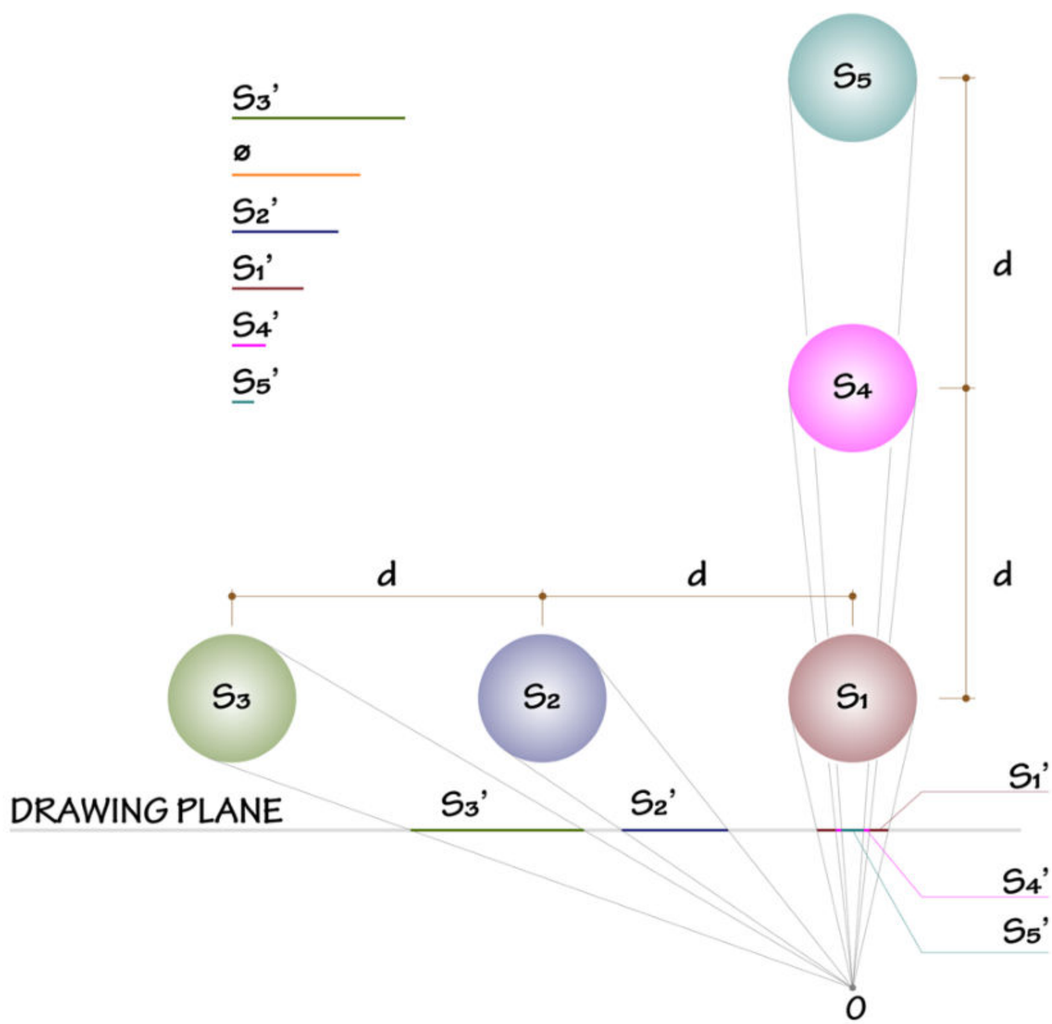


Figure 20: Linear perspective's paradox. According to the diminution of size rule and convergence, the images of objects with equal size should decrease the farer they are from the drawing plane: $\varnothing > S_1' > S_4' > S_5'$. However, their images' size increase if they are placed parallel to the drawing plane $S_3' > \varnothing > S_2' > S_1'$.

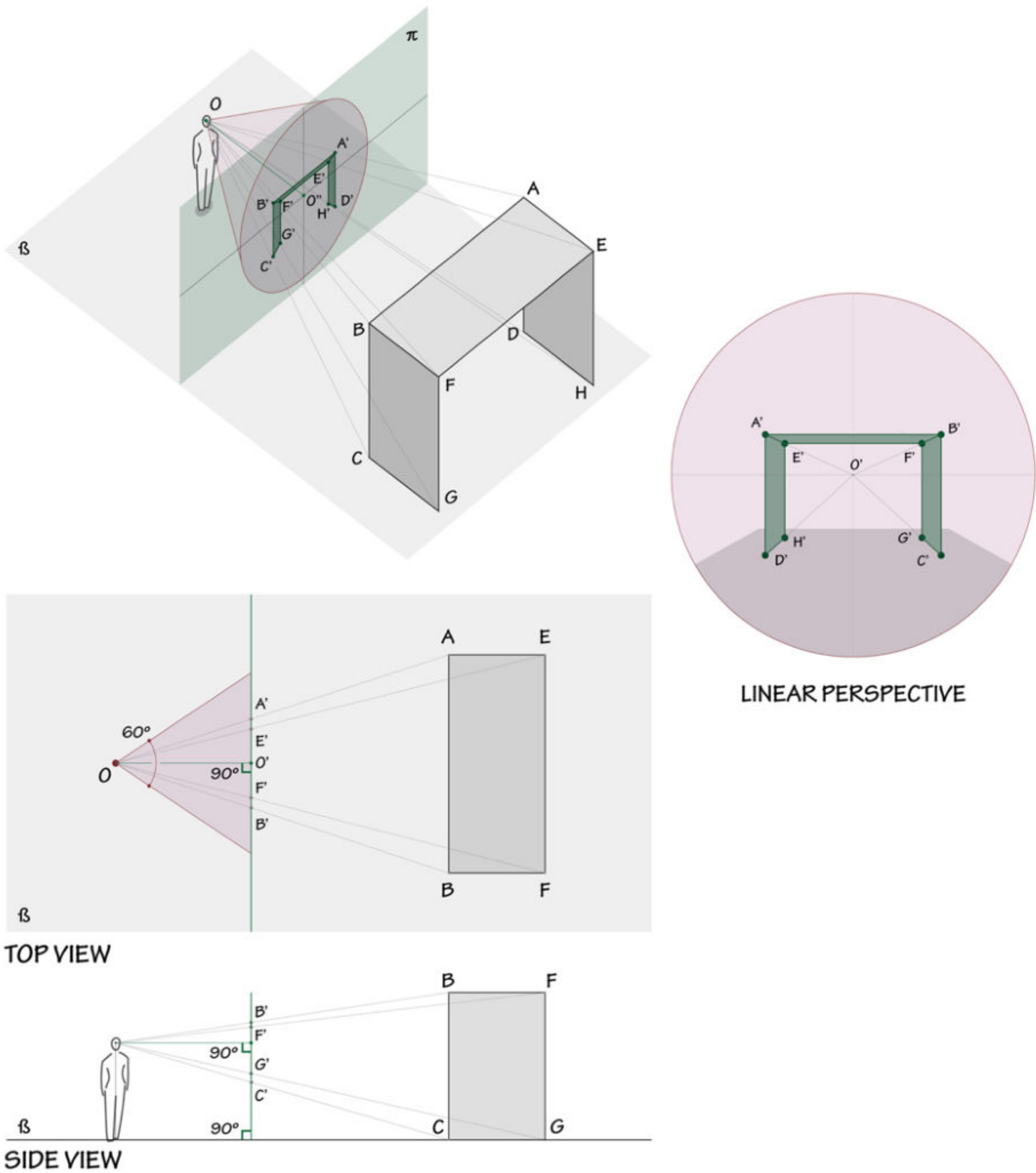


Figure 21: Classical setup of a linear perspective.

If linear perspective uses a plane as a projecting surface and - as described in the historical overview - an anamorphosis has no restrictions in that regard, then we can redefine an anamorphosis as the most general case of conical projection, a relation happening in space among objects and the centre of projection or, in more elegant words, the "equivalence relation between three-dimensional objects, not necessarily flat" (Araújo, 2021a, p. 1). From there, linear perspective is the particular case of anamorphosis onto a plane: "every perspective constitutes an anamorphosis" (Cabezos Bernal &

Manuel, 2015, p. 137). In fact, as seen in Figure 10, every anamorph is equivalent when seen from O regardless their projecting surface. Consequently, all anamorphoses including linear perspective look "wrong" when seen from the incorrect point of view, and "right" when seen from the correct one (Araújo, 2021a; Cabezos Bernal & Manuel, 2015; B. Taylor, 1715, p. 49). See for instance The Ambassadors by Hans Holbein The Young: if the observer looks at the painting standing right in front of the projecting plane (i.e., "perpendicular" to it), then the part of the drawing made with the linear perspective method looks "fine" and the part made with an inclined plane (i.e., the skull) looks "wrong" (Figure 22), but if the observer moves towards the other point of view of the drawing, then the roles invert, the ambassadors look completely distorted and only the skull looks fine. In other words, the misconception that one part of the drawing is right and the other wrong comes from the confusion that a drawing has two (or more) points of observation and projecting surfaces. In this case, one of them may be more common (standing right in front of the artwork, both for looking at it and for painting it) and the other less common (standing afar from the painting and drawing with an inclined canvas), but either case both mechanisms and results are exactly the same.

Figure 22: The Ambassadors (1533) by Hans Holbein the Young. Image distributed under Creative Common Licence.

Hence we can see that every anamorph - including linear perspective - needs two things to "look correct": first, **a correctly created content**, for which the artist has to know how a projection will look like according to the projecting surface, and where is the observation point or centre of projection; and second, **the observation point/s**, from where visitors will see the recomposed shapes.

IV.2 - Projecting onto several planes and/or irregular surfaces

An anamorph can also be done onto a set of surfaces, not necessarily flat and certainly without any limitation on the field of view (Figure 23). Some historical examples are the frescos of Andrea Pozzo in Rome such as *Gloria di Sant'Ignazio* (1691-1694) and *Casa Professa del Gesú* (1681-1686), created with multiple centres of projection onto different sets of vaulted ceilings, corridors, walls, planes, etc. Furthermore, some theoretical developments accompanied these practices, studying the behaviour of projections onto connected planes (Bosse, 1653; Nicéron, 1638). Some contemporary artists pursuing this technique are Adry del Rocío, Jonty Hurwitz (who incorporated digital techniques for the 3D modelling of anamorphic sculptures), Troika, James Nizam, Léo Caillard, digital video installations on curves LED displays such as the Null Station project, etc. (MacNeal, 2022; Station, 2024).

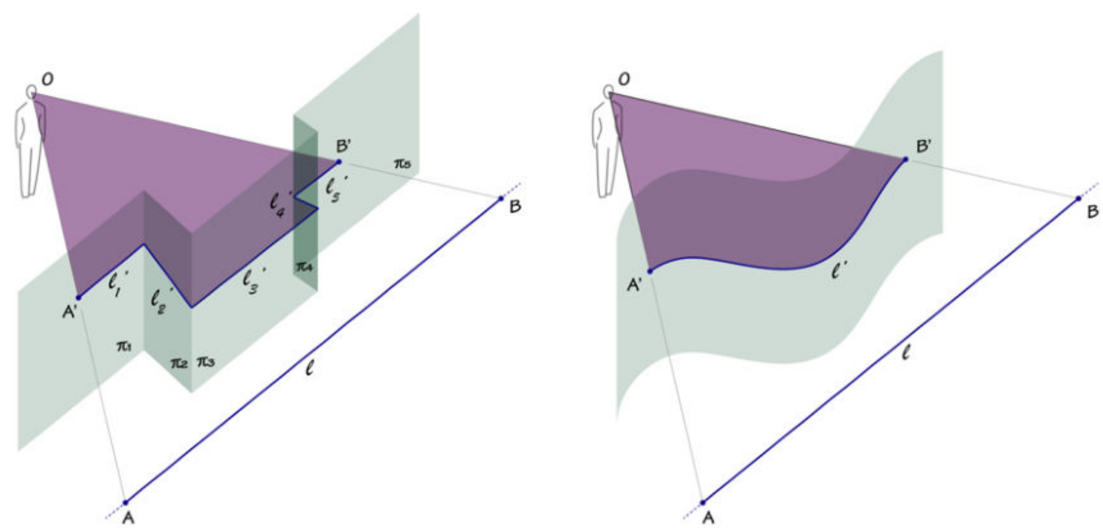


Figure 23: Conical projections onto a set of planes or onto irregular surfaces.

In some cases, the projections onto multiple planes are accompanied by the modelling of the architecture itself, enhancing the perception of depth. Some examples of the so-called "solid perspective" are *Santa Maria presso San Satiro* by Bramante (ca. 1478 - 1490), the gallery of the Palazzo Spada (ca. 1653), Scamozzi's Olimpic Theater of Palladio (1584-1585), and the gardens of the Royal Palace of Caserta (18th century) (Cabezos Bernal & Manuel, 2015, pp. 138–140; M. Rossi et al., 2018).

However, using multiple surfaces poses a big issue: a single plane or a regular surface allows the elaboration of general methods with which artists can create internal constructions and hence solve the representation through logical constructions. In the case of using several planes or irregular surfaces it gets harder - if not impossible - to define general behaviours and rules of symmetry, and hence it becomes an *ad-hoc* method for every different case as we would hardly find twice the same spatial situation, which means that the procedure is hardly repeatable or verifiable, as it happens with the Perspective Boxes. One of the safest and cleanest ways to create the anamorph in this case, is either by creating a draft anamorph following the rules of a known perspective (such as linear perspective) or by creating a 3D digital scene; thus re-projecting the image through some mechanism of reference in the first case (i.e., an anamorph of an anamorph); or with a digital projection in the second case. The first method is explained in Part II, Chapter V.2. I will not dive into the digital case as it will take us far from the content in scope.

Linear perspective - and in general using a single plane as a projecting surface - confines the results to a small field of view, an unwanted limit for artists exploring concepts that show an overall view or that create full immersive experiences (Pagliano, 2015). If that is the case, we could use either a 3D Model or 360° photography, with many advantages to our side since they can offer full immersive and interactive views at once (A. Rossi, 2017; A. Rossi & Cabezos Bernal, 2017). But, as explained before, 3D modelling and photography are limited to material reality, while drawing is not. A solution for representing a fully immersive experience using planes could be stitching several linear perspectives, yet this would be, again, more an *ad-hoc* experience rather than a shareable, transmissible and repeatable knowledge. The solution is to think differently and use other regular and surrounding surfaces, such as the sphere and the cube.

IV.2 - Projecting onto regular surrounding surfaces

In the path to full immersive drawings, the two limitations of field of view (for projections onto single planes) and of systematic methods (for projections onto multiple surfaces), began to see a different light with the introduction of new surfaces. Indeed, the Panoramas introduced the use of the **cylinder** with which it was possible to extend the field of view to a full 360° around the observer, although still with limitations on the content above and below (Figure 24). Drawing panoramas opened the research to a new methods for cylindrical drawing and, even if in the end they still used *ad-hoc* methods (for instance, stitching several classical perspectives, or later on photographs), they opened the door to systematic methods with a first classification of curves that would appear straight from the stage (Grau, 2003, p. 56). The use of the cylinder supposed a revolution, as the immersive experience within the Cycloramas started to emancipate from the physical limitations of the frame, in a shared purpose between drawing and architecture (Pascariello, 2005). Thanks to this, Rotundas and Panoramas turned into a celebrated fashion during the 1800s, promoting for the first time the virtual visit of remote places such as Pompeii's ruins or the Mississippi river from a building physically located in, for example, England.

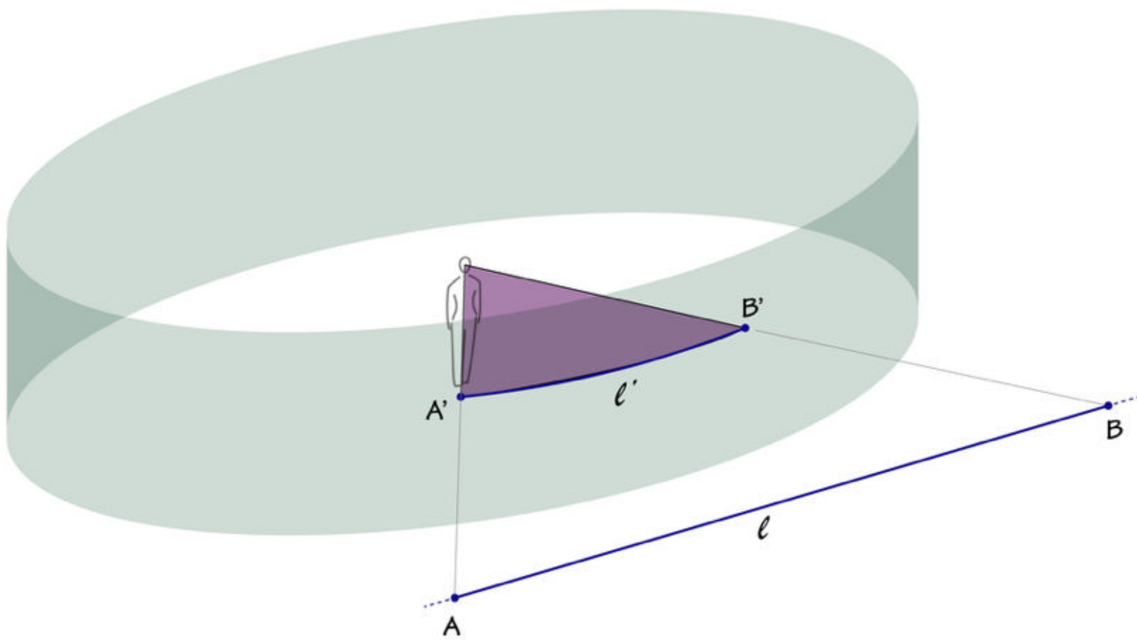


Figure 24: Panoramas use a cylindrical surface.

After the cylinder, the **sphere** was introduced, overcoming both limitations of field of view and systematic methods (Figure 25). Indeed, on the side of the field of view, a spherical drawing can cover entirely the field of view around the observer including the upper and bottom parts; on the side of methods for drawing, several authors attempted full methods for drawing within a flattened sphere (Casas, 1983; Chelsea, 2011; Masetti, 2014; Moose, 1986), until the successful introduction of systematic methods for hemispherical (Barre & Flocon, 1967) and fully spherical perspective drawings (Araújo, 2018c, 2018a). The use of the sphere brought several advantages for creating a conical anamorph. For example, by introducing the notion that every line has exactly two vanishing points and either of them can be used indistinctly with exactly the same result. Furthermore, the different ways of flattening the sphere added new dynamics for drawing by exploding different groups of symmetry.

More recently, the **cube** was added to this bestiary and started to be used as a projecting surface as well (Figure 26), allowing the same solutions than the sphere (i.e., full immersion and systematic methods) but also adding the advantage of being a linear method, and therefore joining the long tradition, familiarity and methods of linear perspective with the advantages and new dynamics of the spherical perspectives (Araújo et al., 2020; Olivero, 2021). The use of the sphere and the cube as projecting surfaces was boosted by their presence through digital technology and in particular through computer graphics where both surfaces have been extensively studied and are part of the common alphabet for creating and rendering environmental maps (Bourke, 2016; Dimitrijević et al., 2016; Greene, 1986; Lambers, 2019; Lambers & Kolb, 2012). Digital panoramic photography also motorised this connection, as their software allow an easy switch between both surfaces, which simplified the interaction with fully immersive drawings.

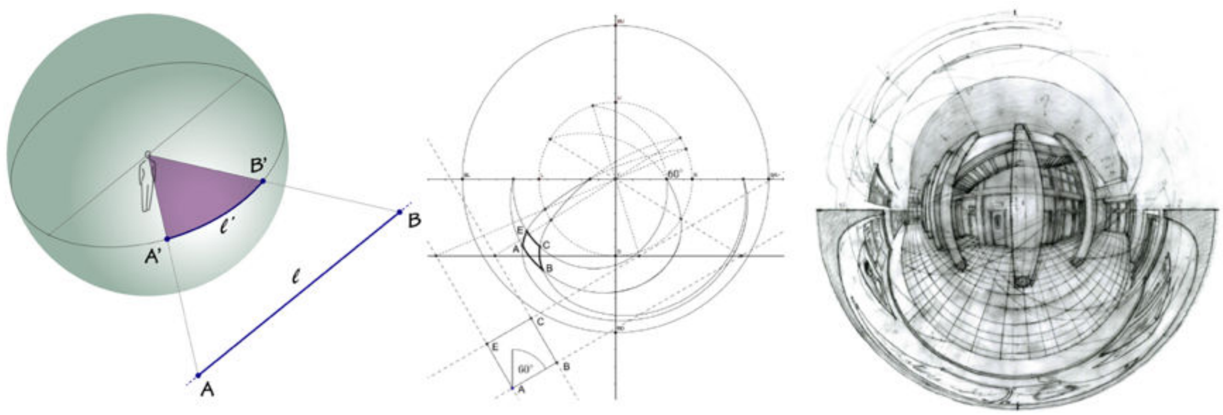


Figure 25: The use of the sphere as a projecting surface and systematic methods for creating spherical perspectives. On the centre and right: construction of an azimuthal equidistant perspective © António Bandeira Araújo, 2018.

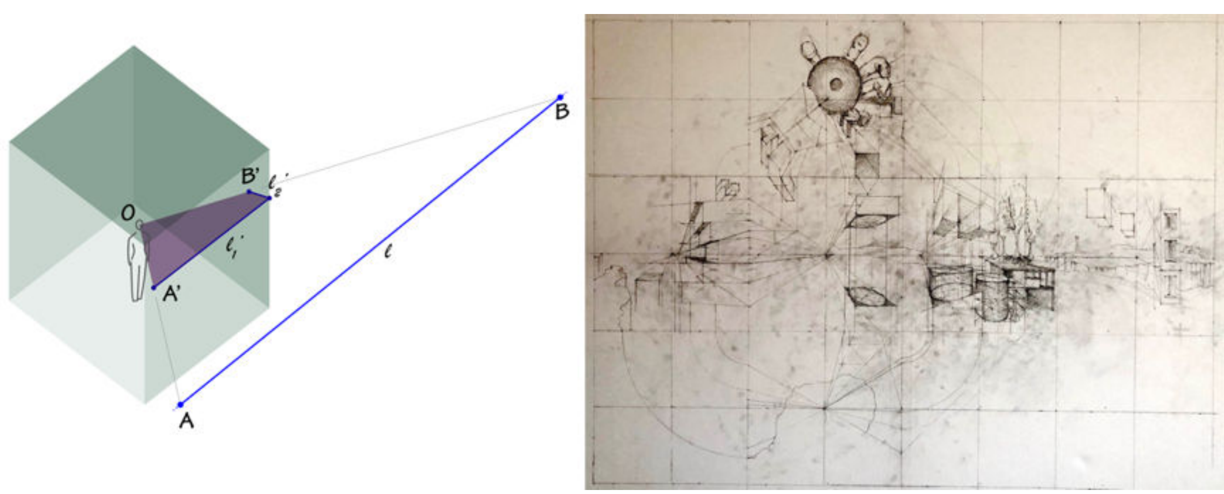


Figure 26: The use of the cube as a projecting surface. The drawing on the right was created using a systematic method © Lufo Art (Lucas Fabian Olivero), 2025.

IV.3 - Interaction with physical anamorphs

Linear perspective aims at mimic the material reality as it naturally appears to the (i.e., to one) human eye, representing spatial objects with the right proportions among them and with the right size according to their distance to the observer (Andersen, 2007, p. 2; Romor, 2015, p. 1). Thus, it is not a surprise why linear perspective got so closely - although misleadingly - connected with the idea that perspective is "the way that a person sees" (Leopold, 2016, p. 409; Panofsky, 1991). We humans do not see as a perspective drawing looks like and, in fact, the specifications for the method to work are hardly fulfilled in real life, as we almost never see through only one and fixed eye:

> "Linear perspective is valid only for monocular vision (…). We almost never view anything in this way. Even with the head in a fixed position, we see through both eyes, which are constantly in motion, roving over and around objects and through ever-changing environments. Thus, linear perspective can only approximate the complex way our eyes actually function" (Ching, 2015, p. 108).

The legitimacy of perspective itself has been put to question when the image is not perceived with one and immovable eye (Panofsky, 1991, p. 29), and it has been argued that having a fixed point for observation is only a social convention since keeping a fixed position and eye is nowadays an impossible practice, especially considering our rushed experience in museums where choosing a privileged point of view is rather a luxury more than a concrete possibility (Dane, 2011, p. 147). Nevertheless, some other scholars put the dilemma in better lines: the immobility of the eye is something *necessary for the composition* of the image, but it is something *relative for the perception* of the artwork, which can actually be seen with both eyes, in freedom of movement within a certain margin[4], and with the real environment behind so to compare; without losing the effect of depth (M. Fasolo & Migliari, 2018, p. 30; Migliari, 2005). Effectively, this margin can be experimented in real person when visiting the amazing frescoes of Andrea Pozzo in Rome, where the observation points are marked but the depth effect still prevails after moving out from them and despite the use of binocular vision. To be noticed that not every visitor has the same height and hence the point of observation also changes with the stature of the visitor. Even more, in the specific case of *Gloria di Sant'Ignazio*, it is practically impossible to separate the transition from the actual architecture to the

[4] According to Migliari (2005), the margin is of 1% of d laterally and up to 5% forward/back, being d the distance to the drawing.

painting, even when moving far away from the observation point, which "involves the observer in a genuine experience of virtual reality *ante litteram*, and without using technological devices" (M. Fasolo & Migliari, 2018, p. 50). The idea of an area of observation is even materialised within the Cyclorama/Rotunda buildings, where one can walk through a circular stage and still have the sensation of being immersed in the environment. In these buildings both the drawing and the architecture played an important role on enhancing the sensation of immersion and the preparation of the observer for the experience (Huhtamo, 2013; Mitchell, 1801, pp. 8, 59). For example, the Rotunda built by architect Robert Mitchell in 1801 materialised many details of Barker's patent. Within it, visitors explored the panorama from a central area after having walked through a dark corridor and climbed a spiral staircase, a whole mechanism aimed to disorient the observer, unplug them from the outside world and boost the first impact (Penny, 1999, p. 81).

Maybe the only strict cases where the projection centre and the observation point are permanently linked were Brunelleschi's *tavolette* and the Perspective Boxes: these devices had a peephole located exactly at the projection centre from which the whole scene was watched and, in the case of the Perspective Boxes, sometimes even using lenses for ensuring the right reconstruction of the anamorph (Nakamura, 2020, p. 3). However, most of the times we see and perceive anamorphs from random located points, and indeed, some authors have pointed out that the movement during the perception is not only possible but actually necessary for the deep understanding of a perspective artwork (Damisch & Leal, 2007, pp. 13–14). This position aligns with the small degree of focus we have despite having a wider vision. In fact, the part in focus of the whole cone of view is of about , the rest is blurred and it gets eventually reconstructed by focusing to a new point (hence, moving the eyes) and acknowledging more details, which is exactly the same mechanism when we read word by word (Cabezos Bernal & Manuel, 2015, p. 71; Casanellas, 2019; Chelsea, 2011; Wakayama et al., 2005).

However, the area of observation is not always obvious for certain anamorphs. For example, catoptric anamorphoses require a mirror to re-define the centre of projection and shape *back* the intended composition (Baltrusaitis, 1977; Wade, 2017, p. 7). Even if the interaction physical anamorphs through devices such as mirrors is possible and an interesting exercise, it is not on the scope of this work, the difference given by the fact that catoptric images are reflections and although they get easily confused with perspectives, they are not the same. In fact, a cylindrical or spherical perspective follows a two-step process: first, a radial projection from the environment towards the centre of the sphere, and second, the flattening of the cylinder or sphere (Araújo, 2018c, 2018a). Hence a spherical perspective image gathers every point of the visual information that can be seen from a certain point O. On the other hand, a cylindrical or spherical reflection is the flattened image of the visual information coming from the environment and reflected on the mirror, a different procedure that allows us to see visual information from the environment that cannot be seen in a perspective defined from O (Araújo, 2018c, pp. 167–168).

For some authors, altering the point of observation is what separates an anamorphosis from linear perspective: "In anamorphic art the appropriate viewpoint differs from normal or perpendicular to the picture planer" (Baltrusaitis, 1977; Wade, 2017, p. 7). Nevertheless, this is not the case, as we can also find linear perspectives with altered and even several points of view. In fact, we saw previously the solution proposed for the so-called lateral distortions of linear perspective, i.e., to ignore the actual projection and force the image to be in a certain way (Dane, 2011, pp. 147–155). This convention has been in use up to our days:

> "(…) at such moments (i.e., when spheres start looking like ellipses) the artist is obliged to overrule the mathematics to avoid apparent distortions, either by cheating or by making sure that the angle of view is quite narrow" (Dixon, 1991, p. 83).

Nevertheless, if we consider the projection of a sphere onto a plane, we will notice that its image will look like a circle only when the base of the visual cone (i.e., the cone composed by all the visual rays from the sphere to the eye) is parallel to the drawing plane (Figure 27, up, right). The image of a sphere will be an ellipse as per conic sections' definition in every other case which means that most spheres look like ellipses within linear perspective, and marginal distortions are the constant rather than the exception of the rule. In fact, if the observer looks from the projection centre O no distortions are noticed, even if we draw within an infinite drawing plane in front of the observer (Cabezos Bernal & Manuel, 2015, p. 137). If we replace ellipses with circles, we are altering the perception from O as we are creating an image with more points of observation. We can see this in Figure 28: the blue image is the actual conic intersection within the drawing plane, while the pink image is a perfect circle. The composition can be considered to have two observation points: one from O, or **linked vision** (*visione vincolata*), and another from somewhere else or **free vision** (*visione libera*) (O. Fasolo, 1980, pp. 50–60).

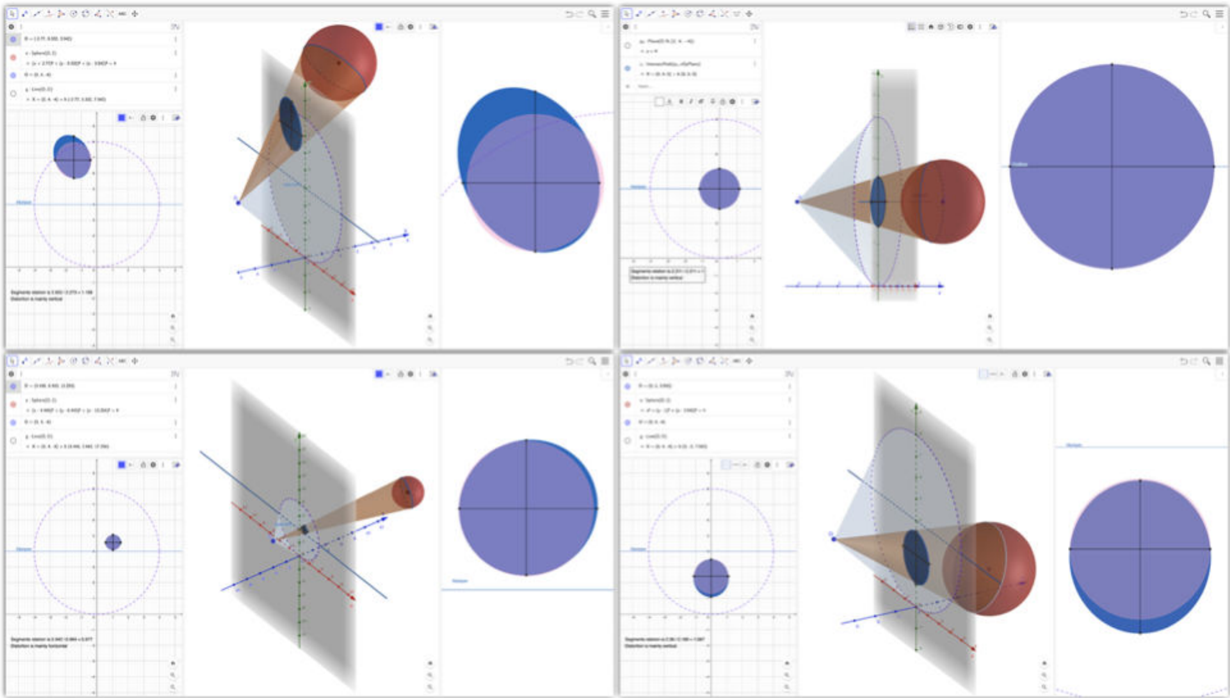


Figure 27: The conical projection of a sphere onto a plane will only look like a circle when the drawing plane is parallel to the base of the visual cone (up, right). In every other situation, the projection will look like an ellipse, as per conic intersections' definition.

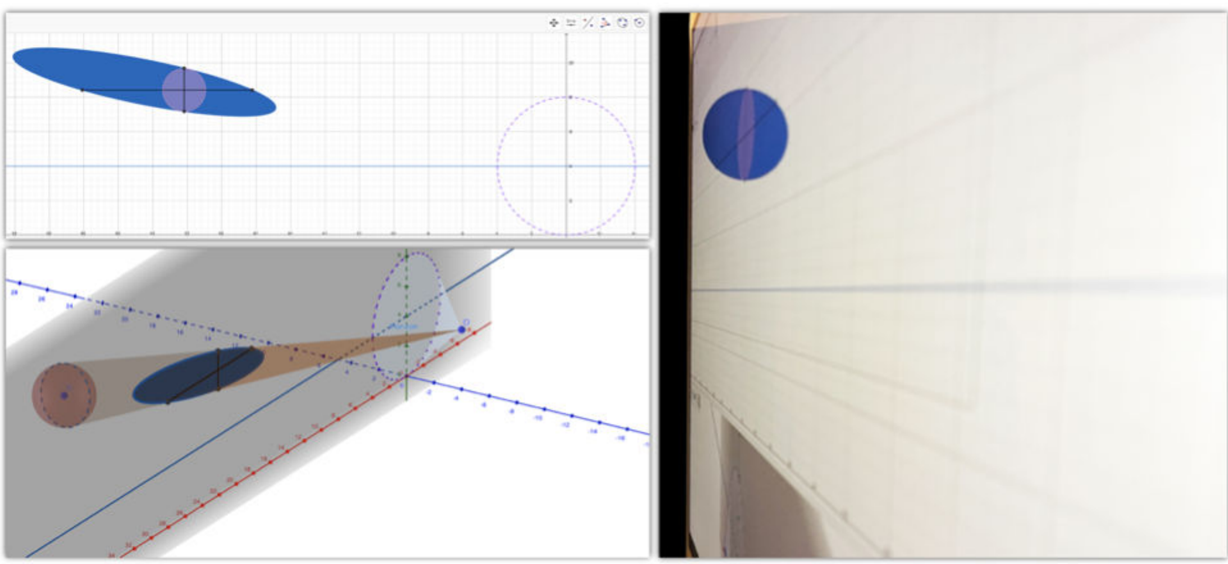


Figure 28: An extreme case with a sphere positioned in a very far away point to the left side of the observer.

In the free vision, Figure 28, left, up, the drawing is either a parallel projection and consequently the observer is placed infinitively in front of the drawing plane, or the drawing is a conical perspective and there is another observation point O_1 aligned with the sphere in such a way so to have a circular projection. Hence, in the free view the blue shape looks like a very elongated ellipse and the pink one is a circle. Within the linked vision instead the roles invert: the blue image looks like a perfect circle while the pink image looks like an ellipse (Figure 28, right). Therefore, if one forces spheres' images to look like circles (or columns to be equally wide, as in an architectural section), one gets drawings made with a mixed method, i.e., with part of the drawing defined by a conical projection while the other by either another projection or with a different projection centre. Notice that these aesthetic alterations might be conditioned by the purposeful decision of forcing a result as a cultural agreement of how those elements should look like (i.e., all spheres as circles, all equal columns in space with the same width); and/or simply for making things easier, as circles are simpler to draw than ellipses. Either case, we have smoothly incorporated and took this dual (or multiple) kind of compositions by linear perspectives, even if they are the result of the combination of different methods (Dane, 2011, p. 148).

Either case, it is true that the manipulation of the projection centre was deeply explored by the so-called *Quadraturisti* so as to accentuate certain perceptions, such as exaggerated depths or a delayed break of the illusion. A classic example of this is the solid perspective at *Santa Maria presso San Satiro* in Milan (Cabezos Bernal & Manuel, 2015, p. 138; Mazzoccoli, 2010, pp. 44–45). Instead, some other artists focused on the perception from one single point and the enhancement produced by projections defined by the strict theory within a larger field of view so as to compose a more effective illusion (Bortot, 2015, p. 120; Mazzoccoli, 2010, pp. 46–47, 52).

IV.4 - Interaction with digital anamorphs

We have seen the different possibilities for exploring physical anamorphs and how the different mechanisms they used brought us closer and closer to a fully immersive experience. Indeed, we have a limited view from the area of observation when the anamorph is made on a plane; a wider and more physical embodiment of the experience with solid perspectives made by a mix of drawing and architecture; and a full rotating view from the central stage when inside a Panorama building. Digital technology however, extended the content and added more degrees of freedom to these possibilities, turning the immersive model into a set that allows the observer to move around freely with either 3 or 6 degrees of freedom (called 3-dof and 6-dof respectively). This means that we can use surfaces surrounding the observer (such as the sphere and the cube), place the observer inside and interact with the content either with a full rotation and tilt around the observation point (e.g., immersive drawings); or with full translation and rotation (e.g., 3D models). I will reduce the state of the art to the first group, according to the scope of this thesis.

Right as it happened with physical creations, digital immersive experiences place the observer physically inside an installation or develop within a smaller device placed in front of their eyes (Grau, 2003, p. 349). Although the developments of this thesis fall within the second group, understanding the first group might help us to open new ways of future collaboration.

Within the first group, some current video installations, such as M.O.D.E. (Reichenbach, 2018) and Pacific Dome (Digital, 2016, 2018), use digital technology and the same idea behind the old Rotundas/Cyclorama and the solid perspectives of the Renaissance, meaning, reinforce and accentuate the immersive experience through the architecture. In this case, the partial (M.O.D.E.) and the full spherical (Pacific) surfaces are canvases where a video gets projected. Compared to a Panorama/Cyclorama, these video installations give probably a less effective and more limited immersive experience since: spectators are more conditioned to freely move or rotate (in the first case they sit and only move their heads, in the Pacific case they move in straight line by crossing the sphere through a walkway); and the linked vision from the centre of projection is more conditioned (by the location of their seat regarding the dome in the first case, and is only available at the centre of the walkway in the second case). The streamed content within these installations is either obtained from full panoramic videos (i.e., predetermined paths within a 3D model or a material environment); or from video collages and digital compositions. In this latter case, the content might not be always adapted to the projecting surface and carry further problems for the installation, which can be solved by better understanding concepts of spherical projections or, in other words, the contents and theory stimulated by this research (Tran Luciani, 2019; Tran Luciani & Lundberg, 2016; Vistisen et al., 2019). Hence, we can say that within these installations the immersive illusion is easily broken in terms of conical projection accuracy. Yet their content is visually impressive and dynamically all-enveloping, provoking a surrounding experience with big impact at the cost of less accuracy, which provides a fertile field for the development of further possibilities and applications for Handmade Immersive Art.

Turning towards the digital immersive installations placed in front of the eyes, I defined in Part I, Chapters I.5 and I.6, how a virtual environment is setup with different projecting surfaces and mentioned that the content has to be a map adapted to such surface for the content to be correctly visualised. In the case of the sphere, we can use several different formats of spherical maps, such as the azimuthal-equidistant (also known as fisheye) or the equirectangular projections. In the case of the cube there are variations such as the regular opening of the cube, known as cubemap projection, or one strip gathering all the six faces, known as cubestrip projection. Regardless which of these projections are used, the position of the observer is always at the centre during the rendering process, and this remains unchanged during the whole interaction as the camera rotates or pivots around O, except if the visualiser is purposefully programmed to allow more than 3-dof. If such is the case, the content will start looking out of place until the visitor might see the sphere from outside, such as it happens with the physical objects (component M3) of the Hybrid Immersive Model. Some projects have played with the movement of the observation point for going even further and forcing a VR stereoscopy, creating an even closer experience to 3D perception. This is accomplished through different mechanisms while using VR glasses, such as fake parallax shift (i.e., slightly deviating O for the right and the left eye, Figure 29), by cropping the images, by simulating a binocular disparity shifting the orientation of the view, etc. (Cabezos Bernal & Cisneros Vivó, 2016, pp. 79–80; Kolor, 2018; Rebecca, 2021).

```
<vrheadsets>
    <headset name="cb1" caption="Cardboard 1"   fov="96.0"  dist="0.60" dist2="1|0|0|0" ca="0.000" vig="100" overlap="1.00" />
    <headset name="cb2" caption="Cardboard 2"   fov="96.0"  dist="1.00" dist2="1|0|0|0" ca="0.000" vig="100" overlap="1.10" />
    <headset name="gvr" caption="GearVR"        fov="112.0" dist="0.95" dist2="1|0|0|0" ca="0.090" vig="100" overlap="1.00" />
    <headset name="one" caption="VR ONE"        fov="109.9" dist="0.00" dist2="1.139|0.093|0.018|0.207" ca="0.090" vig="35" overlap="1.00" />
    <headset name="hom" caption="HOMiDO"        fov="101.0" dist="1.10" dist2="1|0|0|0" ca="0.075" vig="100" overlap="1.00" />
    <headset name="ccr" caption="ColorCross VR" fov="70.0"  dist="0.65" dist2="1|0|0|0" ca="0.000" vig="100" overlap="1.00" />
    <headset name="nod" caption="No Distortion" fov="96.0"  dist="0.00" dist2="1|0|0|0" ca="0.000" vig="100" overlap="1.00" />
</vrheadsets>
```

Figure 29: Different values of overlapping, distances, field of view, etc., for forcing a stereoscopy when using VR glasses. Source code of PanoTour Pro (Kolor, 2018).

During the interaction with the virtual environment, the field of view can be regulated by operating the software via mouse scrolling, different combinations of keys, or using body tracking gestures as it happens with the installation Spheri (see PART IV - Chapter III.8). Thanks to these characteristics of the digital setup, the discussion about apparent distortions of the content, points or areas of observation, etc., gets simplified: the user is not passive anymore, but chooses actively and to their own interest the best spot to observe the content. If the content has been correctly created, then the anamorph will look in its most favourable condition per default during the VR navigation. This implies that there is no need to alter figures such as spheres so to make them look always as circles, on the contrary, we must follow the theory of the projection strictly if we want to have the *right* rendering. Nevertheless, differently to what happens with most physical anamorphs, we now have the two points of observation - linked and free vision - as two separated products within a Hybrid Immersive Model: the linked vision, given by the digital environment (component M2); the free vision, given by the flat artwork (component M1); and a further free vision of a 3D physical object with the spherical perspective wrapped around it (component M3). Consequently, **the Handmade Immersive Art is an experience for understanding an artwork from three different and materialised points of view, giving one more tool to artists to express their concepts and to visitors for discovering the hidden dimensions behind the piece of art.**

V - Methods for creating anamorphs

Anamorphs can be **directly created** on the target surface or traced onto it by **re-projecting a reference drawing**, i.e., by doing an anamorph of an anamorph. For creating the initial drawing, we follow the rules of a certain conical perspective (e.g., linear perspective, equirectangular perspective, etc.). Until the introduction of spherical perspectives in the mid of the 20^{th} century, the creation of anamorphs was limited to linear perspective methods, and hence to its same limitations, such as the restriction of the predetermined cone of view. The Panoramas started to break this limitation by merging several linear perspectives in a cylindrical canvas, up to covering 180° around the observer but their methods were mostly *ad-hoc*.

With the arrival of digital technology and the development of spherical and cubical perspectives, the limitation on the content that can be seen from a certain point O disappeared. Furthermore, the use of projecting surfaces, such as the sphere or the cube, allows a gathering of the visual information with a different dynamic to the plane, as well as the introduction of different and new methodologies for composing the drawing. Let see briefly some of the details behind these methods.

V.1 - Linear perspective

Within the discipline of graphic representation, linear perspective's development stands as a first approach to projective geometry, occupying a big place among the theoretical, practical, and philosophical developments of the field (Candito, 2010). During the 15th century, Filippo Brunelleschi defined its practical principles through an experimentation in which he overlapped an architectural project (i.e., a non-existing, immaterial idea) on top of a reflection of the Baptistery of Florence (i.e., a physical, existing building). Two basic principles for the construction of a linear perspective were deduced from Brunelleschi's experiment: first, straight and parallel lines in the physical world, will look as straight lines converging to one point in the representation; second, it is possible to calculate the decreasing of the physical dimensions in proportion to their distance to the observer by fixing the point of observation and one point of distance (Chiappelli, 1896). The mathematical properties of this experimentation were later generalised and formulated by Leon Battista Alberti (Kemp, 2000, p. 158; Wade, 2017, p. 6) and since then, perspective became a mimetic resource of preference:

> "From the Renaissance onwards, (linear perspective) became, for centuries, the only criterion for constructing a figurative space, at least in the West" (Masetti, 2014, p. 15).[5]

Brunelleschi's experiment had further implications: he surveyed the building as it was and without personal interpretations, and he pushed observers into a specific direction, giving them a focus to see his idea or, in other words, the exercise was a way of documenting the culture of the moment and manifesting the intentions of the artist through the use of linear perspective (A. Rossi, 2005, pp. 24–27). Hence, although linear perspective has often been confused with "the way we see" (see PART II - Chapter III), its validity is not on its successful imitation of the human vision, but on the systematic methods for emulating depth, which gives us a *known* familiarity while perceiving the result, and helps us to understand the scene more naturally (yet not *as* the natural) (Ching, 2016, p. 54). Furthermore, linear perspective deals with the observer's physical and psychical limits: the visual sensation and the visual perception, a big intellectual complication while creating an anamorph:

> "The challenge in mastering linear perspective is resolving the conflict between our knowledge of the thing itself - how we conceive its objective reality - and the appearance of something - how we perceive its optical reality - as seen through a single eye of the observer" (Ching, 2015, p. 108).

In other words, the eye processes the light coming from the physical objects, yet their perception is an intellectual act in which the mind participates actively rationalising and giving meanings to such images.

[5] Translation by the author. Original quote: "*A partire dal Rinascimento questo metodo diventa, per secoli, l'unico criterio per costruire lo spazio figurativo, almeno in Occidente*".

After Alberti, many authors including Filarete, Piero della Francesca, Giorgio Martini, Leonardo da Vinci, Albrecht Dürer, Ignazio Danti, Iacomo Vignola, etc., explored more than 20 theoretical and practical methods that were developed and tested through a combination of Euclidean geometry, optics and surveying, separating the *Perspectiva artificialis* from the *Perspectiva naturalis*, the former providing geometric constructions to create a flat image simulating depth, and the latter dealing with physical and physiological aspects involved in the act of seeing (Candito, 2010, p. 37; Vagnetti, 1979; Veltman, 1996). From within this panorama, two main methods stood out and developed until our days: the **geometric construction** and the **legitimate construction**, either method producing the same result, although back then they were used for different purposes (Candito, 2010, pp. 153–156; Katinsky, 2000, pp. 559–601; Veltman, 1996, pp. 407–411). Nowadays, the **geometric construction** is associated to a method using diagonals and points of distance. Back then, it was more often used to create simpler geometries, such as spatial context elements (pavements, walls, etc.). In turn, the **legitimate construction** is a more mechanical method using what is known today as floor plan and elevation. This method was generally used to represent more complex geometries as it avoids the stacking of lines within intricate representations (Della Francesca, 2016; Romor, 2015, p. 25; Veltman, 1996, p. 409). The legitimate construction fathered the Architect's or Projecting Planes methods. It became the more common method through time thanks to "Leonardo's practical demonstrations (…), a tendency confirmed by Serlio and codified by Danti in his commentary on Vignola's Two Rules of Practical Perspective" (Veltman, 1996, p. 412). More recently, several scholars including Girard Desargues, Guarino Guarini, Amédée François Frézier and Gaspard Monge have contributed to the polishing of linear perspective methods and its more modern merging with descriptive geometry studies, becoming an autonomous chapter of the so-called Sciences of Representation (Comolli, 1791; Docci et al., 2017; Docci & Migliari, 1992, p. 272; Germinal Poudra, 1864; Loria, 1921; Vagnetti, 1979). From within this panorama, we see that linear perspective has been largely studied, worked out and documented, both in theory and in practice, with the development of several methods. This full development will be of much help during the creation of our spherical perspectives within the following chapters. In fact, all these principles find new interpretations within the logic and dynamics of spherical perspectives.

V.2 - Anamorphs of Anamorphs

After the settling of the first methods for creating linear perspectives, artists experimented to conically re-project anamorphs onto combinations of surfaces other than the plane or, in other words, they researched how to do an anamorph of an anamorph. Three of the most common mechanisms include: **the use of reference grids**, **physical aids** (e.g., using needles as visual rays, placing physical grids, etc.) and **the use of light projections** (Camera Obscura and Camera Lucida). In general, the final surface (or combination of surfaces) does not have a particular role in the creation of the anamorph within these practices, since the reference drawing is either made by following linear perspective's methods or capturing "a photography" of the place, hence the subsequent anamorph also inherits both the advantages and limitations of using conical projections onto a plane.

During the Baroque, the use of **reference grids** gave birth to an artistic movement called Quadraturism, which name derives from *Quadrettatura* (i.e., squaring, gridding). In practice, these artists traced a reference grid on top of a reference drawing, then created a grid on top of any combination of surfaces, and translated the content (Bortot, 2015, p. 120; Cabezos Bernal et al., 2014, p. 149; Quadraturismo, 2020; Quadraturisti, 2020). The investigation carried out by this group of artists was - with the due historical differences - art-practice-based research involving geometry, optics, architecture, and arts (Mazzoccoli, 2010). Their work has been documented within several treatises (Barbaro, 1569; Nicéron, 1638; Pozzo, 1693; Pozzo & Panini Editore SpA, 1691; Vignola, 1583) and more recently by historical and critical analysis (Cabezos Bernal & Manuel, 2015, Chapter 6). The grid was used either for amplifying anamorphs (e.g., churches, walls, corridors) or for reducing them (e.g., Perspective Boxes) (Bortot, 2015; Callandriello, 2015; Mazzoccoli, 2010). In some cases, artists used extra physical aids in addition to the grid. For example, Andrea Pozzo placed a physical replica of the grid right before the final surface, then he recreated a visual ray from the observation point by means of a wire, and re-traced the grid onto the final surface, sometimes even attaching lighting mechanisms to the wire to cast the grid's shadows (Figure 30) (Candito, 2010, p. 53; Pozzo, 1693, pp. 220–221). Yet, Pozzo did not always follow the rules at their maximum extent, as he modified some references on-the-fly to play with a "perceptual dynamism", meaning the involvement of the visitor both as an observer and as an actor observed within a scene covering the whole horizontal visual experience (Bortot, 2015, p. 121; Callandriello, 2015, p. 131). Nevertheless, the practice of magnifying anamorphs had the disadvantages of requiring big infrastructures and, as every combination of surfaces needed a different arrangement, the process resulted in an *ad-hoc* procedure made by highly specialised artists, which reduced the availability, raised production costs, and limited the practice to only few artists (Huhtamo, 2013; Kemp, 1992, 2000; Markman, 2008).

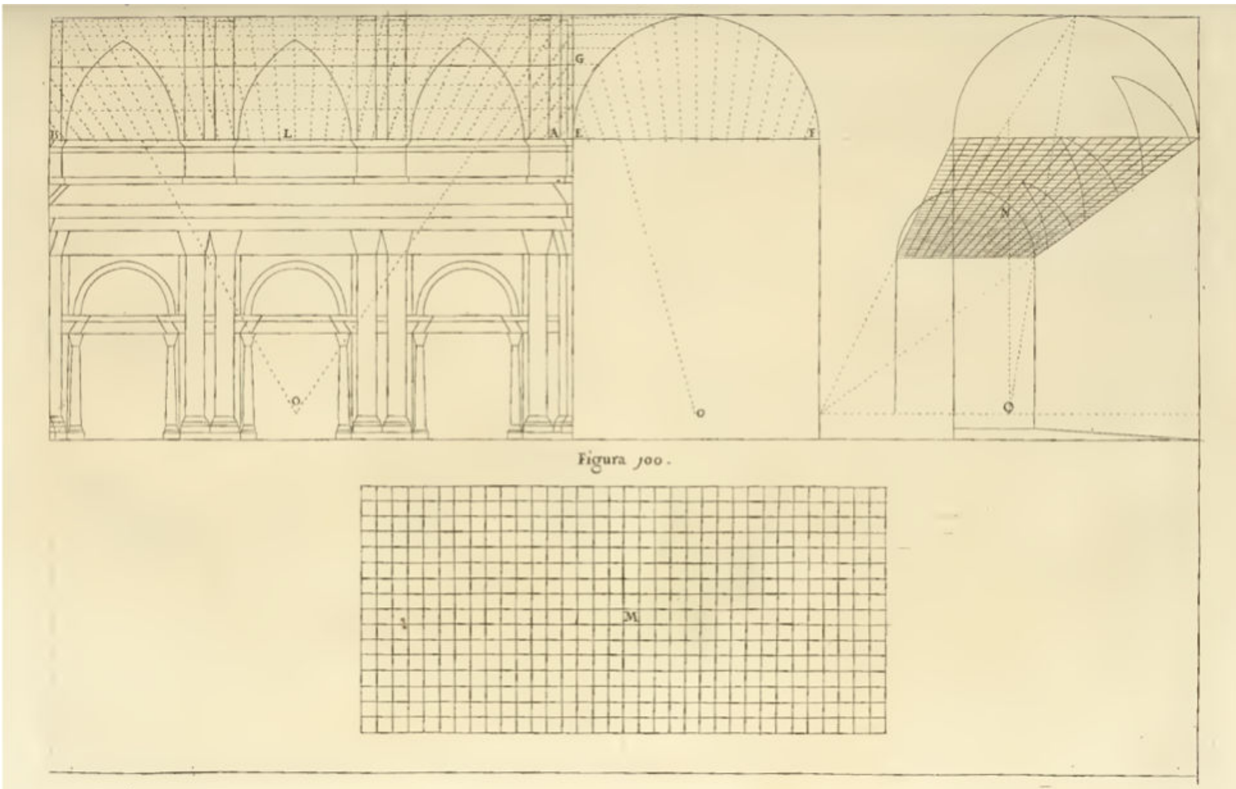


Figure 30: Reference grids by Andrea Pozzo. Image with public licence (Pozzo, 1693, p. 220).

Another **physical aid** to project the image was the use of needles, a mechanism specially used within small devices such as the Perspective Boxes. These devices promoted a first-person experience while drastically reducing the size of the installation within a small polyhedral box (parallelepiped, triangular, octahedral, the choice left to the construction simplicity or the requirements of every case) (Gay & Cazzaro, 2018, p. 9; Spencer, 2018, p. 4; Verweij, 2010, p. 47). A Perspective Box intended to immerse observers by placing a scene right in front of their eyes and shutting down every other image of the real world (Grau, 2003, p. 52). The scene was painted in the inner part of the box's walls and had a diffuse lighting source coming from above. The main problem for its construction was handling the projection of a line falling in more than one wall which, due to the change of direction of each plane, resulted in a fragmented representation. To solve it, artists considered the "Euclidean theorem that if two straight lines meet at an angle, they appear to be continuous if viewed on the same level" (Grau, 2003, p. 52). This theory was carried out in the practice by puncturing through a linear perspective with a needle coming from the peephole and using it as a ray of light to pinpricks reference points within the walls of the device (Grau, 2003, p. 52). Still, this method required a local arrangement for every device and for every pair of walls, not giving a general solution for completing the drawing in the flat (i.e., with all walls open) which would have been the simplest option aimed, but solving locally every particular case. In fact, most of the scene of Perspective Boxes was composed using the needle within the closed box, and further objects (people, animals, objects) were added to cover errors on the composition or conflictive zones, additions which much probably did not follow clear perspective structures as they looked out of place, sometimes even breaking the illusion more than enhancing it (Grau, 2003, p. 52).

The third mechanism, i.e., the use of **light projections** through the principles of photography was explored by many artists for both linear perspective compositions (e.g., Canaletto) and also within the Panoramas. In fact, the first Panoramas were anamorphs created by: first, drawing maps and calculating known points using mathematics and survey techniques; second, manually gluing together several drawings made in-the-spot using descriptive geometry; and third, translating the drawing to the cylindrical canvas using a system of curves that looked undistorted when seen from the stage (Bordini, 1984, p. 75; Grau, 2003, p. 56). However, during the 19^{th} century, the Panoramas were a flourishing business and, as technology progressed, it also did their production workflow and so new machinery, such as the Panoramagraph (1803), the Camera Lucida (1806), Diagraph (1830), Daguerrotypy, and photography were introduced and/or developed, automatising the procedure and giving more realistic results (Andjelkovic, 2020, pp. 22–23; Grau, 2003, p. 56). With the introduction of these devices, the production workflow switched to a first photography taken in the place to be represented; a drawing traced on top of the photography; a further photography of the drawing; a projection of the mixed result onto the cylindrical surface, and its tracing while visually guided by a director from the observation stage(Bordini, 1984, p. 75; Grau, 2003, p. 115). This workflow, mixing art-practice-based research, mathematics and visual empirical methods, simplified many tasks linked to the colossal dimensions of the Panoramas (by the time, with a norm around $2000\ m^2$, according to Grau (2003), p. 119). Nevertheless, as the first acquisition was not drawn but captured from reality and the use of devices such as the Diagraph compensated the curvature of the cylinder guiding mechanically the tracing of lines, this chain of production eventually led to creations lacking full knowledge in perspective and made with only basic drawing skills (Andjelkovic, 2020, pp. 22–23; Grau, 2003, pp. 115, 119).

V.3 - The M1 component: spherical perspectives

Until here, we saw that the first anamorphs (either as final artwork or as a reference anamorph) were drawings made with linear perspective methods or photographs made through light projections. These two mechanisms use and limit themselves to the plane as a projecting surface. Within the Panoramas, the anamorphs' workflow changed to follow the development of a cylinder, yet in many cases the final adjustments were made visually on-the-fly within the cylindrical drawing already mounted (Grau, 2003, pp. 115).

During the 20^{th} century the sphere and the cube were introduced as projecting surfaces. The change was substantial, as for the first time a projecting surface covered the observer entirely. This pushed (and keeps pushing) further developments in the field of graphic representation, opening new research lines in drawing methods that dive into a full or a partial use of these surfaces (Correia et al., 2015; Santoyo & Santoyo, 2021; Barre & Flocon, 1967; Casas, 1983; Moose, 1986; Chelsea, 2011; Araújo, 2018a; Araújo, 2018a; Olivero, 2021; Olivero et al., 2019; Olivero & Sucurado 2019).

But guiding the results from a central stage within a spherical or a cubical building (as with the Panoramas) is far less practical and still does not solve some core problems. In fact, if we draw within the closed surface of a cube for example, we will be facing the same problem than in the Perspective Boxes again (i.e., the fragmentation) and with the same incomplete solution.

Nevertheless, with the arrival of the computer both cube and sphere started to be used for the generation of virtual environments, and because the digital input is always a flat image (a map), then methods for *drawing* a flat spherical or a cubical perspective were developed. Let's see their state of the art and some of the best and more complete methods for the **equirectangular perspective**, the **azimuthal-equidistant perspective (or fisheye)** and the **cubical-spherical perspective**.

V.3.1 - Equirectangular perspective

The equirectangular projection is obtained by opening and stretching the poles of a sphere until having a cylinder with the same diameter as the equator, then the cylinder is cut vertically through one meridian and unrolled until is entirely flat. Within this projection, meridians look like vertical straight lines and circles of latitude (parallels) look like horizontal straight lines within the flattened map (Equirectangular Projection, 2021) (Figure 31). Latitude parallels and meridians are two kinds of lines much used in cartography, and the utility of getting them as straight lines within an equirectangular map is very useful to such a purpose. On the other hand, the flattening of any other kind of line is not such a straightforward process or, at least, not until we know the full theory. Nevertheless, drawing within the equirectangular map has a wide variety of methods, from the most **basic guidelines** up to **full systematic methods**.

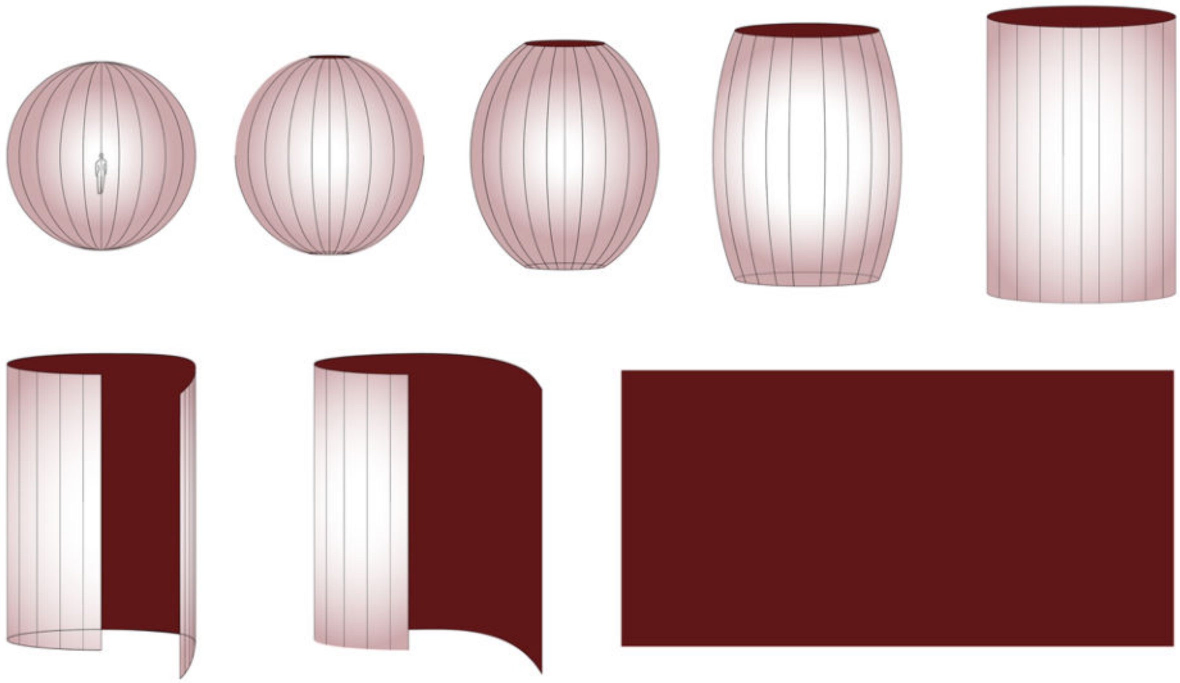


Figure 31: Development of an equirectangular perspective: the visual sphere surrounding the observer is blown up in the upper and bottom poles, opened into a cylinder, and flattened.

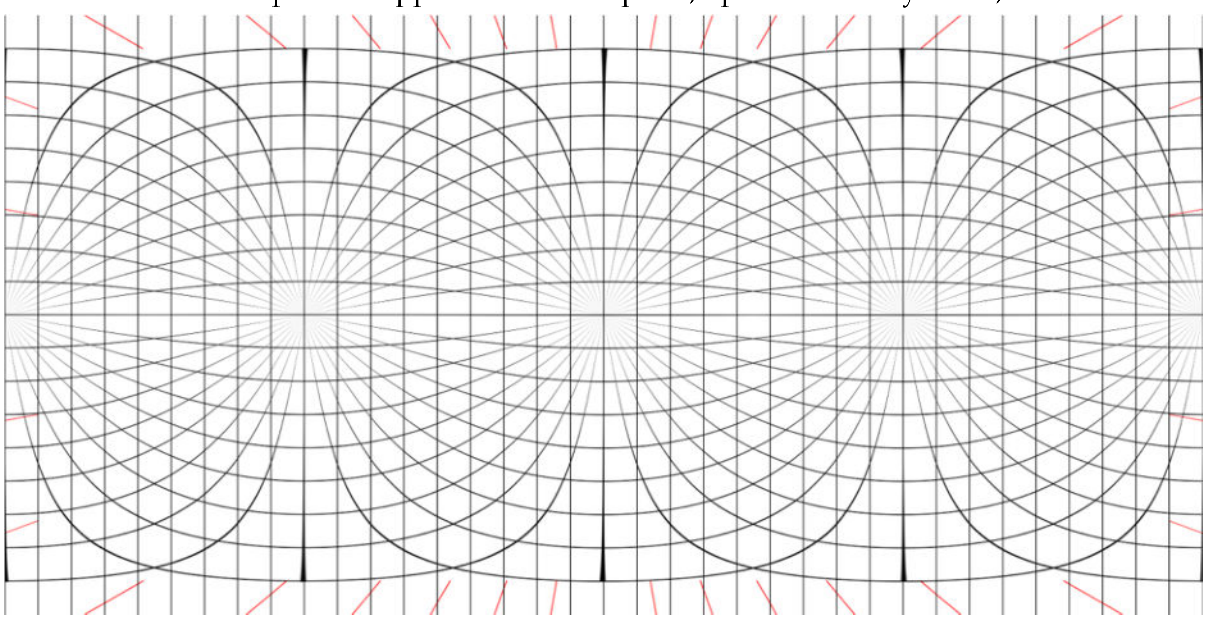


Figure 32: The grid from David Swart's website (Swart, 2016) is one of the most spread equirectangular grids on the Internet. It is often used for explaining the basics of equirectangular drawing, although the theory of why the grid looks like that, and the concepts of spherical perspective are not always properly explained.

Among the **basic guidelines**, we have several sources from tutorials up to commercial startups (ArtStation, 2017; Hohler, 2025a, 2025b; Kurbatov, 2017; Sandnes, 2016b, 2016a, 2016b, 2016a; Sandnes et al., 2017, 2017; Swart, 2016; Theng Seng, 2018). Many of these projects do not deal with the full theory of spherical perspectives, and it is neither guaranteed that their tutors understand it entirely, even if they are fluent in drawing within the equirectangular map. This happens because, right as it occurred with the automatization of the workflow for drawing the Panoramas, several of these tutorials are software dependent and so many times the instructors trial-and-error features offered by a certain software tool or a grid they found on the Internet, promoting the spectacular aspects of the panoramic drawing as an exciting novelty rather than as a consequence of thinking in space, finding analytical solutions and materialising them through drawing. These results are functional but limited: the outputs rely on visual feedback so they might look more or less right although they might not be entirely correct. In fact, many times they reveal the lack of the deep understanding of the theory and the limits of their application. One example of this limit is the use of a basic grid (Figure 32) which is understood as having six vanishing points. However, by a deeper understanding of the theory of spherical perspectives, one will know that it is possible to find infinite pairs of vanishing points by simply sliding the same grid left and right (see António Araújo's method below).

These first guidelines are very helpful for understanding the difference between a linear and an equirectangular perspective in the practice (Olivero & Sucurado, 2019), yet most of the time they fail in transferring complex shapes, proportions, planes not falling within the grid, etc. (Figure 33). Either case, all these resources offer a solid pack of tools and workflows, opening a very valuable first door to artists interested in full panoramic drawing and allowing their practical experimentation straight ahead.

In the side of **systematic methods**, developed following concepts of perspective, we find: Gérard Michel, who calculates and hand draws his grids (Figure 34) (Michel, 2013, 2018b, 2018a), cartoon-based practical tutorials for artists (Chelsea, 2011), books for architects and designers (Marrazzo, 2018), and mathematical integrations and development of spherical projections and scenography (Masetti, 2014). All these methods open a wider gamma of possibilities for drawing equirectangular panoramas, and they also go further by helping their readers to understand the projections in space and the descriptive geometry behind them. This better understanding and knowledge give more freedom to artists for express themselves, as they remove some limitations. For example, Gérard Michel draws with the most common vanishing sets of the grid (Figure 35), but he can also go beyond creating new guidelines to solve in-the-spot whichever situation he finds himself in, including other geometries such as inclined planes and with more random distributions (Figure 36).

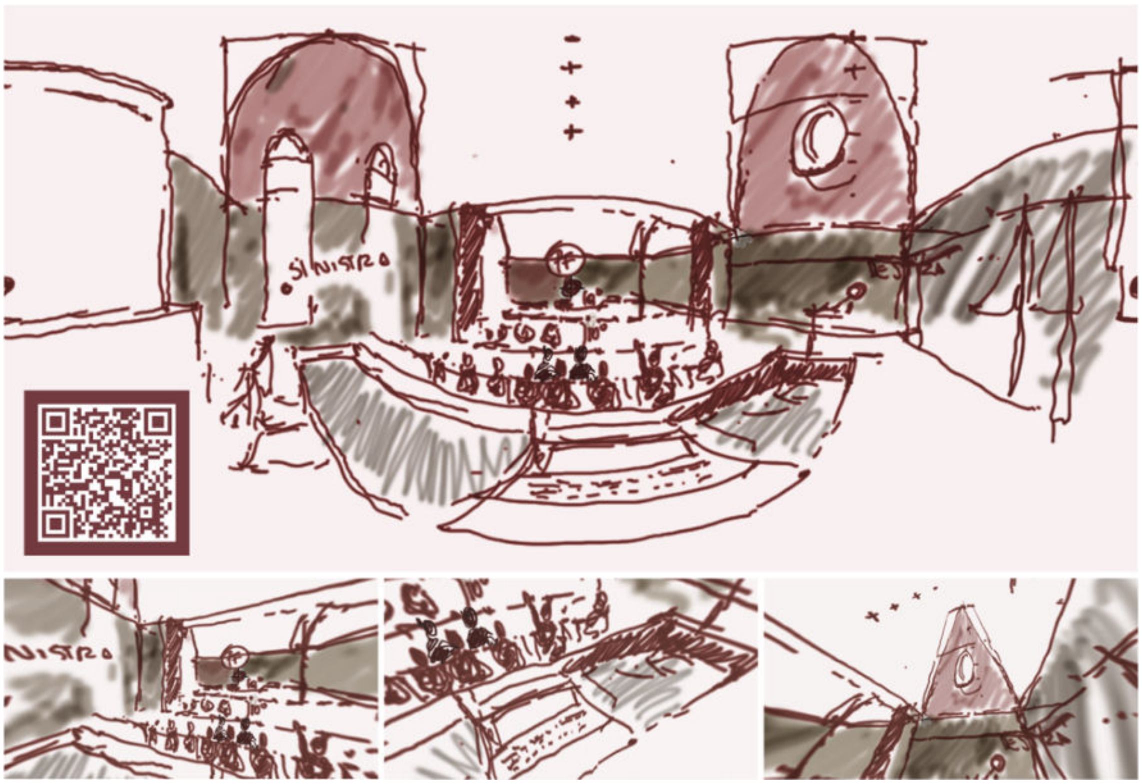


Figure 33: Early self-experience following the grid and basic guidelines for equirectangular drawing. As can be seen, the drawing fails to represent arcs with the right shape and proportion within the VR environment (down, right). The failure highlights the limitation of the knowledge in spherical perspective. Aula Magna, University of Campania © Lufo Art (Lucas Fabian Olivero), 2017.

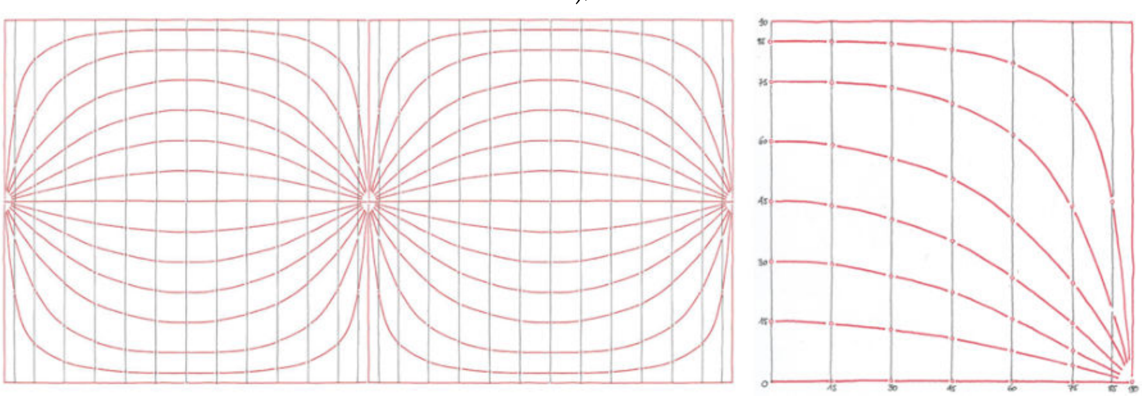


Figure 34: Self calculated and constructed equirectangular grid (left). Detail of the intersections (right) © Gérard Michel, 2018.

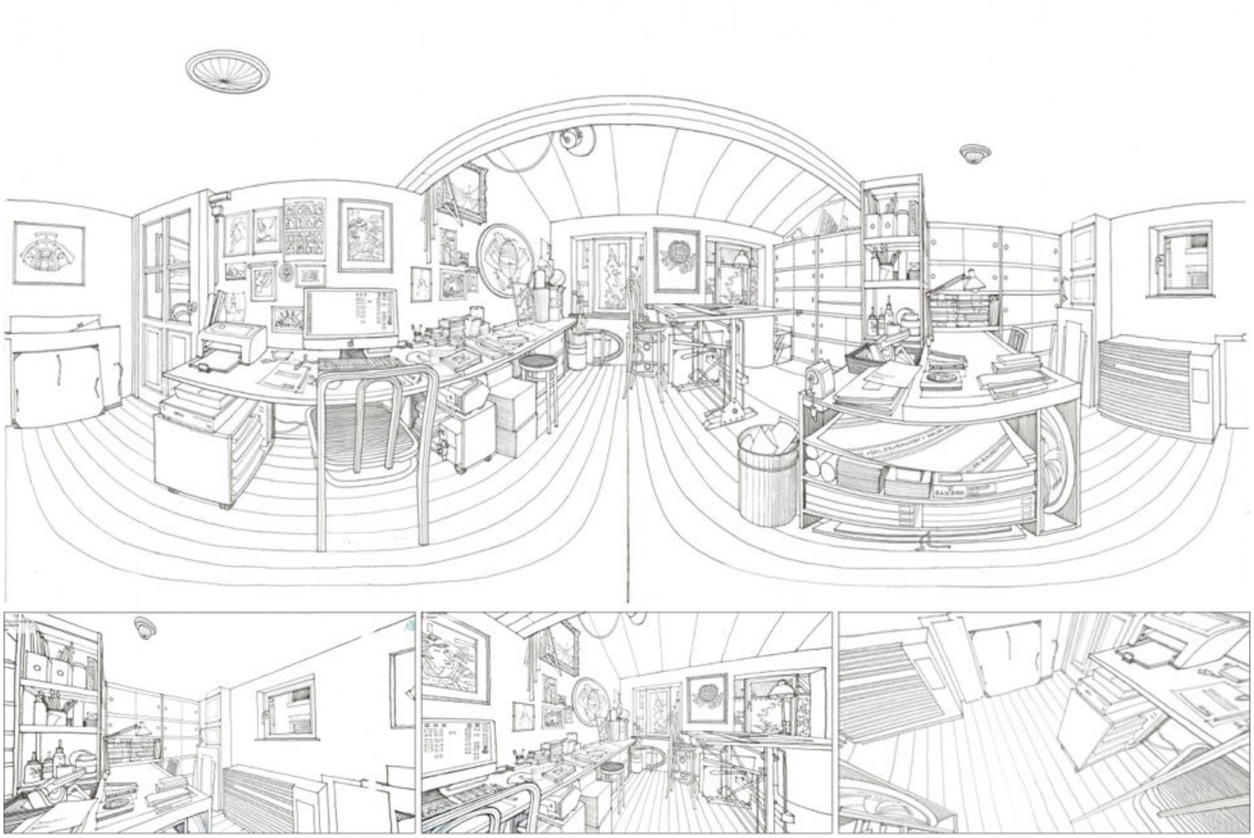


Figure 35: Equirectangular panorama and VR navigation © Gérard Michel, 2018.

A further systematic approach uses the scheme introduced in Part I, Chapter I.5, namely: consider a sphere S centred in O, then first, **project conically the environment towards the centre of projection** O, and second, **flatten the surface to create a map** (Araújo, 2015, pp. 1–6; 2018c; 2018a; 2021b, p. 14; Araújo et al., 2020). The first step defines an **anamorph onto the sphere's surface** (materialised by the component M3 of the Hybrid Immersive Model), while the second step defines a **spherical perspective** (component M1). This scheme was used as a canonical case, a reference from which every spherical perspective (equirectangular, azimuthal-equidistant, cubical-spherical) has been treated as a special case of it (Araújo, 2018c, 2018a; Araújo et al., 2020). Note, that a spherical perspective will not be an anamorph of the represented environment until is folded back on the spherical surface and watched from O. While following this scheme, we can notice that every segment $\overline{AB}$ in space projects as an arc of a great circle (geodesic) of the visual sphere, and that the spatial line that contains it, $l = \overline{AB}$, projects as a unique half of a great circle with exactly two mutually antipodal vanishing points on the sphere (Araújo, 2017b, p. 17; 2021b, pp. 9–12; Masetti, 2014, p. 127). During the second step, the arcs of geodesics are flattened following the rules of the map in question.

Hence a good filter for separating basic guidelines from systematic methods is through the key question: **how to plot the image of a geodesic from only two given points?** Araújo (2018a) replied to this question developing a method that allows the plotting of any kind of line within the equirectangular map: the image of a segment $\overline{PQ}$ can be found by measuring the angles of P and Q either from direct observation or from a floor plan and section; plotting them within the equirectangular map; and sliding the grid until one geodesic joins them (Figure 37). The flattened geodesic joining P and Q is the only possible geodesic passing through them, and hence it is the correct curve representing the equirectangular perspective image of $\overline{PQ}$ (Araújo, 2018a, p. 25). Furthermore, Araújo (2018a) also develops what Gérard Michel does, namely, the creation of a generic equirectangular grid using compass, ruler and protractor (p. 21). The results of Araújo's method can reach a very high complexity, even within a small DIN A4 drawing (Figures 38, 39).

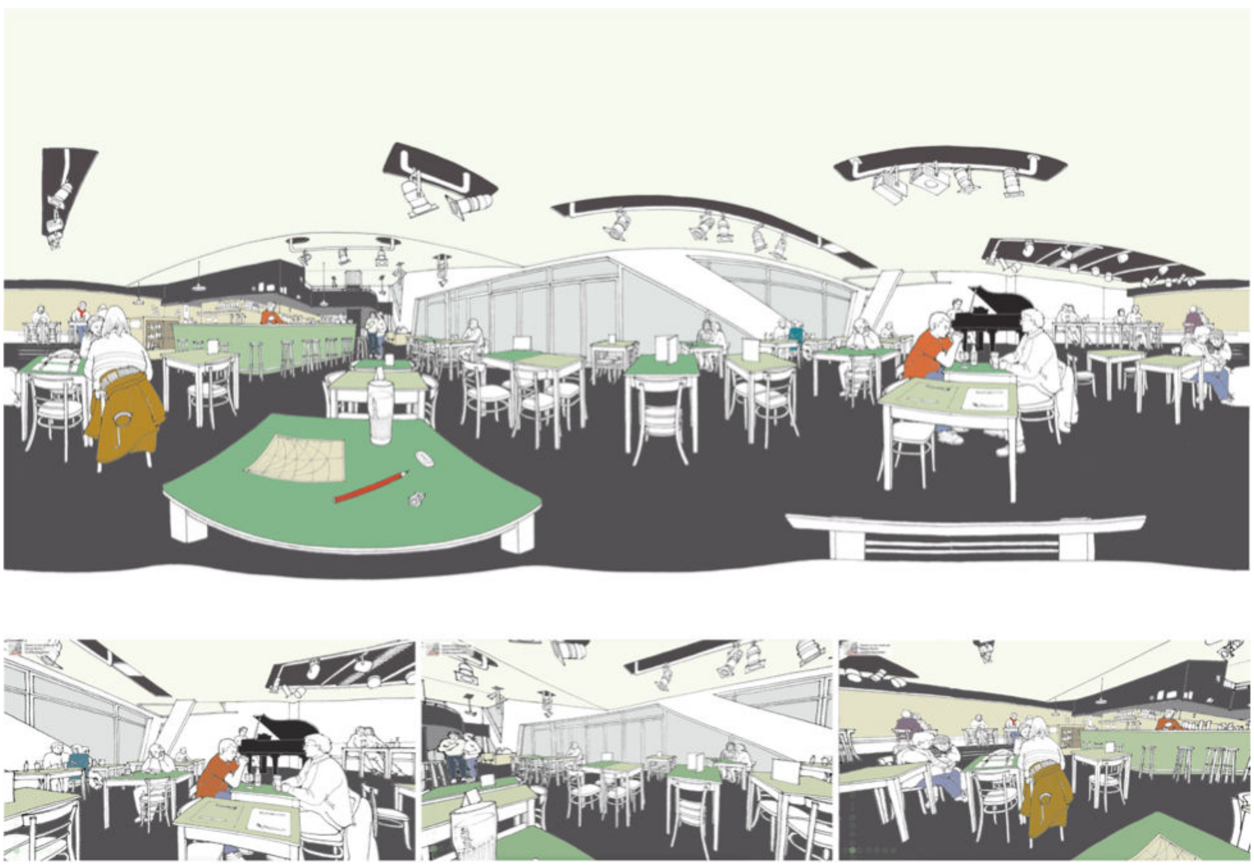


Figure 36: Equirectangular panorama and VR navigation © Gérard Michel, 2018.

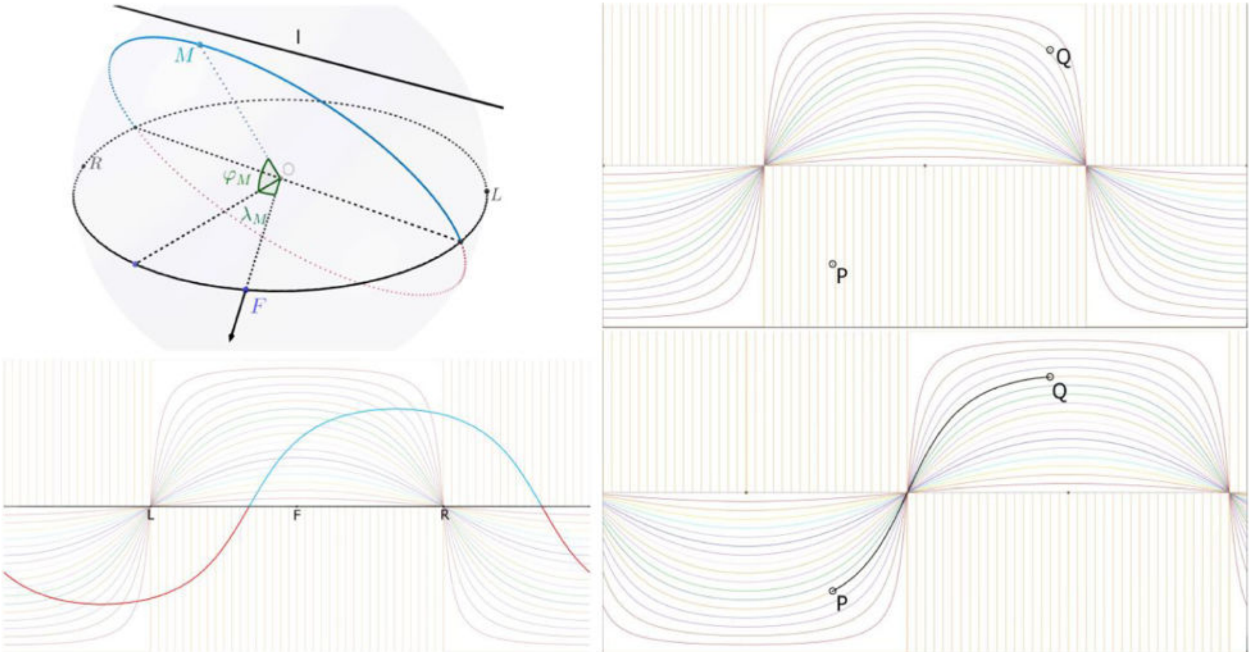


Figure 37: A line l projects as the half of a great circle (left). Given two random points P and Q within the equirectangular map, there is just one geodesic passing through them (right) © António Bandeira Araújo, 2018 (Araújo, 2018a, p. 25).

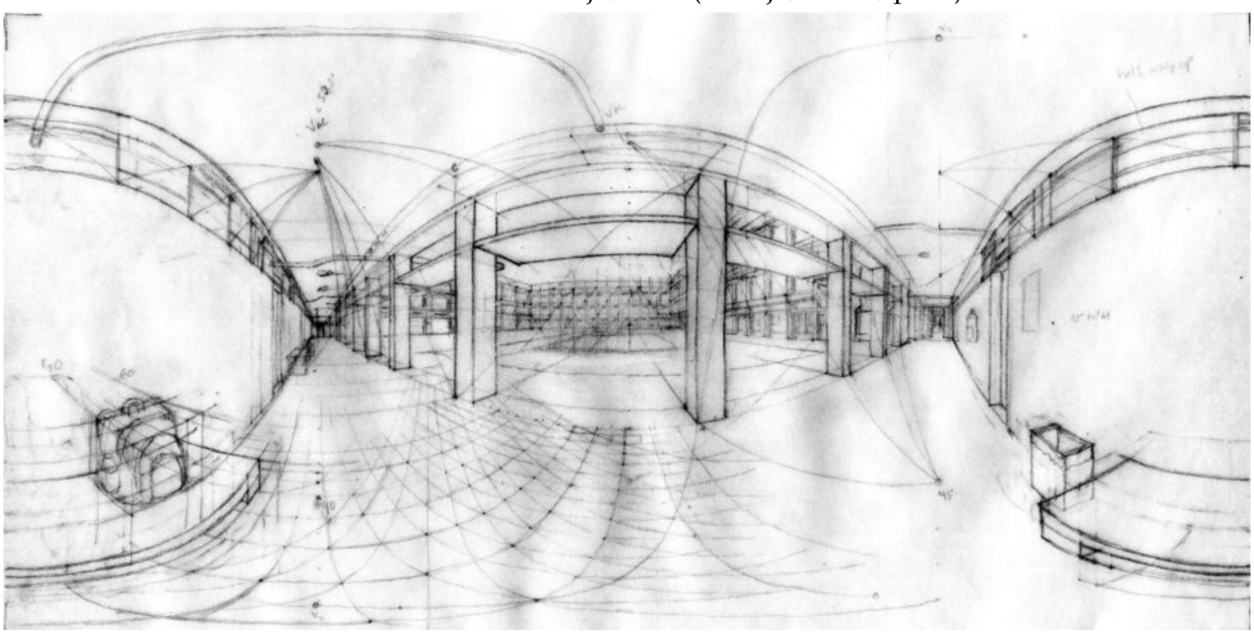


Figure 38: Inner structure of the vanishing points and descriptive geometry constructions behind the artwork Courtyard at ISEL School of Engineering © António Bandeira Araújo, 2018.

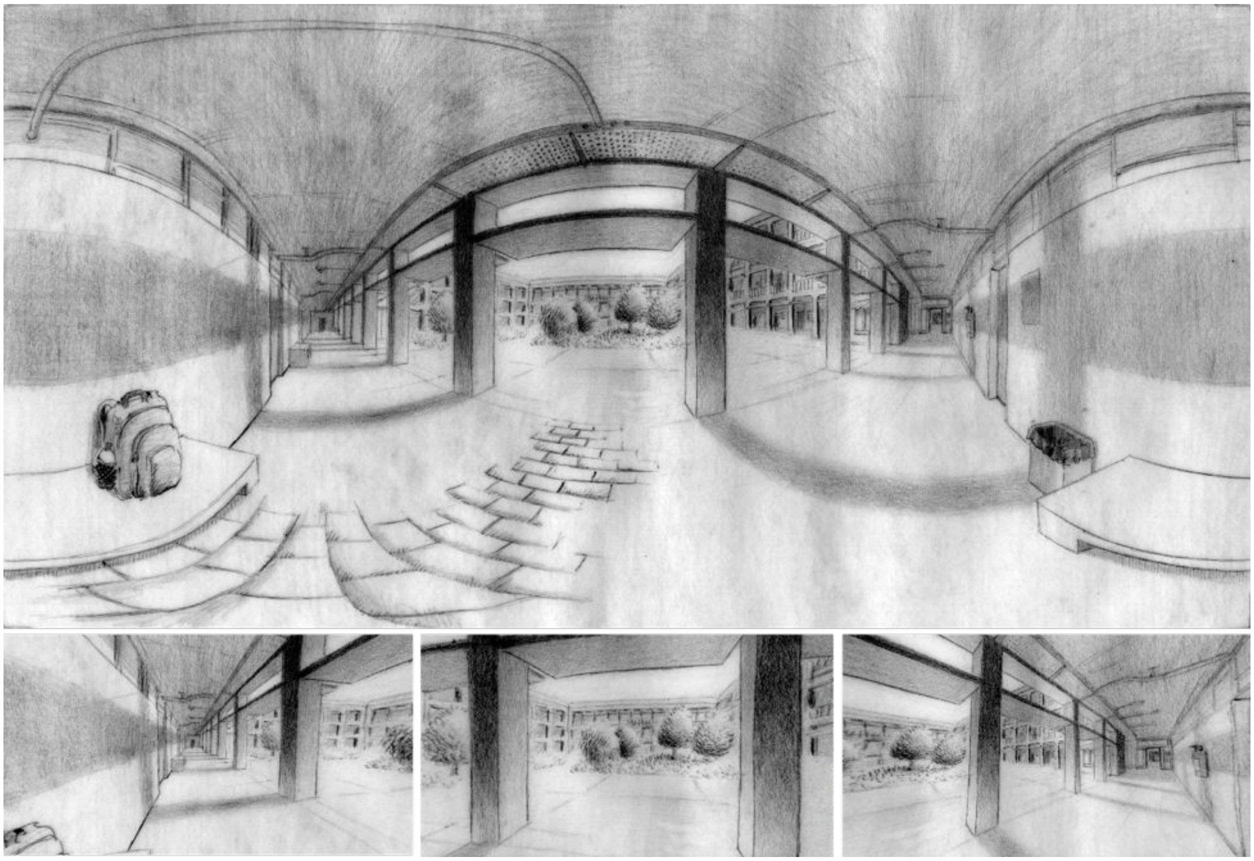


Figure 39: Courtyard at ISEL School of Engineering, equirectangular perspective and VR navigation © António Bandeira Araújo, 2018.

Thus, equirectangular projection has an exhaustive material of drawing methods, from simple guidelines for a quick start to complete procedures that facilitate the creation of highly complex structures. In particular, the method presented by Araújo (2018a) allows the construction of any geometry by means of a line-by-line analysis. In addition, this procedure also follows a dynamic that allows the migration of linear perspective's logical constructions into the equirectangular map in an easy manner.

V.3.2 - Azimuthal-equidistant perspective (fisheye)

The azimuthal-equidistant projection is the result of puncturing the sphere through a point X, stretching X to a circle, and flattening the sphere from the antipode of X (Figure 40, A). The result is a circular chart where "distances (or angles from the centre of the sphere) are preserved along points of each central meridians" (Araújo, 2018c, p. 152). If we consider a classical globe to do the flattening, use the Nord pole as the opening point and use the conventional meridians and parallels, then meridians will render as straight lines converging towards the South pole, parallels render as circles concentric to it, and the Nord pole renders as the outer circle of the map (Figure 40, B). However, the same families of meridians and parallels will render with rather indescribable complex curves when using other points to open up and flattening the sphere, such as one random point at the equator (Figure 40, C) or in any other random position (Figure 40, D). Since a spherical perspective will barely be made only of centred meridians and parallels, understanding these distortions should be at the centre of the methods for drawing a fisheye perspective, yet we will see that this is not always the case. I will speak about the azimuthal-equidistant perspective with the setup specified in (Figure 40, E, F): the hemisphere in front of the observer renders within the red area of the chart, while the hemisphere behind the observer renders in the green area of the chart. Notice that in the chart, due the properties of the projection, the front hemisphere's circumference is halfway between the centre and the outer circle (Figure 40, F).

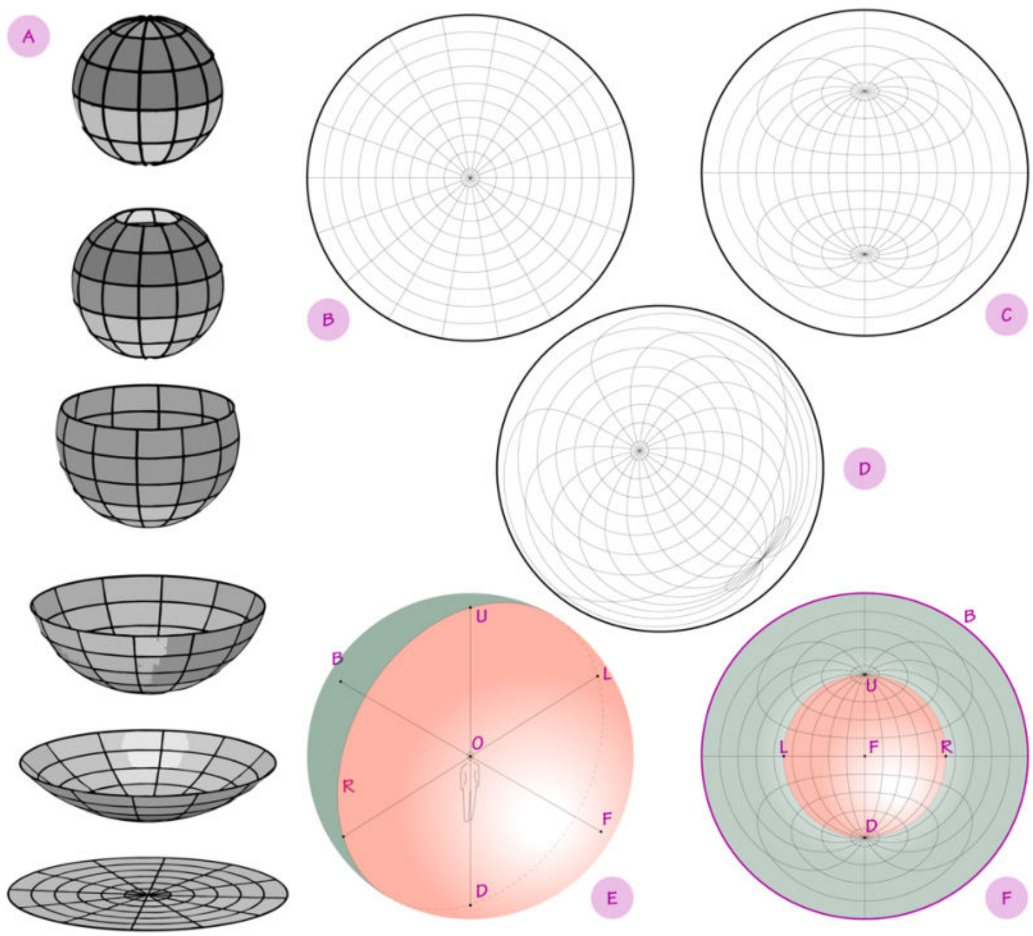


Figure 40: Flattening of the sphere in the azimuthal-equidistant projection © António Bandeira Araújo, 2018 (A). Flattening of the same family of lines but with different centres of projection (B, C, D). Maps generated under CC BY-NC-SA 4.0 licence using the World Map Generator (Stirnemann & Bühlmann, n.d.). Front and back hemispheres in an azimuthal-equidistant perspective in space (E) and in the flattened map (F).

Right as the equirectangular perspective, the azimuthal-equidistant has also a strong presence in literature. In fact, it is very easy to find online tutorials with the most basic guidelines (Alyek, 2023; Beardshaw, 2022; Orłowski, 2018; Steenhorst, 2021). Nevertheless, despite all the goodwill of spreading the drawing technique, many of these tutorials and guidelines do not always develop clear and rigorous concepts, sometimes misleading interested artists towards imprecise or made-up definitions, non-solved problems and limitations to drawings covering the simplest cases. For example, the drawing tutorial by Orłowski (2018) has severe conceptual issues both in the theory and in the practice. On the one hand, the definitions of the projections in space are rather ambiguous (Figure 41). In fact, there is no clear correlation between the orange lines in space and the projections on the azimuthal chart as established by the author (Figure 41, A). For the sake of the argument, I did two hypotheses among the many possible alternatives on how the orange lines could project on the sphere based on the graphic composition made by the author (Figure 41, B, C).

Another issue of the same tutorial comes with the practice. In Figure 40 we saw the development of the background grid: the front hemisphere's circumference is at half the distance between the centre and the outer circle in the standard azimuthal-equidistant projection. Nevertheless, the author states that it should be 3/4 of such distance (Figure 42), confusing the azimuthal-equidistant perspective with a spherical reflection (Orłowski, 2018, min: 1:20). Figure 43 shows the difference between the two projections.

A composition as suggested by Orłowski could be certainly possible, but rather as a rare hack-artistic license to the standard distribution of the azimuthal-*equidistant* map. Nonetheless, this is not clarified at any point by the author, leaving room for learners to confuse a spherical reflection with the standard azimuthal-equidistant projection. Furthermore, there are two big complications with this unusual distribution: first, as there is more distortion in the back hemisphere, the content gets even more compressed and hard to manage due to less available space within the chart. The second problem is during the navigation of the VR environment: the display of the content is compressed and broken, as well as unreadable in some parts (Figure 44). In Figure 45, the content of the frontal hemisphere was adjusted - as best as possible - to a standard fisheye grid, and the improvements during the VR navigation are clearly visible: verticals and horizontals are (almost) verticals and horizontals; orthogonal elements such as tiles are actually orthogonal; and the whole composition makes more sense. This implies that the content within the inner circle is well achieved, yet there are big problems in the representation of the back hemisphere.

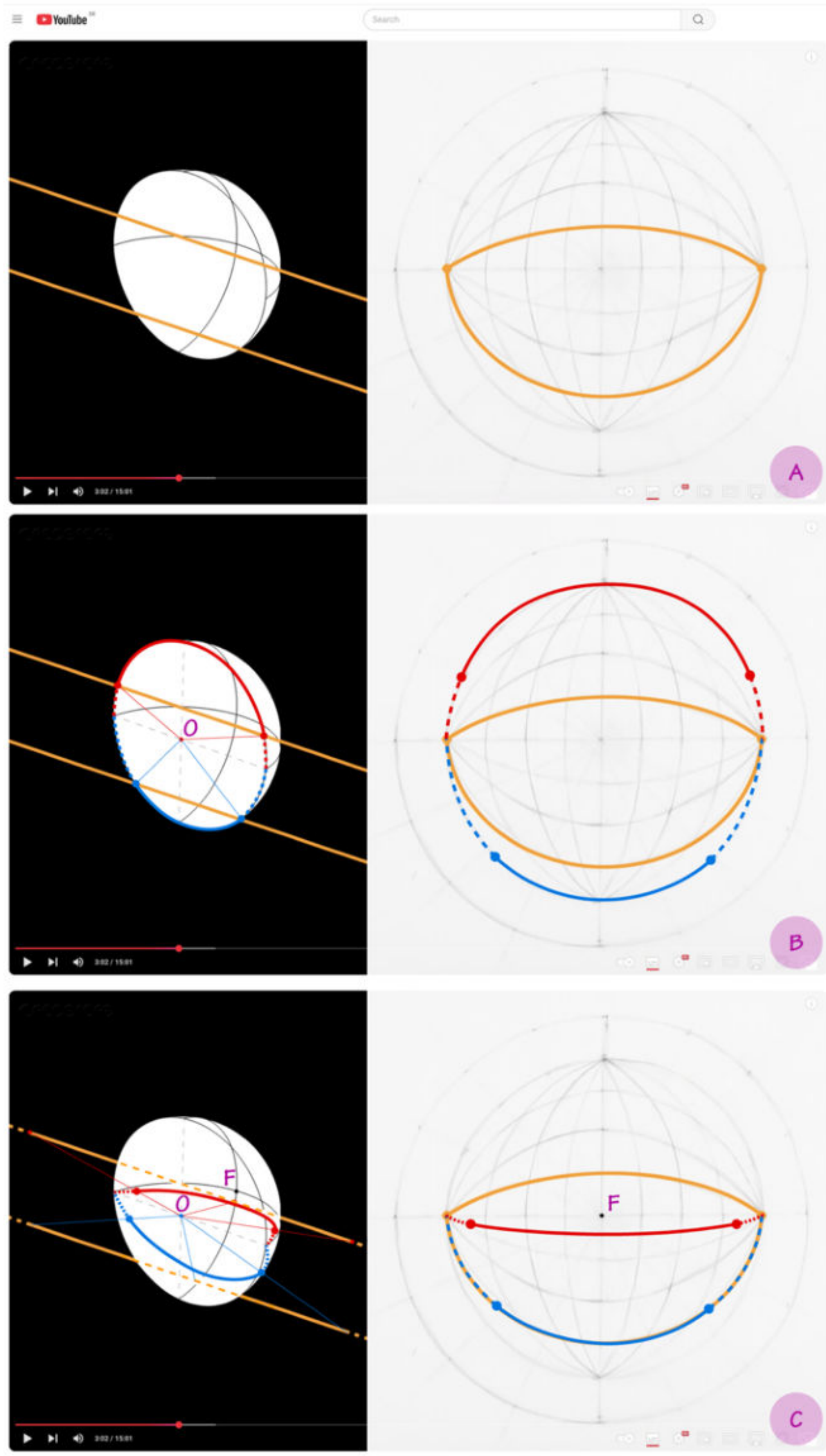


Figure 41: Online tutorial for drawing an azimuthal-equidistant perspective (Orłowski, 2018). In A (composition by © Orłowski Michał, 2018) it is not entirely clear how the lines in space in the left can correspond the projections on the right. Two hypotheses of how the same orange lines could project on the sphere, and their correspondence in the azimuthal-equidistant chart (B, C).

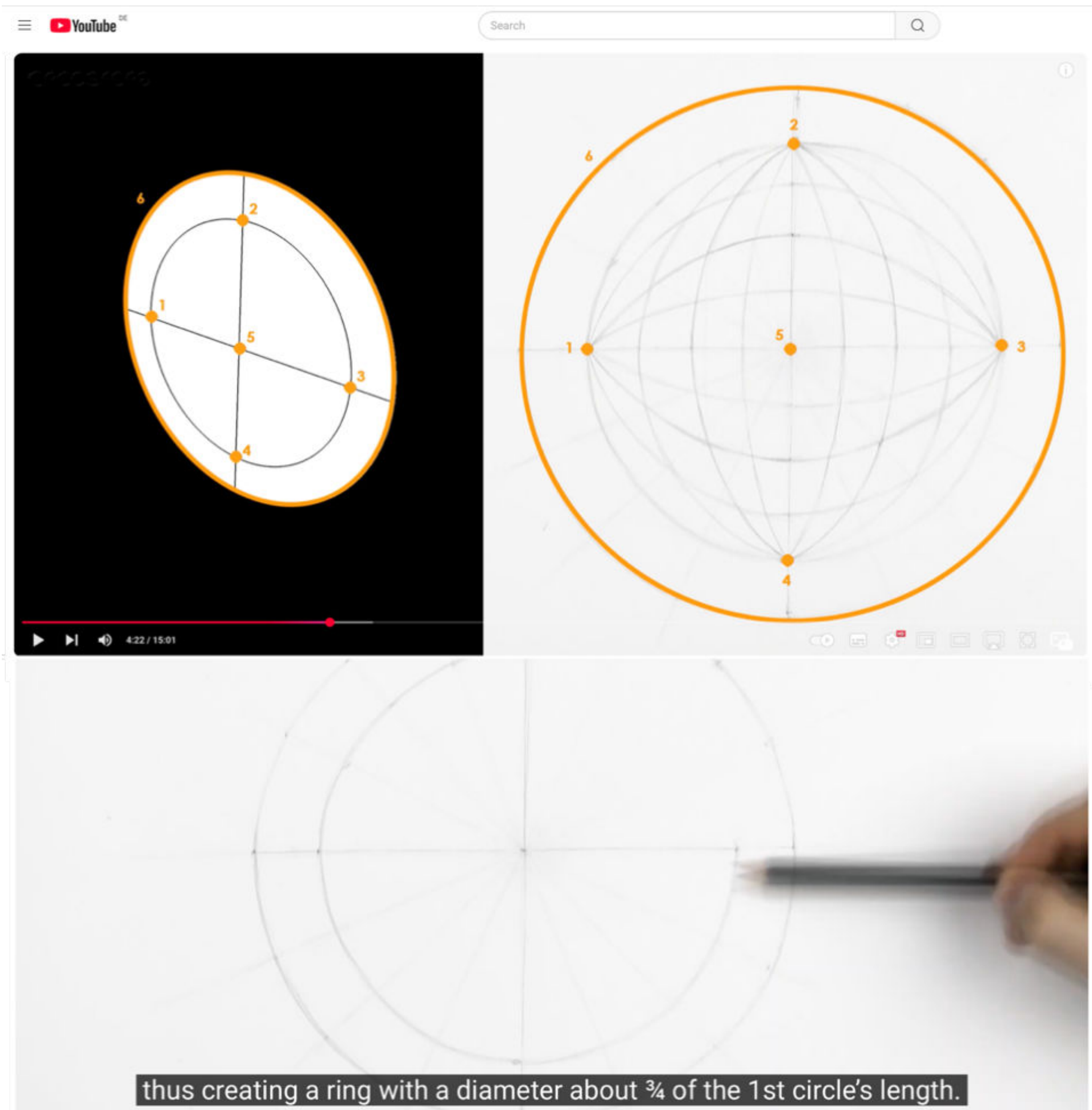


Figure 42: Online tutorial for drawing a fisheye perspective (Orłowski, 2018) © Orłowski Michał, 2018. In a standard azimuthal-equidistant projection, the inner circle containing vanishing points 1-4 should be half the distance between point 5 and the outer circle, not 3/4.

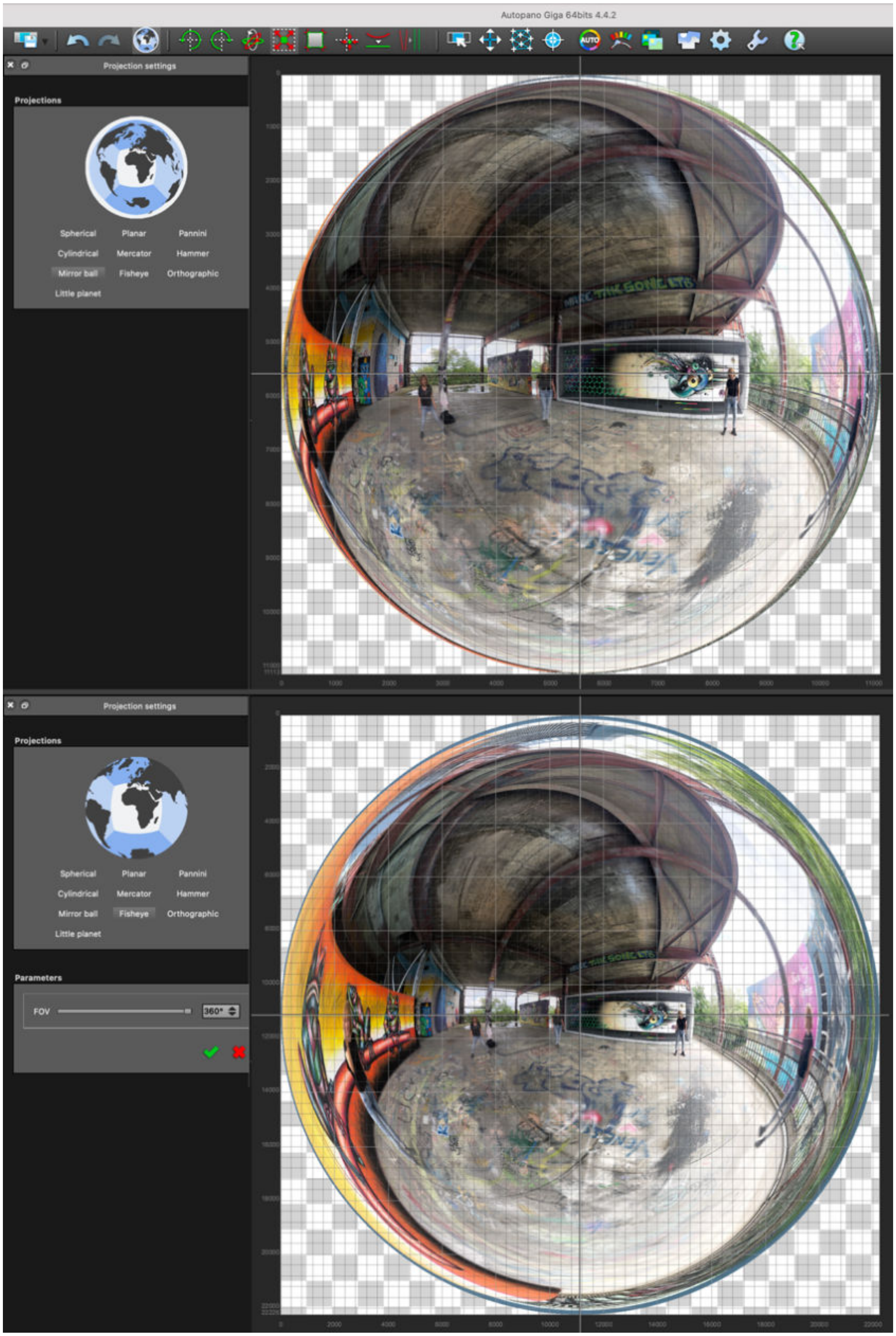


Figure 43: Comparison between a Mirror Ball spherical reflection and an Azimuthal-Equidistant (Fisheye) perspective.

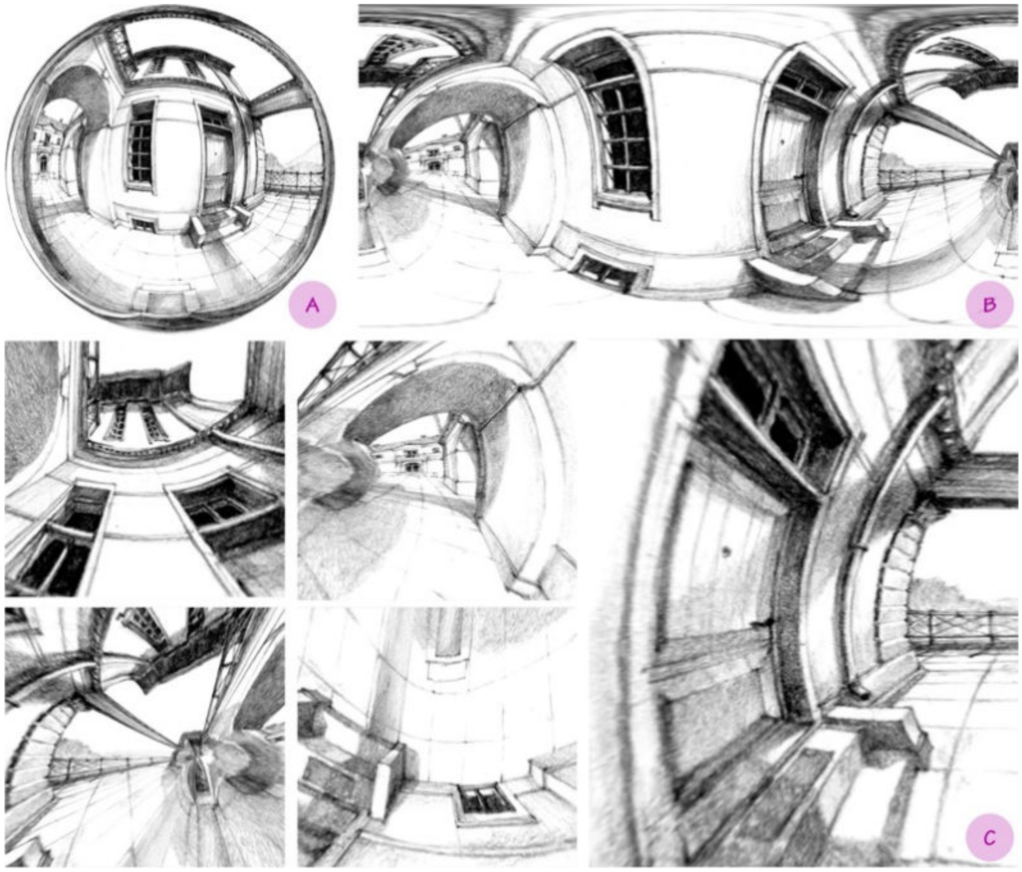


Figure 44: Final composition developed at Orłowski (2018) © Orłowski Michał, 2018 (A). Conversion from azimuthal-equidistant to equirectangular projection (B). VR navigation (C).

The problem of creating and managing the content on the back hemisphere is also related to a further issue, present among several of these guidelines: most of them fail to give a precise method for constructing the back hemisphere's flattened geodesics. For example, Orłowski (2018) states "I connect the opposite horizontal and vertical axes' ends with curves" (min 4:50) and, very similarly, Chelsea (2011) writes "once you get the major landmarks, vanishing points, diagonal vanishing points and corners established, you can draw curved lines between them to fill in your grid" (p. 107). However, in both cases there is no description whatsoever of which kind of curves should one use or in which way could they be drawn with more technical accuracy (Figure 46). Now, Orłowski focuses on a quick learning, lacking in his explanation a more rigorous approach, but Chelsea focuses on developing simple yet very rigorous cartooned explanations for drawing with simple technical instruments (ruler and compass). The absence of further developments in his great guidebook leaves, surprisingly, many questions about how he develops those curves. In fact, he makes a rather big jump during the elaboration of the grid within the back hemisphere, passing from a non-very explicative zoom in detail to the already full developed grid (Chelsea, 2011, p. 107). Another tutorial tries to cover a more exhaustive theoretical and graphic explanation (Gene Bond Art, 2024). In this case, the author draws the main geodesics using key points with precise angles, which leaves less room for speculation on how the curve should develop. Nevertheless, he finds very difficult to describe the curves "you should remember (the flattened geodesics) are not circles, they are kind of… distorted circles like… curvilinear shapes" (min 40:09).

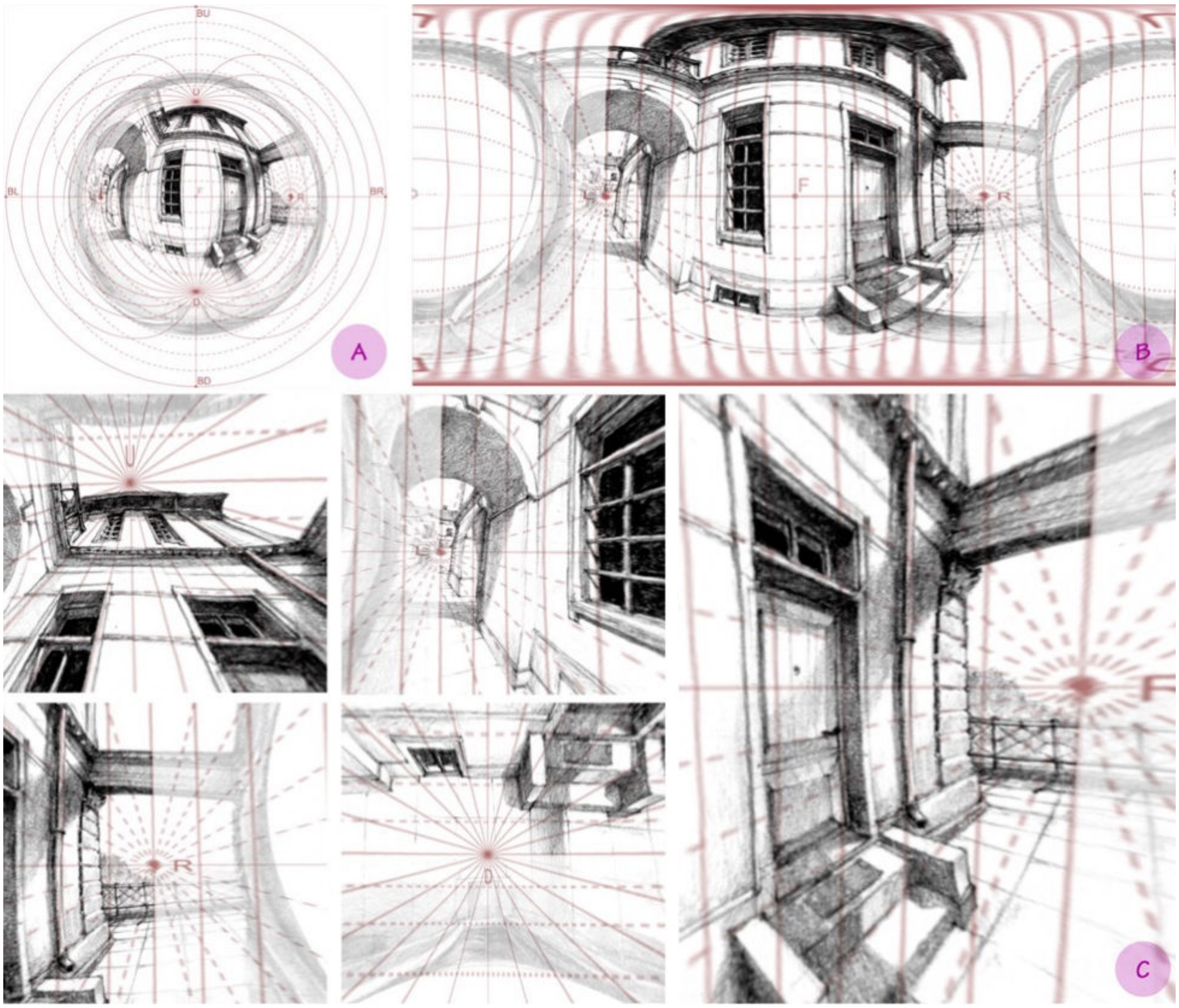


Figure 45: Final composition developed at Orłowski (2018) © Orłowski Michał, 2018, superimposed and partially adjusted to a standard azimuthal-equidistant grid (A). Conversion from the azimuthal-equidistant to the equirectangular projection (B). VR navigation (C).

If we step back in history to see where the problem comes from, we find that the azimuthal-equidistant perspective had a first systematised method for handmade drawing just in the late 1960's (Barre & Flocon, 1967). This method, however, uses only the frontal hemisphere covering up to 180° of the observer's visual field. Nevertheless, although Barre

& Flocon could probably have solved the problem for the the whole visual sphere, it was only very recently that a method for handmade drawing the geodesic curves up to 360° was developed and published (Araújo, 2018c). The method by Araújo completed and complemented previous studies on the subject (Casas, 1983; Moose, 1986) and practices conducted by skilled artists from the 1970's onwards (Araújo, 2018c, p. 146; Michel, 2013), but it was certainly a rather rare knowledge when Chelsea's published his book.

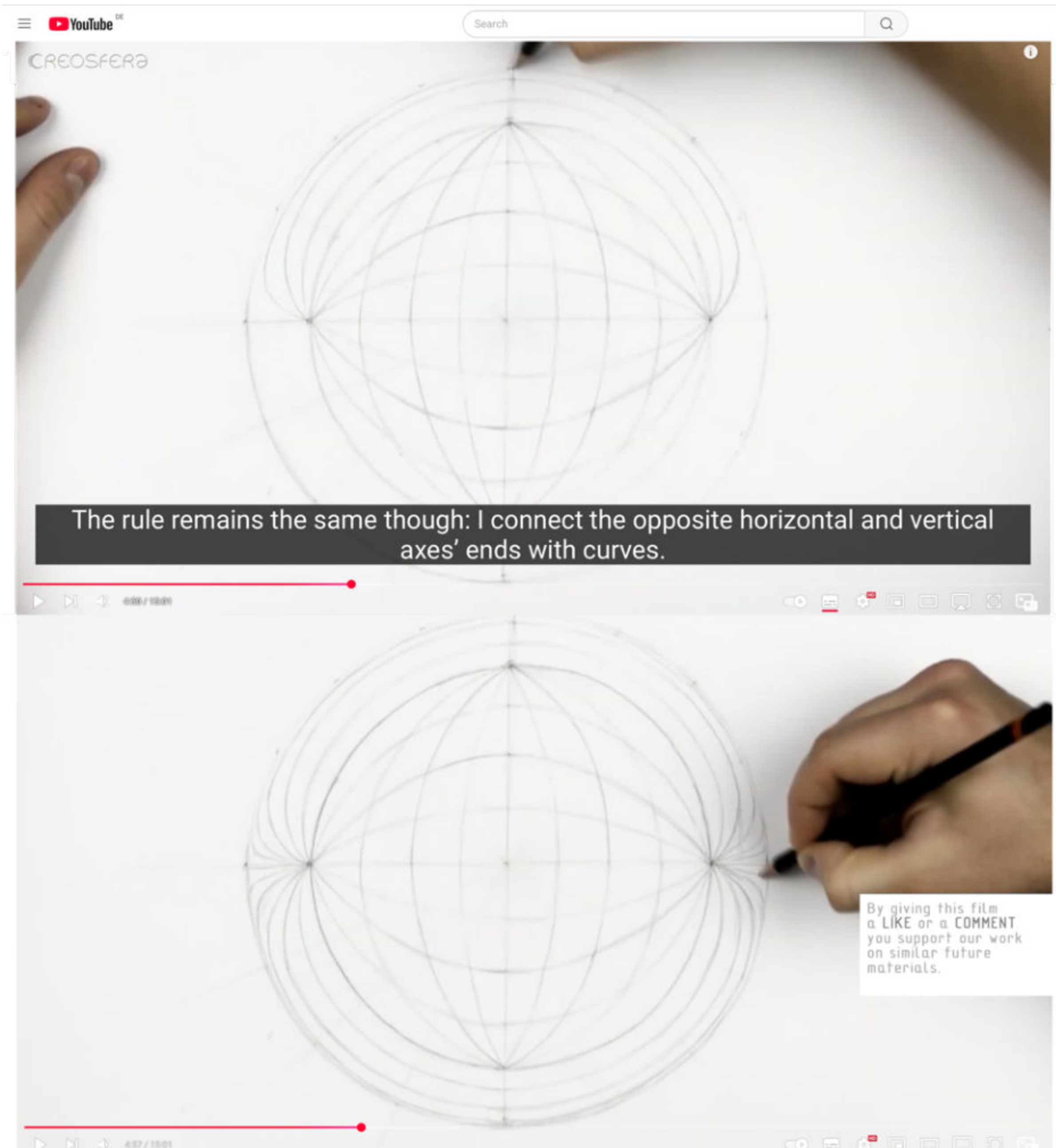


Figure 46: Online tutorial for drawing a fisheye perspective (Orłowski, 2018) © Orłowski Michał, 2018. There is no clear method for drawing the geodesic in the back hemisphere.

Araújo (2018c) developed his method framing the azimuthal-equidistant perspective within the same scheme he used for characterising the equirectangular perspective, i.e., considering a spherical perspective as a two-step process of an anamorphosis onto the sphere followed by the flattening of the sphere. Consequently, the method systematises how to compose a fisheye perspective using all kind of lines, vanishing points, antipodes, etc. Furthermore, the method describes the development of the curves with precision and teaches how to plot the flattened geodesics using a ruler and a nail (Araújo, 2018c, p. 159) (Figure 47). Araújo's method goes further beyond and, in the same way than with the equirectangular perspective, he introduces something never seen before: any line within the azimuthal-equidistant perspective can be drawn with a grid containing only one family of lines (Araújo, 2019a). In practice, we plot two random points by measuring their angles and - thanks to the properties of the projection - we only have to rotate the grid until one geodesic hits both points. Such geodesic will be the only one and therefore, the right projection (Figure 48).

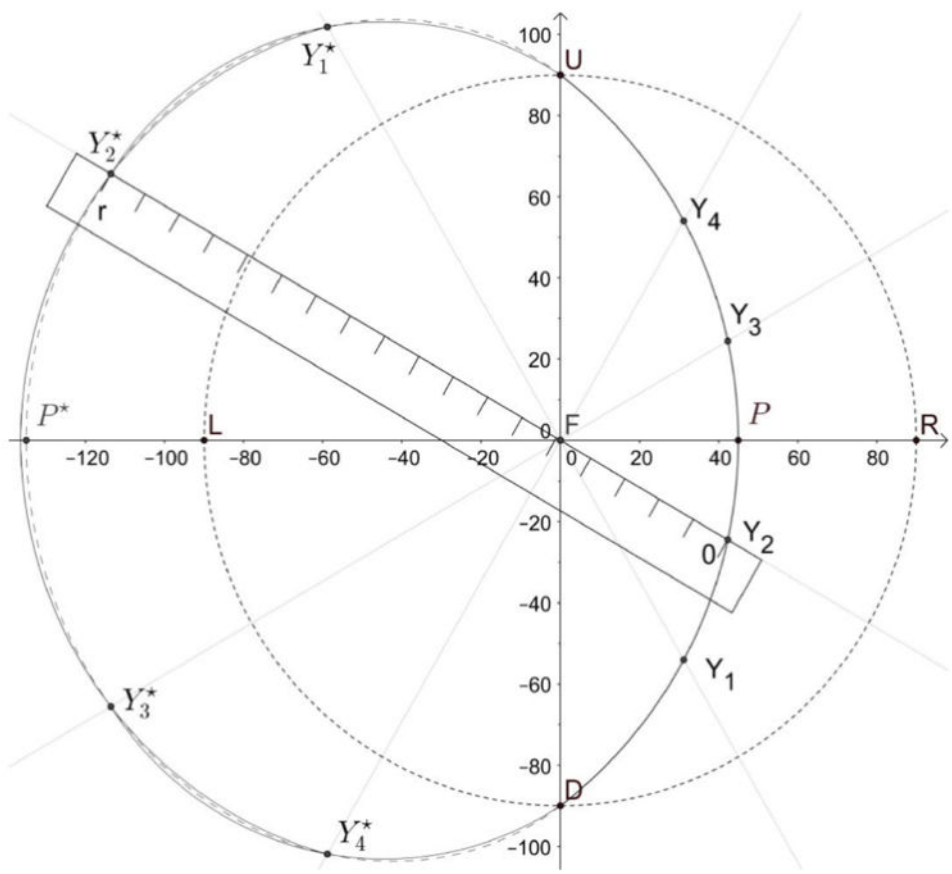


Figure 47: Construction for plotting flattened geodesic curves for any given position within the fisheye chart © António Bandeira Araújo (2018c).

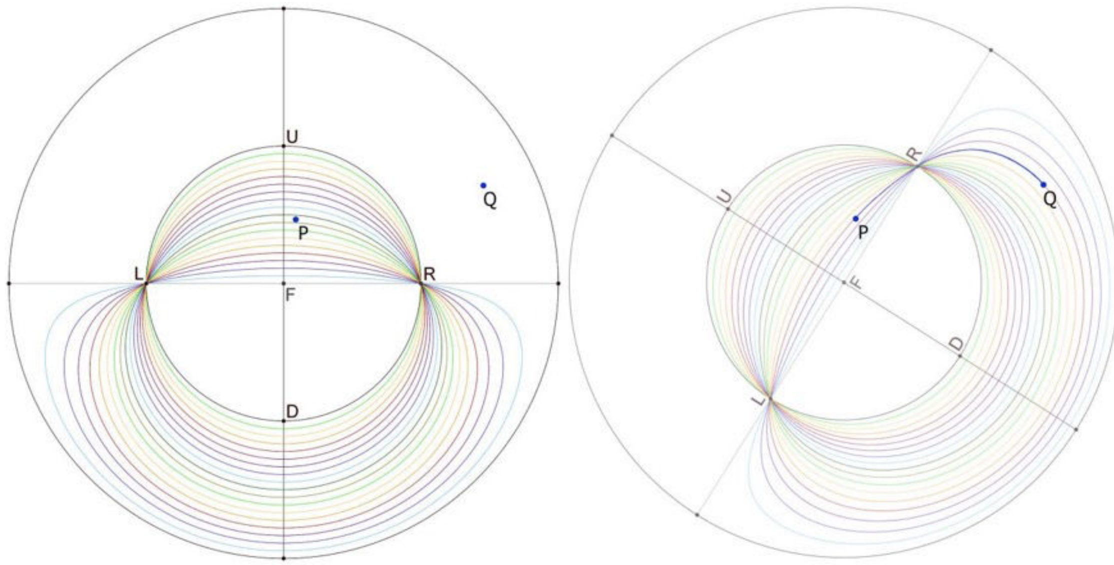


Figure 48: The method for finding the right geodesic for any two given points: plot points P and Q by measuring their angles; then rotate the grid until one geodesic hits them both. That will be the only and right geodesic © António Bandeira Araújo (2019a), p. 661.

Hence, when looking at basic guidelines for fisheye perspective, we find not all of them are entirely exhaustive. However, until some years ago the full theoretical and practical development was not so widely available, for which their possible limitations can be now complemented and easily solved with a deeper study on the subject and, goes without saying, we should be very careful on spreading misinformation: wrong methods can be misleading, interest-killers and/or knowledge-constraints, as artists find themselves more confused and lost without the proper answers.

V.3.3 - Cubical perspective

A cubical map is obtained from the flattening of a cube centred in the observer, cutting some edges and flattening it (Figure 49). Two of the most common ways of cutting and flattening the cube are as a horizontal cross shape, and as a unique stripe with the six faces together (Figure 50). Although these two cubical maps are often used for the generation of digital virtual environments, cubical maps have had less exposure and development than the equirectangular or the azimuthal-equidistant projections. Consequently, cubical representation techniques are less developed, which makes them less known and less considered as a medium for immersive drawing. Nevertheless, cubical perspective represents an interesting alternative with some strong advantages for immersive drawing, as we shall see in the following paragraphs.

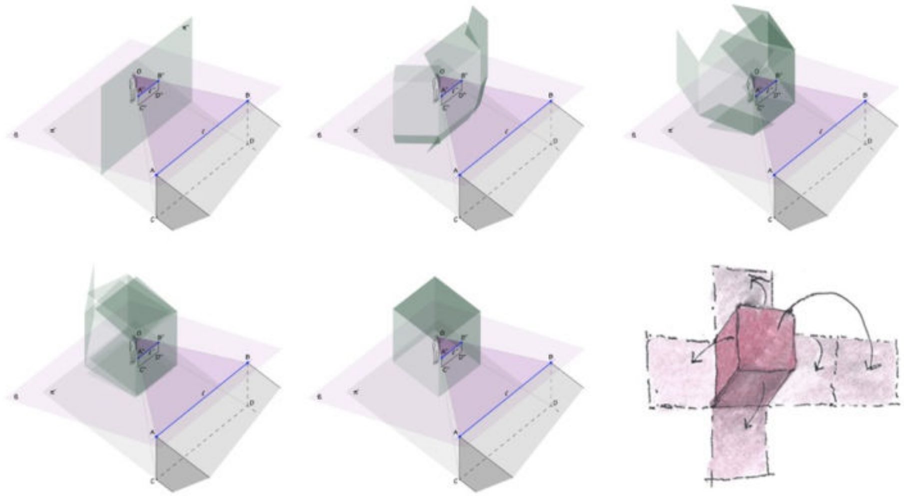


Figure 49: Passing from one plane to the cube and flattening of the cube.

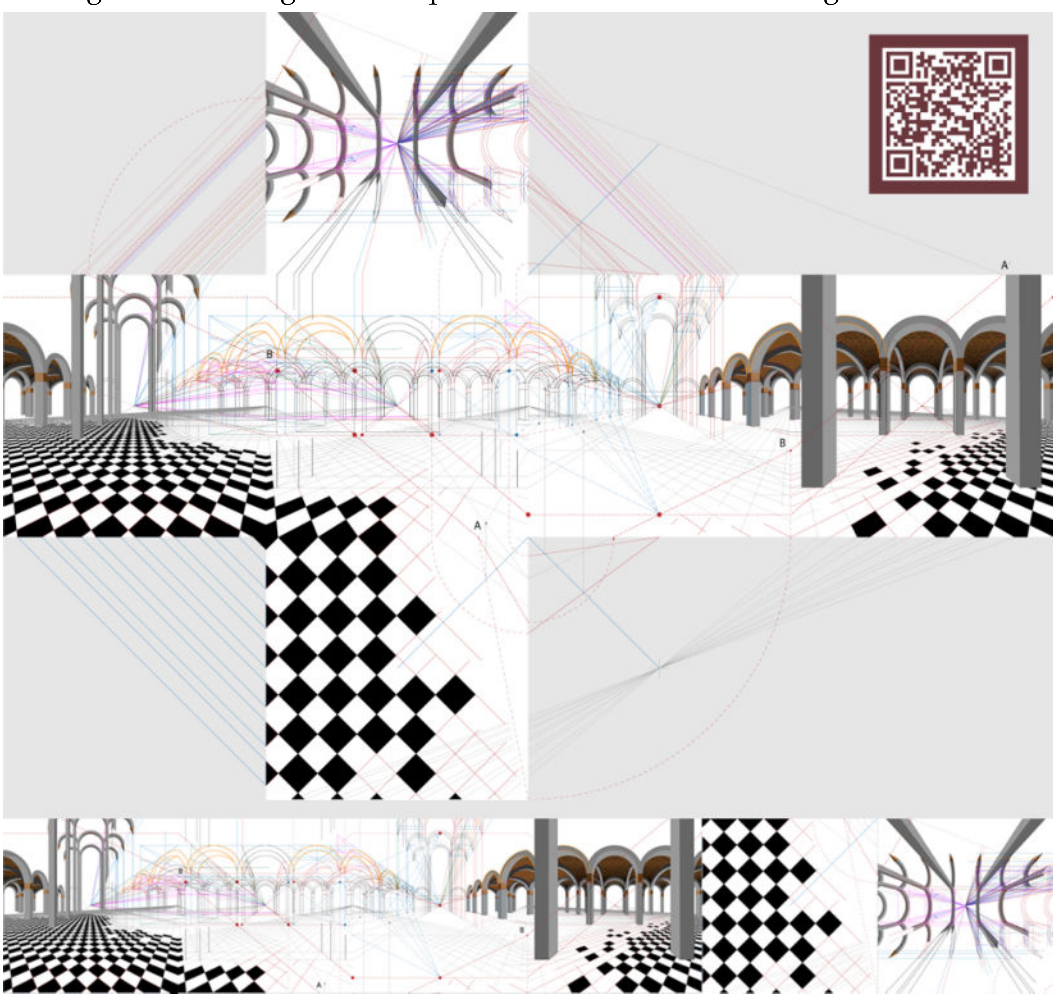


Figure 50: Two different cuttings and openings of the cube: the horizontal cross (up) opens the cube with the minimum number of cuts; the strip (bottom) makes two more cuts, separates the up and bottom faces and glue the six faces in one linear continuous image. Artwork: Head Like a Cube, cubical perspective made on Illustrator © Lufo Art (Lucas Fabian Olivero), 2019.

Using the cube for immersive drawing brings a fundamental problem: in contrast to the sphere - which has a smooth continuous surface - the cube is made by the intersection of six planes and therefore the representation of a generic line or segment results fragmented within different planes (Araújo et al., 2020; Olivero et al., 2019; Olivero & Sucurado, 2019). This problem is not always fully solved by the current methods for cubical drawing, especially among the most basic guidelines, even if the question is essential to the cubical representation and a well-known historical problem while using other polyhedra as a projecting surface, such as the Perspective Boxes (Figure 51).

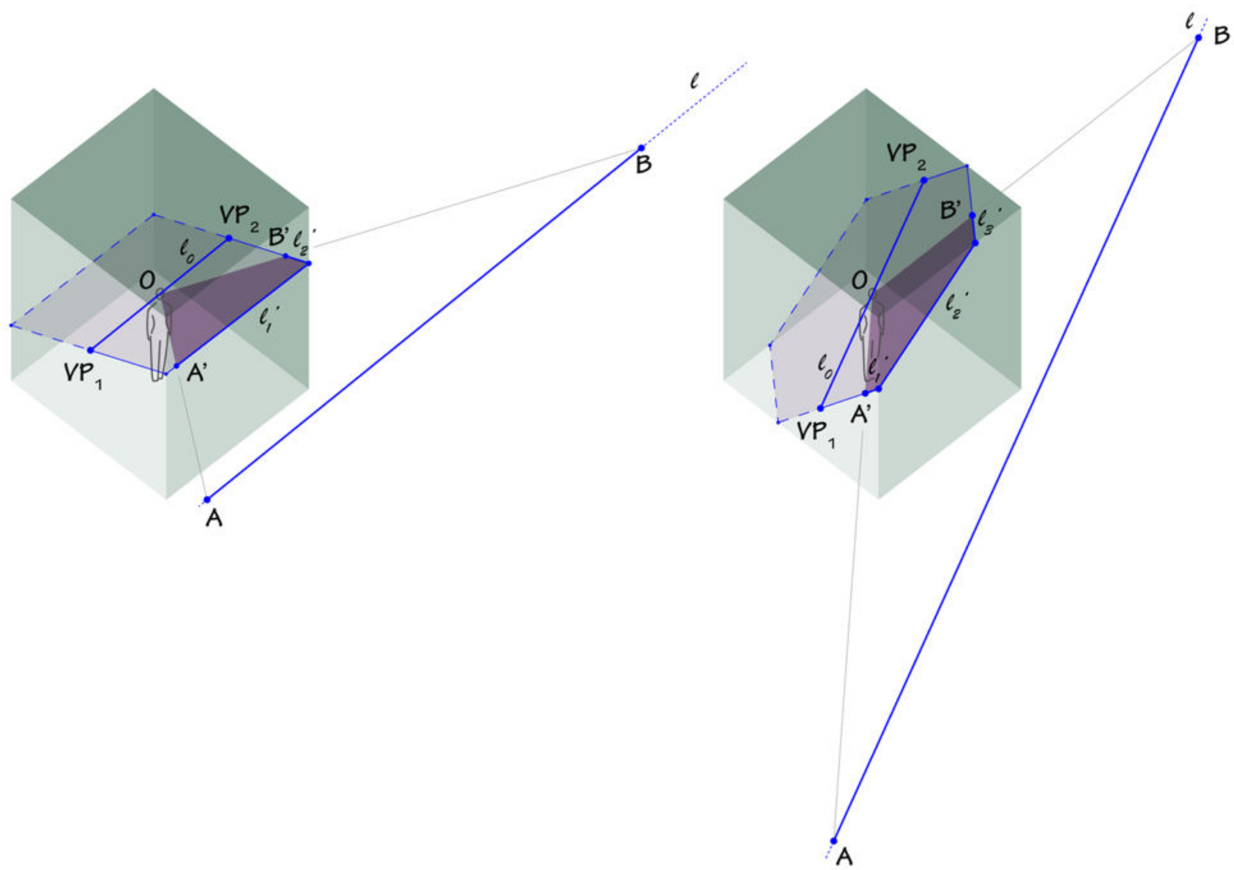


Figure 51: The representation of a line l (which goes from VP_1 to VP_2) is fragmented in four segments. Hence the representation of a segment $\overline{AB}$ can also be fragmented in up to four segments, each of them lying in a different face/plane.

Among **basic guidelines**, we find some turnaround procedures with reflections and/or *ad-hoc* solutions (Godin, 2011; Marrazzo, 2020) and procedures for drawing within the cubical map and evaluating the results through visual feedback (Theng Seng, 2016). Particularly, Theng Seng (2016) wrote a tutorial showing how to convert an equirectangular grid to the cubical format, and how to find solutions by trial-and-error within the converted grid (Figure 52). In this example, the author shows the fragmentation problem and his solution to it is to follow the lines of the converted grid (Figure 53). Furthermore, he understands the cubical map as a set of six classical linear perspectives glued together:

> "Every time you draw something across an individual Cubemap (i.e., face) re-imagine your perspective into a new single point perspective. Always see every Individual Cubemap (face) as a new single-point-perspective-grid" (Theng Seng, 2016).

In parallel to the limitations of drawing within the static equirectangular grid, this first approach limits its applications to the lines covered by the grid. The solution for other kind of lines not covered by the grid remains unanswered and/or to be found through visual feedback during the VR navigation. A global solution to the fragmentation problem is not given or approached. Nonetheless, the tutorial is clearly intended as a blog entry for a quick *how-to* explanation rather than a more exhaustive theoretical development. Further explorations with the cube were abandoned, and the tutorial was deprecated two years after by the same author, who switched from the cubical map to a Photoshop-based tool for spherical drawing (Theng Seng, 2018).

The lack of full methods for creating cubical perspectives opened a new line of academic research with the aim of developing a complete solution (Figure 54). Behind this academical work there was a boost of personal curiosity since, as an artist, the simple idea of drawing everything around the observer without using digital tools was not only appealing but also the door to a new world full of possibilities (Figure 55). And so further guidelines were settled in Olivero & Sucurado (2019); A. Rossi & Olivero (2018); Barba et al. (2018), seeking with them general fundaments within descriptive geometry. This investigation was based and took references from other methods analysed within the state of the art, that could have been adapted to solve the fragmentation problem (Fernández Rodríguez, 2002; Hernández Falagán et al., 2015). The research explored two methodical constructions: first, setting general guidelines and an algorithm for plotting lines parallel to the faces of the cube (Figure 56 and 57) (Barba et al., 2018; Olivero et al., 2019) and second, obtaining the cubical drawing by translation of angle-segments from floor plan and sections to the cubical map (Figure 58) (Olivero et al., 2020). These constructions treated the fragmentation as a problem of angles and, even if they could have solved the representation of any kind of lines, their procedure lacked a full mathematical development for a global understanding of the projections. Nevertheless, these were the foundational stones that left the field opened for further research.

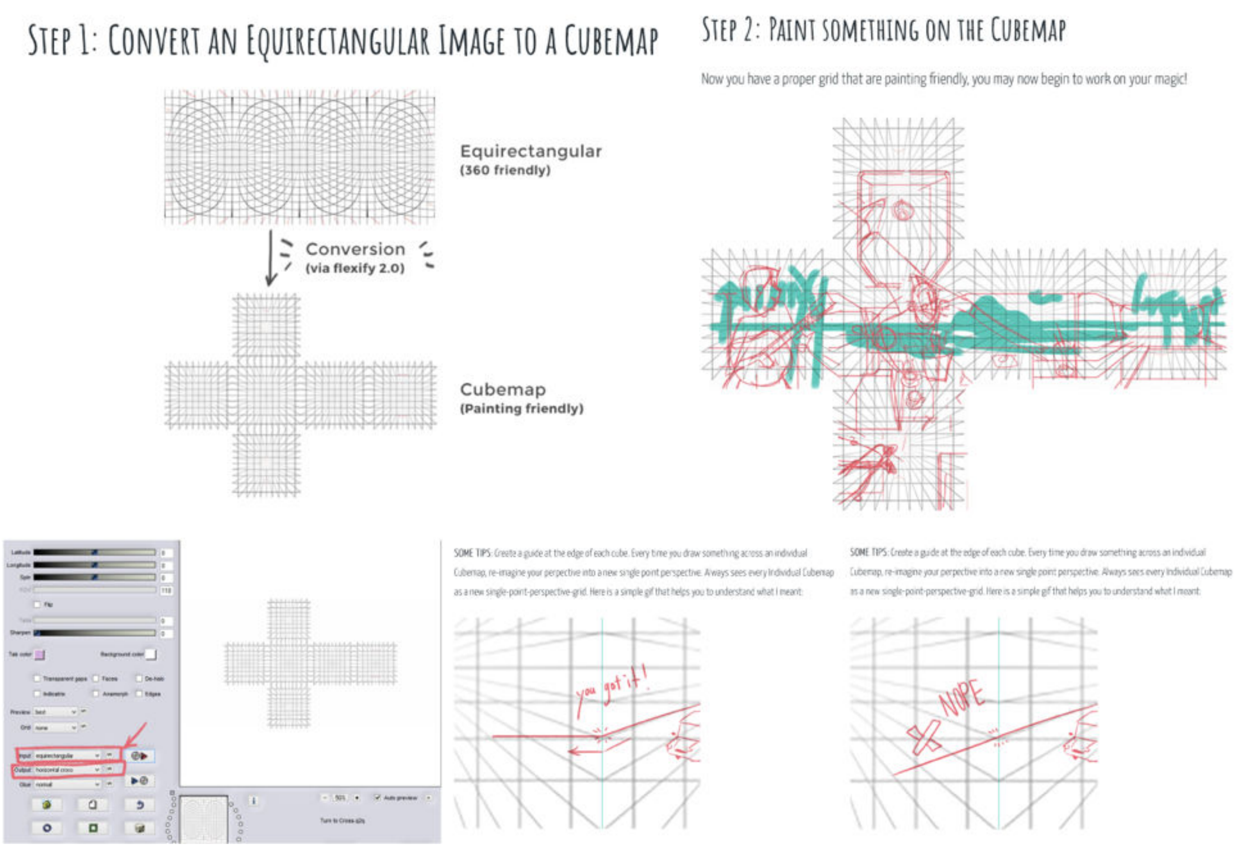


Figure 52: Tutorial for constructing a cubical drawing © Lai Theng Seng, 2016. Converting from equirectangular to cubemap using Flexify (left). Preparatory draft (up right). Graphic explanations for crossing edges (bottom centre and left) (Theng Seng, 2016).

Figure 53: Final illustration and VR navigation © Lai Theng Seng, 2016 (Theng Seng, 2016).

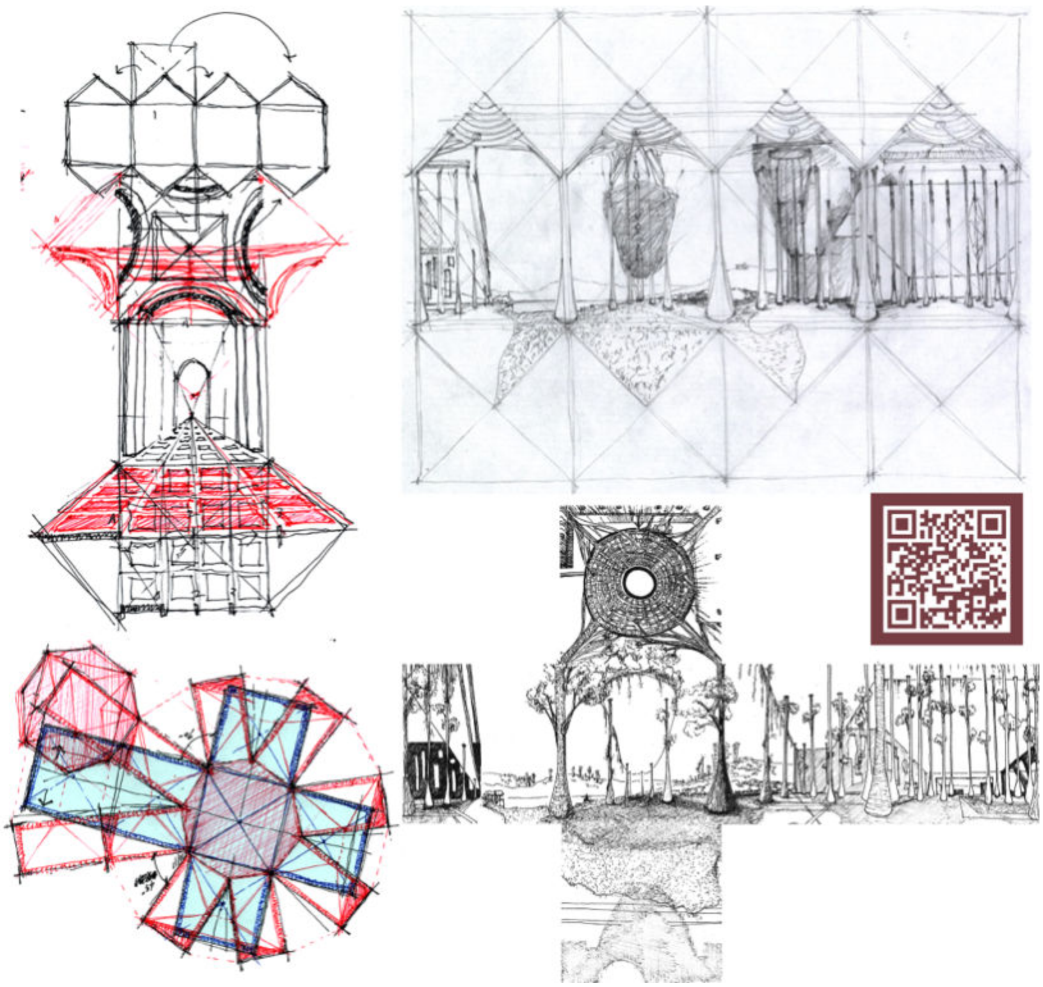


Figure 54: Variations to open the cube, studies of the cube's discontinuities, and use of other polyhedra. Right, below, artwork Minerva © Lufo Art (Lucas Fabian Olivero), 2017.

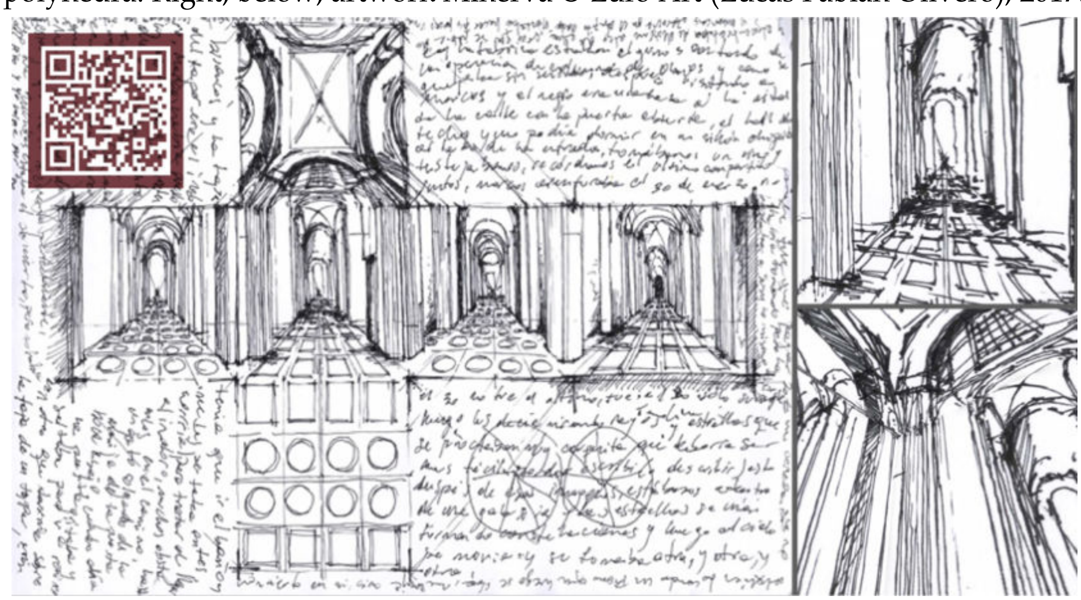


Figure 55: Requiem. Artwork in cubical perspective. © Lufo Art (Lucas Fabian Olivero), 2017.

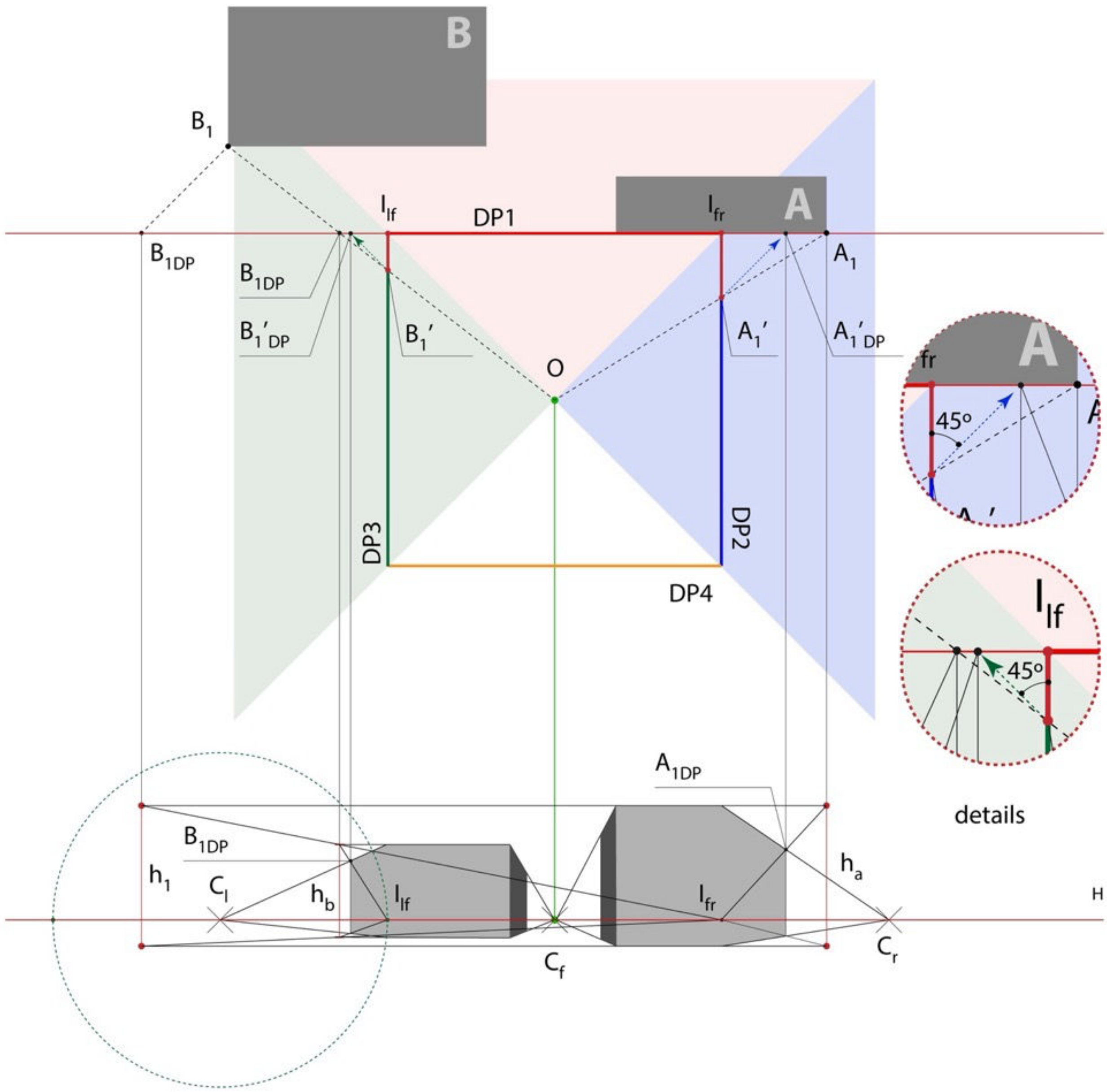


Figure 56: First developments aiming to a systematic definition of the cubical perspective. The method explores how to plot lines that are parallel to the faces of the cube (Olivero et al., 2019).

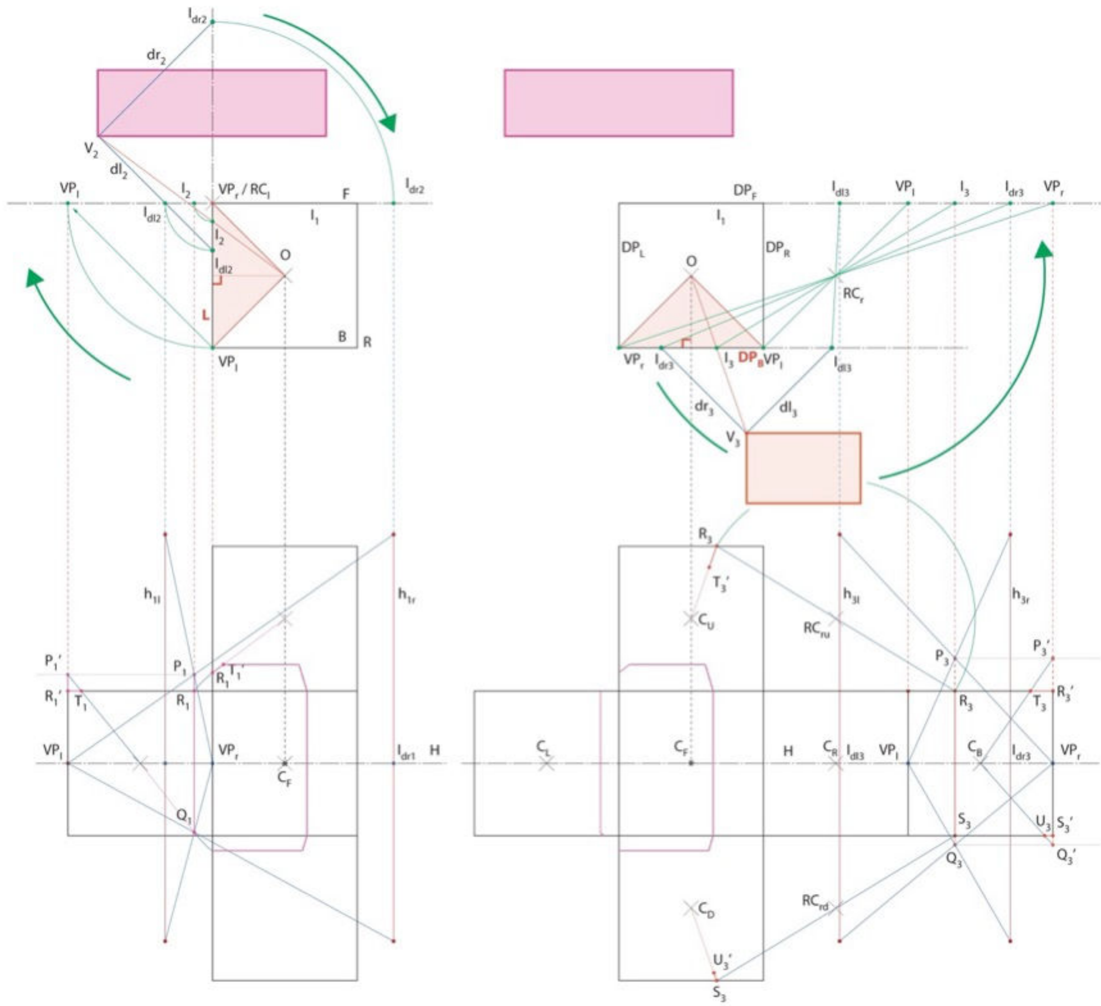


Figure 57: Application of the method developed at Olivero et al. (2019), the points of reference from the different objects are projected onto the cube and then brought to a plane in front of the observer using rotation centres and 45° projections.

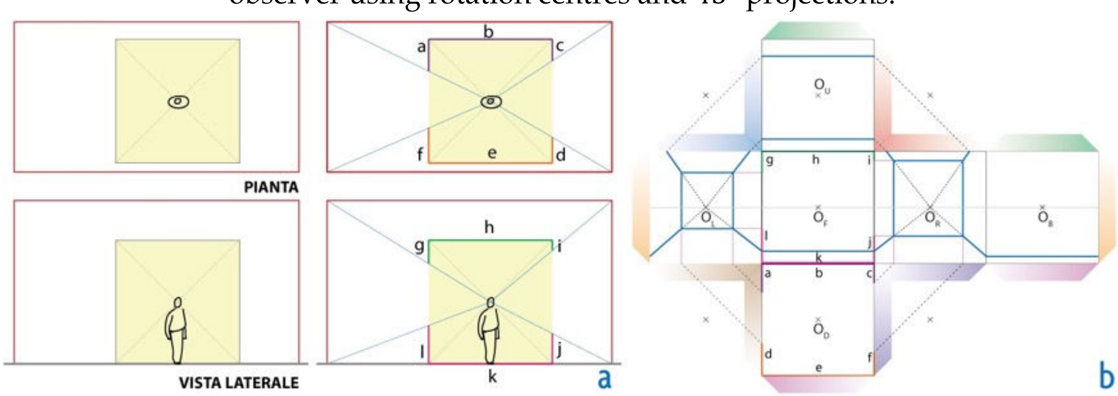


Figure 58: Second method for plotting a cubical perspective: the key points of the geometry are projected within a generic cube centred in the observer. Then, those fragments are translated within the cubical map (Olivero et al., 2020).

The cubical-spherical perspective

None of the above-mentioned methods developed a general solution. Instead, the fragmentation problem could have been solved by framing every particular case as an always-changing case of lines projected onto several planes. Nevertheless, as part of the research in cubical perspective (Olivero, 2021), a full method was developed by considering cubical perspective not as an isolated case of fragmented lines, angles and planes anymore, but as a special case of spherical perspective, from which the solution to the problem focuses on how to plot a geodesic within the cube, this method was called the **cubical-spherical perspective** (Araújo et al., 2020). With this method, it is possible to draw and understand the whole scene (i.e., the six planes) at once: the cube is considered homeomorphic to the sphere and as such the properties of spherical perspectives (lines projecting as great circles, one geodesics per line, two vanishing points per line…) can be directly translated to the cubical case, simplifying the general understanding about how to draw within the open cube (Figure 59). Indeed, two spatial points project as one and only one geodesic onto the cube (Figure 60). The workflow specified in Araújo et al. (2020) to plot the corresponding geodesic consists on measuring and plotting two points within the cubical map (Figure 61), obtaining the image of the corresponding geodesic, finding the two antipodal vanishing points and building other lines (parallel, perpendicular and with other different angles), through different constructions according to the position of the points and vanishing points (Figure 62). The constructions described for this method are, in some cases, quite complex, but the method's main problem arises with the case when two points fall in different and adjacent faces, which requires the most complex construction for obtaining a third, auxiliary point (Figure 63). This complexity is not to be overlooked, as it introduces a further complication for the artistic practice of cubical drawing into the already complex theory about spherical perspectives.

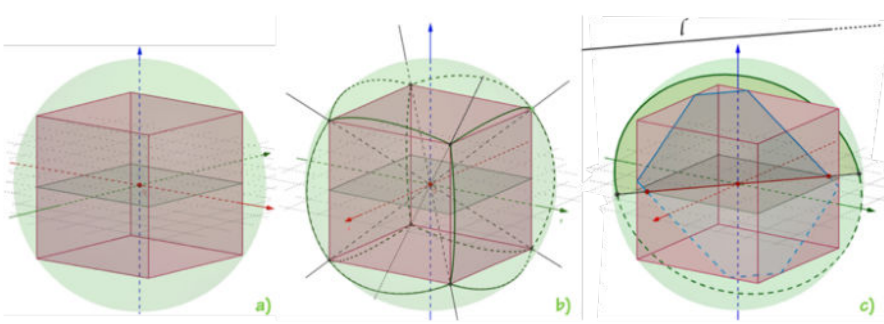


Figure 59: A sphere and cube that are concentric are homeomorphic by conical projection (a). Image of the edges of the cube on the sphere as arcs of geodesic (b). Image of a spherical meridian (spatial line projection) on the cube (c).

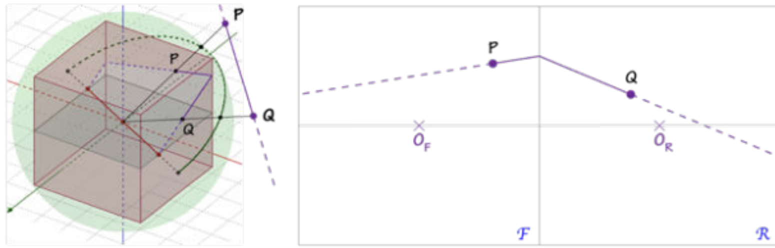


Figure 60: One and only one geodesic projection onto the cube is the image of a spatial line.

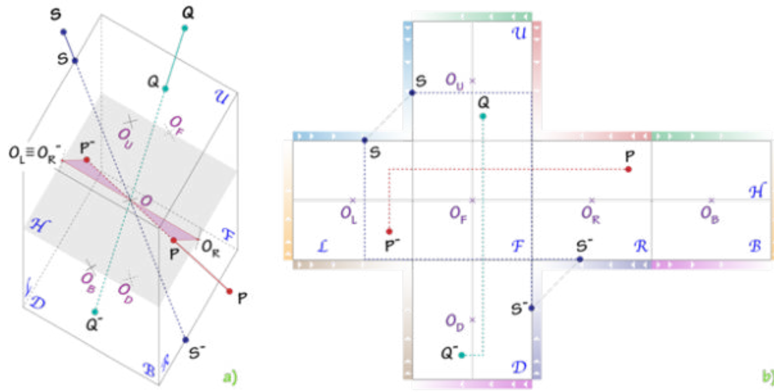


Figure 61: Flattening of the cube and method for plotting antipodal vanishing points.

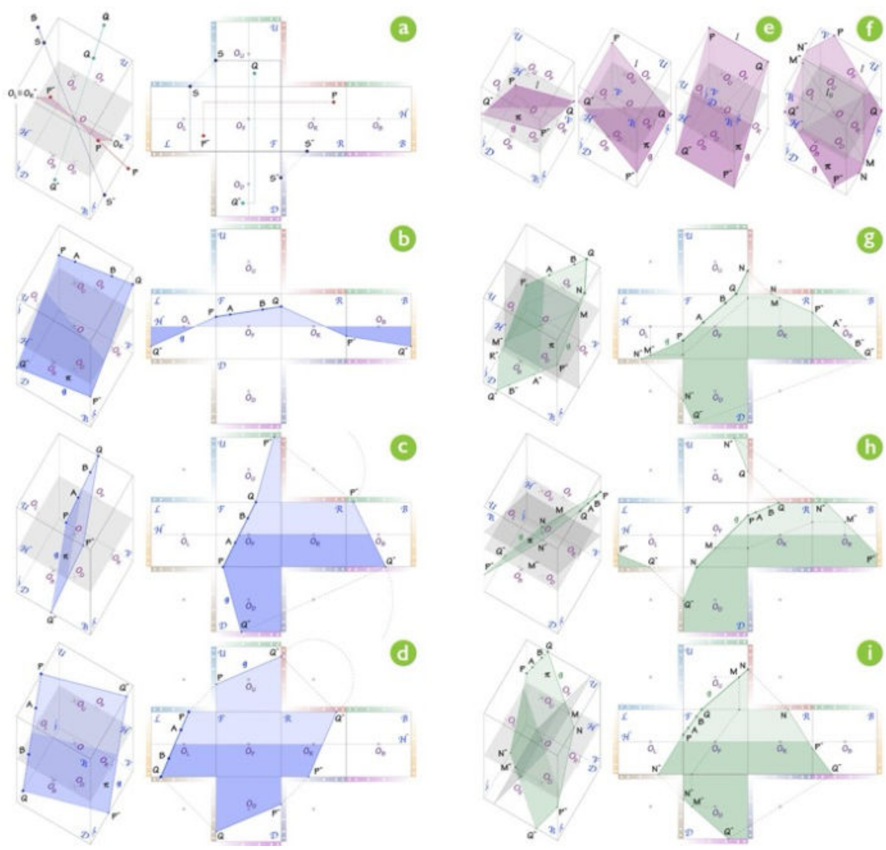


Figure 62: Plotting vanishing points (a). Methods for plotting 4 and 6-sided geodesics (b-i).

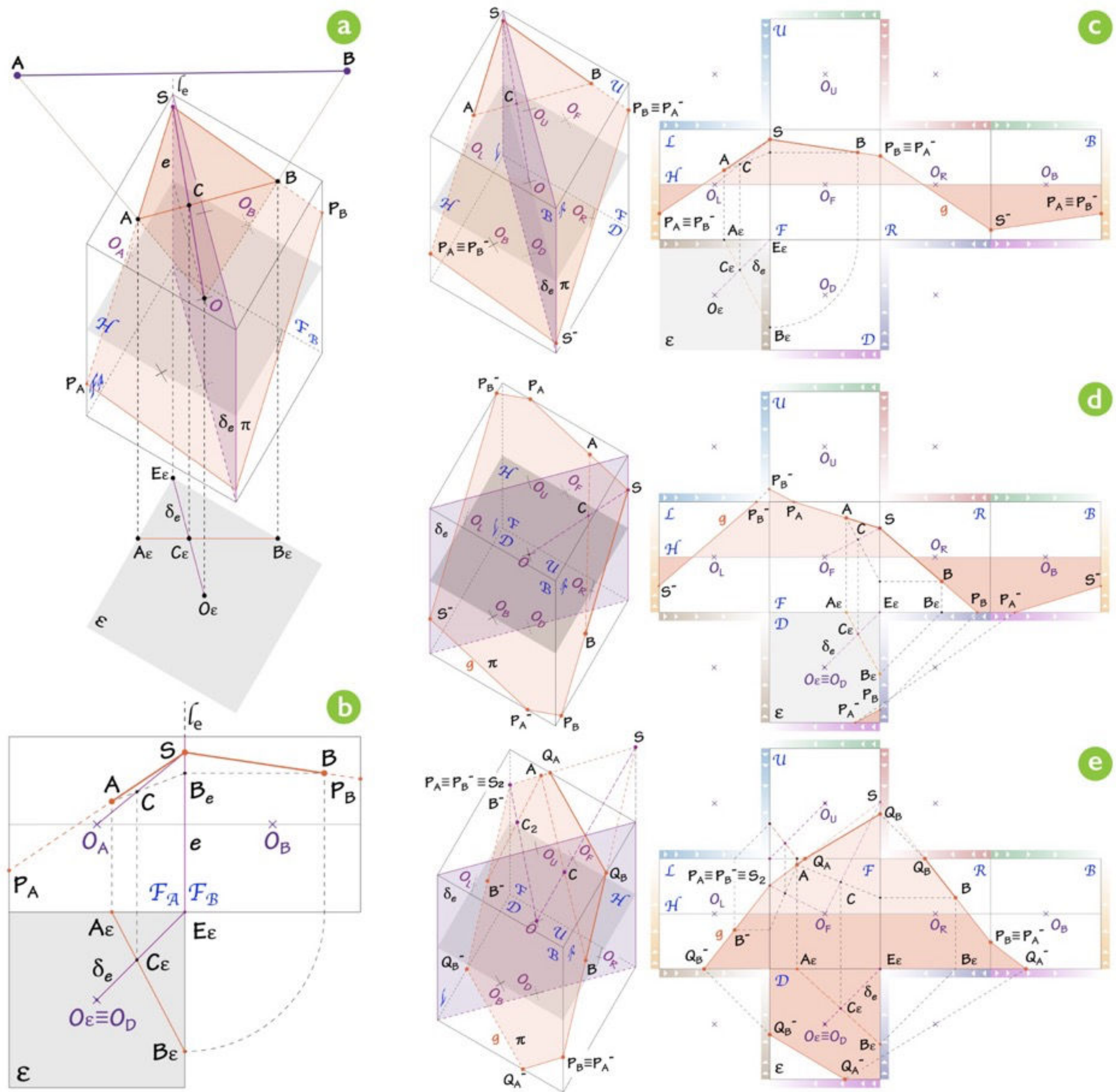


Figure 63: The most complex case in cubical perspective: when *A* and *B* fall in different and adjacent faces. Construction in space (a, b) and constructions in the cubical map (c-e).

Same than in the equirectangular case, the cubical-spherical perspective method allows us to create any kind of grids. If we bring the classical construction of grids from linear perspective, we will notice that cubical perspective has an important advantage: the 45° vanishing points are determined and they do not depend on the distance to the plane, no matter which vanishing points we are using (Figure 64). Furthermore, geodesics simplify other classical constructions, such as the regular repetition or subdivision of elements (Figure 65). In fact, it is well known how the repetition of a regular module in linear perspective worsens with the distance to the observer when the construction goes outside the canvas, but in cubical perspective such problem does not exist: all vanishing points around the observer are within a compact and closed setup. This implies that all constructions and diagrams are within the boundaries of the drawing, no matter how far they are from the observer, unlike in linear perspective (Figure 66). Advantages like these, power up and bridge spherical perspectives and linear perspective constructions within the cubical drawing.

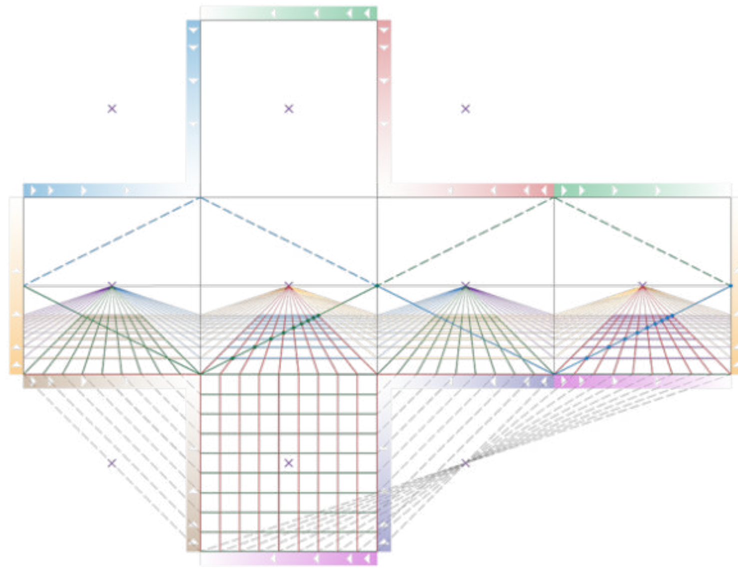


Figure 64: Construction of a regular grid in cubical perspective using the 45° vanishing points. Notice that the 45° vanishing points are always determined within the cubical map, they do not depend on the distance between the observer and the drawing plane, such as in linear perspective.

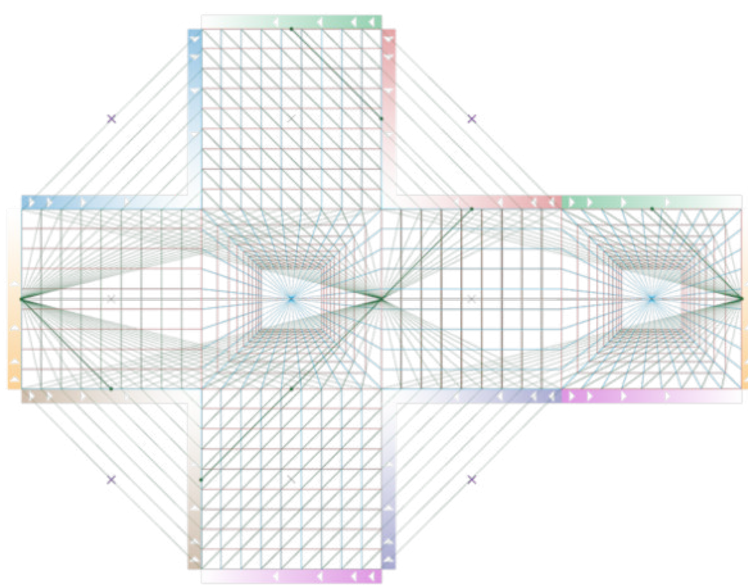


Figure 65: Extending the uniform grid.

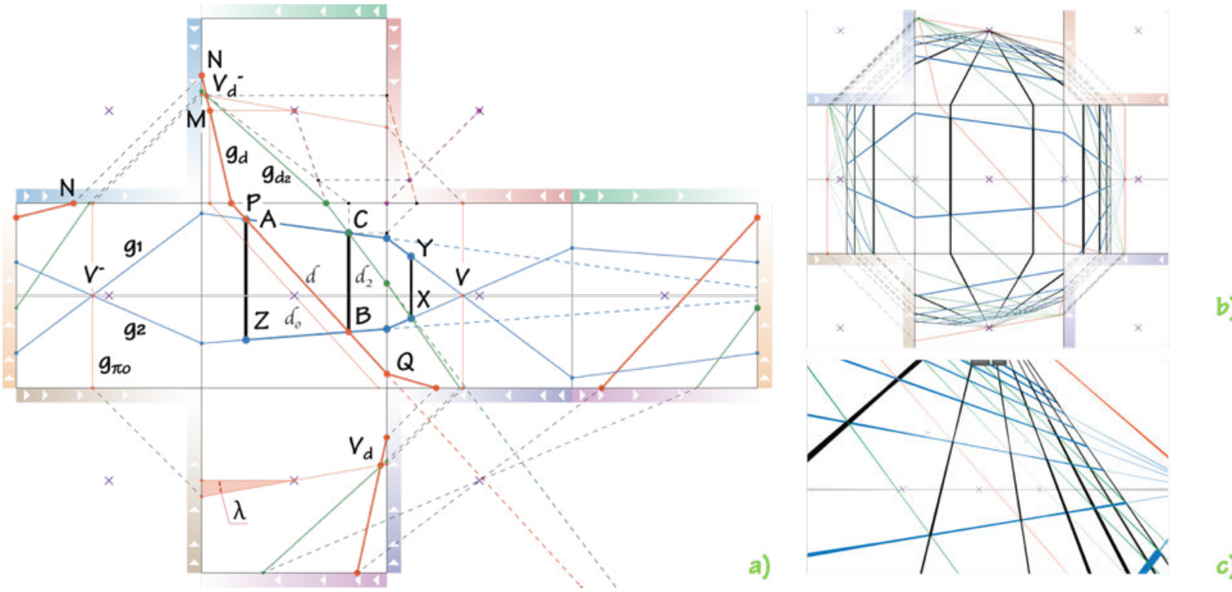


Figure 66: Repetition of equally distanced elements using geodesics (a, b) and VR view (c).

Wrapping up, the current state of the art shows the presence of both systematic and non-systematic drawing methods for cubical perspective, although with far less alternatives than other spherical perspectives. Among the different methods, it stands out the cubical-spherical method, which considers the cubical perspective as a special case of spherical perspective. As part of the spherical perspective family and right as the other members of it, the cubical case has both advantages and disadvantages: on the one hand, it is a linear perspective in each face, which makes it easily recognisable; it has exact constructions thanks to the use of straight lines; and the full method allows the fluid representation of all kind of objects, elements, situations, environments, etc. With this, the cubical representation becomes a powerful alternative for immersive drawing, connecting the most common and basic knowledge in linear perspective (expected to be a regular part of art schools' programs) with the advanced understanding of spatial drawing through the concepts of spherical perspective. Nevertheless, cubical perspective lacks further developments that might simplify its application, the complexity of which certainly hinders the drawing process and the motivation for its use. In fact, in addition to the several possible cases of geodesics, the discontinuities of the cubical map add another level of complexity, something almost reduced to the minimum in other spherical perspectives.

VI - Software for creating HIA

The creation of Handmade Immersive Art involves a series of tasks from which some require software - as they are purely digital - and some can use software as an aid/aid/assistant:

- **Task 1: Drawing the immersive perspective**. The perspective can be equirectangular, azimuthal-equidistant or cubical. For this task, the software is optional, as the same result can be achieved using physical tools.
- **Task 2: Converting/switching among different formats**, for example from cubical to equirectangular perspective. Software is mandatory for this task.
- **Task 3: Creating/navigating the VR environment**. For this we digitally wrap the drawing in a specific way on top of a sphere or a cube. Software is mandatory for this task.
- **Task 4: Enhancing the VR environment.** After the creation of the virtual environment, the user can interact with it in different ways: zooming in/out onto/from details, opening other drawings, different media, interacting with a web browser for an augmented experience, etc. Software is mandatory for this task.

Potentially, any drawing software can be used for creating an immersive drawing (Task 1), even if they were coded with other purposes. For example, one could create a cubical perspective using any advanced vector-based or raster-based program such as Illustrator or Photoshop from the suit of Adobe, or even AutoCAD (Figure 67) but one could also use the most basic drawing software such as Paint for the same task.

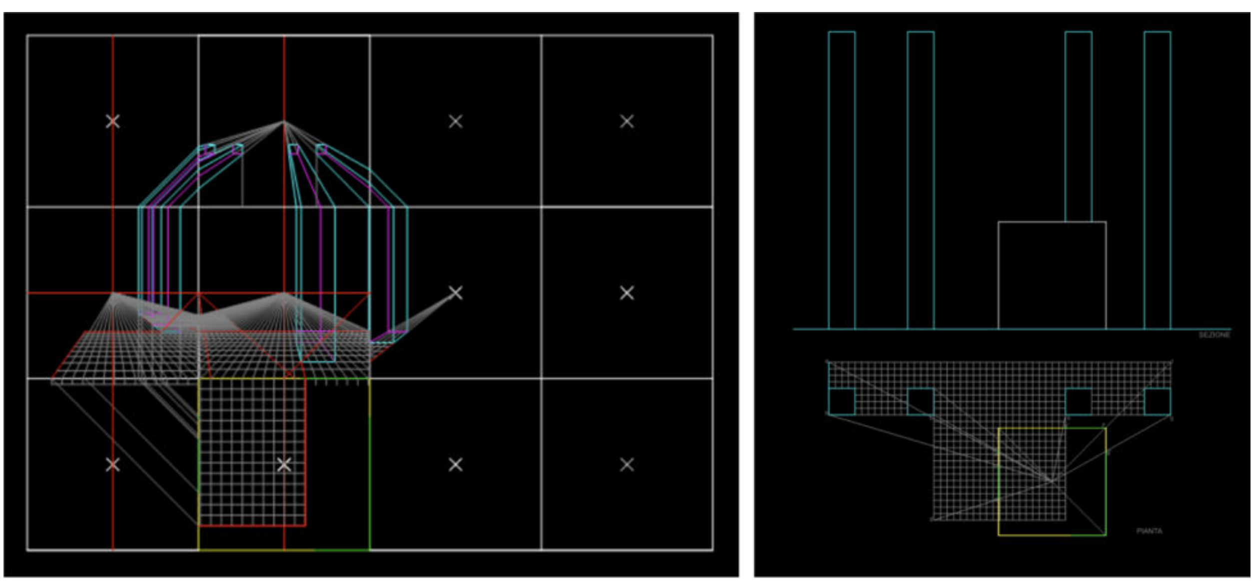


Figure 67: Drawing a cubical perspective with AutoCAD © Teresa di Palma, 2020.

The role of software in Task 1 is accessory: this is a classic example where technology provides very practical tools and good aids to enhance and facilitate the activity of drawing, such as zooming in/out for defining details, the possibility of undo actions without tearing the paper apart, etc., nonetheless, the software is dispensable as we could also do without it. Indeed, the creative process with these programs is exactly the same than with a physical drawing: one draws line by line, composing, analysing, deciding and being critical about the results, and that slow processing requires a conscious human analysis rather than a speeded and massive automatic processing. Despite of this, a piece of software well written can be very helpful for the task, including specific tools for both easing and teaching about the perspective in use. For example, during the creation of HIA is not easy to evaluate if the flat drawing being created is following the rules of a spherical perspective. At least, it is not an easy task if one does not know such rules beforehand and, goes without saying, this is not always the case. Indeed, this dual vision flat spherical perspective/VR correspondence requires much training even for advanced users. This verification is critical for obtaining good results, as the spherical perspective loses the distortion only once is in the VR environment: we create the VR environment to see the undistorted drawing (Task 3), interact with it (Task 4) and evaluate the results. This is not an easy a straightforward process, as many times the input for the VR viewer has to be in a certain format, e.g., equirectangular format. If then, our initial drawing is a cubical perspective or an azimuthal-equidistant perspective, then we will have to convert it to the equirectangular format (Task 2). As one can imagine, this workflow results quite impractical as there are too many steps in between the drawing itself and the VR navigation, steps that make the task more bureaucratic than enjoyable. Hence, a software purely dedicated to the creation of Handmade Immersive Art should keep these things into account and try to include them in a smooth workflow without disrupting the main task: drawing. Let's see a current selection of software that include some of these tasks:

VI.1 - Software for drawing immersive perspectives (Task 1)

VI.1.1 - Photoshop Panorama Tools (deprecated)

Photoshop (2025) includes a tool to switch between an equirectangular map and its VR visualisation (Figure 68). The SphericalMap tool, included in several editions of Photoshop at least since 2018, is mostly intended to retouch and solve small problems within critical regions of full panoramic photographs, such as the nadir and zenith, rather than creating a full spherical perspective. However, the use of this tool was extended and adapted to the task of immersive drawing (Theng Seng, 2018). In practice, The SphericalMap tool results of great help for an early approach: once in the VR viewport, we only see a flattened portion (a linear perspective) of the whole panorama, which simplifies the task for those who do not want to learn or deal with the rules of the full spherical perspective. Furthermore, the tool inherits a great versatility thanks to its integration with the Adobe suite: one can draw with raster-based tools on Photoshop, link an external vector-based file using Illustrator or a pdf file from an AutoCAD file, link a video composition using Premiere Pro, etc. This flexibility covers drawing methods ranging from free improvisations to technical accurate compositions made outside the Photoshop environment. However, the Panorama Tools of Photoshop do not work smoothly: the VR navigation is not fluid, and it consumes many resources from the computer, the heavier is the panorama or linked file, the more difficult is the use of the tool. Furthermore, Adobe has been announcing the deprecation of Photoshop’s 3D motor since 2022, which includes the SphericalMap tool (Adobe, 2022). By May 2025, the tool is still available, yet it will force those who use it to switch towards other alternatives the moment in which it will disappear.

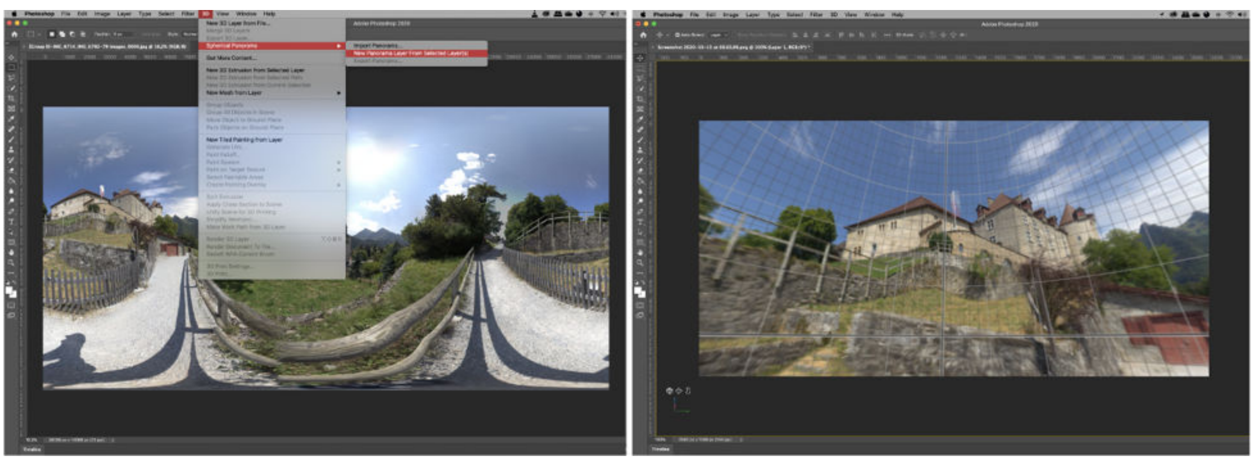


Figure 68: Switching from equirectangular to the VR viewport (left) and immersive view (right) (Photoshop, 2025).

VI.1.2 - Oniride 3D Art (deprecated)

The Oniride 3D Art plugin for Photoshop is one of the few examples of software for drawing in the cubical format (Oniride, 2016). Sadly, the plugin was discontinued several years ago and since then no alternatives have shown up for the cubical map. As with the Photoshop Panorama Tools, the plugin had great versatility thanks to its integration with the Adobe suite: you could draw in Photoshop itself, in Illustrator or in AutoCAD (via pdf export), and use

Photoshop/Oniride to view the results (Figure 69). This flexibility allowed a wide range of cubical methods, from the basic guidelines which results are only visually validated (e.g., Theng Seng (2016); A. Rossi & Olivero (2018)), until the most advanced and precise constructions with vector-based tools (e.g., A. Rossi et al. (2021a); Olivero et al. (2020)). Furthermore, Oniride had several functions proper of cubical immersive drawing: one could draw on the cubical map, open a separate viewport and visualise it as a VR environment. Furthermore, the edges of the cubical map were marked with colours, guiding and helping users to deal with the many discontinuities of the cubical map. Another strong point for Oniride was the three different layers that had by default, from which one could create a far, an intermedium, and a closer layer. On the pitfall sides, the VR viewport of Oniride did not update automatically, instead, one should open the viewport, wait until the 3D motor loaded, click on Preview Cube Map, and only then see the VR environment and interact with it. Furthermore, its strength of being part of Adobe also brought it several weaknesses: as a dependent plugin it needed constant updates for every new version of Photoshop, yet the Oniride company closed the project, and the plugin fall in deprecation (last working version was Photoshop 2015.5).

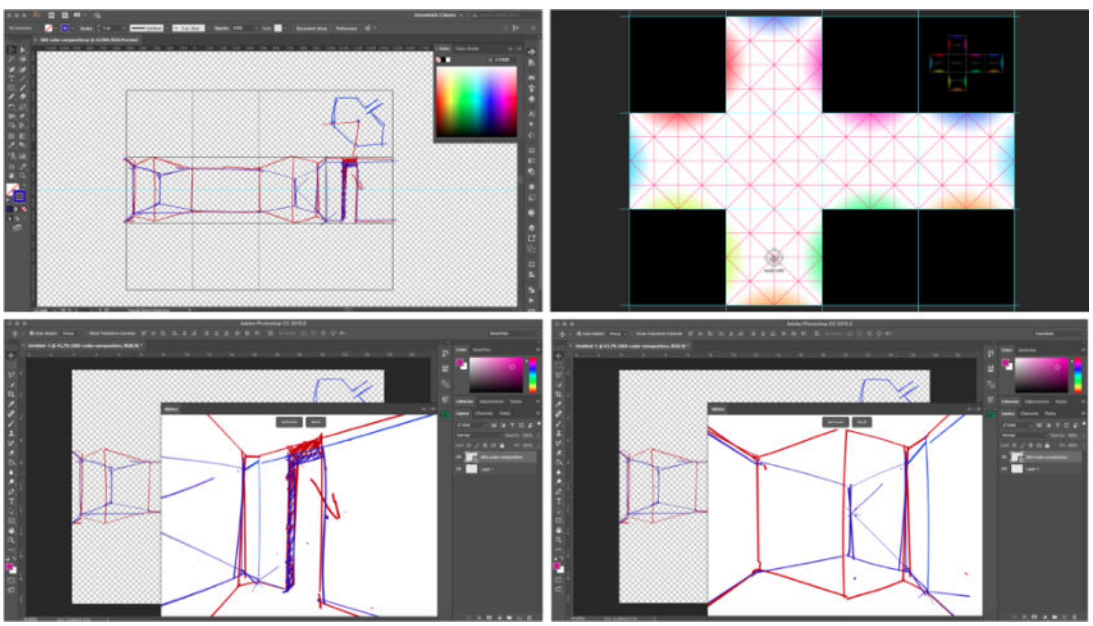


Figure 69: Drawing in the cubical map with illustrator (top, left). Oniride 3D Art plugin interface in Photoshop 2015.5 (top, right). Using the external viewport for the VR navigation of the drawing made in Illustrator (linking dynamically the Illustrator file to Photoshop) (bottom).

VI.1.3 - Harmony

The software Harmony by Toon Boom specialises in animation, and it includes powerful snap-to-guide tools for assisting the drawing of perspectives (Boom, 2024). In particular, their perspective tool allows the customisation of several parameters, including the quantity and position of vanishing points, quantity of guidelines, dynamic definition and superposition of grids, etc. Furthermore, it is possible to select between linear and curvilinear perspectives, including a grid for an up to 180° fisheye perspective (Figure 70). Since at least their 17th version, their perspective tool includes the alternative of keeping the brush stuck to the guidelines, which renders the drawing experience very smooth and guarantees the artist to be drawing the right curve (Figure 71). The software runs without issues in both Windows and MacOS operative systems. The pitfall side: its price, which makes it not really accessible.

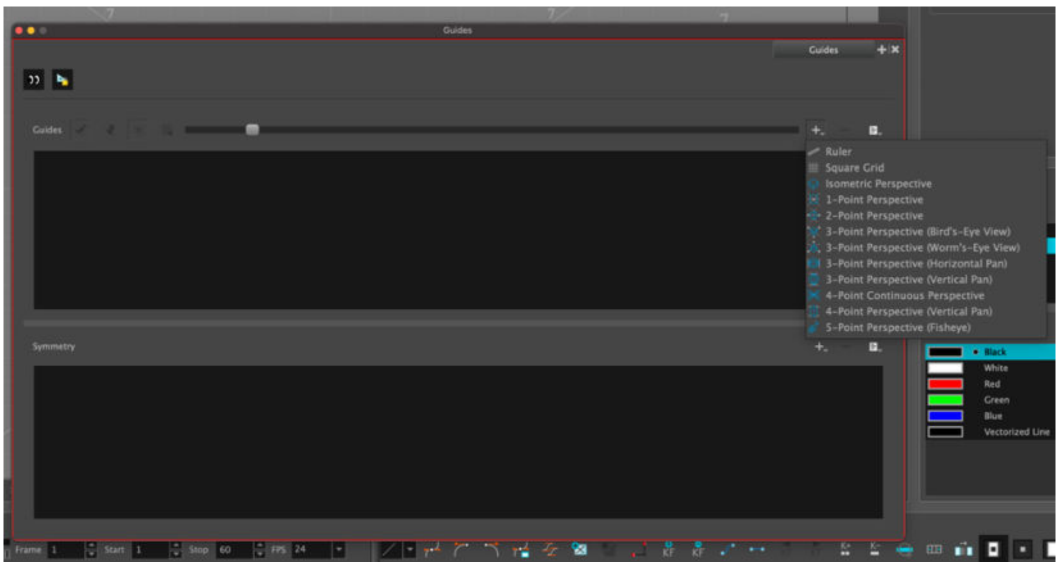


Figure 70: The perspective grids available in Harmony Premium 24 (Boom, 2024).

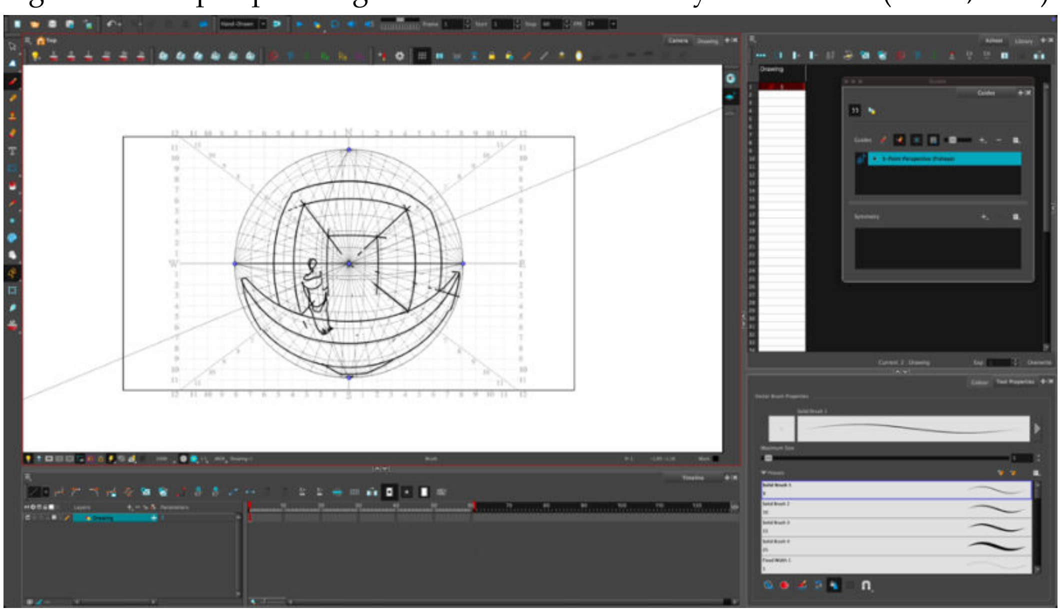
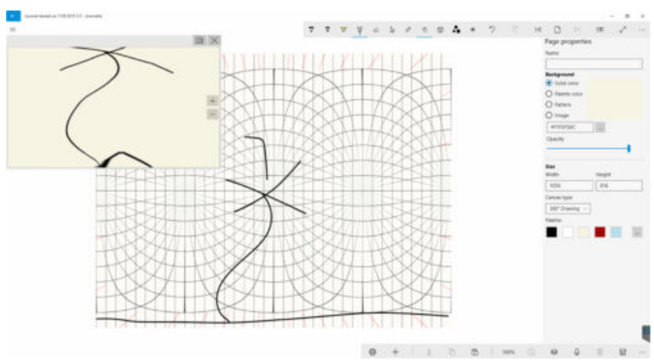


Figure 71: Very basic composition in Harmony 24 using the azimuthal-equidistant 180° perspective tool guides.

VI.1.4 - Sketch 360

The raster-based software Sketch 360 by Michel Scherotter (2018) runs as a Windows-based application and it is available for free at the Microsoft store. In this case, the user draws on top of the equirectangular grid and sees the results in a parallel VR viewport (Figure 72). Since its creation in 2018, Sketch 360 incorporated many specific tools for spherical drawing such as the equirectangular grid and most recently the Eq A Snap equirectangular stencil - originally developed for Eq A Sketch 360 (Araújo, 2019b) - which forces the brush to follow a geodesic curve from any two random points. As part of its latest developments, Sketch 360 was also optimised for devices with double screen, such as the Surface Duo (Figure 73) and it started the coding for having compatibility with iOS devices too (at least, as can be seen on Github Scherotter (2025)). However, the last updates within the official Github repository were made three years ago, which leaves open the possibility of a discontinued product. Last, no further integrations with other media were possible to test so far due to operating system limitations.



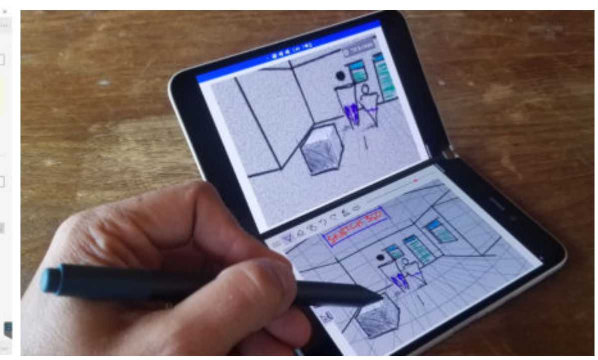


Figure 72 and 73: Sketch 360 running on Windows 10. The tracing on top of the grid is visualised in VR in the upper left viewport (Left). As of its last developments, Sketch 360 was optimised to also run on Microsoft Surface Duo (Right). © Michael S. Scherotter (2025) Github repository.

VI.1.5 - Eq A Sketch 360

Eq A Sketch 360 has been promoted as a *serious toy* aiming to:

> "(…) develop sketching intuition regarding the structure of equirectangular drawing as proper perspective drawing, with its specific constructions of vanishing points, geodesic segments, line projections, antipodes, and grids" (Araújo, 2019b, p. 1).

The first versions of the software were compiled using Processing and tested successfully in both Windows and MacOS in their latest versions (Figure 74). Eq A Sketch 360's development has been slow yet relentless during the years, perhaps due to the lack of funding and a bigger corporate team. However, it is still fully working in both operating systems by 2025. The latest version has commands to draw geodesics and vertical lines, erasing, saving, importing and exporting the equirectangular panorama. Furthermore, users can shift the background grid with an accuracy of 1°or 5°, or switch it upside down. Eq A Sketch 360 is as a technical drawing assistant that gives full control to users within the equirectangular map thanks to a control panel indicating bearing, elevation, the offset of the grid, apex, etc. The core function developed by Eq A Sketch 360 since its very beginning (later incorporated by Sketch 360) is the equirectangular ruler Eq A Snap, which consists in guiding the drawing through the right geodesic: the user fixes any two points within the grid and then drags the brush, which will automatically follow the correspondent great circle among the two points. Although Eq A Sketch 360 allows freehand drawing, its code discourages the user from following the grid by hand, the focus of the program has been put on the snapping tool for a reason which is that every straight-line projects as a geodesic in the equirectangular map (see V.3.1). The equirectangular stencil adds precision to the artwork and allows the construction of geometries in a linked way, for example, one can fix one of the points, use it as a vanishing point, placed the second in a new measured or wished position, and trace again. Although the current version of Eq A Sketch is raster-based, there are plans for creating a vector-based alternative shortly. Either case, the current setup allows exporting the drawing without the grid and with enough resolution for importing it into vector-based programs where it can be traced and filled with shadows or gradients (Figure 75).

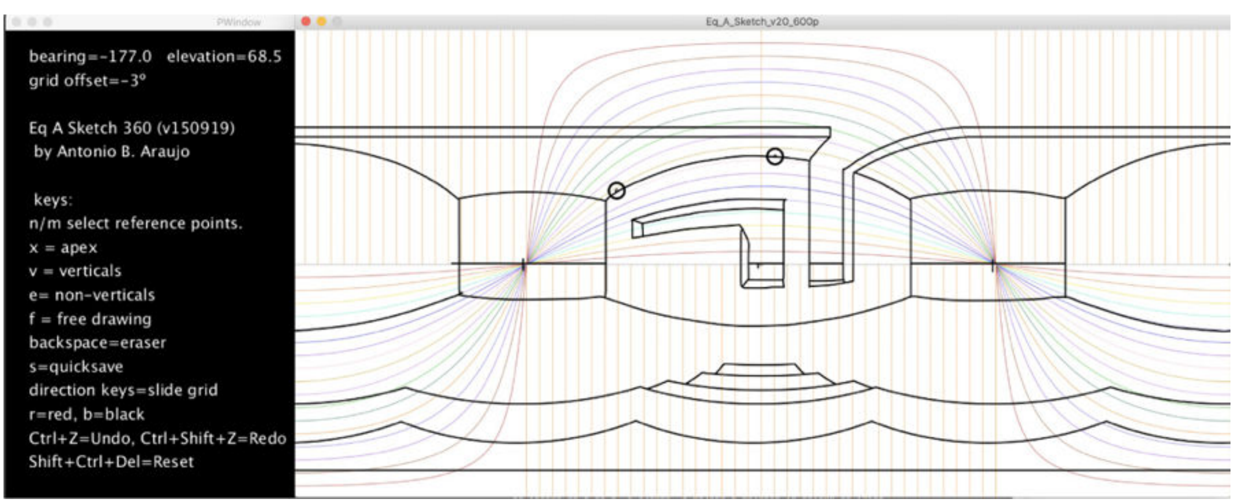


Figure 74: Drawing on MacOS using Eq A Sketch 360 and the geodesic-based construction tool.

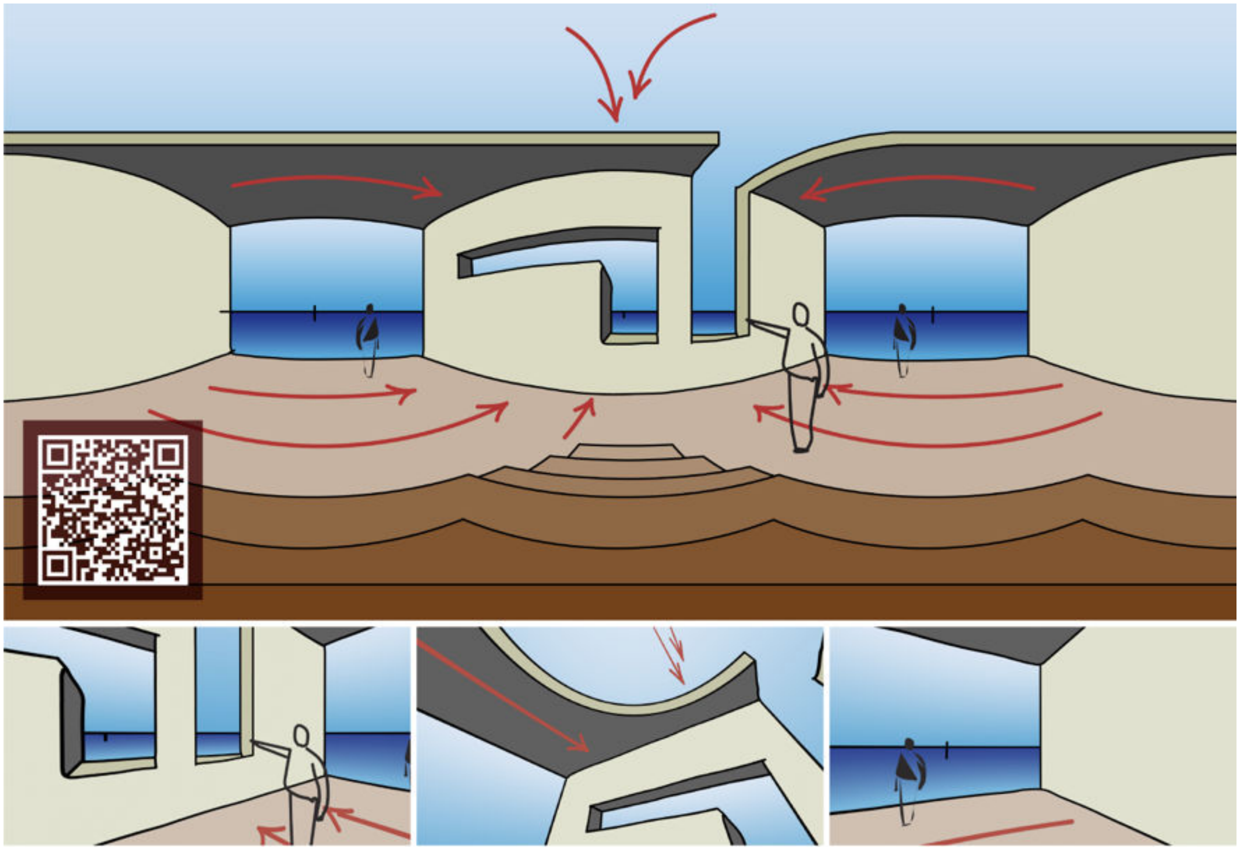


Figure 75: Equirectangular imaginary space created with Eq A Sketch (up). VR navigation (down).

VI.1.6 - Azimuthal-equidistant GeoGebra Script

Surprisingly, the azimuthal-equidistant perspective does not have a current accessible software option such as Sketch 360 or Eq A Sketch 360 despite being the oldest sister of the family with its first developments dating back to Barre & Flocon (1967), and the development of very practical methods for drawing panoramas covering the full visual sphere around the observer (Araújo, 2018c). The closest option is a GeoGebra script recently launched by the same programmer of Eq A Sketch 360 (Araújo, 2020b) and, as such, the script has a clear orientation towards the teaching of spherical perspectives while drawing. The program is the digital implementation of the drawing method developed back in 2018, using the many advantages provided by this projection such as groups of symmetries by rotation (instead of sliding as in the equirectangular format). Although the script might be complex for beginners, it allows artists to quickly familiarise with this projection and play without limits in their creations and without sacrificing accuracy thanks to the neat controls programmed by Araújo and managed by GeoGebra. In fact, one can create classical constructions using vanishing points, multiplication and division of modules, etc. (Figure 77), achieving very complex and defined results (Figure 78). One further advantage of this script is the open compatibility with every kind of device, as it can run either locally in the computer or through the browser directly from the GeoGebra website.

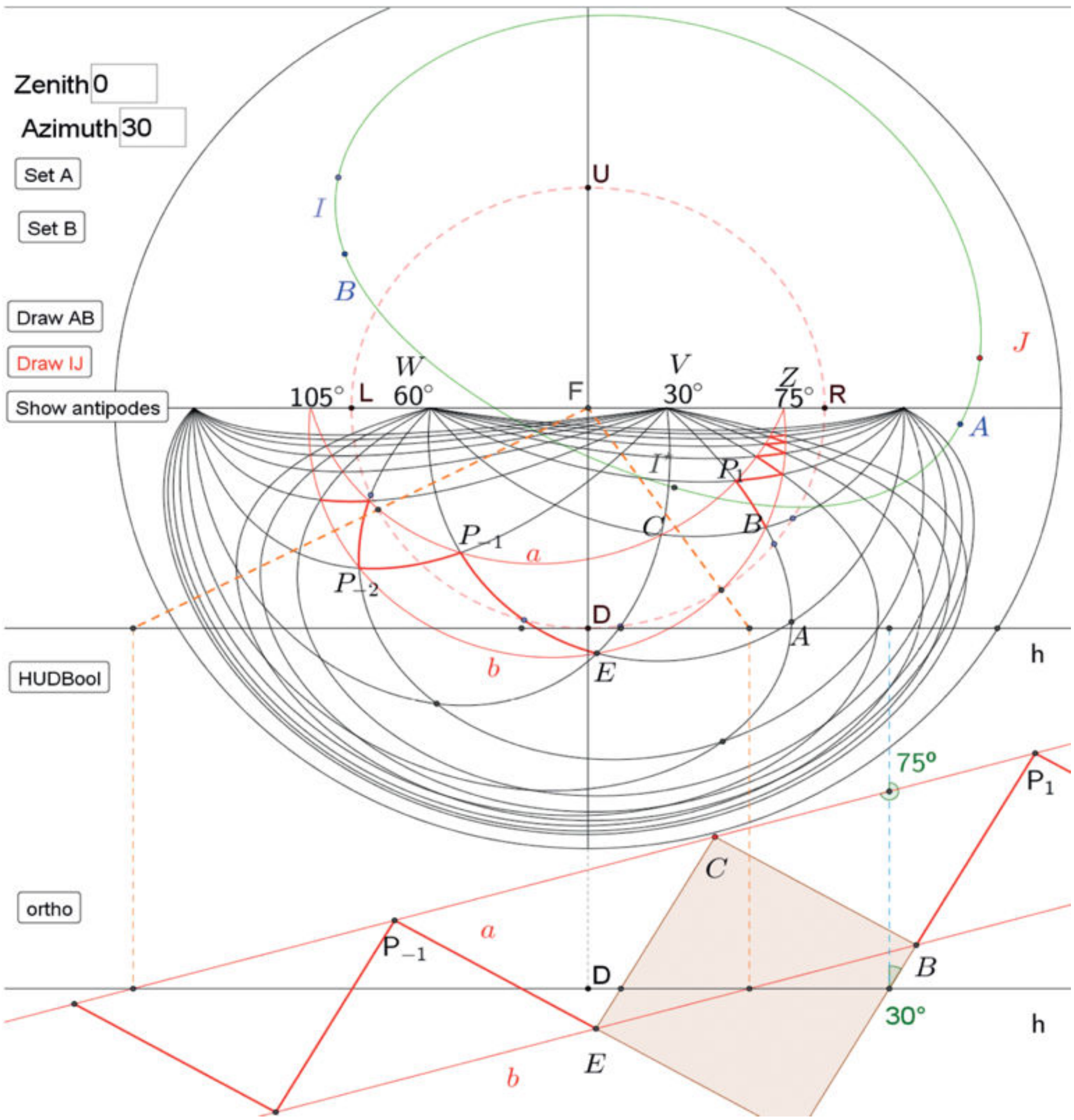


Figure 76: Construction of a grid in the azimuthal-equidistant GeoGebra script © António Bandeira Araújo, 2020.

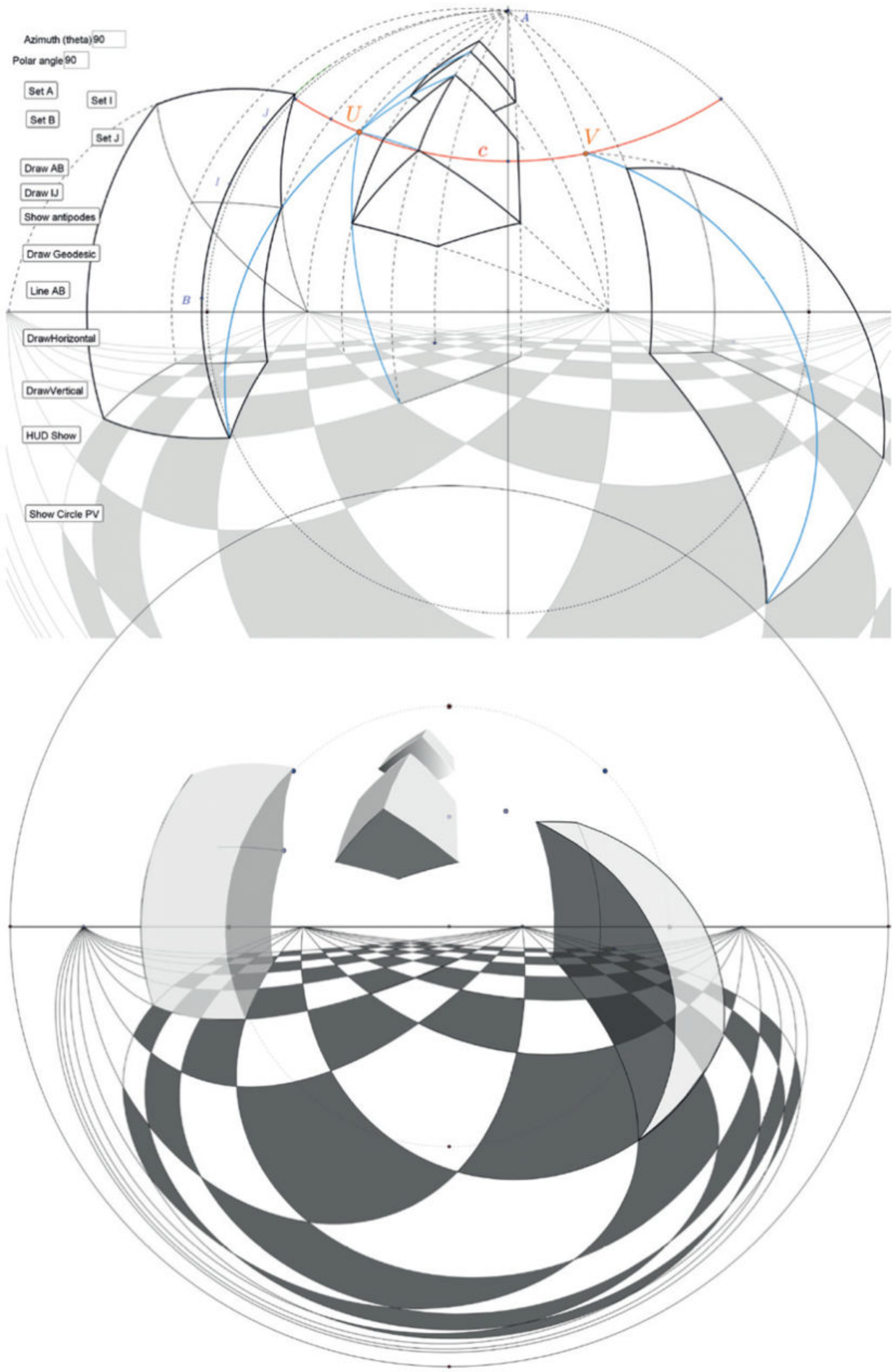


Figure 77: Construction of ramps, boxes and grids (top). Final artwork shaded in Inkscape © António Bandeira Araújo, 2020.

As far as this research can tell, there are no specific software options for drawing in cubical perspective using a snap-to-guides tool such as Eq A Sketch 360, Sketch 360 (for equirectangular perspective), the GeoGebra Script by Araújo or Harmony (for the azimuthal-equidistant perspective), which leaves an open gap in the software industry.

VI.1.7 - Recap

Photoshop offers (for now) the possibility of raster-based drawing either on the equirectangular map or within the VR viewport yet working with both at the same time is not possible. Oniride 3D Art, the only option for raster-based drawing and interacting with a VR environment made from a cubical map, has been deprecated and it is no longer available. Harmony represents an interesting alternative for fisheye perspective up to 180°, but it is a high fee paid option. Sketch 360 has the possibility of drawing in the equirectangular map using the snap tool for geodesics and live watching the VR results in a separate viewport, but it is only compatible with Windows. Eq A Sketch 360 has the possibility of drawing in the equirectangular map with the original snap tool and with more tools for precision drawing, it is compatible with both MacOS and Windows, but it has no live VR viewport. Finally, the Azimuthal-equidistant Geogebra script is the only available option for drawing in the so-called fisheye perspective with an algorithm that *forces* the user to understand and learn about the perspective in use, although it also lacks a live VR viewport.

All in all, the software options for immersive drawing seem limited (specially for cubical and azimuthal-equidistant perspectives). For which a call to the community of programmers is made, for them to develop an open-source, widely accessible and complete suite that might cover both raster-based and vector-based drawing in equirectangular, cubical, and azimuthal-equidistant perspectives, using snap-to-geodesic tools, other aids for precision drawing, and the live visualisation of the results in a parallel VR viewport.

VI.2 - Software for converting/switching spherical maps (Task 2)

The task of switching among different maps is well-known in computer graphics and it can be addressed with a variety of software. This has been largely explored in a classical scenario among photographers, i.e., the composition of a full panoramic photography. One common way of composing a full panoramic photography implies taking several pictures with a studied overlap among them and capturing the whole visual field around one point; then the individual shots are automatically processed by a software that performs a content analysis, finds homologous points and composes one single panoramic picture by stretching and stitching the individual shots Figure 78. Once the full panoramic photography is ready, photographers switch back and forward between the cubical and the equirectangular projections for different aims and purposes (Antinozzi, 2019, pp. 99–105; 2023; A. Rossi, 2017).

Figure 78: Composing the panorama from several overlapped pictures using Autopano Giga (up). Final equirectangular panorama shot at Teufelsberg, Berlin, Germany (below). Scan the QR code for the immersive navigation. Collaborator: Ana Aparicio. Panorama © Lucas Fabian Olivero, 2023.

The reasons for switching back and forward between formats are connected with the advantages and disadvantages of each of them. For example, one can understand better the whole scene in one single picture using the equirectangular format, an advantage regarding the cubical format - which has several interruptions. Furthermore, the equirectangular projection is a very well-known standard format for the creation and navigation of VR environments and a canonical input of reference for getting any other projection such as cubical, azimuthal-equidistant, little planet, etc. (Figure 79). On the other hand, an advantage of using the cubical projection is that the apparent distortion of the poles is better known (a linear perspective), and hence nadir and zenith can be edited without dealing with the complicated distortions of the equirectangular or the azimuthal-equidistant formats (Figure 80). These correspondences between equirectangular and cubical projections have been around since the 80’s (Greene, 1986) and several studies deepened the subject (Dimitrijević et al., 2016; Lambers, 2019; Lambers & Kolb, 2012; Wong et al., 2007), from which many pieces of software were developed.

As the projections used for immersive drawings are the same than those used for panoramic photography, we might be tempted to think that we can use the same software for converting panoramic photographs, however this is not always the case. Within the applications for switching projections among panoramas, the conversion can be **direct**, i.e., as simple as selecting an input, an output format, and getting the conversion done (Figure 81); or **indirect**, i.e., the conversion tool gets available inside the production workflow only after a project has been created.

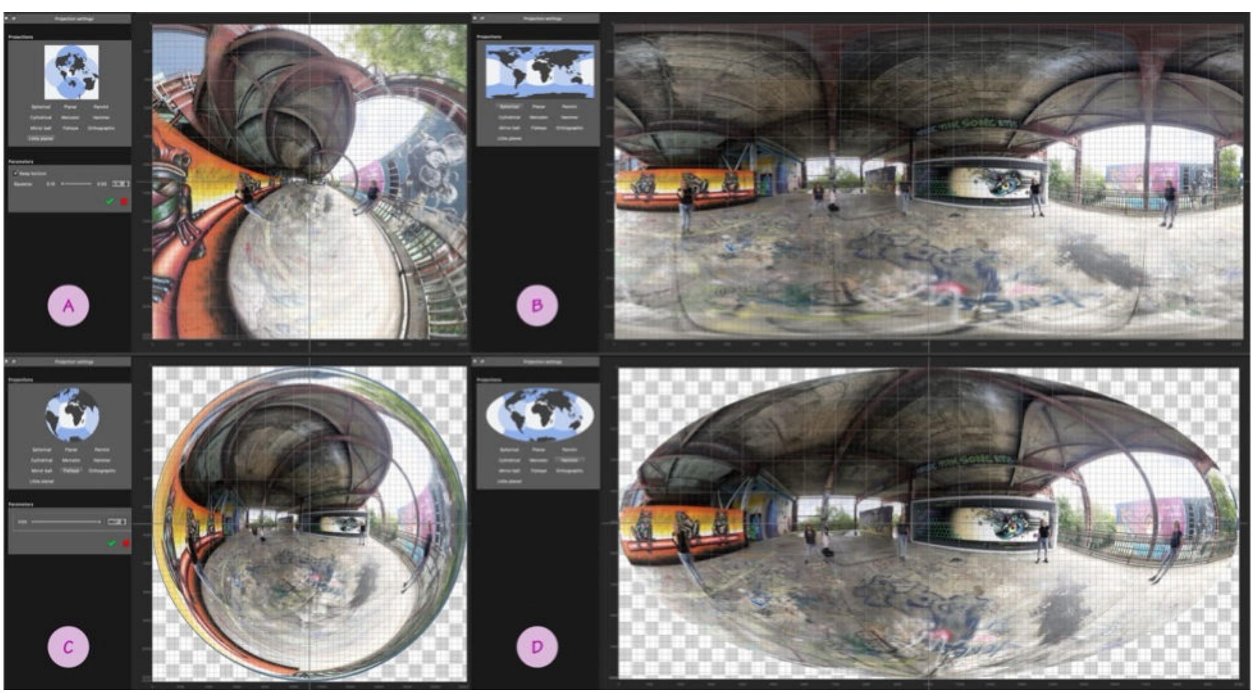


Figure 79: Conversion among spherical projections: little planet (A), equirectangular (B), azimuthal-equidistant (C), hammer (D).

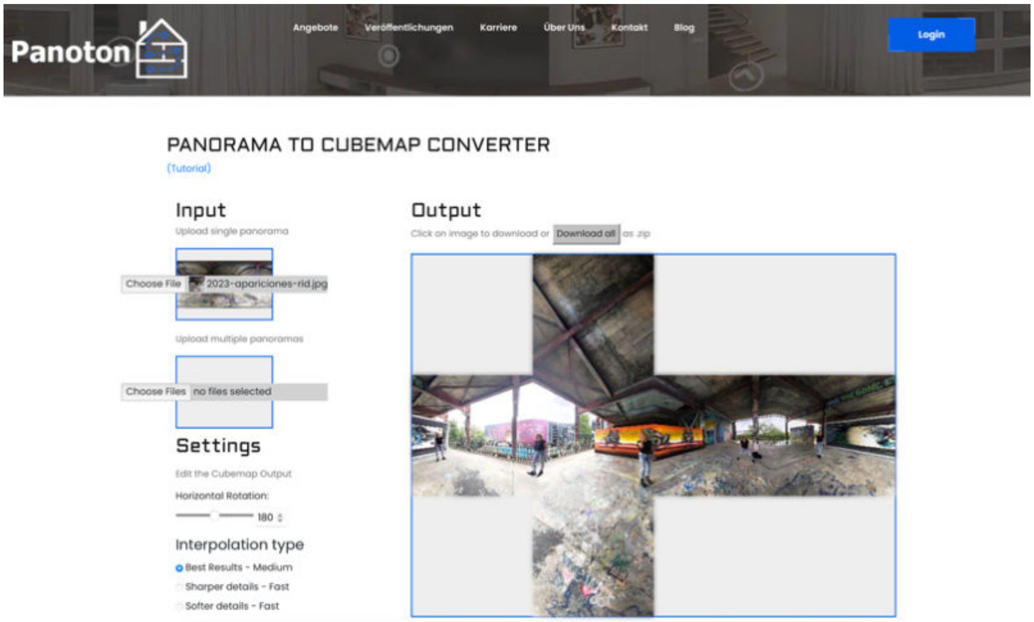


Figure 80: Conversion from the equirectangular to the cubical format using the online tool (Panoton, 2025).

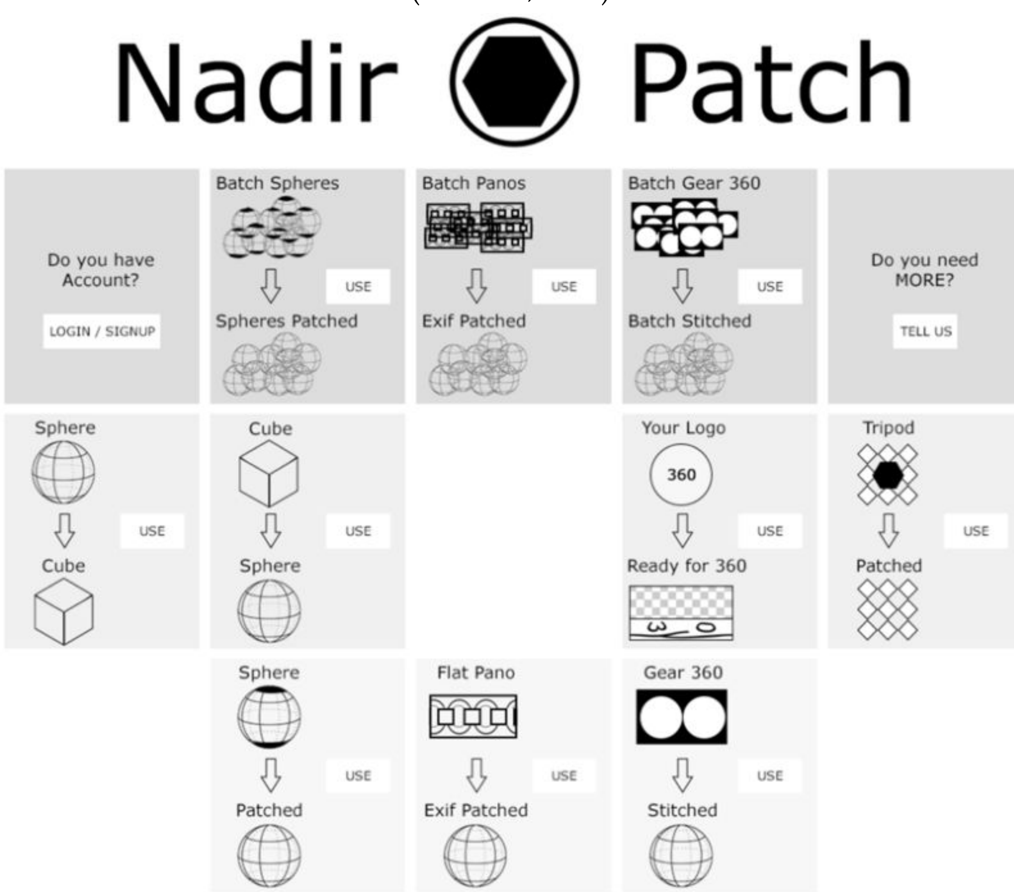


Figure 81: The Nadir Patch website offers a direct and simple conversion between equirectangular and cubical projections © (NadirPatch, 2025).

The software with **direct** conversion can be used straight ahead with drawings, as there is no difference between an image file containing photographic or drawn information. Some examples are Nadir Patch (NadirPatch, 2025), Panorama to Cubemap (Crane, 2025), Panoton (Panoton, 2025), Cube2DM (Tomonori, 2017), Bixorama (Outerspace, 2025), Flexify 2 (direct but inside the Photoshop environment) (Pear Software, 2025), and Kolor Autopano (Kolor, 2023).

However, there is a substantial difference if we want to use programs with an **indirect** conversion pipeline: a panoramic drawing is not a composition made of several images stitched together, there are no automatic procedures analysing each image, finding analogous points and positioning them within the spherical map like in photography. Instead, we only have one file: the final, full panorama, and so the software should process the file right as we upload it, without any internal analysis. Yet, many of these programs allow the customisation and improvement of the position, cut and alignment of the individual pictures. In fact, – sometimes the equirectangular panorama we see within the program is actually a preview of the stitching result, not one single image (the individual full panoramic image is an output generated only after the rendering). An example of this is Kolor AutoPano (Kolor, 2023), a program with several options for switching among spherical projections, but with the limitation that it requires the processing of the individual photographs to access the conversion tool. Furthermore, in this program we cannot create a project with one single existing panorama previously done, which breaks our chances of using it for drawings as there are no easy turnarounds. On the other hand, other stitching programs such as Hugin (D'Angelo & Various, 2024) and PTGui (BV, 2025) also require the building of a project, but they can be forced by replacing pictures with drawings, hence accessing the conversion tools and getting the conversion done. Clearly, our best and more straight option for converting drawings is the first group of software. However, they tend to be either online applications that appear and disappear year after year, e.g., 360 toolkit (Alshaker, 2018), or plugins behind a paywall, e.g., Flexify 2 for Photoshop (Pear Software, 2025), Bixorama (Outerspace, 2025). Another option for more advanced/tech users is to use the libraries behind several of the programs mentioned above, i.e., the Panorama Tools library (Postle et al., 2023). This library offers free, open source and updated conversion tools but it requires interaction through the terminal. All in all, the conversion of drawings might become problematic: in certain scenarios, if we do the maths and deduct software where the conversion tool can only be accessed within the workflow of certain software; minus those that can only be accessed through a paywall; minus the vanishing websites; minus those that work but have not all the projections available; minus those that are only compatible with certain operating systems or require coding skills; then sometimes we find in a situation in which we are left with very few, if any, options. For this reason, we have to consider a wide spectrum of possibilities, including software and applications that are easy, open and accessible but maybe less reliable in the long term; options that can be accessed through workarounds; and other workflows that are a bit more intricate but also more generic (i.e., possible to develop with different pieces of software or through the source libraries) and consequently more stable over time (Figure 82).

SOFTWARE / APPLICATION	LICENCE	PLATFORM / COMPATIBILITY	POSSIBLE CONVERSIONS	DIRECT CONVERSION	COMPLEXITY OF USE	SUPPORTED IMAGES	LIVE FEED SUPPORT
Nadir Patch	Free	Online (Browser)	equirectangular ↔ cubical	Yes	Easiest	Any	No
Panorama to Cubemap (jaxry)	Free	Online (Browser)	equirectangular → cubical	Yes	Easiest	Any	No
Panoton Cubemap Converter	Free	Online (Browser)	equirectangular → cubical	Yes	Easiest	Any	No
Flexify 2 (Flaming Pear PS plugin)	Paid	Windows/macOS (Photoshop plugin)	equirectangular ↔ cubical ↔ fisheye	Yes	Easiest	Any	No
Bixorama	Paid	Windows	equirectangular ↔ cubical ↔ fisheye	Yes, inside Photoshop	Easy	Any	No
Kolor Autopano Giga	Free (Discontinued)	Windows/macOS	equirectangular → fisheye	No, it requires a stitching project. It might be possible to force it	Easy	Pictures only	No
Kolor Panotour Pro	Paid (Discountinued)	Windows/macOS	equirectangular ↔ cubical	Yes, inside Panotour Pro	Easy	Any	No
Cube2DM	Free (¿Discontinued? Last update 2017)	Windows	equirectangular ↔ cubical ↔ fisheye	Yes	Easy	Any	No
Panorama Tools (libpano13)	Free / Open Source	CLI Windows/macOS /Linux	equirectangular ↔ cubical ↔ fisheye	No, it requires command line operations	Medium	Any	No
Hugin	Free / Open Source	Windows/macOS /Linux	equirectangular ↔ cubical ↔ fisheye (up to 180º)	No, it requires a stitching project. Yet, it is possible to force it	Medium	Any	No
PTGui	Paid	Windows/macOS	equirectangular ↔ cubical ↔ fisheye	Yes for equirectangular → cubical and fisheye → cubical. The other way around requires some extra setup	Medium	Any	No
Pano2VR	Paid	Windows/macOS /Linux	equirectangular ↔ cubical ↔ fisheye (up to 180º)	Yes, although it requires knowing the interface	Medium	Any	No
Unity (Engine)	Free	Windows/macOS	equirectangular ↔ cubical ↔ fisheye	No, it requires setting up a 3D scene	High	Any	N/D
TouchDesigner	Free (non-commercial) and Paid	Windows/macOS	equirectangular ↔ cubical ↔ fisheye	No, it requires setting up a 3D scene	High	Any	Yes

Figure 82: Comparative of software for converting and switching among spherical projections.

If no direct option is available, then we can force a project for the software to assume it is working with photography. Let's explore a workflow example using open-source and free software, in this case, I used Hugin for switching from the cubical to the equirectangular projection. Figure 83 shows a cubical drawing made on-the-fly with chalk on a board during a class. One could digitise the drawing either by taking one picture including the whole content (quicker), by taking six individual shots at every face (more work but better final resolution), or using a regular paper scanner (best option as it has no lens distortion and high resolution). As this experience was during a class with limited time available, I opted to take a single photo, adjust the lens distortion once, and edit the file to align verticals and horizontals, get it cropped to a 4:3 ratio and invert the colours to improve the visibility (these tasks can be done with any raster-based editor). After having prepared the full cubical map, the six individual faces in 1:1 proportion were exported from the photo editor and imported in Hugin. As a stitching software, Hugin tries to find homologous points among pictures but as in this case there are no such points (there is no overlapping among them), we must force the position of every picture by giving them a specific position within the full panorama. The individual faces are setup accordingly with values of Pitch, Yaw and Roll: front (0, 0, 0); right (90, 0, 0); back (180, 0, 0); left (270, 0, 0); up (0, 90, 0); down (0, 270, 0), and set in values of FOV at 90° and Focal Length at 15,3 (Figure 84). At this point it is possible to preview and check the full panorama before its rendering. The blending mode must be set to Hard Seam, so to keep the stitching without colour processing which may give unexpected results. After rendering, we finally have the equirectangular projection (Figure 85).

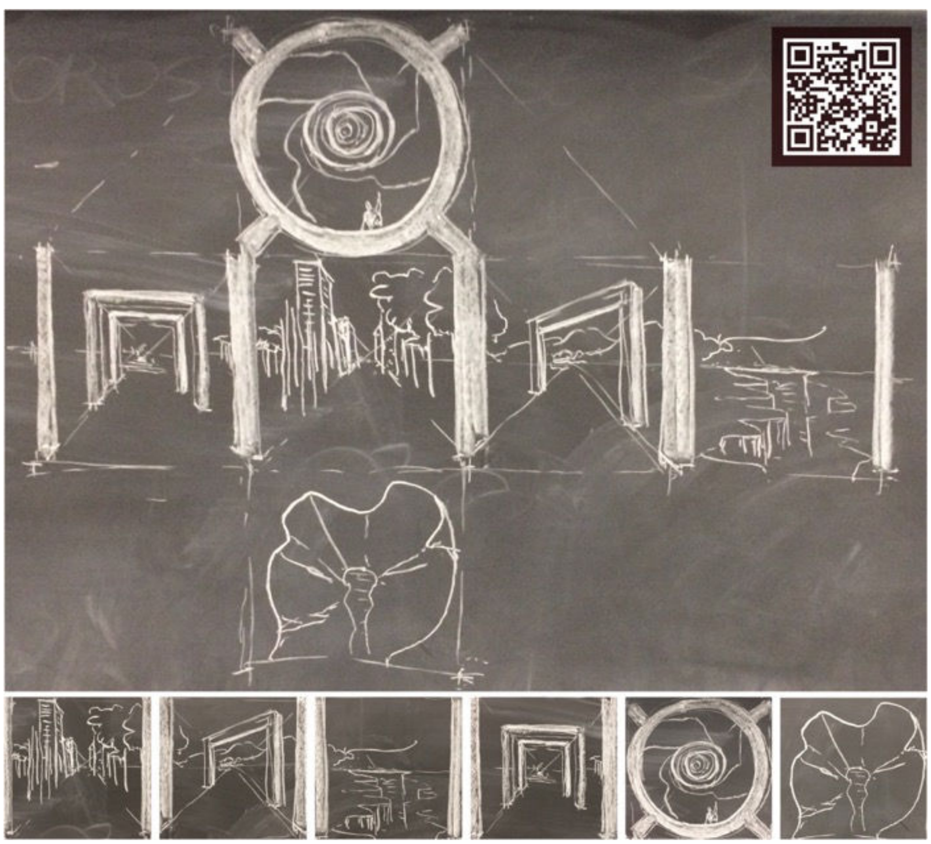


Figure 83: Drawing in cubical perspective made in the board (top). Independent faces (bottom).

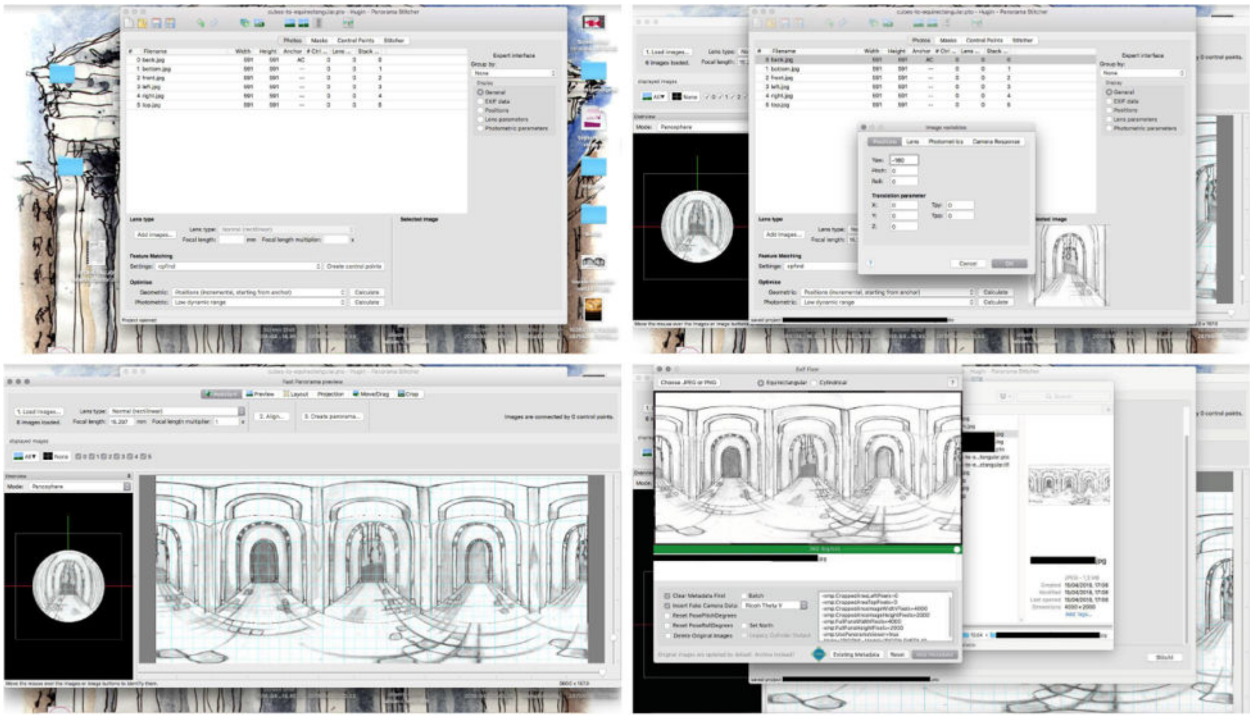


Figure 84: Setting the equirectangular panorama using Hugin and Exif Fixer.

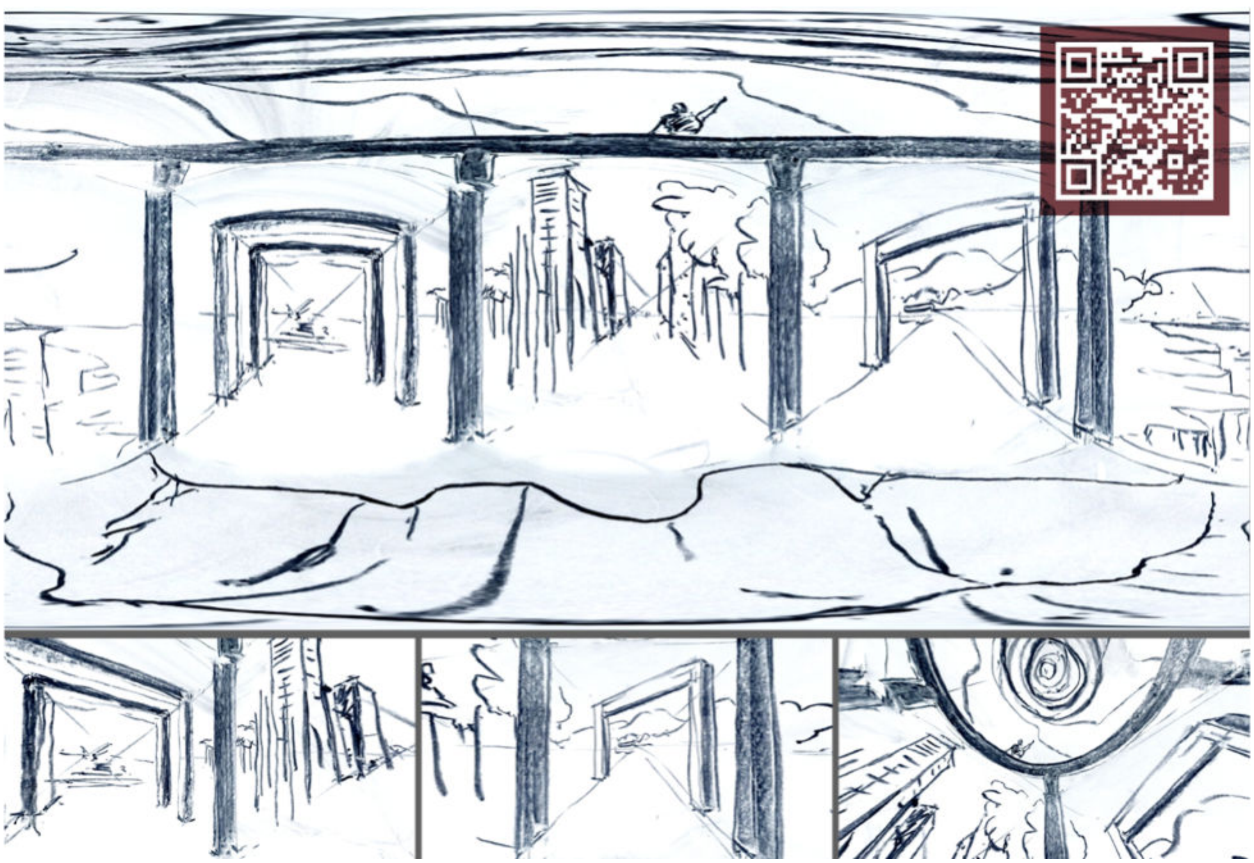


Figure 85: Equirectangular output in inverted colours (top) and VR navigation (bottom).

In a different workflow, some authors start from a 3D model or a point cloud and obtain either cubical or equirectangular panoramas through plugins of 3D motors such as SketchUp or 3D Max (Huang, 2014; Marrazzo, 2020; Nazarenko, 2021). Some examples of plugins are CubicPano Out (Wehby, 2010), WebGL Cubic Panorama (Rami, 2016), CubicVR (Cadalog, 2016), etc. Within these plugins, the images are automatically processed and generated through 3D reflections, they do not propose a technique for immersive drawing *per se* although they could eventually be adapted. For example, one could get the six faces of a cubical map or the equirectangular panorama from the 3D model or point cloud and importing/exporting them within any drawing software.

VI.3 - Software for creating/navigating the VR environment (Task 3)

From Part I, Chapter I.6 we know how a virtual environment is created from an immersive picture or drawing: the software creates a digital sphere, maps the image as the sphere's texture, and places a camera centred in the sphere. Users interact pivoting the camera and modifying its field of view, as if they would be turning their head around a fixed point and/or zooming in/out onto/from details. This interaction can be achieved as the single visualisation of one file (Task 3) or as a part of a bigger project where several panoramas, media, and other interactive elements are involved (Task 4).

The navigation of the single panorama can be achieved through several options: among the easiest ones, we have online tools such as Renderstuff (Nazarenko, 2024), or Photo Sphere Viewer (Heleine, 2025), in which we drag and drop the panorama, and interact with it even from our mobile phone without further concerns or setups. We also have desktop applications such as FSP Viewer (Senore, 2025), which require software installation on a PC and hence they might bring compatibility/updates problems. Finally, classical web editors such as Wordpress also have plugins for panoramic navigation (Wordpress, 2016), or if we have some coding skills, we can build our own visualiser through libraries like Panellum (Petroff, 2019).

Same than with the previous task, the easiest options are normally browser apps, which have wider compatibility although they might result less reliable in the long term. On the other hand, the use of desktop programs and libraries be might more complex to operate, but a better long-term solution. In most of these applications, the standard input is the equirectangular format, some of them might also accept the cubical map and very few options take the azimuthal-equidistant (generally the programs requiring knowledge on coding). Either case, within all these options the conversion is asynchronous, meaning we can use an existing file but not a live content, created and captured on-the-fly. This is not a small detail: the applications are optimised for showing a final product, i.e., a full panoramic photography already elaborated. However, in the case of panoramic drawing we have to consider that showing the partial results of the process is an important step during the teaching of spherical perspectives (as it is a fundamental part for students to learn and visualise the correspondence between the flat drawing and the VR drawing), and if an artist wants to do a live drawing performance using these projections. Within the current options, an immediate visualisation is none but the intricate process of taking a picture and cropping the drawing, converting it from one projection to another (if the program we want to use for visualising does not support the projection we are using) and finally visualising the results in VR.

VI.4 - Software for enhancing and sharing the experience (Task 4)

Another option for exploring immersive drawings is to make them part of a virtual tour, where more interactive elements can be involved, enriching the experience with extra media, information and other panoramas. For example, one additional enhancement of creating a virtual tour is the possibility of accessing the VR function, a modality optimised for using VR glasses. In this modality, the software creates two environments, one with the camera placed slightly to the right of the centre and the other with the camera slightly to the left. The screen is then divided in two parts, with every part projecting two slightly different images, which forces a depth-like effect through a fake stereoscopy (Figure 86). This way, it is possible to interact with the panorama using a mobile phone and VR glasses, or a VR headset: the images projected in the screen will use the phone's gyroscope and reply to the rotation of our head (Figure 87).

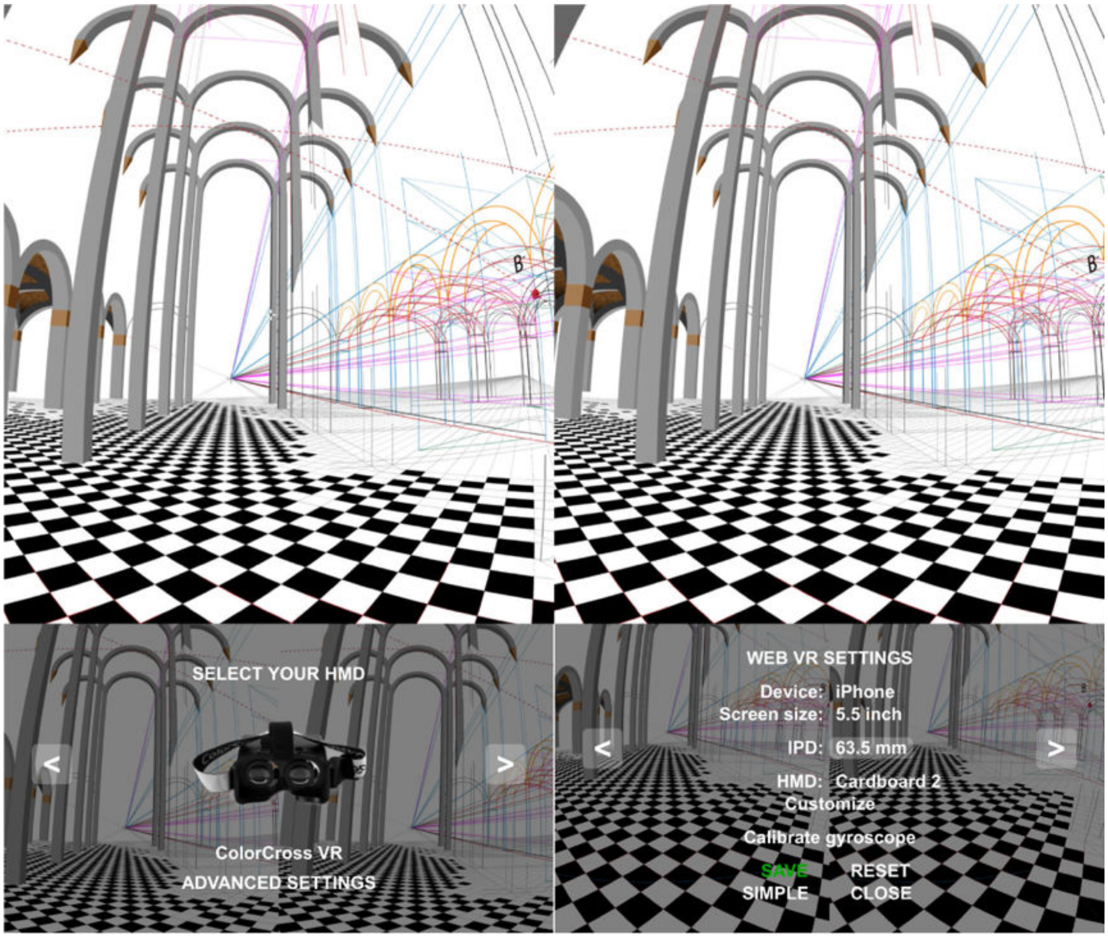


Figure 86: Forced stereoscopy within the VR modality created with PanoTour Pro. It is also possible to select different pre-set of VR goggles or to fine-tune the parameters.

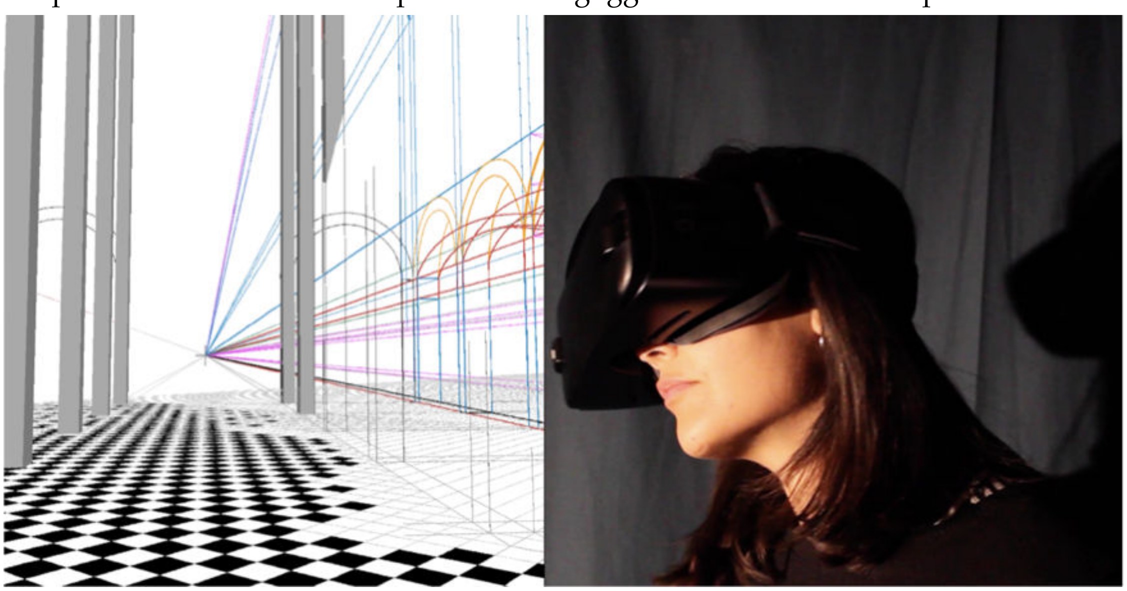


Figure 87: Immersive VR visualisation of a cubical perspective drawing using headsets and a mobile phone.

Further enhancements of creating a virtual tour are:

- **Connection with other panoramas and full panoramic videos:** we can create a path going from one drawing to another, useful for example for showing a collection of drawings.
- **Extended experience:** we can add hyperlinks, texts, documents, videos, images, sounds, etc. This information will help the user to have an extended understanding of the content and a deeper interaction with its creative process or what the creator of the drawing would like to focus on.
- **Localisation and Google Street View integration:** the scene can be placed within a map via geo-localisation or within a floor plan showing its exact location. This can be very handy for showing where a drawing has been done (e.g., as a survey), for building a spatial interaction with a real building or installation, etc.
- **Election of the interaction mode:** one can switch between dragging the sphere or rotating the camera, the former mechanism being optimised for devices with touch commands and the latter for VR goggles and navigation with the mouse.
- **Multi-resolution (HLOD) visualisation of panoramas:** a very high-resolution panorama can be split in several pieces (tiles) per layer. These tiles are then progressively loaded accordingly to the user's position, avoiding the use of unnecessary resources of the computer, a technology called HLOD or Hierarchical Level of Detail visualisation (Dimitrijević et al., 2016, pp. 259–260; Grimm & Niebruegge, 2007, p. 29; Hancher, 2016; Song & Li, 2018). Notice, that the cubical format is a better format for HLOD visualisation, for which virtual tour programs convert the equirectangular format into the cubical one first, and then split every face of the cube into smaller tiles. During the navigation, these tiles are loaded progressively and accordingly to where the user is looking at.

All these elements and functions help us to give the user a better, smoother and lighter (in terms of computer resources) experience. Building a virtual tour, however, requires a certain amount of time and production that it only makes sense for end products. In terms of software options, there is the application Marzipano (Cabral & Cabral, 2025), which offers the possibility of creating a simple virtual tour with: navigation toolbars with basic functions (movement, zoom, full screen, autorotation), a viewport with the other panoramas, and hotspots with text information or to/from other panoramas (Figure 88). Marzipano operates through a web interface and does not storage the information online (Figure 89). It is also possible to operate it through the libraries, and it has the source code open on Github and mainly updated by Google.

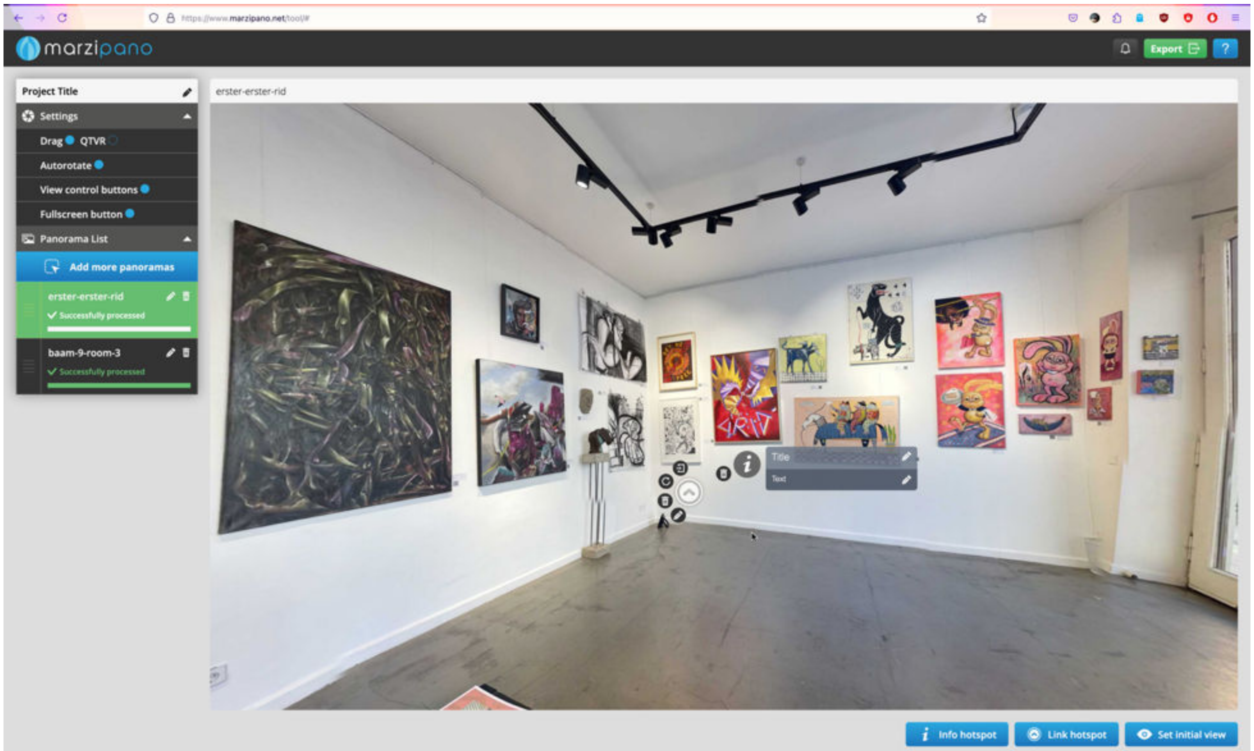


Figure 88: Creating a simple virtual tour with the Marzipano web application.

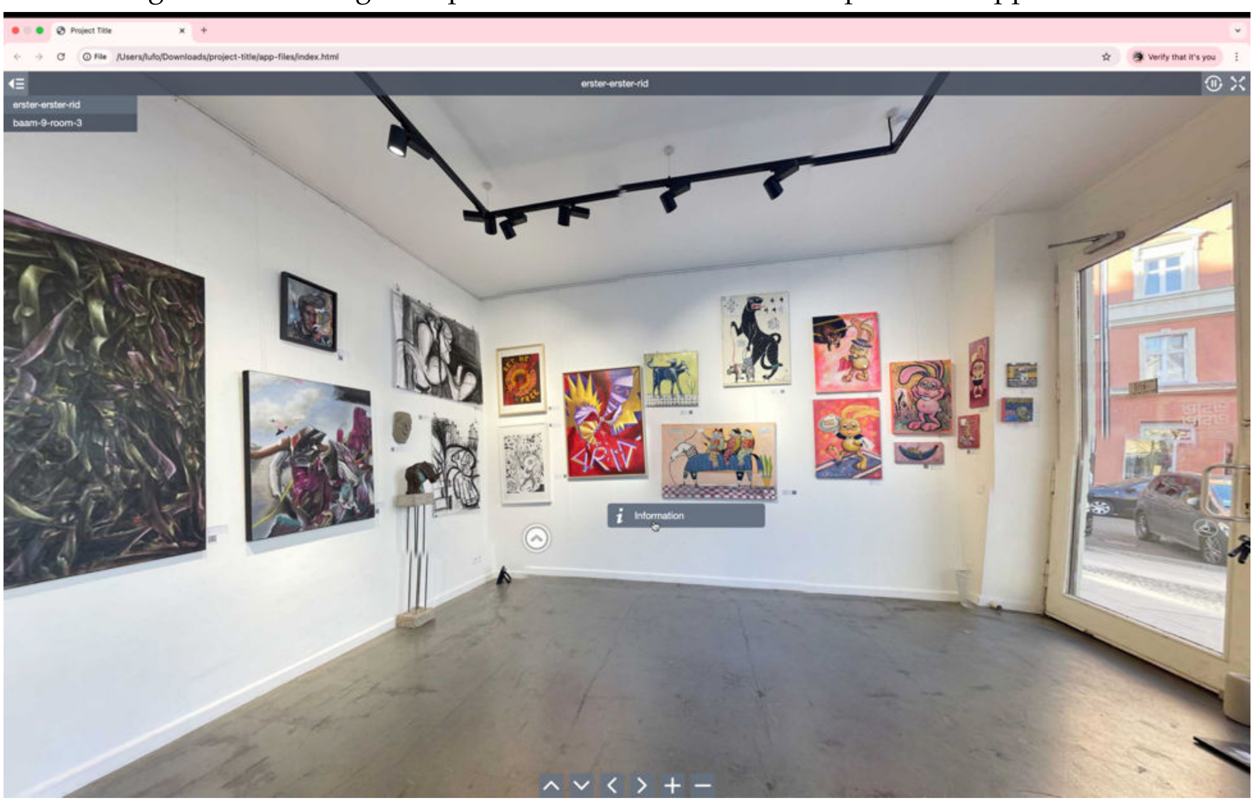


Figure 89: Navigating the virtual tour from the exported files

Other programs can achieve richer and more complete results, including all the features mentioned before and even a smoother integration with VR devices. Some examples are Pano2VR (Gnome, 2025), VRTourMaker, Tourweaver and Panoweaver by Easypano (Easypano, 2025), Krpano (Reinfurt, 2025), PanoTour Pro (Kolor, 2018), etc. Most options are either entirely behind a paywall or have free test but with limited functionalities and watermarks, being Marzipano one of the few with free full access. Nevertheless, the results can turn into an experience full of different interactive possibilities (Figures 90-92).

When it comes to sharing the virtual tour, this can be done through different channels. For example: on social media, our own website, on video platforms supporting full immersive media, etc. Some examples are YouTube, 360Cities, Flickr, Google Streetview, Panoptica, etc. In some of them it might be necessary to add metadata information for passing the drawing as a full panoramic photography or video (Cheng, 2016). This can be easily achieved with applications such as Exif Fixer (Keit, 2025); by duplicating the data extracted from an existing full panoramic photography or creating our own template using programs like Adobe Bridge (Adobe, 2021); or by replacing the graphic content of a panoramic photography using any raster-based program.

Figure 90: virtual tour with several full panoramas scenes, flat scenes (i.e., only a linear perspective), floor plan, videos, sounds, 3D models, animated gifs, embed websites, text information, etc. © Alessandra De Luca and Viviana Vollono, University of Campania, T.A.R., Teachers: Fausta Fiorillo and Lucas Fabian Olivero, 2017-18.

Figure 91: the main space is a full panorama scene where it is possible to interact with several elements. In this picture, the pop-up image shows four different purse models designed and inspired in Dalí's mustachios. The colours were selected by sampling Dalí's paintings © Alessandra De Luca and Viviana Vollono, University of Campania, T.A.R., Teachers: Fausta Fiorillo and Lucas Fabian Olivero, 2017-18.

Figure 92: one of the adjacent rooms is a flat perspective showing different purse models, in this case it is also possible to interact with embed 3D models and animated GIFs © Alessandra De Luca and Viviana Vollono, University of Campania, T.A.R., Teachers: Fausta Fiorillo and Lucas Fabian Olivero, 2017-18.

VII - Applications

Among the enthusiasts of immersive drawing, we count with some great illustrators such as Gérard Michel, Bruno Sucurado, Paul Heaston, Michael Scherotter, Matthew Lopas, Jackie Lima, Arno Hartmann, Sara Antinozzi, Chiara Masiero Sgrinzatto, Tom Lechner, Julieta Gordillo, António Bandeira Araújo, David Swart, etc. (Antinozzi, 2019; Hartmann, 2019; Heaston, 2020, 2025; Hohler, 2025a; Jara, 2019; Kurbatov, 2017; Masiero Sgrinzatto, 2020a, 2020b, 2021d, 2024a; Masiero Sgrinzatto & Zilio, 2024; Michel, 2013; Olivero et al., 2020; Olivero, 2021; Olivero & Sucurado, 2019; A. Rossi et al., 2021a; Scherotter, 2018; Sucurado, 2025; Swart, 2016; D. Termes, 1998). In the following paragraphs I will use some of these authors to explore a few applications of immersive perspectives. It goes without saying that the cited authors are only representatives of several others accomplishing similar applications. Hence, we have:

- **Conceptual stages of design and architecture projects:** immersive drawings can be a powerful tool for exploring conceptual design and/or architectures before they are built. Through them, a potential client can see and experience in VR immerse modality the visuals of a certain space. Figure 93 shows an exploratory example using a physical handmade equirectangular perspective and digital processing of textures. Figure 94 shows a sketch made *a priori* the final composition, where it can be seen a first organisation of thoughts and elements in space.

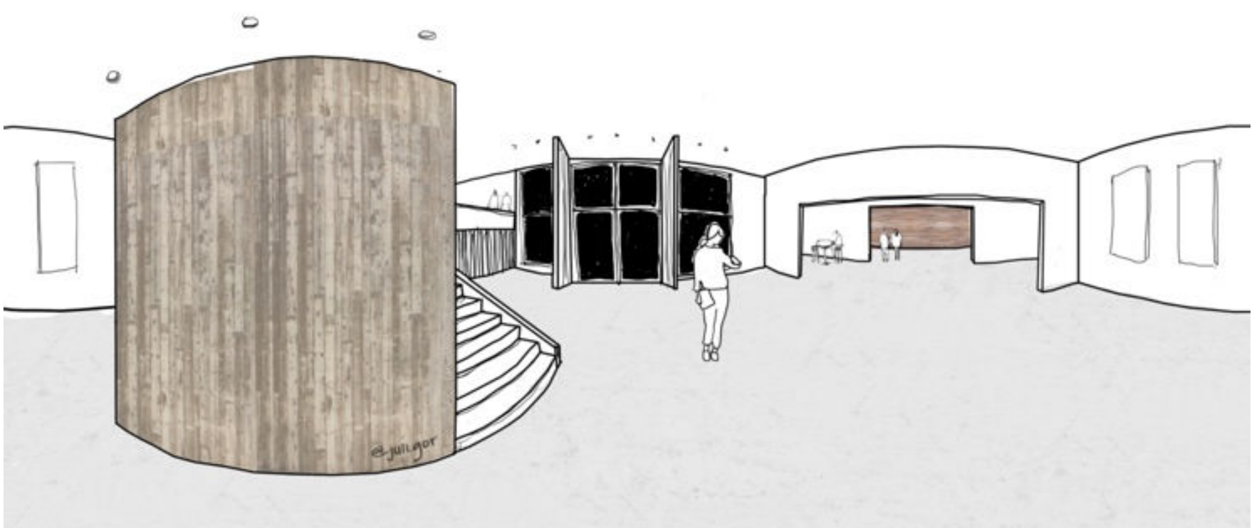


Figure 93: Pre-visualisation of an architecture early conceptual design © Julieta Gordillo, 2021.

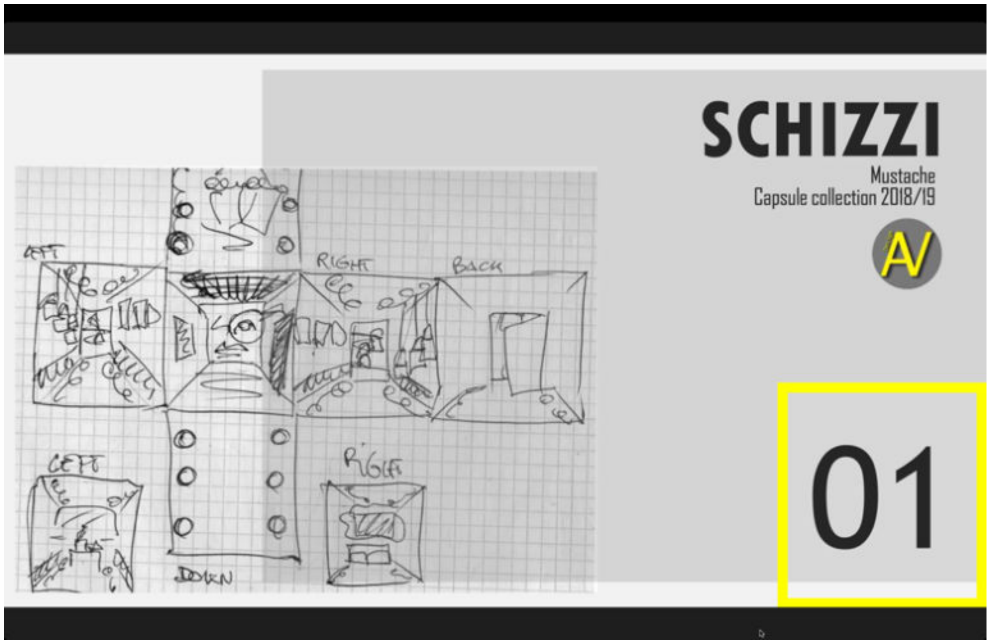


Figure 94: Draft schemes in cubical perspective organising a virtual tour © Alessandra De Luca and Viviana Vollono, University of Campania, T.A.R., Teachers: Fausta Fiorillo and Lucas Fabian Olivero, 2017-18.

- **Urban sketching / Survey of existing buildings:** thanks to its close connection to drawing, immersive perspectives have widened the possibilities for the group of urban sketchers. This group meet and draw the city as they see it, capturing its essence through their eyes and following a manifesto that establish what is and what is not a urban sketch. One of their rules is to draw on-the-spot (i.e., neither from home nor by copying a photography), and that is what António Araújo did at the ISEL School of Engineering of Lisbon, Portugal (Figure 95). Nevertheless, instead of drawing several classical linear perspectives, Araújo drew only one compact DIN-A4 sized equirectangular perspective, capturing all the visual data around his point of view. With this drawing, he shows the potential of using some very practical tools for urban sketching that spherical perspectives give: in the example below, Araújo develops a courtyard with regularly repeated columns, yet instead of repeatedly measuring and drawing, he minimises the measurement operations, then apply geodesic constructions and obtains the repetitions by logical deduction, i.e., as an internal consistent construction. The VR navigation of the panorama shows such consistency of distance among columns. Notice that Araújo also uses these logical constructions and geodesics for obtaining the repetition of tiles, right as the classical perspective methods do but using linear constructions. With this technique, the urban sketch of the ISEL results not only on a sensitive and intellectual record of the current state of the building, but also a representation of it with a certain accuracy that could eventually be enhanced by using more sophisticated measurements tools (e.g., a theodolite).

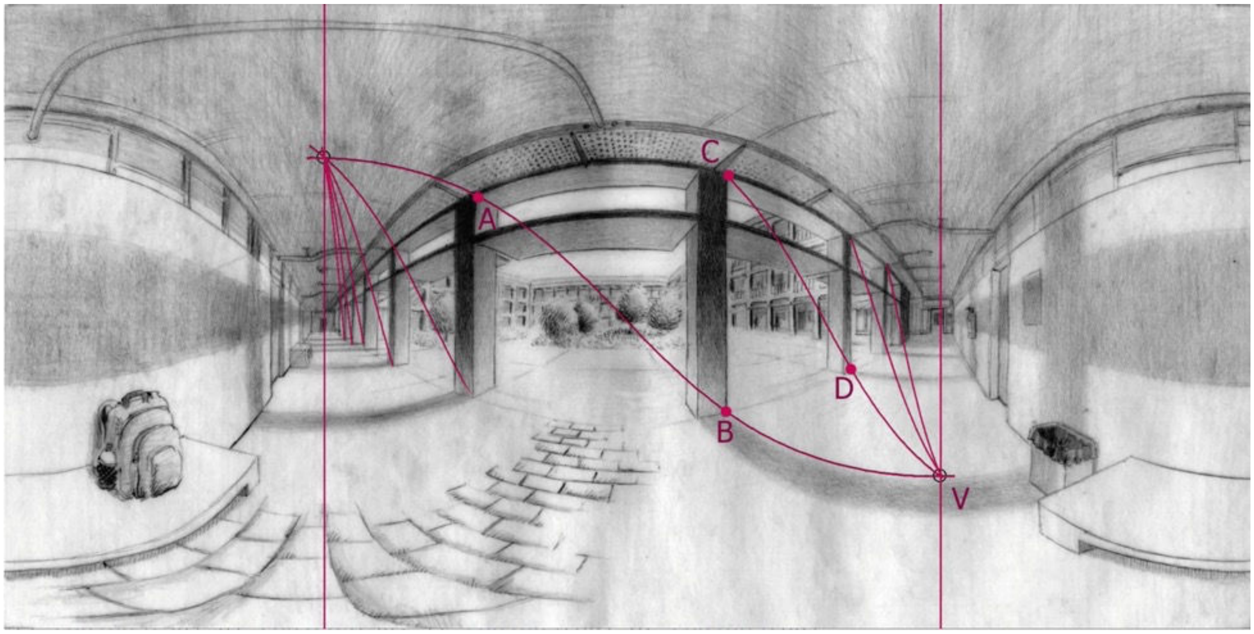


Figure 95: the use of geodesics and logical constructions for the repetition of regularly separated elements © António Bandeira Araújo, 2018.

- **Study of the immaterial relation among structural components of a building:** the example of Figure 96 shows a selection of elements resulting from the analysing of the inside geometry of the Solimene factory in Italy (A. Rossi et al., 2021a). In this case, it was used a cubical perspective format, and the students completed a series of analysis using vanishing points, geodesics and the proportions of the main elements provided by the construction documents. From these studies, they concluded possible construction pathologies and possible misalignments of the structural elements, hypothesis that could be verified in the future using complementary equipment, such as laser scanners.
- **Survey, study and preservation of cultural heritage:** A. Jara carried on an investigation project exploring ways to represent urban space by combining physical handmade sketching with 360° panoramic photography (Jara, 2019, 2024) In the specific, Jara's drawings focus on the image preservation of buildings located in La Plata, Argentina. These drawings were then digitally processed and integrated into interactive 360° virtual tours where the mix of traditional and digital media allows viewers to experience the city in an immersive way and in an architectonic/artistic graphic style. Furthermore, the project explores how these hybrids methods enrich spatial representation and communication, especially in educational and artistic contexts (Figure 97, 98, and 99).

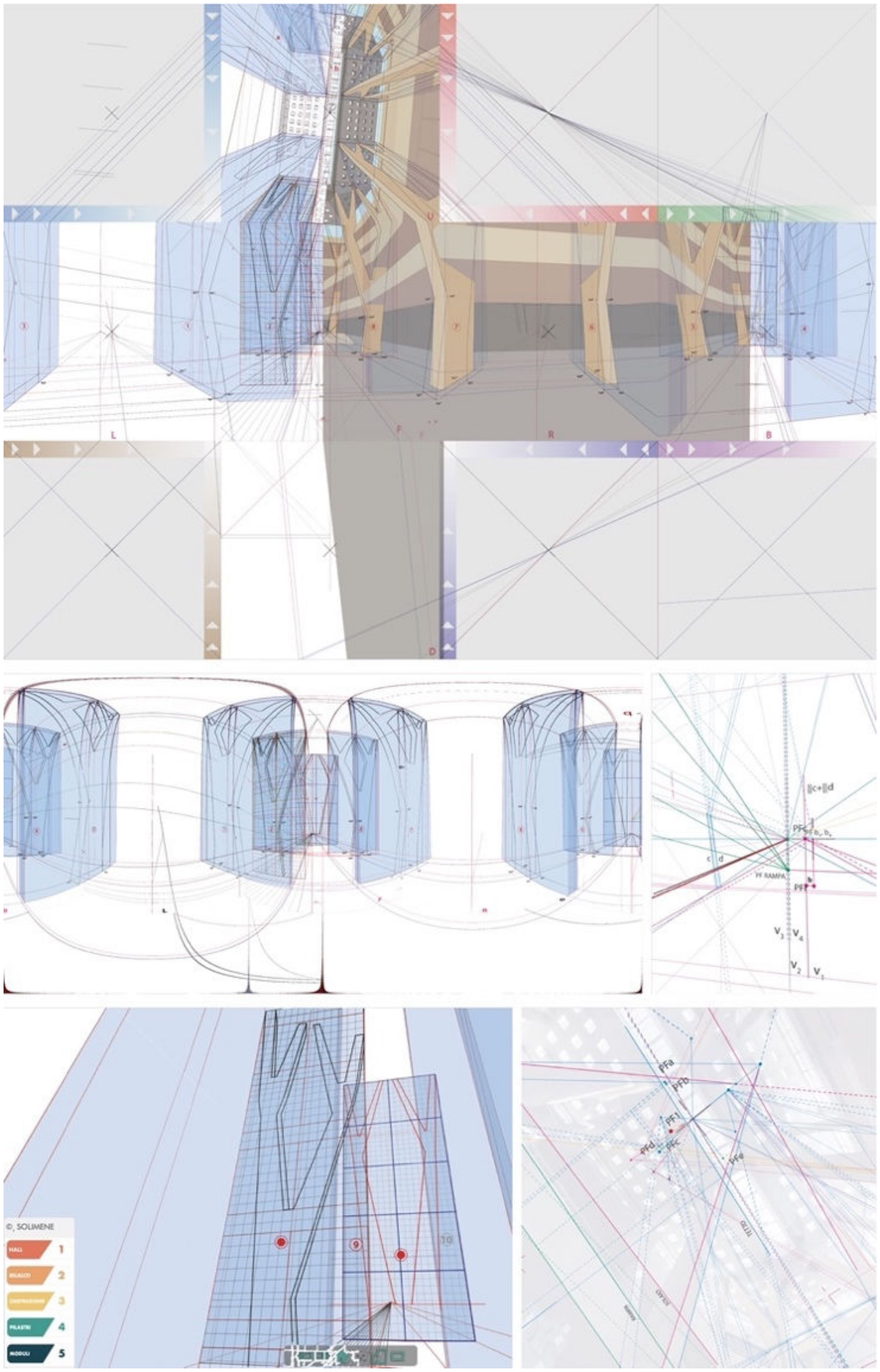


Figure 96: Study of the Solimene Factory. Equirectangular perspective and immersive views of the geometries highlighted during the analysis and the selection criteria. Authors: Assia D’Alessio, Teresa Di Palma, Caterina Crispino, Marta Campanile, Maria Petrillo, Lorenzo Villani and Lucas Fabian Olivero, 2020.

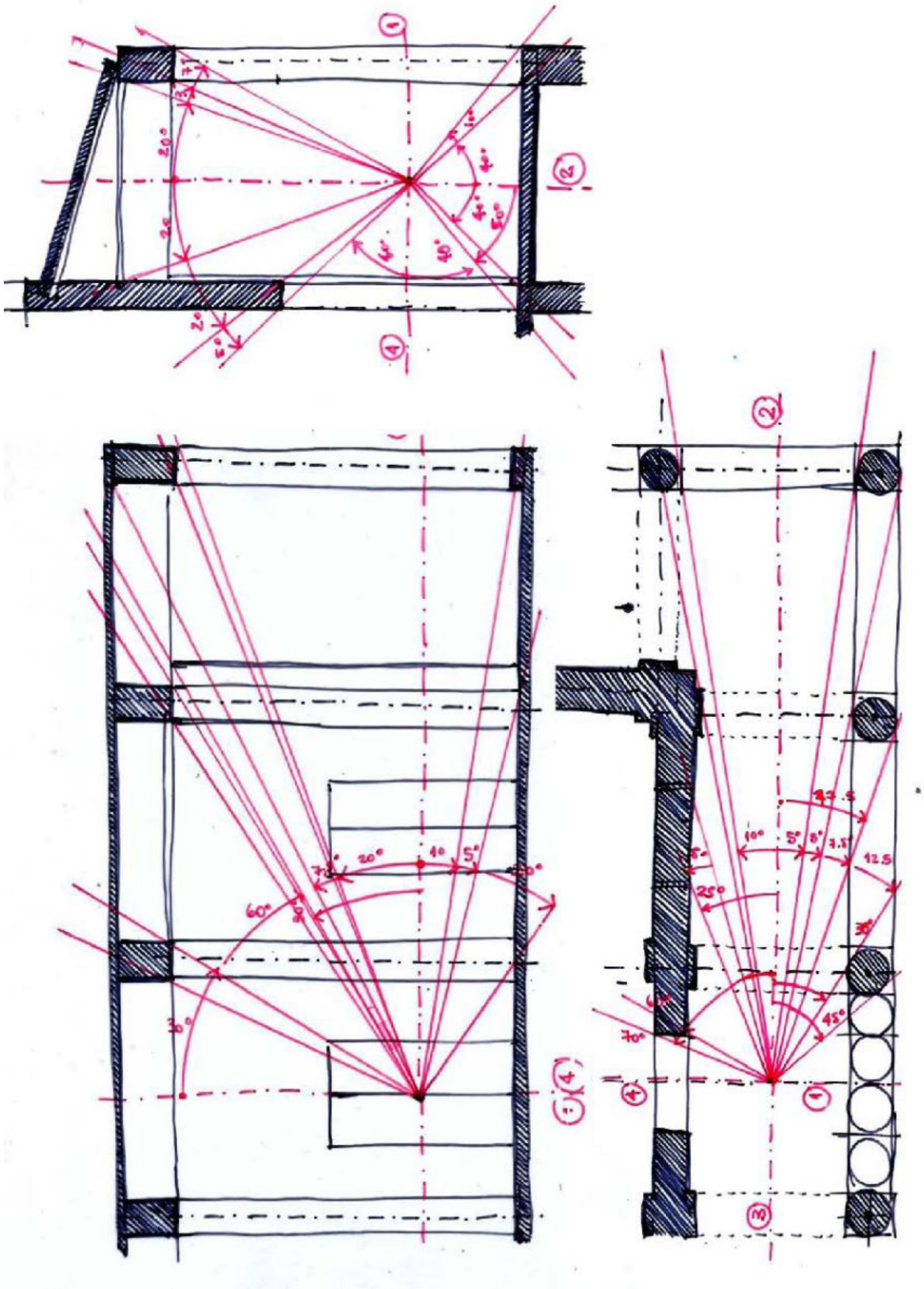


Figure 97: analysis of the building Partenón UNLP at La Plata university campus. The measurements in the floor plan and section were then translated to the equirectangular grid for composing the immersive drawing © Analía Jara, 2019.

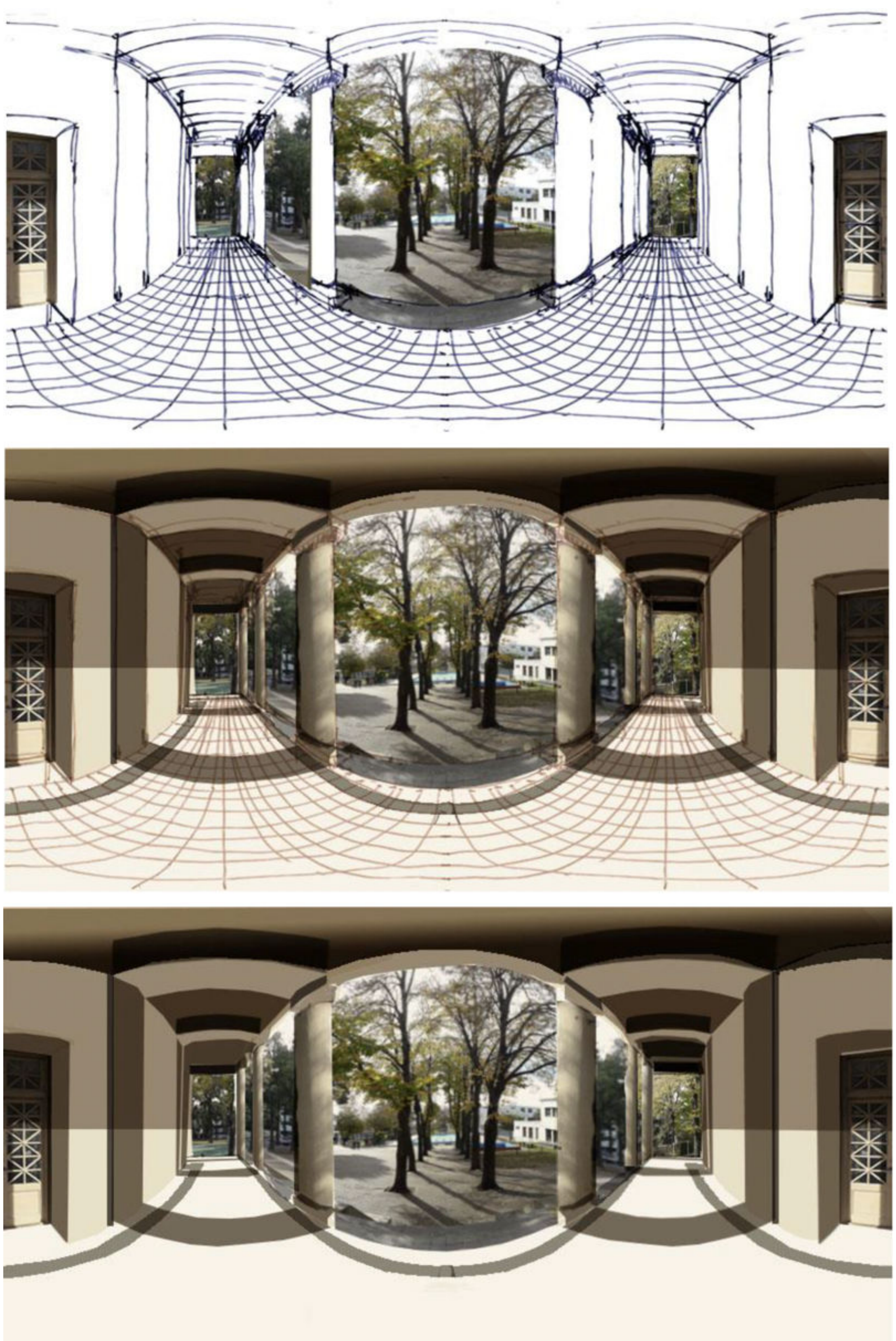


Figure 98: composition overlaying photography and handmade drawing © Analía Jara, 2019.

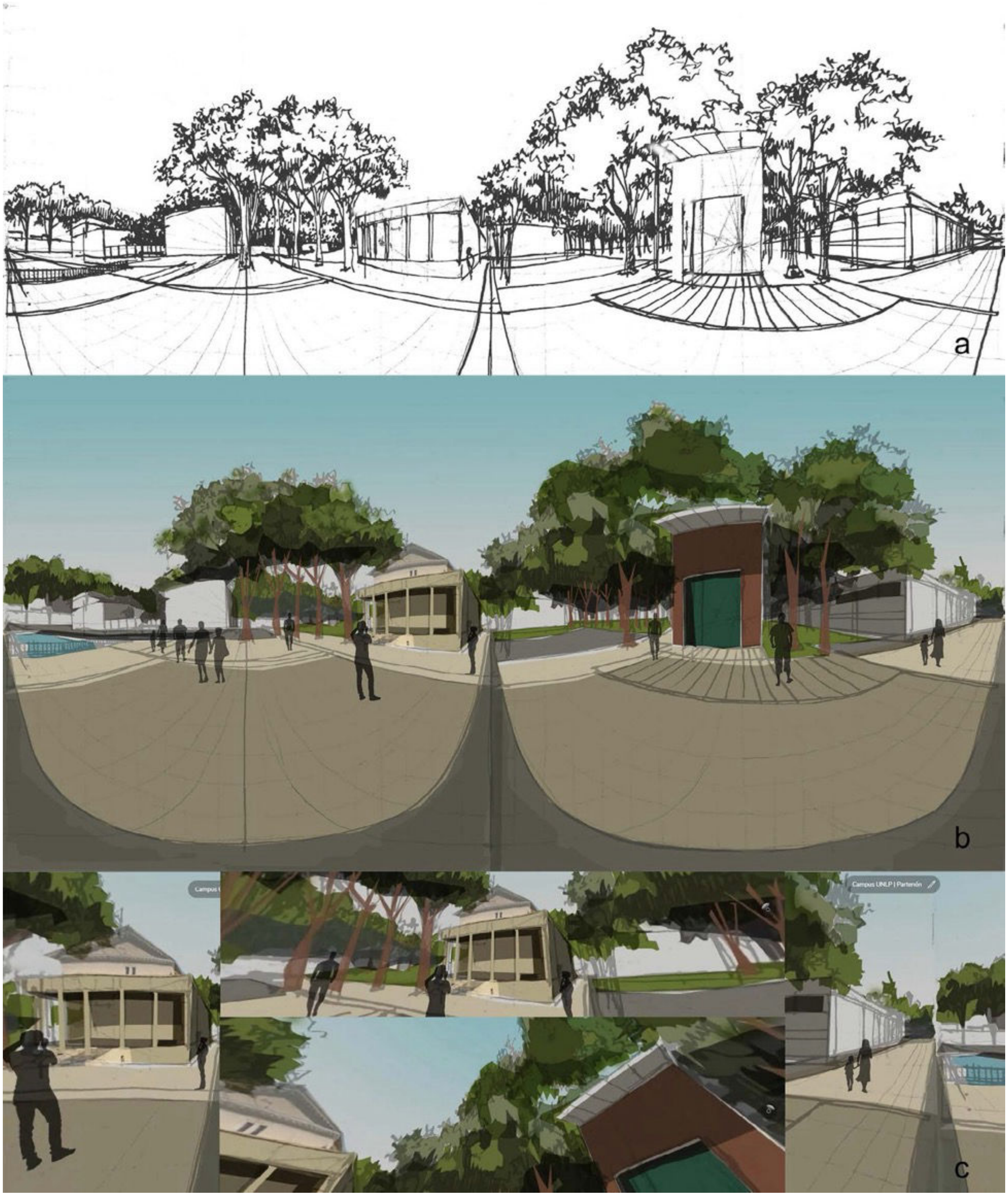


Figure 99: Campus U.N.L.P. Partenón. a) Handmade equirectangular drawing. b) Digital retouching in Photoshop. c) Immersive visualisation. © Analía Jara, 2023.

- **Cultural heritage restoration possibilities:** Figure 100 shows the reconstruction of a very damaged Byzantine painting from the 12^{th} century. The painting was found during the excavation of a wall behind the altar of a chapel in the little town of Sambuco, where it was without any preservation care whatsoever. A team from the University of Salerno of Italy completed a photographic survey on-the-spot and used equirectangular drawing for highlighting what it could be a hypothesis of reconstruction based on visual feedback and similar paintings documented in the same area and from the same age (Antinozzi, 2023, p. 127).

Figure 100: Digital reconstruction of a 12^{th} century painting from church Santa Maria della Pomice at Sambuco, Ravello, Italy. Panoramic survey done with Nikon D3 and Nodal Ninja by students of Rilievo dell'Architettura 2017/18, within the studies for the master's degree in architecture and Building Construction, University of Salerno. The work was part of the Spring School at Villa Rufolo, Ravello, between the 3^{rd} and 7^{th} of April 2018, in collaboration with Foundation Villa Rufolo and the University of Campania. Credits: Sofía Arrigone, Francisco Artigas, Maiten Bierti, Suyay Jara Provoste, Sebastian Martin and Julieta Yadarola. Collaborations: Sara Antinozzi and Sara Morena. Coordinators: Prof. Salvatore Barba and Dr. Secondo Amalfitano. Tutor: Lucas Fabian Olivero © Laboratorio Modelli UNISA, 2018.

- **Urban and artistic historical studies:** Figure 101 shows a project mixing drawing, photography and handmade tracing. From the original 18^{th} century painting *Veduta di Chiaia* (View of the Chiaia), the author did philological research to find out the exact location in the city from which the painting was made. Then, she took a full panoramic photography on-the-spot, superimposed the painting, reconstructed the surroundings of Naples' Bay considering the graphic information provided by the picture, and discussed the match between the city as it was in the 18^{th} century and in 2019 (Antinozzi, 2019, pp. 94–97).

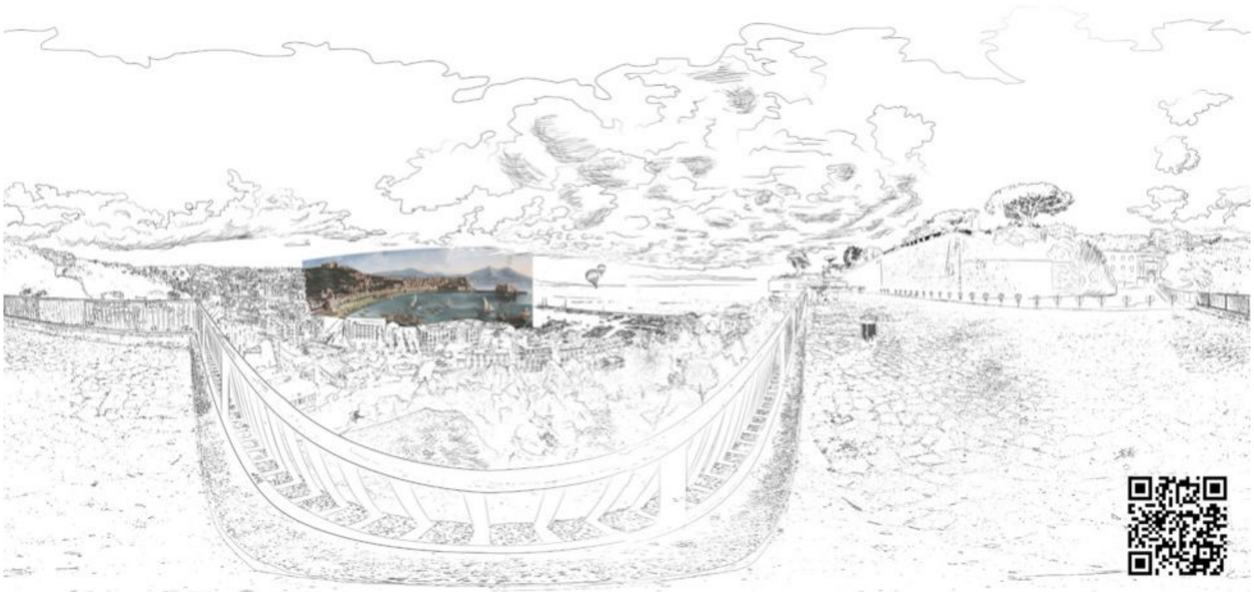


Figure 101: Application of immersive perspectives using the equirectangular projection. The painting used as reference is attributable to one of the two brothers Ruiz Tomaso and Juan and it is exhibited at the Gaetano Filangieri Civic Museum of Naples © Sara Antinozzi, 2019.

- **Recreating or remote accessing places or buildings not existing anymore:** Chiara Masiero Sgrinzatto has several examples of reconstructions made on-the-spot using equirectangular perspectives (Masiero Sgrinzatto, 2021a). For example, she recreates landscapes in the region of Veneto, Italy, collecting panoramic views opening up a vision of the Asiago Plateau, the Dolomites and Belluno Pre-Alps at the time of the Great War and the Vaia storm (Figure 102) (Masiero Sgrinzatto, 2021b; TSD Project Lab, 2021). In this case, her work documents destruction and rebirth across centuries, inviting readers to reflect about environmental and human responsibility while connecting past and future through spherical perspectives, art, geography and memory.
- **Alternative e-commerce virtual tour:** a quite innovative use of the hybrid immersive models was proposed within the project Venice Original, promoting venetian craftsmanship through an e-commerce connected to a spherical perspective (Figure 103, 104) (Masiero Sgrinzatto, n.d., 2021d). In practice, visitors access the virtual environment, visit this handmade created venetian-like space, and find classical objects of the venetian tradition that can buy right away by clicking and checking out. The use of spherical perspectives helps in this case to the promotion and preservation of the artisanal know-how and the intangible cultural heritage.

Figure 102: Equirectangular drawings produced for Schianti © Chiara Masiero Sgrinzatto, 2021

Figure 103: Drawing for the Venice Original e-commerce © Chiara Masiero Sgrinzatto, 2021.

Figure 104: Equirectangular illustration of Venice Original + Sphere made on paper from the same drawing © Chiara Masiero Sgrinzatto, 2021.

- **Accessing remote places and playing with the imaginary of the city:** the architect Bruno Sucurado recreated the city of Atrani, Italy, without actually visiting the place (Figure 105). This panorama of the Amalfi coast was included as a complementary material and a sensitive registry within the project Gigakahn, which gathered full panoramic photographs taken in the same spots where the architect Louis Kahn drew back in 1929 during his visit to Italy (Donato, 2017). Sucurado went further and played with the traditional architecture of Atrani by mixing it with iconic modern buildings built by Louis Kahn, as a form of unseen possibilities. Due to the graphical style of Sucurado, the drawing results an interactive game of seek and find, for which the virtual tour had to be specially programmed in a particular way.
- **Advertising, gaming and entertainment applications:** the French artist Kevin Hohler developed a series of handmade spherical illustrations as advertising campaign of a beer brand, to innovate the game "Where is Wally?" (Figure 106) and even to recreate a zombie attack for celebrating Halloween (Hohler, 2015, 2018, 2025b). Although Hohler never revealed publicly his drawing method (instead, he created a paid course (Hohler, 2025a)), he seems to have switched in the last months towards an automatised line of work using artificial intelligence.

Figure 105: Equirectangular drawing of Atrani, Italy, composition created using a panoramic photography taken on-the-spot and mixing it with buildings designed by Louis Kahn from all around the globe © Bruno Sucurado, 2017.

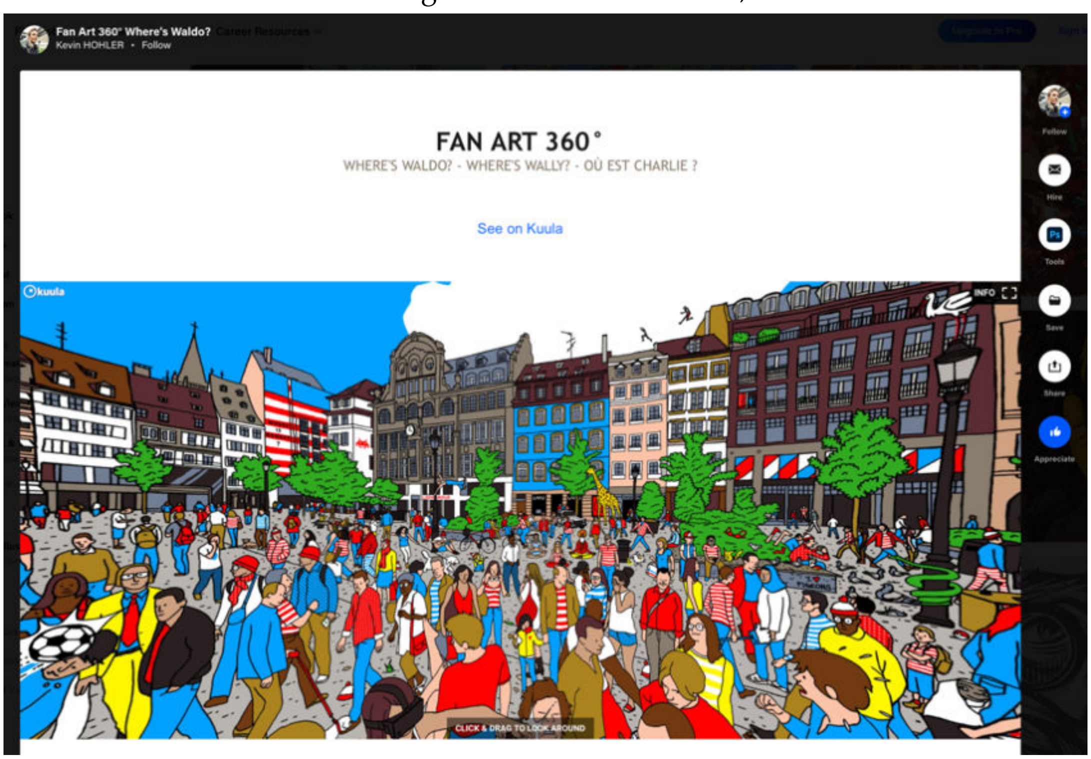


Figure 106: Spherical perspectives used for promoting commercial products through the well-known game Where is Wally? © Kevin Hohler, 2018.

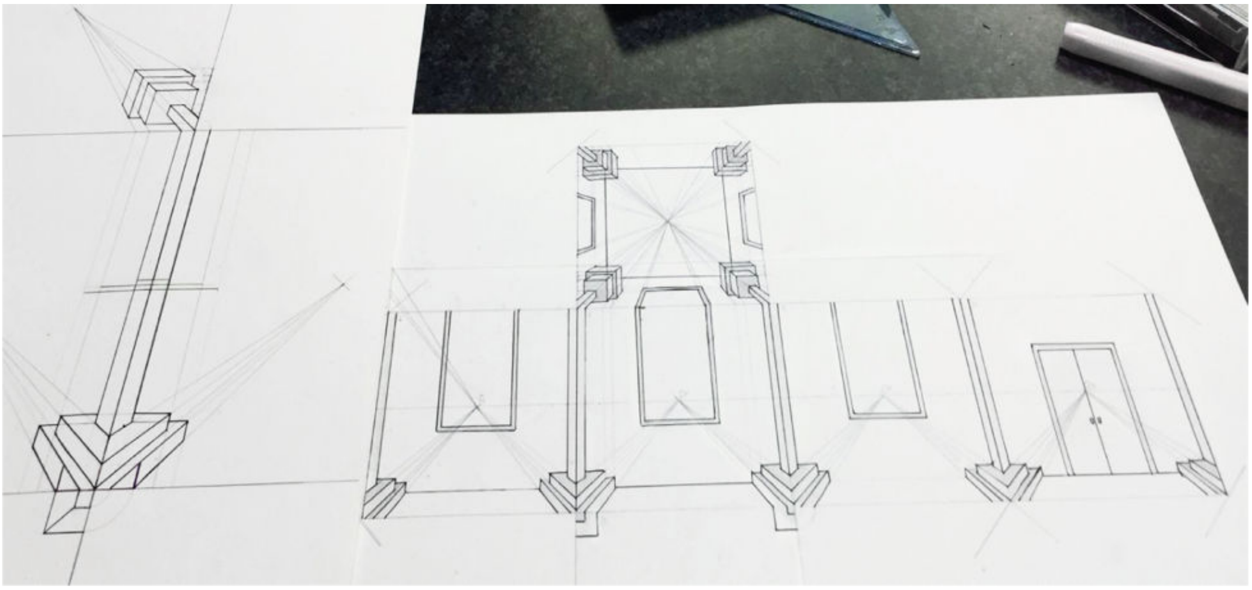


Figure 107: Exploratory drawings for columns projecting on three faces of the cubes; and a composition of an exhibition room © Giuseppina Rao, course T.A.R. Unicampania 2018-19.

- **Art exhibition rooms:** during some courses developed at the University of Campania, students produced virtual environments through handmade cubical and equirectangular perspectives. In one of them, students focused on the use of spherical perspectives for creating art exhibition rooms. Figures 107 and 108 show an example of this application: the student got inspired by a visit to an exhibition about M. C. Escher and created a room for showing some of his artworks in an innovative way. The student had to deal with more than one complex constructions in the cubical map, such as columns and spirals projecting on several faces of the cube, for which she used a method for obtaining the projections on the cubical map from floor plan and sections (Olivero et al., 2020). The result is a virtual visit where the visitor can enjoy Escher's artworks in combination with her own creative manifestation.
- **Showroom for the exhibition of product design:** as part of another experience in the classroom at the University of Campania, students from product and fashion design explored the use of cubical perspective for the creation of showrooms exhibiting their new modelled products. Figures 109 and 110 show one of those examples in which students created a collection of purses based on Dalí's mustachios, after getting inspired by a visit to an exhibition about the artist. The students created a virtual tour with several rooms, each of them showing a different product of the collection. The example shows the potential of using a full virtual tour construction and immersive drawings: the visit contains a floor plan to indicate users where they are placed; interactive elements including videos, audios, documents and websites; and even embed 3D models with which visitors can interact.

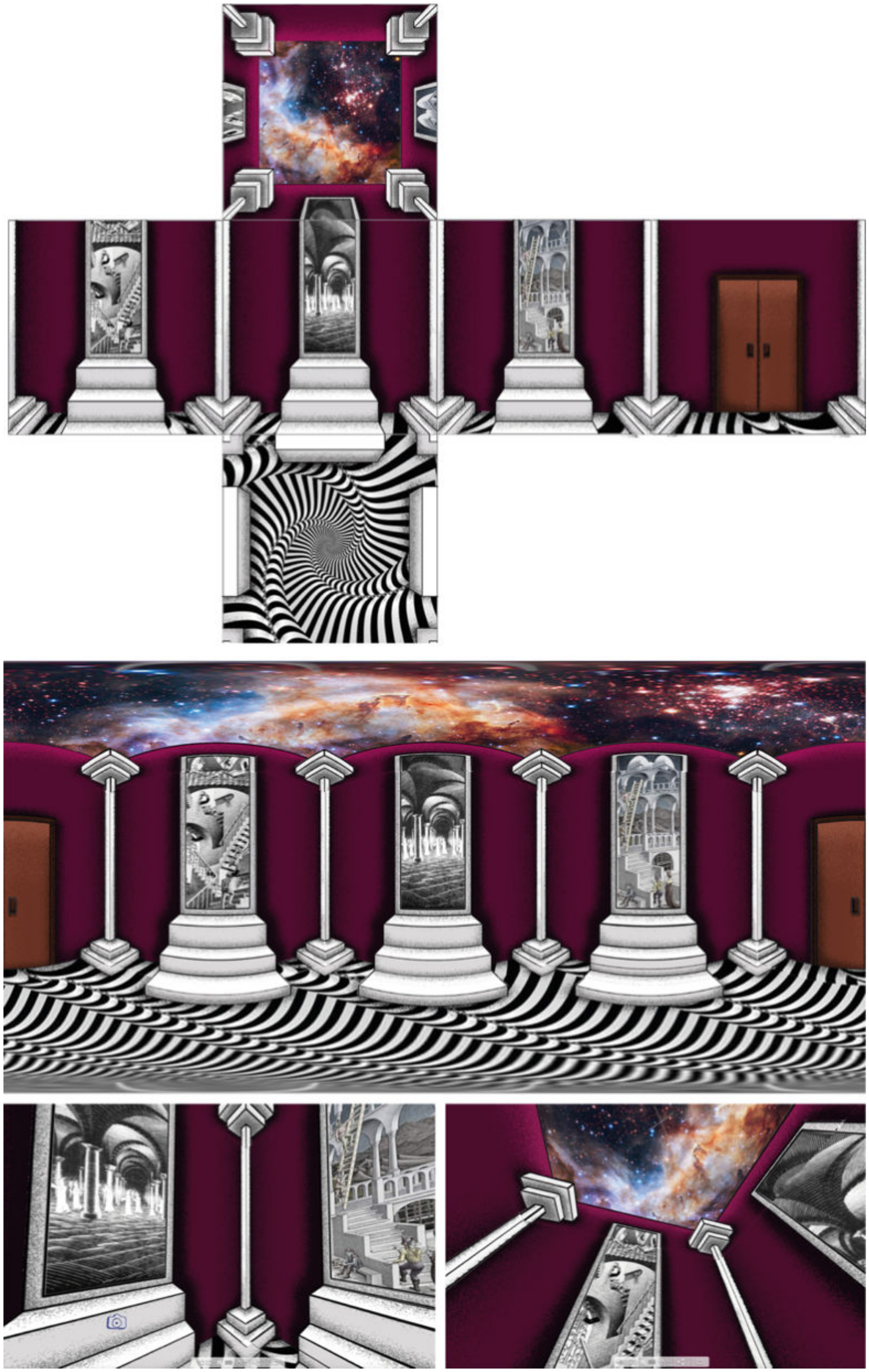


Figure 108: Exhibition room Escher. Note that it was also necessary to study the projections of the textures on the floor. Escher Room' in equirectangular format (top). Immersive views (bottom) © Giuseppina Rao. T.A.R. Unicampania 2018-19.

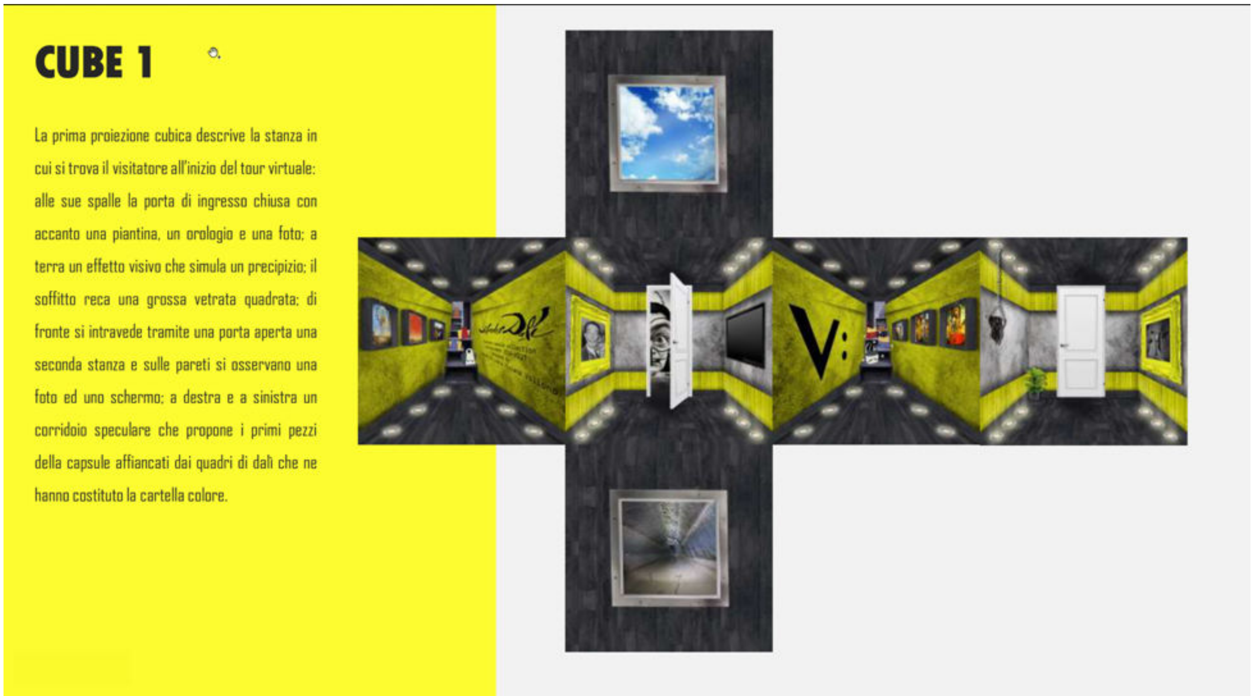


Figure 109: cubical composition of the main space of a virtual tour, made as a digital collage mixing physical and digital drawing, photographs and textures © Alessandra De Luca and Viviana Vollono, University of Campania, T.A.R., Teachers: Fausta Fiorillo and Lucas Fabian Olivero, 2017-18.

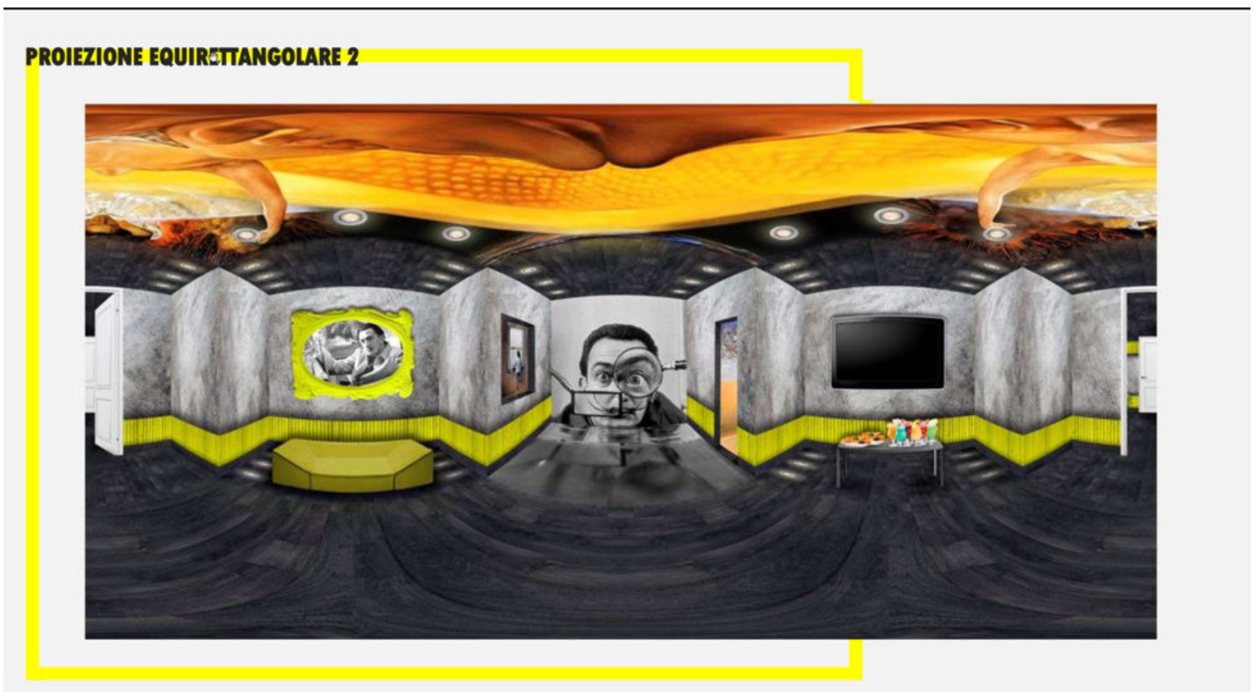


Figure 110: equirectangular panorama after the conversion of an original cubical collage composition © Alessandra De Luca and Viviana Vollono, University of Campania, T.A.R., Teachers: Fausta Fiorillo and Lucas Fabian Olivero, 2017-18.

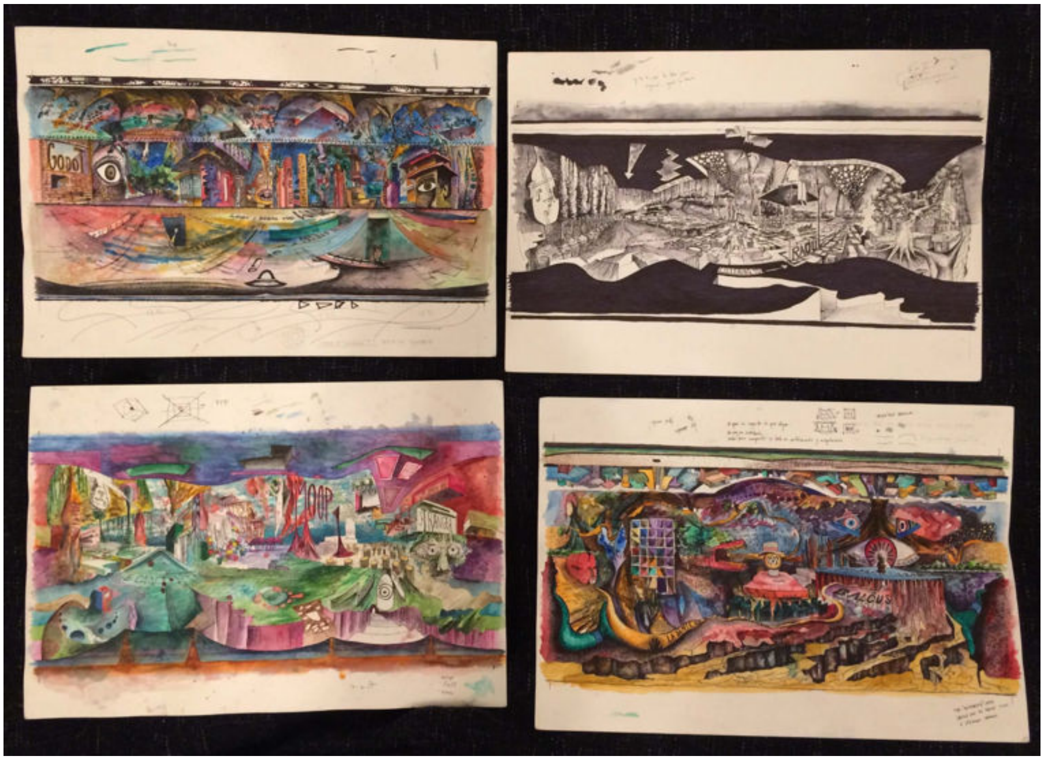


Figure 111: The collection of four handmade immersive artworks made live during a series of concerts at the Godot Art Bistrot of Avellino, Italy © Lufo Art (Lucas Fabian Olivero), 2017.

Figure 112: The flat drawing and design objects made with the same spherical perspective © Lufo Art (Lucas Fabian Olivero), 2017.

- **Representation of dreamlike and whimsical imaginary spaces:** further applications of spherical perspectives focus entirely in the creation of Handmade Immersive Art. Figure 111 and 112 show a collection of four drawings made in 2017 and aimed to capture the essence of the live music concerts of four different artists: Campos Band (Figure 111, up, left), Raoul Vignal (Figure 111, up, right), Mary Ocher (Figure 111, down, left) and Elizabete Balčus (Figure 111, down, right, Figure 112). This collection was used for developing the first concept within the new developments of this thesis (see Part IV - Chapter III.3).

VII.1 - Recap

There is a strong presence of applications within architecture, engineering and design (product, fashion, communication). Many of these applications were born during the teaching of immersive perspectives within courses in such careers (Olivero et al., 2020; A. Rossi et al., 2021a, 2021b), for which it can be highlighted the importance of spreading the knowledge within drawing courses in the university, in private and public environments. Immersive drawing has some applications in the field of art, but it still a very weak presence and indeed, most of the above-mentioned people are architects while very few artists. For this reason, it is important to highlight the necessity of an extended dissemination of immersive perspectives within art and communication careers, and to continue with the current dissemination within the fields of architecture, engineering and design. In terms of drawing procedures, most of these applications use the equirectangular projection, a few less the cubical one, and even less the azimuthal-equidistant perspective. These applications follow the above-mentioned methods ranging from trial-and-error up to accurate descriptive geometry constructions. However, this hard division among methods does not fully exist as many times illustrators switch back and forward among methods, in their path for discovering and mastering the technique.

PART III - STATE OF THE PROBLEMS

I - PROBLEMS

From the analysis of Part I and Part II, it is possible to see some gaps and problematics in the insertion, integration and development of Handmade Immersive Art:

1. **Lack of an art-practice-based research methodology.** The migration of the Hybrid Immersive Models into the world of digital art needs a fresh research approach that might fit better the logic and requisites for the development of a digital art product.
2. **The spreading and application of cubical perspective is presently limited.** The latest developments of drawing methods for creating VR environments out of handmade line-by-line constructions give a theoretical background for artists to learn a variety of spherical perspectives without any software/hardware dependences. However, in particular with the cubical perspective, the only fully systematic method developed until now presents several complications during the practice, which hinders the drawing process.
3. **Few artistic applications, low diffusion and spreading among artists.** The application of the concepts of anamorphs, linear, spherical, cubical and fisheye perspectives are not among those favoured by contemporary artists. It is enough to visit any exhibition space to see how the primacy is on movements such as conceptual, political, expressionist, "minimalistic", generative, artificial intelligence-generated art, etc. Perspective drawings have very little presence, and mostly limited to well-known classical, historical artists. In fact, very few contemporary artists (e.g., Ben Johson, Patrick Hughes, David Schnell, Yadegar Asisi) have created an innovative and personal artistic style based in the rigorous definition of linear perspective. Nowadays, the term *perspective* might be mostly related to *one's opinion* rather than the drawing technique. Nevertheless, on top of the many benefits that anamorphs and linear perspective can give to artists, spherical perspectives in their connection with VR provide a new fresh resource for artists to express themselves even freer in the intersection between the digital and the physical world.
4. **Limitations for the conversion drawing/VR.** The workflow of converting from one projection to another is sometimes chaotic yet widely covered by different pieces of software, existing both paid and free options, with complex and simple processing, closed and open-source code, etc. However, there is no simple way (if any at all) of doing such conversion as a live streaming for an on-the-fly parallel reading, which is very useful for showing the correspondence between the flat drawing and the VR environment during the teaching of spherical perspectives.
5. **Low teaching dissemination.** Most of the current applications are related to the world of architecture, engineering and design, which is exactly where many workshops and

teaching courses of spherical perspectives were given. The results that came out from those lessons and integrations within drawing courses are creative and integrative towards other representation techniques, for which it can be assumed that there is a legitimate interest on exploring immersive drawing as a novel way of graphic expression but not a large integration yet.

6. **Lack of drawing software (or suites) for spherical perspectives.** Although there are some programs covering spherical drawing, there are no stable and unified options for having them all together in one same, (ideally) open and free, and widely compatible program. The current broken compatibility or lack of options (for example, for drawing a cubical perspective) are barriers for the spreading of the knowledge and the open practice of spherical perspectives.

II - HYPOTHESIS

The above-mentioned problems can be addressed with tangible solutions so to give HIA a wider application field. The hypothesis is that several but concrete solutions (Table 1) on multiple fronts will contribute to the expansion, improvement and further development of spherical perspectives within the world of digital art:

Table 1: Problems, proposed solutions and expected results.

	Problem	Proposed solution	Expected result
1	Lack of an art-practice-based research methodology.	Definition of a specific research methodology for integrating HIM-HIA within the world of art.	A guiding structure for organising the content of the research, developing solutions, presenting the outcomes and sharing the results.
2	The spreading and application of cubical perspective is presently limited.	Study the problematic that hinders cubical perspective applications, propose a simpler method, and get it mathematically proven.	Get a shorter and simpler way of solving geodesics within cubical perspective, ideally, an all-in-one construction that might simplify cubical drawing.
3	Limitations for the conversion drawing/VR.	Development of an application for the live conversion of flat spherical perspectives to its correspondent VR environment.	Have a highly compatible and easy-to-use application to show the live VR environment in parallel to the spherical perspective drawing.
4	Few artistic applications, low diffusion and spreading among artists.	Hold more art exhibitions showing the potential of spherical perspectives, and the knowledge that anamorphs and perspective can offer to artists.	Raising the interest of artists and art visitors towards perspective compositions, and specifically towards the interaction with spherical perspectives.
5	Low teaching dissemination.	Aim for more stable teaching integrations, ideally with drawing or representation courses permanent within the studies curricula.	Reach more students (ideally, art students), show them extended possibilities and integrations of spherical perspectives and the connections with the VR technology.
6	Lack of an integrative software for spherical perspectives	Development of a suite for immersive drawing, including (to begging with) equirectangular, cubical, and fisheye systems; with the openness for integrating other systems in the future.	Have a software or website of reference that could gather the currently widely spread software options.

PART IV - THESIS - NEW DEVELOPMENTS

I - SOLVING PROBLEM 1: the HIA-HIM methodology

Note: this chapter brings part of the content developed, peer-reviewed and published in an article presented at the congress ARTeFACTo 2022 (Olivero, 2022h).

Due to the nature of this thesis' components, the frame of work has to consider two complementary sides of study: first, a field of mathematical definitions (for determining new drawing methods) and software definitions (for interactive methods of visualisation); second, a humanistic field of considering ways of exploring, highlighting, interacting, curating, and exposing the intrinsic and original artistic value of the artworks, as well as holistic approaches to allow multiple readings (phenomenological, hermeneutic, ethnographic aspects) of the same data. Nevertheless, since this research focuses the art practice, the first two sides will be balanced within an art-practice-based research methodology that combines elements from existing methodologies and articulates more rigid (or positivist) and more relatives (or interpretative) approaches. In other words, the methodology is the theoretical and practical creative ensemble investigating these two fields simultaneously through the artistic practice and relating, strengthening and enriching them mutually.

I.1 - In search of an art-practice-based research methodology

The art-practice-based research is a hybrid field that combines arts, social science and humanistic research, with the aim of communicating and producing new knowledge (Carpentier & Sumiala, 2021, pp. 4–7). In this approach, artistic practice and academic research cooperate in an interdependent and complementary way: artistic practice is research, and both affect the way new knowledge is communicated and produced (Carpentier, 2022). This means that art-practice-based research nurtures augmented ways of acquiring, promoting, evoking, and stimulating knowledge, going beyond the classical form through academic writing:

> "(…) arts-based research articulates knowledge as a non-dualist assemblage of intellect and affect, acknowledging that knowledge can be understood, felt and experienced" (Carpentier & Sumiala, 2021, p. 6).

On an art-practice-based research, the investigation is shaped by both the academic research and the artistic practice, and the results of one are intimately related to the enquiry in the other: the research questions and the answers for improving the practice arise from the process of practice (Candy & Edmonds, 2018, p. 63). Because of this intimate relationship, it is possible to see artistic outputs as the materialisation of academic questions and academic questions as the written synthesis of the artistic practice, and so the innovation in one also leads to the innovation in the other.

A tangible and historical example illustrating this innovation is linear perspective: its practice led to its academic development and the academic development promulgated, spread and diffused the practice. Renaissance painters and architects did not limit themselves to creating artworks that reconstructed a scene through geometry, but they also investigated the new relationship with reality by constructing linear perspectives not only with pencil and paper but also through apparatuses called Prospectographs which, in turn, were improved and extended by the teachings of practice and theoretical generalisations (Maschietto, 2005). In other words, the artistic practice was the research, and the research was the artistic practice, which created a spiral of mutual growth. It is therefore equally important that both academic research and artistic practice develop in a parallel and innovative way. The concentration on one to the detriment of the other could reinforce aspects preventing their communication, one of the strengths of the research based on the artistic practice (Carpentier & Sumiala, 2021, p. 8). Consequently, a methodology based on the artistic practice fits within the import of Hybrid Immersive Models to the artistic field, as it approaches the subject from visual arts creation and theoretical studies. I will consider for the investigation the interaction between the user (a reflective person), the representation system (production and elaboration), the message (visual art product) and the digital medium (VR visualisation, drawings' construction, and interaction)

I.1.1 - A/r/tography and A/r/cography

A/r/tography and a/r/cography are both methodologies for research based on the artistic practice:

On the one hand, a/r/tography focuses on the link between being a(rtist), r(esearcher) and t(eacher) and how they connect to the research "The spelling of (a/r/tography) indicates the ways multiple roles of artist, researcher, and teacher are folded in the process of inquiry" (Schultz & Legg, 2020, p. 244). One of the artists/researchers/teachers who coined this approach, confirms that the name itself emphasises the characteristics of the conceptual vision, an approach that encompasses art and graphics and the identities of artist, researcher and teacher in a continuous and intertwined relationship (Irwin et al., 2011, p. 70).

On the other hand, a/r/cography focuses on the practice of digital art, reaching out to artists and researchers who are not necessarily teachers, and exploring the link between a(rtist), r(esearcher) and c(ommunicator) (P. A. da Veiga, 2019, p. 335). The alteration enhances the broader and more comprehensive role that communication has in our society, leaving researchers free from traditional paradigms, such as the paradigm of reward and punishment, with which we are in constant close contact even from an early age:

> "(…) communication can be regarded as a more encompassing two-way concept than teaching/learning, and an adequate generalisation in the present day (as) direct communication between artists and audiences through social media or at cultural events is now a prevalent option" (P. A. da Veiga, 2019, p. 336).

I.1.2 - Rhizomatic schemes

A/r/tography and a/r/cography are both methodologies that structure the dynamic from the situations created during the research through rhizomatic schemes, which implies an iterative process in continuous feedback:

> "a/r/tography is rhizomatic (think intertwined roots of a tree), meaning it has no true beginning or true end. It can be entered from multiple vantage points and exited the same. It is polyvocal, involving the voices, art, and ideas of the participants, the researchers, and the audience" (Schultz & Legg, 2020, p. 245).

The slashes in their names symbolise an identity based on the multiplicity of concepts suggested by the terms, rather than a punctual delimitation of such ideas (Irwin et al., 2011, p. 70).

In a broader sense, new artistic media and digital art in particular, are nurtured by multidisciplinary teams and skills, with cross-disciplinary knowledge spanning different disciplinary areas and sectors. This suggests that a collaborative, communicative, non-linear and non-borrowed method (from other disciplinary areas) seems much more appropriate than a personal, hermetic, linear, serial and adapted method from other disciplines.

Reinforcing the use of a rhizomatic scheme, there is the fact that the use of a flexible scheme matches better the forms that artists are more familiar with, namely, the construction of the meaning of the work of art while the work itself is being made:

> "(…) a creative, reverberative, communicative or analytic stage of practice-based research, can potentially lead to (i) a more refined and expected evolution or (ii) a new and independent line of work. This a very familiar situation for artists" (P. A. da Veiga, 2019, p. 337).

The flexibility of the approach is central for a better adaptation and mutual reinforcement with an approach from a different disciplinary area. In this sense a/r/tography and a/r/cography differ since the former encourages a live, fluid and adaptable form of inquire without providing methods and rules for reaching valid conclusions (Schultz & Legg, 2020, p. 244) while a/r/cography starts from those living and dynamic situations but adds connecting arcs, which gives the a/r/cographer the possibility to use the arc as a conducting instrument if they get lost during the process. Thus, the arc guides the creative process through points of departure and arrival, even considering that the creative process can deviate at any moment as the exploration progresses, going from/to another point of the practice/research path (P. A. da Veiga, 2019, p. 337).

I.2 - Further components

A/r/tography and a/r/cography are examples of methodologies suited to the contemporary artistic exploration. In particular, the a/r/cographic methodology is a more narrowed and complete way of passing through, materialising, sharing and visualising the labyrinth of the creative process while investigating the Handmade Immersive Art. In fact, a/r/cography proposes a specific way of facing the nature of digital media through a flexible method of inquiry. Furthermore, the methodology should also consider some components developed by Leavy (2020) as essential for art-practice-based research methods, such as:

- **Question-method fit**: The previous research on HIMs had a strong component of hard sciences since it aimed specifically at the development of a drawing method. Those definitions shaped a method for expressing something using immersive perspectives, although they did not discuss the concept, narrative or aesthetic behind the created content. The HIA research will have to face differently this aspect and dig into the semantic side of the products to position the investigation within the artistic field. Indeed, the new questions and objectives should strongly and clearly investigate the relationship between HIMs and their artistic side.
- **Translation:** The research on Hybrid Immersive Models proposes a model of thinking through drawing and materialising an idea trough stroke. Hence, a HIM translates an idea into a graphic scheme but with immersive characteristics. This materialisation can be shared, criticised, and interpreted by other people, researchers, artists, etc.
- **Holistic Approach:** Some important values for the artworks produced within HIA, are internally consistent, congruence, and thoroughness. From there, it is

important to consider a holistic approach with broader perspectives over the physical, digital and combined realities.

- **Data Analysis, Usefulness, Audience Response:** The model of thought proposed with the HIM does not go in the same direction than important and massive current trends with digital tools, such as the automatic generation of images using artificial intelligence. Therefore, it is important to test the usability and impact of the proposed techniques with the public. It will be necessary to consider cycles of tests to understand the will of both the public and the artists to learn and use *slow methods* of representation.

I.3 - The HIA-HIM methodology

The knowledge within an art-practice-based research is a creative and dynamic process in continuous change and evolution (Sullivan, 2005, p. 99). Therefore, it is important to focus how knowledge is defined within the three axes (positivist – interpretive – art-practice). Every research connects how we perceive the reality with the beliefs that we hold and the way we understand a certain knowledge is constructed or, in other words, it connects with their ontological and epistemological framework (Zanela Saccol, 2009, p. 251). In particular, the ontological position that the researcher acquires serves as a basis for delimiting the problem of study, then defining the epistemology, thus also the method that the research will require (Zanela Saccol, 2009, p. 252). Therefore, the research can be structured following these principles:

For the first axis (**mathematical and software definitions**) HIA needs a structure with a positivist approach, i.e., verifying knowledge using logical-deductive hypotheses. This means that we theorise using entities that have observable consequences through the quantification of causes and effects, even though the entity itself does not necessarily exist (Lee, 1991). In this case, the knowledge proves its validity through the principles of falsity, logical consistency, explanatory power relative to other theories, and survival. The positivist approach is fundamental for the HIA-HIM research to nurture and incorporate new knowledge, heavily filtered by the understanding provided by logic, which is crucial for the affirmation and confirmation of mathematical postulates.

For the second axis **(the digital art product),** an interpretative approach is more appropriated, as the research cannot neglect the humanistic component of an artistic practice. Thus, first, phenomenological sociology will help us to understand knowledge as the subjective meaning of the actions of human beings, a meaning built by the social reality (Lee, 1991, pp. 347–348). Second, hermeneutic studies guide the investigation to the possible original meaning of a content, considering the cyclical construction that complex knowledge entails, or Taylor's hermeneutic circle (C. Taylor, 1971). Third, ethnography provides the interpretation of knowledge in terms of the local system as the *in-situ* experience is important for an interpretative reading to be authentic (Zanela Saccol, 2009, p. 265).

Finally, the third axis **(the theoretical/practical/creative set)** is structured on the a/r/cography approach. The a/r/cographic method is the most suitable to nurture, enrich and enhance the research from and with other methodologies thanks to the flexibility and adaptability. This fits the thoughts of Sullivan (2005) who promotes the idea of a flexible theoretical framework rather than a rigid model of non-negotiable definitions, which allows the incorporation or the transference to/from other methodologies, as well as the development of an autonomous theoretical and practical framework for artistic research and practice thus "ceasing to borrow methods from other fields" where "the criteria must move beyond probability and plausibility towards possibility" (pp. 95, 96).

These principles give a solid structure to research through the artistic practice, a framework not only to explain facts but also to generate new understandings of the artistic expressions of Handmade Immersive Art. Hence considering the developments of this research: Part II contains the state of the art and current definitions for the first two axes, Part III states the problems detected on Part II and in Part IV the proposed solutions are carried out, developing and braiding on-the-go the three axes through the artistic practice but a clear accent on the predominant axis.

II - SOLVING PROBLEM 2: a shortcut for cubical perspective drawing

The rather low presence of cubical perspective applications is strongly marked by two components: the low reach of the latest methods and hence the lack of knowledge by artists, students and general public; and the complexity of its application. This chapter will face the complexity of its application as the low dissemination and future integration (such as the programming of algorithms for drawing software) will go smoother the easier is the method for drawing.

II.1 - Context of the developments

Note: this chapter brings most of the content of an article developed, peer-reviewed and published in the Nexus Network Journal (Olivero et al., 2025).

In Part II, Chapter V, I introduced a full method for cubical perspective: **the cubical-spherical perspective method** (Araújo et al., 2020; Olivero, 2021). So far, this is the most complete development for drawing using the cubical map. Yet, there is a case of line rendering within this method that requires an awkward auxiliary construction. Albeit the method provides a solution for rendering every case of line projection in the cube, its application is heavily hindered by this issue, and by extension it is also a contribution to problems 2 (low artistic applications) and 5 (dissemination). In response, this chapter develops a replacement for the complex construction of Araújo et al. (2020) with a simpler, self-contained diagram. I will first introduce the original construction, explore the new construction, its mathematical proof, and finally test the application through a case study.

In the previous chapters I developed how the cubical surface can be used for creating a full immersive representation. The sphere is the natural fully immersive surface, but it is non-developable, so one cannot get the spherical drawing by directly stitching linear perspectives. Instead, the cube is a nice compromise as it is fully immersive and simply joins six linear perspectives. However, if we use a physical cube (e.g., for a big installation such as the Panorama) its corners will create cues that break immersion (Grau, 2003). These difficulties disappear with digital media where virtual viewer placement and lighting are fully controllable, making both sphere and cube more credible and viable fully immersive environments (Jerald, 2015, p. 15). As a digital media, the *cubical environmental mapping* has seen continued applications since its introduction in the ’80s, bringing different and sometimes better features than the sphere (Greene, 1986) and with many different applications, such as skyboxes and the so-called CAVEs (Boddien et al., 2017; Cruz-Neira et al., 1992; Israel et al., 2009, 2010; Wikipedia, 2018b). However, research into this field focused on *computer rendering* (Grimm & Niebruegge, 2007; Lambers, 2019; Lambers & Kolb, 2012; Wong et al., 2007), while cubical *drawing* as a research problem in *technical drawing* only appeared recently (Olivero et al., 2019; Olivero & Sucurado, 2019). The technical drawing of a cubical perspective presents particular geometrical problems: the main challenge being the fragmentation of lines, since a full line projects on up to four segments in four cube faces. When seen on the flattened cube –where one wishes to draw– the segments will meet at variable angles and sometimes on disjoint faces (Figure 113).

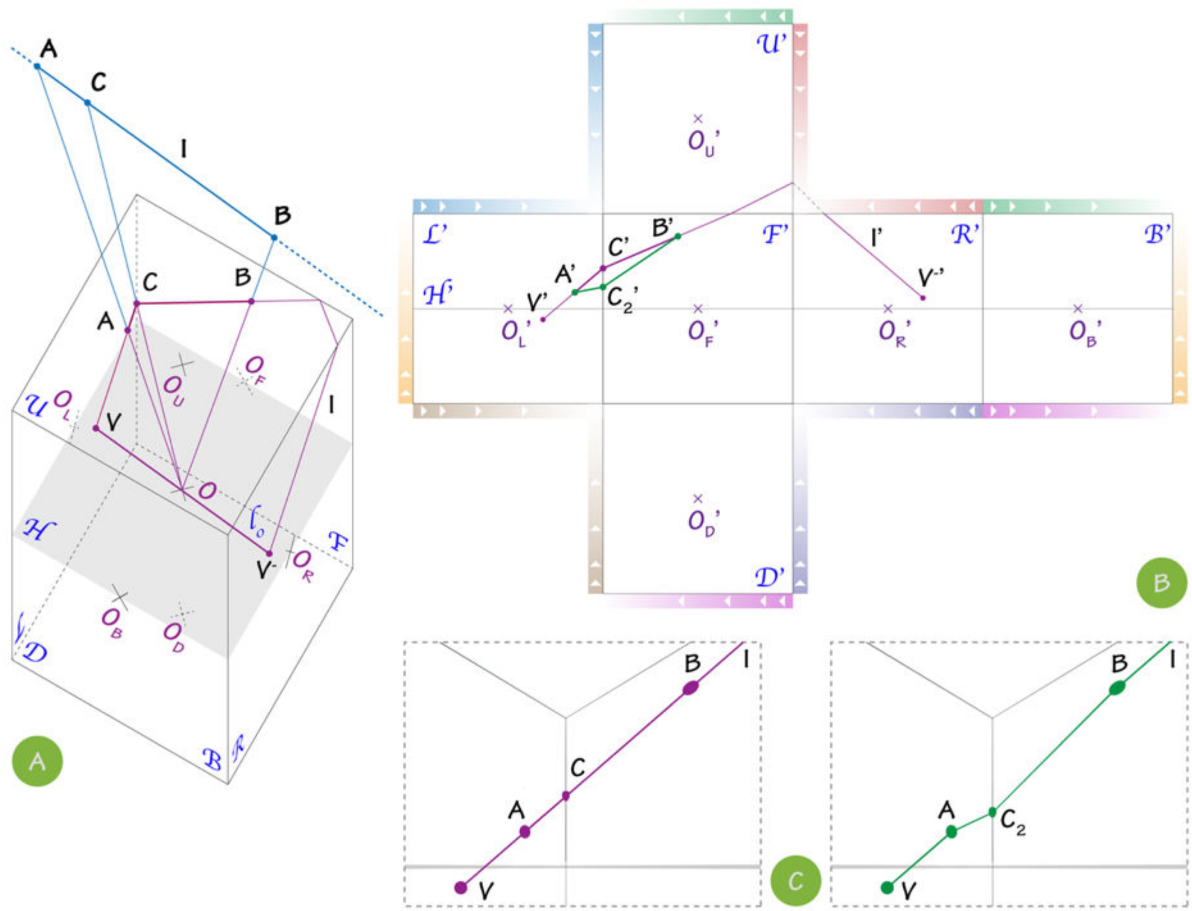


Figure 113: Line fragmentation problem (A, B): only point makes the line look straight in VR (C).

In the historical overview, of Part II, Chapters III and IV, I mentioned how line fragmentation was previously investigated, for example in projections onto connected planes such as walls, ceilings or inside perspective boxes. However, they presented a related yet different problem: the perspective boxes were *parallelepipedal*, not necessarily cubical, and its content was created from a non-central viewpoint onto the closed, not flattened box (Gay & Cazzaro, 2018, p. 9; Spencer, 2018, p. 4; Verweij, 2010, p. 47). These *ad-hoc* solutions are inappropriate for cubical perspective which required a general method for drawing on the flattened cube. This issue was first seen as a problem of angles and either partially or fully solved with at least two different methods using floor plan and section and bringing the projections into the cubical map (Olivero et al., 2019, 2020).

Later, the problem was fully solved with a smoother approach by considering cubical drawing as a case of spherical perspective (Araújo et al., 2020).

Within the cubical-spherical method the cubical perspective is treated as a special case of spherical perspective, where the flattening contains a sub-step of projection from sphere to cube (Figure 114). Consequently, the fragmentation problem was handled as the classification of spherical geodesics on the cube, providing a complete solution and rendering methods using descriptive geometry for all geodesic arcs between any given pair of points on the cube.

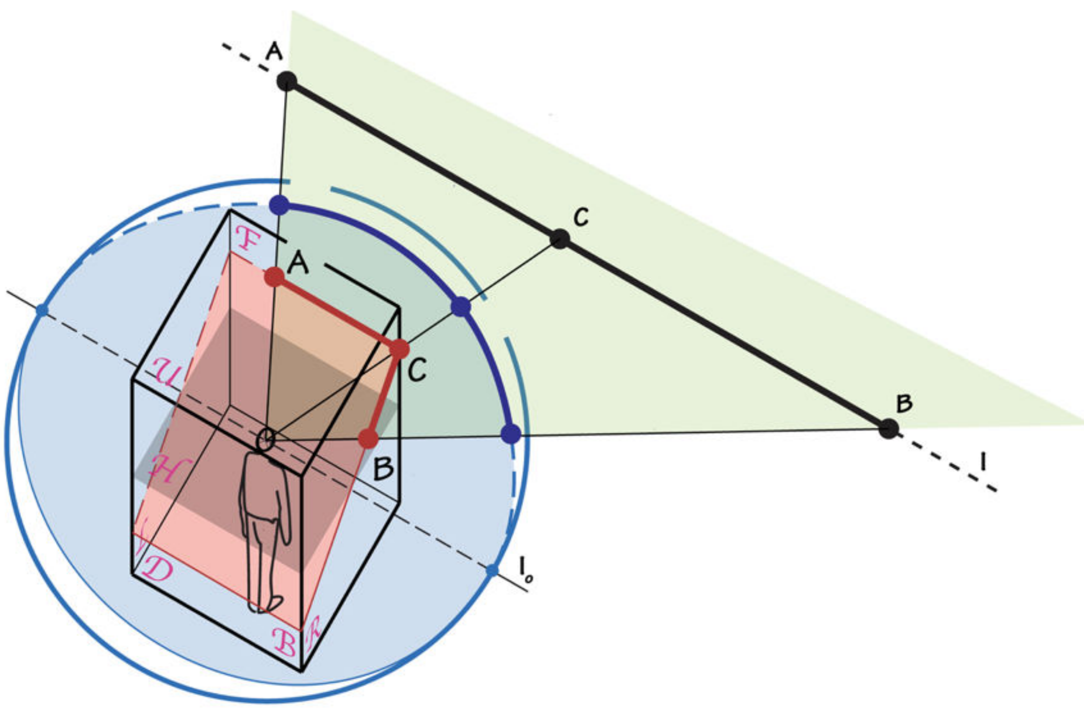


Figure 114: A segment projecting onto a geodesic arc and its cubical anamorph.

II.2 - Notation and problem

We denote elements in space as $\mathbf{P}$ (bold lettering), their conical projection onto the cube's surface as P (regular lettering), and their cubical perspective image within the cubical map as P' (prime index). We denote the centre of the cube by the letter O. Call horizon (denoted H) to the plane OO_FO_R (Figure 113). Call horizontal (resp. vertical) any plane parallel (resp. orthogonal) to H. Call height of P (denoted $z(P)$) to the distance of P to H. Given a point P we say its antipode is the point P^- such that $\overrightarrow{OP} = -\overrightarrow{OP^-}$.

II.2.1 - The problem

Two points A, B define a line AB in space and a plane through O. The intersection of this plane with a sphere centred in O is a geodesic. Geodesics are essential to plot lines: the conical projection of AB on the sphere is half of that geodesic, ending at two antipodal vanishing points. We call *geodesic* to both the intersection of that plane with the concentric cube and its image on the flat cubical map. The main problem of cubical perspective is to draw the geodesic that passes through two points whose images are given on the cube. The most laborious case arises when the projections A, B fall on two adjacent faces (Araújo et al., 2020; Olivero et al., 2019): we need a third point C to get the cubical perspective image of AB.

Construction (Figure 115): let A, B be two points in space. Let g be the conical projection of the geodesic of $l = AB$. Thus, $A, B \in g$. Suppose that $A \in F_A$ and $B \in F_B$ such that F_A and F_B are adjacent faces of the cube. Let e be the edge between F_A and F_B and l_e the vertical line through e. Let δ_e be the plane through e and O. Let $C = AB \cap \delta_e$. Then, $C = OC \cap l_e$.

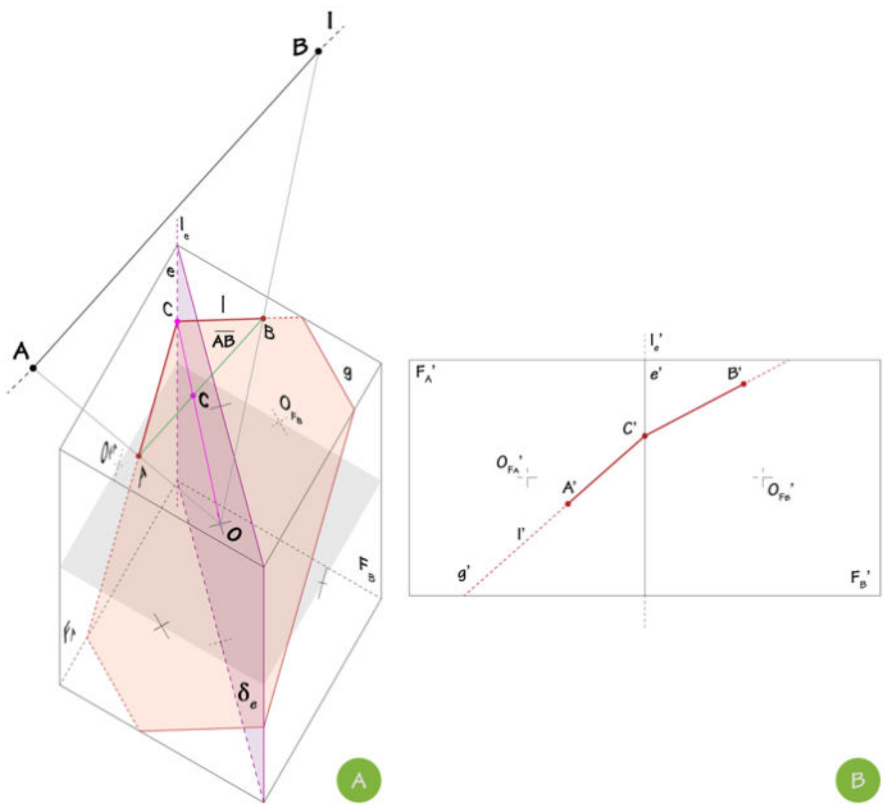


Figure 115: Construction in space (A) and in the cubical map (B).

The image of AB onto the cube's surface is the union of AC and CB, and therefore the image of AB in the cubical map is $A'^{C'} \cup C'^{B'}$. **The question, then, is how to get point C' within the flat cubical map** using descriptive geometry. The solution proposed by Araújo et al. (2020), p. 39 for finding C' follows Figure 116: project $AB \cap \delta_e$ onto an auxiliary plane perpendicular to δ_e to find $C_\varepsilon{}'$, which determines the orthogonal projection $C_{F_B}{}'$ of C on face F_B. Then $O_{F_B}{}'C_{F_B}{}'$, the orthogonal projection of OC onto F_B determines C' on edge $l_e{}'$. We will refer to this as the Old Construction from now on.

Problem: Can we find a construction of C' that requires no external auxiliary plane?

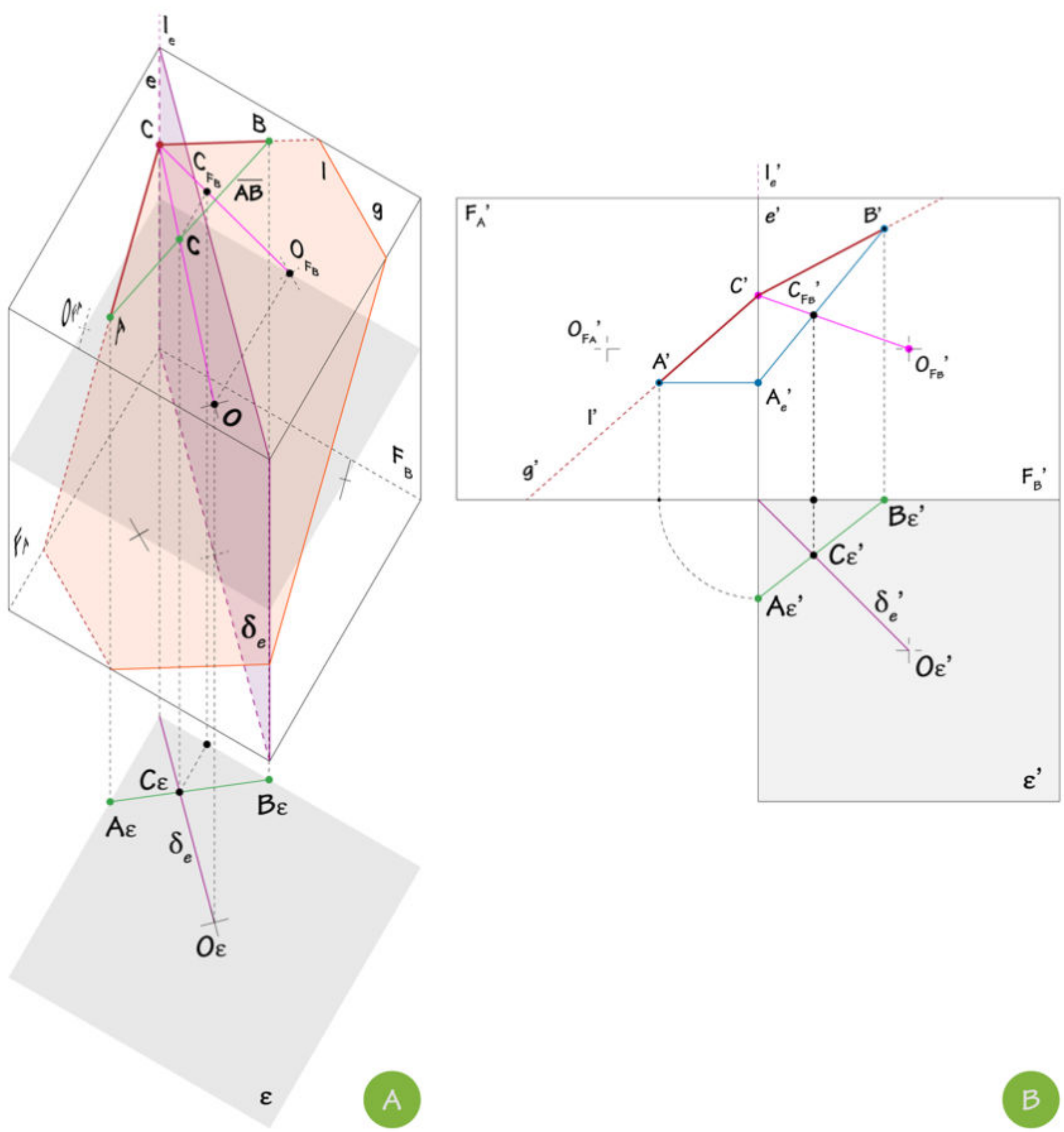


Figure 116: Old Construction in space (A) and in the cubical map (B).

II.3 - The new A-Construction

In contrast to the Old Construction, the new A-Construction gets point C' within faces F_A and F_B right after A' and B' are plotted (Figure 117, B). All what we need for getting C' is the same spatial elements stated in 4.2 but without the vertical plane δ_e (Figure 117, A).

A-Construction: Let A', B', l_e' be the image of A, B, l_e in the cubical map (Figure 118, B). Suppose $z(A') \neq z(B')$. Let A_e' be the foot of the perpendicular from A' to l_e'. Let $X_e' = A'^{B'} \cap l_e'$. Let h_{Xe}' be the horizontal line passing through X_e'. Let $X_{F_B}' = h_{Xe}' \cap A_e'B'$. Let O_{F_B}' be the centre of face F_B'. Let $X' = O_{F_B}'X_{F_B}' \cap l_e'$.

Theorem: $X' \in g$ and the image of AB on the cubical map is $A'^{X'} \cup X'^{B'}$.

The theorem follows by relating the two constructions:

Theorem: $X'\ (A - Construction) = C'\ (Old\ Construction)$

which in turn follows trivially from the following lemma, which we will prove:

Lemma: $X_{F_B}'(A - Construction) = C_{F_B}'(Old\ Construction)$.

Proof: Consider the construction of Figure 119, where A and B are the points on the cube and C is the intersection of AB with the vertical plane δ_e through O and l_e. Let β be a vertical plane not intersecting the cube that makes an angle of $\alpha = 45^{\circ}$ with respect to both F_A and F_B (Figure 119, A-D). Let f be the orthogonal projection onto β. We use the notation $P'' = f(P)$ (double prime) to denote images of points by f.

We say that three points are in the relation $A - B - C$ if they are in the same line and B is between A and C. Because f is an orthogonal projection it preserves the collinearity of $A - C - B$, that is, we have $A'' - C'' - B''$. Because β is a vertical plane it also preserves the heights of the points.

Let C_e be the point at l_e that has the same height as C (Figure 119, C). $A''^{C_e''}$ (respectively $C_{e''B''}$) relate to AC_e (respectively C_{eB}) by a horizontal scaling around l_e. In fact, because β makes an angle of 45° with both F_A and F_B (Figure 8D), we have $d(A'', l_e'') = d(A, l_e)\cos(45^{\circ})$ and $d(B'', l_e'') = d(B, l_e)\cos(45^{\circ})$. Since horizontal distances are scaled on both sides of l_e by the same factor while vertical heights are preserved, the slopes of C_eA and C_eB remain equal to each other on both sides of l_e.

The perspective images A' and B' are obtained from A, B by a rotation around the folding line l_e, so the perspective image preserves both the heights and the horizontal distances from l_e to each of these points, and furthermore preserves the position of $C_e \equiv C_e'$. Hence the slopes are again preserved, and therefore $A' - C_e' - B'$. Hence C_e' is the intersection of $A'B'$ with l_e', that is, C_e equals the X_e defined in the A-Construction (compare Figure 119, B and E), and therefore we have shown that X_e has the height of C. Then X_{F_B}, which is the point of $A_e{}'B'$ in the same horizontal as X_e also has the height of C and therefore point X_{F_B} in the A-Construction equals the C_{F_B} of the Old Construction. **Q.E.D.**

Both theorems above follow as corollaries, so the cubical perspective image of AB is $A'^{X'} \cup C'^{X'}$, where X' is obtained by the A-Construction.

The shortcut covers all the most difficult cases with C within or outside e (Figure 120)[6]. Special cases: 1) the A-Construction assumes $z(A') \neq z(B')$ otherwise $X_{F_B}{}'$ is undefined. If $z(A') = z(B')$, take either antipode (say A^-) and then $z\big((A^-)'\big) \neq z(B')$ and the construction can be applied, as antipodes fall on the opposite faces but on the same geodesic. 2) Adjacent cube faces may be non-adjacent on the cubical map. This also happened in the Old Construction, and the solution is the same as in that case: face images are made adjacent through translation and rotation/reflection, or antipodes are used instead (Figure 120, F-G).

II.4 - Comparison of methods

The Old Construction builds C' externally, outside the faces of A' and B', requiring descriptive geometry operations onto an external auxiliary plane δ_e. This complicates and slows down the drawing process especially when outside of a studio environment. Instead, the new A-Construction builds C' internally, without further operations on an external plane. This is important because handmade drawing errors propagate with the number of operations and with the crowding of construction lines especially outside of studio conditions. This new solution compresses the scheme to fewer lines condensed in a self-contained outline, reducing the number of steps and improving the user's ability to use cubical perspective for sketching and simplifying/accelerating the studio process. Notice that both constructions can still coexist. When points A' and B' have similar heights, the lines obtained by the Old Construction may touch at a larger angle than those of the A-Construction, making the plotting of the intersection more precise. Another option is to take antipodes, as described in the special cases on the previous section. The more convenient choice may in these cases be left to the illustrator's discretion.

---

[6] Actually, the complete accuracy of the 2D to 3D pull back passage depends on making certain assumptions due to radial occlusion. Strictly speaking, it is not possible to have the exact position of a point in space without a double projection.

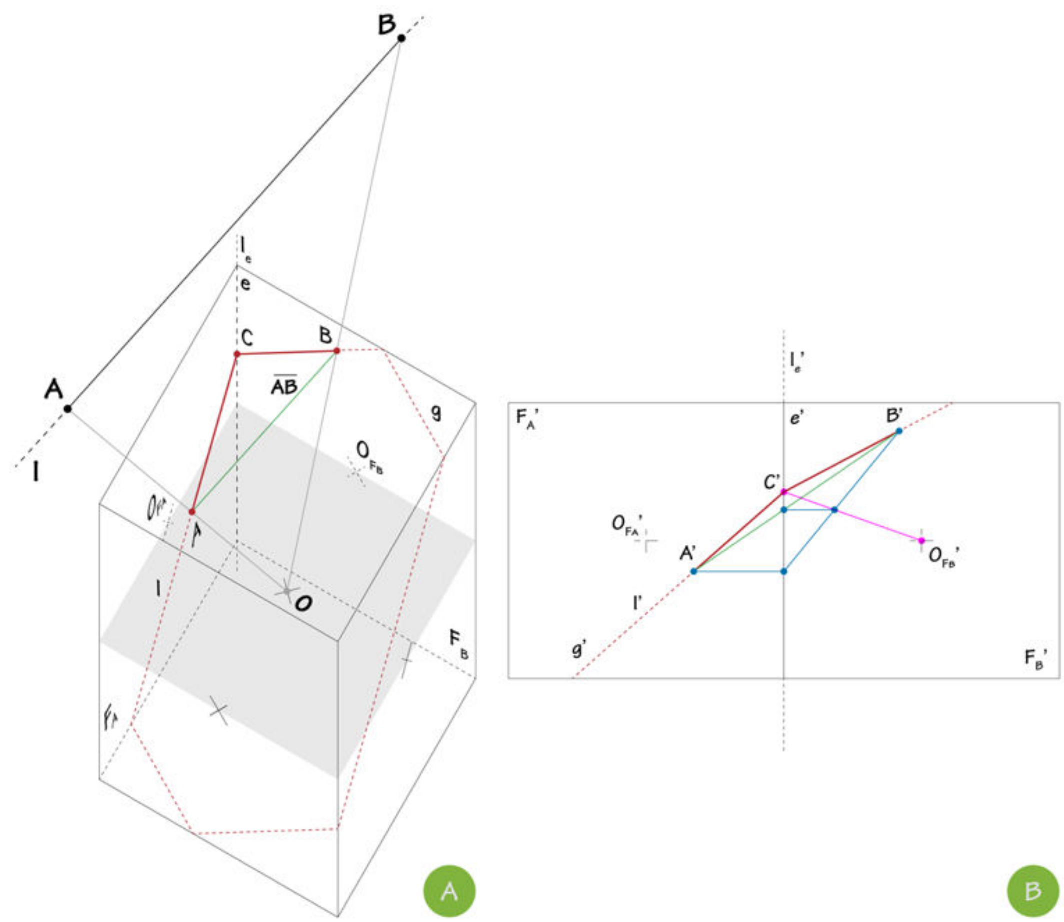


Figure 117: Spatial elements needed for the A-Construction (A). A-Construction (B).

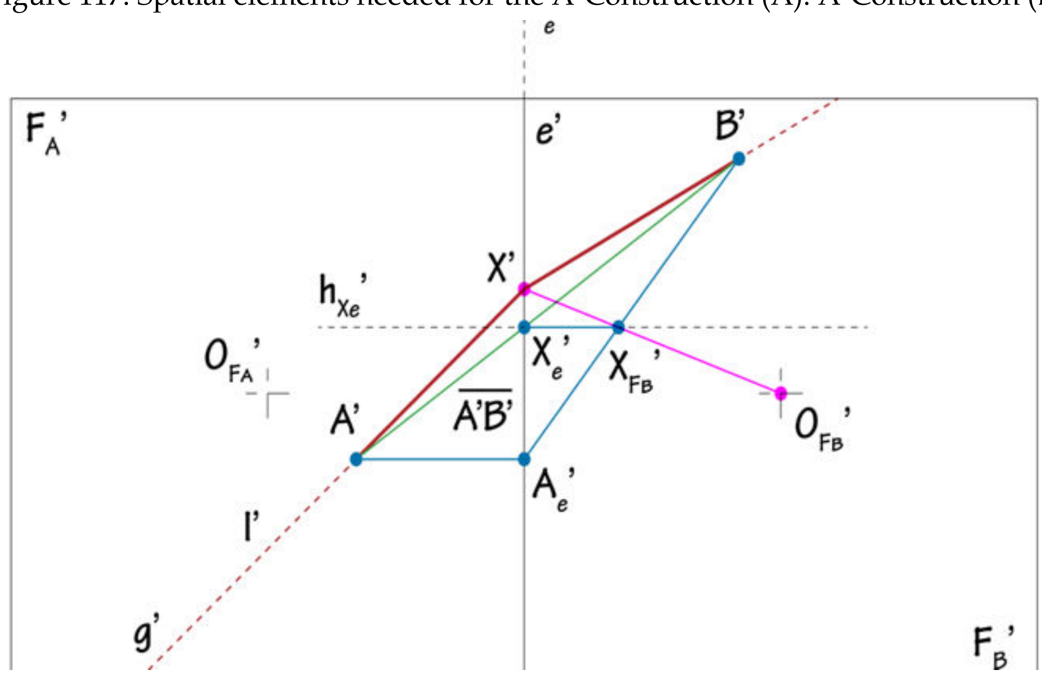


Figure 118: A-Construction in the cubical map.

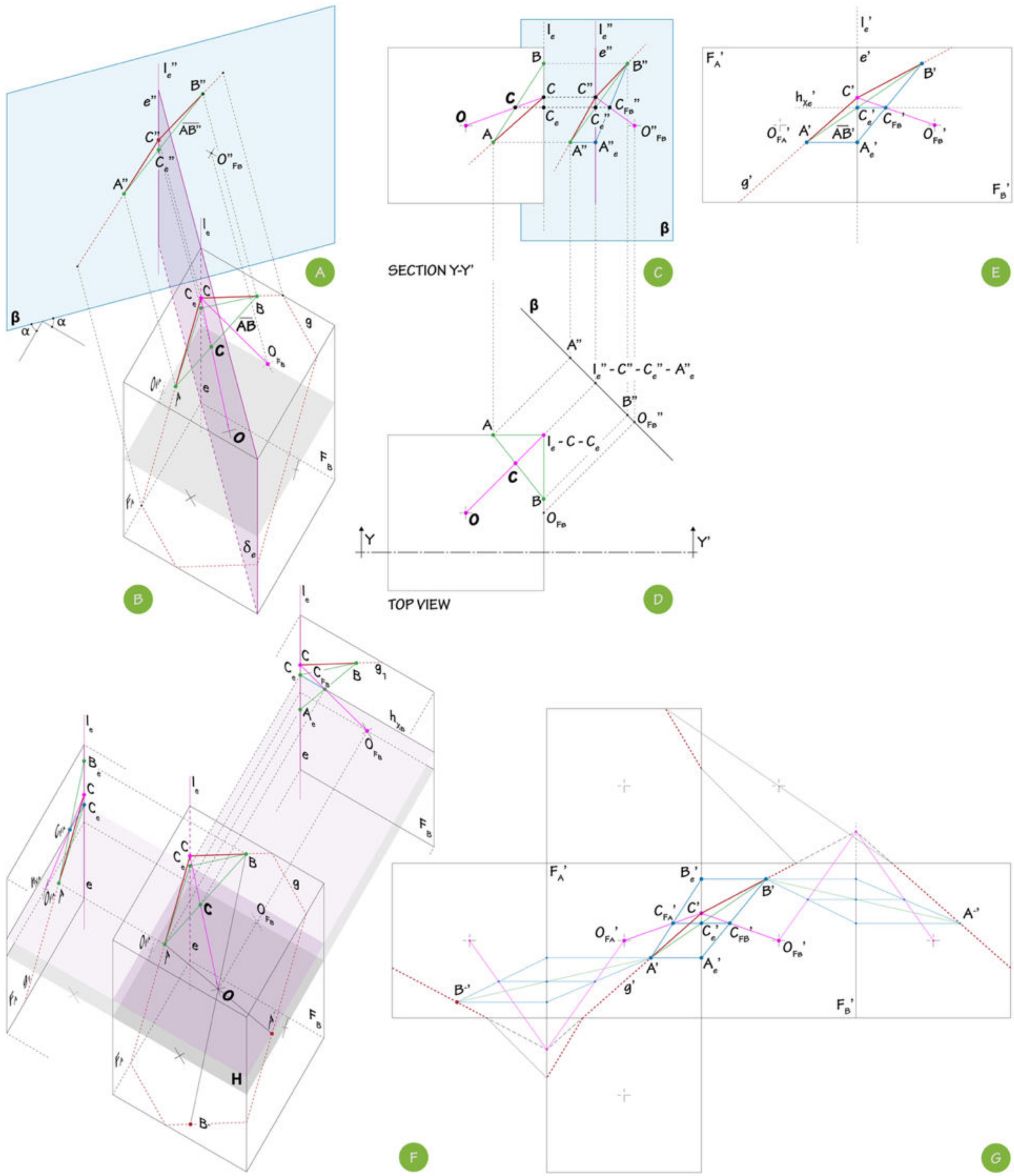


Figure 119: A-Construction, projections on plane β (A-D), A-Construction with antipodes (F, G).

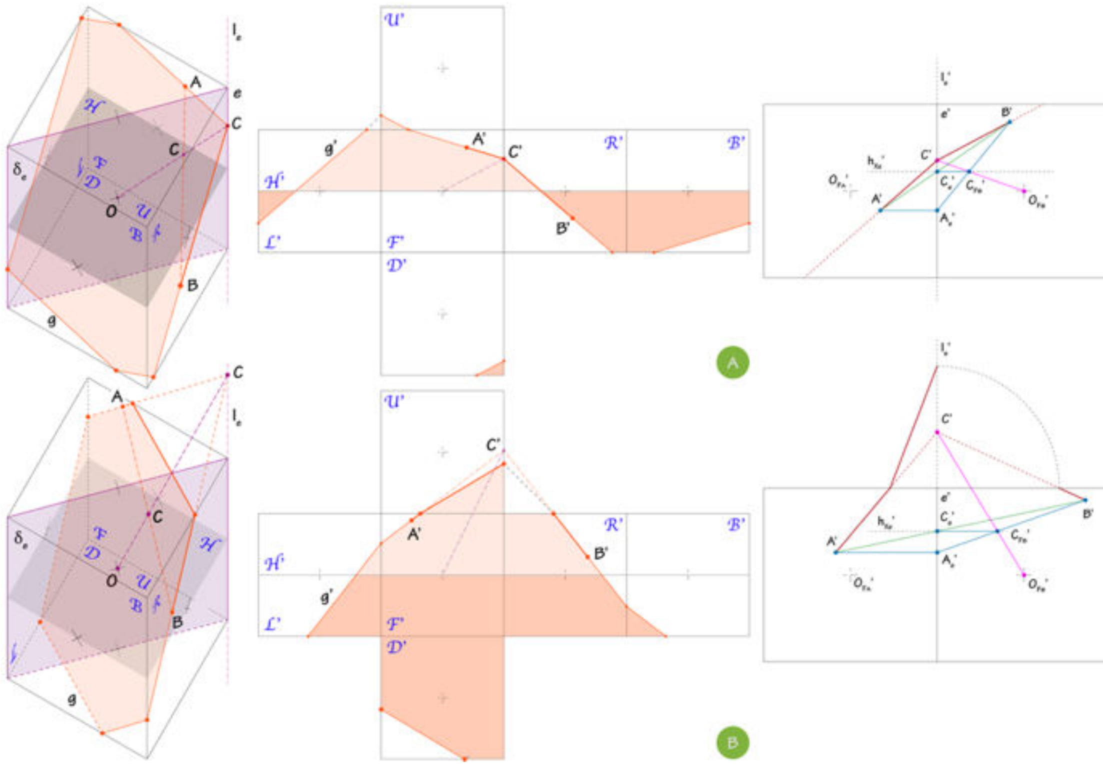


Figure 120: Application with the Auxiliary point C inside l_e (A) and outside (B).

II.5 - Applications

Figure 121 shows the artwork Hello Alice, which was created using the shortcut within a cubical perspective setup. Although the drawing has been made only on four faces of the cube, it can be clearly seen that the continuities are correctly constructed: compare for example the person behind the window (and surrounding elements) at the centre of the bottom, right image, and their correspondence in the cubical construction. The artwork represents a quite complex construction which could have been extremely complex to build using only the old method.

Instead, the shortcut proportioned a handy solution for solving all kind of situations. Another case study is The Eye in the Sky, an artwork made on canvas and soon to be painted with acrylics (Figure 122). In contrast with the previous artwork, The Eye in the Sky explores more geometrical shapes, applying the A-Construction and other forthcoming shortcuts to build an imaginary world with shapes floating in space, cliffs and classical constructions in linear perspective (Figure 123). The Eye in the Sky is the first big format canvas presenting Handmade Immersive Art, until now the explored artworks were made with ink and watercolours on paper. The purpose of this election is to also show further possibilities to artists working with this technique.

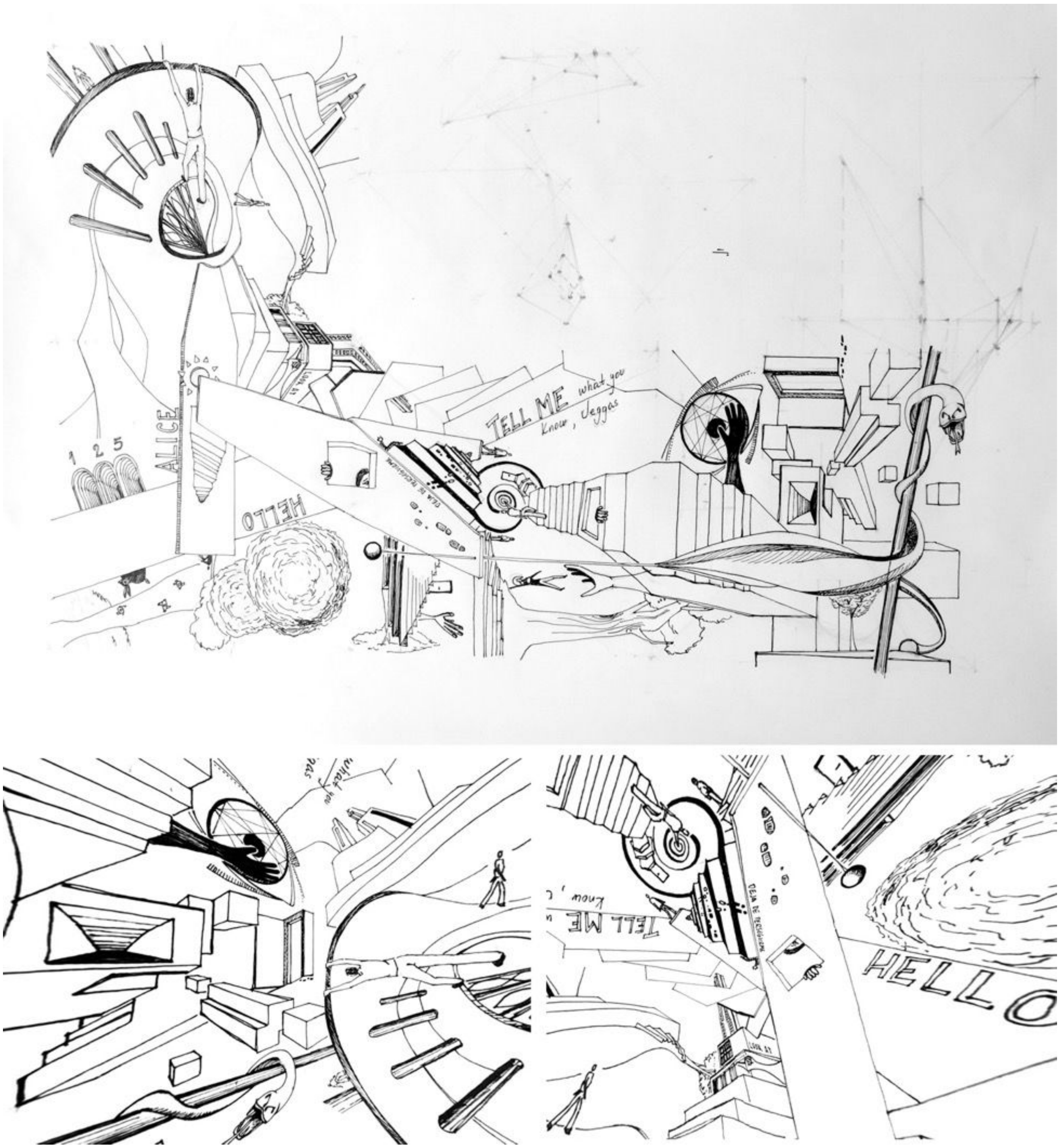


Figure 121: Hello Alice, Handmade Immersive Artwork made in cubical perspective with pencil and ink on paper, 42 x 29,7 cm. (up). VR views (bottom) © Lufo Art (Lucas Fabian Olivero), Forthcoming.

II.6 - Section’s highlights

The method that considers the cubical perspective as a special case of spherical perspective has one big issue when compared with other spherical perspectives: its large casuistic to solve geodesics within the cubical map (Araújo et al., 2020; Olivero et al., 2019). In the research for optimising the application of the cubical-spherical method, we developed the shortcut A-Construction, obtained first from an intense graphic experimentation thus mathematically proved through a descriptive geometry characterisation. This shortcut concentrates the previous constructions into one shorter, more understandable, and self-contained graphical arrangement. The A-Construction (together with other already found shortcuts but not fully developed and presented in literature yet) recall and enhance the properties and advantages of the already published methods for cubical drawing, as well as their specific benefits for drawing Handmade Immersive Art, making the practice lighter and more stimulating for every advanced or beginner user.

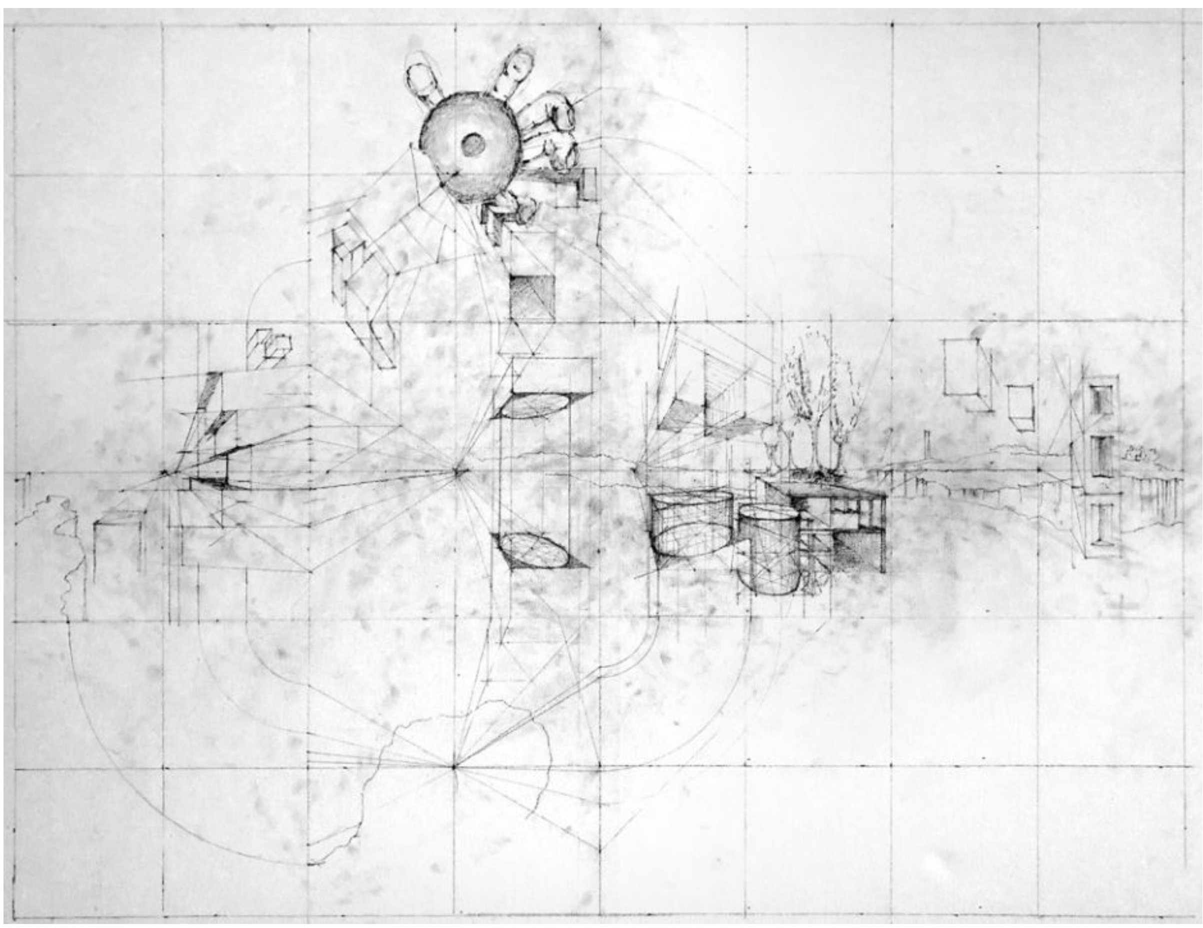


Figure 122: The Eye in the Sky, Handmade Immersive Artwork in cubical perspective made with pencil on canvas (soon to be painted with acrylics), 120 x 90 cm. © Lufo Art (Lucas Fabian Olivero), Forthcoming.

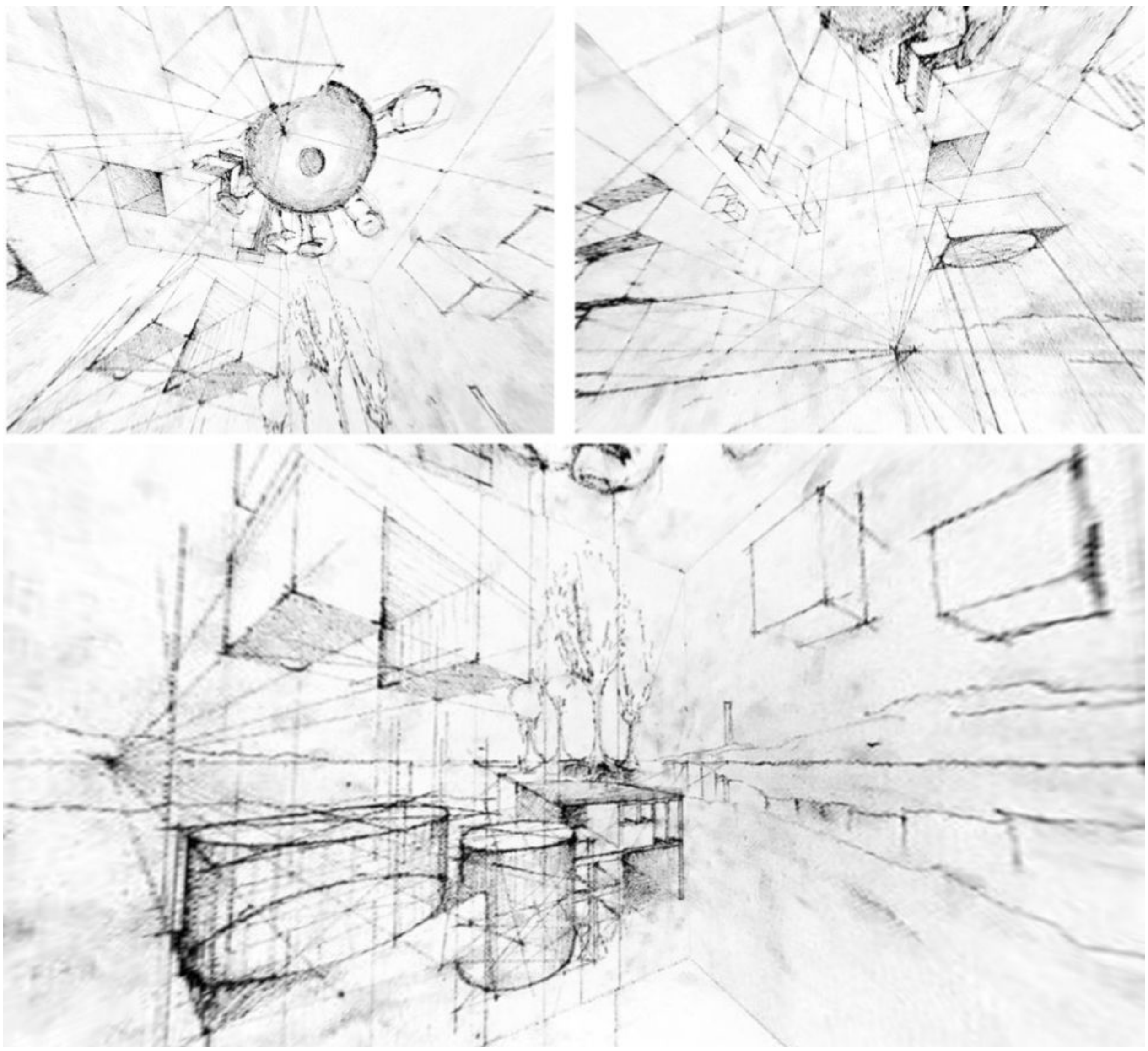


Figure 123: The Eye in the Sky, VR views from the current state of the artwork © Lufo Art (Lucas Fabian Olivero), Forthcoming.

III - SOLVING PROBLEM 3 AND 4: Installations and exhibitions

The installations presented in the next chapters are centred in solving Problem 3, while the exhibitions focus in solving Problem 4. However, it has been impossible to separate them in two consecutive chapters and get a pleasant lecture of the results, and so I attached to the third axis of the methodology and braided installations and exhibitions through a line (more or less chronological) of joint and correlated events, which testifies much better how things really developed in real life, i.e., the advancements of the one pushing the advance of the other, and vice versa.

This chapter brings the content of several articles developed, peer-reviewed and published in the I-Com Journal Olivero & Araújo (2022); in the congresses Artech 2021 (Olivero & Araújo, 2021b), Artech 2023 (Olivero, 2023) and exhibitions in Portugal and Germany (Olivero, 2022a, 2022b, 2022c, 2022g, 2025; Olivero & Araújo, 2021a).

III.1 - Installation I: IMWYM v1

This section introduces the design requirements of a software for constructing immersive environments from handmade spherical perspective drawings in a performative setting, meaning with a concurrent, interactive and live feed of the VR visualisation presented to an audience while the drawing is executed. The requirements are synthesised in a first version, called IMWYM v1 (I'm Watching You/Me), as functionalities, improvements, possible integrations and future developments obtained from the analysis of **the current best practices and state of the art of spherical perspective drawing** (PART II) (equirectangular, azimuthal equidistant and cubical); the **available software for their practice**; and the **experimentation with a novel installation**, built using the node-based program TouchDesigner (Derivative, 2017) and from which emerges a workflow prototype before entering a pure coding stage. Ideally, the software in aim should smoothly integrate with digital art practices, stimulate and facilitate the practice of anamorphic handmade spherical drawings, and expand spherical perspectives' applications through the emerging media of Hybrid Immersive Models (HIMs).

III.1.1 - Summary of current software options

In PART II - Chapter V, I developed methods for drawing either physical or digital spherical anamorphoses (equirectangular, fisheye or cubical) with different levels of accuracy. In terms of **software** corresponding those drawing methods, there are stand-alone software developed for the equirectangular format, such as Eq A Sketch 360

(Araújo, 2019b) and Sketch 360 (*Sketch 360*, 2025). For the cubical perspective there is no functioning drawing software, and for the azimuthal equidistant there is a vector-based GeoGebra tool (Araújo, 2020a) and a paid animation suite covering raster fisheye drawing up to 180° (Boom, 2024). Most of these programs are compatible with Windows and macOS operative systems.

In terms of **parallel visualisation viewports** of the flat drawing and its correspondent VR environment, Sketch 360 allows a simultaneous view of the drawing and the VR result in a parallel viewport. Yet, the viewport must be updated every time by the illustrator, which may not fit the requirements of a performative dynamic app as we want to produce. The GeoGebra tool for azimuthal equidistant format and Eq A Sketch 360 has no direct VR visualisation available. In the GeoGebra tool case, the drawing must be converted to the equirectangular or the cubical format before navigation is possible (the azimuthal equidistant is not currently a standard input within most visualisation software).

As for the **conversion of the drawings**, the current software options force the user to follow a chain of steps (often cumbersome) before seeing the VR results. But in the meantime, is hard to guess the immersive result without a certain level of knowledge on spherical perspective, which discourages the beginner and limits advanced artists from using equirectangular perspectives in live presentations, as the untrained audience cannot easily decode the perspective picture in their minds. In fact, in several exhibitions already held (Araújo et al., 2019; Olivero, 2017, 2018a, 2018b), visitors experimented many difficulties understanding the correlation between the flat drawing and the VR rendering: a verbal or written explanation might result too theoretical, yet when they experience the sphere from within (i.e. with the help of VR glasses) the comparison is more straightforward, giving a better appreciation of the drawing/VR correspondence.

Hence, considering the options and functions provided by current software, the first prototype of the aimed installation should cover the gap of the live drawing/VR conversion. In more detail, the software should provide the core function of **live capturing a handmade drawing (made either with physical or with digital means), use it as texture, and create a virtual environment that live updates while the drawing is being made.**

III.1.2 - Components, interaction and functionality

The first version of the software IMWYM was mounted as a prototype using TouchDesigner and tested during some exhibitions before entering the pure code stage. TouchDesigner is a platform for visual nodal programming and real time interactive multimedia content, optimised for giving a versatile support to live performances (Derivative, 2017, Section about). The program has both free non-commercial and paid pro licenses. The free non-commercial, includes all operators and functionalities, but is limited to a resolution of 1280 x 1280 px. The program has six family operators: Component (COMP), Texture (TOP), Channel (CHOP), Surface (SOP), Material (MAT) and Data (DAT), through which the installation's network was built (Figure 124). TouchDesigner also allows a large interactivity with media inputs and data devices through CHOP operators (here used for importing IN-4 data) and, although its code is closed, it allows a wide spectrum of possibilities and variations thanks to its seamless integration with Python code within all its operators, commands and parameters.

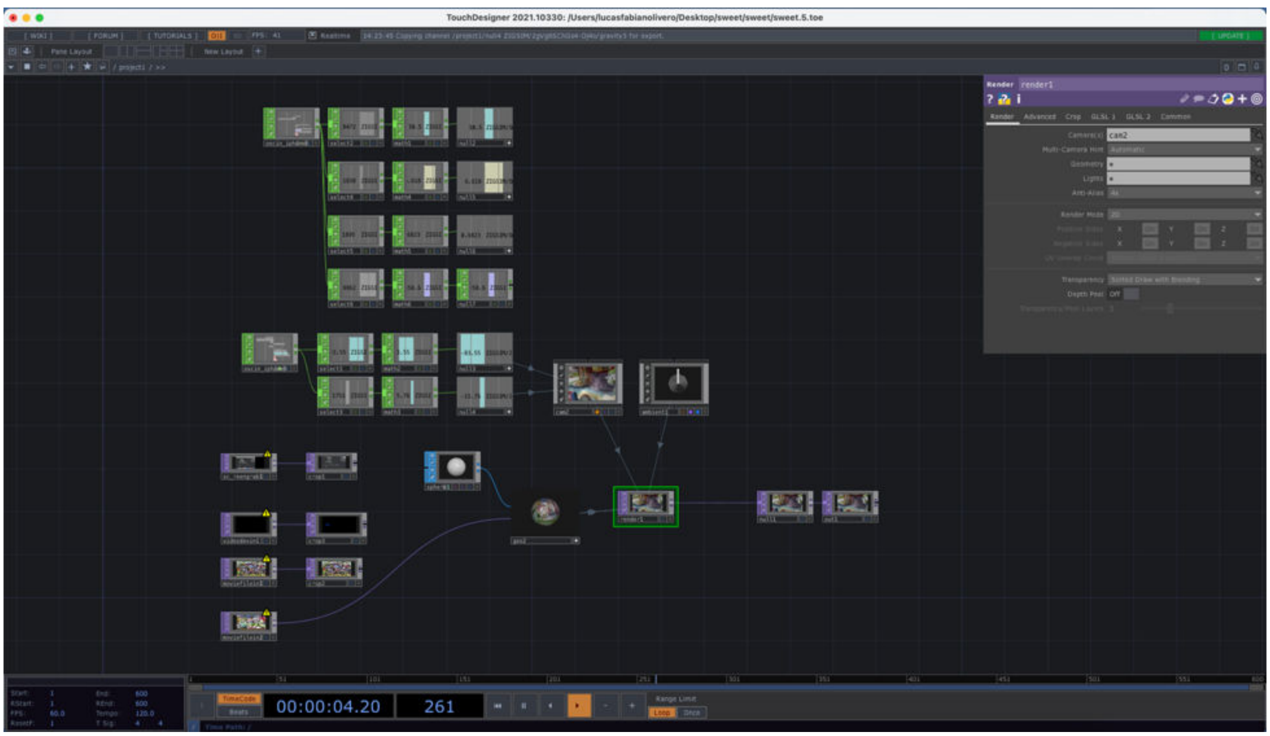


Figure 124: Installation's network on TouchDesigner.

The components and functionalities of IMWYM v1 were organised in the following way:

- IN-1: a physical handmade drawing captured with a camera. It can be, for example, a paper fixed on the desk, or a drawing board fixed on the wall (Figures 128, centre and 131).
- IN-2: a digital input directly recorded from the computer's screen. This input grabs content from any drawing software, such as Eq A Sketch 360 (Figures 128, top and 131).

- IN-3: an already existing media, such a spherical drawing, a panoramic photo, or a panoramic video (Figures 128, bottom and 131).
- IN-4: a mobile phone with movement sensors, the device must be running any app, such as ZigSim, able to transmit wired or wireless OSC data to TouchDesigner (Figure 132).
- IN-5: a video camera.
- OU-1: a screen projection on a wall.
- OU-2: an external screen.

The functioning of the installation was structured as follows:

- The artist (AR-1) chooses an input medium IN-1, 2 or 3 (Figures 125, 126). It is possible to choose one, or to mix several inputs. This latter option allows the possibility of drawing and composing interactively together with other artists or even with the public (maximum one per each medium).
- When the chosen input is the handmade drawing, the video camera IN-5 captures the equirectangular drawing, which is then cropped inside TouchDesigner and used as the texture of the digital sphere.
- An external visitor (VI-1) interacts with IN-4 sending orientation data. The program defines the orientation of the device through Compass and Gravity sensors, thus filtered to channels Gravity 3 and Compass 1 (Figure 132). Every phone movement updates the virtual environment camera thus displaying a new section of the immersive drawing to the audience.
- OU-1 shows the classical perspective resulting from the VR modality, that is, the spherical anamorphosis is dynamically converted into a linear perspective, which is shown in the viewport according to the camera's position within the visual sphere (Figure 129).
- OU-2 can be used to give further visual support, for example having the installation's net on TouchDesigner running on the computer's screen while OU-1 shows the VR and OU-2 displays IN-1, IN-3 or the program running IN-2.

In short, a first subject (AR-1) live draws in equirectangular projection using either traditional or digital techniques. At the same time, a second subject (VI-1) defines the position of the camera sending data through a mobile phone (IN-4). AR-1, VI-1 and the audience watch the results through OU-1. Note that this is a generic operational workflow, not necessarily connected with TouchDesinger. In fact, the same principles should translate easily to other platforms as the whole network has been assembled using well-known components: the geometry of a sphere, an equirectangular projection input, screen recording, a standard external camera, a mobile phone and OSC data from a free app (ZIG SIM).

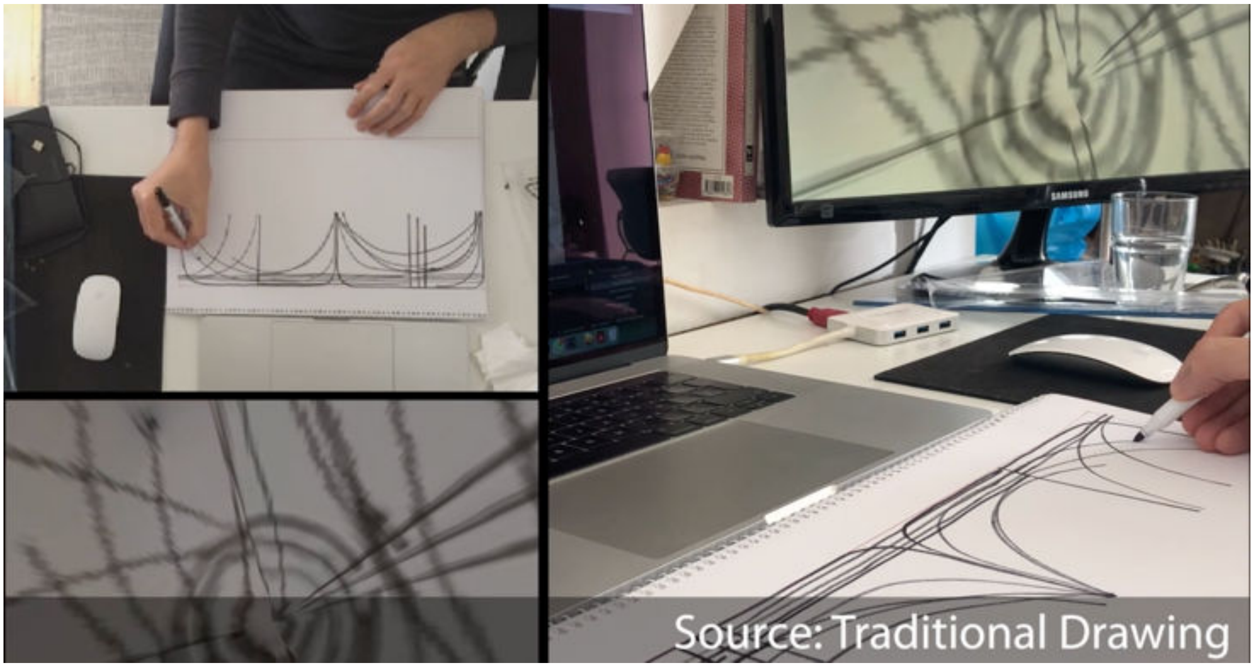


Figure 125: IN-1: input from a physical drawing.

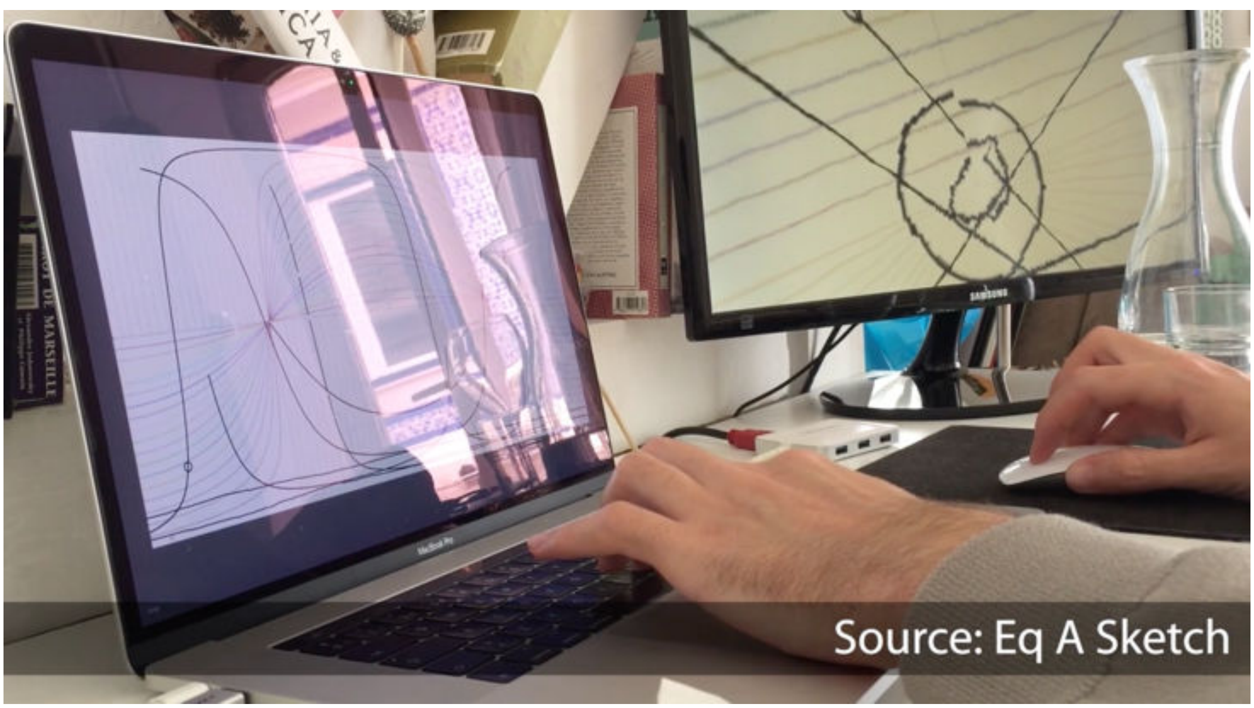


Figure 126: IN-2: input from a physical drawing.

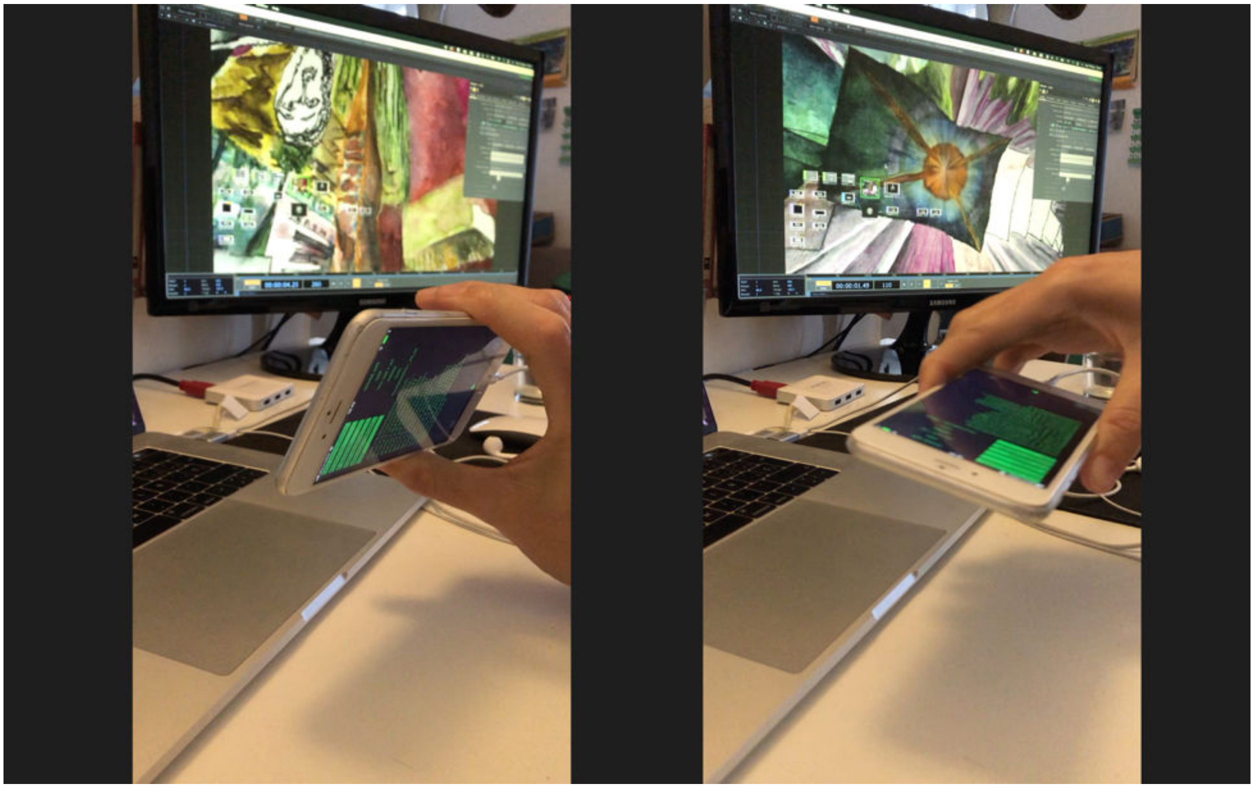


Figure 127: OU-1: the camera replies to IN-4's movement.

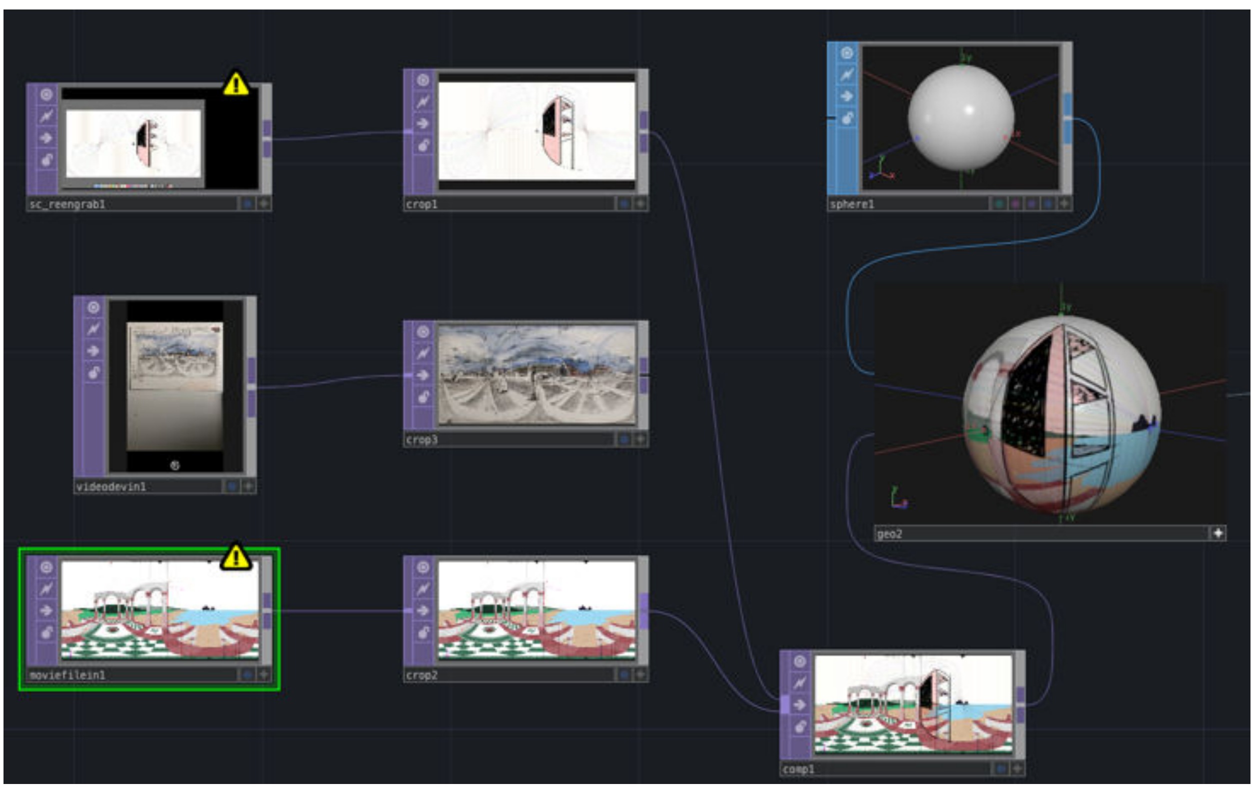


Figure 128: Mixing inputs (IN-2 + IN-3).

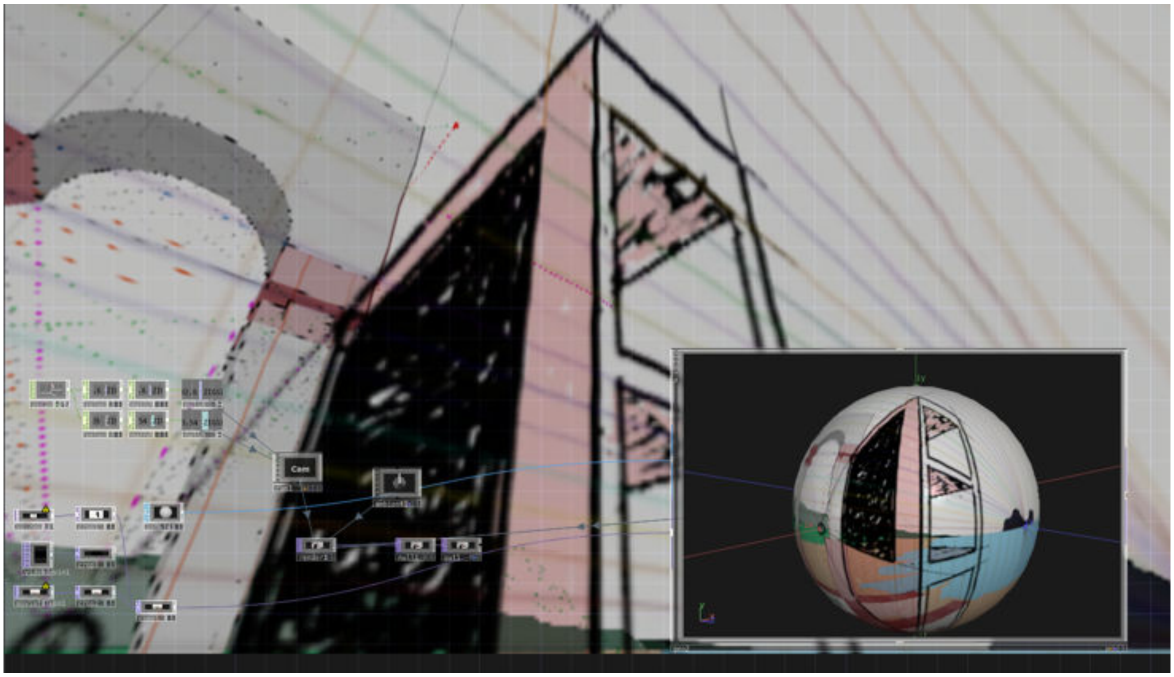


Figure 129: Live VR result of the mix. Field of View set at 90°

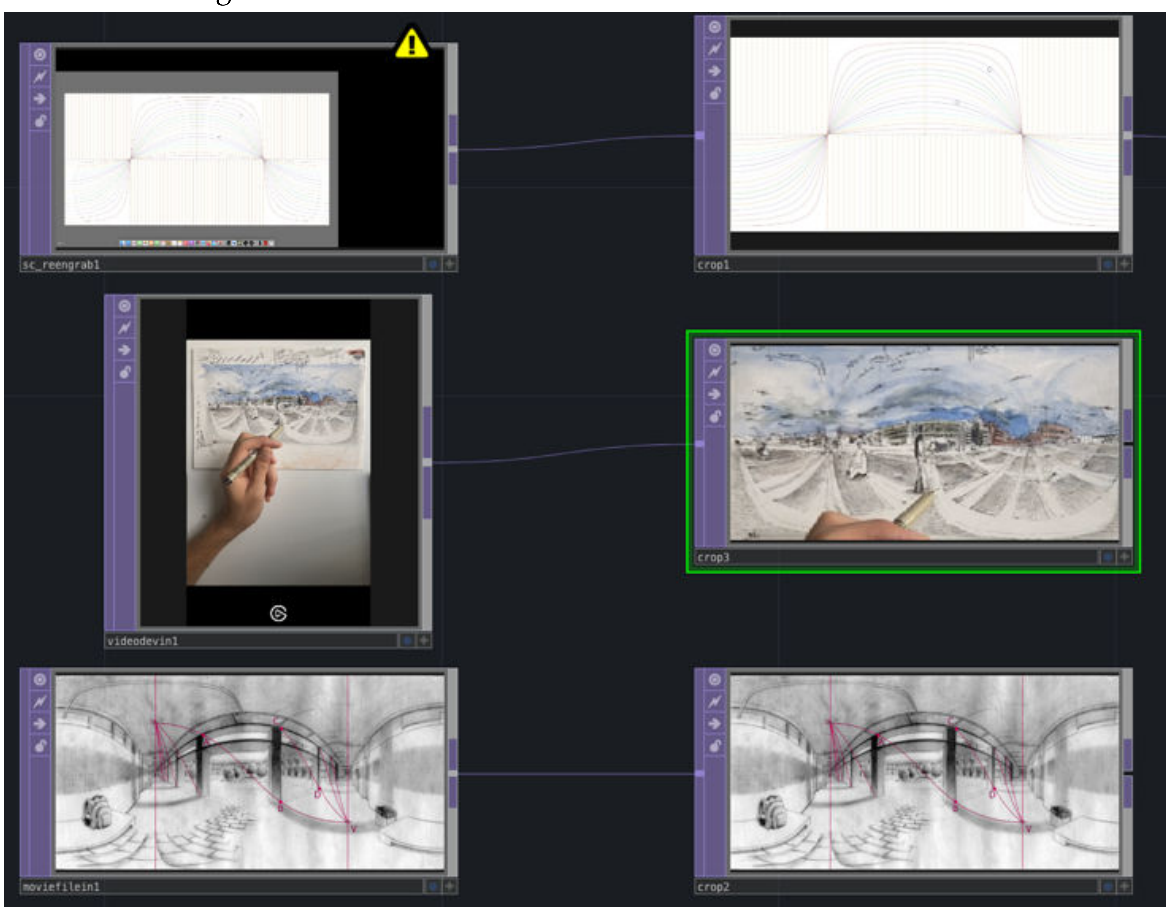


Figure 130: Image input: Eq A Sketch 360's interface (top), handmade drawing (centre) and existing panoramas (bottom).

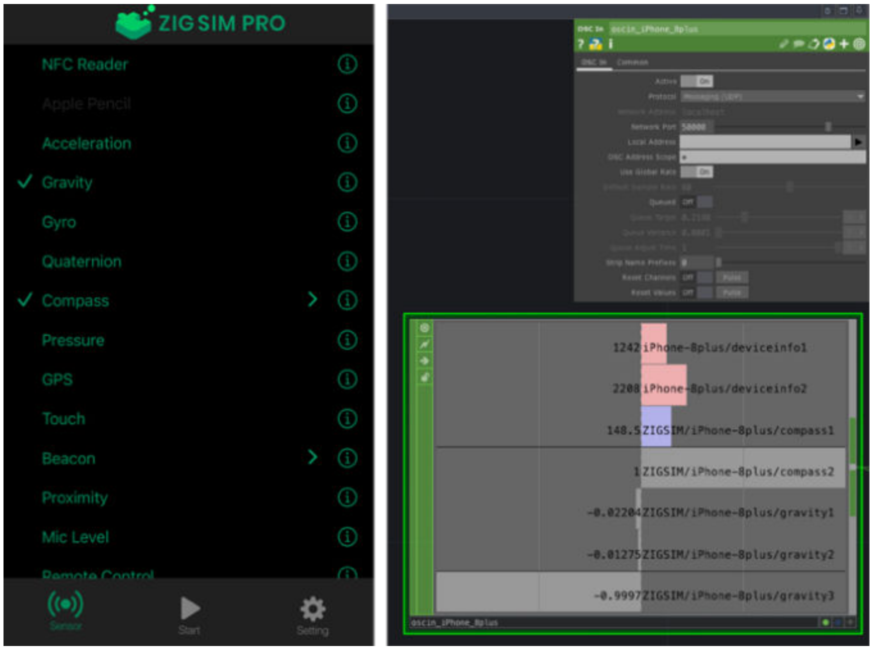


Figure 131: OSC input: Gravity and Compass sensors.

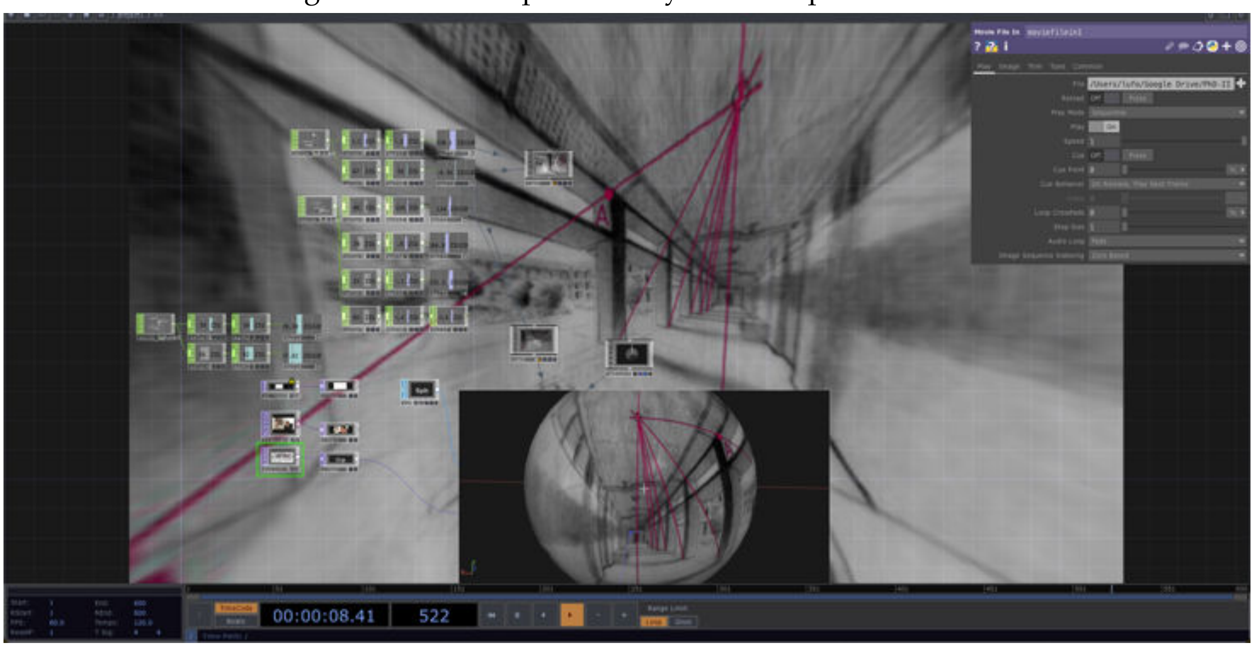


Figure 132: The sphere from within (background) and from outside (bottom).

III.1.3 - Novelties

Thanks to IMWYM v1, the artist can focus on the drawing while members of the audience are free to choose their preferred point of view. The artist has a wider and more complex view, perceiving the macro and the micro at once, keeping both the whole and the detail in view during the entire process. Instead, visitors can appreciate the results by directly watching at the VR image. Furthermore, a curious or perspective-knowledgeable visitor can also perceive the connection between all the elements in one same intellectual, interactive, and dynamic exercise. Drawing a spherical perspective allows artists and designers to explore their ideas without any limitations in their surrounding observation field. With the aid of digital technology, the installation gives the user the possibility to explore the artwork from inside the visual sphere and to extend such a possibility to a live audience in a real-time interaction. In short, the installation presents some important novelties regarding the previously analysed software:

- it opens the possibility of using **spherical perspectives within live performances**, showing an on-the-fly dynamic and interactive visualisation of the result.
- it offers the possibility of **mixing several inputs into one unified output** (Figures 128, 129), integrating inputs from other already existing programs.
- it covers to the needs of both beginner and expert artists, introducing the former to spherical perspectives through an instant trial-and-error game; while the latter can draw the most complex constructions and use the software to share, explain and communicate results to the public.

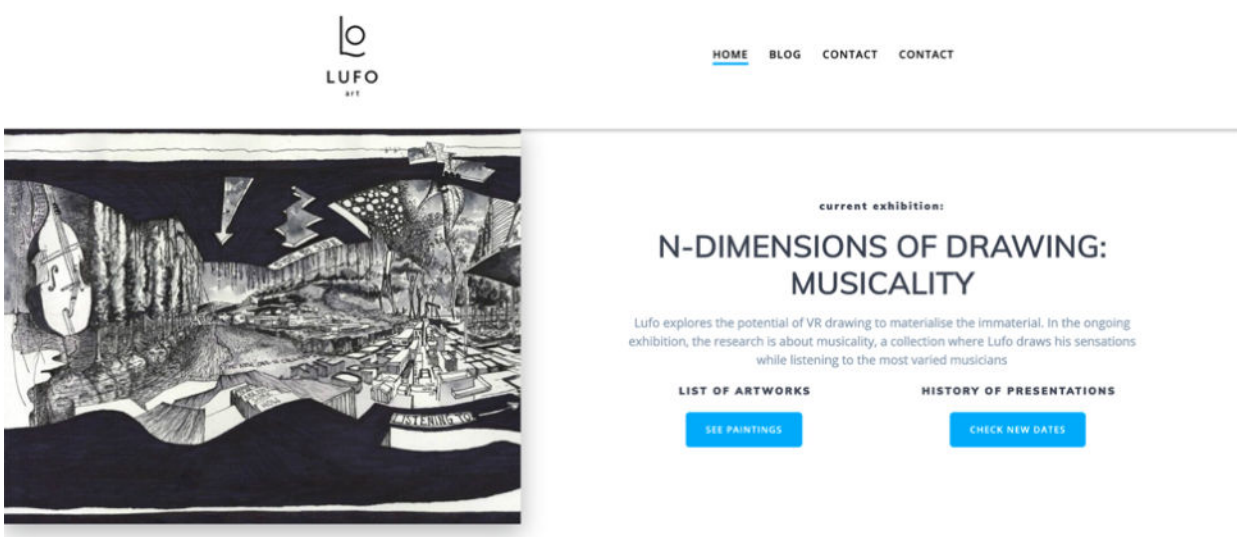


Figure 133: Announcement of IMWYM v1 at lufo.art.

III.2 - Exhibition I: I'm watching ~~you~~/me (Braga, Portugal)

The first version of the installation was presented with a homonymous name during the congress in digital media art Artech 2021 (Lopes et al., 2021; Olivero & Araújo, 2021a). The presentation showed Handmade Immersive Art through a live drawing performance using immersive perspectives and the installation as a way of expanding spherical perspectives' applications. The whole presentation focused on showing the technical advancement provided by the new software. In artistic terms there was not a clear concept, but rather the underlaying generic idea of exploring non-traditional dimensions through drawing, in this case the *musicality*, meaning the artist's interpretation of music through graphical impressions in equirectangular format created while listening to live concerts (Figure 133).

III.2.1 - Users' experience

The installation was introduced to the audience during the first day with a live drawing demo (Figures 134, 135). The software was tested during the congress by both general and specialised public, from which some testimonies were gathered, outlining the overall reception of the installation. One of the testers was Chiara Masiero Sgrinzatto, a key person to evaluate the usability of the software since her career is strongly based on equirectangular drawing (Figure 136). After testing the installation thoroughly, she reported as follows:

> "Thanks to the ability to display the drawing both in equirectangular and in interactive format, it is easy to understand how the immersive drawing is taking shape to people who are not familiar with spherical perspective. In a future development as a software, the system could be very helpful for education projects, for live painting performances, and for all the purposes involving a general public that could not understand clearly the distortions of the spherical drawing. It would be an interesting feature to add the possibility to interact on the three-dimensional re-projection: a tool for sketching or taking notes on the output canvas, allowing a bi-directional participation to stimulate design processes and ideas sharing". Chiara Masiero Sgrinzatto, independent artist, illustrator and designer, Venice, Italy.

I also gathered reviews from people with different backgrounds, not necessarily related to the field of drawing. The installation had to be useful for live performances, in such a way that it could allow the artist to freely draw in equirectangular perspective while the visitor might be watching and interacting with the VR results. Therefore, I spoke with random visitors, asked them about their background and interests, and then about the impact produced by the installation:

> "I haven't had many experiences with spherical perspectives before, maybe we learned a bit about the theory in school, but nothing I would clearly remember. I, therefore, do not regard myself as savvy regarding this subject. I am an interaction designer and researcher working in the field of smart textiles, specifically in designing ways to communicate this new medium to everyday users. Although this may not actually be accurate, I understood the drawing and the artifact as "theory" and "practice" of the project. As the drawing

showed how it is done, the artifact allowed me to see the immersed representation of what it is. This hugely increased my understanding of the drawing and the project itself. The whole setup was not very intuitive, I initially perceived it as a performance, and without a call to action would probably never discover the artifact on the table. However, once my attention was brought to it, it was immediately clear what the purpose of the artifact is and how it can be used. It added a big wow effect already, it might be even more impressive and immersive with a VR headset instead of the phone. What I particularly enjoyed was that the immersive representation through the artifact was changing in real-time, as the drawing was being drawn”. Sara Mlakar, media Interaction Lab, University of Applied Sciences Upper Austria, Hagenberg, Austria.

“I am a multimedia artist, journalist, researcher and doctoral student in Digital Media Art. I hold a Masters’ Degree in Literature and Culture. I lectured at the Department of Languages, Literature and Modern Cultures at the University of Bologna, Italy, and I had experiences as an Assistant Professor of Journalism at Universidade Veiga de Almeida, in Rio de Janeiro, Brazil. In the live action experience, it can be seen that the artifact transforms something mathematical into a performative exploration. Through interactivity, the application provides an immersive and playful experience at the same time, and also allows the lay public in general to understand how the drawing is generated. It felt like having an ‘Escher effect’ literally, in the palm of your hand”. Juliana Wexel, Centro de Investigação em Artes e Comunicação (CIAC), Universidade do Algarve, Portugal.

“The experience allowed me to get closer to spherical perspectives. I liked that it linked traditional drawing methods with new technologies. I could say that the experience suggests an intimacy between the viewer and the work, however, I would like to have a device that allowed me to be more immersed and intimate with the artist’s work (maybe a VR headset)”. Anonymous user.

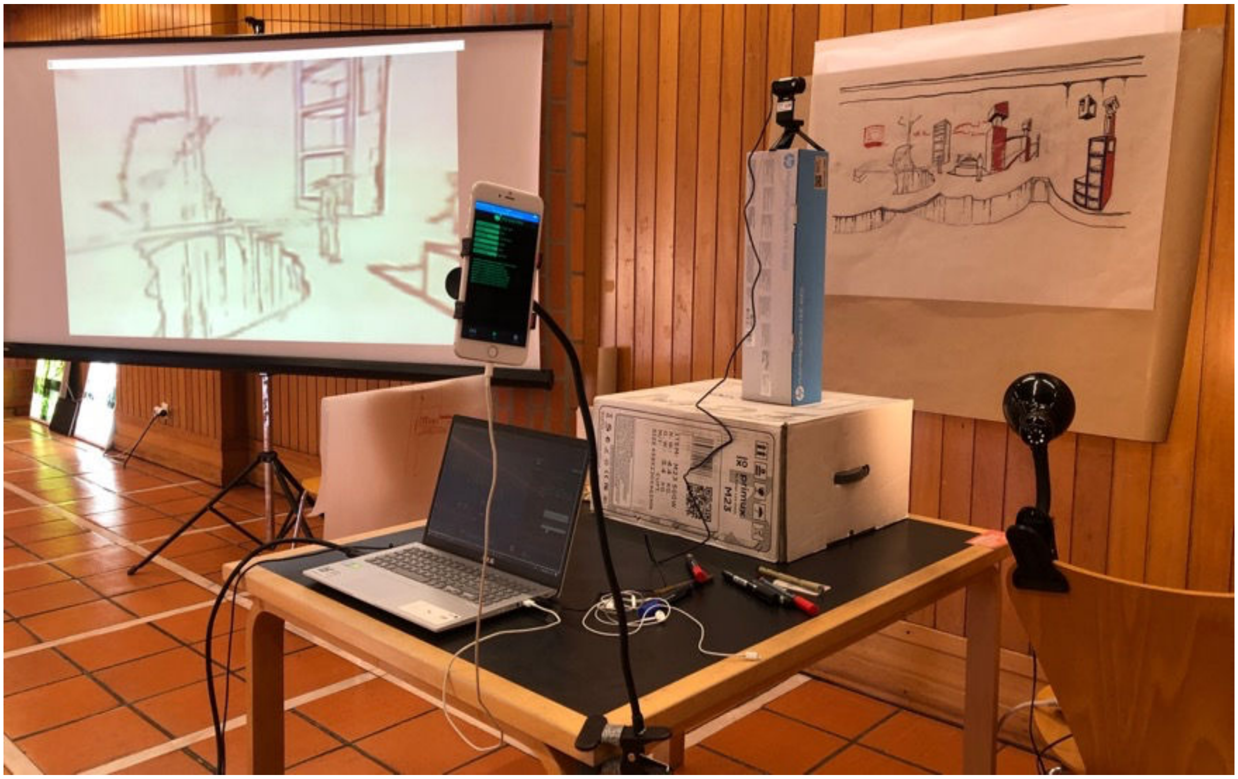


Figure 134: The installation during the exhibition at Artech 2021.

Figure 135: António Bandeira Araújo and Lucas Fabian Olivero explaining the installation and performing a live demo on equirectangular drawing. Ph: Juliana Wexel.

Figure 136: Chiara Masiero Sgrinzatto testing the installation during the exhibition.

III.2.2 - Necessary improvements

The following list was elaborated based on the current state of the installation and the feedback received during the exhibition. It addresses the most important points to be reviewed and some necessary improvements to be made before entering the pure coding stage:

- Camera's position is determined using Compass and Gravity sensors. Presently, a glitch occurs during the navigation: there is an inversion/discontinuity of the view under certain rotations, probably due to the use of Euler angles; this will be solved by using Quaternion-based calculations.
- OSC data is provided by a wired connection, and the use of Zig Sim forces the phone to be constantly on and with the application open. It will be useful to develop an open-source app to send wireless data in the background and leave the phone screen for other uses, e.g., to stream back the output content and test a forced stereoscopy with VR glasses. This way, a visitor wearing the VR glasses can determine the camera's position through the movement of the head and be free to move about in space at the same time.
- There is no front-end interface available for switching among inputs. This is necessary for a more efficient and simplified operation.
- Currently, the Field of View can be modified within TouchDesigner, but it remains constant while the live streaming is running. It would be useful to add a functionality for changing it during runtime directly from the front-end interface.

- This first application works with equirectangular projection, yet it should ideally integrate also cubical and azimuthal-equidistant perspective inputs.

III.2.3 - Evaluation of IMWYM v1

The first version of the installation aimed at the design of a platform integrating spherical perspectives and live performances. I mapped requirements and features from the state of the art and currently existing software; prototyped some of them in an installation built with TouchDesigner and got a first impression on the user experience during an exhibition focused on Handmade Immersive Art.

During the exhibition, the software allowed a dynamic and interactive perception of spherical perspective content, with the added feature of mixing inputs from several sources, enabling live collaborative works. Thanks to the software, the result can be shown directly in VR modality, saving the long list of cumbersome steps currently necessary to pass from the drawing to its visualisation. The live exhibition highlighted the versatility of the installation for allowing exchanges on different levels of knowledge about spherical perspective: while the more specialised user appreciated more details of the whole installation; the non-specialised user was attracted to explore the native relationship between drawing, sphere, and VR.

At this point of the research and the DMAD course, some big updates on the investigation came out, for which I elaborated a list of issues of the installation considering:

- The **live testing of the installation**, which helped to highlight many functional, aesthetic, interaction, and conceptual issues. For this, I considered both my own critique and analysis, and the visitors' feedback.
- The **new developments**, among which I opened up and explored important topics not previously considered such as art-based and art-practice-based research methodologies, and the methodological definitions for the HIA-HIM (Part IV, Chapter I).
- **The reviewers' notes,** regarding two articles about the installation (Olivero & Araújo, 2021b, 2022).
- An updated state of the art.

Table 2 enumerates the issues and drafts a possible fix to be either implemented or explored within a second version. The problematics were structured in three sets: narrative/development, interaction/evolution, and experience/fruition, following the reference given by the a/r/cography methodology (P. A. da Veiga, 2019).

Table 2: Evaluation of IMWYM v1

Issue	Criticality and draft solution
NARRATIVE - DEVELOPMENT	
1 - Missing concept. IMWYM 1 focused on a technical advancement. There was neither a clear artistic concept nor a defined narrative. As the goals of the research changed, the new edition focuses on the artistic application. Consequently, both concept and narrative were critical improvements for integrating IMWYM with the new goals.	**Critical issue.** IMWYM 2 would not have any sense without the definition of a concept and a narrative. **Solution**: elaboration of a concept and a narrative for redirecting and integrating the installation to/with artistic purposes, and for highlighting the particularities of its components. For example, the installation has a strong focus on the interaction with 360 contents, which might open a wide range of possibilities for exploring VR content using gamification.
2 - Missing narrative. IMWYM 1 was included within the shared exhibition Contingency within the congress Artech 2021, yet neither limited nor oriented towards any specific direction for it. This lack of narrative was both with the general exhibition, and within the prototype.	
INTERACTION - EVOLUTION	
3 – Lack of a front-end interface. An interface was critically necessary for a more efficient and simplified operation. For example, one characteristic of the installation was the possibility of switching or adding inputs and then interacting with them. Yet, visitors would not know how to do it since the available screen was showing pure visual code, something not inviting to interact with.	**Critical issue.** The interface is the connection between the content and the interaction. As so, it is very important for a simplified operation and for gathering visitors' feedback. The data of how visitors relate and react to the installation is the base for understating the phenomenological reading of visitors' interaction. Furthermore, the artist's guidance is required without the interface (issue 5). **Solution**: elaboration of a front-end interface that enables a fluent interaction with the content, gather data from it, and show a menu for visitors to get help and read information.
4 - Dependence on the artist's presence. Due to issue 3, and missing additional graphic material (flyers, posters), the interaction with the installation was very hard to understand. This required the artist's presence for operating the installation and explaining its functioning.	**Critical issue.** The installation should stand independently with a minimum of explanations. **Solution**: addition of supplementary material explaining the setup and functioning, distributed either digitally with an external device (e.g., a tablet) and/or with printed material.
5 - Fixed FOV. Currently, the field of view can be set in TouchDesigner but remains constant at runtime. It might be useful to add a function for setting it dynamically so as to zoom in and out while looking at details.	**Low priority.** This issue is not connected with the basic user experience but rather is an advanced interaction and visualisation feature. **Solution**. add a button/function on the interface to change the FOV dynamically.

EXPERIENCE - FRUITION	
6 – Software incompatibility. The first compatibility problem arose while setting up the installation in a computer with Windows (the net was originally composed on MacOS). Using the same program on both operative systems one might have expected a better integration. Yet, I needed to rework some key components. The second incompatibility was with the external camera (IN-5). The one provided by the organisation was dated and incompatible, for which it was needed a last-minute run to find another camera.	**Medium priority.** Compatibility issues are a big problem only when one is using an unknown computer system. **Solution**: ask for access to the local facilities with more anticipation to extensively test the software. Otherwise, it can be solved using the original laptop (or a similar one) with which the installation was built. In any case, it would be more opportune to have a web-based solution to avoid any OS' limitations.
7 - Navigation glitch. Compass and Gravity sensors determined the camera's position. A glitch occurs during the navigation: there is a jump of the view under certain rotations.	**Low priority.** The navigation is less trustable but still functioning. **Solution**: use of Quaternion-based calculations instead of Euler angles.
8 - Zig Sim app. The app needed to be always on and onscreen to send the OSC data. Furthermore, the wireless connectivity was also an issue due to OS' restrictions. Consequently, the installation needed to run with a wired connection both to keep the phone's battery loaded, and to simplify the net connection.	**Medium-high priority.** The problem intricates a smoother interaction with the content. **Solution**: a mobile application able to send OSC data running on the background. The creation of a dedicated application might be useful for other purposes (e.g., using the phone within a VR headset).
9 – Limited inputs' projection. The presented version was limited to the equirectangular projection.	**Medium priority.** It is important to integrate better the theory of the research. **Solution**: add cubical and azimuthal-equidistant perspectives as inputs.
10 - Calibration of the camera (IN-5). The calibration of the camera was very fragile, which forced a recalibration very often.	**Medium-high priority.** The live capturing should not rely on a physical calibration, but on a dynamic calibration based on the analysis of the image. **Solution**: use of markers on the paper or board and live image-processing tools.
11 - IN-2 and OU-2 were not live tested. Due to spatial and equipment constraints in the room, these components were not possible to evaluate.	**Low-medium priority.** The functioning of both components was verified during the programming stage. However, IN-2 might result difficult to whom is not familiarised both with the device and spherical drawing. Hence, much likely IN-2 might be only on the interest of dedicated artists or teachers. OU-2 is needed for separating the equirectangular inputs and the interface. **Solution**: larger space and equipment availability.

12 - Setup IN-1 / AR-1 / IN-4. This configuration generated a rather obvious problem: being the physical drawing hanged on the wall, the artist casted shadows while drawing and the visual captured by the camera was partially blocked.	**Low priority.** The problem is more aesthetic since does not block the functioning nor avoids the normal interaction with the installation. **Solution**: consider a setup for drawing onto a glass (or something transparent), and a camera capturing the drawing from the rear side.
13 - Setup IN-1 / OU-1. During the first presentation, IN-1 and OU-1 were almost parallel and within the same line. Therefore, it was very complicated for the artist to watch the VR results and having instant visual feedback.	**Low priority.** The issue is only for the artist using the installation and not for regular visitors. **Solution**. Build a flexible setup considering the installation with and without the live drawing performance and pay attention to the perspective that both artist and visitors have.

III.3 - Installation II: IMWYM v2

The second version of the installation integrated several of the solutions developed in the table above. The focus was given to those issues with high and medium-high priority. The prototype installation was called [IN]Musicality and it was presented during the shared exhibition *[IN]Tangibilidades Digitais* (digital intangibilities) in Portugal. The next paragraphs extend the details of the adopted solutions considering generic definitions for presenting the installation at any place.

III.3.1 - Addressing issue 1: missing art concept

The definition a specific concept gave the installation a clearer artistic focus. The concept, called [IN]Musicality, explored how music affected the creation of Handmade Immersive Art through two paths: on the one hand, considering how to graphically express music through immersive drawings, and on the other hand, how visitors perceived the musicality within those drawings. Reflecting about this relation between music and drawing and specifically about his strong visual experiences during the representation of operas, Kandinsky writes:

> “I felt that I had all my colours in front of me. Disorderly and almost absurd lines were forming in front of me” (Düchting, 2013, p. 10).

Thanks to his synaesthetic ability, Kandinsky perceived the power of music and painting at the same time. For him, the relationship between colours and sounds was not only supposed but actually existed, and it captivated him to such an extent that it became one of his artistic pillars (Düchting, 2013, p. 10). Within my own experience as an artist, I can see the musical atmosphere in which my artworks were created: it is the same music but with a different structure, accordingly either to the aesthetic results of the flat perspective or to the VR navigation. This experimentation started back in 2017, when I attended a live concert by the Campos Band at the Godot Art Bistrot of Avellino, Italy. I had been invited to live draw during the concert, in a mixed experience of graphic and sound expressions. For me, the experience was new, the music was new and so I decided to explore what it was the newest technique I had learnt: spherical perspectives. During the concert by Campos Band I drafted a scene, defined some lines within the spherical map, and put some watercolours which I felt captured the essence of the music. The result was an appealing trip within the moment: a platform containing the observer, a roof limiting the upper vision and an infinite horizon with thousand stories going on (Figure 137).

After Campos, I attended a second concert by Elizabete Balčus from which a second live-created spherical artwork was born (Figure 138). The piece Elizabete: Hat, Fruit or Flute shows more plasticity, fluidity and colours, while the inner shapes connect many points around the visual sphere that one can follow within the virtual environment. I realised that by all means this was how I perceived Balčus' music: her compositions have certain elements and passages connected within different songs, like different acts of a same symphony; colours, shapes, fruits, tastes mix and get melted in a free-of-drugs psychedelic experience.

A further experience was with Raoul Vignal, from which Waking Up 360 Times was born (Figure 139). This piece is black and white, uses shapes with a more defined outline, and guides the visual experience towards certain specific points of view. In the same direction, Raoul Vignal's music has softer variations than, for example, Elizabete's ups and downs, as if all the songs were based on the same harmony, something that I perceive as a black and white composition. Raoul's music has subtle and delicate structures, that forward the listener to certain horizons, as the perfect soundtrack for a road trip.

The fourth artwork of this experience in Italy was *Lo Schifo Moop* (Figure 140), born while listening to Mary Ocher. In this case, the colours and expression are childish, full of *capricci* and tantrums, just like the kicks Mary gave to her tambourine or the unexpected endings of her songs that left more than one person of the audience with a sense of disruption. Yet, the presence of her music is there, and one can jump from one structure to another, getting lost in the forest of Mary's stories.

Figure 137: Camposgodot. Handmade Immersive Art in equirectangular perspective made with ink and watercolours on paper. Scan the QR to see the VR environment © Lufo Art, 2017

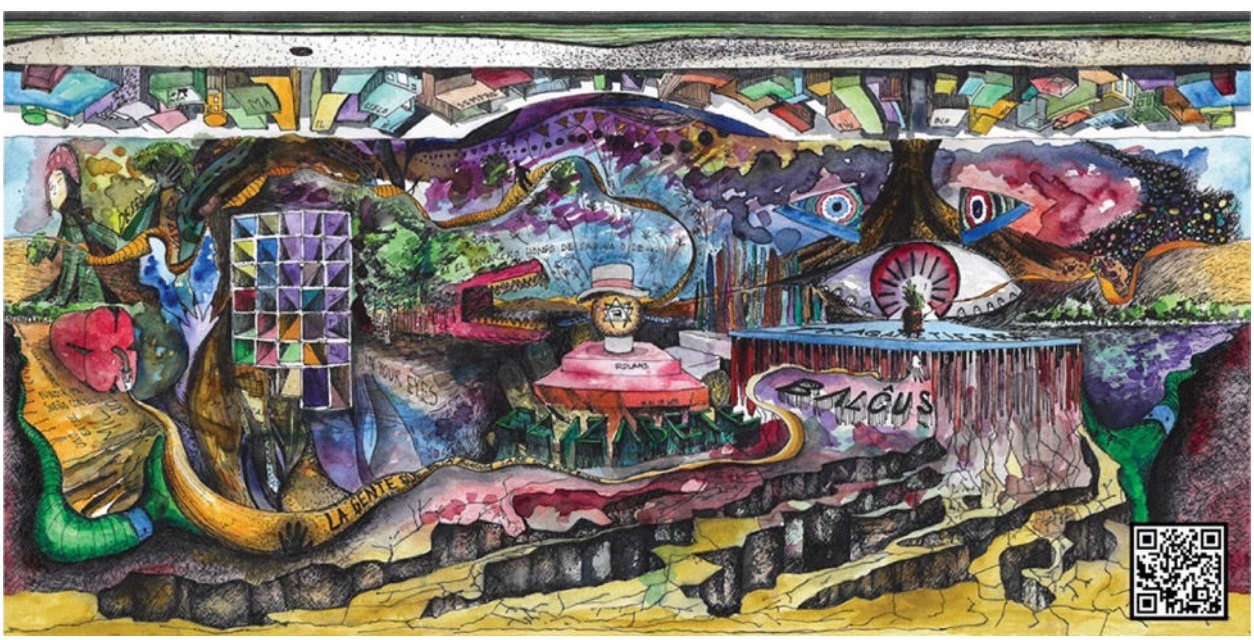


Figure 138: Elizabete, Hat, Fruit or Flute. Handmade Immersive Art in equirectangular perspective made with ink and watercolours on paper. Scan the QR to see the VR environment © Lufo Art (Lucas Fabian Olivero), 2017.

Figure 139: Waking Up 360 Times. Handmade Immersive Art in equirectangular perspective, ink and watercolours on paper. Scan the QR to see the VR environment © Lufo Art, 2017.

Figure 140: Lo Schifo Moop. Handmade Immersive Art in equirectangular perspective made with ink and watercolours on paper. Scan the QR to see the VR environment © Lufo Art, 2018.

With this experience, and thanks to the use of Handmade Immersive Art, I discovered how the music was shaping, defining, and modelling the scenes: I can clearly see the *here and now* of my vision as an artist, the historical moment of Walter Benjamin (Benjamin, 2008), my own historical moment, the *aura* of the artwork, stamped on those artworks even if I was not aware of those element's existence during the drawing session. Nowadays, I can hear again the music of Elizabete Balčus, Campos Band, Mary Ocher and Raoul Vignal while I navigate the VR environment. However, can the visitor see what I see? If the visitor would be asked to describe the music that they hear while watching to those VR drawings, what would you they say that the music is like? From here, the concept Musicality of Drawing, or [IN]Musicality, investigates the reflective actions of:

- How does the artist express music using graphical signs and immersive perspectives?
- How do visitors read the musicality of a hybrid immersive perspective?
- How do we see music?
- What music is created in the mind of a viewer?
- What is the degree of accuracy for transmitting from the artist to the viewer, a certain sensation caused by music using a hybrid immersive model?

[IN]Musicality was then posed as an installation to reflect on those questions, focusing on the visitor's experience while interacting with a dedicated set of Handmade Immersive Artworks (no longer a random selection as in the first version) and focusing on how visitors relate those HIM-HIAs with musical tracks.

III.3.2 - Addressing issues 3 and 4: front-end interface and dependence on the artist's presence

The definition of a front-end had its own requirements based on the expected functionalities, but it also contemplated the just added concept and narrative. Hence it was determined the interface should:

- Give access to drawings (both existing and created on-the-fly) and to songs.
- Allow the interaction with a gallery of VR drawings while listening to the music.
- Allow the pairing of a certain drawing with a certain song.
- Collect data in the background for an anonymous survey of the interaction and options taken by the visitors.

After these definitions, the interface was created within TouchDesigner and Python for some functions (Figure 141). This gave a first autonomous interactive experience between the visitor and the installation, in which visitors matched one drawing with one song according to what they considered to be the best match. This quiz (without right or wrong answers) defined a pre-set path to interact with the installation, solving the problem previously pointed out during the visitors' interviews: what was the installation for, what should I do with it? This was also reinforced with a Help screen, which will explain the path of interaction in a simple and iconic way.

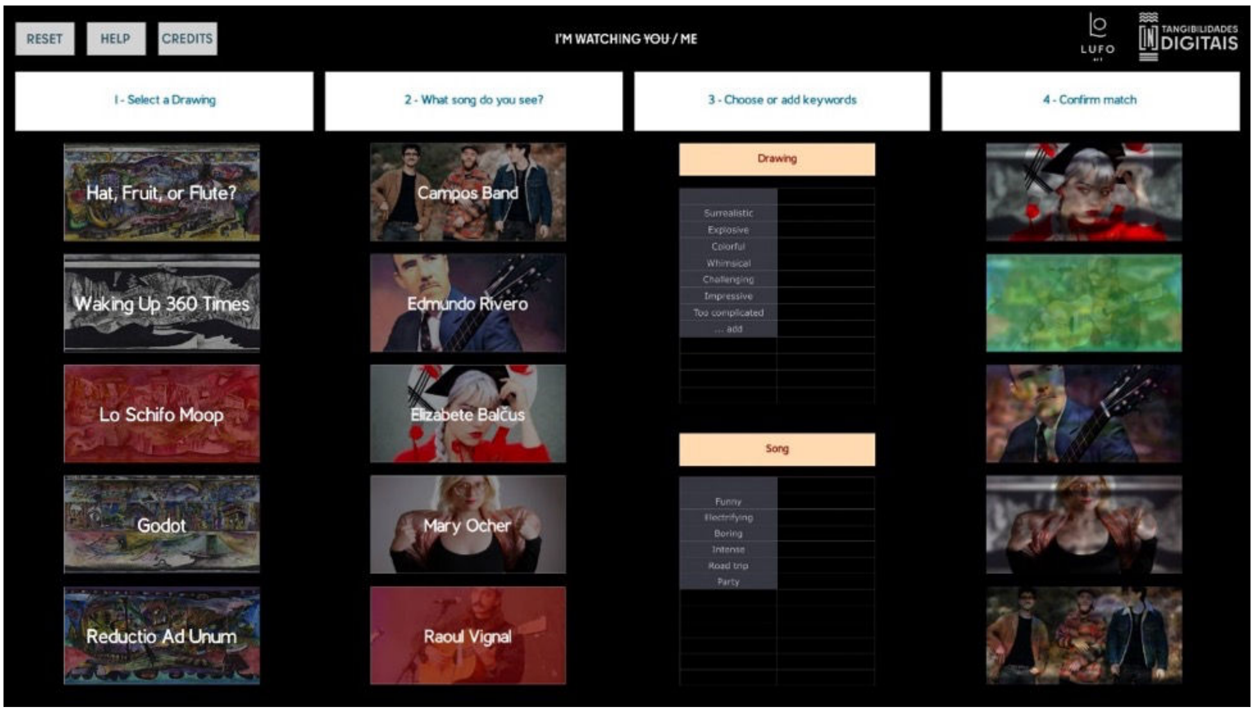


Figure 141: Main screen of the interface.

As for reading the interaction of the public, the data was collected anonymously using local databases and saving which drawing was associated with which song, how many interactions were made, and what was the users' best match. The data was then thought to be used for structuring a study of the sociological reading of the experience and the understanding of the concept.

III.3.3 - Addressing issue 4: dependence on the artist's presence

Printed material, a digital logbook and YouTube videos were generated as a way of complementing the front-end interface development, so to remove the necessity of having the artist to explain what the installation was for. This material explained the functioning, concept and narrative of the installation, it was written both in English and in Portuguese and it was physically and digitally distributed at the venue. Among the material, there were **flyers and posters** with the narrative of the shared exhibition and the concept of each individual installation including DIN A4 individual sheets, DIN A2 posters and A1 fold-out room sheets; **online promotional material** through a dedicated entry within the Research Centre's website (dmad.ciac.pt); and **three videos**: one about the functioning of the software and the installation (Olivero, 2022f), the second about the concept and the narrative (Olivero, 2022d) and the third one (made after the exhibition) for the shared curatorship and the future version of the installation (Olivero, 2022e).

III.3.4 - Addressing issues 12 and 13: inconveniences on the spatial setup (ideal solution)

Figure 142 presents an ideal scheme for solving the spatial setup, such as the artist blocking the camera's view (Issue 12), having the output projection, and the input drawing parallel so that the artist could not see the VR feedback easily (Issue 13).

III.3.5 - Components, interaction and functionality

The components for the installation remain the same than the previous edition, yet there are some changes in their definition and in their scheme (Figure 142):

- IN-1: a physical drawing (a paper on a transparent structure, with a rear camera).
- IN-2: a digital drawing (made either with a drawing pad or a table, or with a drawing software, such as Eq A Sketch 360.
- IN-3: a gallery of pre-existing drawings in equirectangular format (in this case, five drawings from the same collection).
- IN-4: a mobile phone with orientation sensors.
- IN-5: a high-resolution camera.
- OU-1: a projector screen.
- OU-2: an external monitor.
- OU-3: the computer's screen.

Regarding the functioning, there were substantial differences with the previous version. The incorporation of the interface allowed a better exposition of the concept but also a better self-explanatory general experience. For this second version, the emphasis was to clarify how to operate and interact with the software: at the beginning, a very simple welcome screen appeared in the three outputs monitors (Figure 143). Upon the user's click (OU-3), the installation switched to the Home Screen, where visitors could access a Help Screen explaining the installation with short videos; the Credits Screen with a brief explanation of the concept and a mini biography of the artist; and a button to switch between the two modalities of the installation: drawing and visualisation.

The **interaction and visualisation modality** was intended to visitors. In this modality, the OU-1 showed the VR navigation with a camera previously setup with a FOV of 60° (Figures 144, 145), OU-2 remained on the welcome screen (it was reserved to only show content within the drawing modality) and OU-3 showed to visitors the Main Screen with five songs and five drawings. The visitor would have to choose one song and one drawing and interact with them through the mobile phone (Figure 144). Same as previously, the movement of the device sent data through compass and gravity sensors, updating the VR camera with every new orientation of the phone, and discovering a new part of the drawing (Figure 145). Each song represented the musicians or bands to which the drawings were drawn to. Visitors interacted with the installation by selecting different pairs of drawings and songs and associating representative keywords to each of them. There were some pre-set keywords available (e.g., Surrealistic, Explosive, Colourful, Whimsical, Challenging, Impressive, Funny, Electrifying, Boring, Intense, Road trip, Pop, Party, Oldies), although it was also possible to add new keywords that stayed in screen for the next visitor. Once visitors were comfortable with a match between a certain drawing and a certain song, they had to confirm the correspondence. The software then saved the pair and the keywords in an external file and turned the selected drawing and song as inactive. The user could then start a new cycle with another drawing and music. Finally, the program showed the closing screen after the user confirmed all five pairs and executed a restart function for the next visitor (Figure 143, bottom, right).

The **drawing modality** was intended to be mainly used by artists. In this case, artist could access the function through the drawing/visualisation switch at the Home Screen and pass from the pre-loaded drawings/music experience to the live drawing modality. In this modality, the external monitor OU-2 showed the canvas of Eq A Sketch 360, while OU-1 showed the VR navigation of the content created by the artist. The artist could choose in any moment one medium between IN-1, 2 or 3 based on a personal preference. If the artist had chosen the drawing board, the camera IN-5 captured the drawing on-the-fly (Figure 146). Furthermore, through the Main Screen it was possible to select up to two parallel inputs, meaning that the drawing could have been composed interactively and collaboratively along with another artist or visitor. If such was the case, the software would convert and mix the inputs by graphically adding both pixels and stream the result back on OU-1. The artist had visual feedback in VR modality on the projector screen and in equirectangular mode through the external monitor OU-2 when using Eq A Sketch 360.

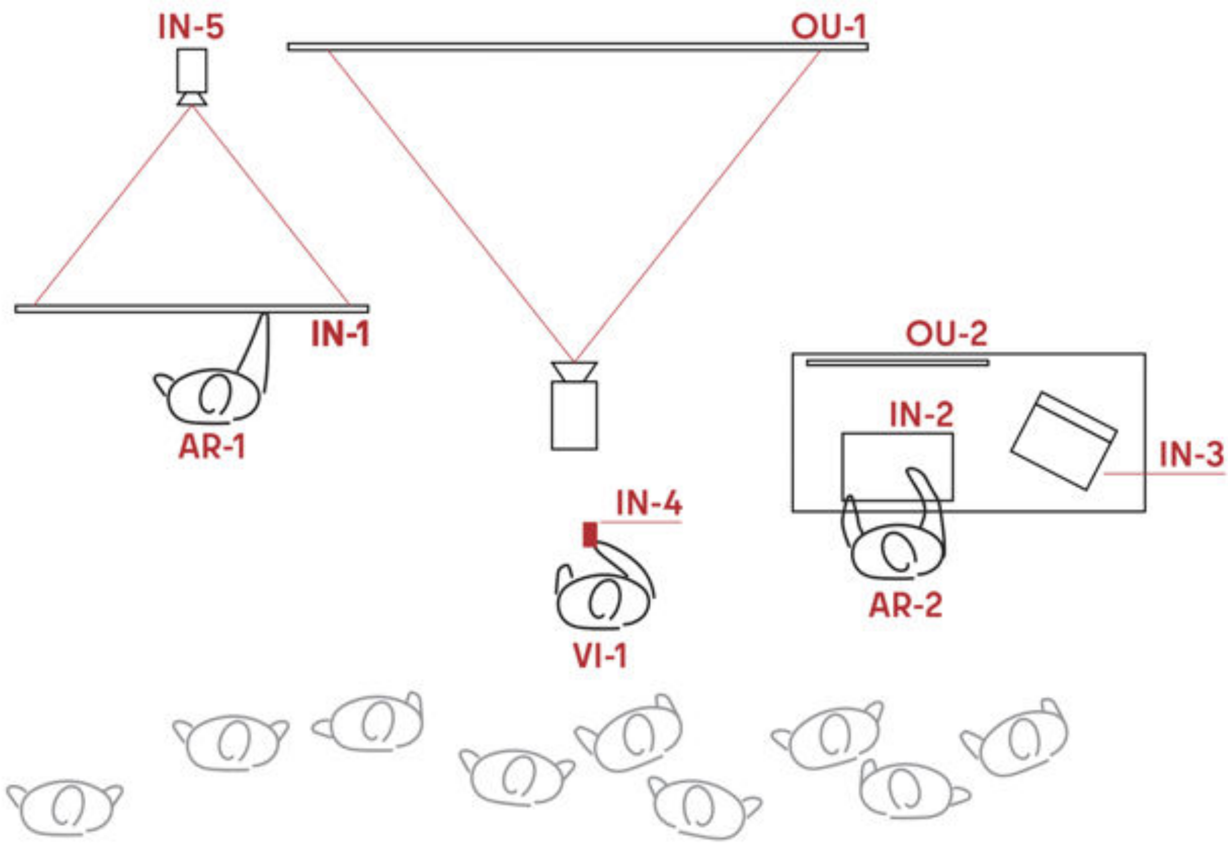


Figure 142: Ideal scheme for an optimised running of the installation.

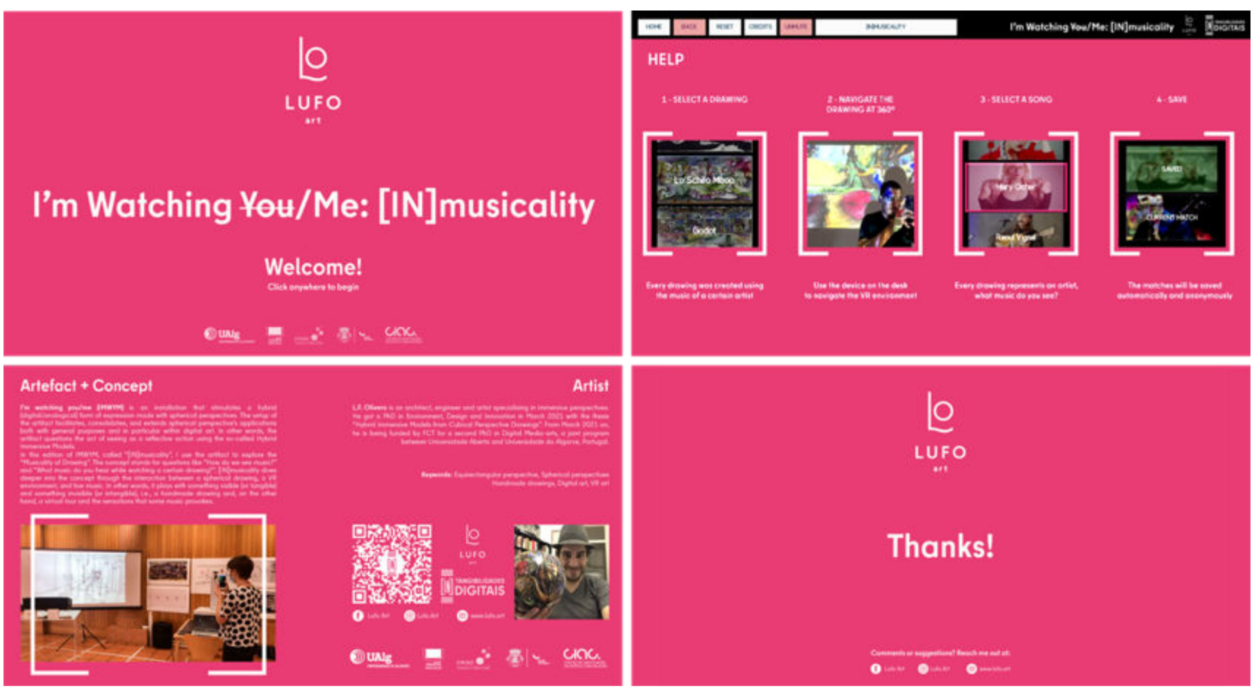


Figure 143: Splash, Help, Credits, and Thanks Screens.

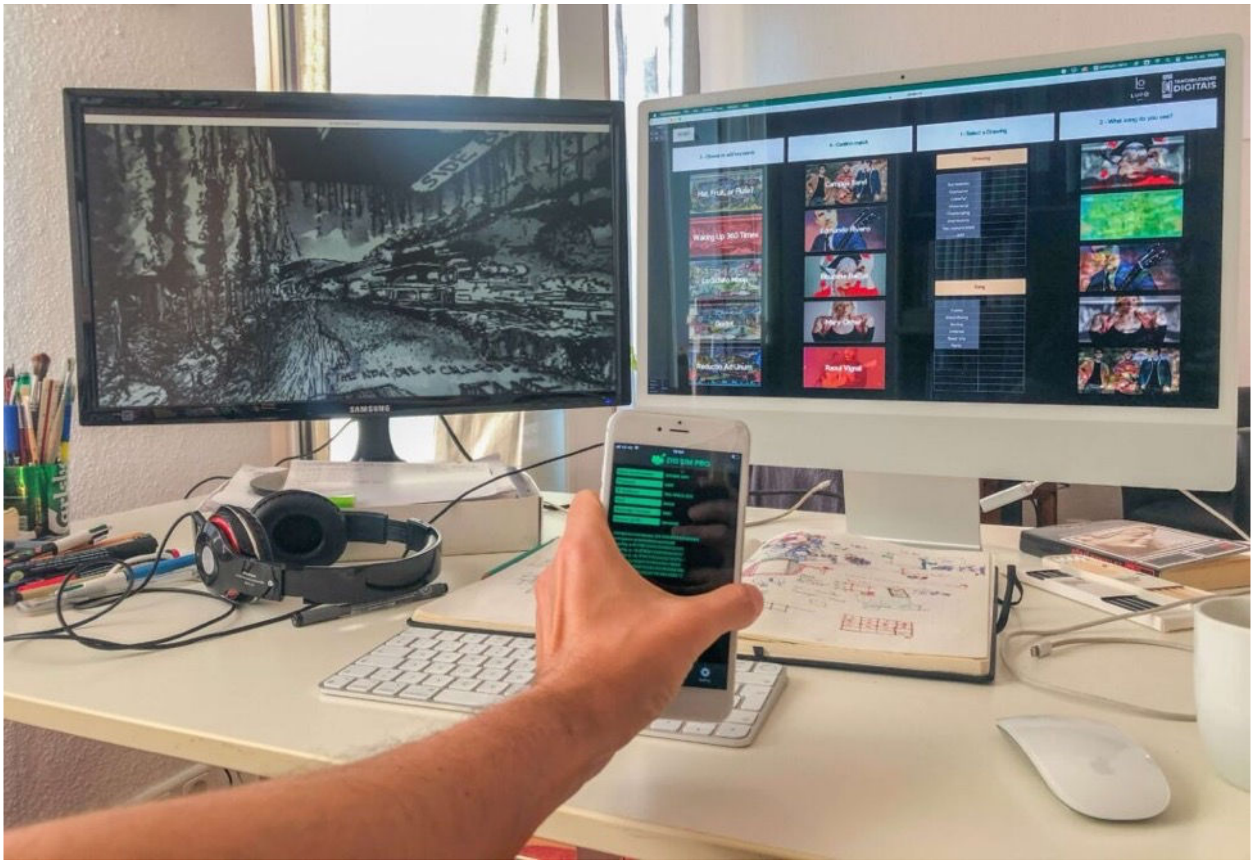


Figure 144: VR Navigation Screen (left) and Main Screen (right).

Figure 145: Navigation screen during the exhibition.

Figure 146: Final setup during the exhibition at Loulé. Interactive modality (up, right) and drawing modality (bottom and up, left).

III.4 - Exhibition II: [IN]Tangibilidades Digitais (Loulé, Portugal)

The shared exhibition *intangibilidades digitais* was held between 12 and 15 July 2022 at the Espírito Santo Convent of Loulé, Portugal, as part of the 9^{th} Doctoral Retreat on Digital Media Art 2022 (Olivero, 2022a). Within this exhibition, a total of 9 artists from different countries presented their artistic installations, their PhD thesis proposal, and the works made during the academical year 2021/22. All artists developed together the many aspects behind the curatorship of a digital art exhibition considering the point of view of the artist, the curator, and the public. We analysed carefully the advantages and disadvantages for each problem and elaborated a detailed list with the required activities. After a general discussion and considering the parallel developments for each individual media art project, the group defined:

- **A graphical identity**, including a logo, individual and group room sheets, promotional posters, maps, etc.
- **A cohesive narrative**, as a path for visiting every installation as an harmonic ensemble. The narrative invited participants to come across matters inherent to working with digital art through the exploration of the tangible/intangible binomial.
- Individually, each artist developed an **artistic concept** for their installation, yet joining the general narrative as a way of unification.
- **A calendar of activities.**
- **Individual and collective websites**, for spreading the information about the exhibition and every individual creative processes.

III.4.1 - Addressing issue 2: missing narrative

One critical issue for an artistic integrating of the installation was the definition of a cohesive narrative, which mostly lacked in the first version. This way, the second version was presented during the exhibition *[IN]Tangibilidades Digitais* (Figure 147). The story of *[IN]Tangibilidades Digitais* invited participants to come across matters inherent to working with digital art through the exploration of opposite binomial pairs: tangible/intangible, near/remote, palpable/impalpable, material/imaginary, in/out, etc. In other words, the digital intangibilities played with the materialism of Berkerley: "things only exist as soon as they are perceived" (*Esse rerum est percipi*) (Borges, 2017, p. 252); and it proposed to perceive what is commonly not perceived and hence does not exist.

Figure 147: Concept, narrative and artists' collective of *[IN]Tangibilidades Digitais*.

III.4.2 - Addressing issues 12 and 13: inconveniences on the spatial setup (real possibilities at the venue)

Regarding the ideal solution to the inconveniences of the setup given in the previous chapter, there were some changes matching the real possibilities and venue of *[IN]Tangibilidades Digitais*. The scheme could not be entirely followed due to logistical reasons and consequently some components had to be left out of scope. (Figure 148) presents sketches of schemes specifically focused on the venue's place: the Convent of Santo Espíritu in Loulé, Portugal. These sketches researched for the better distribution considering the issues 12 and 13, the ideal scheme (Part IV, Chapter III.3.5), the integration with other exhibitions, and the assigned spot within the Convent.

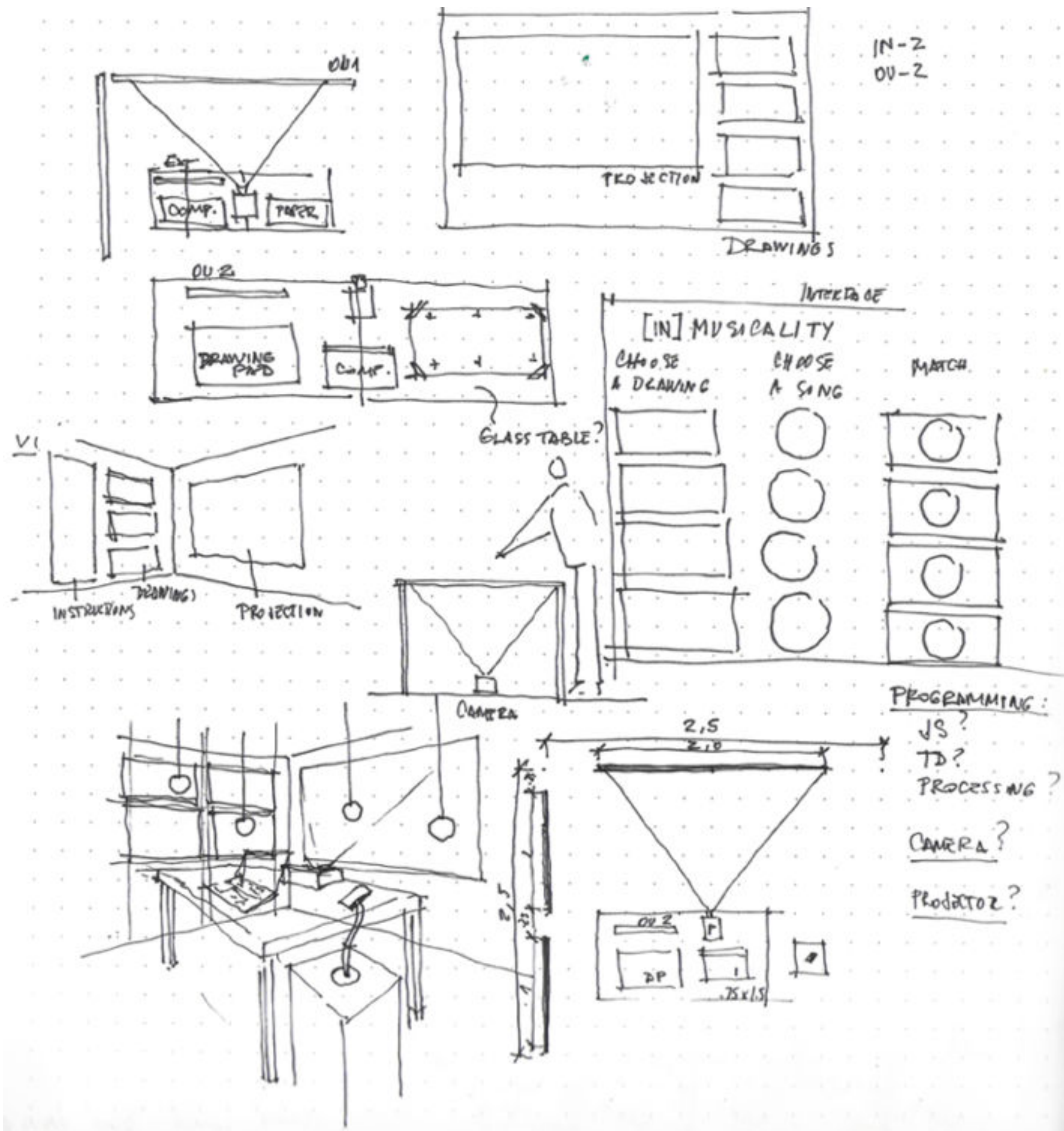


Figure 148: Studies for the best setup considering the given space at the convent.

In turn, Figure 146 shows the real distribution, with two main differences regarding the ideal scheme: first, the drawing board was attached to the wall instead of using a transparent support and a retro camera, and second, there was only one output screen (OU-1) and two inputs (IN-1, and IN-3). IN-2 and OU-2 had to be left untested. Furthermore, During the mounting of [IN]Musicality there were some issues related to: hanging the drawing board to the wall (the material would not adhere); the compatibility of the camera used as input for the live drawing modality (which turned to be incompatible as it was dated as in the previous exhibition. This forced a last-minute research of a new device); the physical distribution of the components and availability of electrical plugs; problems of keeping some devices functioning without air conditioning (they turned off due to overheat).

III.4.3 - Development and feedback

The opening of the exhibition took place on the 12^{nd} of July 2022. That day, every artist introduced their projects while visitors walked with them and interacted with the different installations. The basic functioning of [IN]Musicality was briefly introduced to the public, but it was also left some space for them to discover the ways of interaction by themselves. During the exhibition, visitors gave their feedback about the functioning of the installation and the software. The following paragraphs (summarised in Table 3) address the core issues elaborated from the participants' responses and a general evaluation of the installation:

- **Difficulties in understanding the concept and the paths of interaction:** the concept expected an intricate workflow of interaction, using both the mobile phone and the computer. On the one hand, the user had to use the mobile phone for orienting the camera of the drawing's VR view. On the other hand, they also had to use the computer to choose a drawing, a song, keywords, and a match. It was simply, too much. The overly complex UI/UX and several details of the installation (including criticalities and further expected developments) were discussed and settled after the presentation in Loulé (Olivero & Araújo, 2022).
- **Concern about the use of the mobile phone and the computer**: the devices were not inviting to the interaction for mainly two reasons: these were (almost) post-pandemic times and so people were still wearing masks and very concerned about what they were touching; and visitors would rather expect something to happen automatically, without them needing to touch anything at all, as it happens in a video installation. In fact, visitors will touch the devices very delicately and only when they were told to do so, as if they were afraid of breaking something or touching the devices would be something not allowed. This fear remained even after they were introduced to the installation and the concept and, although the

mobile phone was blocked to the touch, the screen had numbers showing the OSC data and changing rapidly, making it look a more sophisticated and delicate device that it really was. These were great setbacks not considered during the prototyping stage that made very clear that the interaction was not intuitive for most visitors.

- **Not enough data:** some visitors understood easily the concept and the functioning of the installation, matching all pairs and completing the path of interaction. This data, gathered anonymously and automatically, might have been useful to understand better how visitors related music and immersive drawings. However, the actual data was insufficient to obtain reliable results: very few visitors came to the exhibition and even less completed the expected interaction. Therefore, the data was not considered as any possible conclusion would have been mostly biased. Maybe with further editions enlarging the samples I could get more representative results.

III.4.4 - Evaluation of IMWYM v2

The evaluation of IMWYM v2 (Table 3) considers:

- **Visitors' feedback.**
- **The operating the installation**, including the two modalities (interactive/visualisation and drawing) which were both tested: António Bandeira Araújo used the live drawing modality with teaching purposes during the workshop *Ambientes Immersivos* (Araújo, 2022) (Part IV, Chapter IV), while visitors used the interactive modality with [IN]Musicality.
- **The evaluation of the front-end interface**, including data gathering, help, credits, reset functions, and the switch between live drawing and visualisation/interactive content modalities.
- **The feedback by external evaluators:** the last day of the exhibition I discussed the research proposal, goals, the plan of work, the research questions, the methodology, the state of the art and the research activities. The members of the jury visited and interacted with the installation, completing the theoretical feedback with practical suggestions from their field of specialisation. One of the criticisms was the use of the phone, which confirm what visitors already said: the devices were not inviting visitors to interact. The suggestion was to use body tracking, so to not have any intermediate device which was implemented within the third version of the installation.

Table 3: Evaluation of IMWYM v2

Issue	Criticality and draft solution
NARRATIVE - DEVELOPMENT	
14 - The concept and its path of interaction was not always clear. Some visitors expressed their struggle to grasp the core idea of [IN]Musicality without the artist's explanation.	**Medium priority.** The theoretical concepts of spherical perspective are already quite complex to be understood by a general public, hence having also an artistic concept too complex could lead to confusion, reducing the engagement and feedback. The concept and the narrative should be simpler, so to not compete and undermine the whole experience. **Solution:** this might or might not be an issue, but there were not enough people to evaluate with certainty. If it can determine (with enough participants) that the complexity of the concept is an obstacle, then another concept would have to be developed. It is also possible that the operation of the interface (more than the concept) is complicating the whole experience, hence an UI/UX expert evaluation would be very helpful to determine the degree of complexity of the whole experience.
15 - The general narrative might have added more complexity. There were so many things happening at the same time and the location of the installation was almost by the end of the visitors' trail, for which visitors might have arrived already exhausted to [IN]Musicality.	**Low priority.** A standalone narrative might help, but if the interaction is not self-explanatory, it might not have a great impact. **Solution:** test the result of the interaction with other narratives, if possible, both shared with other artists and alone.
INTERACTION - EVOLUTION	
16 - Too complex UI interaction. Users found the dual-device (phone + computer) workflow as a non-inviting configuration. **17 - Physical shared devices discouraged engagement.** Post-pandemic hygiene concerns made visitors wary of touching the shared phone or keyboard.	**Maximum priority.** Without a simple and clean way of interaction, the installation might never be taken as an interactive, viable and open option but rather as a virtuoso niche application. This might lead to visitors to take the installation as a something to contemplate rather than something interactive. **Solution:** search for simpler and cleaner options of interaction, such as contactless body-tracking and air gestures (as natural as possible) for visitors to operate the installation.
18 - Insufficient or biased interaction data. Very few visitors completed the full interaction sequence, yielding unreliable data.	**Medium priority.** On the one hand, inadequate sample size invalidates any statistical or qualitative claims on user behaviour. On the other hand, those statistics are meant to investigate about this particular concept. Hence

	an update of the concept might also affect the way and aim for collecting the data. **Solution:** if the installation is to be repeated with the same concept, then additional editions of the same exhibition might help to grow samples. It might also be helpful to integrate data-logging from partial interactions.
EXPERIENCE - FRUITION	
19 - Too complex UX workflow. Users feared of breaking something, even when were assured that manipulating the two devices would not interrupt the experience (it was actually needed).	**High priority.** Without interaction, there is no engagement and hence the correspondence between the flat drawing and the VR environment is not explored. **Solution:** simplify the user experience. Bring the operation of the installation to the minimum complexity possible, so users can concentrate into the spherical perspectives rather than in how to operate the installation. It would be very helpful to study which gestures can be taken as more natural by most people, and to implement them with body-tracking navigation.
20 - Expected behaviour misunderstanding. Visitors expected the installation to do something automatically, rather than them triggering the interaction by operating the computer.	**High priority.** If visitors do not perceive something happening right after they step in front of the installation, they might lose interest rapidly, leaving the installation behind as something broken or simply not working. **Solution.** Use body or object tracking so to detect when users are within the installation's radio of influence, and trigger something immediately

Despite the complications, [IN]Musicality accomplished several goals as the corollary of a full academic year of work. In fact, with the newly introduced features the installation got more related and focused as an artistic application; several critical issues from the previous edition were solved; and it was possible to monitor much closer the user interaction and experience.

III.5 - Installation III: IMWYM v3

The 3^{rd} version of the software/installation was born after the implementation of some solutions from the previous table. In particular, the far-too-complex user experience was particularly enlightening as it opened the idea of using a contactless alternative, leaving the phone behind and substituting it with body tracking. In fact, in this new version, motion capture functions operate the VR camera, select the drawings and the songs. The body tracking data is provided by the machine learning library MediaPipe (Google, 2022) which algorithm uses any regular computer webcam to gather image data, then it performs an analysis detecting objects and body landmarks and returns position data for each predetermined landmark within several groups, such as Face, Mesh Face, Pose, Hand, Object, etc. (Figure 149). Creating functions using body landmarks opened a whole world of possibilities and new ways of interacting using gestures.

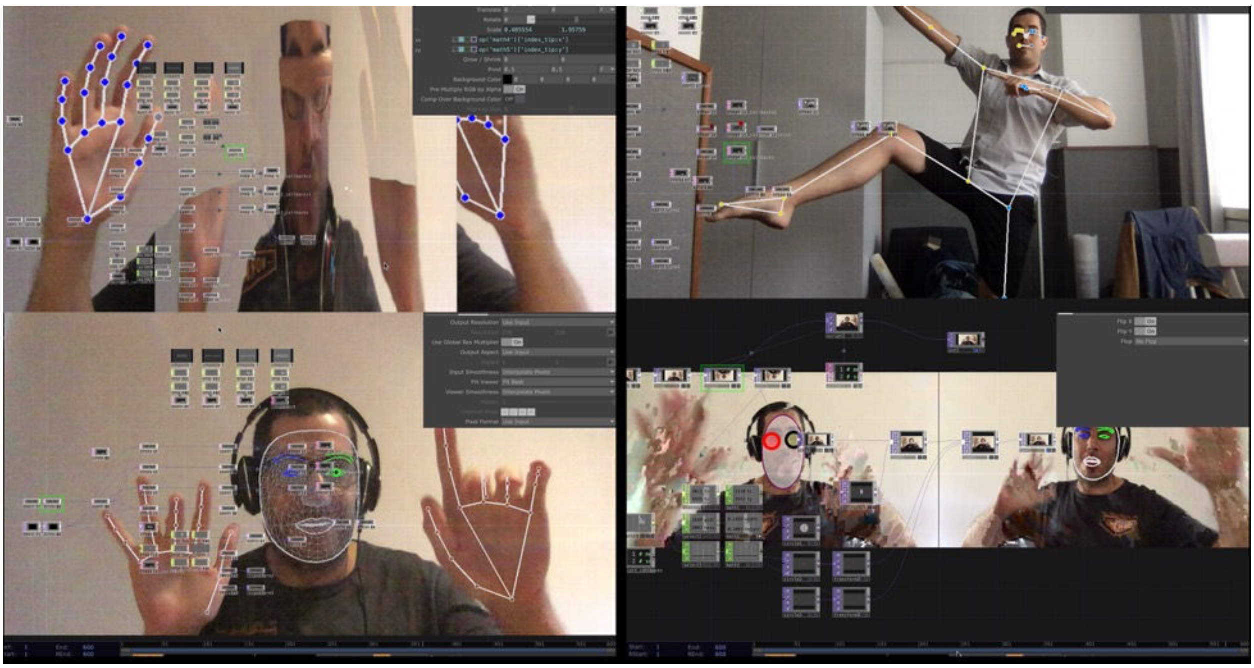


Figure 149: Tests using MediaPipe within TouchDesigner.

III.5.1 - Addressing issue 20: automatic start

After the integration of MediaPipe within TouchDesigner, a very simple function was defined: when a person is detected (i.e., if any landmark returns non-void values) the program switches from the Welcome Screen to the Main Screen. This way, the experience starts autonomously as soon as a visitor is detected in the camera's field of view.

III.5.2 - Addressing issues 5 (fixed FOV), 7 (navigation glitch), 8 (phone constantly on), 16 (complex UI), and 17 (low engagement due to shared physical devices)

The introduction of body-tracking gestures solved several issues at once. Indeed, as the phone was dropped from the interaction, issue 8 (screen of the phone always on) was immediately solved. For this new version, the right-hand wrist landmark defines the orientation of the VR camera: the centre of the screen is taken as the origin of a Cartesian plane with x-y axes. A hand shift in the screen's x-axis rotates the virtual camera around its z-axis. A hand shift in the screen's y-axis rotates the virtual camera around its x-y plane. The definition of this alternative orientation system solved immediately the navigation glitch given by the OSC data sent by the phone (issue 7), as now the orientation of the camera is unequivocally determined. Furthermore, the use of the computer was also dropped, finishing to solve the problem with shared physical devices (issue 17). In this new version, the left-hand wrist's landmark controls the navigation of the mouse, while a small distance between the tips of the index and thumb fingers of the left-hand triggers a click. These two functions use the Button and Controller functions from the pynput.mouse library. Furthermore, the field of view is not fixed anymore as in the previous versions, but proportional to the distance between the tips of the index and thumb fingers of the right hand. Hence the user can update dynamically the FOV factor by either pitching (zoom in) or opening their hand (zoom out). This also works with the user approaching or walking far from the camera, as the computer will read a closing/opening either way. The new body gestures also had the goal of simplifying and making more natural the operation of the installation (issue 16), so visitors would be able to interact without the fear of breaking something. Thanks to the body tracking functions the interaction with the computer and the mobile phone were entirely dropped, notably simplifying the visitors' experience.

III.5.3 - Addressing issues 14 (concept), 18 (insufficient data) and 19 (complex UX)

Given the hard times that users had for understanding the paths of interaction during the exhibition in Portugal (issue 19), the experience of [IN]Musicality was simplified. In fact, the selection of keywords was taking out, shortening the concept (issue 14) and narrowing it down to the most basic of it, meaning, selecting a drawing, a song, and confirming the pair. Furthermore, the buttons were rearranged in the screen (issue 16, complex UI), giving priority to the interaction with the virtual environment and the comparison with the flat drawing. In v2, all buttons were on the computer screen (OU-3), while the projection screen (OU-1) was exclusively used for showing the VR navigation. This setup divided the attention of visitors in four: the flat drawing (hanging on the walls); the VR result (projected screen); the interface (computer); and the navigation of the VR (mobile phone). With the aim that visitors only had to concentrate in two things (the VR and the flat drawing), the interaction was simplified for a better experience but also as a natural consequence of the new technology. Consequently, buttons and VR were arranged in one same screen, with the buttons on the left, matching the side of the hand used for selecting those elements (otherwise visitors would have found themselves crossing their hands to reach the buttons on the right). These simplifications aimed to improve the interface, the usability and users' experience while dealing with the concepts of spherical perspective in an interactive way (Figure 150).

III.5.4 - Addressing issue 9: cubical perspective input

Another important new feature of IMWYM v3 is the addition of the cubical map format. Until v2 it was only possible to use the equirectangular format as image input, both if the input was a live drawing or an existing artwork. Other formats such as the cubical map and the azimuthal-equidistant formats were just partially tested but not completely included in the workflow. This 3^{rd} version added the possibility of using a cubical map as an input in both live and storage access modalities. This extension brought new possibilities for testing the installation with teaching purposes (see Part IV, ChapterIV).

III.6 - Exhibition III: [IN]Musicality at the CLB Space (Berlin, Germany)

The first opportunity for live testing IMWYM v3 was using the drawing modality for teaching cubical perspective during a workshop conducted in Finland (see Part IV, Chapter IV). A further opportunity, this time for the modality of interaction and visualisation, came up with the exhibition Ubiquitous Music + [IN]Musicality, held between the 17^{th} and the 18^{th} of November, 2022 at the CLB Space of Berlin, Germany. The available room at CLB allowed several possible arrangements, for which we explored several options matching the requirements of all three presentations (Figure 151).

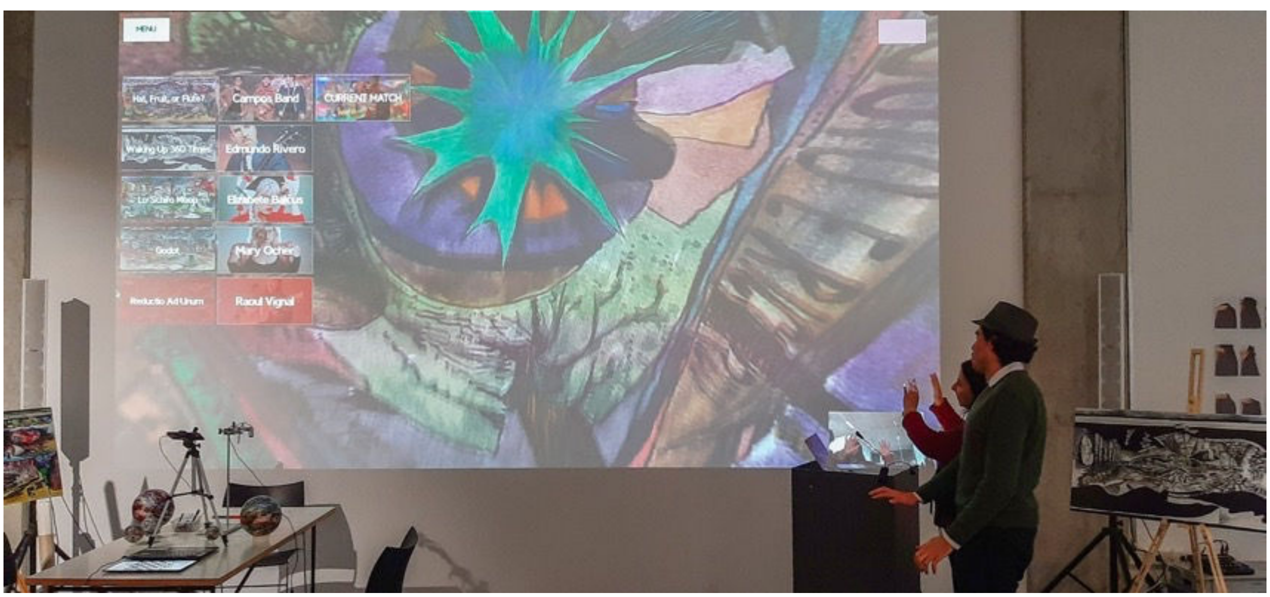


Figure 150: Reorganisation of the interface: buttons and VR are now concentrated in one screen (compare with Figure 141).

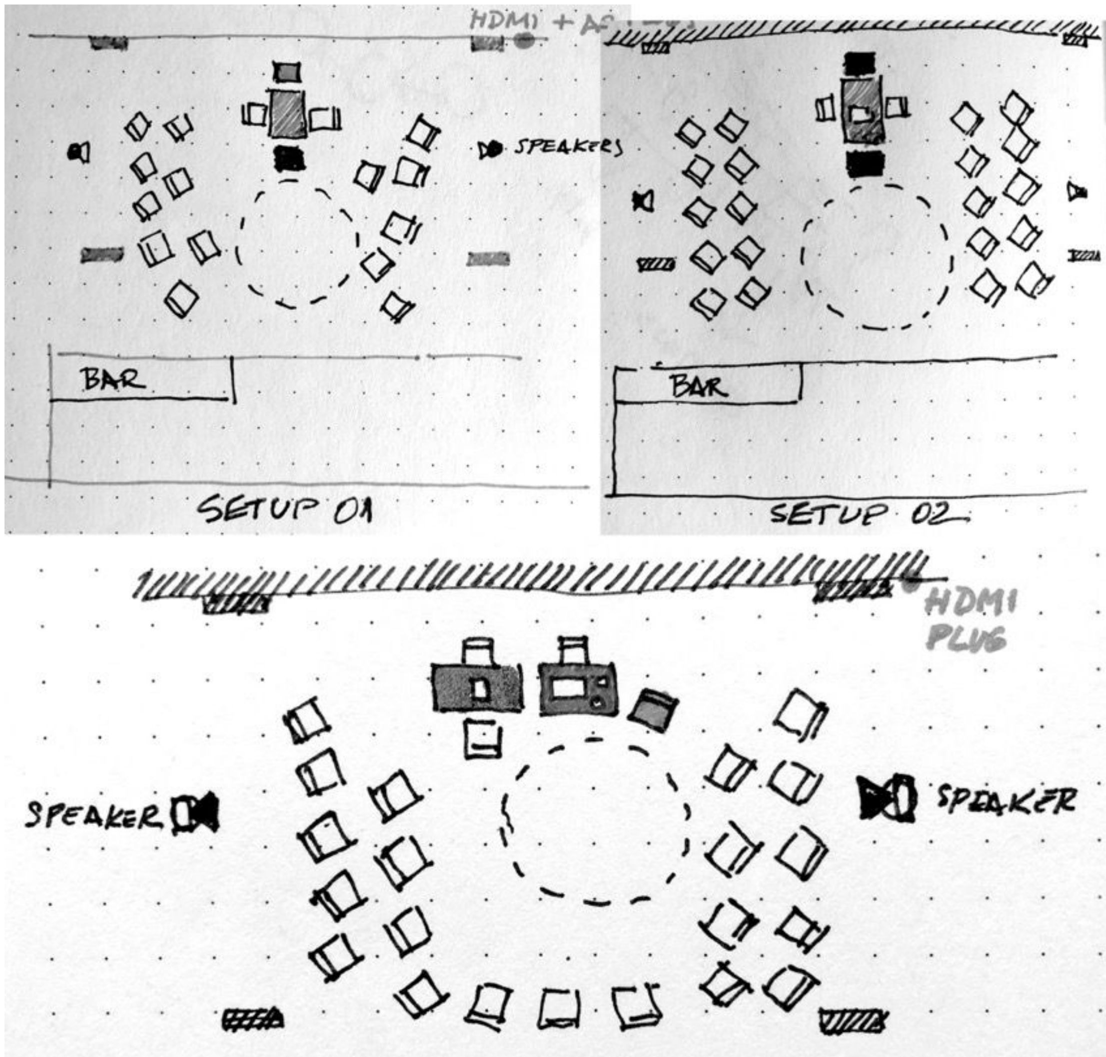


Figure 151: Study of the possible setups at CLB.

Flat spherical perspective paintings were arranged right next to the projection screen (Figure 152), with the intention of allowing a comparative feedback. Nevertheless, this did not happen, as the projection screen was very big (so visitors were more immersed and amazed with the VR interaction rather than focused on the comparison) and the painting remained partially in shadows due to the lighting conditions.

The exhibition in Berlin gave the opportunity for testing the installation within a narrower narrative (issue 15): only three artists exhibited, bringing visitors through a path for discovering emerging ways of creating, interacting and enjoying musical art. [IN]Musicality invited visitors to explore the graphical manifestations of music through an immersive an interactive installation using Handmade Immersive Art. The other two presentations included a lecture by Damián Keller, who spoke about some of the recent artistic innovative initiatives in the field of music-making; and a live performance presented by Guido Kramann where music was live generated directly from the data given by two chess players playing in-the-spot and driving a tango composition with their actions (Olivero, 2022c).

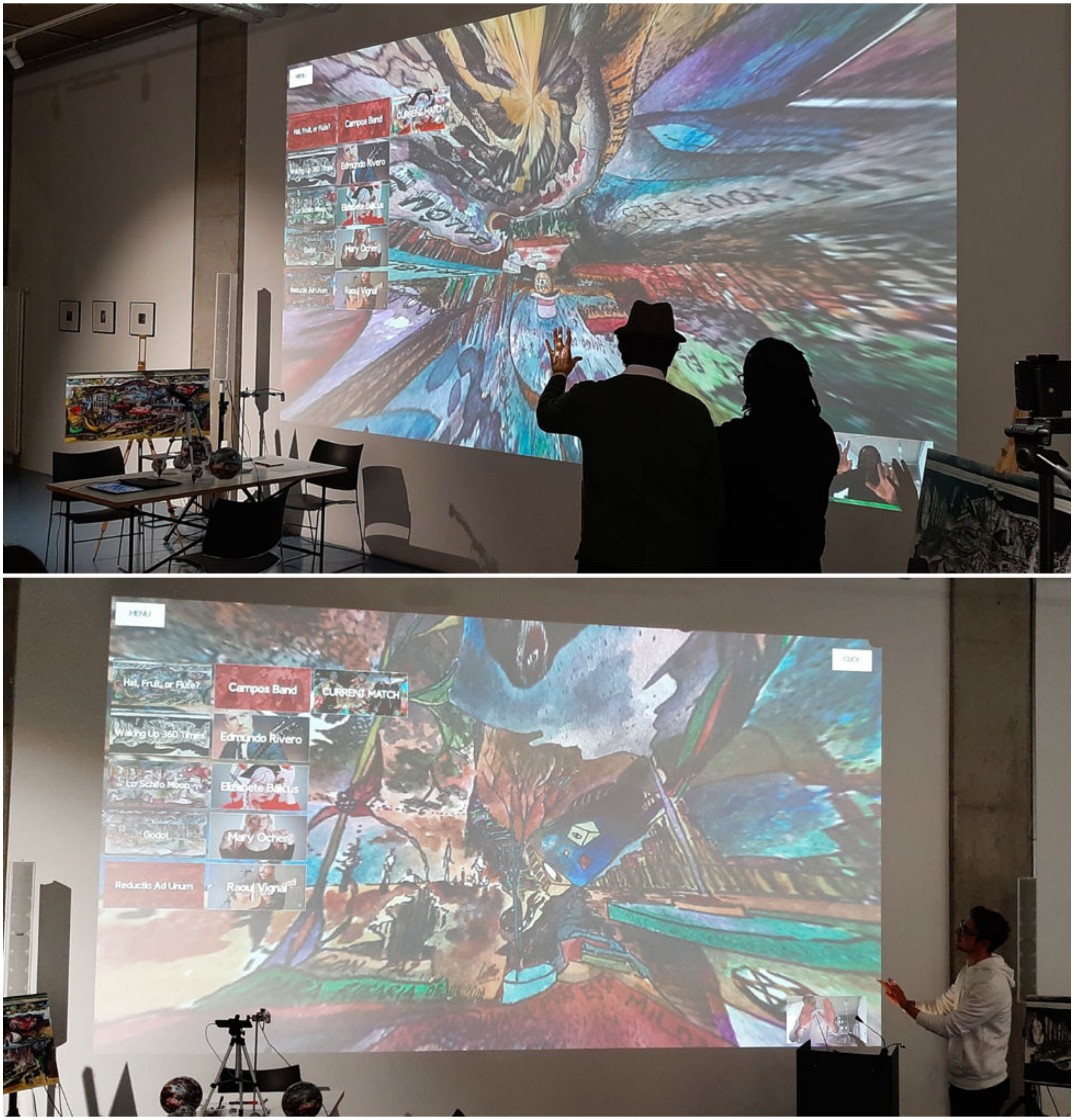


Figure 152: Users experimenting with body tracking and [IN]Musicality at CLB Space, Berlin.

This shorter narrative was a good omen for an expanded interaction and, furthermore, the night of the opening there were around 50 visitors. These two factors combined provided a larger amount of interaction data (issue 18), despite the fact that the installation remained for only two days (less than v2). However, there was a big problem with the data as it was biased due to time restrictions and complications during the interaction. On the side of the time, the total amount of time dedicated to [IN]Musicality was of 45 minutes in the program, but due to the extension of the previous lecture the interaction lasted only 20 minutes. This forced visitors to only have a very short time window to learn how to operate the installation and complete the expected path, a time that was certainly not enough. On the side of the interaction, there was a complication with the pointer, which proved difficult for some visitors to handle. One problem with the pointer was purely visual: due to time limitations, it was not possible to change the pointer's design to make it more evident on a large projection, so some users lost the pointer during the interaction. Another problem mentioned by the visitors was to click by *pinching in the air*, some of them even expressed that it would have been easier to click while touching something, as one does when using the mouse. These complications on the use of the pointer significantly skewed the gathered data, as many visitors clicked involuntarily on the drawings or the songs while learning to grasp the sensibility of the *air click*. By the time they got used to the controls, it was time to leave another visitor to interact. On a safe side, many visitors did not bother to try to change the artwork, the song or matching the pairs: they got engaged moving the VR camera and contemplating the drawing they found in the screen. In short, it was very positive that visitors got more focused in only one interaction in only one screen, instead of dividing their attention in four parallel commands, but the data gathered during their interaction reflected mostly testing actions rather than controlled experiences. Considering visitors' feedback, who gave very valuable insights about the user experience, difficulties and gifts of the concept, and the use of motion capture; IMWYM should return to a classical physical device (that is where it comes from!), yet the feedback did put one more argument pointing to the same direction: the concept and the interaction were too complex (issues 14 and 19), too many things were happening at the same time. Nonetheless, the new contactless option was definitively more inviting than the previous edition: most visitors expressed their amazement for being able to move both the pointer and the VR camera just by waving their hands in front of the camera without wearing anything at all, neither wireless controllers of any kind nor special gloves. Almost all visitors highlighted this as the most impressive aspect of the installation and the software, which raised the question if the used technology was so edge-cutting that gave no room for appreciating the Handmade Immersive Artworks.

III.7 - Exhibition IV: [IN]Musicality at ArtsIT (Faro, Portugal)

[IN]Musicality was also presented during an exhibition and drawing workshop held the 21^{st} and 22^{nd} of November 2022 at the Hotel Eva Senses, Faro, Portugal (Araújo et al., 2022; Olivero, 2022b, 2022g) (Figure 153). The presentation was within in the coffee break room for which there were moments of intense activity during the pauses of the congress in which the visitors interacted during short spans of time between a sip of coffee and a bit of cake. The general reception was very good, and the installation and the software were evaluated by a more specialised audience, mainly composed by researchers with artistic and technical background in fields of Computer Sciences, UX/UI and Digital Media Arts. Their feedback confirmed what most visitors expressed previously: the most innovative and impressive aspect of the installation was the wireless management of the pointer, the air click, and the VR navigation by sliding and pinching in the air; yet the concept and the paths of interaction were too complex for an installation in which one has to learn something new (the freehand gesture commands) and apply it within a short time of interaction. This discussion made evident what it was seen in the previous experiences: too many things were happening at the same time, distracting the visitors with many new insights, for which the appreciation of the Handmade Immersive Art was neither a priority nor a natural consequence of the interaction. Some of the visitors suggested the possibility of doing a short training session before jumping on the full experience, but some UI/UX experts pointed out that the focus should rather be on one aspect: either the air gestures using only one hand and applied to only one drawing; or several spherical perspectives but in a passive way, for example through a video. Some of these suggestions were implemented within the next and last exhibition covering this research. Some more interesting questions arose from these exchanges: why the command of the pointer is made with the left hand while we normally use the right hand for such a task? Would it not be more natural to rotate our hand instead of sliding left/right up/down? It was also discussed how to stabilise the navigation to fix small jumps and shakes made by the pointer and the VR camera (this solution is implemented within the next version of the software).

Figure 153: IT and UX/UI specialised audience testing IMWYM.

III.7.1 - Evaluation of IMWYM v3

Table 4 briefs the issues raised from the two exhibitions:

Table 4: Evaluation of IMWYM v3.

Issue	Criticality and draft solution
NARRATIVE - DEVELOPMENT	
14 - Concept and path of interaction not always clear. Despite the simplification, the concept remains too complex for a short interaction.	**Maximum priority.** The new technology strongly opaques the concept. Without a simpler concept the installation will never overcome the "high-tech advancement" flag given by the body tracking features. **Solution:** for the installation to accomplish the purpose of highlighting the concepts behind spherical perspectives, the path of interaction has to be either drastically narrowed down or changed to a simpler concept. Furthermore, if the installation is to be presented within a shared narrative, then the new
15 - General narrative might add more complexity. The interaction with other artists at CLB Space shortened the time for experiencing [IN]Musicality, while the moments of interaction were short by nature at ArtsIT, as the exhibition was in a coffee break room.	

	concept/experience has to be something possible to complete within a short span of interaction time, as the presence of other installations leave no much space and availability, even if they are only a few.
21 - The tech novelty overshadows the concept. Visitors were more engaged learning the hand gestures than with the conceptual framing of [IN]Musicality.	**Maximum priority.** If the technology opaques the story, the research concept loses impact. **Solution A (reduce the technological impact):** either reduce the use of body tracking to only one hand or simplify the current gestures. **Solution B (simplify concept):** eliminate the game of pairing songs and drawings and show only one drawing. **Solution C (deliver an express experience):** split the concept between what can be experimented in-situ and what can be learned with calm at home (to integrate with the solution for issue 25).
INTERACTION - EVOLUTION	
22 - Gesture learning curve. New users struggle to discover which gestures (pinch, shift, open hand) trigger which commands. This happens particularly with the orientation of the VR camera: the current gesture expects sliding the right hand on one same plane, parallel to the computer screen. However, visitors tend to rotate their hands as if they were grabbing a sphere with their hand.	**Low-medium priority.** The installation can be used as it is now, until more important matters are addressed. However, as the current gestures sometimes bring confusion, they should be addressed at a certain point. **Solution:** note that addressing issue 21 will affect this issue as well. To minimise the learning curve, it could be added in-screen animated prompts or short demos showing the corresponding gestures. Furthermore, these demos could be accompanied by the simplification of the installation's use, eliminating the gestures harder to grasp, such as the command of the pointer. This simplification could be done either by using only one hand with two gestures (one for orientating the VR camera, and one for zooming in and out) or by using the same gesture (the rotation of the hand as when we grab a physical sphere) in both hands. This last gesture could orient the VR camera when done with one hand and change the selected drawing when done with the other hand.
23 - Low pointer visibility. On large projections the pointer blended into the background, causing users to lose track.	**Low priority.** Losing the pointer might lead to a skewed interaction data as the user could click involuntarily.

	Solution: redesign the pointer with high-contrast outline and slight glow; implement a brief pulsating animation when idle. Note that this issue might get automatically solved if the air click experience is removed (solution of issue 21 and 22).
24 - Cubical map input not integrated within the interface. The integration of the cubical format gives more flexibility and possibilities for creating and exhibiting Handmade Immersive Art. However, the switch of projection has to be done manually in the backend so currently the possibility of switching among inputs is not fully integrated within the interface.	**Low priority.** Switching between input formats is a feature for those who are more familiar with the spherical perspective. The priority is first to get people within the basic concepts of spherical perspective, and later in the subtleties of the different possible formats. **Solution:** simply integrate the cubical format within the interface.
EXPERIENCE - FRUITION	
18 - Insufficient or biased interaction data. The complexity of the path of interaction and the hand gestures reduced the experience to a minimal action: a test of the air commands and the exploration of only one artwork. Most users did not complete the full expected path.	**Low priority.** The gathering of data should follow the rework of the concept and the reduction of the technological impact. **Solution:** either drop the current data gathering or adjust it accordingly to a simpler concept.
25 - Time constraints. The setup of the exhibitions held until now left little time to learn, explore, and complete the matching task.	**High priority.** Short sessions for complex concepts yield incomplete experiences and biased data. **Solution:** deliver an express experience by using the installation as the teaser of a deeper concept, something to be explored from another more reflective and less time-restricted sources. For example, it could be provided a printed storyboard leaflet that situates the spherical artwork within the broader view of the research and/or reinforced with a brief explanatory video that could auto-start before the user starts the interaction.
26 - Unstable navigation. Both the pointer and the VR camera do not stay in a permanent position when the user intends to do so.	**Low priority.** The impact of this issue is almost unnoticeable, as the range of confidence with which MediaPipe returns the values is very small. Hence is more an aesthetic rather than functional solution. **Solution:** Take average values to ease the final coordinate. This will result in a more stable position both for the pointer and the VR camera.

III.8 - Installation IV: Spheri

Spheri considers all the previous functionalities gathered from IMWYM, focusing on the real-time flat drawing/VR conversion and enabling artists, designers and illustrators to create and witness the transformation, complexity and innovation between a spherical perspective and the virtual reality environment created out of it. Spheri includes some important improvements that detach it from the previous software, namely: **it is the first independently coded and web-based version of the software** (solves issue 6); within the drawing modality, a novel **illustrator-centred system of navigation** follows the movement of who is actually drawing to orientate the VR camera; it has a **stabilised and smoother navigation** that uses the average value to ease the movement and orientation of the camera; and incorporates a **simplified system of navigation for selecting drawings** within the interactive/visualisation modality, narrowing down the hand commands to one similar gesture for both hands.

III.8.1 - Addressing issue 6: independent code

Spheri is the first standalone web-based platform version of the software, which provides a more accessible and flexible option for open implementation. This transition marks a significant milestone as it liberates the platform from its prior reliance on TouchDesigner, bringing with it several advantages including the removal of restrictions on video output resolution, the elimination of compatibility issues across different devices, and an improved accessibility. The first open access version of Spheri was released on 01/01/2024, it has been hosted at https://spheri.art, and a change log is available at https://spheri.art/changelog.txt. This version has been successfully tested in computers with Windows and MacOS using the most common web browsers and devices. The code has been developed using JavaScript, incorporating Three.js for the geometry and lights, and MediaPipe for the body tracking functions. Regarding the previous versions, the code has been cleaned up, simplifying the execution but also the external reading by a third part. The goal of this open access is to provide the digital artistic community a direct and free way of using the installation and apply it to live performances, collaborative drawing installations, workshop lessons, exhibitions, etc. This opening to external use seeks to enhance more applications and feedback on Spheri's new features, strengths, its usability for teaching workshops, for exploring and interacting with spherical perspectives in exhibitions, etc.

III.8.2 - Addressing the complexity of the experience (issues 19, 16, 21, 22, 23, 25): the new navigation system and the simplification of the experience

The experience with IMWYM exposed the need of a change of concept. Regardless which kind of new experience could have been proposed, it was very important to simplify both the concept and the interaction to focus the audience into spherical perspective concepts and, at the same time, give them an innovative conceptual experience through the technical and performative strength of the installation and the software. In this direction, the operation of IMWYM was quite complex: on the one side, within the interactive/visualisation modality, the user had to use the two hands at the same time, in two different ways and to do several different things; on the other side, the drawing modality required two people, one to operate the VR camera (first with the mobile phone, then by sliding their hand in front of the computer) while the other was drawing (compare with Figure 146). Hence, Spheri simplifies drastically the command of the installation, reducing the complexity of its use and consequently the time the user needs to learn how to operate the installation. The new paths of interaction are:

For the **interactive/visualisation modality**, the first concept created for interacting with the installation is dropped: [IN]Musicality gave too much spotlight to the technological advancement, opaquing the exposition of the Handmade Immersive Art. Instead, Spheri will introduce two sub-modalities: **single HIA** and **collection of HIA**.

- The **single HIA** sub-modality is aimed to be used for expositions with short time of interaction: it shows only one Handmade Immersive Artwork at a time and the functioning and the commands to be learnt are minimum. The visualisation might have or not music, but either way is meant to accompany the graphical experience, and it is not possible/meant to change by the visitor. In this modality, the concept of the exhibition matches the concept of the drawing, concentrating the experience on the artwork more than in the installation. Furthermore, the concept gets automatically refreshed with every new exhibition as every drawing is attached to a different concept while the installation remains the same, which is the opposite of what happened with IMWYM. Keeping the installation more stable might have a long-term impact, helping users with the familiarisation of the commands and giving them more security to explore the artworks. In this sub-modality, only one hand is used. For the first edition of Spheri the gesture will be the same than previously, i.e., sliding the hand up/down and right/left for rotating the camera and pinching for zooming in/out. However, in the future this could be improved by using one same gesture, such as a hand rotating (as grabbing a sphere) for orientating the VR camera and getting closer/farer to the computer camera for zooming in/out.

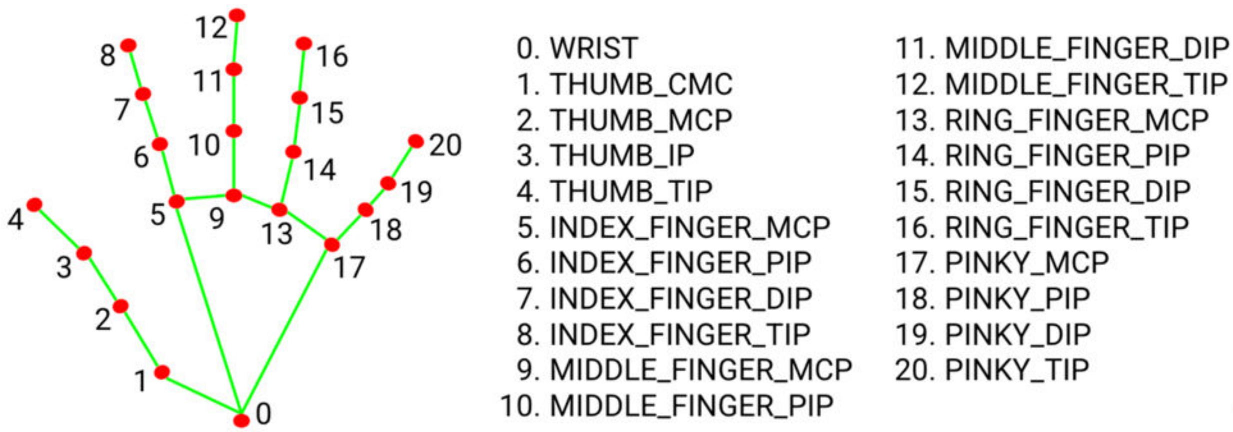


Figure 154: Hand landmarks detected by MediaPipe.

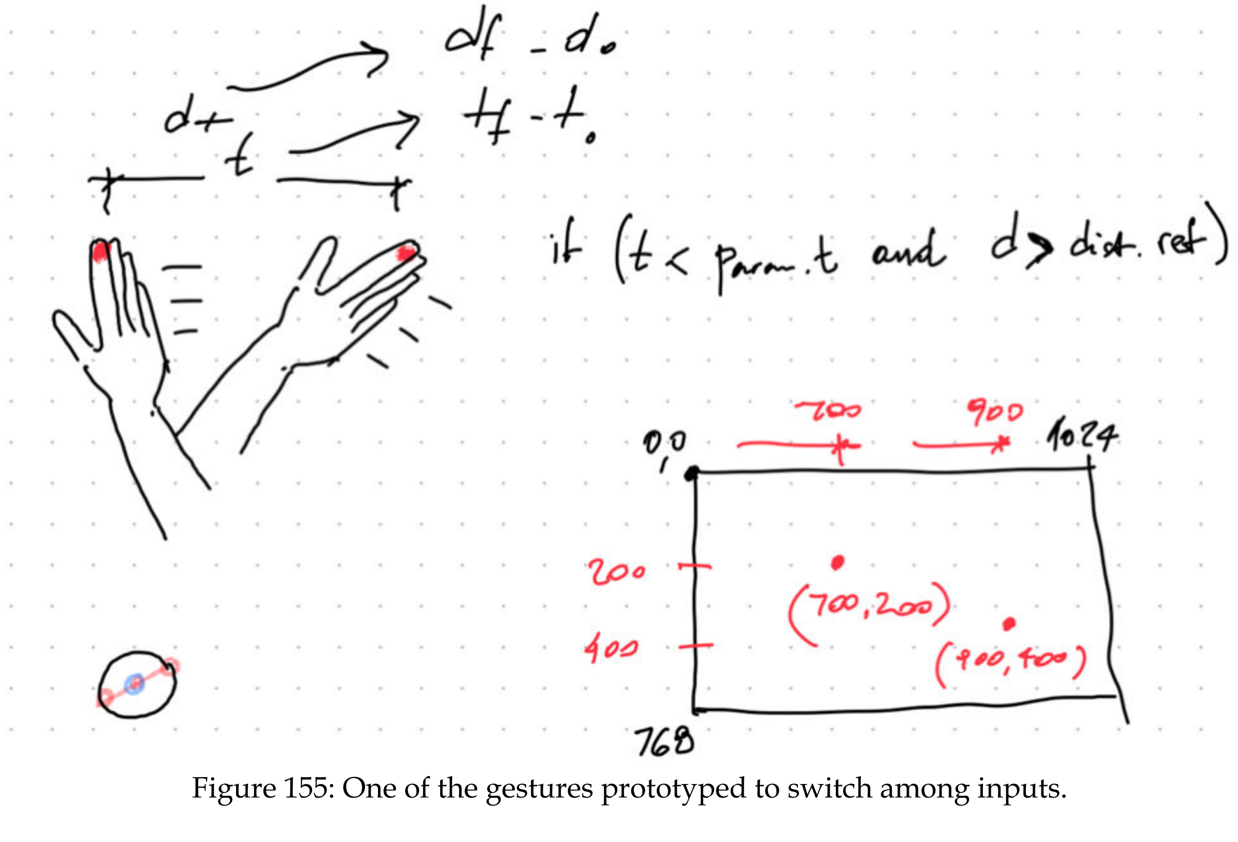


Figure 155: One of the gestures prototyped to switch among inputs.

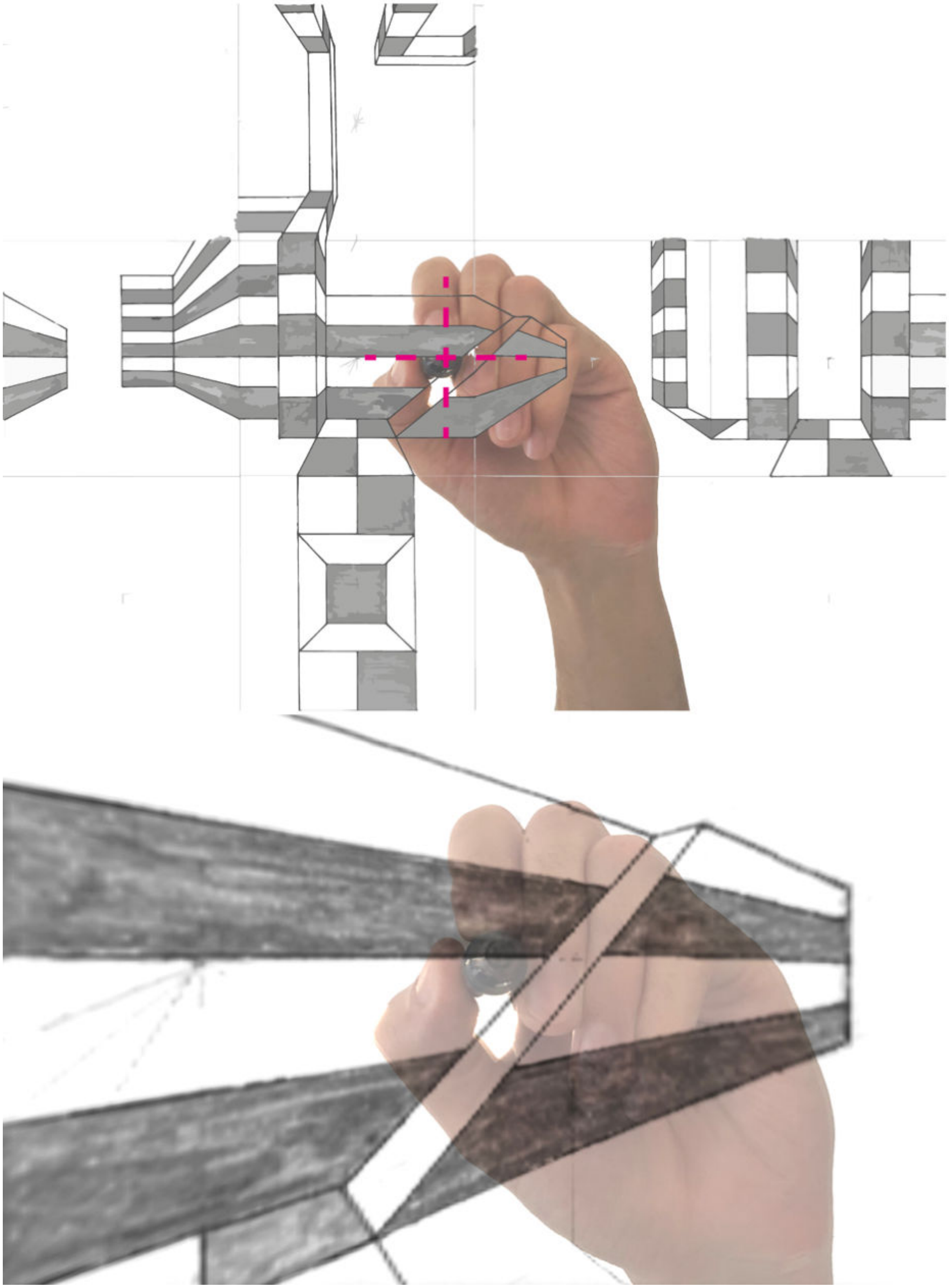


Figure 156: The navigation system of Spheri follows the drafter's hand: view on the cubemap (up) and in VR (down).

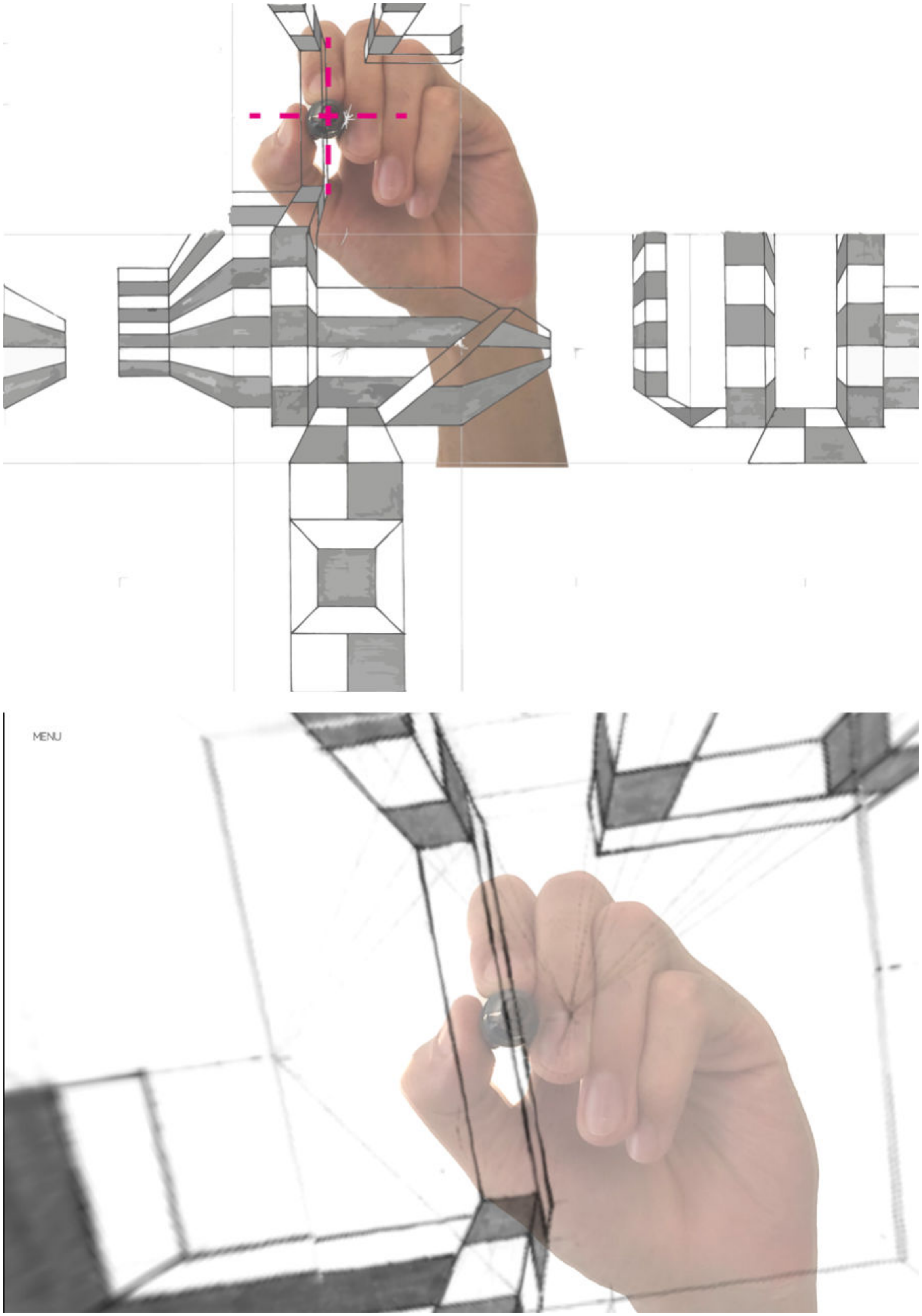


Figure 157: Drawing in the upper part of the cubical map (up) and VR view (down).

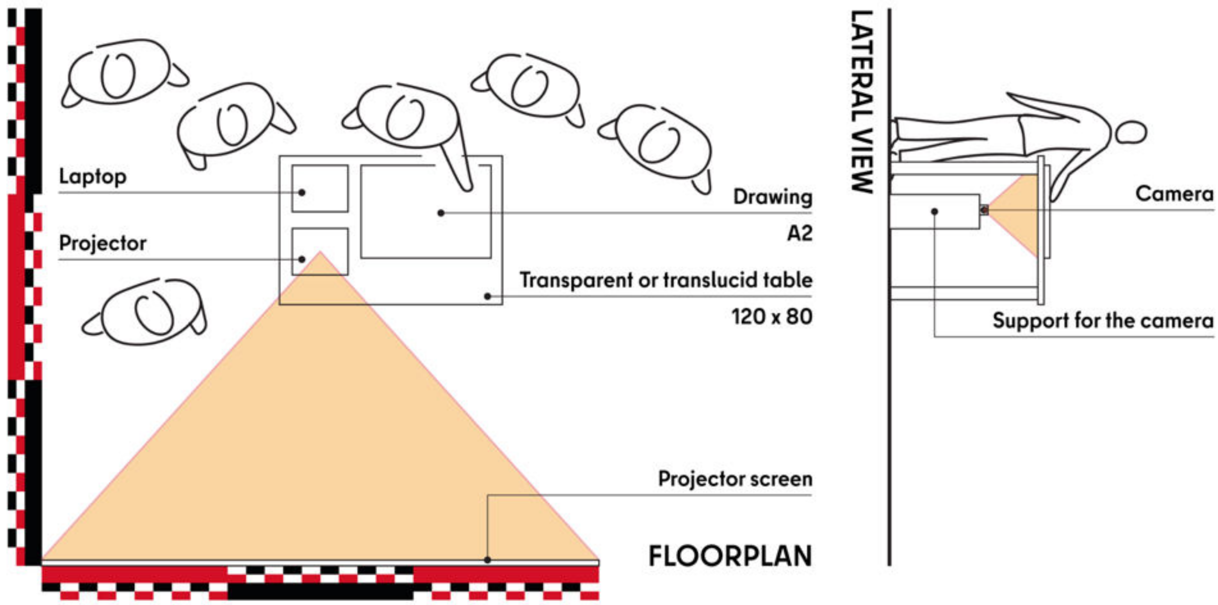


Figure 158: Ideal scheme of the installation.

- The sub-modality **HIA collection**, is aimed to exhibitions with longer times of interaction and for presenting more than one handmade spherical artwork. There are two gestures in this case: one for operating the VR camera, and one for selecting a drawing from a gallery. The gesture of selection is heavily simplified (the hand-controlled pointer is dropped) and although it is in prototyping stage now it could be either the same gesture used for operating the VR camera (i.e., a hand "grabbing" a sphere) but done with the other hand; or a simple swipe gesture triggering the action regardless the used hand. In the former case, one hand would be used for navigating the VR and the other for selecting the drawing from a rotating wheel. In the latter case, the program monitors landmark 8 (Figure 154), and it switches the drawing if a certain distance is covered by the landmark within amount of time. This means that the input will switch if users move their hand quick, while the input will not change if they move the hand slowly like when they are exploring the virtual environment (Figure 155).

Regarding the **drawing modality**, Spheri joins the features of navigation and drawing in one same person: the hand landmark used for the orientation of the camera is taken from the hand of who is drawing (not from another person). This implies that the drawing modality can be now used individually for drawing and navigating at the same time (Figures 156, 155). To reach this, the drawing is made in a transparent surface, with the camera behind or below (Figure 158). This implies that the person operating the installation has to be either touching the drawing or effectively doing it, so to navigate the VR camera. Thanks to this, the body tracking feature *forces* the visitor to explore the drawing and find a correlation between the flat and the VR view by a direct experience.

To improve the user experience within the adjusted modalities, Spheri includes a new stabilisation function that smooths the navigation. Indeed, if one would left the hand fixed in a point, for example for evaluating a detail a little bit longer, the camera will make little jumps in the screen. This happened because per default MediaPipe returns the coordinates of position within a certain range of confidence that can be setup within the code but the returned values move unpredictably within the defined range. This was enough to generate oscillations and shakings either in the VR view or in the pointer's position. Spheri solves this problem and facilitates the navigation with a function programmed to store the last 15 position values provided by MediaPipe, returning their average value (which eases and smooths the navigation) and determining the camera's position with more stability, making the experience more user friendly.

III.8.3 - Expanding functionalities

As preannounced in Olivero (2023), Spheri added some new functions, including: **Snapshot to VR,** now users can take a screenshot and use it for creating the VR environment, which comes very handy when the user has not access or chooses not to use a transparent canvas; **dynamic canvas trim**, for an on-the-fly fine adjustment of the selected input (live video, screenshot, storage); and **customised input,** which gives users the possibility to load their own input and see the VR result, this function works only in equirectangular format for now, although it is expected within the near future the inclusion of the cubical perspective and the azimuthal-equidistant formats too.

III.8.4 - Future improvements

Although there are still many functions and improvements to implement within Spheri, these are some features expected to be deployed within the near future:

- **Auto-calibrating tracking system:** this should simplify the setup of the installation for the modality of drawing, avoiding the fine and fragile calibration currently needed. Furthermore, this function could allow Spheri to be used dynamically from a mobile phone without any tripod or stabilisation system.
- **Implementation of the azimuthal-equidistant perspective as input and integration of the cubical perspective in the online version and the interface:** this could be very beneficial to keep expanding the available options among the full bestiary of spherical perspectives.
- **Wireless mobile phone/computer synchronisation:** a function to allow the use of the phone as a remote input.
- **Online galleries:** either pre-set or user based.

- **Online format converter:** for switching between spherical projections on-the-fly.
- **Custom gestures:** for users to define their own operation gestures, according to what they intend is more natural, or for customising and adding functionalities.

III.9 - Collection I: Spheritivity

The concepts and the narratives presented within this investigation are two key and delicate points on the integration of HIA within the field of digital arts (Issues 1, 2, 14 and 15). We have seen above how a failure in planning a good narrative can leave the installation without visitors or with rushing visitors with no time for experimentation. We also saw that if the concept is too complex the installation fails on gathering trustable interaction data, as visitors get overwhelmed with the quantity of things happening at the same time. Considering the strengths and weaknesses of the experimentations, the whole research, the ideas discussed in the first chapters, and the new developments made for the HIA investigation; I introduce an artistic product and output of this research which can act as a self-contained concept and narrative: Spheritivity. Spheritivity is a collection of Handmade Immersive Art exploring the influence of hybrid (physical/digital) perspective artworks for boosting artists' creativity. The collection exposes applications of this research and the wide range of possibilities that perspective (as knowledge) can offer to artists, from the mastering of geometries in space up to the creation of digital environments using the latest advancements in the field of graphic representation, i.e., spherical perspectives. Furthermore, Spheritivity is enhanced with an **intellectual component** (visual paradoxes) and an **interactive component** (Spheri). The visual paradoxes are Escher-like visual games, such as never-ending stairs, non-orientable surfaces, etc. Spheritivity upgrades these paradoxes to a never-ending canvas (via digital technology) and considering all vanishing points around the observer (via spherical perspectives). In turn, Spheri provides Spheritivity with an interactive framework for visitors and artists to discover the potential and applications of VR environments created from spherical perspectives.

In a general view, Spheritivity seeks to stimulate and promote the most recent developments on spherical perspectives and anamorphoses. It is expected that the engagement of artists and visitors might show, materialise, and present them with part of the potential that both classical and spherical perspective systems can offer.

Some specific goals are:

- For the use of **visual paradoxes**: to experiment with optical illusions (e.g., never-ending stairs, paradoxes of continuity, non-orientable surfaces) and bring them to an upper level, exploring how these optical games are built using all the vanishing points around the observer, considering an unlimited canvas and not only a framed window, how they are perceived in a virtual space, how digital technologies affect their creation and interaction, what are the implications of mixing systems (e.g., how to represent a paradox developed in parallel perspective using an equirectangular canvas where we normally draw using a conical projection), etc.
- For the use of **Spheri**: to understand how visitors react to the interaction, giving insights on, for example, what is the most natural (i.e., chosen) hand gesture for moving the sphere when they are not given any instructions. The answers to these questions are planned to be gathered in a survey within the next exhibition.
- For the exhibition of **Spheritivity**: to present publicly the results of the Handmade Immersive Art research, for the academic and artistic community to debate, analyse, criticise and, hopefully, explore, improve and extend in the future.

III.9.1 - Inspirations for Spheritivity: perspectives not perspectives

PART I - Chapter II developed a theoretical frame on how the knowledge in perspective can give a plus to artists, helping them to get their particular style and giving them more freedom to develop their own creations. The following examples illustrate practical applications of those theoretical concepts, showing how some artists create anamorphs using a mixture of methods, and own adaptations and/or interpretations of systematic methods. These variations depend on several factors, from partial knowledge of the methods to the purposeful decision of altering some parameters so as to accentuate a certain aspect of a projection.

For example, **Jan Van Eyck** created remarkable depth effects through the masterful painting of lights and shadows, yet his knowledge of linear perspective method was only approximate, as it has been proved by not less than six different hypotheses (Elkins, 1991, p. 53). Even without a deep biographic knowledge on his creative process, one will find several incoherences analysing his paintings before assessing them as methodical linear perspectives. For instance, if we analyse the Virgin of Chancellor Rolin (1434-35 ca.), and assume certain things about the geometry of the represented space, such as the back and side walls are orthogonal to each other, and tiles are equally sized, equally spaced and aligned to them; then it can be noticed that there are several vanishing points or, apparently, even parallels lines for groups of lines that should share one unique vanishing point (Figure 159 bottom right). Furthermore, also the diagonals through the tiles do not converge towards one common vanishing point on the horizon, but to several points on top of it[7] (Figure 159, right, up). Although it is clear not all the parallel lines are converging towards one unique vanishing point, and that the diagonals do not converge towards one common point neither, the mechanism used by Jan Van Eyck is very close to what one could have done following Alberti or Della Francesca's rules. Hence the diminution of the objects' size according to their distance is not entirely proportionated, but the construction is close to the principles mathematically described and systematised those same years. This implies that even if Jan Van Eyck might not have had the full knowledge of what he was doing (in linear perspective terms), he certainly had *some* kind of system and understanding of the spatial distribution of the geometry in space:

> "Jan van Eyck presumably had no interest or awareness of these analytic finesses, and we need not assume he had any 'system' in mind, the differences (…) are great enough to argue against that. Yet he accomplished by eye, and with consistency between paintings, a compromise between medieval and Renaissance sensitivities" (Elkins, 1991, p. 62).

If Jan Van Eyck *almost* reached accurate representations, **Maurits Cornelis Escher** went far beyond, even considered the historical differences and the gap in scientific knowledge between the two. In fact, Escher followed the path laid that mathematical logic laid out for him, walking on paths even unknown for other artists, exploring further the known Euclidian geometries and the codified drawing techniques of his time, and pushing forward not only the shape of geometry but also their perception and the ambiguity behind the representation systems (Ferrero et al., 2009, pp. 307–308). The mathematician Albert Flocon, who was among Escher's influences, put him among artists that are also *penseurs nets* (net thinkers), such as Piero della Francesca, Leonardo da Vinci, Albert Dürer, Jamnitzer, Bosse-Desargues, Jean-François Nicéron and many others (Bosse, 1653; Flocon, 1965; Kersten, 2018; Nicéron, 1638). Escher's interest and instinct for going deeper into the rules behind the representation systems was made clear in artworks such as Concave and Convex (1955) (Figure 160), Hand with Reflecting Sphere (1935), House of Stairs (1951), Up and Down (1947) in which he explored spherical reflections and games of perspectives made with curves (Piller, 2020). By the time Escher did those artworks, curvilinear systems were being explored and pushed forward to be formalised. For example, there was still no systematic

[7] The horizon is not entirely clear in the painting. I assumed it as the horizontal line passing through the face of the represented subjects, as it seems to be its most likely position and where most of the vanishing sets converge.

methods developed for drawing spherical perspectives, and although a spherical reflection is not the same, it materialises the interest of Escher on the opening of new fields and finding out of mathematical rules. Thirty years after, Escher met his "French kindred spirit and life-long penfriend" Albert Flocon (Ernst, 2003, p. 10; Kersten, 2018), and two years after that Flocon characterised a first semi-spherical perspective through the azimuthal-equidistant projection (Barre & Flocon, 1967). Escher did not only get nourishment from Flocon's universe but also found in him further sources of deeper graphical and modelling explorations. One such example are Flocon's knots, which obsessed Escher till his death:

> "There is actually nothing that interests me at the moment, except that idea, which, once, must become a visually perceptible image. Strictly speaking, I have no "right" to design anything new. (…) My contact with Albert Flocon in Paris caused a spark to ignite, a light that continued to burn for weeks (…) It is just a KNOT that I want to make, the classic, topological, triple-bent knot, "Le Nœud". Is it not surprising that a common knot, which seems so simple, turns out to be so difficult when you start drawing it?" (Hazeu, 1998 pp. 455-458 apud Kersten, 2018).

M. C. Escher acquired mathematical principles and through it developed an enormous capacity to understand and construct accurately complex representations and ambiguous, paradoxical compositions (Escher & Vermeulen, 1989, p. 60).

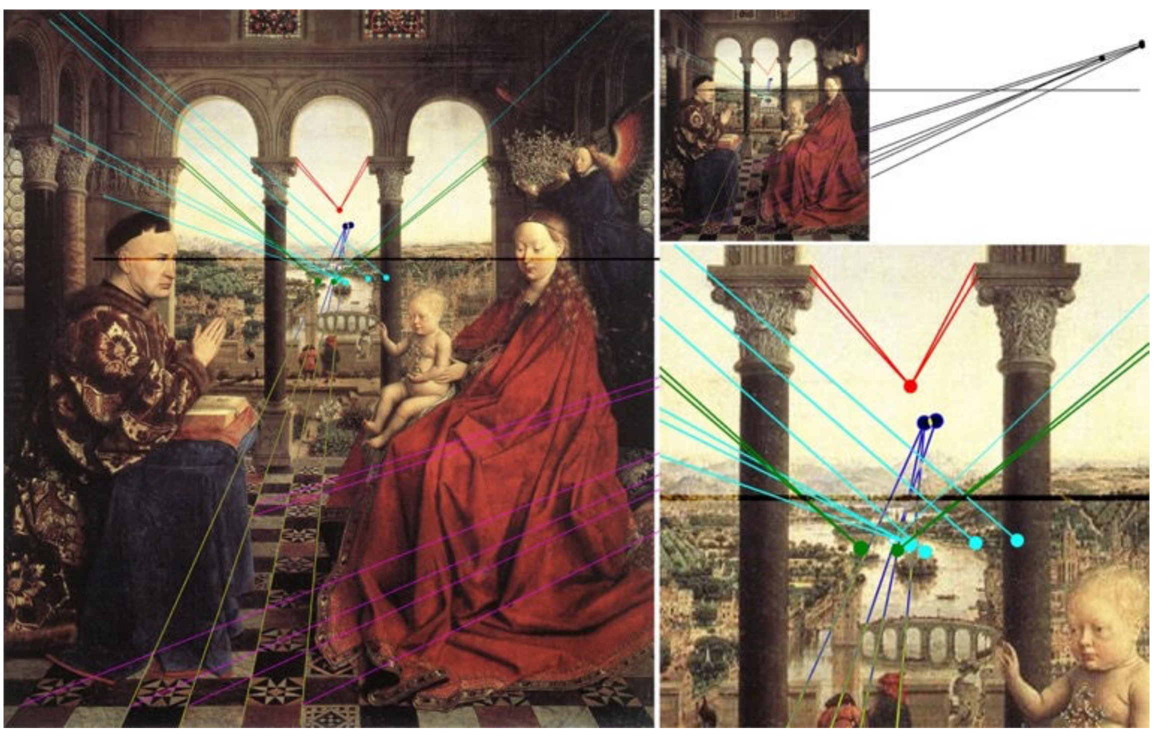


Figure 159: The Virgin of Chancellor Rolin (1434-35 ca) by Jan Van Eyck. Image under public domain (Eyck, 1434).

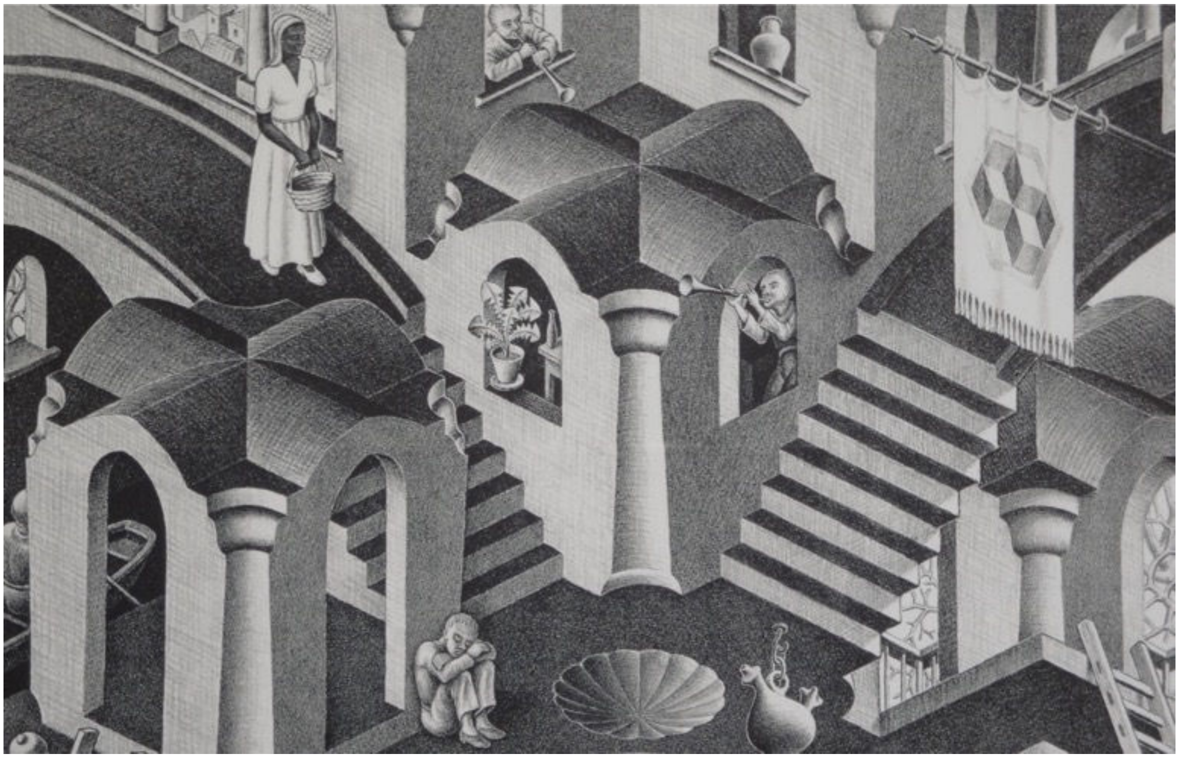


Figure 160: Concave and convex (detail) by M. C. Escher (1955) © Picture taken by Esparaz Marco Aurélio and distributed under Creative Commons licence (Escher & Esparaz (photographer), 1955).

The third example is the work of **Chiara Masiero Sgrinzatto**, who applies the equirectangular format for drawing architecture on-the-fly (survey) but also for illustrating inexistent or immaterial places, such as reconstruction (see Part II, Chapter VII) or places from her memories (Masiero Sgrinzatto, 2021b, 2021a, 2024a). Chiara has been creating handmade VR content since 2004, not limiting her immersive artworks only to its descriptive purposes but enhancing their narrative features through concepts and stories associated to every virtual tour she creates. In her last developments, she has dived into the generation of panoramic illustrations with artificial intelligence in its fusion with handmade drawing and several other creations for the re-valorisation of cultural heritage such as historical Panoramas from Africa, Nord America, and Europe (FilmEU, 2025; Masiero Sgrinzatto & Zilio, 2024). All this training gave her a position and knowledge for which Chiara is at the point of no needing any grid anymore. In a way, she freed herself from it, giving more flexibility to the final expression and drawing on-the-fly with her hand light as a feather. In fact, the curves of the equirectangular projection are in her mind after she got so used to it (in part, influenced by her works with photographic virtual tours). Yet, illustrations such as Bird's Eye View of Venice demonstrates her mastering of the perspective (Masiero Sgrinzatto, 2021c). Indeed, Chiara likes to tease and play, altering the system of reference and dealing with the distortion in the poles in some alternative ways: In her work at the Palazzo Grimani Museum in Venice, she solves strategically the upper pole in a very simple and - somehow unexpected - way: she draws the top part using a regular linear perspective, and then merges the illustration within the main panorama (Masiero Sgrinzatto, 2020b). This way, Chiara's composition follows the equirectangular distribution where distortions are simpler to handle, and a classical perspective for the upper part where spherical distortions are more complex (Figures 161, 162). Another strategy she applies is the so-called "laundry machine" scheme, that is, a rotation of the system of reference (Masiero Sgrinzatto, 2021a, Calle Varisco). In this example, Chiara puts the z/x plane matching the horizon, which is the place we normally find the x/y plane, this means that the verticals, parallels to the z-axis, do not vanish toward the upper and bottom parts of the equirectangular map, but toward the centre and back points, for which Chiara is able to concentrate the profiles of the alley in the less distorted zone of the equirectangular map (Figure 163). Once the drawing is finished, the reference system can be easily put back using software for panoramic photography. With these games, Chiara shows how an artist can be differently creative in the game of composing their own spherical perspective, according to the circumstances and the better convenience.

A final example is the case of António Bandeira Araújo who, as the attentive reader will have noticed, is one of the most brilliant and undoubtedly most influential mathematical minds alive in the world of spherical perspectives. António has not only developed (either alone or as main collaborator) three full spherical perspectives (Araújo, 2018a, 2018c; Araújo et al., 2020), but he has also presented a framework for guiding the definition of almost whichever other immersive perspective could be systematised in the future. His mastering of the theory on spherical perspectives has, to my knowledge, no equal in this moment, which allows him to create, manipulate, twist and push the boundaries of any situation. In the example of Figure 164, he creates his own composition, something that might look like the right perspective at first sight, but the careful observer will find out it is not. The image is a fisheye composition made at the Faculty of Arts, in Lisbon, standing in the middle of a corridor near the main staircases. However, certain parts of the content (like the staircases) were arranged to be shown although they are not fully seen from the chosen point in the corridor. This situation could have been forced even more to show even a further development of the staircases, which in the projective space would be the equivalent of projecting onto not one but two joint spheres.

Figure 161: Palazzo Grimani's Museum at Venice. Mixed composition: equirectangular panorama + classical linear perspective made with pencil and ink on paper © Chiara Masiero Sgrinzatto, 2020.

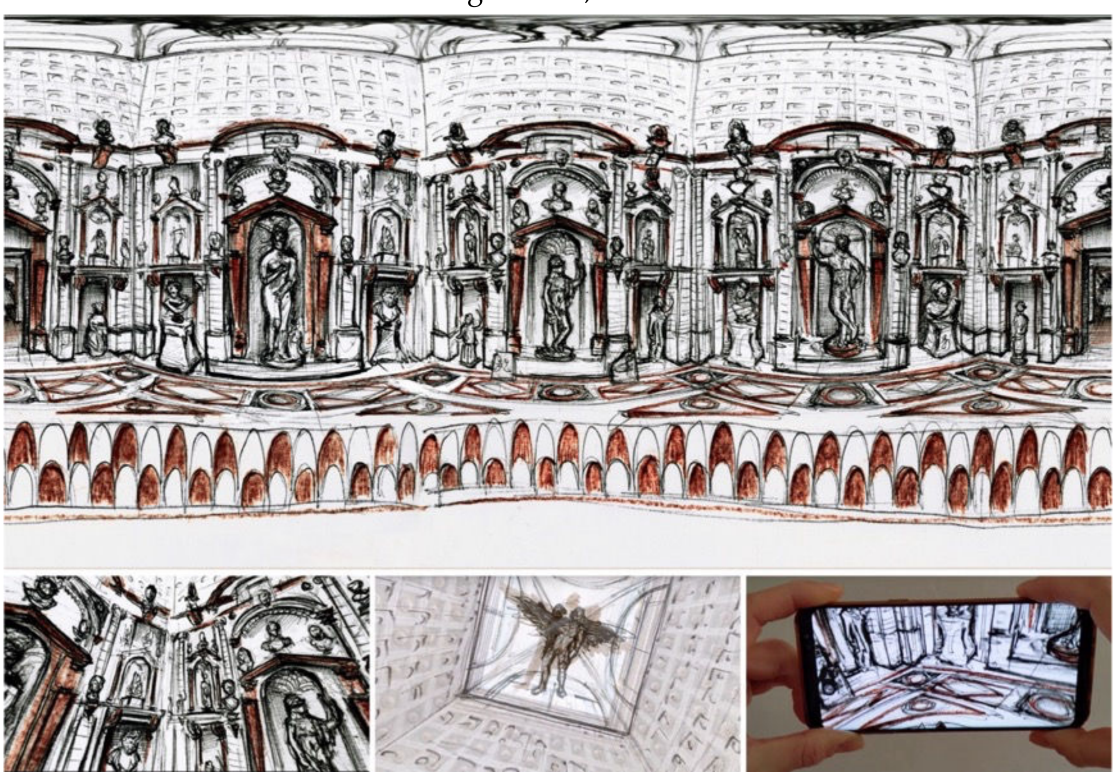


Figure 162: Palazzo Grimani's Museum at Venice. Final equirectangular composition and VR visualisation © Chiara Masiero Sgrinzatto, 2020.

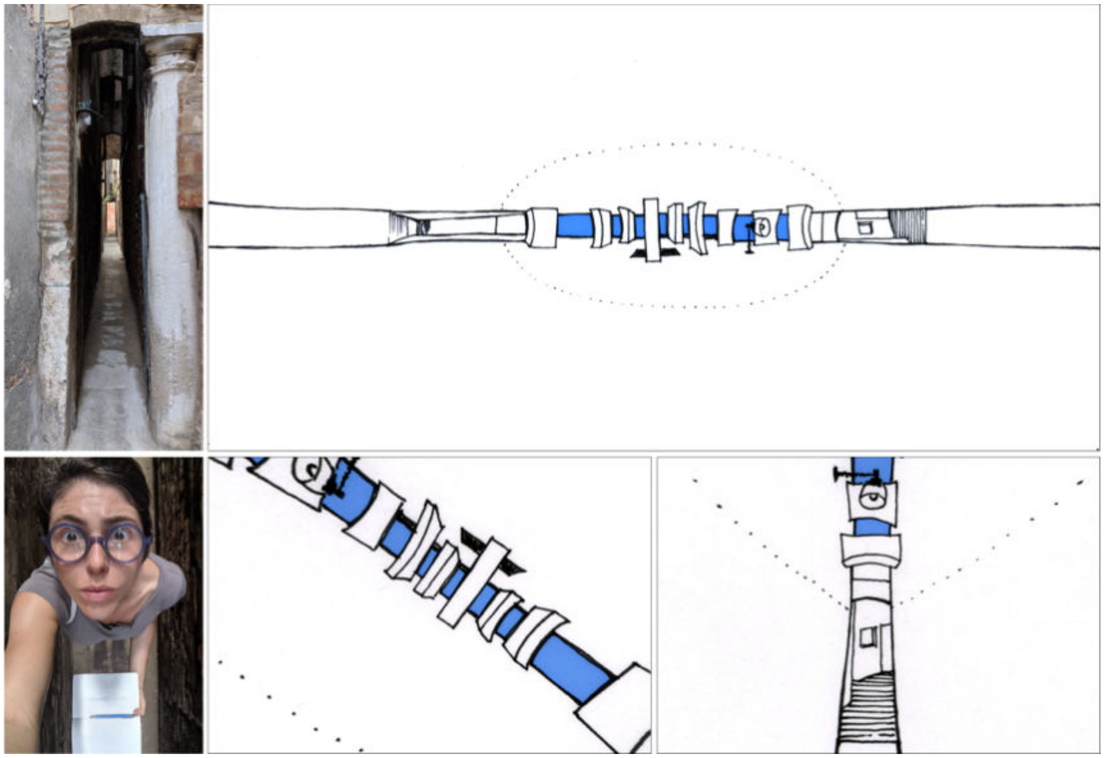


Figure 163: Varisco's street, the narrower alley of Venice. Equirectangular panorama, VR navigation and pictures on-the-spot © Chiara Masiero Sgrinzatto, 2019.

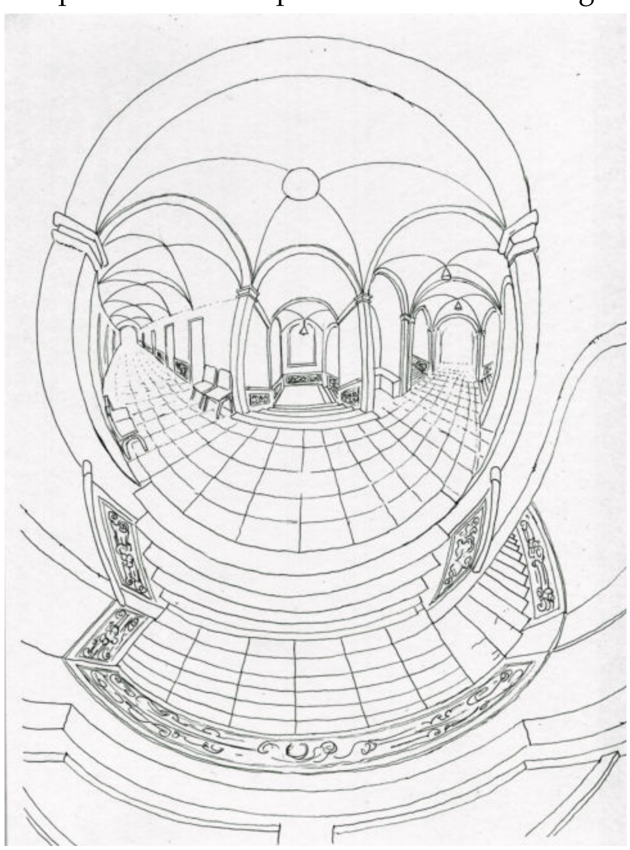


Figure 164: Studies on fisheye perspective at the Faculty of Arts in Lisbon © A.B. Araújo, 2020.

All these examples expose how certain artworks can follow logical and precise geometric systems and still not strictly adhere to a predetermined perspective system, even if they appear to do so. Far away from being a disadvantage or an error, the election of twisting and manipulating a perspective can sometimes be the biggest strength of the artwork, their hidden variable only visible to those eyes that can see underneath and beyond the first aesthetic impact. The intellectual manipulation of a perspective denotes the knowledge of the canonical theoretical system of reference, which is an important point to highlight: who fully knows a perspective system can twist it and go beyond or even choose not to follow it; however, the other way around, i.e., an artist that does not know the rules of a perspective and wants to do one by the books using the right composition, is not only less likely but mostly impossible. Nevertheless, even not knowing the perspective system, it is also possible to push the boundaries of the state-of-the-art, such as happened with Jan Van Eyck or M. C. Escher: they pioneered through a profound drawing-practice-based research, finding their own constants and systems through an attentive, careful and conscious practice. But still, their discoveries still needed the support of an abstract mathematical thinking to be fully systematised which, in turn, gave (especially in the case of Escher) a further limit and boundary to keep exploring. In other words, the system fed and strengthened itself through the art practice. In brief, by knowing the general rules it is possible to play, break and distort them, not just with straight linear systems but also with curvilinear ones, and not just with Euclidean dimensions but also in n-dimensional spaces.

III.9.2 - Concept (artistic statement without a scientific proof)

In the world of art, creativity gets often related to ideas like "opening the mind", "stretching boundaries", "leaving structures behind", "searching for the unknown", etc. Many times, all these actions get associated to the consume of psychotropic compounds or alcohol, as they help to put the guards of our consciousness down to open the doors of freedom and creativity. Nevertheless, the human mind can also be highly creative and flight free of structures without consuming anything, right as many children can easily demonstrate. In fact, adult minds might get more limited not by the absence of substances but by the idea of how the final artwork must be, by the expectations on how the artwork should have been, by the frustration of all the things they did not do instead of the joy of all the things they did do. In such cases, the creative process is focused on the result, rather than in the construction behind it, the slow process of building an image. This has been increasingly going on and on, up to the current climax and ecstasy in which we live nowadays, where an *impressive artwork needs nothing but seconds to be generated by an artificial intelligence. But, as António Bandeira Araújo put in better words: "Suppose we invent a machine that make love better than you, would you stop making love? The machine can do it instead of you, but it cannot do it for you". And indeed, are we not built and shaped by our experiences? We must pass through life to know what life is, we must love to discover what it feels like, no matter how many books you read about it, how many and how good people explains it to you, or how much of it you watch on a screen. Spheritivity strongly adheres to this. Indeed, we can enjoy the slow process of building an image, making it appear as if a meditation would be. The more tools and knowledge you have about graphic representation and perspective, the more you will enjoy playing in the abstract space, and the more creative and wilder your mind will go on the canvas…* ***And everything for free and without brain damage!***

III.9.3 - The collection

Spheritivity brings together several physical artworks made using watercolours, ink, acrylic and oil on both paper and canvas. They gather a graphic experimentation hold since 2022 where the first ideas of playing with visual paradoxes started. It includes: **parallel perspectives projected on a plane**, 6 artworks including isometric, dimetric, trimetric compositions (Figures 165 to 170); **conical linear perspectives projected on a plane**, 9 artworks from one up to five vanishing points materialised in the drawing plane (Figures 171 to 179); **cubical perspectives (Handmade Immersive Artworks)**, 3 artworks including practices on both paper and in canvas (Figures 180 to 182). **Equirectangular perspectives (Handmade Immersive Artworks)**, 10 artworks (Figures 183 to 192) made in paper, cardboard-canvas and regular canvas, painted with watercolours or acrylics and ranging sizes from 6 x 12 cm. (Figure 184) up to 80 x 40 cm. (Figure 187). **Free mixed-up perspectives**, 11 artworks (Figures 193 to 203) exploring non-standard perspective compositions and/or the interplay with different systems. These artworks range from 14,8 x 21 cm watercolour on paper (Figure 193) up to 90 x 120 cm. acrylic on canvas (Figure 197). Some special notes: Figure 180 is an all-inclusive exercise used during the teaching of cubical perspective (see Part IV, Chapter IV), by doing this drawing, a learner practices all the basic constructions and geodesics, including the hardest case explained in Part IV, Chapter II and its solution using the shortcut. Figures 181 and 182 are further explained in Part IV, Chapter II.5. Figures 191 and 192 are preparatory drawings aimed to an ambitious 2 x 1 m oil on canvas to be completed within the next two years.

Parallel perspectives on a plane

Figure 165: Deconstructing Berlin, ink and watercolours on paper, 42 x 29,7 cm. © Lufo Art, 2023.

Figure 166: Who Wants to Kiss, ink and watercolours on paper, 42 x 29,7 cm. © Lufo Art, 2023.

Figure 167: Labyrinth 01, ink and watercolours on paper, 30 x 30 cm. © Lufo Art, 2023.

Figure 168: Io Vivo Quasi in Ciel, oil on canvas, 30 x 30 cm. © Lufo Art, 2024.

Figure 169: Labyrinth 02, ink and watercolours on paper, 14,8 x 21 cm. © Lufo Art, 2023.

Figure 170: All You Need is Art, ink and watercolours on paper, 29,7 x 42 cm. © Lufo Art, 2024.

Conical linear perspectives on a plane

Figure 171: Impossible Things, ink and watercolours on paper, 29,7 x 42 cm. © Lufo Art, 2023.

Figure 172: Whatever it Might Be, ink and watercolours on paper, 29,7 x 21 cm. © Lufo Art, 2023.

Figure 173: Mitte, ink and watercolours on paper, 42 x 29,7 cm. © Lufo Art, 2023.

Figure 174: Running All Day, ink and watercolours on paper, 29,7 x 42 cm. © Lufo Art, 2023.

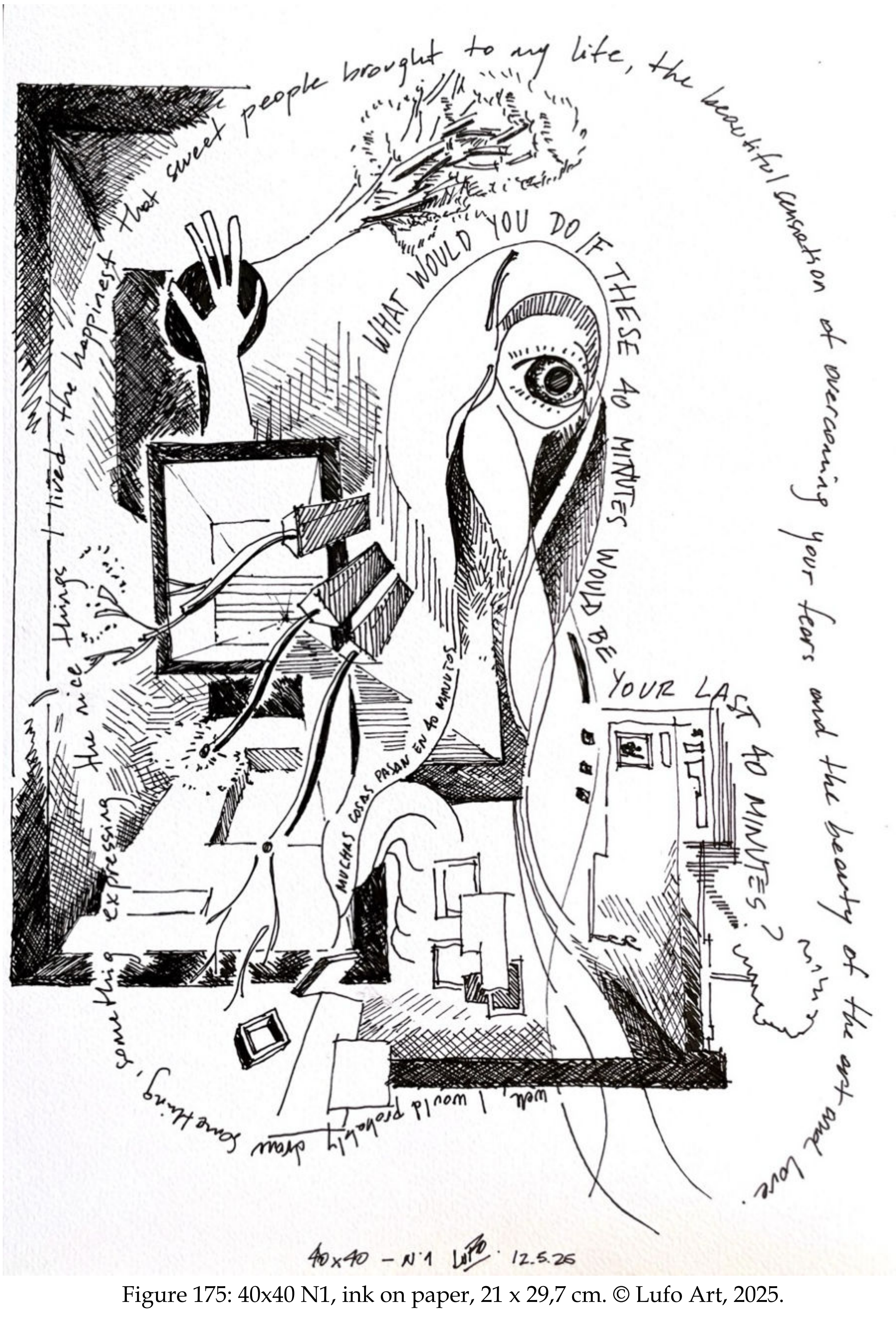


Figure 175: 40x40 N1, ink on paper, 21 x 29,7 cm. © Lufo Art, 2025.

Figure 176: 40x40 N2 Love is a Burning Thing, ink on paper, 21 x 29,7 cm. © Lufo Art, 2025.

Figure 177: 40x40 N3, ink and markers on paper, 21 x 29,7 cm. © Lufo Art, 2025.

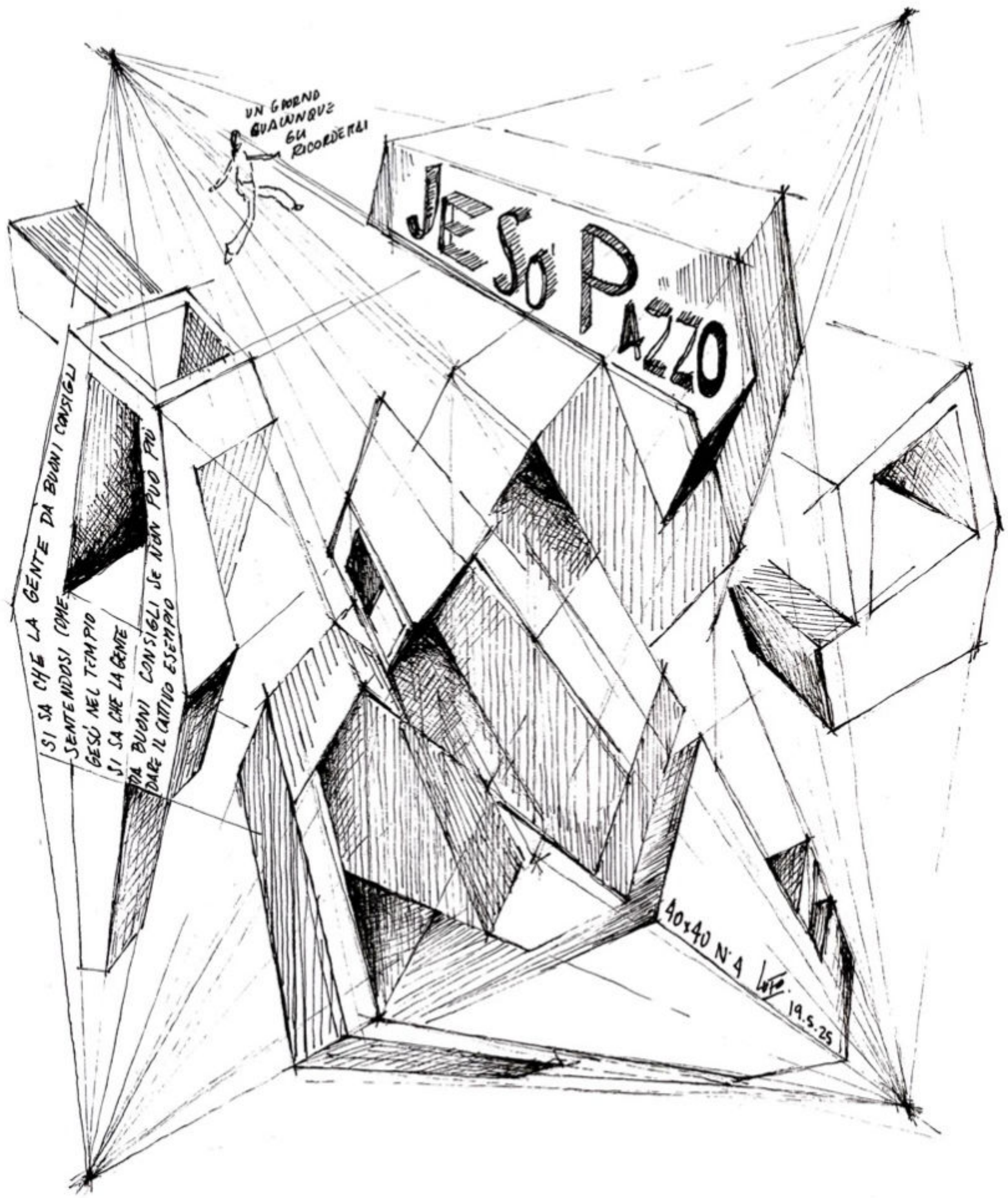


Figure 178: 40x40 N4 Je So’ Pazzo, ink on paper, 21 x 29,7 cm. © Lufo Art, 2025.

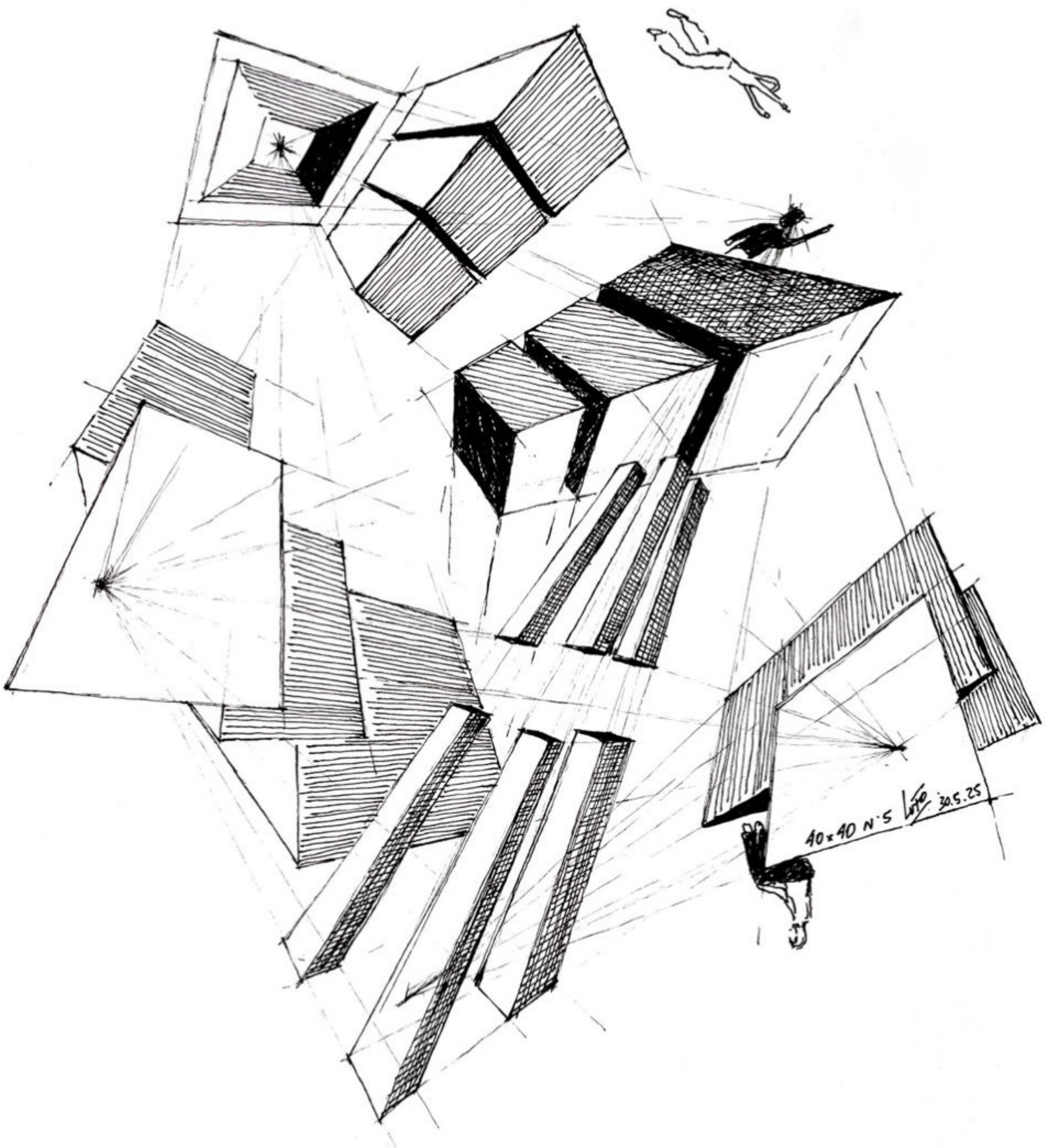


Figure 179: 40x40 N5, ink on paper, 21 x 29,7 cm. © Lufo Art, 2025.

Cubical perspectives (Handmade Immersive Artworks)

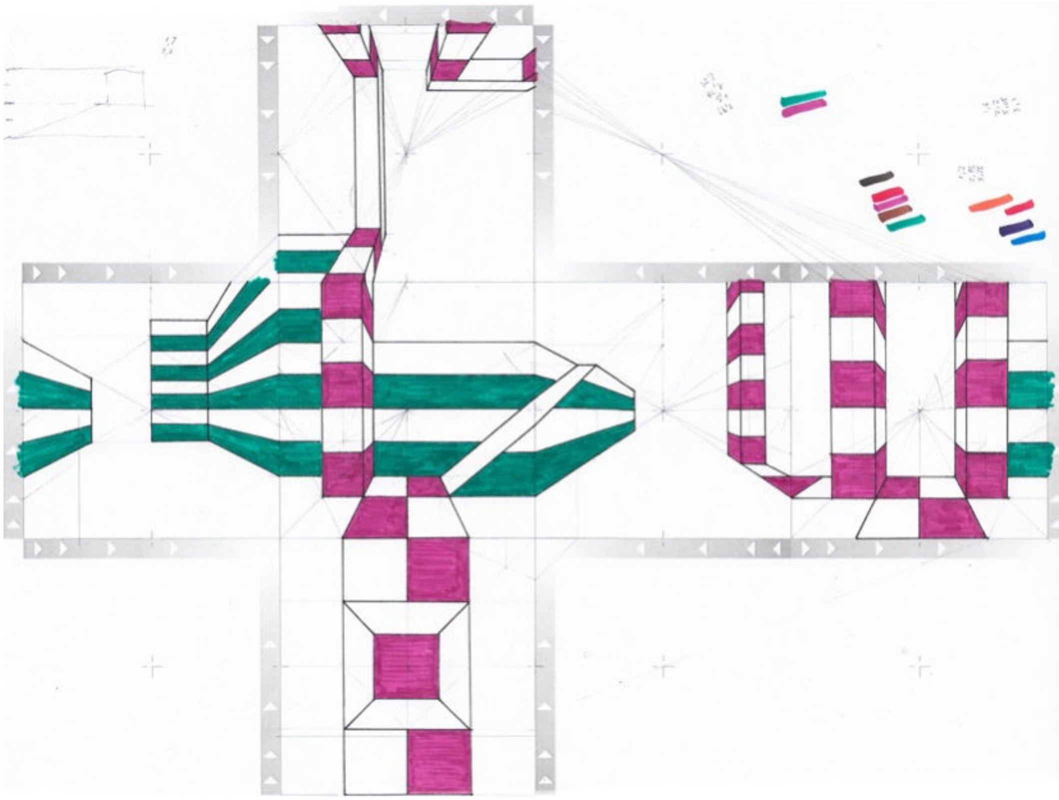


Figure 180: Los Chicos Solo Quieren Rock, ink and markers, 42 x 29,7 cm. © Lufo Art, 2022.

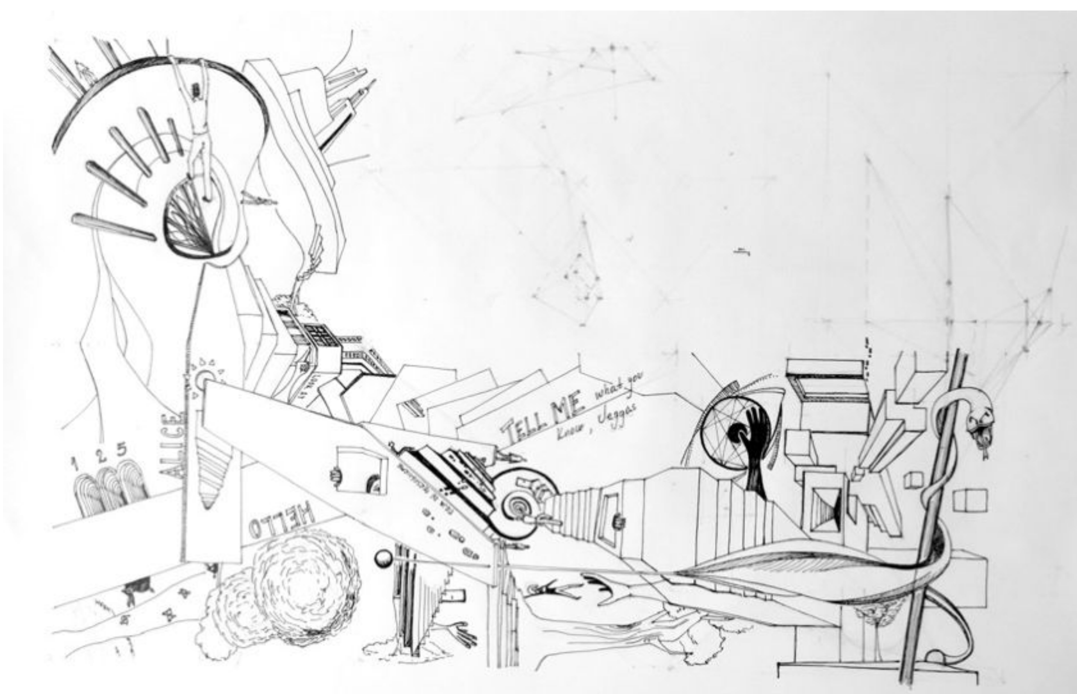


Figure 181: Hello Alice, pencil and ink on paper (future watercolour painting), 42 x 29,7 cm. © Lufo Art, Forthcoming.

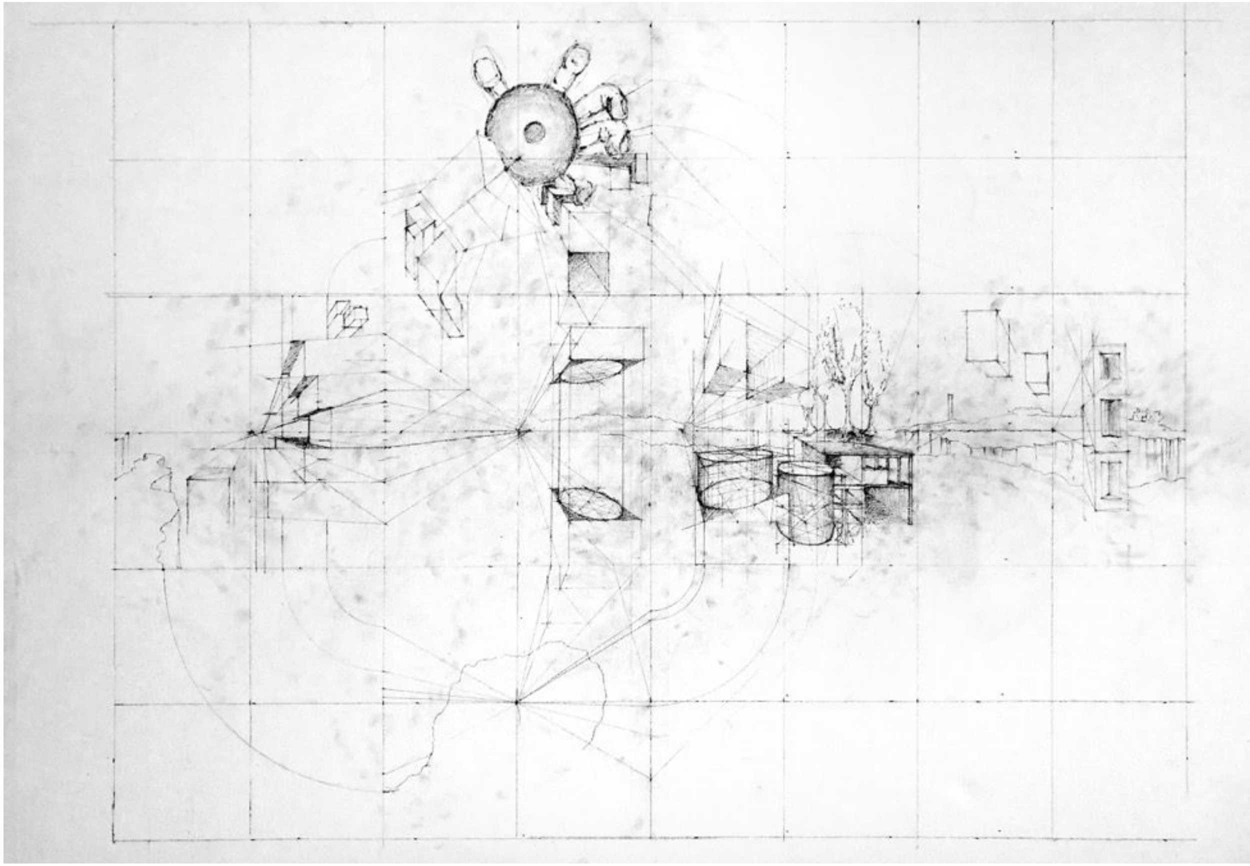


Figure 182: The Eye in the Sky, pencil (future acrylic) on canvas, 120 x 90 cm. © Lufo Art, Forthcoming.

Equirectangular perspectives (Handmade Immersive Artworks)

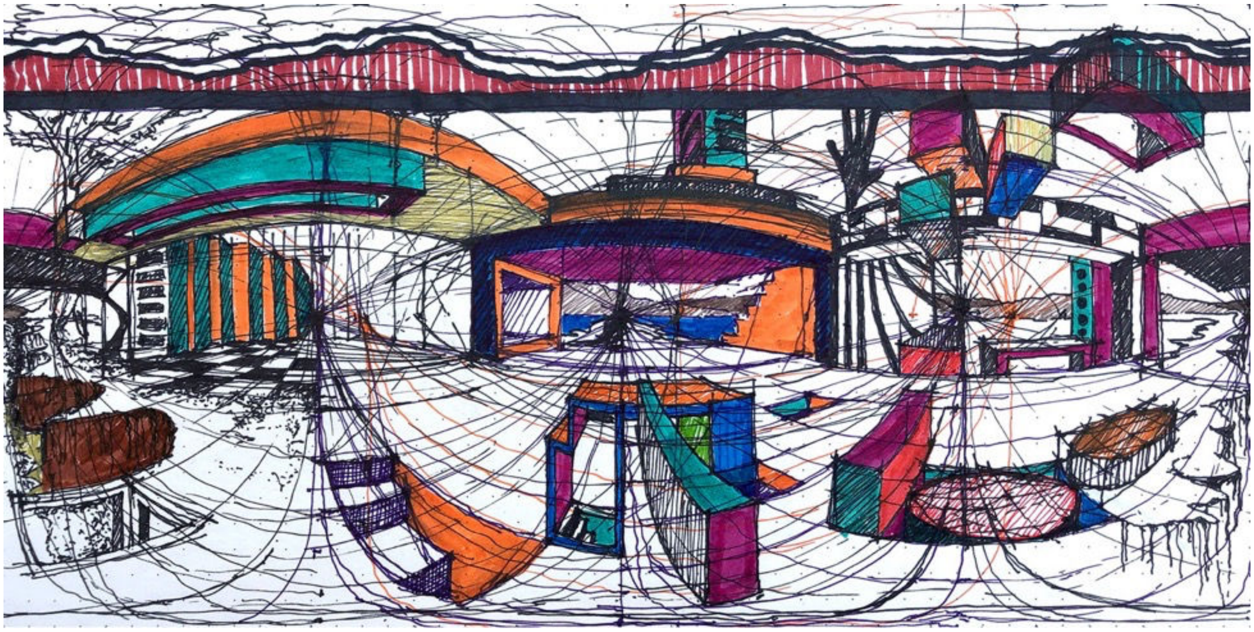


Figure 183: Un Faro en la Noche, markers and ink on paper, 29,7 x 21 cm. © Lufo Art, 2022.

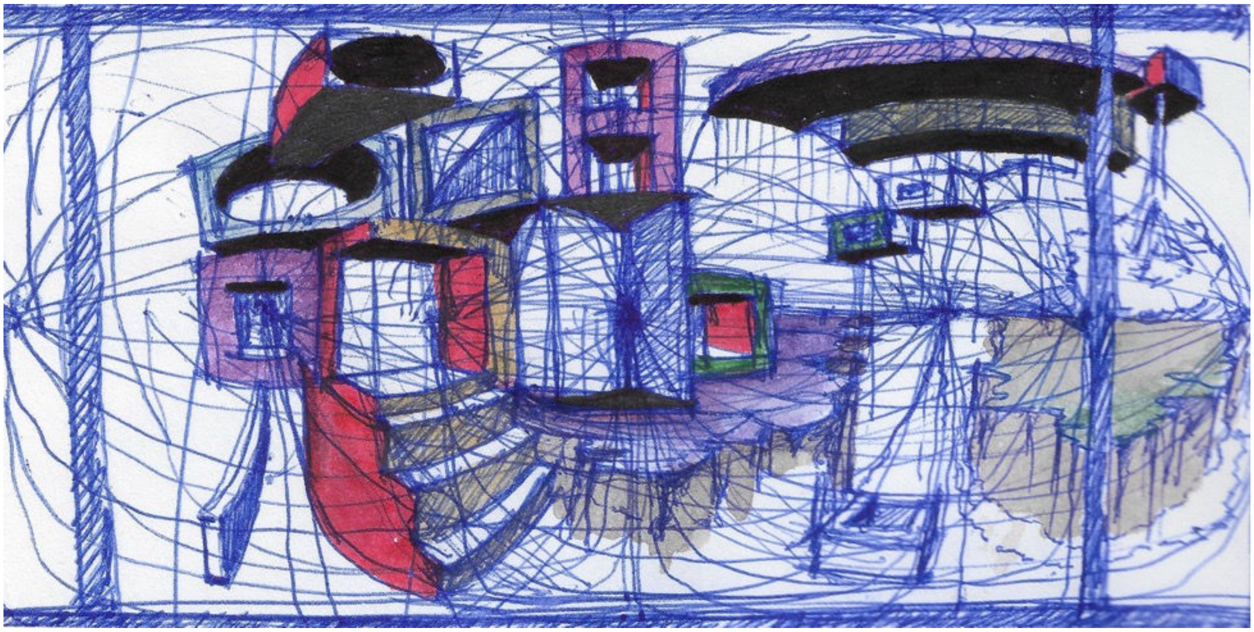


Figure 184: La Petit Tempete, pen and markers on paper, 12 x 6 cm. © Lufo Art, 2023.

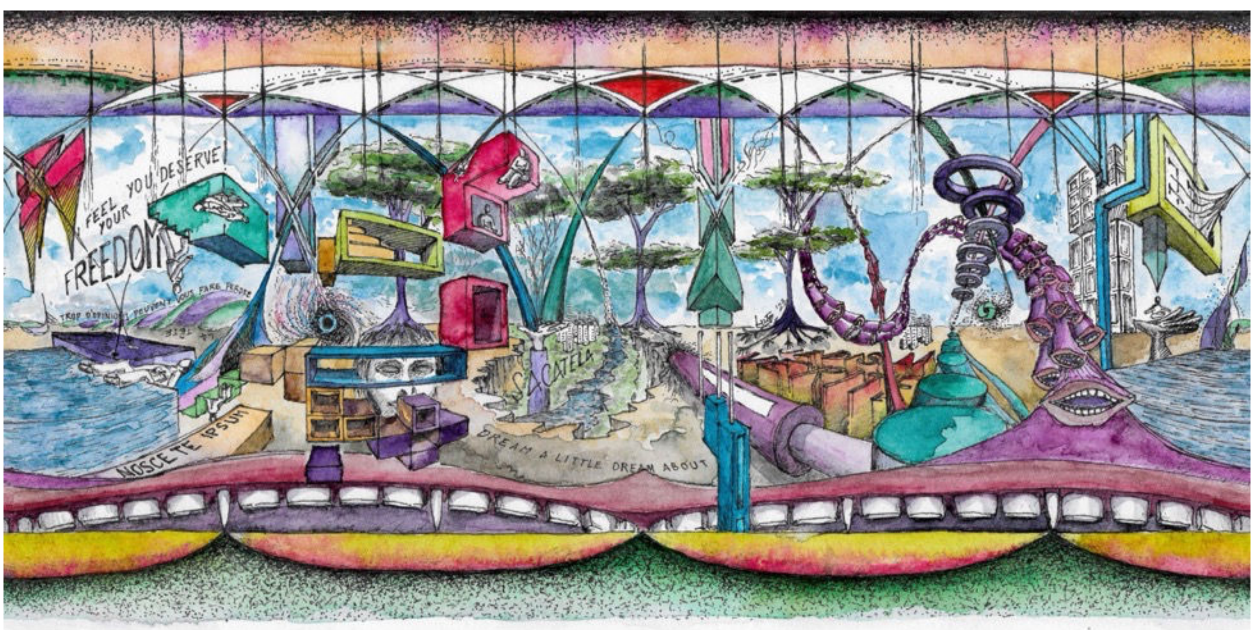


Figure 185: A Miracle, ink and watercolours on paper, 29,7 x 21 cm. © Lufo, 2023.

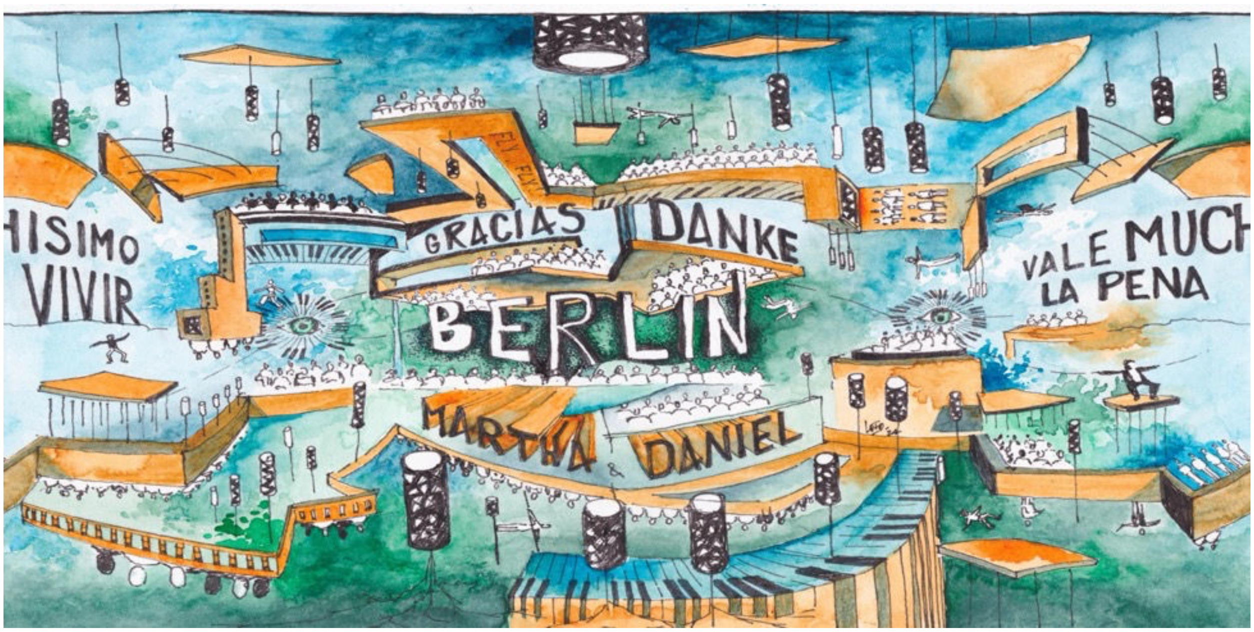


Figure 186: Armonía, ink and watercolours on paper, 29,7 x 21 cm. © Lufo Art, 2024.

Figure 187: Du Bist Liebe, ink and watercolours on paper, 80 x 40 cm. © Lufo Art, 2023.

Figure 188: Enjoy the Silence, ink and watercolours on paper, 29,7 x 21 cm. © Lufo Art, 2024.

Figure 189: Portal, ink and watercolours on paper, 29,7 x 21 cm. © Lufo Art, 2024.

Figure 190: Moebiuslin, acrylic on canvas, 60 x 40 cm. © Lufo Art, 2025.

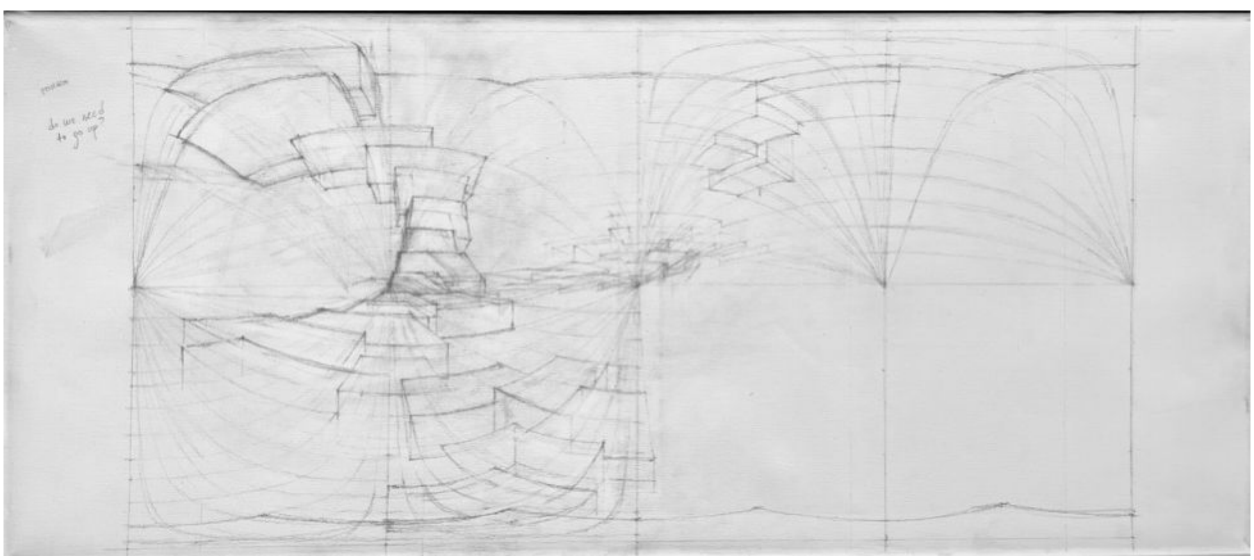


Figure 191: Labyrinth 03, pencil on canvas (future acrylic painting), 60 x 30 cm. © Lufo Art, Forthcoming.

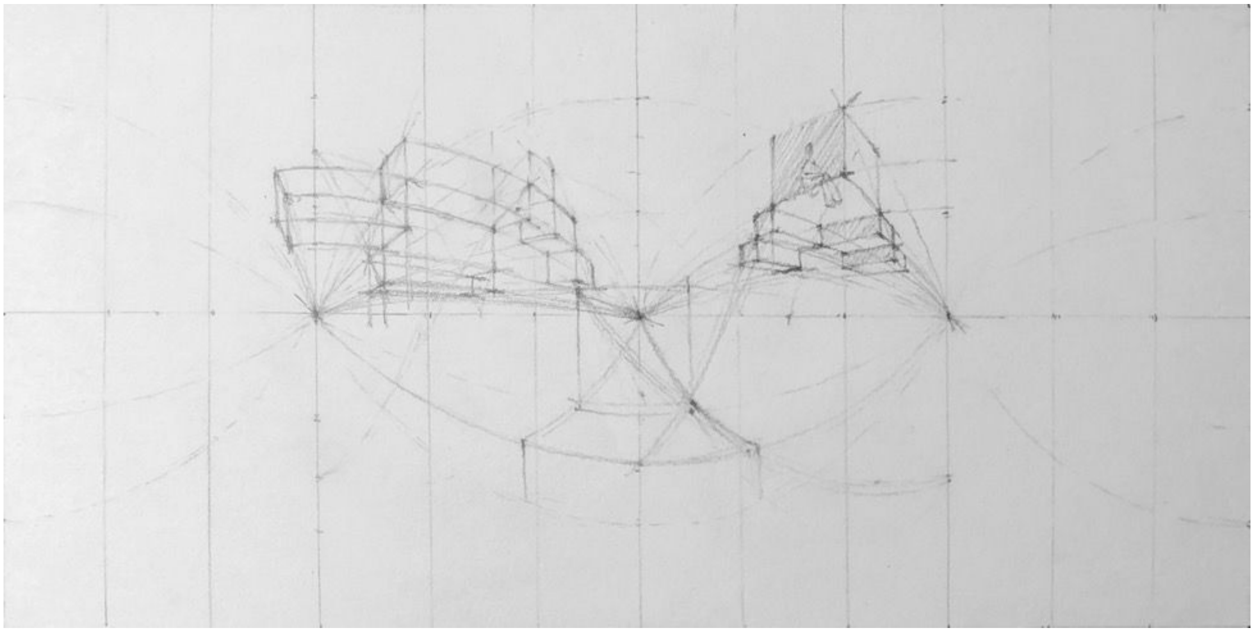


Figure 192: Paradoxes, pencil on paper (future watercolour painting), 29,7 x 21 cm. © Lufo Art, Forthcoming.

Free mixed-up perspective systems

Figure 193: Was ist jetzt an der Zeit, ink and watercolours, 29,7 x 21 cm. © Lufo Art, 2024.

Figure 194: A Wizard Without a Shadow, ink and watercolours, 14,8 x 21 cm. © Lufo Art, 2023.

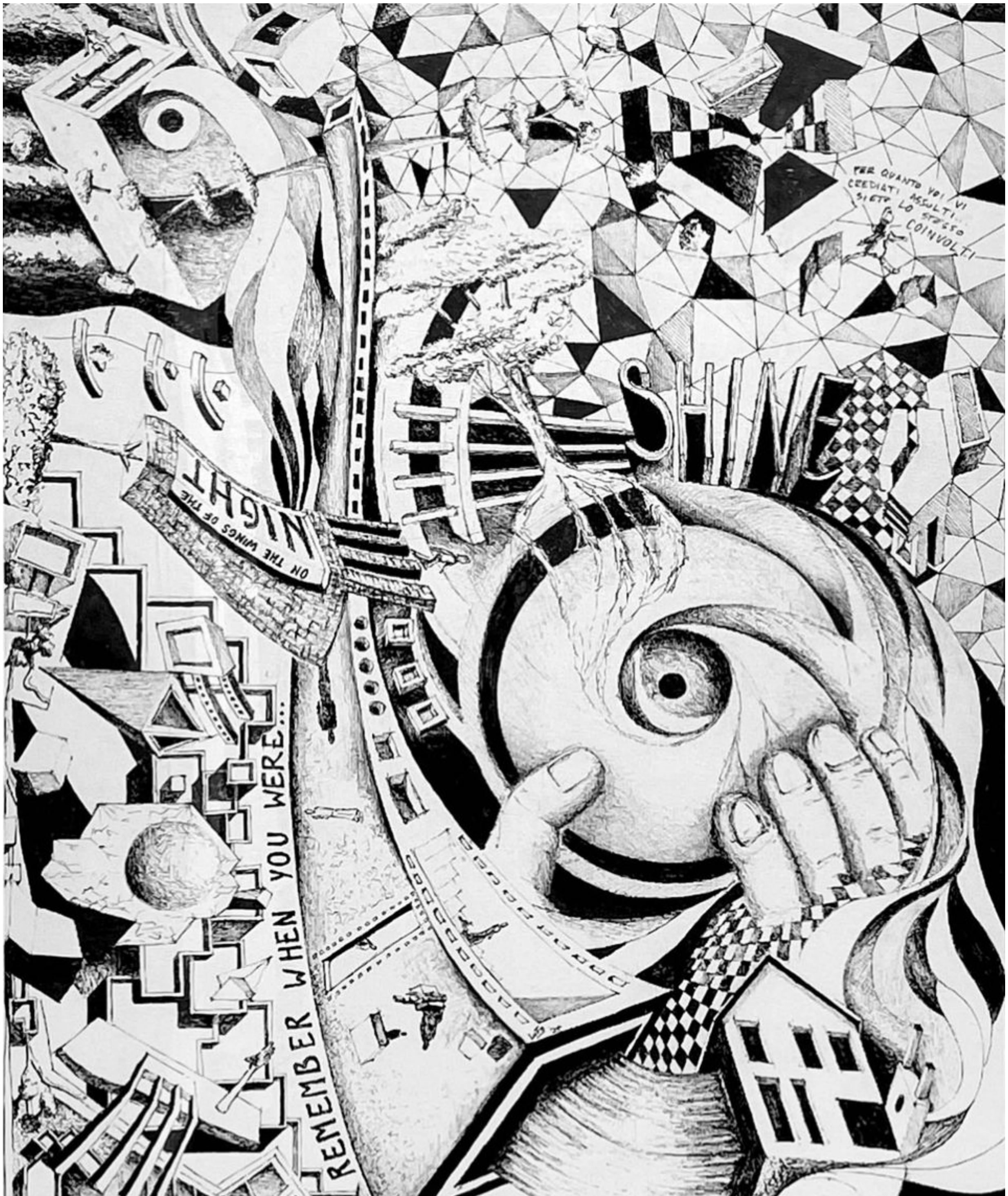


Figure 195: A Shadow Without a Wizard, ink on canvas, 50 x 70 cm. © Lufo Art, 2024.

Figure 196: Set Me Free, acrylic on canvas, 50 x 60 cm. © Lufo Art, 2024.

Figure 197: Sulle Corde di Aria, acrylic on canvas, 90 x 120 cm. © Lufo Art, 2024.

Figure 198: Rudolph Deconstructed, acrylic on canvas, 30 x 30 cm. © Lufo Art, 2024.

Figure 199: Upon What, acrylic on canvas, 30 x 30 cm. © Lufo Art, 2024.

Figure 200: Der Wind, ink and watercolours, 21 x 29,7 cm. © Lufo Art, 2025.

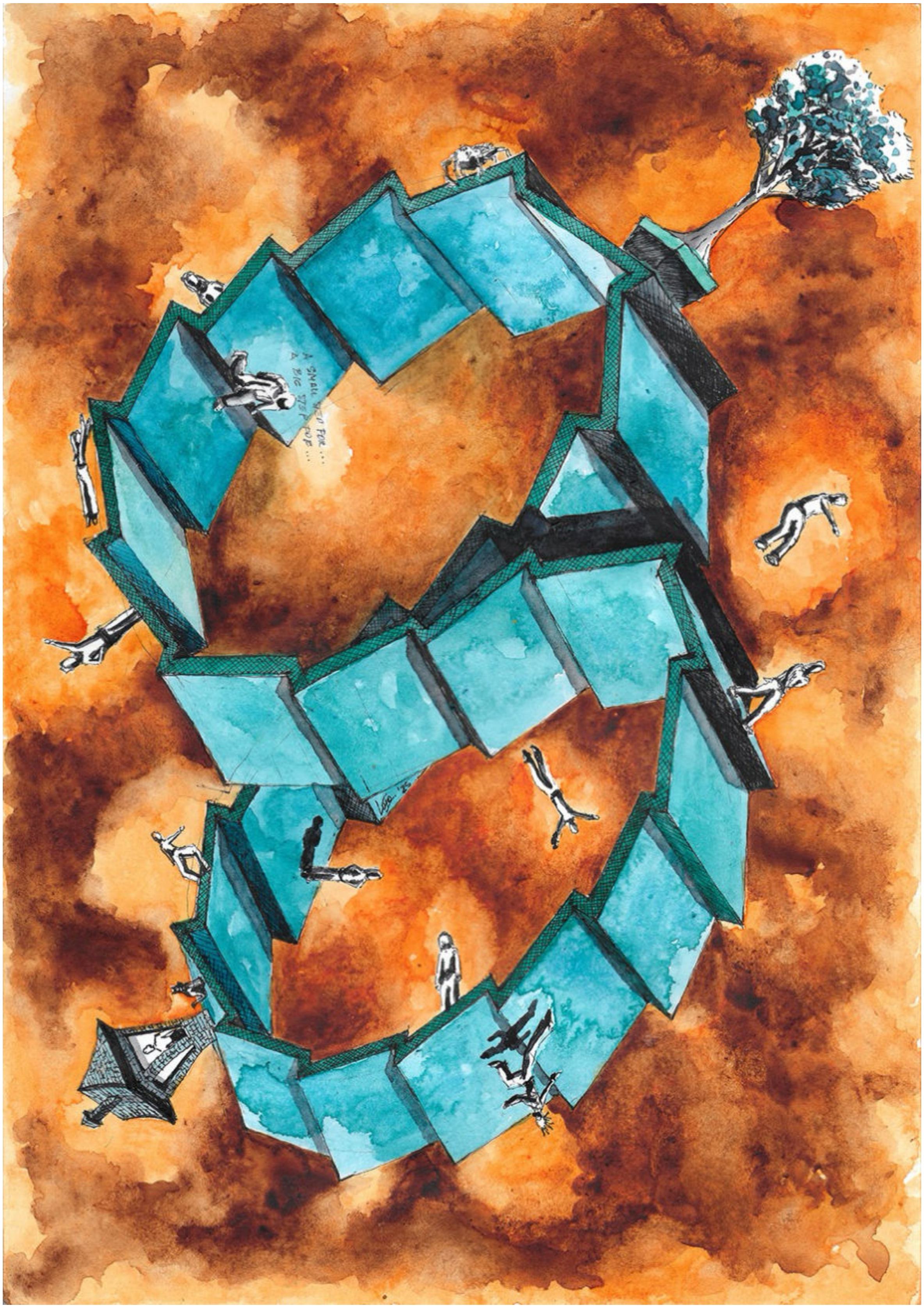


Figure 201: The Eighth Step, ink and watercolours, 21 x 29,7 cm. © Lufo Art, 2025.

Figure 202: Me Quedo Aquí, acrylic on canvas, 40 x 30 cm. © Lufo Art, 2025.

Figure 203: Noch einmal, pencil on canvas, 60 x 50 cm. © Lufo Art, Forthcoming.

III.10 - Exhibitions V, VI, VII and VIII: Spheritivity at A Hidden Variable, KUI 2025, BAAM 3 and Artech 2025

The artworks of Spheritivity were presented in several venues and exhibitions during 2025:

- **A Hidden Variable**, Denizen Art & Coworking Space, 1 to 15 July 2025, Berlin Germany.
- **XXII Conference Culture and Computer Science: Remixing Analog and Digital KUI 2025**, Kulturforum, 25 and 26 September 2025, Berlin, Germany.

Furthermore, Spheritivity is currently being evaluated or soon to be submitted to be presented at:

- **HAAM 3, Hamburg Artists Art Market**, 18 to 21 September 2025, Hamburg, Germany.
- **12th International Conference on Digital and Interactive Arts: Media Art Cultures, Communities & Territories**, Artech 2025, 26 to 28 November 2025, Braga, Portugal.

III.10.1 - Components, interaction and functionality

To focus on evaluating the simplest version of Spheri, the sub-modality **single HIA** will be used for the 2025 exhibitions while the other two continue their development. The single HIA modality is expected to use a computer running Spheri directly on the web browser with a desirable setup of around 12-16 m2 following the scheme detailed in Figure 204. The installation requires a table, a computer, a beamer, an art easel for every spherical perspective and 4 to 6 wall hangers for paintings. The final quantity of artworks in display are to be decided with every curator, for example, the setup in Figure 204 has one spherical perspective and four artworks in the wall, which has been already confirmed for the first two exhibitions. The interaction is as follows: the easel with either a spherical or a cubical perspective is placed next to the table; the virtual environment generated with such drawing is previously loaded on the computer; visitors interact with the computer by waving their hands in front of the camera, while the projector shows the VR result of the interaction in the wall in front of the visitor. Visitors can compare the flattened drawing with the VR environment and either seek for conclusions on the artwork/VR environment correlation (if they are new to immersive and handmade perspectives), and/or analyse and discuss how the most complex parts were solved (e.g., the poles within an equirectangular perspective, the faces' discontinuity within a cubical perspective). On the side wall, some artworks of the collection show the path of perspective knowledge with at least one artwork per category (one parallel perspective, one conical linear, one conical curvilinear, one mixed). Visitors can follow this path and discover the many possibilities that perspective can offer for boosting creativity and the versatility of the technique to be explored either through more precise methods (like tracing with ink on paper) up to freer methods such as oil and acrylics on canvas.

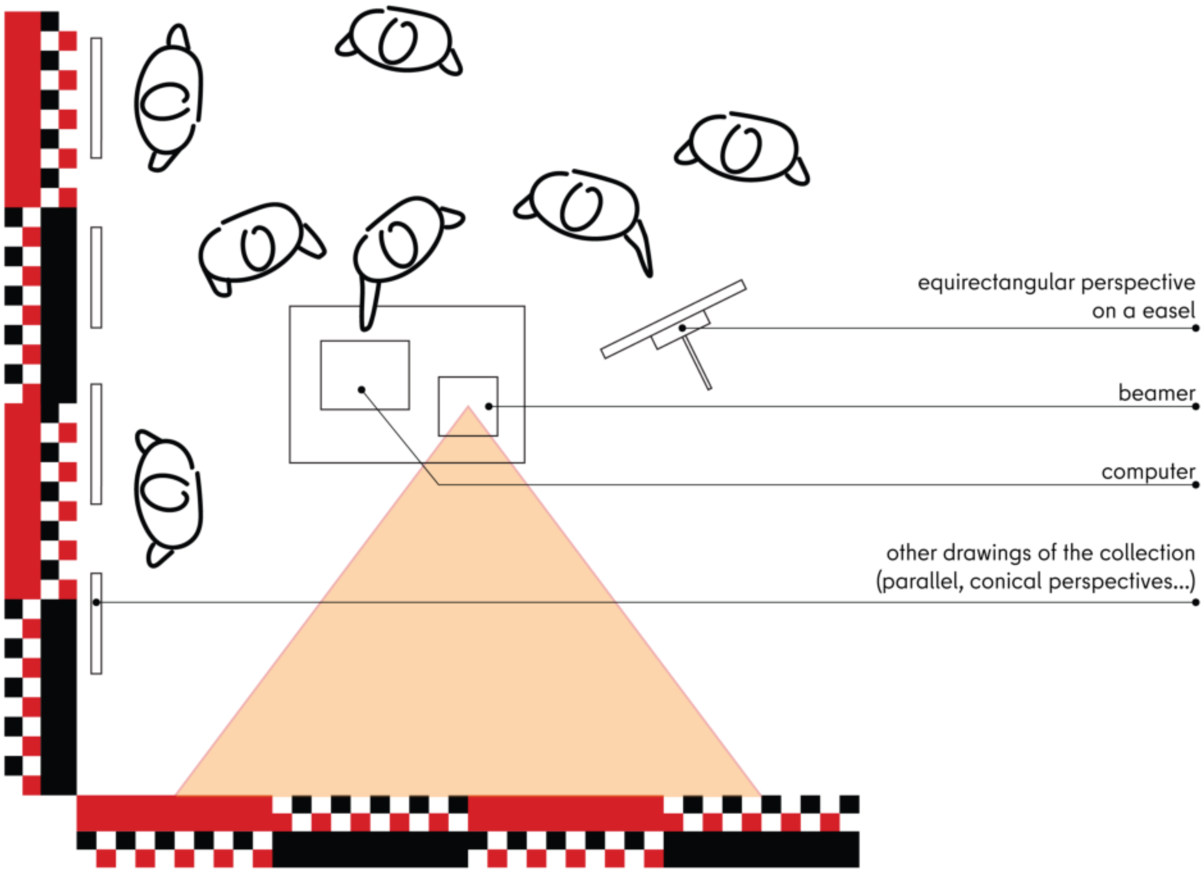


Figure 204: Desirable setup for Spheritivity.

III.10.2 - After interaction survey

Further data will be gathered during the next exhibitions, so to evaluate the impact, utility and general reception of the installation. For the exhibitions programmed for 2025, visitors will be able to take a gift postcard containing a print of the spherical or cubical drawing in exhibition and a QR-code. That QR-code will give them access to the VR environment in their mobile phone, to an deeper explanation of the concept, the installation and details of the artworks, and finally to an anonymous survey. Particularly, the survey aims to rate the experience, so visitors will be able to express their opinion and give feedback about the installation. It is expected that this information, which include scales, guided choices, media sharing, etc., will give quantitative data on usability and perceptual impact; and qualitative insights to be processed and elaborated for improving both the user interface and experience in further editions of Spheritivity. Some of the questions are as follows:

- Background
  1. Are you an artist? Answer: Yes / No.
  2. What would you say is your **theoretical** knowledge on perspective? Answer: Score scale 1–10.
  3. What would you say is your **practical** knowledge on perspective? Answer: Score scale 1–10.
- Gesture Intuitiveness
  4. Did the hand gestures feel natural? Answer: Score scale 1–10 for "orienting the camera" gesture + Score scale 1–10 for "zooming in/out" gesture.
  5. Which other/s gesture/s would you suggest? You can also upload a short video. Answer: Text field and/or upload video.
- Ease of Interaction
  6. How easy was it to learn the hand-gesture controls without instructions? Answer: 5-point Likert scale (1 = Very easy; 5 = Very difficult).
- Spatial Understanding
  7. Did you notice differences between the VR environment and the flattened drawing? Answer: 5-point semantic differential (1 = Not at all; 5 = A lot).
  8. Which ones? Answer: Text field.
- Perceived Creative Insight
  9. Did exploring a Hybrid Immersive Artwork give you ideas you never had from a flat drawing alone? Answer: Yes / No + Text field: "If yes, please describe briefly".
- Visual Paradoxes
  10. Did you notice any Escher-like visual paradoxes or impossible geometries? Answer: Yes / No + Text field: "If yes, which illusion stood out most?"
  11. Did you notice them better on the flattened drawing or during the VR navigation? Answer: Flat drawing / VR.
- Learning Transfer and Utility

12. Did you know you can create a virtual environment using a physical handmade drawing? Answer: Yes / No
13. Do you feel confident you could sketch a simple spherical-perspective scene on paper after seeing all the artworks of Spheritivity? Answer: 5-point Likert scale (1 = Not confident; 5 = Very confident) + Upload button: "if yes, share it with me!"

- Open Reflection

14. Any other thoughts or suggestions about Spheritivity, Handmade Immersive Art, or Spheri? Answer: Text field.

IV - SOLVING PROBLEM 5: Low dissemination

Note: this chapter brings part of the content developed, peer-reviewed and published in an article presented at the congresses Artech 2023 and KUI 2023 (Araújo & Olivero, 2023; Olivero, 2023; Olivero & Araújo, 2023).

Teaching spherical perspectives helps artists and beginners of the field to acquire a knowledge that does not cease to exist with any update: the person internalises the process by doing it with their own hands. This is one of the biggest motivations for which teaching perspective - rather than software tools - is worth. In the past, we have seen how Perspective Boxes, most of the so-called anamorphosis and the Panoramas were made by people with a very specific knowledge: the practice was mainly hold by virtuoso artists as they were the ones with the secrets of its theory (Grau, 2003; Spencer, 2018). Those conditions no longer apply, and the knowledge is open and accessible to everyone, for which anyone without recommendation of the Phillip King of France can learn to create art and materialise their thoughts through the use of perspective. Even more, through spherical perspectives and Handmade Immersive Art is nowadays possible to bring up a whole world as an immersive and interactive experience born from an artist's mind using only a small piece of DIN A4 paper, a pencil and a phone. Furthermore, as the fundamental requirement for doing a spherical perspective is a rational, slow processing of constructing vanishing sets, building grids and materialising any geometry line by line; the students' minds and hands co-evolve, fostering reflective thinking as they draw. Keeping this vision in mind, a series of workshops were conducted as part of this research, aiming to show to students the many possibilities that a meta knowledge in perspective can bring for boosting their creativity and as a way of embedding the reflective creative actions of drawing while thinking and thinking while drawing.

IV.1 - Methodological and technological challenges and proposed solutions

While analysing the teaching of fisheye perspective, one can see that in the 180° case the drawing methods are not very time-consuming since every line projection is an arc of circle. However, as we saw previously, things get more complicated in the 360-degree case, which requires more care with approximations, and this is even more in the equirectangular case where each line projection requires careful constructions with auxiliary diagrams. In other words, spherical perspectives are a studio drawing experience if accuracy is required, rather than free spontaneous expression. Nevertheless, freehand sketching is also very much possible and even be done for production purposes. The purpose of having precise methods is turning these practices into disciplines that both entice the eye and stimulate the mind, yet this is quite hard to do teach within a limited time of a few hours. As an alternative to teaching the full method, grids can be used to accelerate the learning experience: artists can draw on top of them and use them as guidance. The limitation of grids is that drawing what is outside of it turns into a guessing experience, which complicates more elaborate constructions. To solve this, A. B. Araújo elaborated methods of dynamic grids that use transformation groups to draw any line projection from a single grid, in both equirectangular and fisheye perspective (see Part II, Chapter V). The dynamic grid method presented in two consecutive editions of the Bridges conference (Araújo, 2018b, 2019a), giving to students the opportunity of creating complex results using equirectangular and fisheye perspective in a very compressed span of time. Finally, in 2022 the cubical case was presented (Araújo & Olivero, 2022), trying to adapt the same set of basic constructions from the two previous cases. However, it was not an easy translation, as the cubical case has not a developed dynamic grid-based method. The strategy then, was to use one "all-inclusive drawing" made of a series of internal constructions, i.e., starting from one square and then multiplying, dividing, translating it so to build the rest of the geometry.

In terms of technology, as seen during the developments of this research and in particular while developing the motivations for the creation of IMWYM/Spheri, one of the major challenges in teaching spherical perspectives to beginners is the visualisation of what one is doing as one does it. A further complication is complicated to the visualisation of the teacher's drawing which, if it is either too small or not have enough contrast, it might get hard to visualise by the attendees. These problems were noticed at several drawing workshops in equirectangular, fisheye and cubical perspectives held since 2018. As seen in Part IV, Chapter III, IMWYM/Spheri addresses some specific solutions for facilitating the dissemination, such as the dual vision flat drawing / VR environment, and the integration of drawing software to the platform, solving the visualisation issues.

IV.2 - Conducted workshops

Since 2018, spherical perspectives have had many chances to be captured by an extensive public, both on location and through online teaching, reaching an audience with a wide spectrum of educational backgrounds from artists in this same PhD program, passing through undergraduate architects and designers, at Macau's University of St. Joseph and at the University of La Plata in Argentina (Figure 205), up to a group of researchers from Finland's Aalto University (Olivero & Araújo, 2023). Table 5 details the workshops for teaching spherical perspectives specifically hold during this investigation:

Table 5: Workshops carried on during the HIA investigation.

Date & Location	**Workshop**	**Attendes and Background**	**Duration**	**Perspective**	**Software**
Sep 2021, La Plata, Argentina, University of La Plata	Dibujo 360 para arquitectos y artistas - TAC course	42 Architecture	8h (divided in 2 days)	Equirectangular	Eq A Sketch and FSP Viewer
Jul 2022, Loulé, Portugal, Convento do Santo Spirito	Ambientes Immersivos	6 Arts	1h30m	Equirectangular	IMWYM v2
Aug 2022, Helsinki, Finland, Bridges Conference	How to Draw a Virtual Cubical Perspective Box	11 Arts, Mathematics	1h30m	Cubical	IMWYM v3
Aug 2022, La Plata, Argentina, University of La Plata	Dibujo 360 para arquitectos y artistas - TAC course	64 Architecture	3 h	Equirectangular	Eq A Sketch and IMWYM v3
Nov 2022 Faro, Portugal, ArtsIT Conference	Drawing Handmade Virtual Reality Panoramas	7 IT, UI/UX, Mathematics	1h15m	Equirectangular	Spheri

Nov 2022, Faro, Portugal, Artech 2023	Drawn onto a Skybox (not realised)	-	-	Equirectangular	Spheri
Aug 2023, La Plata, Argentina, University of La Plata	Dibujo 360 para arquitectos y artistas - TAC@ course	128 Architecture	3 h	Equirectangular	Eq A Sketch and Spheri (offline)
Aug 2024, La Plata, Argentina, University of La Plata	Dibujo 360 para arquitectos y artistas - TAC@ course	Unkwown Architecture	3 h	Equirectangular	Eq A Sketch and Spheri
Oct 2024, Florence, Italy, University of Florence	Drawing Handmade Virtual Reality Panoramas	ca. 10 IT, UI/UX, Architecture	4 h	Equirectangular	Spheri

Within these courses and workshops, audiences have varied to a maximum of 128 students in August 2023 during one of the collaborations with the Argentinian course TAC@ (Figure 205). In total, near 300 students attended the lessons on spherical perspectives since the collaboration with Tania Zuccari and Analía Jara started.

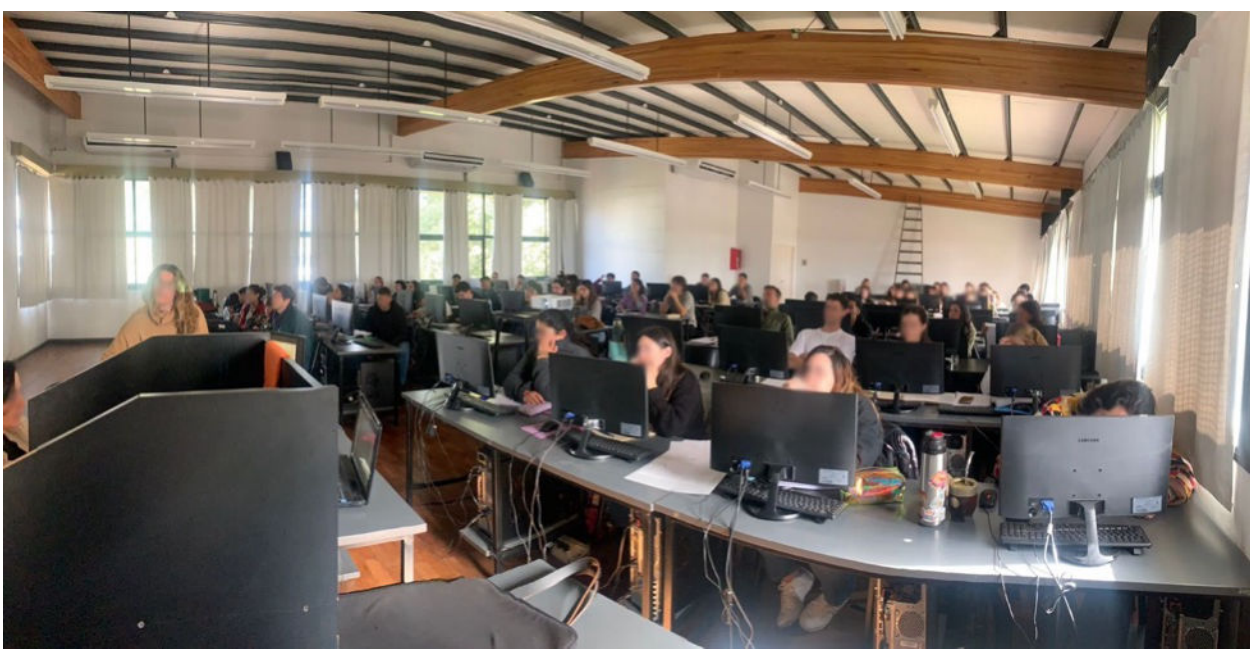


Figure 205: TAC@ course 2023, with 128 attendees, at the University of La Plata, Argentina.

IV.3 - Long courses and short workshops

As can be deduced from the table, the equirectangular syllabus has been the most extensively tested. In turn, the cubical perspective has been in development until very recently (in concrete terms, it still is), with the very last article published within this year (Olivero et al., 2025). Furthermore, and comparing with previous years, there are now more tools available to allow a smoother teaching experience thanks to Spheri[8]. For these reasons, it can be expected a raising interest in the spreading of cubical perspective within the next few years. One more highlight in this regard is that cubical perspective is, so far, the only perspective given as a long form course. In fact, thanks to the support of Professor Adriana Rossi from the university of Campania, Italy, students of Engineering, Architecture and Design received theoretical and practical concepts and delivered innovative results in the form of virtual tours from 2017 until 2021. A full development of these experiences can be consulted in (Olivero et al., 2020; Olivero, 2021; Olivero & Araújo, 2023; A. Rossi et al., 2021a, 2021b).

Teaching and applying cubical perspective as a long format course left parameters of reference to compare the creativity and complexity of the results. In fact, no surveys were conducted to extract conclusions from the students' experience (a weak point of the investigation) but some constants can be read comparing and analysing short workshops and long term courses graphical outputs: on the one hand, long term courses that integrated spherical perspectives within the regular curricula have worked better in terms of the transmission of knowledge and the comprehension of the concepts. Within these courses it was possible to do a different training of several small exercises and their correspondent practices, with results far more complex and developed.

Notice, for example, the case developed in Figures 206 to 209, where the student was not given any exercise for solving pointed arcs, but still, she decided to use them and solve their cubical perspective by her own initiative using the knowledge acquired during the course. On the other hand, short workshops tend to start with participants making the constructions alongside with the instructors, yet due to the complexity of the matter, many times the presentation finishes as a demo, with overwhelmed participants watching the instructors performing more advanced constructions. Much likely this is

[8] I will refer the installation only as Spheri, although I might be using IMWYM v3, like in the case of Finland. I will keep the names unified to avoid confusions, as it was precisely during these workshops that the installation was transitioning from IMWYM to Spheri and sometimes I used intermediate prototype versions.

happening due to the lack of necessary time for students to absorb and assimilate the theoretical concepts and the practical execution. See for example the example of Figure 210, which is one drawing in cubical perspective made within 1:30 hours during the workshop at the Bridges conference 2022: although some of the constructions were well done (e.g., the column going to the upper face), there is a clear block on the management of the ramp (centre and right faces), which was one of the hardest exercises conducted during the workshop. Much likely, this happened while the student was trying to assimilate - not without a certain confusion - the theoretical concepts, the practical lesson and draw at the same time.

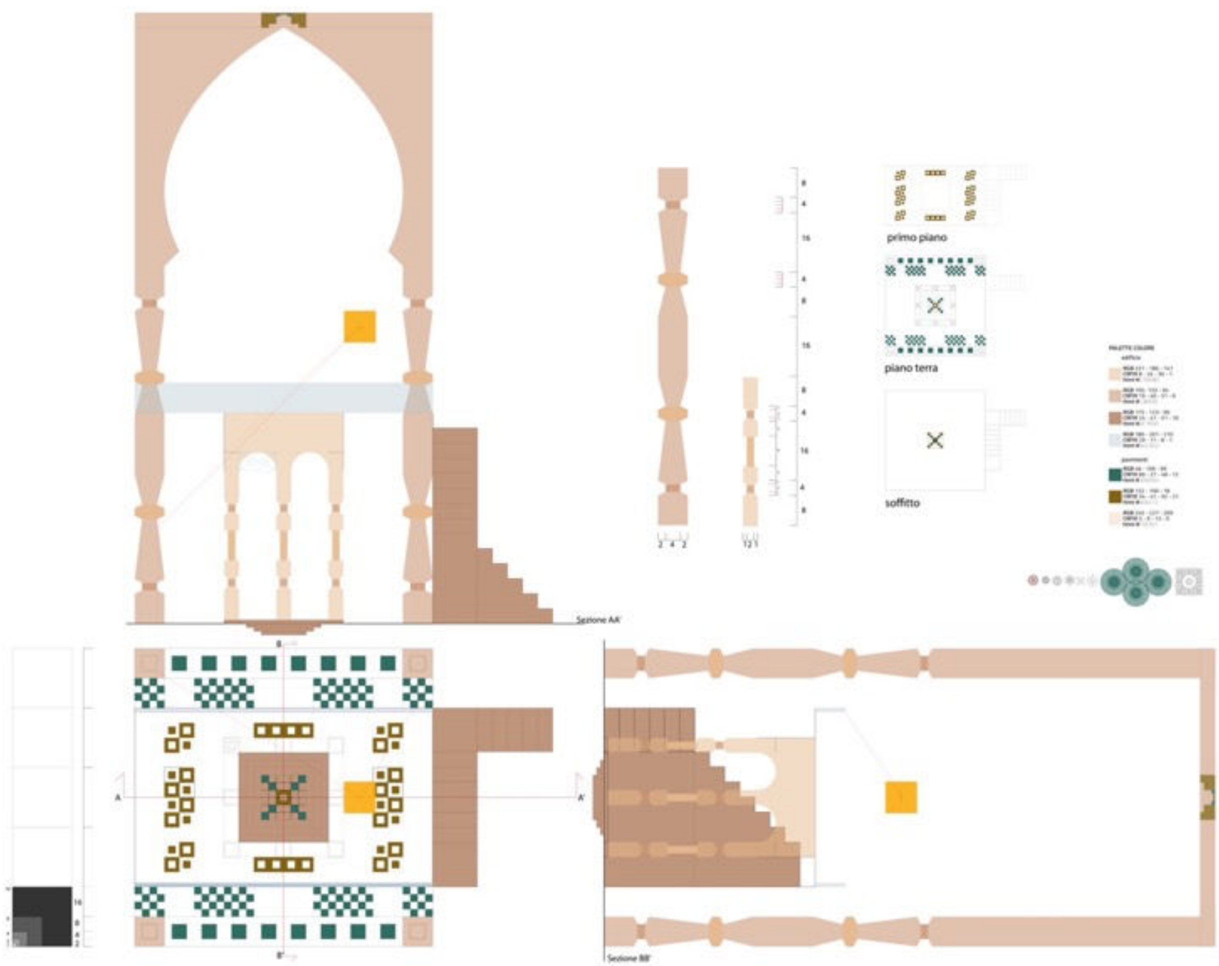


Figure 206: Composition exercise. A student's architectural proposal based on a pre-established set of proportions and patterns © Ibtissam Jaed, 2020.

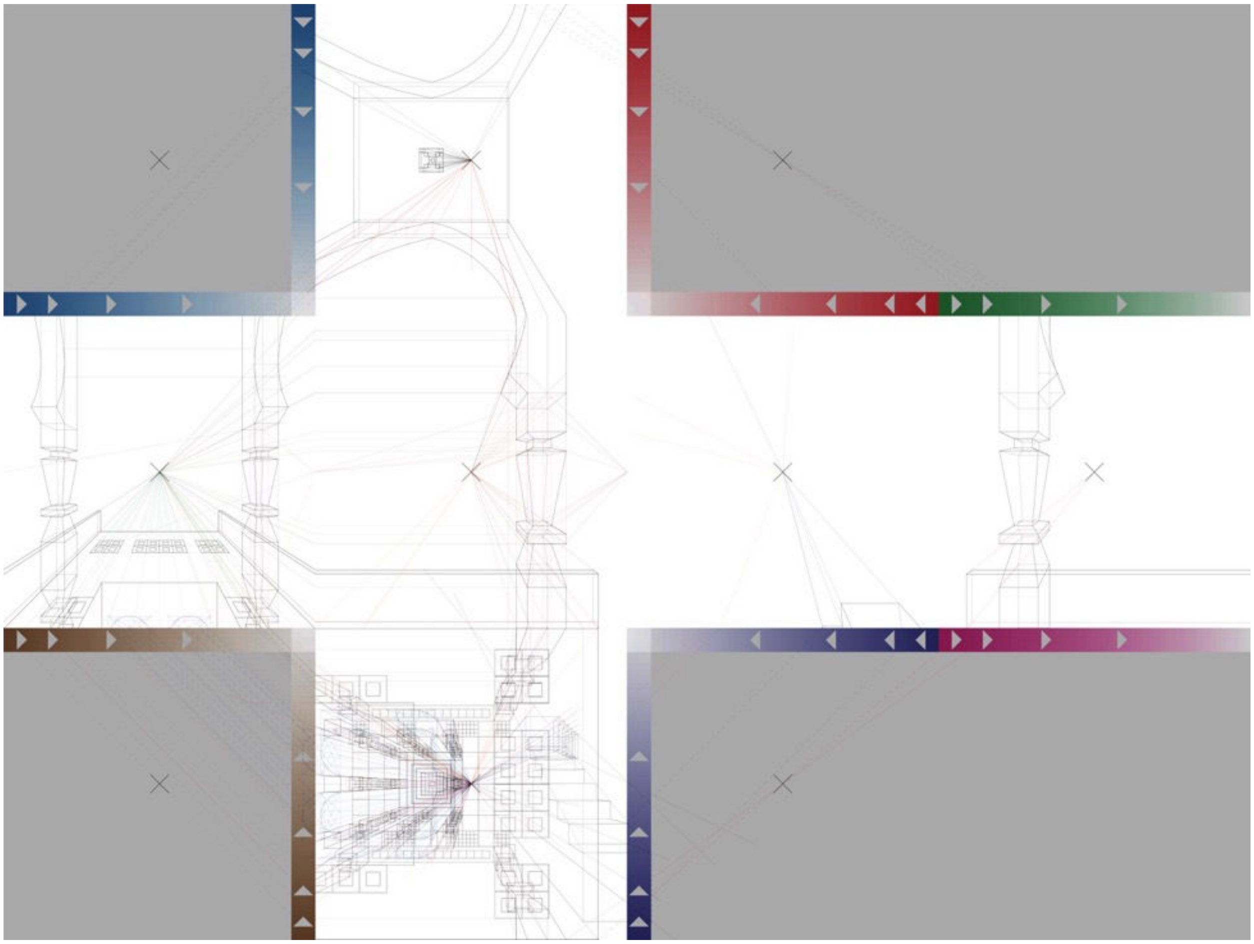


Figure 207: Cubical composition. The drawing combines several complex constructions, including pointed arcs which were never given during the classroom, she pursued the goal of building the by her own initiative and solved them using her recently acquired knowledge © Ibtissam Jaed, 2020.

The advantages of long courses are, therefore, noticeable. However, let me compare two short workshops to extract some further conclusions. The following paragraphs briefly compare "How to Draw a Virtual Cubical Perspective Box" (teaching cubical perspective in Finland, Araújo & Olivero, 2022), and "Drawing Handmade Virtual Reality panoramas" (teaching equirectangular perspective in Portugal, Araújo et al., 2022). The available time for the developments of the workshops were 1h30m and 1h15m respectively, a very short time even to transmit the most basic principles. Time is always one big limitation, especially when people attending the lesson have little or no background in perspective. However, some other factors affected very much both the results and the effective transmission of the knowledge. Let me show an analysis of both workshops through the following components: classroom setup; use of Spheri; given exercises; instructors; participants' background; and outcomes.

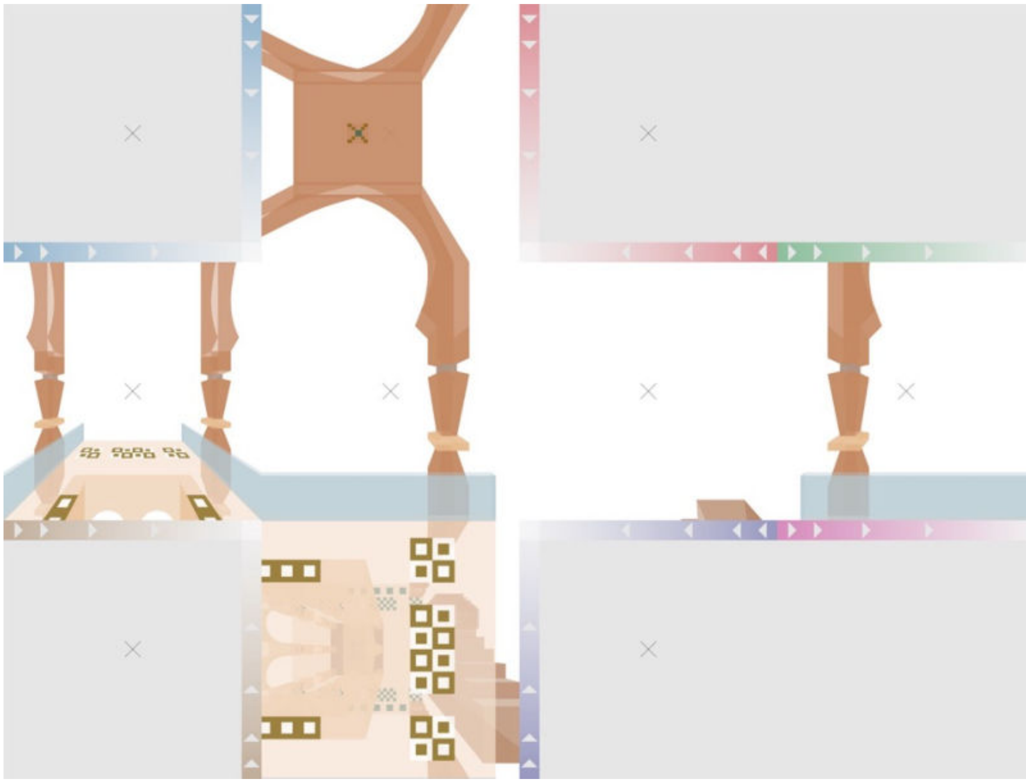


Figure 208: Vector-coloured cubical composition © Ibtissam Jaed, 2020.

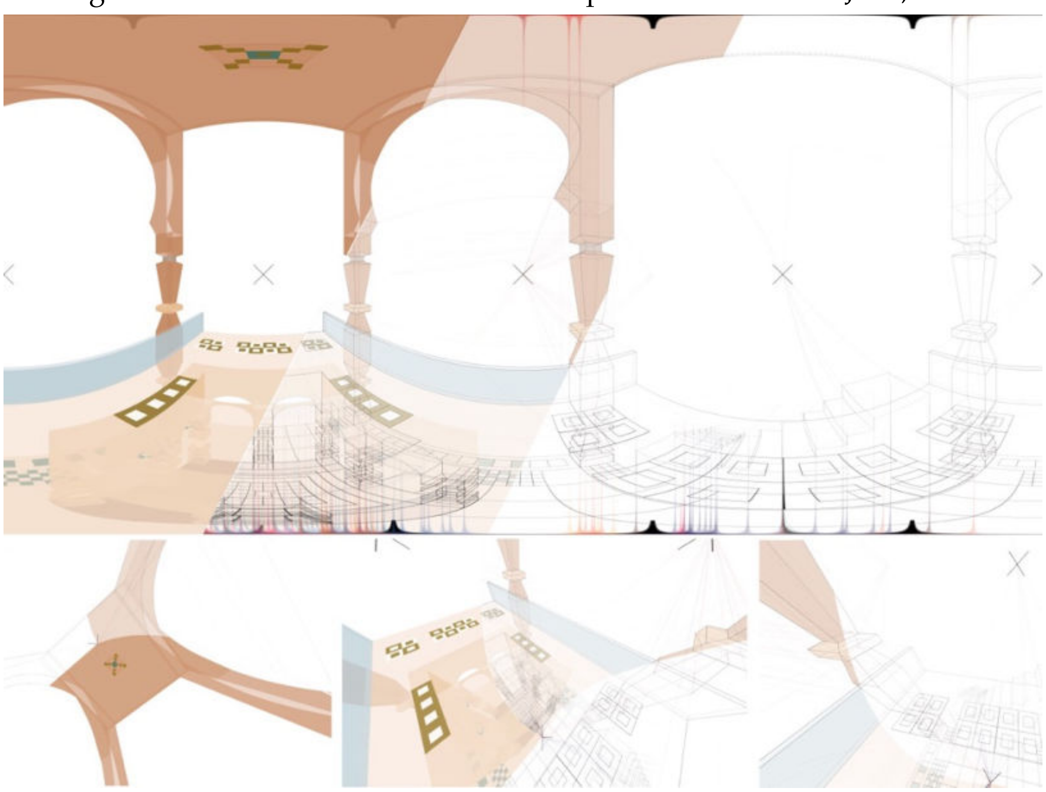


Figure 209: Mixed equirectangular panorama including the outline, the coloured surfaces and an intermediate merging (up). VR navigation (bottom) © Ibtissam Jaed, 2020.

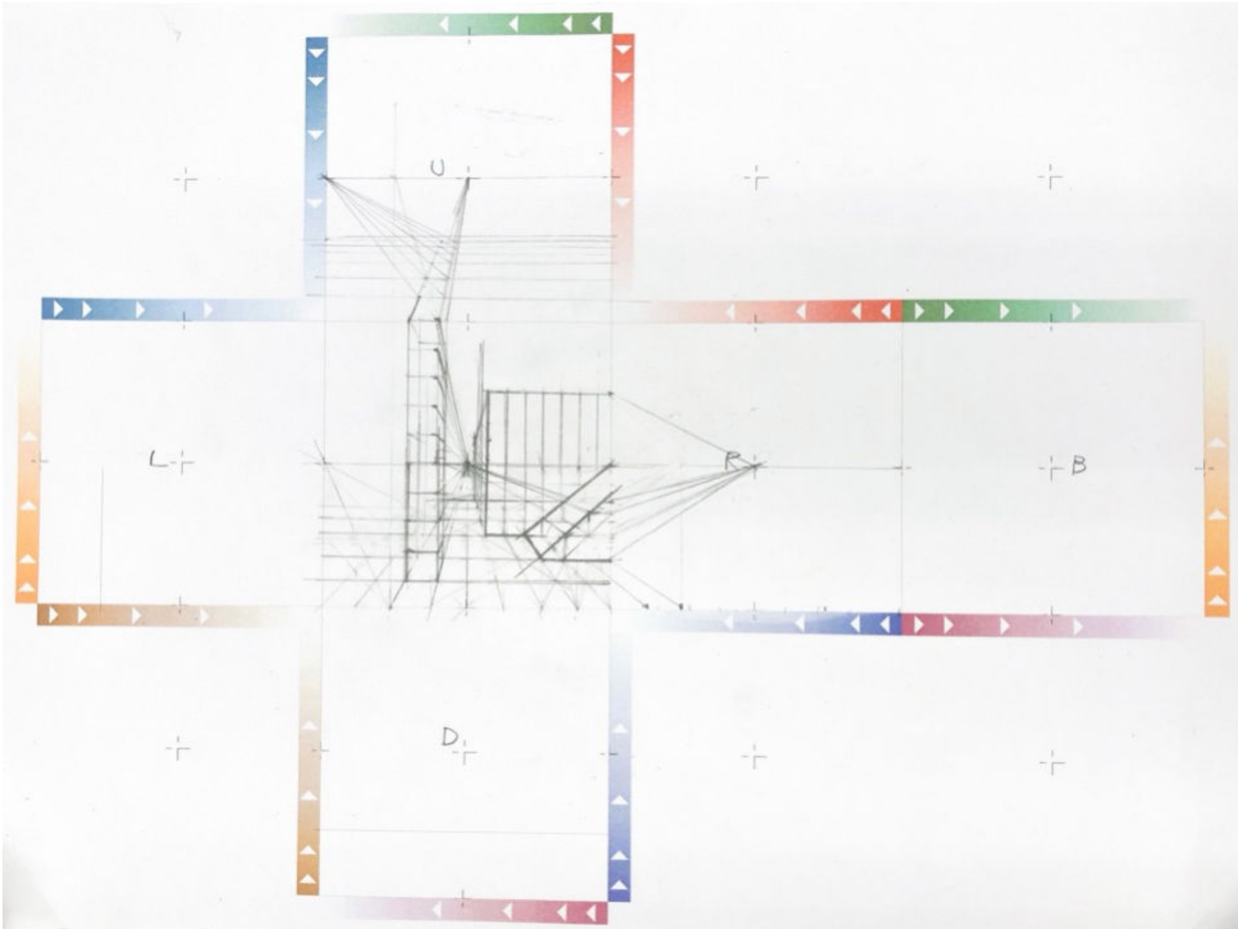


Figure 210: Cubical drawing of the Student A during the workshop at Bridges 2022.

IV.3.1 - The experience in Finland

Classroom setup: the workshop at Aalto University was hosted in a very comfortable and spacious room. This space was very well prepared for lessons, providing a setup combining four projectors with possibility to project different sources in each screen. For this workshop, two computers and two cameras were arranged over the main desk (pointing downwards) (Figure 211).

Spheri: the versatility on the arrangement's classroom enabled the use of Spheri at its best. Indeed, the physical handmade flat drawing and its VR correspondent view were shown independently and in parallel during the lesson: the camera C1 used one of the computers and broadcasted the physical drawing through projectors P1 and P4 while the camera C2 was connected to the second computer and broadcasted the VR viewport through Spheri, to projectors P2 and P3 (Figure 212). Having both the physical drawing and the VR viewport in different screens allowed the participants to see every detail from the physical drawing, the movement of the instructor, and find at the same time every correspondence within the virtual reconstruction of the cubical environment. Spheri took full advantage of the classroom features for the intended purpose of teaching spherical perspectives, solving several of the problems mentioned above.

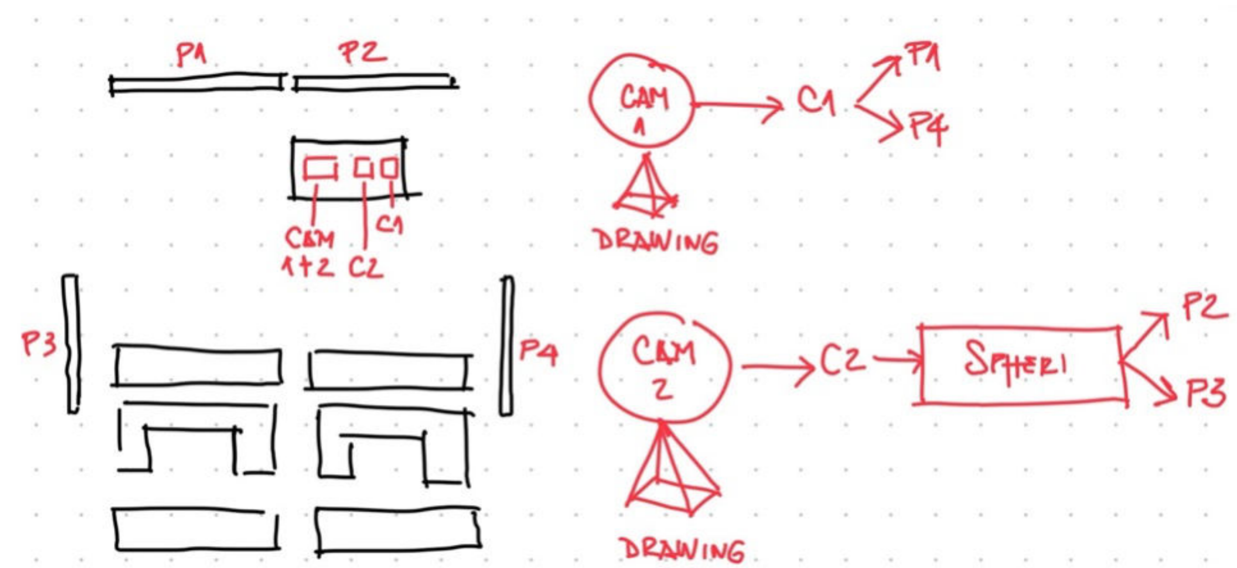


Figure 211: Setup during the workshop at Aalto University.

Figure 212: Using Spheri in Finland. Screen 2 is projecting the flat drawing (left) while Screen 1 is projecting the VR view (centre). The two cameras arrangement and the drawing used for the lesson (right).

Exercises: Finland's workshop had a very well planned and previously prepared set of exercises: one whole and internally consistent cubical drawing, which should have to be completed after a limited quantity of steps with increasing complexity (Figure 213).

Thanks to this preparation, the lesson could go as far as the audience was able to understand in the allotted time. All participants (11 in total) received a cubical map with a coloured frame of reference that helps identifying the connections between faces.

Figure 213: The composition used for learning how to draw a cubical perspective. See the full artwork at Figure 180 © Lucas Fabian Olivero, 2022.

Instructors: the lessons were given together with A. B. Araújo. It was necessary to divide tasks and act simultaneously to fully reach the teaching goals: while one instructor was concentrated in drawing and explaining, the other operated the platform and helped to solve the participants' doubts. Without this division, it might have been result cumbersome and time-inefficient to operate the installation and give the lesson at the same time by just one person.

Participants' background: the attendance at the Bridges conference was composed by a crowd with mixed backgrounds including mathematicians, architects, designers and artists. Regrettably, as no specific survey was conducted, the specific background of work, motivations for the attendance and previous drawing skills could not be ascertained.

Results: thanks to the combination of elements described above, the participants were able to follow every construction step-by-step, reaching almost the same level of finishing (Figures 210, 214, 215).

Hence, judging by the consistency of the graphical results, the interaction with participants, and our own comparative experience relative to similarly timed workshops in the past, the Finland workshop resulted in a much smoother teaching experience, with a clear and more orderly transference of perspective's main concepts.

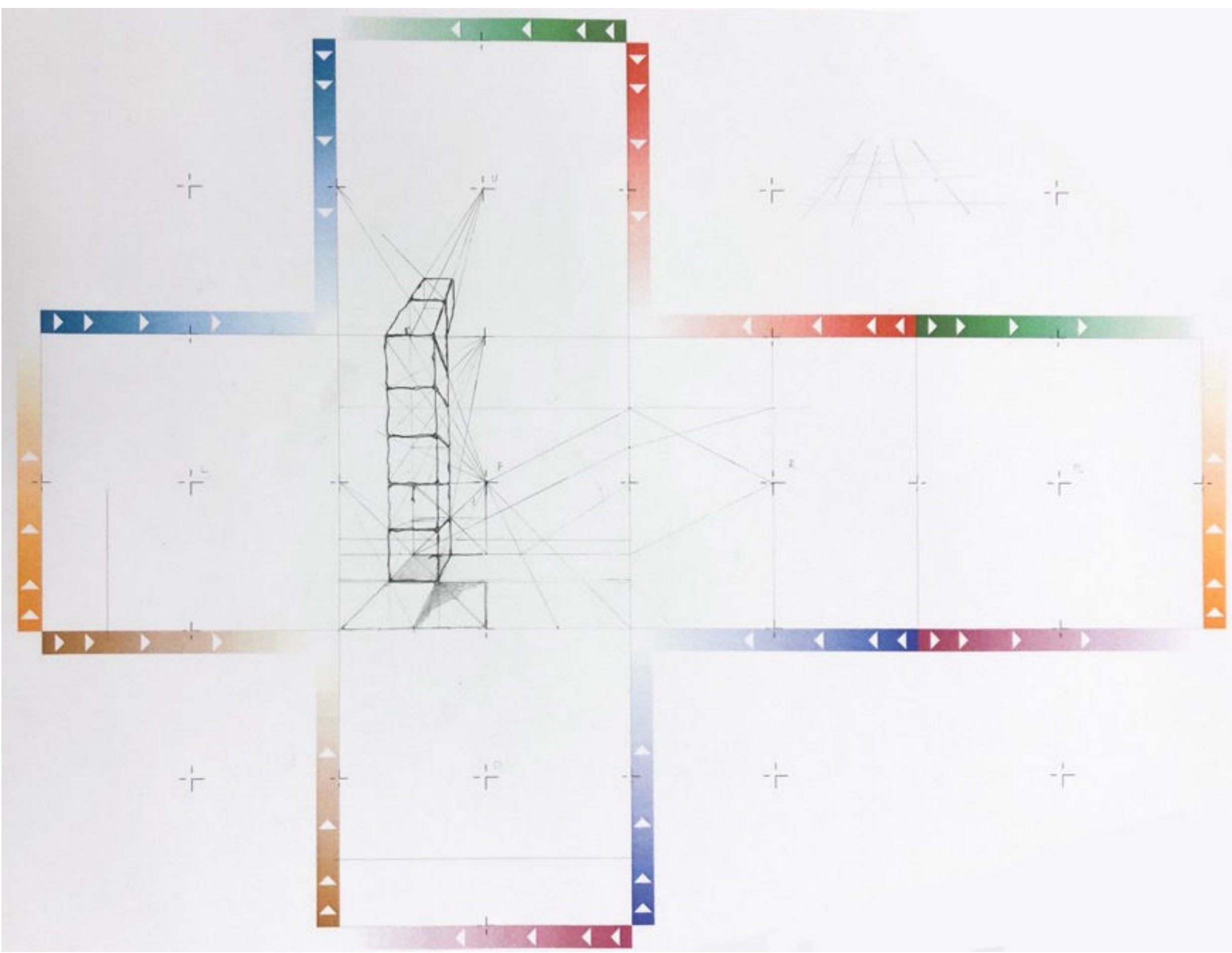


Figure 214: Cubical drawing of the Student B during the workshop at Bridges 2022.

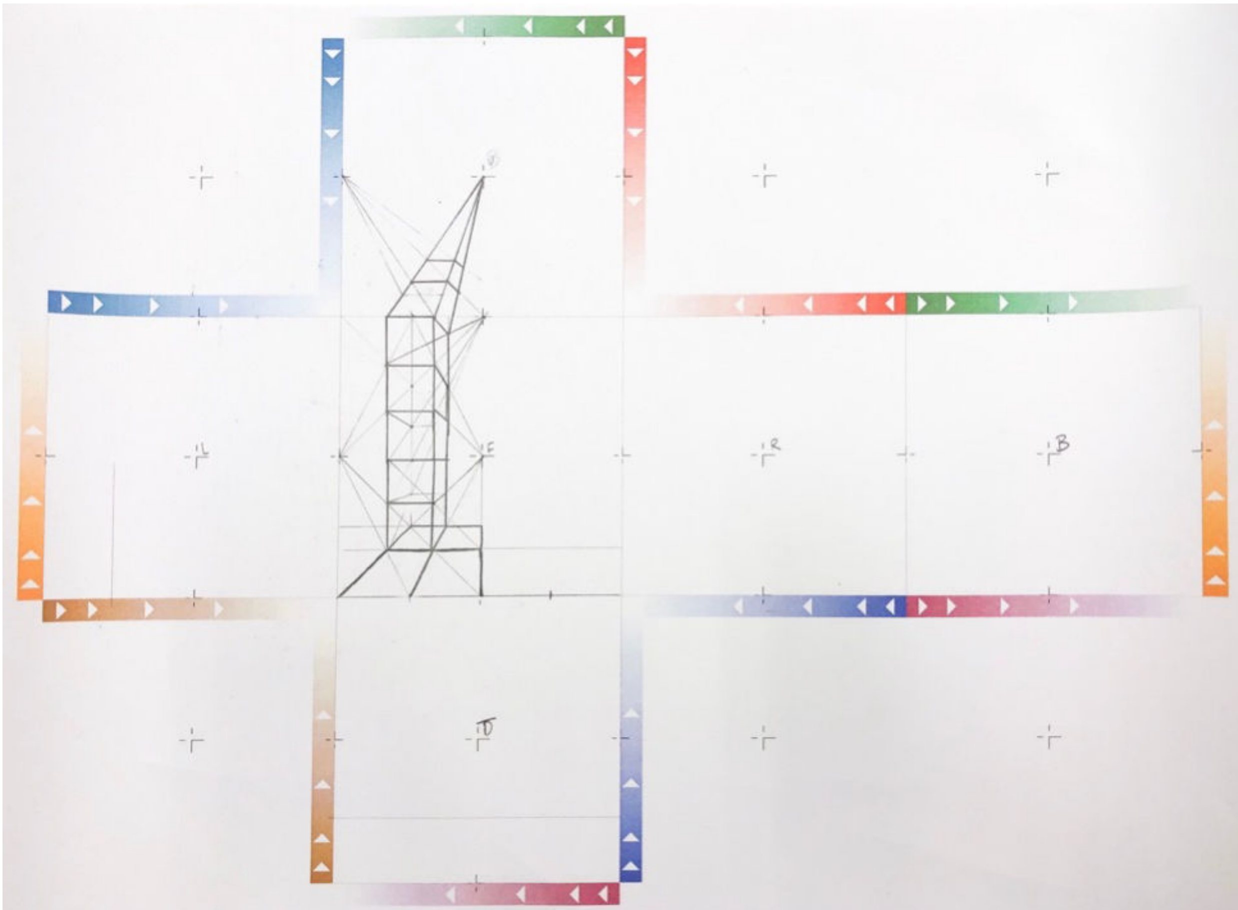


Figure 215: Cubical drawing of the Student C during the workshop at Bridges 2022.

IV.3.2 - The experience in Portugal

Classroom setup: the workshop in Portugal was not held in a proper classroom but arranged in an open space between two conference rooms (Figure 216). This workshop turned into a more informal event held in what was, simultaneously, the coffee break room. In fact, the arrangement posed some serious learning barriers: participants had to sit on the floor and draw by supporting their paper in the carpet; noises and voices came out from the conference rooms, getting mixed with instructors' voices and therefore making communication harder; the informality of the setup broke the attention of the participants several times as some people walked in coming in for a coffee and left as soon as they will finished it, making noise and talking on top of the class; only one projector was available and neither the lighting conditions nor the quality of recording were optimal for the projected image (Figure 217); finally, the layout posed problems for the camera, as the drawing surface was vertical on the wall, hence the drawing would sometimes be covered by the instructor working on it, hiding both the construction and the drawing motions.

Spheri: because only one projector was available, Spheri had to be adapted to one screen and instead of having one full screen for the flat drawing and another for the VR viewport, both views needed to be rearranged onto a single split output showing the two images side-by-side (Figure 217).

Exercises: this time there was not a pre-established set of exercises. Instead, participants were guided to draw the workshop's room from direct observation. As the room was a simple and a clean geometry, it represented a good example for understanding the very basics of spherical perspective and the equirectangular format. However, participants did not receive any grid to get oriented within the equirectangular map since using dynamic grids without a proper hard support would have turned to be even more complicated. The frame of reference was created on-the-fly by folding the paper in regular sections until reaching a 2x1 proportion.

Instructors: the workshop was delivered together with A. B. Araújo and C. M. Sgrinzatto. Although we all provided crossed knowledge, helped the students and at each other during the whole workshop, A. B. Araújo focused on the theory, C. M. Sgrinzatto in the practice of basic guidelines, and I took care of the flat drawing / VR view correspondence using Spheri (Figure 218).

Participants' background: although it was not verified through a survey, it is feasible to assume an audience specialised in IT and design careers, with artistic and technical background in the fields of Computer Sciences, UX/UI and Digital Media Arts due to the nature of the ArtsIT congress.

Results: this time, the graphical results were more mixed: some participants managed to grasp some of the basic principles and materialise them on the paper, yet some others did not manage to do so at all (Figure 219). Once more, surveys might have given a better answer to determining the reasons for such a disparity, but at least by analysing the outputs we could venture that participants might have encountered more complications in translating the principles to the paper (in part due to the lack of reference grid) than in the theoretical understanding of the new perspective. This conclusion is based on the fact that several of the drawings are qualitatively but not quantitatively consistent within the principles - for example, in the way the geodesics are developed on the equirectangular map.

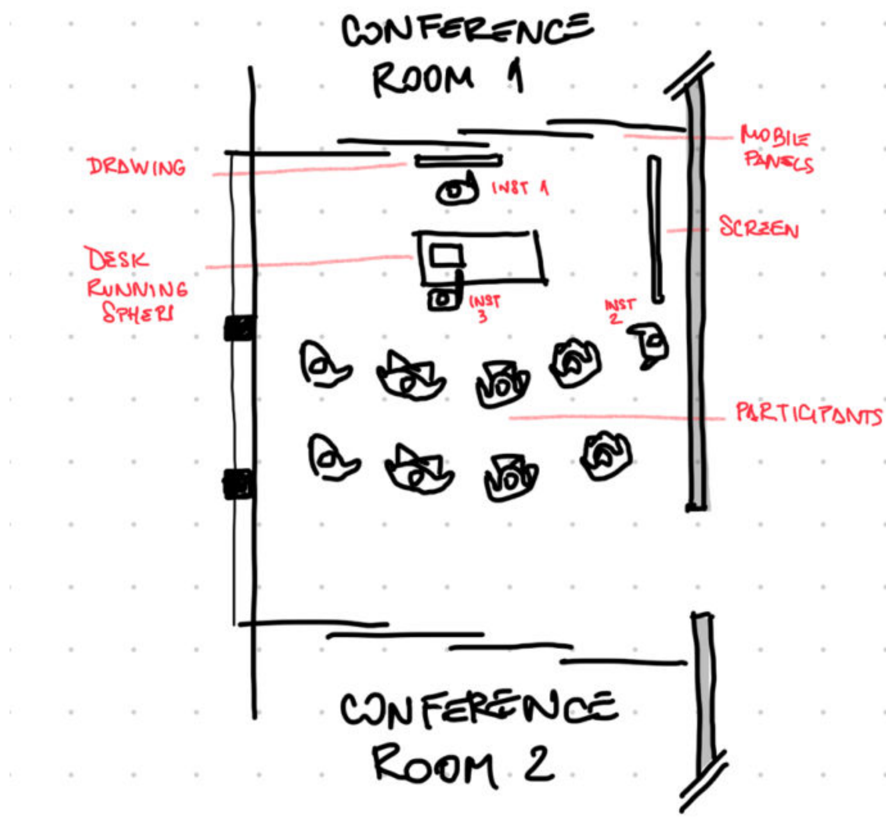


Figure 216: Setup during the workshop at the EVA Senses hotel, Faro, for the ArtsIT conference.

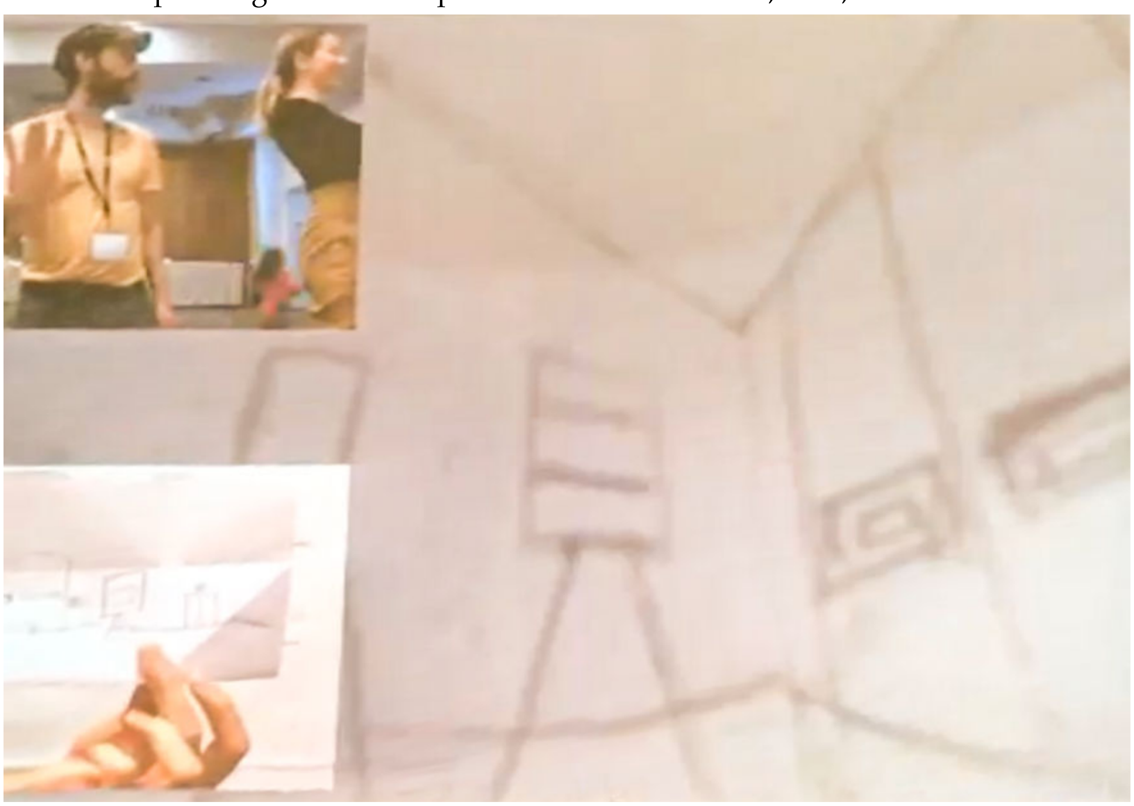


Figure 217: A. B. Araújo performing the VR navigation of Mathilde Papillon’s drawing.

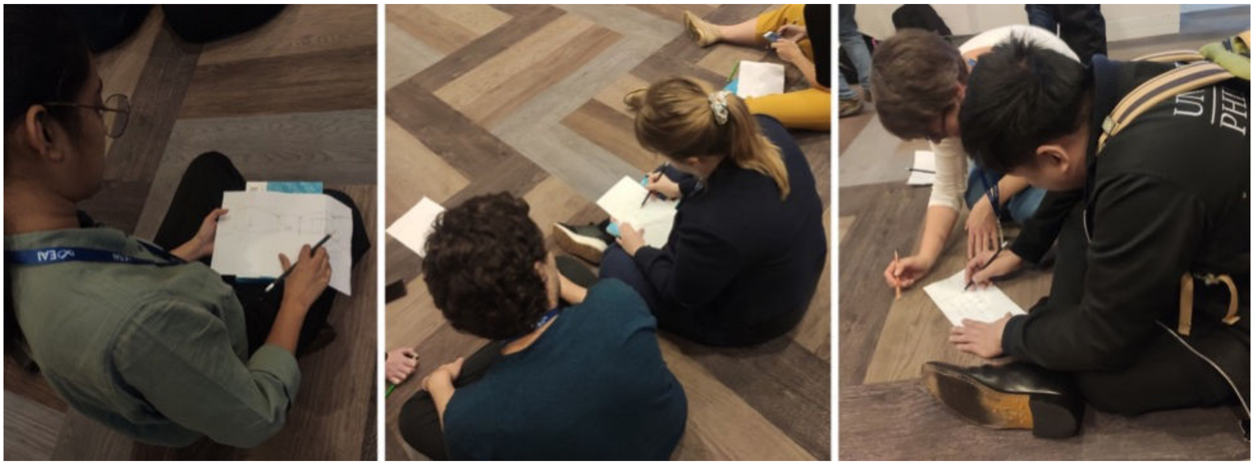


Figure 218: Instructors helping the participants.

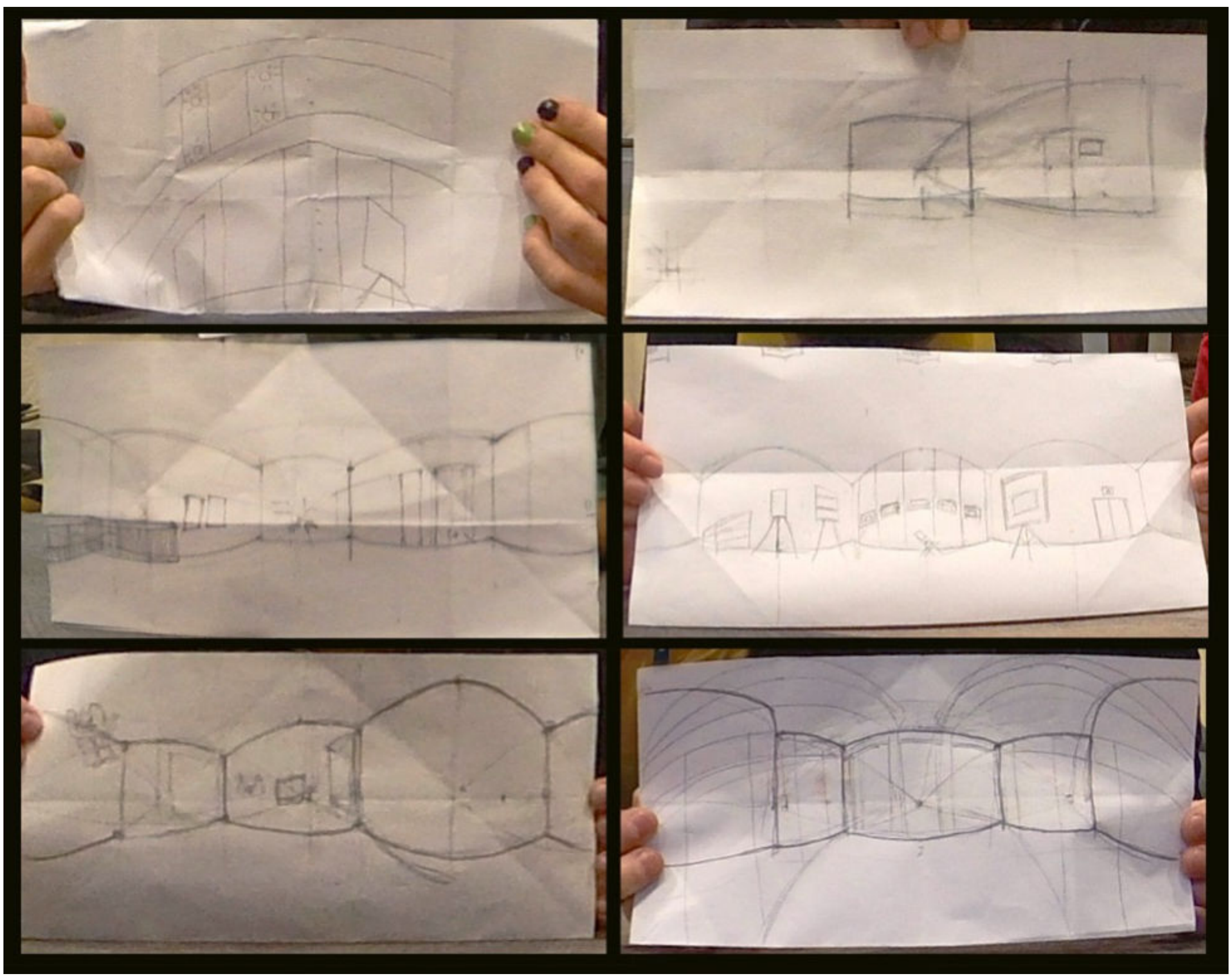


Figure 219: Results from some of the participants.

In short, the workshop in Portugal was another opportunity to test Spheri with the equirectangular format and with only one output screen. Despite this limitation, the use of Spheri offered an interactive hands-on learning experience, allowing participants to engage in practical exercises by drawing the room from direct observation. Although the workshop had good points (it attracted a diverse audience, promoted interdisciplinary learning and collaboration, had the presence of three instructors with crossed-knowledge in theory, practice, and technology) that provided participants with a comprehensive learning environment in a relaxed venue; there were also some important cons and challenges impacting the overall learning conditions (the workshop's setup, logistic limitations, noise interference, suboptimal lighting, and limited recording quality). Furthermore, the absence of surveys hindered the ability to determine the reasons for mixed results, limiting the feedback and insights for improvement to the graphic results.

IV.4 - Reference exercises

From the experiences during the workshops, it can be seen the importance of having preset exercises to compress the learning experience without losing effectiveness. In Bridges, we used an all-inclusive composition to teach cubical perspective, involving the construction of **squared tiles** (Figure 220); **a cube**, using one of those tiles as a base (Figure 221); **columns extending across edges**, tiling uniformly in different faces (Figure 221); **walls**, with given proportions and sub-divisions (Figure 222); **ramps** connecting two given levels (Figure 223); and the **extension of geometrical elements across faces with discontinuous gaps** (e.g., top and back faces) (Figure 224).

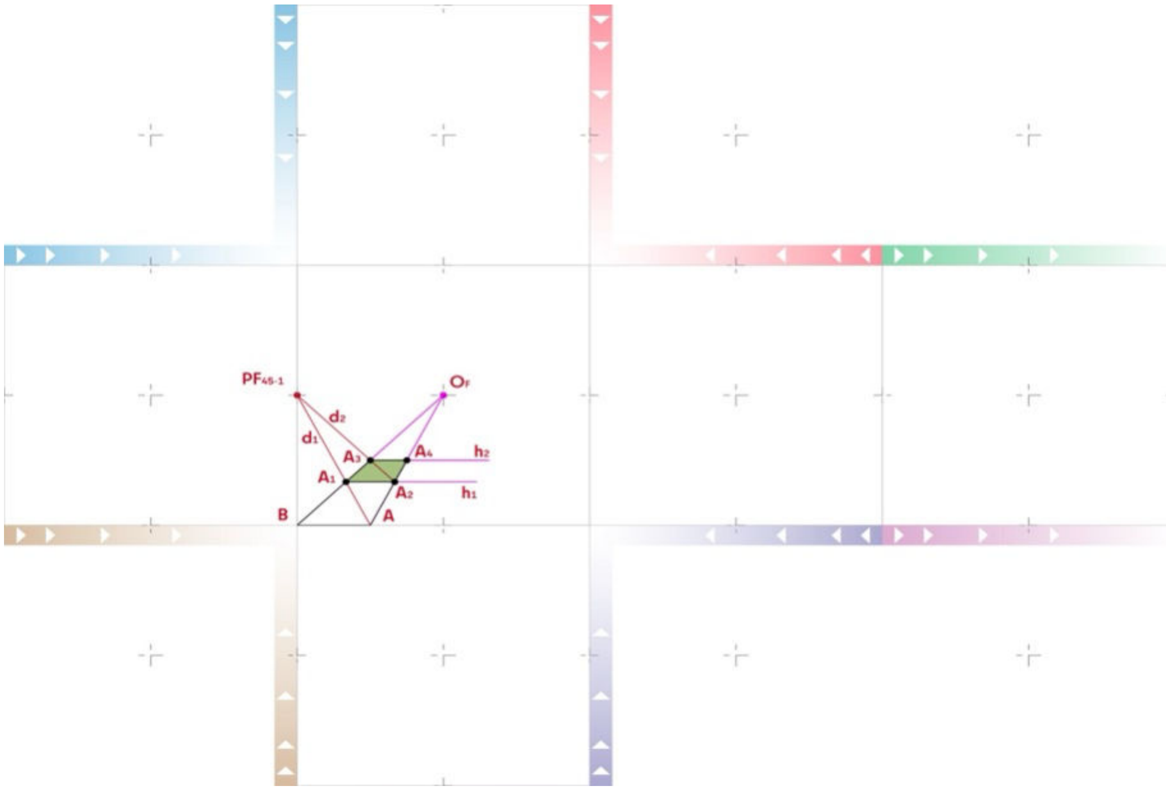


Figure 220: Construction of the first squared tiles.

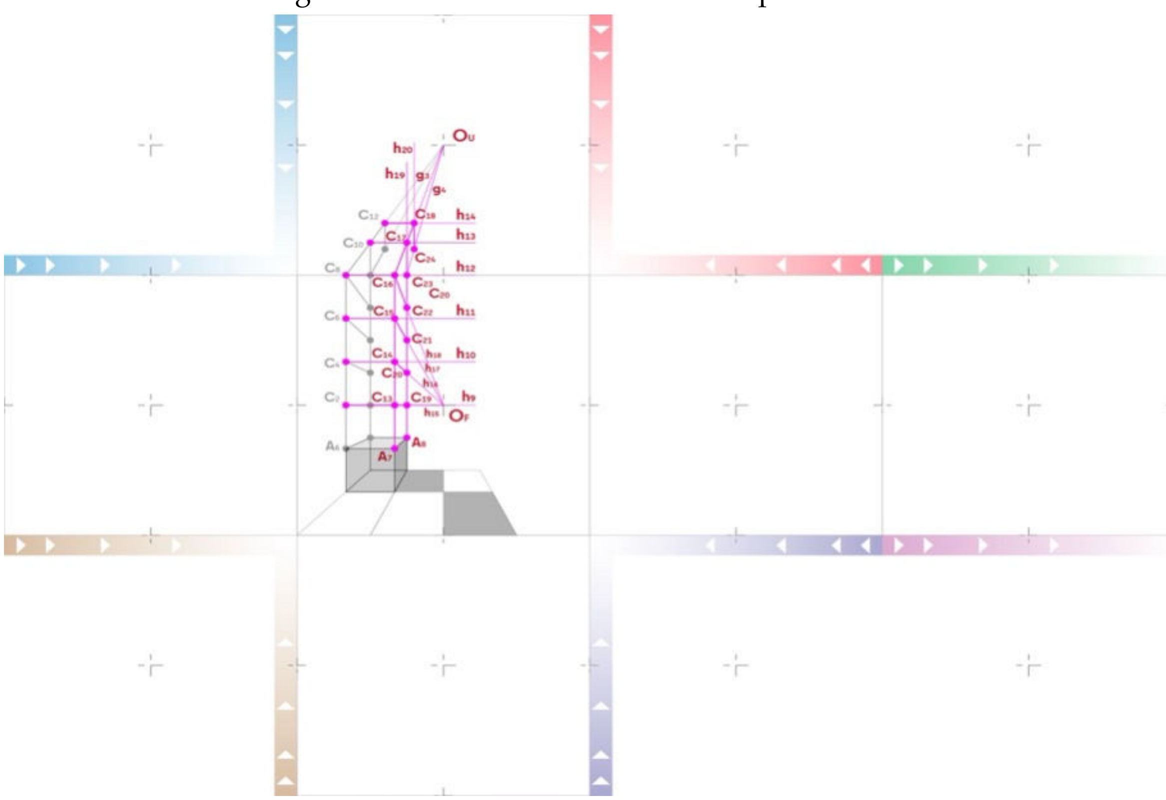


Figure 221: Raising a column in two different faces.

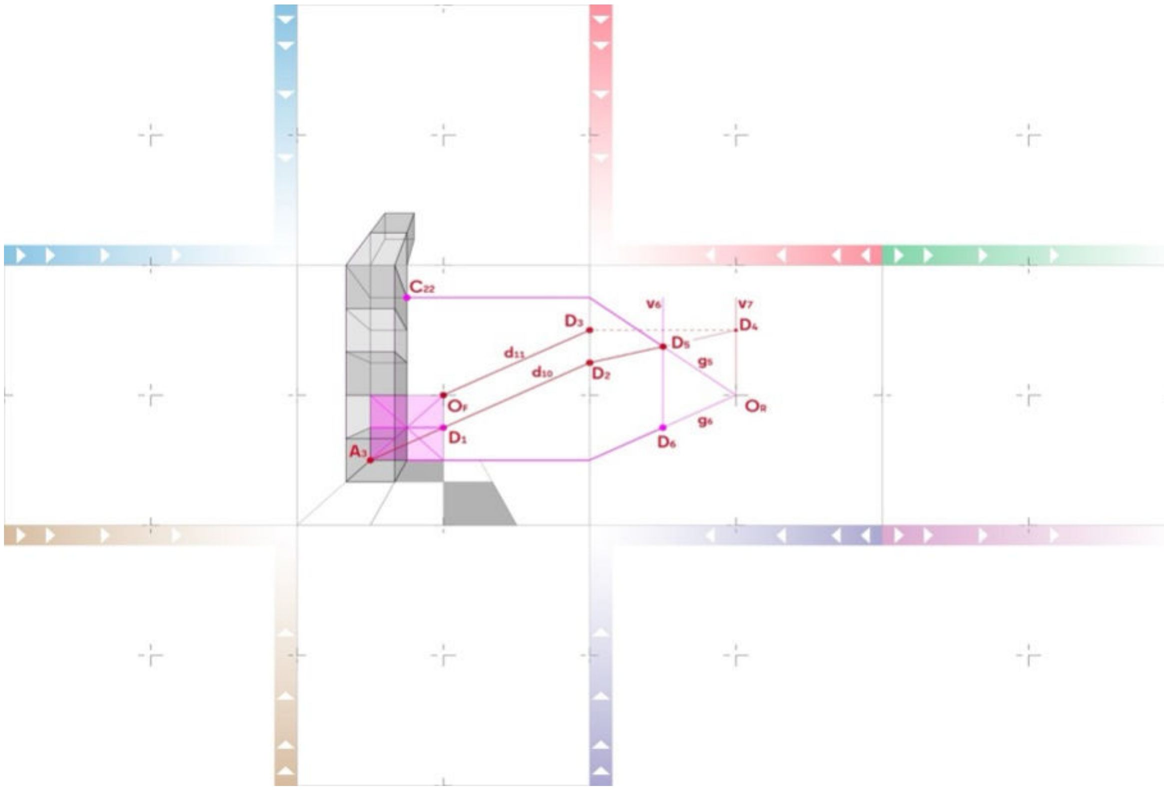


Figure 222: Drawing a wall with a given proportion.

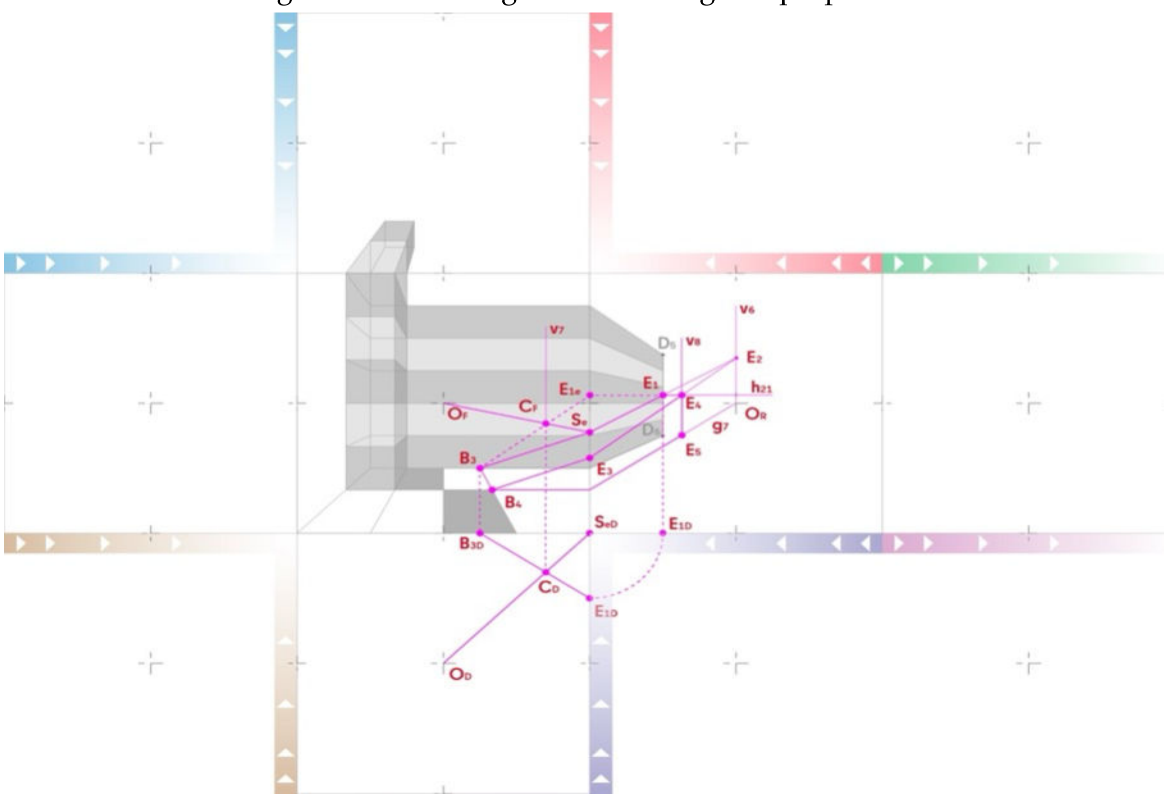


Figure 223: Building a ramp using both the A-Construction and the Old-Construction.

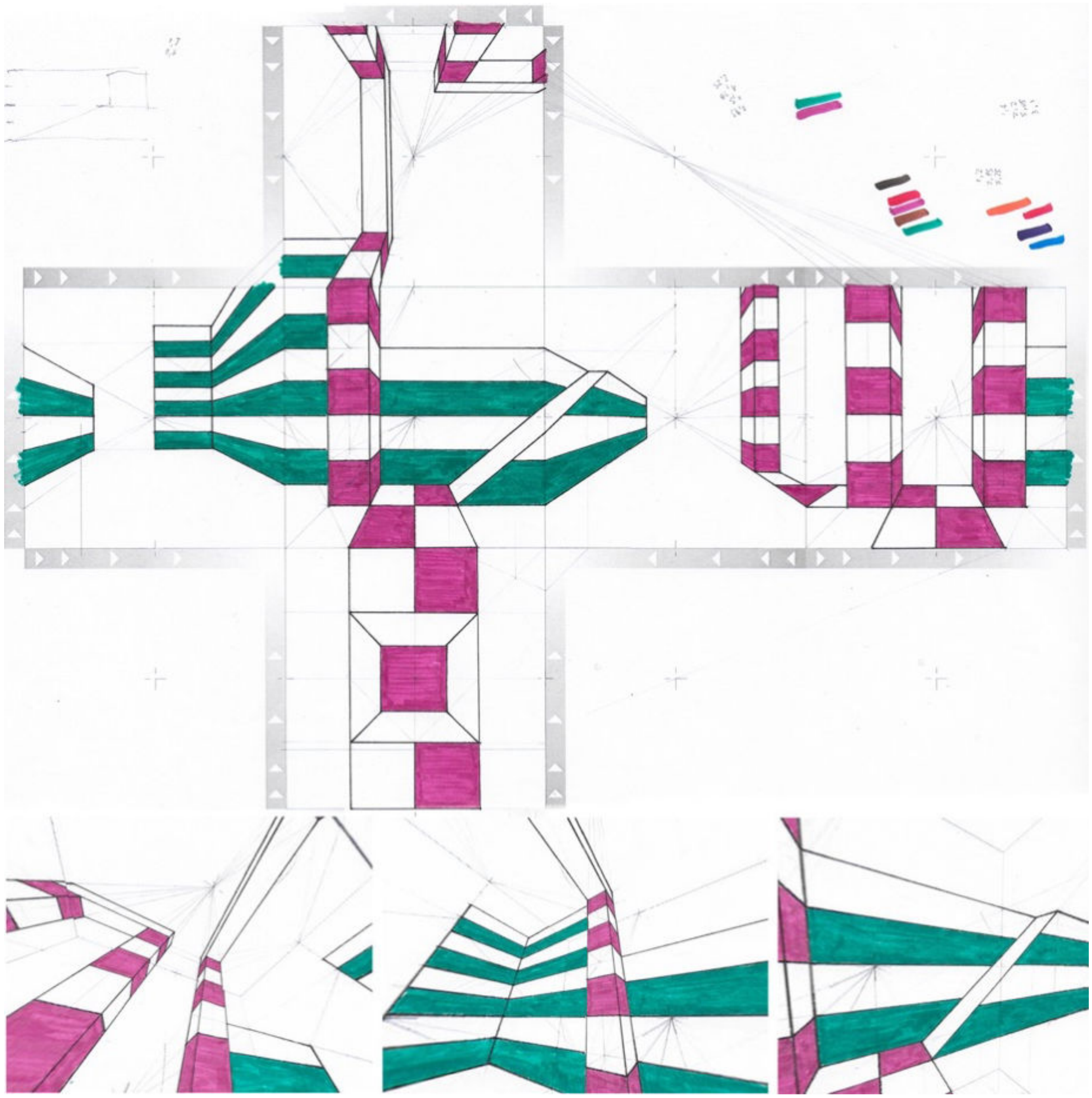


Figure 224: The complete artwork for teaching cubical perspective used in Bridges 2022 (top). VR navigation (bottom).

This same idea but using the equirectangular format was used for the workshops in Argentina. Notice that, even if this is another perspective, the exercises can be pretty much the same and keep their effectivity on teaching spherical perspective's concepts. This applicative case starts with the same tile than previously (Figure 225), builds up a cube and a column by multiplying that cube (Figure 226), then builds up ramps (Figure 227) and geometries behind the observer (Figure 228). In this case there is also a particular variation: staircases, for which the equirectangular perspective has a smooth method for plotting them by using geodesics and alternating vanishing points (Figure 229).

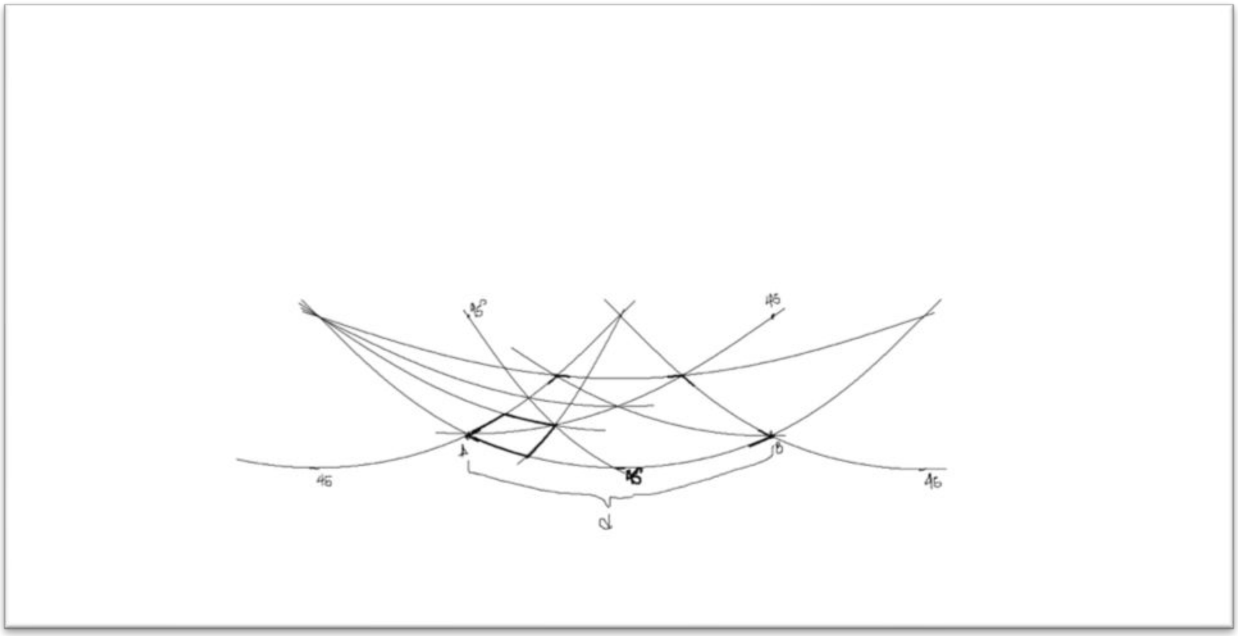


Figure 225: Building a tile by subdividing a module.

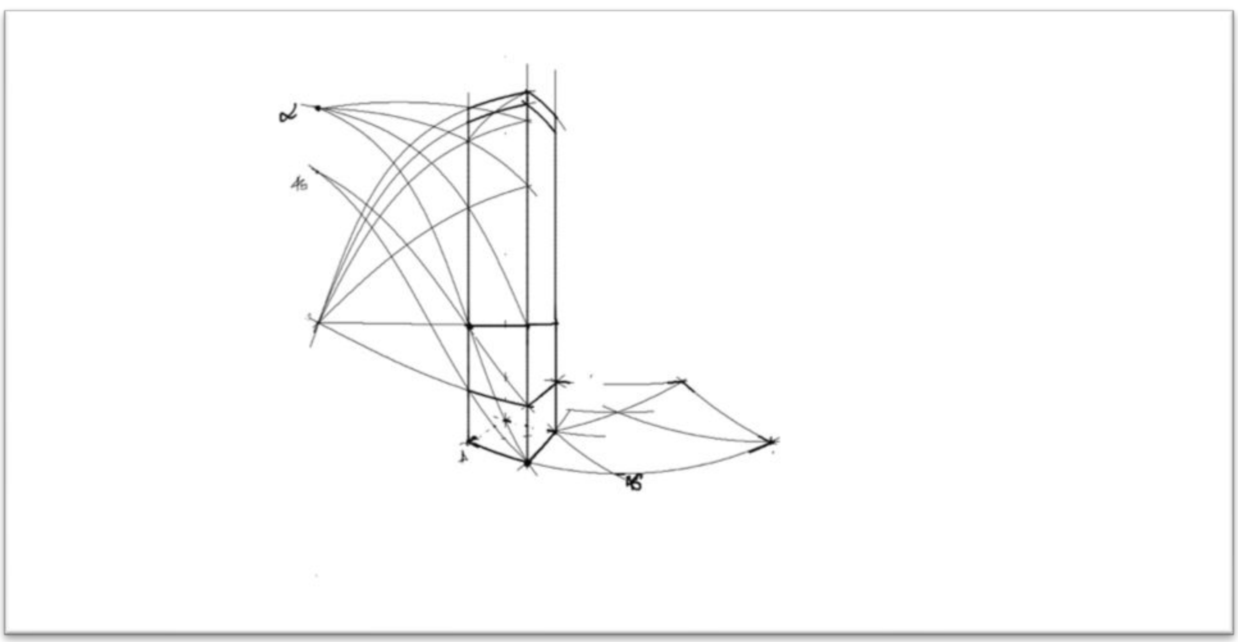


Figure 226: Drawing a cube and a column via multiplication of modules.

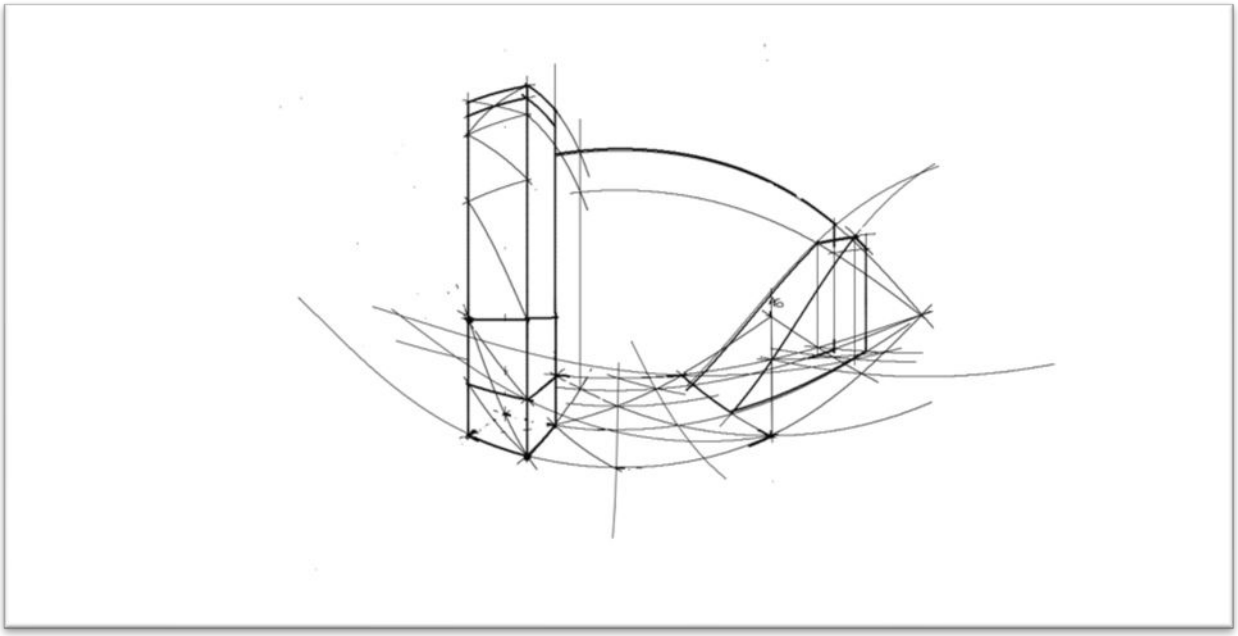


Figure 227: Drawing ramps and walls given certain proportions and angles.

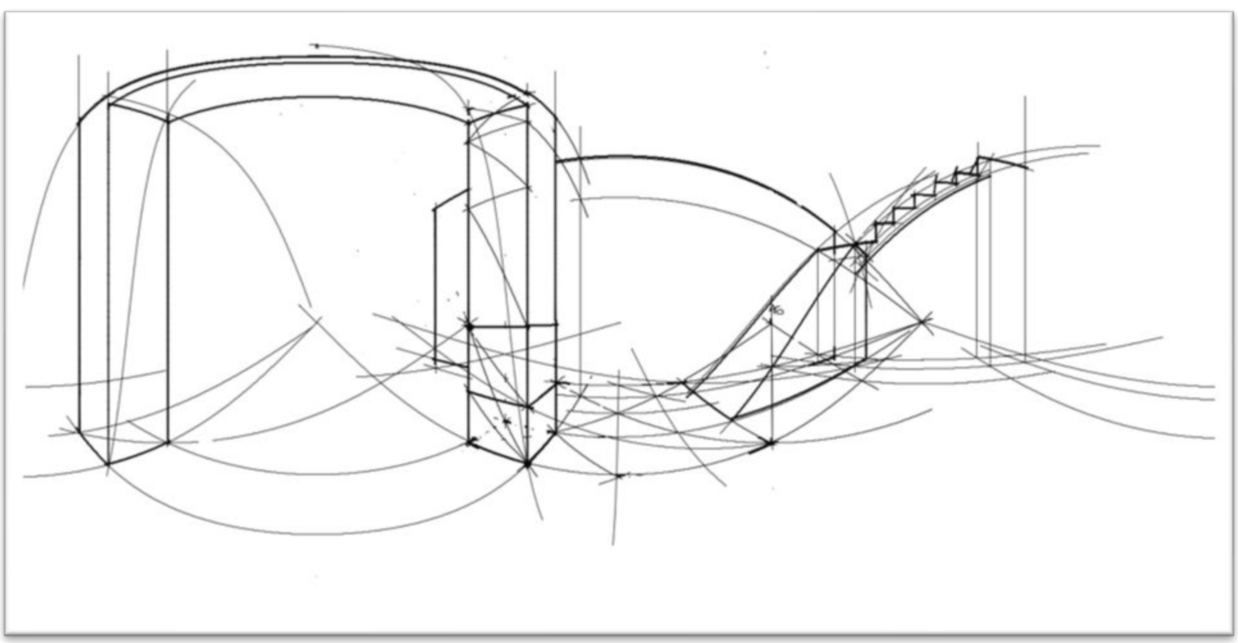


Figure 228: Completing staircases and geometries behind the observer.

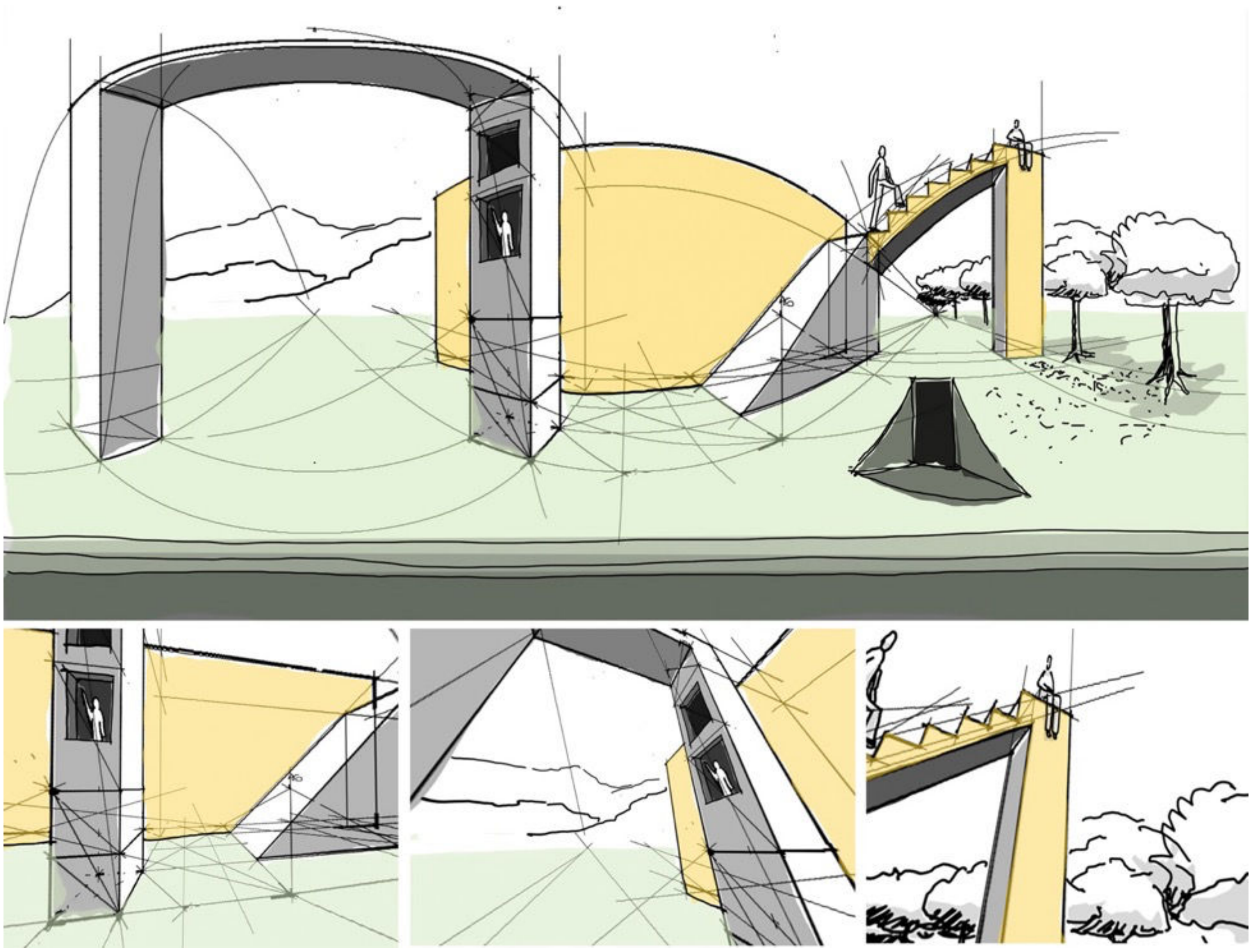


Figure 229: Coloured final composition (up) and VR images (bottom).

IV.5 - Section's highlights

The teaching applications put under the spotlight certain aspects that strongly condition the transference of the knowledge on spherical perspectives. For example, the extension of the teaching sessions is mostly condensed to short workshops, as spherical perspectives *per se* do not have their own discipline within the regular courses, neither in arts nor in architecture nor other related careers. The most regular option was with the course "TAC@" (Advanced Techniques for the Communication of Architecture, former "TAC" Technology, Architecture and Communication) at the Faculty of Architecture of the University of La Plata, Argentina, whose professors on charge Tania Zuccari and Analía Jara gave us the opportunity to hold the workshop every year since 2019. This constancy on the frequency allowed the definition of a package of exercises that optimised during the years, accelerating and condensing the teaching to key elements within the available time.

Furthermore, the teaching applications also gave the space for experimenting new features of the Spheri. For instance, the cubical perspective input was tested and live shown to the attendees of the course at Bridges 2022 (Araújo & Olivero, 2022). Even if the feature was still in the stage of prototyping and backend operated; the chance at Aalto University proved successfully that the installation was in its good way on becoming a useful tool for teaching cubical perspective.

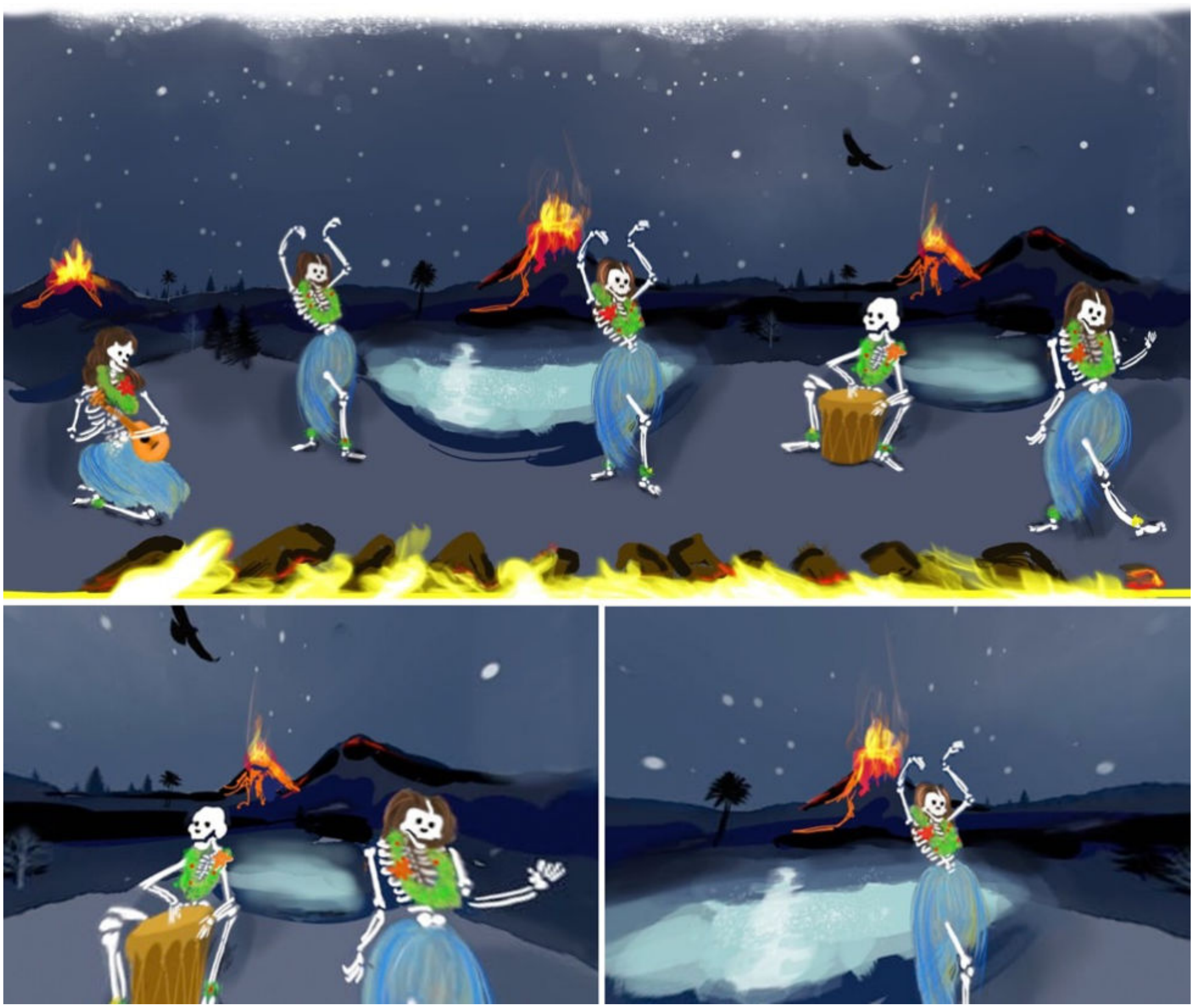


Figure 230: Ritual de calaveras, equirectangular perspective to recreate the day of the dead © Jimena Sierra, 2021.

For this purpose, the installation was setup with the input camera pointing to a paper fixed on a desk and, thanks to a generous setup with multiple projectors, it was possible a flawless and fluid on-the-fly interaction between the flat cubical perspective drawing and the VR content along the workshop. Furthermore, the body tracking functions helped to show the VR results and focus details as they were being created. Finally, the different workshops also helped to reach a large audience comprehending almost 300 students with backgrounds in arts, architecture, mathematics, computer sciences and UX/UI, with impressive and creative applications ranging from surrealistic composition of mythological scenes, passing through the design of architecture and up to the reconstruction of environments based on an artwork (Figures 230, 231).

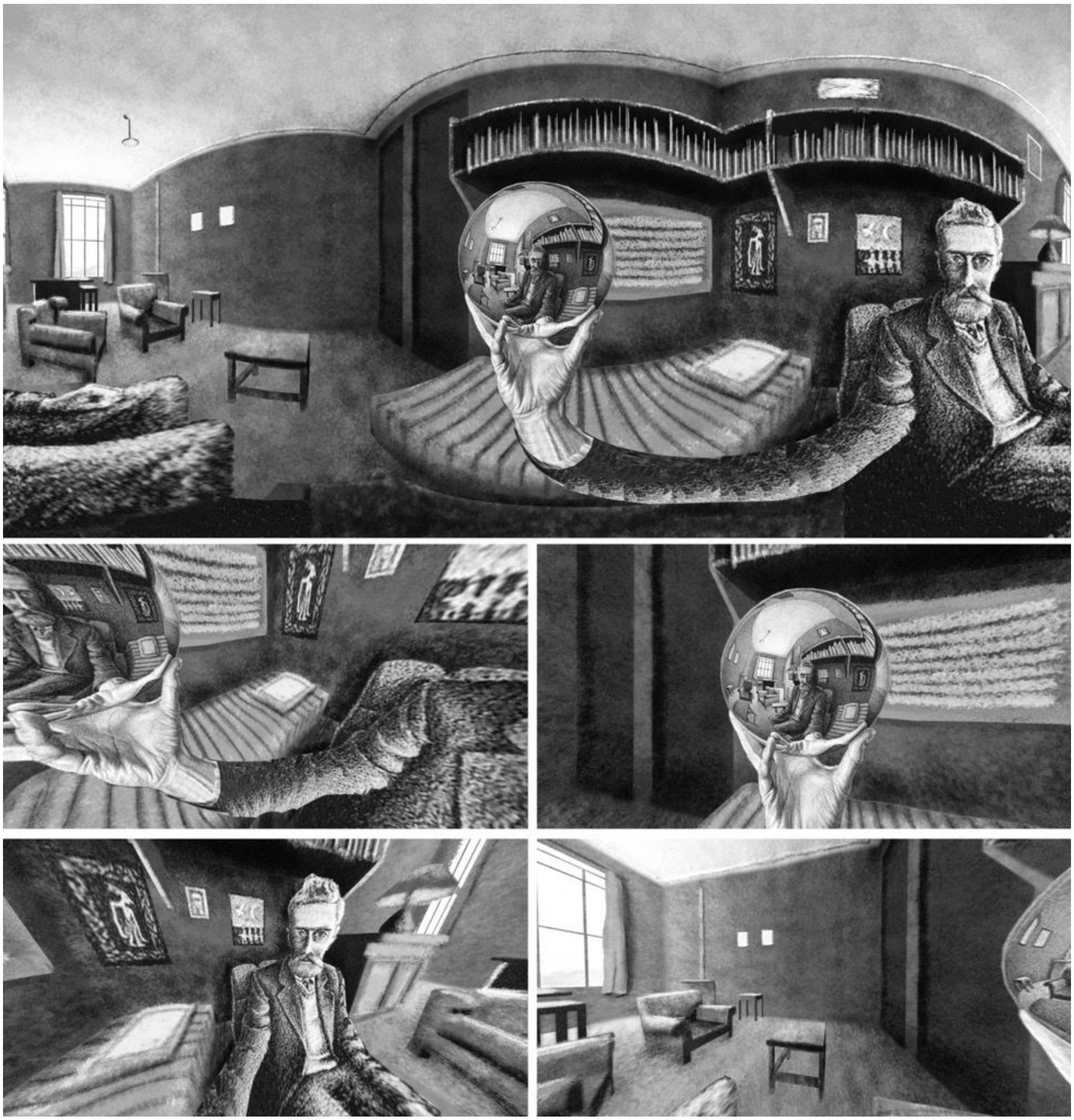


Figure 231: Reconstruction of the room reflected in Hand with Reflecting Sphere by M. C. Escher © Julian Alcalde, 2021.

All in all, the experimentation of spherical perspectives needs the support of the teaching community, since it is them who open the doors to new opportunities and creative chances. Sadly, there was no chance to hold workshops in the environment of art faculties, but it is expected this investigation will motivate new collaborations for discovering, enhancing, promoting and enhancing the use of spherical perspectives and Handmade Immersive Artworks.

V - SOLVING PROBLEM 6: Lack of drawing software (or suites) for spherical perspectives

The state of the art showed some programs for spherical drawing, although there are no stable and unified options for having them all together in one same (ideally) open and free, and widely compatible program. The current broken compatibility or lack of options (for example, for drawing a cubical perspective) are barriers for the spreading of the knowledge and the open practice of Handmade Immersive Artworks. Sadly, it was not possible to develop any tangible solution in this regard, although some algorithms for cubical perspective were tested in the GeoGebra environment which could eventually be incorporated within a drawing program, there was no physical time for accomplishing this goal. In either case, **I call the digital art community to continue this investigation and develop what is missing in this direction.** The bases for building a whole suit of programs based on spherical perspectives are given and openly available, they just need some hands and brains to compile them all. The possibilities on the horizon are endless, for example, thinking of Handmade Immersive Artworks as an integration and complement of ongoing investigations in 3D drawing and CAVE-based drawing projects (Boddien et al., 2017; Bonnici & Camilleri, 2023; Israel et al., 2009, 2010; Keefe et al., 2007; Machuca et al., 2024; Schulze et al., 2024).

CONCLUSIONS

Six main problems were encountered, structured and extracted from the state of the art, namely: 1, the lack of an art-practice-based research methodology for this specific investigation; 2, the limitations on the current methods for drawing a cubical perspective; 3, the low artistic applications, low diffusion and spreading among artists; 4, the limitations for the live conversion of the flat drawing to the VR environment; 5, the low dissemination of spherical perspective teaching workshops and courses; and finally 6, the lack of a comprehensive drawing software for spherical perspectives. Five out of six problems were faced during the developments of this research, bringing as a result tangible solutions such as 1, the definition of an art-practice-based research to articulate the investigation; 2, the definition and mathematical proof of a shortcut to draw cubical perspectives; 3, the promotion and presentation of Handmade Immersive Artworks within four exhibitions, one collection of drawings and three more programmed exhibitions within 2025; 4, the development of four installations and software; and 5, the presentation of eight drawing workshops within several universities and congresses realised in several countries of Europe and South America.

The novel A-Construction (**solution 2**) simplifies the most complete (but also more complex) method for drawing a cubical perspective: the cubical-spherical method. The new shortcut both accelerates and simplifies the studio process, reducing systematic errors and making freehand sketching more viable and precise. The A-Construction was proven and tested with the hardest cases of line projections, rendering the image of geodesics from any two given points and eliminating the external auxiliary plane. The A-Construction simplifies cubical perspective drawing, making the practice lighter and more stimulating for artists with or without previous knowledge in the method.

Regarding the installations, exhibitions (**solution 3**), software (**solution 4**) and workshops (**solution 5**); considering the artistic/conceptual, artistic/technical, and artistic/performative advancements, it results that:

IMWYM v1 introduced a **purely technical advancement through a live drawing performance.** Neither the drawing made during the presentation, nor the technical advancement itself were supported by a strong **conceptual experience**. However, this version presented an important feature for the development of both drawing performances and artistic concepts using spherical perspectives: **the live and interactive VR feedback from a spherical perspective input**.

IMWYM v2 did not introduce big **technical advancements** but tested [IN]Musicality as a **conceptual artistic experience**. [IN]musicality was a field of experimentation, sharing, and learning, in which the tangible manifestation of an art-practice-based research helped visitors to interact and perceive the intangible musicality of drawing, setting an important milestone for the goals of the research in Handmade Immersive Art. Although the path and ways of interaction were not clear enough nor sufficient the quantity of participants, the 1st presentation gave very valuable feedback to solve the intricate UX/UI, the conceptual and the narrative experience.

IMWYM v3 introduced both **technical advancements** (body tracking features) and a shorter version of the **conceptual experience** and this time [IN]Musicality was tested with a larger audience. Some visitors understood easily how to operate the installation and successfully completed the path of interaction. But some others got lost in what to do, how to do it, and in using which gesture for which command. The numerical data gathered during the experience got strongly biased and therefore not reliable. Visitors spent more time trying to learn how the commands were or only contemplating one artwork and interacting with the VR camera, but without completing the quiz. This revealed that the technical strength of the motion capture features, and the contemplation of only one artwork were stronger when compared with the proposed path concept.

Spheri introduced a further significant **technical advancement** for interacting with spherical perspectives, building the experience upon the previous versions of IMWYM and incorporating new features to enhance the user experience. This time the software went out to the world as an open access option, introducing a further possibility for addressing artistic, technical, and conceptual aspects of Handmade Immersive Artworks and stretching the boundaries of digital art to expand the possibilities for artistic creation.

To complement the pure technical advancement, Spheritivity complemented Spheri by introducing a **novel conceptual and narrative artistic experience** through a collection of non-automatised perspective drawings and exposing the potential that perspective knowledge gives to artists for boosting their creativity. The collection includes parallel and conical projections (both linear and curvilinear) onto planes, spheres or cubes. Spheritivity highlights applications following the latest methods for spherical perspectives, enriching digital arts with artworks enhanced with an intellectual component (optical paradoxes) and an interactive component (Spheri). The setup of the exhibition shows a path of knowledge from the most well-known systems up to the newest developments, leaving place for free and mixed systems. Within the presentation of Spheritivity it is expected to be carried out a voluntary and anonymous survey for collecting both qualitative and quantitative data to enhance future editions. By boosting the association between perspective and creativity, Spheritivity contributes to a broader dialogue about innovation and the knowledge of projective geometry, encouraging a deeper understanding of perspective as a theoretical and practical whole, what is its role within artistic processes and the relationship between perception, imagination, and art.

Both IMWYM and Spheri were also used for **teaching purposes (solution 6)** on several occasions for both equirectangular and cubical perspective, providing a powerful tool for live showing the correspondence between the flat drawing and the VR visualisation.

Hence, the different installations introduced **technical, performative, teaching and conceptual artistic advancements**, with a slightly stronger accent in the technical and live performative applications. This puts some important questions for the further steps of the research, such as:

- Does the conceptual artistic experience *have* to be as stronger as the technical and performative advancements, for the application to be valuable within the field of digital media arts?
- How to make the conceptual artistic experience as valuable as the technical and performative advancements?
- Which other concepts might fit better the installation?
- Is the current focus on the technical and performative sides a limitation?
- If yes, is it a characteristic of the software/installation (meant just to be a technical and performative device), a characteristic of the concept (meant to be complex and not massive), or a limitation caused by the inexperience of the artist to define a simpler concept?
- How to measure the success of a concept?

Assessing the use, impact and significance of this investigation's developments are an important goal for the research. Hence in conclusion: the six above-mentioned problems represented the main barriers for spreading, integrating and applying spherical perspective's techniques within the field of digital art; however, with the new developments of this investigation it can be expected a boost of applications and future developments that might help, promote and develop the integration of Handmade Immersive Artworks, not just as a mere artistic product but as a way of thinking art through drawing, giving artists one more tool for surviving in an everyday more demanding world where personal thinking and style get harder and harder to achieve.

ACKNOWLEDGEMENTS

The author L. F. Olivero was financially supported by FCT national funds though projects UI/BD/150851/2021 (March 2021 to February 2025) and by CIAC – Research Centre for Arts and Communication, Portugal.

Furthermore, the author was emotionally supported by so many people that he does not dare to name them one by one… so he will simply say "thank you all", from the very bottom of his heart.

REFERENCES

Abreu, F. M. de, Estadieu, G., Ng, S. O., Farinha, D. F., Caires, C. S., & Fernandes-Marcos, A. (2025). *ARTeFACTo 2024 macao : 4th international conference on digital creation in arts, media, and technology creative digital intelligence conference proceedings*. USJ Academic Press. https://books.usj.edu.mo/index.php/usj-acaedemicpress/catalog/book/27

Ackerman, J. S., & Slosburg-Ackerman, J. (2002). *Origins, imitation, conventions: Representation in the visual arts*. MIT Press.

Adobe. (2021). *Adobe bridge digital asset management software* (Version 2021) [Computer software]. Adobe. https://www.adobe.com/products/bridge.html

Adobe. (2022). *Photoshop 3D common questions on discontinued 3D features*. https://helpx.adobe.com/photoshop/kb/3d-faq.html

Alshaker, O. (2018, January). *360Toolkit - convert and view panorama pictures instantly. 360Toolkit*. https://www.360toolkit.co

Alyek. (2023, May 31). *How to make use of the fish-eye perspective! Make better art - CLIP STUDIO TIPS*. https://tips.clip-studio.com/en-us/articles/7961

Andersen, K. (2007). *The geometry of an art: The history of the mathematical theory of perspective from Alberti to Monge*. Springer-Verlag. https://doi.org/10.1007/978-0-387-48946-9

Andjelkovic, K. (2020). Of innovations in panoramas: Art meeting the sciences. *International Panorama Council Journal. Selected Proceedings from the 29th IPC Conference*, *4*, 22–26. https://panoramacouncil.org/pics/files/documents/IPC_Journal_Volume_4.pdf

Antinozzi, S. (2019). *Acquisizioni a 360º e trattamento infografico per la generazione di immagini digitali, la misurazione e la divulgazione dei dati* [Master's degree disertation]. University of Salerno.

Antinozzi, S. (2023). *Appunti per l'infografia di modelli immersivi*. Libreria Universitaria Minerva. https://www.researchgate.net/publication/373718864_Appunti_per_l'infografia_di_modelli_immersivi

Araújo, A. B. (2015). A construction of the total spherical perspective in ruler, compass and nail. *arXiv:1511.02969 [Math]*. http://arxiv.org/abs/1511.02969

Araújo, A. B. (2017a). Anamorphosis: Optical games with perspective's playful parent. In *Proceedings of recreational mathematics colloquium v - G4G (europe)* (Jorge Nuno Silva, pp. 71–86). Associação Ludus. https://repositorioaberto.uab.pt/handle/10400.2/6647

Araújo, A. B. (2017b). Guidelines for drawing immersive panoramas in equirectangular perspective. *Proceedings of the 8th International Conference on Digital Arts*, 93–99. https://www.doi.org/10.1145/3106548.3106606

Araújo, A. B. (2018a). Drawing equirectangular VR panoramas with ruler, compass, and protractor. *Journal of Science and Technology of the Arts*, *10*(1), 15–27. https://www.doi.org/10.7559/citarj.v10i1.471

Araújo, A. B. (2018b). Let's sketch in 360º: Spherical perspectives for virtual reality panoramas. In C. S. Eve Torrence Bruce Torrence & K. Fenyvesi (Eds.), *Proceedings of bridges 2018: Mathematics, art, music, architecture, education, culture* (pp. 637–644). Tessellations Publishing.

Araújo, A. B. (2018c). Ruler, compass, and nail: Constructing a total spherical perspective. *Journal of Mathematics and the Arts*, *12*(2), 144–169. https://www.doi.org/10.1080/17513472.2018.1469378

Araújo, A. B. (2019a). A fisheye gyrograph: Taking spherical perspective for a spin. *Bridges 2019 - Mathematics, Art, Music, Architecture, Education, Culture*. Bridges.

Araújo, A. B. (2019b). Eq A Sketch 360, a serious toy for drawing equirectangular spherical perspectives. *Proceedings of the 9th International Conference on Digital and Interactive Arts*, 1–8. https://doi.org/10.1145/3359852.3359893

Araújo, A. B. (2020a). A GeoGebra tool for drawing immersive perspectives. *ARTeFACTo2020. International Conference on Digital Creation in Arts and Communication*, 155–160. https://repositorioaberto.uab.pt/handle/10400.2/10297?mode=full

Araújo, A. B. (2020b). *Drawing app for the azimuthal-equidistant spherical perspective (360-degree fisheye)* (Version v1.0) [Computer software]. https://www.geogebra.org/m/z57ws2bn

Araújo, A. B. (2020c). Explorations in rational drawing. *Journal of Mathematics and the Arts*, *14*(1), 4–7. https://doi.org/10.1080/17513472.2020.1734437

Araújo, A. B. (2021a). Anamorphosis reformed: From optical illusions to immersive perspectives. In B. Sriraman (Ed.), *Handbook of the mathematics of the arts and sciences* (pp. 175–242). Springer International Publishing. https://doi.org/10.1007/978-3-319-57072-3_101

Araújo, A. B. (2021b). Spherical perspective. In B. Sriraman (Ed.), *Handbook of the mathematics of the arts and sciences* (pp. 527–587). Springer International Publishing. https://doi.org/10.1007/978-3-319-57072-3_100

Araújo, A. B. (2022). *Ambientes imersivos* [Drawing Workshop]. Drawing Workshop. https://dmad.ciac.pt/workshop-ambientes-imersivos/

Araújo, A. B., & Olivero, L. F. (2022). How to draw a virtual cubical perspective box. In D. Reimann, D. Norton, & E. Torrence (Eds.), *Proceedings of bridges 2022: Mathematics, art, music, architecture, culture* (pp. 475–480). Tessellations Publishing. http://archive.bridgesmathart.org/2022/bridges2022-475.html

Araújo, A. B., & Olivero, L. F. (2023). Drawn onto a skybox: An invitation to collaborative immersive drawing using the spheri platform. *Proceedings of the 11th International Conference on Digital and Interactive Arts*, 1–8. https://doi.org/10.1145/3632776.3632826

Araújo, A. B., Olivero, L. F., & Antinozzi, S. (2019). HIMmaterial: Exploring new hybrid media for immersive drawing and collage. In P. Arantes, V. J. Sá, P. A. Da Veiga, & F. M. Adérito (Eds.), *Proceedings of ACM ARTECH conference (ARTECH2019)* (pp. 247–251). ACM Press. https://www.doi.org/10.1145/3359852.3359950

Araújo, A. B., Olivero, L. F., & Masiero Sgrinzatto, C. (2022). *Drawing handmade virtual reality panoramas* [Drawing Workshop]. Drawing Workshop. https://artsit.eai-conferences.org/2022/workshop-drawing-handmade-virtual-reality-panoramas/

Araújo, A. B., Olivero, L. F., & Rossi, A. (2020). A descriptive geometry construction of VR panoramas in cubical spherical perspective. *Diségno*, *6*, 35–46. https://doi.org/10.26375/disegno.6.2020.06

Arnheim, R. (1954). *Art and visual perception. A psychology of the creative eye.* (Second Edition). University of California Press. https://www.ucpress.edu/book/9780520243835/art-and-visual-perception

ArtStation. (2017, April 12). *360 pano painting tutorial with jama jurabaev* [Video recording]. https://www.youtube.com/watch?v=_cfb8u9wCC8

Baltrusaitis, J. (1977). *Anamorphic art*. Chadwyck-Healey Translated by WJ Strachan. Cambridge, England.

Barba, S., Rossi, A., & Olivero, L. F. (2018). CubeME, a variation for an immaterial rebuilding. *Rappresentazione / Materiale / Immateriale. Drawing as (in)tangible Representation*, 31–36. http://hdl.handle.net/11591/392282

Barbaro, D. (1569). *La pratica della perspettiva*. Appresso Camillo & Rutilio Borgominieri fratelli. https://cicognara.org/catalog/809

Barker, R. (1796). *Repertory of arts and manufactures - specification of mr barkers patent for displaying views of nature at large* (Patent 258.d.13-27). https://www.bl.uk/collection-items/specification-of-mr-barkers-patent-for-displaying-views-of-nature-at-large

Barre, A., & Flocon, A. (1967). *La perspective curviligne: De l'espace visuel à l'image construite*. Flammarion.

Beardshaw, D. (2022, April 5). *How to draw in 5 point perspective (FISH EYE) - interior view drawing tutorial* [Video recording]. https://www.youtube.com/watch?v=PYAdcZiJvhI

Benjamin, W. (2008). *The work of art in the age of mechanical reproduction: Walter benjamin* (J. A. Underwood, Trans.; 1st edition). Penguin. https://web.mit.edu/allanmc/www/benjamin.pdf

Bigg, C. (2007). The panorama, or la nature a coup d'oeil. In *Observing nature - representing experience. The osmotic dynamics of romanticism 1800-1850* (Erna Fiorentini, pp. 73–96). Dietrich Reimer Verlag GmbH.

Boddien, C., Heitmann, J., Hermuth, F., Lokiec, D., Tan, C., Wölbeling, L., Jung, T., & Israel, J. H. (2017). SketchTab3D: A hybrid sketch library using tablets and immersive 3D environments. *Proceedings of the 2017 ACM Symposium on Document Engineering*, 101–104. https://doi.org/10.1145/3103010.3121029

Bonnici, A., & Camilleri, K. P. (Eds.). (2023). *Interactive sketch-based interfaces and modelling for design*. River Publishers.

Boom, T. (2024). *Harmony* (Version 24) [Computer software].

Bordini, S. (1984). *Storia del panorama: La visione totale nella pittura del XIX secolo*. Officina.

Borges, J. L. (2017). *Borges esencial. Edicion conmemorativa / essential borges: Commemorative edition* (Commemorative ed. edition). Real Academia Española / Alfaguara.

Bortot, A. (2015). Il dinamismo percettivo nel refettorio di andrea pozzo. In M. T. Bartoli & M. Lusoli (Eds.), *Le teorie, le tecniche, i repertori figurativi nella prospettiva d'architettura tra il '400 e il '700: Dall'acquisizione alla lettura del dato* (pp. 119–126). Firenze University Press. https://air.iuav.it/handle/11578/281873?mode=full.380

Bosse, A. (1653). *Moyen universel de pratiquer la perspective sur les tableaux, ou surfaces irregulieres. Ensemble quelques particularitez concernant cet art, & celuy de la graveure en taille-douce.* Bosse. http://catalogue.bnf.fr/ark:/12148/cb301347273

Bourke, P. (2016). *Converting to/from cubemaps. Paul bourke's website*. http://paulbourke.net/miscellaneous/cubemaps/

Brisbin, C. (2007). Spatial transfiguration: Anamorphic mixed-reality in the virtual reality panorama. *Proceedings 24th International Conference of the Society of Architectural Historians Australia and New Zealand [SAHANZ]*. Panorama to paradise: Scopic regimes in architectural and urban history and theory.

BV, N. H. I. S. (2025). *PTGui - photo stitching and 360 degree panorama image software* (Version 13.1) [Computer software]. https://www.ptgui.com/

Cabezos Bernal, C., & Manuel, P. (2015). Imágenes estereoscópicas aplicadas a la representación arquitectónica. *Riunet*. https://doi.org/10.4995/Thesis/10251/46640

Cabezos Bernal, P. M., & Cisneros Vivó, J. J. (2016). Panoramas esféricos estereoscópicos. *EGA Expresión Gráfica Arquitectónica*, *21*(28), 70–81. https://doi.org/10.4995/ega.2016.6264

Cabezos Bernal, P. M., Cisneros Vivó, J., & Soler Sanz, F. (2014). Anamorfosis, su historia y evolución. *EGA Expresión Gráfica Arquitectónica*, *Núm. 23 (2014): Conversando con... JUAN NAVARRO BALDEWEG*. https://doi.org/https://www.doi.org/10.4995/ega.2014.2184

Cabral, A., & Cabral, M. (2025). *Marzipano* (Version 0.10.2) [Computer software]. Google. https://github.com/google/marzipano

Cadalog, I. (2016). *CubicVR SU podium help. SU podium*. https://www.suplugins.com/podium/help/cubicVR.php

Callandriello, A. (2015). Andrea pozzo a roma: Nuove ipotesi fruitive del refettorio di trinità dei monti. In M. T. Bartoli & M. Lusoli (Eds.), *Le teorie, le tecniche, i repertori figurativi nella prospettiva d'architettura tra il '400 e il '700: Dall'acquisizione alla lettura del dato* (pp. 127–134). Firenze University Press.

Candito, C. (2010). *Il disegno e la luce. Fondamenti e metodi, storia e nuove applicazioni delle ombre e dei riflessi nella rappresentazione.* (Alinea Editrice). Grafiche PDB - Tavarnelle Val di Pesa.

Candy, L., & Edmonds, E. (2018). Practice-based research in the creative arts: Foundations and futures from the front line. *Leonardo*, *51*(1), 63–69. https://doi.org/10.1162/LEON_a_01471
Carpentier, N. (2022). *Arts-based research in communication and media studies: The example of silencing/unsilencing nature*. https://www.youtube.com/watch?v=B4f4HHHyYgc
Carpentier, N., & Sumiala, J. (2021). Introduction: Arts-based research in communication and media studies. *Comunicazioni Sociali : Journal of Media, Performing Arts and Cultural Studies : Nuova Serie : XLIII, 1, 2021*. https://doi.org/10.26350/001200_000125
Casanellas, F. (2019). *Natural perspective*. https://doi.org/10.13140/RG.2.2.22666.72645
Casas, F. R. (1983). Flat-sphere perspective. *Leonardo*, *16*(1), 1–9. https://doi.org/10.2307/1575034
Catalano, G. M. (1986). *Prospettiva sferica: Punto di vista al centro del quadro sferico* (Università di Palermo). Co.Gra.S. https://www.academia.edu/39263419/SPHERICAL_PERSPECTIVE
Chandler, D., & Munday, R. (2011). *A dictionary of media and communication*. Oxford University Press. https://www.oxfordreference.com/view/10.1093/acref/9780199568758.001.0001/acref-9780199568758
Chelsea, D. (2011). *Extreme perspective! For artists* (Pap/Cdr edition). Watson-Guptill.
Cheng, E. (2016, June 10). *Editing 360 photos & injecting metadata. Eric cheng*. https://echeng.com/articles/editing-360-photos-injecting-metadata/
Chiappelli, A. (1896). Della vita di filippo brunelleschi attribuita ad antonio manetti con un nuovo frammento di essa. Tratto da un codice pistoiese del sec. XVI. *Archivio Storico Italiano*, *17*(202), 241–278. http://www.jstor.org/stable/44455873
Ching, F. D. K. (2015). *Architectural graphics* (6. ed). Wiley.
Ching, F. D. K. (2016). *Manual de dibujo arquitectónico* (Quinta edición revisada y ampliada). Editorial Gustavo Gili.
Comolli, A. (1791). *Bibliografia storico-critica dell' architettura civile ed arti subalterne*. Stamperia Vaticana.
Correia, J., Costa, M., Guerreiro, A., & Romao, L. (2015). Eyesight cartographies-unfolding the visual sphere. *Journal for Geometry and Graphics*, *19*(1), 117–130.
Crane, L. (2025). *Panorama to cubemap. Panorama to cubemap*. https://jaxry.github.io/panorama-to-cubemap/
Cruz-Neira, C., Sandin, D. J., DeFanti, T. A., Kenyon, R. V., & Hart, J. C. (1992). The CAVE: Audio visual experience automatic virtual environment. *Commun. ACM*, *35*(6), 64–72. https://www.doi.org/10.1145/129888.129892
D'Amelio, J. (2004). *Perspective drawing handbook*. Dover Publications, Incorporated.
D'Angelo, P., & Various, A. (2024). *Hugin - panorama photo stitcher* (Version 2024.0.1) [Computer software]. http://hugin.sourceforge.net/
Da Vinci, L. (2008). *Notebooks* (I. A. Richter, T. Wells, & M. Kemp, Eds.; New Edition). Oxford University Press.
Damisch, H. (1987). *L'origine de la perspective* (Cons. L'origine della prospettiva 1992, Flammarion). Guida.
Damisch, H., & Leal, J. C. (2007). *Entrevista com hubert damisch*. *3*, 7–18. https://run.unl.pt/handle/10362/12466
Dane, J. A. (2011). Chapter seven. The representation of representation: Versions of linear perspective. In *Out of sorts. On typography and print culture* (pp. 141–163). University of Pennsylvania Press. https://doi.org/10.9783/9780812203639.141
De Rosa, A., & Giordano, A. (2018). La geometria, lo spazio, la configurazione: un incontro con Anna Sgrosso. *diségno*, *2*, 009–015. https://doi.org/10.26375/disegno.2.2018.2
Della Francesca, P. (2016). *De prospectiva pingendi: Vol. I* (C. Gizzi, Ed.). Università Ca' Foscari Venezia, Italia. https://doi.org/10.14277/978-88-6969-099-0
Derivative. (2017, September 13). *Touchdesigner*. https://derivative.ca/about-derivative
Dictionaries, L. (2019). *Definition of anamorphosis. Lexico dictionaries english*. https://www.lexico.com/en/definition/anamorphosis
Digital, O. (2016, April 25). *Pacific domes home page. Pacific domes, inc*. https://pacificdomes.com/
Digital, O. (2018). *Pacific domes virtual reality VR sphere, 360 immersion, dubai 360 – VIDEO* [Video recording]. https://www.youtube.com/watch?v=kxIn1Nj6C_8
Dimitrijević, A. M., Lambers, M., & Rančić, D. (2016). Comparison of shperical cube map projections used in planet-sized terrain rendering. *Facta Universitatis, Series: Mathematics and Informatics*, *31*(2), 259–297. http://casopisi.junis.ni.ac.rs/index.php/FUMathInf/article/view/871
Dixon, R. (1991). *Mathographics*. Dover publ. https://archive.org/details/mathographics0000dixo_v3i5/page/78/mode/2up
Docci, M., Maestri, D., & Migliari, R. (2017). *Scienza del disegno* (UTET Università). UTET Università. https://www.libraccio.it/libro/9788825174144/mario-docci-diego-maestri-marco-gaiani/scienza-del-disegno.html
Docci, M., & Migliari, R. (1992). *Scienza della rappresentazione. Fondamenti e applicazioni della geometria descrittiva*. Carocci.
Donato, C. (2017). *GigaKahn: Un proyecto gráfico de documentación, comunicación y valorización inspirado en el viaje de louis kahn en la costa amalfitana GigaKahn: Un progetto grafico di documentazione, comunicazione e valorizzazione ispirato al viaggio di louis kahn in costiera amalfitana.* [Masters' Degree]. University of Salerno.
Düchting, H. (2013). *Kandinsky*. TASCHEN.
Easypano. (2025). *VRTourMaker, tourweaver, panoweaver* (Version VRTourMaker 1.6, Tourweaver 7, Panoweaver 10) [Computer software]. Easypano Holdings Inc. https://www.easypano.com/virtual-tour-software.html
Elkins, J. (1991). On the arnolfini portrait and the lucca madonna: Did jan van eyck have a perspectival system? *The Art Bulletin*, *73*(1), 53–62. https://doi.org/10.2307/3045778
Equirectangular projection. (2021). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Equirectangular_projection&oldid=998076451
Ernst, B. (2003). Selection is distortion. In D. Schattschneider & M. Emmer (Eds.), *M.c. Escher's legacy: A centennial celebration* (pp. 5–16). Springer. https://doi.org/10.1007/3-540-28849-X_2
Escher, M. C., & Esparaz (photographer), M. A. (1955). *Convex and concave* [Graphic]. https://commons.wikimedia.org/wiki/File:Concavo_e_Convexo,_litografia_de_1955_produzida_pelo_g%C3%AAnio_das_xilogravuras,_litografias_e_meios-tons_(mezzotints),_Maurits_C._Escher,_exposta_Centro_Cultural_Banco_do_Brasil_em_S%C3%A3o_Paulo_-_panoramio.jpg
Escher, M. C., & Vermeulen, J. W. (1989). *Escher on escher: Exploring the infinite*. Harry N. Abrams.

Eyck, J. van. (1434). *The virgin of chancellor rolin* [Graphic]. https://commons.wikimedia.org/wiki/File:Jan_van_Eyck_The_Virgin_of_Chancellor_Rolin.jpg
Eyck, J. van. (2020). The arnolfini portrait. In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Arnolfini_Portrait&oldid=995353758
Eyck, J. van, & Sailko. (1434). *The arnolfini portrait (portrait of giovanni arnolfini and his wife)* [Graphic]. https://commons.wikimedia.org/wiki/File:Jan_van_eyck,_i_coniugio_arnolfini,_1434,_01.jpg
Fangi, G., Pisa, C., & Zeppa, F. (2011). Spherical photogrammetry for cultural heritage—san galgano abbey and the roman theater, sabratha. *J. Comput. Cult. Herit.*, *4*(3), 9:1–9:15. https://doi.org/10.1145/2069276.2069278
Fasolo, M., & Migliari, R. (2018). Decio gioseffi and perspective as 'symbolic form'. *Disegnare Idee Immagini*, *57*, 46–57. https://doi.org/10.36165/2679
Fasolo, O. (1980). *Fondamenti geometrici della rappresentazione progettuale e tecnica dell'architettura 1: Vol. I* (Kappa). https://www.unilibro.it/libro/fasolo-orseolo/fondamenti-geometrici-rappresentazione-progettuale-tecnica-dell-architettura-1/461749?idaff=facebook
Fernández Rodríguez, M. (2002). Homología entre figuras de tercera categoría. *Congreso Internacional de Ingeniería Gráfica de INGEGRAF*. XIV congreso internacional de ingeniería gráfica de INGEGRAF. http://ingegraf.es/wp-content/uploads/2017/03/XIVCONGRESO.ISO
Ferrero, G., Cotti, C., Rossi, M., & Tedeschi, C. (2009). Geometries of imaginary space: Architectural developments of the ideas of m. C. Escher and buckminster fuller. *Nexus Network Journal*, *11*(2), 305–316. https://doi.org/10.1007/s00004-008-0090-1
FilmEU. (2025). *The latests updates and news. Decolonising the panorama of congo*. https://congopanorama.filmeu.eu/news/
Flocon, A. (1965). *A la frontière de l'art graphique et des mathématiques: Maurits-Cornelis Escher*. Jardin des Arts.
Fukuoka, M. (2005). Contextualising the peep-box in tokugawa japan. *Early Popular Visual Culture*, *3*(1), 17–42. https://www.doi.org/10.1080/17460650500056998
Gaiani, M. (2018). La rappresentazione dell'architettura: sapere e saper fare. *MeTis - Mondi educativi. Temi indagini suggestioni*, *8*(2), 13–49. http://www.metisjournal.it/index.php/metis/article/view/179
García-García, C., Galán Serrano, J., & Arce Martínez, J. M. (2016). The hybrid drawing as a way of architectural representation. In *Dibujar, Construir, Soñar. Drawing, Building, Dreaming* (I, pp. 1037–1049). Tirant lo Blanch.
Gay, F., & Cazzaro, I. (2018). Venetian perspective boxes: when the images become environments. Low-tech high-knowledge media to teach the historical heritage of the (interior/exterior) environments. *Proceedings of the 1st International and Interdisciplinary Conference on Digital Environments for Education, Arts and Heritage, Brixen, 5-6 July 2018, Springer International Publishing*. https://doi.org/10.1007/978-3-030-12240-9_11
Gene Bond Art. (2024, December 12). *How to draw 6 point perspective grid. Spherical perspective.* [Video recording]. https://www.youtube.com/watch?v=KTWkOdzNObE
Germinal Poudra, N. (1864). *Histoire de la perspective ancienne et moderne: contenant l'analyse d'un très grand nombre d'ouvrages sur la perspective et la description des procédés divers qu'on y trouve : faisant suite au Cours de perspective professé à l'École d'état-major*. Corréard.
Gnome, S. (2025). *Pano2VR* (Version 7.1.9) [Computer software]. Garden Gnome Software. https://ggnome.com/pano2vr/#download
Godin, J. (2011, December 7). *How the hell do i make a cubemap with my own art? The art of jude godin*. https://judegodin.wordpress.com/2011/12/06/how-the-hell-do-i-make-a-cubemap/
Google. (2022). *MediaPipe. Mediapipe*. https://google.github.io/mediapipe/
Grau, O. (2003). *Virtual art: From illusion to immersion* (G. Custance, Trans.). MIT Press. https://books.google.pt/books?id=7OYaXjE5_lcC
Grau, O. (Ed.). (2007). *MediaArtHistories*. The MIT Press. https://doi.org/10.7551/mitpress/4530.001.0001
Grau, O. (2016). *On the visual power of digital arts: For a new archive and museum infrastructure in the 21st century*. Ediciones de la Universidad de Castilla-La Mancha.
Grau, O. (Ed.). (2017). *Museum and archive on the move: Changing cultural institutions in the digital era*. De Gruyter. https://doi.org/10.1515/9783110529630
Greene, N. (1986). Environment mapping and other applications of world projections. *IEEE Computer Graphics and Applications*, *6*(11), 21–29. https://doi.org/10.1109/MCG.1986.276658
Grimm, C. M., & Niebruegge, B. (2007). Continuous cube mapping. *Journal of Graphics Tools*, *12*(4), 25–34. https://doi.org/10.1080/2151237X.2007.10129250
Hancher, M. (2016, December 10). *Introduction to map projections with google earth engine: Part 1*. https://medium.com/google-earth/introduction-to-map-projections-with-google-earth-engine-part-1-7840e4ca6264
Hansen, R. (1973). This curving world: Hyperbolic linear perspective. *The Journal of Aesthetics and Art Criticism*, *32*(2), 147–161. https://doi.org/10.2307/429032
Hartmann, A. (2019). *Grafik · architektur · webdesign*. http://www.arnohartmann.de/sonstiges-zeichnungen.html
Heaston, P. (2020, November 14). *Paul heaston art. Paul heaston's art blog* [Personal blog]. http://paulheaston.blogspot.com/2020/11/blog-post_14.html
Heaston, P. (2025). *Paul heaston on kuula. Kuula* [Virtual Tours made easy. Create, edit, share.]. https://kuula.co/profile/paulheaston
Heleine, J. (2025). *Photo sphere viewer*. https://photo-sphere-viewer.js.org/
Hernández Falagán, D., Signes Orovay, F., & Berdié Soriano, A. (2015). *Sistema cónico-diédrico*. SdR - Sistemes de representació - Escola Massana. https://sistemesderepresentacio.files.wordpress.com/2015/03/03.pdf
Hohler, K. (2015). *Halloween - pop shop invasion. Kevin hohler - 360° illustration*. https://kevin-hohler.artstation.com/projects/OkzRg
Hohler, K. (2018, April). *Where's waldo? - where's wally? - où est charlie? Behance - kevin hohler - 360° content creator in paris, france*. https://www.behance.net/kaache?
Hohler, K. (2025a). *360 Drawing - Dessinez à 360° de A à Z*. https://360-drawing.com

Hohler, K. (2025b). *360° images (photographies and illustrations). Kuula*. https://kuula.co/profile/KevinHohler
Hoogstraten, S. van. (1969). *Inleyding tot de hooge schoole der schilderkonst: Anders de zichtbaere werelt; verdeelt in negen leerwinkels, yder bestiert door eene der zanggodinnen; ten hoogsten noodzakelijk, tot onderwijs, voor alle die deeze edele, vrye, en hooge konst oeffenen, of met yver zoeken te leeren, of anders eenigzins beminnen*. Davaco. http://archive.org/details/inleydingtotdeho00hoog
Huang, D. (2014, March 21). *Interactive 360 panorama view in sketchup. Payette*. https://payette.com/technology/interactive-360-panorama-view-in-sketchup/
Huhtamo, E. (2013). *Illusions in motion: Media archaeology of the moving panorama and related spectacles*. MIT Press.
Irwin, R., Beer, R., Springgay, S., Grauer, K., Guxiong, & Bickel, B. (2011). *The rhizomatic relations of a/r/tography*.
Israel, J. H., Wiese, E., Magdalena, M., Rainer Georg, S., & Christian, Z. (2009). Investigating three-dimensional sketching for early conceptual design. Results from expert discussions and user studies. *Computers & Graphics*, *33*(4), 462–473. https://doi.org/10.1016/j.cag.2009.05.005
Israel, J. H., Zöllner, C., & Müller, A. (2010). *Sketching in space. The constitute*. http://theconstitute.org/sketching_in_space/
Jara, A. (2019). Proyecto de producción artística "ciudad de la plata en 360°." *Actas de Trabajos Extensos Del XVI Congreso Nacional de Profesores de Expresión Gráfica En Ingeniería, Arquitectura y Carreras Afines: La Representación Gráfica de Naturaleza Técnica*, 49–53. https://sedici.unlp.edu.ar/handle/10915/129738
Jara, A. (2024). From sketch to immersive reality: Construction methodology of the 360° panoramic drawing from planimetric information. The case of the heritage buildings of the universidad nacional de la plata. In Francesco Stilo, Vittoria Castiglione, Irene Cazzaro, Michela Ceracchi, Fabrizio Natta, Marta Pileri, Lorella Pizzonia, Andrea Tomalini, Noemi Tomasella, & Maria Bélen Trivi (Eds.), *Explora UID 2024. Virtual journeys to discover innacessible spaces* (Publica, pp. 210–221).
Jerald, J. (2015). *The VR book: Human-centered design for virtual reality*. Association for Computing Machinery; Morgan & Claypool.
Katinsky, J. R. (2000). Florentine perspective and the development of modern science. *Llull: Revista de La Sociedad Española de Historia de Las Ciencias y de Las Técnicas*, *23*(48), 599–642. https://dialnet.unirioja.es/servlet/articulo?codigo=2959897
Keefe, D. F., Feliz, D. A., Moscovich, T., Laidlaw, D. H., & Viola, J. L. (2001). CavePainting: A fully immersive 3D artistic medium and interactive experience. *Proceedings of the Symposium on Interactive 3D Graphics*, 85–93. https://experts.umn.edu/en/publications/cavepainting-a-fully-immersive-3d-artistic-medium-and-interactive
Keefe, D. F., Zeleznik, R. C., & Laidlaw, D. H. (2007). Drawing on air: Input techniques for controlled 3D line illustration. *IEEE Transactions on Visualization and Computer Graphics*, *13*(5), 1067–1081. https://doi.org/10.1109/TVCG.2007.1060
Keit, T. (2025). *Exif fixer* (Version 1.0) [Computer software]. Exif Fixer. https://exiffixer.com/
Kemp, M. (1992). *The science of art: Optical themes in western art from brunelleschi to seurat* (Reprint edition). Yale University Press.
Kemp, M. (2000). *The oxford history of western art*. Oxford University Press, USA.
Kersten, E. (2018, August 11). *Knots with albert flocon. Escher in het paleis*. https://www.escherinhetpaleis.nl/escher-today/knots-with-albert-flocon/?lang=en/
Kolor. (2018). *PanoTour pro* (Version 2.54) [Computer software]. Kolor SARL.
Kolor. (2023). *AutoPano giga* (Version 4.4.2) [Computer software]. Kolor SARL. https://hdrmaps.com/blog/autopano-giga-is-now-free/
Koslow, S. (1967). De wonderlijke perspectyfkas: An aspect of seventeenth century dutch painting. *Oud Holland – Journal for Art of the Low Countries*, *82*(1), 35–56. https://doi.org/10.1163/187501767X00206
Kurbatov, V. (2017, January 18). *Draw sketches for virtual reality like a pro. Inborn experience (UX in AR/VR)*. https://medium.com/inborn-experience/vr-sketches-56599f99b357
Kwiatek, K. (2005). *Generation of a virtual tour in the 3D space applying panoramas, exercised on the sites of dresden and cracow* [Unpublished Diploma Thesis, AGH University of Science; Technology]. http://www.kwiatek.krakow.pl/diploma_thesis/diploma_thesis_karol_kwiatek_2005.pdf
Kwiatek, K. (2012). 360º film brings bombed church to life. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XXXVIII-5/W16*, 69–76. https://doi.org/10.5194/isprsarchives-XXXVIII-5-W16-69-2011
Lambers, M. (2019). Survey of cube mapping methods in interactive computer graphics. *The Visual Computer*. https://doi.org/10.1007/s00371-019-01708-4
Lambers, M., & Kolb, A. (2012). *Ellipsoidal cube maps for accurate rendering of planetary-scale terrain data*. https://doi.org/10.2312/PE/PG/PG2012short/005-010
Leavy, P. (2020). *Methods meets art: Arts-based research practice* (Third edition). The Guilford Press.
Lee, A. S. (1991). Integrating positivist and interpretive approaches to organizational research. *Organization Science*, *2*(4), 342–365. http://www.jstor.org/stable/2635169
Leopold, C. (2016). Points of view and their interrelations with space and image. *Geometrias & Graphica 2015 Proceedings*, *1*, 365–373. https://www.academia.edu/23357642/POINTS_OF_VIEW_AND_THEIR_INTERRELATIONS_WITH_SPACE_AND_IMAGE
Lopes, M. M., Bastos, P. B., Araújo, A. B., Olivero, L. F., & Adérito, F. M. (Eds.). (2021). *Proceedings of ACM ARTECH conference (ARTECH2021) - 10th international conference on digital and interactive arts*. ACM Press. https://dl.acm.org/doi/proceedings/10.1145/3483529
Loria, Gino. (1921). *Storia della geometria descrittiva dalle origini sino ai giorni nostri*. Ulrico Hoepli. //catalog.hathitrust.org/Record/006510476
Luhmann, T. (2004). A historical review on panorama photogrammetry - semantic scholar. *Panoramic Photogrammetry Workshop*, *XXXIV PART 5/W16*. /paper/A-Historical-Review-on-Panorama-Photogrammetry-Luhmann/6e4224c8ef297ced99e0c896a7f3fe50185e1b8f
Machuca, M. D. B., Israel, J. H., Keefe, D. F., & Stuerzlinger, W. (2024). Toward more comprehensive evaluations of 3D immersive sketching, drawing, and painting. *IEEE Transactions on Visualization and Computer Graphics*, *30*(8), 4648–4664. https://doi.org/10.1109/TVCG.2023.3276291
Macnair, J. L. P. (1957). Spherical perspective. *Journal of the Royal Society of Arts*, *105*(5010), 762–780. http://www.jstor.org/stable/41368614

MacNeal, D. (2022, June 4). *8 people pushing anamorphic art to new limits. Art of play*. https://www.artofplay.com/blogs/stories/8-people-pushing-anamorphic-art-to-new-limits

Maldonado, T. (1987). Questioni di similarità. *Rassegna*, *32*, 57–61.

Markman, E. (2008). "Spectacles within doors": Panoramas of london in the 1790s. *Romanticism*, *14*(2), 133–148. https://doi.org/10.3366/E1354991X0800024X

Marrazzo, M. (2018). *How to draw curvilinear perspective*.

Marrazzo, M. (2020). *Cubic panorama. Biodomotica*. http://www.biodomotica.com/cubic_panorama.htm

Maschietto, M. (2005). I prospettografi: dalla storia alla scuola. In P. A. Bertacchini, E. Bilotta, M. G. Lorenzo, M. Francaviglia, & P. Pantano (Eds.), *Atti del Convegno "Matematica, Arte e Industria Culturale"*. EGS - Università della Calabria.

Masetti, M. (2014). *La prospettiva e la costruzione dello spazio figurativo* (Youcanprint). https://www.youcanprint.it/architettura-generale/la-prospettiva-e-la-costruzione-dello-spazio-figurativo-9788891154750-ebook.html

Masiero Sgrinzatto, C. (n.d.). *Venice original interior*. Retrieved September 20, 2021, from https://superkiro.s3.eu-west-3.amazonaws.com/202103_veniceoriginal/$(VIRTUALTOURURL)/index.html

Masiero Sgrinzatto, C. (2020a). *Tribuna grimani VR – chiara masiero sgrinzatto. Chiara masiero sgrinzatto - handmade illustrated 360º panoramas* [Personal blog]. https://www.chiaramasierosgrinzatto.com/2020/05/07/tribuna-grimani-vr/

Masiero Sgrinzatto, C. (2020b, April 28). *Tribuna grimani VR behind the scenes* [Video recording]. https://www.youtube.com/watch?v=AhsLevw3ZW8

Masiero Sgrinzatto, C. (2021a). *Illustrated 360º panoramas*. https://www.chiaramasierosgrinzatto.com/

Masiero Sgrinzatto, C. (2021b). *Schianti. Tracce panoramiche per raccordare i secoli* (E. Zilio, Ed.). Grafiche Veneziane.

Masiero Sgrinzatto, C. (2021c). *Venice, bird's eye view. Chiara masiero sgrinzatto - handmade illustrated 360º panoramas* [Personal blog]. https://www.chiaramasierosgrinzatto.com/2021/01/01/venice-birds-eye-view/

Masiero Sgrinzatto, C. (2021d). Venice original: A spherical illustration of an imaginary environment. *Proceedings of ACM ARTECH Conference (ARTECH2021)*, 679–682. https://doi.org/10.1145/3483529.3483754

Masiero Sgrinzatto, C. (2024a). Recreating a lost world through immersive illustration: A view from napoli capodichino. In M. C. Briggs, T. Logge, & N. C. Lowe (Eds.), *Panoramic and immersive media studies yearbook* (pp. 185–196). De Gruyter. https://doi.org/10.1515/9783111335575-014

Masiero Sgrinzatto, C. (2024b, June 2). *Multiplicity - 12 Retiro DMAD. CIAC – Centro de Investigação em Artes e Comunicação* [Personal blog]. https://dmad.ciac.pt/chiara-masiero-sgrinzatto/

Masiero Sgrinzatto, C., & Araújo, A. B. (2024). MultipliCity, a case study in generative AI-assisted immersive illustration workflow. *Creative Digital Intelligence Conference Proceedings*, 261. https://books.usj.edu.mo/index.php/usj-acaedemicpress/catalog/view/27/83/125

Masiero Sgrinzatto, C., & Zilio, E. (2024). Panoramas, keys to unlock complexity in digital humanities and data humanism. Methodological analysis, performance assessment and cataloguing of 31 real cases. *Magazén*, *1*, JournalArticle_18168. https://doi.org/10.30687/mag/2724-3923/2024/01/005

Mazzoccoli, F. (Ed.). (2010). L'arte della prospettiva e i mirabili disinganni di andrea pozzo. *Fondazione Geometri Italiani*, *9*, 86. http://www.collegio.geometri.bg.it/documenti/2010/7015.asp?DocID=7015&SettoreID=1708

Mazzola (Parmigianino), G. F. M. (2020). Self-portrait in a convex mirror. In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Self-portrait_in_a_Convex_Mirror&oldid=993142155

Mekni, M., & Lemieux, A. (2014). *Augmented reality : Applications , challenges and future trends*. https://api.semanticscholar.org/CorpusID:15436826

Michel, G. (2013). L'œil, au centre de la sphere visuelle. *Boletim Da Aproged*, *30*, 3–14.

Michel, G. (2018a). *Bureau visite virtuelle. Virtual tour*. http://autrepointdevue.com/blog/wp-content/vv/vv-gm-bureau/vv-gm-bureau.html

Michel, G. (2018b). *Visite virtuelle du cinéma sauvenière*. http://autrepointdevue.com/blog/wp-content/vv/vv-gm-sauveniere/vv-gm-sauveniere.html

Migliari, R. (2005). La prospettiva e panofsky. *Disegnare Idee Immagini*, *31*, 28–41.

Migliari, R. (Ed.). (2008). *Prospettiva dinamica interattiva. La tecnologia dei videogiochi per l'esplorazione dei modelli 3D di architettura*. Kappa.

Migliari, R. (2018). Lo specchio alle origini della prospettiva - The mirror at the origin of perspective. *Disegnare Idee Immagini / Drawing Ideas Images*, 42–51. https://www.academia.edu/37119898/Lo_specchio_alle_origini_della_prospettiva_-_The_mirror_at_the_origin_of_perspective

Mitchell, R. (1801). *Plans, and views in perspective, with descriptions, of buildings erected in england and scotland: And also an essay, to elucidate the grecian, roman and gothic architecture, accompanied with designs*. London: Printed by Wilson & Co. for the author. http://archive.org/details/plansviewsinpers0000mitc_a5n1

Moose, M. (1986). Guidelines for constructing a fisheye perspective. *Leonardo*, *19*(1), 61–64. https://doi.org/10.2307/1578303

Muñoz Viñas, S. (2004). *Teoría contemporánea de la restauración*. Sintesis S.A. https://www.academia.edu/36293739/VINAS_Salvador_Munoz_Teoria_Contemporanea_de_la_Restauracion_pdf

NadirPatch. (2025). *NadirPatch.com VR photography tools. VR photography tools*. https://nadirpatch.com/

Nakamura, J. P. (2020). *Seeing outside the box: Reexamining the top of samuel van hoogstraten's london perspective box. Journal of historians of netherlandish art*. https://jhna.org/articles/seeing-outside-the-box-reexamining-the-top-of-samuel-van-hoogstratens-london-perspective-box/

Nazarenko, A. (2021). *Rendering 360° panorama complete guide*. https://renderstuff.com/tutorials/panorama-360-in-3ds-max-and-v-ray-tutorial-133/

Nazarenko, A. (2024). *Renderstuff. 360° panorama viewer online*. https://renderstuff.com/tools/360-panorama-web-viewer/

Nicéron, J. F. (1638). *La perspective curieuse, ou Magie artificielle des effets merveilleux de l'optique, par la vision directe, la catoptrique, par la réflexion des miroirs plats, cylindriques et coniques, la dioptrique, par la réfraction des crystaux* (BnF Gallica). P. Billaine. https://gallica.bnf.fr/ark:/12148/bpt6k853939w

Olivero, L. F. (2017). *Live art painting sessions* [Art Exhibition]. Art Exhibition.
Olivero, L. F. (2018a). *360 points of view* [Art Exhibition]. Art Exhibition.
Olivero, L. F. (2018b). *360 points of view - al passo* [Art Exhibition]. Art Exhibition.
Olivero, L. F. (2021). *Hybrid immersive models from cubical perspective drawings - modelli ibridi immersivi da disegni in prospettiva cubica* [PhD thesis, University of Campania Luigi Vanvitelli]. https://lufo.art/hybrid-immersive-models-from-cubical-perspective-drawings-phd-thesis
Olivero, L. F. (2022a). *I'm watching you/me 2: [IN]musicality* [Shared exhibition]. Shared exhibition. https://dmad.ciac.pt/lufo-lucas-fabian-olivero/
Olivero, L. F. (2022b). *[IN]musicality v3 at ArtsIT 2022* [Shared exhibition]. Shared exhibition.
Olivero, L. F. (2022c). *[IN]musicality v3 at CLB berlin* [Shared exhibition]. Shared exhibition.
Olivero, L. F. (2022d, June 16). *I'm watching you/me 2: [IN]musicality* [Video recording]. https://www.youtube.com/watch?v=OQj4jpx4UGc
Olivero, L. F. (2022e, June 20). *I'm watching you/me (IMWYM) v1* [Video recording]. https://www.youtube.com/watch?v=9JCo-Q1LJFo
Olivero, L. F. (2022f, September 1). *I'm watching you/me v2: [IN]musicality (the shared curatorship)* [Video recording]. https://www.youtube.com/watch?v=LBp9-_gTFCM
Olivero, L. F. (2022g, November). [IN]musicality: A collection of VR drawings and music as an artistic application of hybrid immersive models. *ArtsIT 2022*. EAI ArtsIT 2022 - 11th EAI international conference: ArtsIT, interactivity & game creation. https://doi.org/10.1007/978-3-031-28993-4_1
Olivero, L. F. (2022h, November). Methodological definitions for the art-practice-based research handmade immersive art. *ARTeFACTo 2022: Emerging Extended Realities*. 3rd international conference on digital creation in arts, media, and technology. https://doi.org/10.1109/ARTeFACTo57448.2022.10061259
Olivero, L. F. (2023). Spheri v1. A body tracking artefact to interact with spherical perspective drawings made on-the-fly. *Proceedings of ACM ARTECH Conference (ARTECH2023)*. 11th international conference on digital and interactive arts.
Olivero, L. F. (2025). *Spheritivity - a hidden variable 1st edition* [Shared exhibition]. Shared exhibition. https://ahiddenvariable.art
Olivero, L. F., & Araújo, A. B. (2021a). *I'm watching you/me. Live drawing and VR visualization of spherical perspectives* [Shared exhibition]. Shared exhibition.
Olivero, L. F., & Araújo, A. B. (2021b). I'm watching you/me. Live drawing and VR visualization of spherical perspectives using TouchDesigner. *Proceedings of ACM ARTECH Conference (ARTECH2021)*. 10th international conference on digital and interactive arts. https://doi.org/10.1145/3483529.3483778
Olivero, L. F., & Araújo, A. B. (2022). Desiderata for a performative hybrid immersive drawing platform. *I-Com*, *21*(1), 33–53. https://doi.org/10.1515/icom-2022-0009
Olivero, L. F., & Araújo, A. B. (2023). Enhancing the teaching of spherical perspective with spheri. *Proceedings of KUI 2023 Conference*. XX international conference on culture and computer science. https://doi.org/10.1145/3623462.3624637
Olivero, L. F., Araújo, A. B., & Rossi, A. (2020). Applications of cubical perspective in architecture, engineering and product design. In M. Fátima Silva, M. A. Carreira, E. Negas, & R. Seco (Eds.), *4.º seminário internacional de arquitectura e matemática* (Universidade Lusíada, Vol. 1, pp. 63–86). Universidade Lusíada. https://doi.org/10.34628/pzqj-p639
Olivero, L. F., Araújo, A. B., & Rossi, A. (2025). A novel shortcut to cubical perspective drawing. *Nexus Network Journal*, *27*(1). https://doi.org/10.1007/s00004-024-00810-y
Olivero, L. F., Rossi, A., & Barba, S. (2019). A codification of cubical projection for the generation of immersive models. *Diségno*, *4*, 53–63. https://www.doi.org/10.26375/disegno.4.2019.07
Olivero, L. F., & Sucurado, B. (2019). Analogical immersion: discovering spherical sketches between subjectivity and objectivity. *ESTOA. Revista de la Facultad de Arquitectura y Urbanismo de la Universidad de Cuenca*, *8*(16), 47–59. https://www.doi.org/10.18537/est.v008.n016.a04
Oniride, 360. A. (2016). *Oniride plugin for photoshoph* [Computer software]. Oniride S.R.L. http://www.oniride.com/360art/
Orłowski, M. (2018). *Drawing tutorial - how to draw 6 point perspective ("street")* [Video recording]. https://www.youtube.com/watch?v=Hu68wkxq-gY
Osorio García, S. N. (2012). Ciencias de la complejidad, pensamiento complejo y conocimiento transdisciplinar: Re-pensando la Humana Coditio en un mundo tecnocientífico. In *La Crisis axiológica raíz de todas las crisis que sufre nuestro mundo: Cómo manejarnos con ella* (Bubok Publishing S.L, pp. 223–259). CETR. https://www.bubok.es/libros/222657/LA-CRISIS-AXIOLOGICA-RAIZ-DE-TODAS-LAS-CRISIS-QUE-SUFRE-NUESTRO-MUNDO-Como-manejarnos-con-ella
Outerspace. (2025). *Bixorama 360° photo software* (Version 6.2.0.3) [Computer software]. Outerspace Software. https://www.outerspace-software.com/bixorama
Oxford, L. (2019). Anamorfosis. In *Lexico dictionaries spanish*. https://www.lexico.com/es/definicion/anamorfosis
Oxford, R. (n.d.). Suspension of disbelief. In *Oxford reference*. https://doi.org/10.1093/oi/authority.20110803100544310
Pagliano, A. (2015, October 22). Anamorphic perspectives for archeological heritage. *REUSO 2015*. III congreso internacional sobre documentación, conservación, y reutilización del patrimonio arquitectónico.
Panofsky, E. (1991). *Perspective as symbolic form* (C. S. Wood, Trans.; First Edition). Zone Books. https://doi.org/10.2307/j.ctv1453m48
Panoton. (2025). *Panorama to cubemap converter in browser. Panoton* [Virtual tours]. https://www.panoton.de/tools/cubemap-converter/
Pascariello, M. I. (2005). *Oltre il punto di vista*. Alinea.
Pear Software, F. (2025). *Flexify 2 plugin for photoshop* (Version 2) [Computer software].
Penny, N. (1999). Review of the panorama: History of a mass medium, ; the panorama. *AA Files*, *39*, 80–82. https://www.jstor.org/stable/29544162
Petroff, M. A. (2019). *Pannellum: A lightweight web-based panorama viewer* [Computer software]. https://doi.org/10.21105/joss.01628

Photoshop. (2025). *Photoshop: Photo, image & design editing software* [Computer software]. Adobe. https://www.adobe.com/products/photoshop.html
Piller, M. (2020). *Hand with reflecting sphere. Escher in het paleis*. https://www.escherinhetpaleis.nl/story-of-escher/hand-with-reflecting-sphere/?lang=en/
Polato, P. (1991). *Il modello nel design, la bottega di giovanni sacchi*. Hopeli.
Postle, P., D'Angelo, P., & Various, A. (2023). *Panorama tools* (Version Libpano13-2.9.21) [Computer software].
Pozzo, A. (1693). *Perspectiva pictorum et architectorum*. Romae: Typis Joannis Jacobi Komarek ... http://archive.org/details/gri_33125008639367
Pozzo, A., & Panini Editore SpA, F. C. (1691). *Gloria di Sant'Ignazio* [Graphic]. https://www.haltadefinizione.com/image-bank/andrea-pozzo-gloria-di-santignazio-1691-1694/
Praun, E., & Hoppe, H. (2003). Spherical parametrization and remeshing. *ACM Transactions on Graphics*, *22*(3), 340–349. https://doi.org/10.1145/882262.882274
Purini, F. (1996). *Una lezione sul disegno* (First Edition edition). Arte, Arredamento, Disegno.
Quadraturismo. (2020). In *Enciclopedia Treccani*. http://www.treccani.it//enciclopedia/quadraturismo
Quadraturisti. (2020). In *Enciclopedia Treccani*. http://www.treccani.it//enciclopedia/quadraturismo
RAE, D. de la lengua española. (2019). Anamorfosis. In *Diccionario de la lengua española - Edición del Tricentenario*. https://dle.rae.es/anamorfosis
Rami, lpm. (2016). *WebGL cubic panorama* (Version 0.33) [Computer software]. https://sketchucation.com/plugin/1143-ramtools_panorama
Rebecca. (2021, May 31). *Create your own panning stereoscopic (3-d) photographs! The stereoscopy blog*. https://stereoscopy.blog/2021/05/31/create-your-own-panning-stereoviews/
Rehkämper, K. (2002). *Bilder, Ähnlichkeit und Perspektive: Auf dem Weg zu einer neuen Theorie der bildhaften Repräsentation*. Deutscher Universitätsverlag. https://doi.org/10.1007/978-3-663-09414-2
Reichenbach, D. (2018). *M.o.d.e.* https://dianareichenbach.com/mode
Reinfurt, K. (2025). *Krpano* (Version 1.22.4) [Computer software]. krpano Gesellschaft mbH. https://krpano.com/
Romor, J. (n.d.). *La prospettiva nel novecento*. Retrieved November 29, 2018, from https://www.academia.edu/22049441/La_prospettiva_nel_Novecento
Romor, J. (2015). Righe di legno, righe di carta e fili di seta: per una 'costruzione' della prospettiva secondo Pierodella Francesca. In M. T. Bartoli & M. Lusoli (Eds.), *Le teorie, le tecniche, i repertori fi gurativi nella prospettiva d'architettura tra il '400 e il '700* (pp. 25–44). Firenze University Press. https://www.academia.edu/22052929/The_construction_of_perspective_image_for_a_digital_representation_of_Piero_della_Francesca_s_procedure
Rossi, A. (2005). *Disegno Design. Natura morta e vita metafisica: Vol. I*. Officina edizioni. https://iris.unicampania.it/handle/11591/161583?mode=full.14
Rossi, A. (2017). *Immersive high resoluttion photographs for cultural heritage* (Adriana Rossi, Vol. 2). libreriauniversitaria edizioni.it. https://iris.unicampania.it/handle/11591/377418?mode=full.335#.XBES8S2cZZI
Rossi, A., & Cabezos Bernal, P. M. (2017). Tecniche di musealizzazione virtuale. Galleria 3D per la fruizione della cultura romanica virtual musealization techniques. A 3D gallery for the contemporary fruition of romanesque culture. *UID PER IL DISEGNO*, 597–604. https://books.google.it/books?id=2U03DwAAQBAJ&pg=PR8&lpg=PR8&dq=rossi+%22Virtual+musealization+techniques%22&source=bl&ots=4IEONn13SH&sig=o-T0c7Fu9ShHHHte-V08uzumxzo&hl=en&sa=X&ved=0ahUKEwiJ6cmPpo_bAhWGkywKHbwFBVoQ6AEIQDAD#v=onepage&q=rossi%20%22Virtual%20musealization%20techniques%22&f=false
Rossi, A., & Olivero, L. F. (2018). Immersive models from analogical sketches applied to solimene's factory. *VII Congreso Internacional y XV Congreso Nacional de Expresión Gráfica En Ingeniería, Arquitectura y Carreras Afines*, 55. http://hdl.handle.net/11591/396733
Rossi, A., Olivero, L. F., & Araújo, A. B. (2021a). For representation, a new reality: Hybrid immersive models. In P. Magnaghi-Delfino, G. Mele, & T. Norando (Eds.), *Faces of geometry: II edition* (pp. 263–275). Springer International Publishing. https://doi.org/10.1007/978-3-030-63702-6_20
Rossi, A., Olivero, L. F., & Araújo, A. B. (2021b). Spazi digitali e modelli immersivi: Applicazioni di prospettiva cubica. *CONNETTERE CONNECTING Un Disegno Per Annodare e Tessere Drawing for Weaving Relationships*, 2621–2642. https://www.doi.org/10.3280/oa-693.148
Rossi, M., Mele, G., & Buratti, G. (2018). La prospettiva come architettura immateriale. Il finto coro di santa maria presso san satiro/the perspective as immaterial building. The fake choir of santa maria by san satiro. *Rappresentazione/Materiale/Immateriale. Drawing as (in)tangible Representation*, 215–224. https://re.public.polimi.it/handle/11311/1065785?mode=full.755#.XGwady2cZZI
Sandnes, F. E. (2016a). Communicating panoramic 360 degree immersed experiences: A simple technique for sketching in 3D. *Universal Access in Human-Computer Interaction. Interaction Techniques and Environments*, 338–346. https://doi.org/10.1007/978-3-319-40244-4_33
Sandnes, F. E. (2016b). PanoramaGrid – a graph paper tracing framework for sketching 360-degree immersed experiences. *2016*, 342–343.
Sandnes, F. E., Lianguzov, Y., Rodrigues, O. V., Lieng, H., Medola, F. O., & Pavel, N. (2017). Supporting collaborative ideation through freehand sketching of 3D-shapes in 2D using colour. In Y. Luo (Ed.), *Cooperative design, visualization, and engineering* (pp. 123–134). Springer International Publishing. https://doi.org/10.1007/978-3-319-66805-5_16
Santoyo, J., & Santoyo, M. Á. (2021). The 360° curvilinear perspective: A hybrid hypercubic angular space grid based on the 1968 barre and flocon proposal. *Nexus Network Journal*, *23*(3), 717–735. https://doi.org/10.1007/s00004-021-00552-1

Scherotter, M. (2018). *Sketch 360* [Computer software]. Microsoft Store. https://www.microsoft.com/en-us/p/sketch-360/9p89s2qlh11t

Scherotter, M. (2025). *Microsoft/sketch360: Cross-platform 360 degree panoramic sketching app*. https://github.com/microsoft/sketch360

Schön, D. A. (2017). *The reflective practitioner: How professionals think in action*. Routledge. https://doi.org/10.4324/9781315237473

Schultz, C. S., & Legg, E. (2020). A/r/tography: At the intersection of art, leisure, and science. *Leisure Sciences*, *42*(2), 243–252. https://doi.org/10.1080/01490400.2018.1553123

Schulze, M., Keppler, S., Meinhardt-Injac, B., & Israel, J. H. (2024). Evaluating stereo and head-coupled perspective cues in collaborative immersive environments. *2024 10th International Conference on Virtual Reality (ICVR)*, 198–206. https://doi.org/10.1109/ICVR62393.2024.10868926

Senore, F. (2025). *FSPViewer*. http://www.fsoft.it/FSPViewer/

Sgrosso, A. (1969). *Il problema della rappresentazione e dello spazio attraverso i tempi* (Stabilimento poligrafico IEM).

Sketch 360. Microsoft garage. (2025). https://www.microsoft.com/en-us/garage/profiles/sketch-360/

Song, Z., & Li, J. (2018). A dynamic tiles loading and scheduling strategy for massive oblique photogrammetry models. *2018 IEEE 3rd International Conference on Image, Vision and Computing (ICIVC)*, 648–652. https://doi.org/10.1109/ICIVC.2018.8492731

Spencer, J. (2018). Illusion as ingenuity. Dutch perspective boxes in the royal danish kunstkammer's "perspective chamber." *Journal of the History of Collections*, *30*(2), 187–201. https://www.doi.org/10.1093/jhc/fhx024

Stark, M., Thielen, E., Holtmann, C., Selmanagić, A., Droste, M., & Barsht, L. (2022). XR art and culture: Successful collaborations in interdisciplinary development processes. *I-Com*, *21*(1), 123–138. https://doi.org/10.1515/icom-2022-0011

Station, N. (2024, March 30). *Anamorphic LED display: The evolution of an art form*. https://www.nullstation.co/anamorphic-illusions-on-led-displays-the-evolution-of-an-art-form/

Steenhorst, A. (2021, September 10). *How to draw a 5-point perspective like kim jung gi* [Video recording]. https://www.youtube.com/watch?v=sPKpIAJukx4

Stirnemann, J. M. (2018). *Über projektionen: Weltkarten und weltanschauungen: Von der rekonstruktion zur dekonstruktion, von der konvention zur alternative*. transcript Verlag.

Stirnemann, J. M., & Bühlmann, R. (n.d.). *Your viewpoint – world map generator. Your viewpoint – worldmapgenerator*. Retrieved May 1, 2025, from https://www.worldmapgenerator.com/

Sucurado, B. (2025). *Bruno sucurado. Behance* [Personal blog]. https://www.behance.net/brunosucurado

Sullivan, G. (2005). *Art practice as research: Inquiry in the visual arts*. SAGE.

Swart, D. (2016, June 28). *Drawing a spherical panorama. D. M. swart*. https://dmswart.com/2016/06/28/drawing-a-panorama/

Talbot, R. (2003). Speculations on the origins of linear perspective: Including analyses of masaccio's trinity and piero's flagellation. *Nexus Network Journal*, *5*(1), 64–98. https://doi.org/10.1007/s00004-002-0005-5

Taylor, A. (2019). *Plate 14: Section of the rotunda, leicester square, in which is exhibited the panorama.* [Graphic]. https://commons.wikimedia.org/wiki/File:Mitchell_LeicesterSquareRotunda_05-11-20.jpg

Taylor, B. (1715). *Linear perspective: Or, a new method of representing justly all manner of objects as they appear to the eye in all situations*. R. Knaplock. https://archive.org/details/bim_eighteenth-century_linear-perspective-or-_taylor-brook_1715

Taylor, C. (1971). Interpretation and the sciences of man. *The Review of Metaphysics*, *25*(1), 3–51. http://www.jstor.org/stable/20125928

Termes, D. (1998). *New perspective systems. Seeing the total picture: One through six point perspective* (1st edition). Author's edition.

Termes, D. A. (1991). Six-point perspective on the sphere: The termesphere. *Leonardo*, *24*(3), 289–292. https://doi.org/10.2307/1575568

The National Gallery, L. (n.d.). *Samuel van hoogstraten (1627 - 1678). National gallery, london*. Retrieved January 30, 2021, from https://www.nationalgallery.org.uk/artists/samuel-van-hoogstraten

The National Gallery, L. (photograph)., & Hoogstraten, S. van. (1655). *A peepshow with views of the interior of a dutch house* [Graphic]. https://commons.wikimedia.org/wiki/File:Hoogstraten_Perspective_Box.jpg

Theng Seng, L. (2016, December 25). *4 steps to create a 360 VR illustration/painting in photoshop (with pictures) – studio behind 90 – indie motion graphic design studio. Behind 90 studio*. https://studiobehind90.com/2016/12/25/how-to-create-360-panorama-painting-in-photoshop/

Theng Seng, L. (2018, November 1). *How to creating 360 virtual reality (VR) illustration with adobe photoshop CC (2017 & 2018) – studio behind 90 – indie motion graphic design studio. Behind 90 studio*. https://studiobehind90.com/2018/11/01/how-to-360-virtual-reality-vr-illustration-photoshop-cc17-cc18/

Tomonori, N. (2017). *Cube2DM – image projection converter* (Version 2017/03/12) [Computer software]. https://t.nomoto.org/Cube2DM/index_en.html

Tran Luciani, D. (2019). *Designing for sketching to support concept exploration* [Doctoral thesis, comprehensive summary, Linköping University Electronic Press]. https://doi.org/10.3384/diss.diva-161712

Tran Luciani, D., & Lundberg, J. (2016). Enabling designers to sketch immersive fulldome presentations. *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, 1490–1496. https://doi.org/http://doi.acm.org/10.1145/2851581.2892343

TSD Project Lab. (2021). *Schianti. Think, say, do*. https://www.tsd-projectlab.it/onair/schianti

United States. War Dept. Division of Military Aeronautics. (1918). *Panoramic drawing: One-point and cylindrical perspective. Department of ...* Govt. print. off. http://archive.org/details/panoramicdrawin00unkngoog

Vagnetti, L. (1979). *De naturali et artificiali perspectiva: bibliografia ragionata delle fonti teoriche e delle ricerche di storia della prospettiva : contributo alla formazione della conoscenza di un'idea razionale, nei suoi sviluppi da Euclide a Gaspard Monge*. Edizione della Cattedra di composizione architettonica IA di Firenze e della L.E.F.

Veiga, P. A. da. (2019). A/r/cography: Art, research and communication. In *Proceedings of the 9th international conference on digital and interactive arts*. Association for Computing Machinery. https://doi.org/10.1145/3359852.3359859

Veiga, P. A. da. (2020). *O museu de tudo em qualquer parte: Arte e cultura digital: Interferir e curar*. Grácio Editor. https://repositorioaberto.uab.pt/handle/10400.2/11265?mode=full

Veltman, K. H. (1996). Piero della francesca and the two methods of renaissance perspective. In M. D. Emiliani (Ed.), *Piero della francesca tra arte e scienza* (pp. 407–419). Fondazione Piero Della Francesca. https://www.worldcat.org/title/piero-della-francesca-and-the-two-methods-of-renaissance-perspective/oclc/886822999

Verweij, A. (2010). Perspective in a box. *Nexus Network Journal*, *12*(1), 47–62. https://www.doi.org/10.1007/s00004-010-0023-7

Vignola, I. B. da. (1583). *Le dve regole della prospettiva pratica* (Getty Research Institute). In Roma, Per Francesco Zannetti. http://archive.org/details/dveregoledellapr00vign

Vistisen, P., Luciani, D., & Ekströmer, P. (2019). Sketching immersive information spaces: Lessons learned from experiments in "sketching for and through virtual reality." *Proceedings of the 7th eCAADe Regional International Symposium: Virtually Real*, 147–157. https://vbn.elsevierpure.com/en/publications/sketching-immersive-information-spaces-lessons-learned-from-exper

Wade, N. J. (2017). Early history of illusions. In *The oxford compendium of visual illusions.* (pp. 3–37). Oxford University Press.

Wagensberg, J. (2003). *Ideas sobre la complejidad del mundo*. Tusquets Editores.

Wakayama, A., Matsumoto, C., & Shimomura, Y. (2005). Binocular summation of detection and resolution thresholds in the central visual field using parallel-line targets. *Investigative Opthalmology & Visual Science*, *46*(8), 2810. https://doi.org/10.1167/iovs.04-1421

Wehby, J. (2010). *Smustard(TM) - the companion to sketchup(TM) - CubicPanoOut* (Version 1.100) [Computer software]. Smustard. http://www.smustard.com/script/CubicPanoOut

Wikipedia, E. (2018a). Cube mapping. In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Cube_mapping&oldid=837243861

Wikipedia, E. (2018b). Skybox (video games). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Skybox_(video_games)&oldid=825433763

Wong, T.-T., Wan, L., & Leung, C.-S. (2007). Isocube: Exploiting the cubemap hardware. *IEEE Transactions on Visualization & Computer Graphics*, *13*(4), 720–731. https://doi.org/10.1109/TVCG.2007.1020

Wordpress. (2016, December 9). *Embedding 360° photos and virtual reality (VR) content. Support — WordPress.com*. https://wordpress.com/support/embedding-360-photos-and-virtual-reality-vr-content/

Zanela Saccol, A. (2009). Um retorno ao básico: Compreendendo os paradigmas de pesquisa e sua aplicação na pesquisa em administração. *Revista de Administração Da Universidade Federal de Santa Maria*, *2*(2), 250–269. https://www.redalyc.org/articulo.oa?id=273420378007