Enhancing the Teaching of Spherical Perspective with Spheri

Lucas Fabian Olivero
Research Centre for Arts and Communication CIAC, PhD Student in Digital Media Arts, Universidade do Algarve and Universidade Aberta Lisbon, Portugal
lufo@lufo.art

António Bandeira Araújo
Research Centre for Arts and Communication CIAC, Departamento de Ciências e Tecnologia, Universidade Aberta, Lisbon, Portugal
antonio.araujo@uab.pt

ABSTRACT

Spherical perspectives and the practice of immersive drawing are going through a period of rapid development along with a concurrent growth of interest in their applications to various fields. The teaching of new practitioners must often be done in short workshops lateral to established curricula, which is a challenge due to the complexity of the subject. We present a digital tool for performative immersive drawing that can be instrumental in enabling a quick and informative transmission of the principles of immersive drawing to a student audience.

CCS CONCEPTS

• **Human-centered computing** → Visualization; • **Applied computing** → Arts and humanities; Fine arts; Arts and humanities; Media arts.

KEYWORDS

Spherical perspective, handmade drawing, digital art, VR art, Spheri

ACM Reference Format:
Lucas Fabian Olivero and António Bandeira Araújo. 2023. Enhancing the Teaching of Spherical Perspective with Spheri. In *XX. International Conference on Culture and Computer Science (KUI '23), September 28, 29, 2023, Lisbon, Portugal.* ACM, New York, NY, USA, 11 pages. https://doi.org/10.1145/3623462.3624637

1 INTRODUCTION

Spherical perspectives are drawing methods that allow for a single handmade drawing to capture a complete immersive view of a 3D environment. These drawings can then be scanned and visualized as interactive VR environments. Spherical perspectives have been the subject of intense recent theoretical and methodological developments [4, 5, 8, 26] and a matching interest in their applications in painting, commercial illustration [18, 19, 28], architecture and the documentation of cultural heritage [1, 17, 25] and even visual education at the elementary school and high-school level [13, 14].

But this rising interest faces a considerable hurdle. Spherical perspectives are a technical subject that requires careful development and extensive teaching. The authors had the rare opportunity to deliver multi-week courses under such favorable conditions to audiences of architects, designers and artists in Portugal, Italy, Finland, and Macau, and can confirm that under such conditions the subject is well received and well absorbed. Most of the times, however, the subject is taught to very enthusiastic audiences but only as a lateral subject, usually awarded only single session workshops and taught in parallel to more established subjects, or as an advanced item of more established curricula. This is the opposite of what is desirable – in fact it has been suggested that immersive perspectives are more properly seen – mathematically and philosophically – as a foundational subject from which linear perspective should be derived from as a special case [12]. Be that as it may, since most opportunities to teach this subject – and therefore to spread the field – come in the form of (far too short) workshops, this teaching scenario must be handled optimally. In this paper we discuss a new tool that is extremely useful in facilitating the teaching of spherical perspective methods, especially under severe time constraints.

KUI '23, September 28, 29, 2023, Lisbon, Portugal

ACM ISBN 979-8-4007-0836-7/23/09.
https://doi.org/10.1145/3623462.3624637

2 A BRIEF REVIEW OF SPHERICAL PERSPECTIVES

Spherical perspectives have been extensively treated elsewhere and we will only give the briefest context here. The foundational text of the field is Barre and Flocon's text [9–11] which however handles only the 180-degree case of the azimuthal equidistant ("fisheye") perspective, hence is not truly "spherical". The generalization of Barre and Flocon to 360 degrees was done by Araújo in [4], which also characterized the theory of spherical perspectives in general, suggesting a strategy for solving these perspectives that was later applied to the equirectangular case in [5] and to the cubic case in [8]. Recently Santoyo et al. [26] have also attacked the case of the Mollweide spherical perspective, through a different analytical approach.

Here it will be enough to say that spherical perspectives are two-step processes. In the first step, the objects of a 3D environment are radially projected onto the surface of a sphere centred on the observer's eye, the visual sphere. Second, the sphere is flattened onto a region of the plane. The projection on the sphere is called the anamorphosis and its image on the flat is called the spherical perspective. Obviously, what we get depends on the flattening process chosen, and therefore there are as many types of spherical perspectives as there are appropriate cartographic maps (azimuthal equidistant, equirectangular, cubical, Mollweide, etc.) each of which has not only its own distinctive appearance but also its particular rules for drawing. They all have something in common, though: they all derive from the spherical anamorphic image, where each line projects as a meridian (half a geodesic) ending at a pair of antipodal vanishing points. Araújo [4] has pointed out that this suggests a common strategy to attack each perspective: one should be concerned not with drawing lines directly, but to draw the images of planes through the eye point. These project as geodesics of the sphere, and the images of lines will be meridians (halves) of these geodesics, ending at two diametrically opposite vanishing points. One should therefore "solve" a perspective by finding out how to classify and efficiently render the natural classes of geodesic images of each perspective. Drawing lines will then be a matter of cropping the geodesics at the appropriate antipodal sets of points. What the "natural" classification of geodesics is may depend for instance on the groups of symmetries of each perspective, or on some other properties. In some cases, there may not even be a good classification or indeed a good solution at all – that is why we talk of a "strategy" and not an "algorithm" for solving these perspectives. Let us stress here that the problem is how to draw them efficiently *by hand* using simple instruments – all of these perspectives are quite simple to plot using computers, but we are interested in technologies that extend rather than replace the discipline of handmade drawing.

3 CHALLENGES IN TEACHING SPHERICAL PERSPECTIVES

3.1 Methodological challenges and their solutions

The main thing about the methods of Barre and Flocon is that they are ruler and compass methods in the tradition of classical perspective. In the 180-degree fisheye case these methods are not very time-consuming since every line projection is an arc of circle. But in the 360-degree case things become more complicated, requiring more care with approximations, and this is even more so in the equirectangular case where each line projection requires careful constructions with auxiliary diagrams. This makes equirectangular perspective into a studio drawing experience if accuracy is required. This is not to say that freehand sketching is impossible. It is very much possible and done even for production purposes. It was possible to do fisheye-like perspectives before Barre and Flocon, as it was possible to do linear perspective before its formalization. The purpose of having precise methods is that it turns perspective from the primordial swamp of rule-of-thumb into the realm of a discipline that both entices the eye and stimulates the mind. But his is hard to do when one is slaving away to render a single line projection. It also makes it hard to teach in a limited time. In a 3-hour session most of the time would be wasted in the required but quite unenlightening manipulation of drafting tools.

The alternative to ruler and compass methods is grid methods. Artists would calculate equirectangular grids of horizontals and verticals on a computer and draw on top of these prints, using them as guidance. The problem is that anything other than the set of pre-calculated curves had to be guessed at, which eliminates the possibility of elaborate perspective constructions. To solve this (in the equirectangular case) Araújo proposed [5] a method of dynamic grids for equirectangular perspective, that uses transformation groups to draw any line projection from a single grid. The process depends on dual realizations: 1) that one should be concerned with the images of planes through the centre of the visual sphere (geodesics) instead of lines and 2) that rotation geodesics around the vertical axis in space is the same as translating them horizontally in the equirectangular plane projection. The dynamic grid method provides in effect the equivalent of a straightedge for equirectangular perspective, which changes radically the nature of what can be done with it and how it can be taught in a limited time. Instead of guesswork exercises this enables one to perform, in equirectangular perspective, the same kind of reasoned, exact constructions that were possible in linear perspective. In the 2018 Bridges conference (Bridges is a major conference on art and mathematics) Araújo created and tested out a syllabus in a workshop [2]. This didactic sequence has since become a well-tested standard: students are first taught the dynamic grid method and how to plot points using angle measurements (from nature, using the "astronomer's method" or from plan and elevation diagrams using a protractor), then taught how to do perspective arithmetic (multiplying and dividing a square), drawing uniform tiling of the plane using vanishing points, drawing controlled slopes and stairs, and approximating general curves such as circle images. This sequence has been extensively repeated and refined both by the original author and later by the present authors working collaboratively.

In the Bridges conference of 2019 [6] an analogous system of dynamic grids was proposed for the azimuthal equidistant (360-degree fisheye) case, this time using the conjugate rotations around the vertical axis of the sphere and the rotations around the central point on the perspective disc. The same set of constructions of the equirectangular syllabus can be executed with this method, using analogous methods adapted to the specific perspective. This syllabus has been much less tested since the fisheye case is not as easy to pass into VR. Nevertheless, this difficulty can be easily solved by using Spheri, as it was solved the cubical case (see ahead). We hope this may help popularize this very elegant but underused perspective.

Finally, in Bridges 2022, the present authors tested a method to adapt the same set of basic constructions to the cubical case [7]. This was not as straightforward as the translation to the fisheye case, as cubical perspective is quite different from equirectangular. Cubical spherical perspective is the perspective we obtain if we project the spherical anamorphosis radially from the sphere onto a concentric cube and then flatten the cube by cutting and rotating around its edges (Figure 1).

This case is interesting because the cubical case cannot be treated as the previous two cases. Cubical perspective does not have a good group of transformations to generate all geodesics from a grid – so it has no dynamic grid methods. Instead, a different method had to be used. Because ruler and compass constructions were to be avoided in a short workshop, a method of *internal* constructions were used, that is, constructions done without recourse to plan and elevation diagrams. Only a base square was plotted in plan and elevation and all other constructions were obtained by operations on this square: multiplications, divisions, translations, etc., which use only ruler-based operations on the flattened cube, and reflections instead of rotations (recall from geometry that rotations can be obtained as entailments of reflections). Cubical is an interesting case also because the lack of a good group of transformations is compensated by the fact that lines project as sets of line segments, hence we do not require a special tool or grid to draw geodesics; however this is paid for by having a larger casuistic that must be followed according to the position of the geodesics one wished to plot (see [8] for a full classification of the cubical geodesic projections).

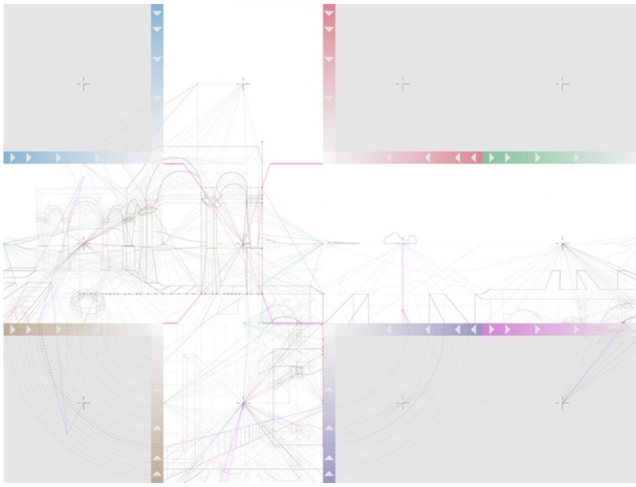

Figure 1: A cubical spherical perspective

As for the Mollweide spherical perspective that was recently studied by Santoyo et al. [26], we have at present no method for approaching it in a succinct manner, since the form of its geodesics is not well fitted for any of the previous approaches.

3.2 Technological challenges and their solutions

A major challenge in teaching spherical perspectives to beginners is the ability to visualize what one is doing as one does it. There are in fact two related visualization difficulties. In the first Bridges workshop of 2018 a major hurdle was in communicating what the instructor was drawing on paper. The dynamic grid method is usually applied with an A3 tracing paper enveloping an A4 printed grid, as described in [2]. This was hard to show to a large room, especially as the drawings themselves were small and detailed.

The first problem was solved by a mix of complementary strategies, each of them flawed in some way: drawing the main steps on a larger grid on a board (which had to be a fixed grid, not a dynamic one), showing other pre-rendered steps in projection, and describing others in a whiteboard or sometimes even parading the A4 sheet along the room. This worked, but it was far from ideal. The clearest images were the pre-rendered projections, but these hinder any possibility of improvisation in response to participant cues or unexpected conditions. All such improvisation had to be done on the blackboard and required a strain of visual imagination that was hard on the participants.

The second problem is communicating the VR rendering of the drawing. The process of converting a handmade drawing on paper to a VR panorama is straightforward in theory but cumbersome in practice. One must scan or photograph the drawing, crop carefully to an exactly 2:1 format, and only then render. One does not want to go through this multiple times in a workshop, as it simply takes too much time and breaks the workflow.

This second problem was solved again through pre-renderings, but this was even less amenable to improvisation. One would wish to be able to change a drawing's plan, make additions or on-the-fly corrections and annotations, and visualize the process seamlessly, preferably at the same time as the full flat drawing was worked on.

These difficulties led to the creation of the program Eq A Sketch 360 [3]. This program implements digitally the sliding grid method and allows the user to draw a snap-to geodesic for any two given points. Using this tool with a projector was far clearer and allowed for improvisation. The authors have used Eq A Sketch 360 extensively for workshops, and it is exceptionally useful in online courses where paper drawing was especially difficult to communicate. Still, it has several flaws, the main one being that it leads the participants away from the handmade frame of mind, and onto the digital drawing realm, even if it is explained that the software is only necessary for demonstration. The other is that Eq A Sketch 360 is a barebones program that does not include an integrated VR visualizer. The picture must be saved and opened in another program. This was much faster than the scanning process but still not ideal. In a collaboration with Araújo, Michael Scherotter from Microsoft adopted the sliding grid and geodesic rendering of Eq A Sketch 360 into his own Microsoft garage project, Sketch 360 [27]. This is a more sophisticated app, which includes an integrated VR renderer, but it is less suited to geometric constructions, having been made with journaling in mind, so at present both approaches are flawed in some way, for our purpose. Either way, they both suffer from being digital drawing tools when one would prefer a simple way to convey purely physical drawing. And this is where Spheri's proposal comes in.

3.3 Time challenges and their solutions

Of the cases discussed above, the equirectangular syllabus has been the most extensively tested, both on location and through online teaching by both authors:

Author A. B. Araújo has conducted regular classes since 2018 in a course for artists and school teachers and for a Ph.D. program on Digital Media Arts, and since 2020 to an undergraduate class for architects and designers in Macau's University of St. Joseph (all multi-weeks courses). Longform testing was also performed in Finland's Aalto University for a group of researchers.

A short workshop has been conducted yearly since 2021 by both authors in collaboration, for architects in Argentina, at the courses "TAC" (Technology, Architecture and Communication) and "TAC@" (Advanced Techniques of Architectural Communication) hosted at the University of La Plata[1] since 2019.

The cubical case has been tried in longform testing by L. F. Olivero at University of Campania Luigi Vanvitelli[2] (2019-2020) for students of Engineering and Design and, by both authors, in a short workshop at the Bridges 2022 conference, which we will discuss ahead.

Audiences have varied from the dozen to a maximum of 128 students in August 2023 during the latest collaboration with the Argentinian course TAC@ (Figure 2, Figure 3). So far, the authors have not conducted surveys, so as to support conclusions with data from these students' experiences. Nevertheless, we can read some constants by analyzing the graphical outputs from the students: long term classes and courses that integrate constant curricula have worked better so far in terms of knowledge retention and comprehension. In contrast, short workshops tend to start as workshops in

[1]In collaboration and by invitation of T. Zuccari and A. Jara.
[2]In collaboration and by invitation of A. Rossi.

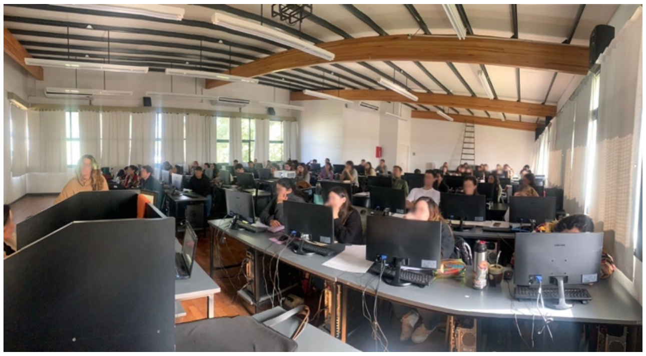

Figure 2: TAC@ course at the University of La Plata

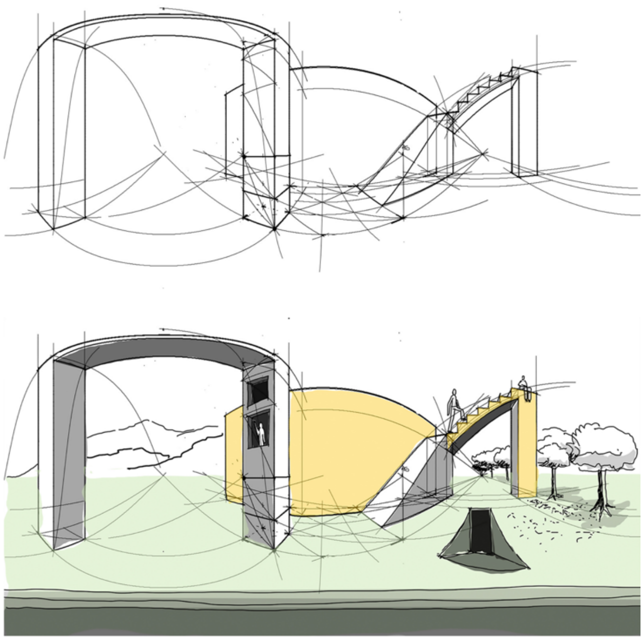

Figure 3: Equirectangular drawing made for the TAC@ course

the proper sense, with participants performing the constructions along with the instructors, but almost always end as a demo, with participants watching the instructors perform the most advanced constructions, due to the lack of time necessary for absorbing the new concepts and finding their correspondence within the practical execution. As we will see in the further sections, Spheri helped to bridge the gap between theory and practice, by providing a technological solution that communicates in real-time the VR rendering and the flat drawing.

4 SPHERI

Spheri is a digital platform created for the purpose of providing a real-time conversion of the flat view of a spherical perspective into its VR immersive experience [23, 24].

The first version of the platform was part of an artefact/installation called "I'm Watching You/Me", presented in October 2021. That first version operated a VR camera through a mobile phone sending orientation data in real time. This data was then used to turn a digital view cone within a digital visual sphere. On top of such a sphere there was projected an equirectangular drawing, made on-the-fly, and live captured by a camera (Figure 4).

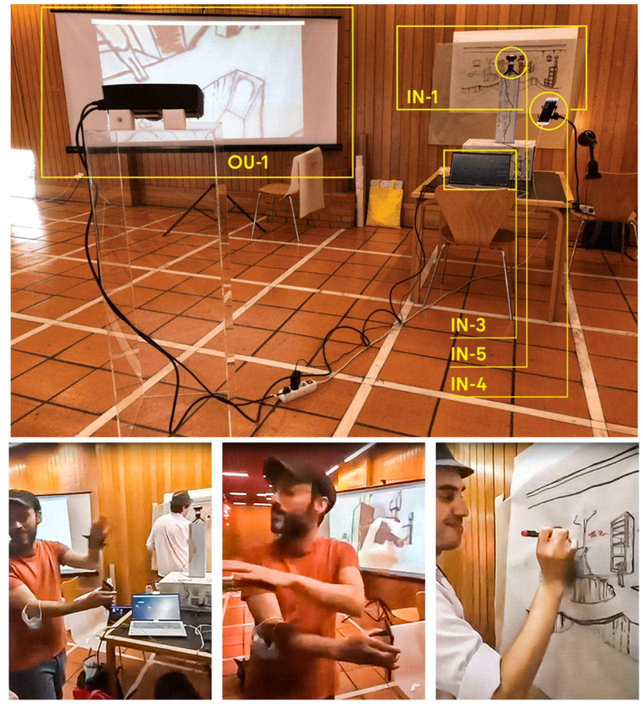

Figure 4: Live drawing performance

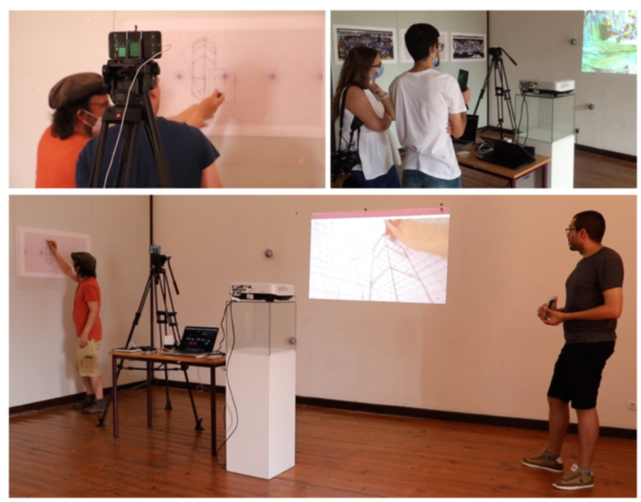

Figure 5: Using the artefact for both artistic and teaching purposes

The second version introduced some alterations such as the optimisation of components and layout, the addition of an artistic

Figure 6: - Presentation of Spheri in Berlin

concept and narrative, a graphical interface for an enhanced interaction, and a more stable and independent user experience. This version was used by L. F. Olivero for his [IN]Musicality exhibition [20] and for a drawing workshop[3] by both authors, showing the platform's dual role both for hybrid (physical-digital) spherical media art installations and for teaching (Figure 5).

The third version was released in August 2022, and it introduced the use of body tracking through video image analysis and the use of the MediaPipe machine learning library for the VR navigation. It also added the possibility of choosing either a cubical or an equirectangular perspective input. This version was, again, used both with artistic [21, 22] (Figure 6, Figure 7) and with teaching purposes [7], although the new improvements marked significatively the possibility of including Spheri as an essential tool to improve the teaching experience. In the following section we present the results of the last two teaching applications and the role of Spheri within them.

4.1 Towards a dedicated platform for teaching spherical perspectives

From the third version on, the platform incorporated the MediaPipe machine learning library for motion capture. MediaPipe analyses the images captured by a camera, identifies body landmarks (Figure 8), and returns their coordinates. This data was used for creating functions through hand gestures, i.e., using the relative distance between landmarks for triggering actions. The first functions added to the platform were:

[3]https://dmad.ciac.pt/workshop-ambientes-imersivos/

Figure 7: Presentation of Spheri in Portugal

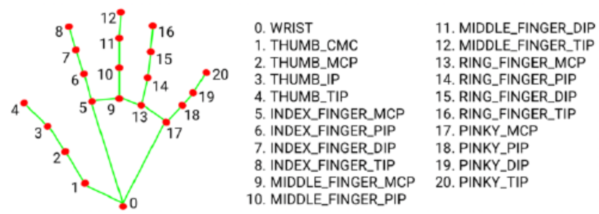

Figure 8: Hand landmarks detected by MediaPipe

- **Automatic start:** a function switched from the welcome to the main screen autonomously after detecting a visitor.
- **Hand to VR camera:** the movements of the right hand controlled the orientation of the VR camera through the relative position of the landmark 0 (wrist) within the screen.
- **Hand to Pointer:** the movements of the left hand determined the pointer's position within the screen through the relative position of the landmark 0 (wrist) within the screen. This function calls the functions "button" and "controller" from the pynput python library.
- **Pinch to Zoom:** the field of view shown on the VR viewport adjusted proportionally to the relative distance between the right thumb (landmark 4, thumb tip) and index (landmark 8, index fingertip) fingers.
- **Pinch to Click:** the relative distance between the left thumb (landmark 4, thumb tip) and index (landmark 8, index fingertip) fingers triggered the mouse's left click.

This version of the platform also introduced the use of cubical maps as an input format. Although the conversion between environmental maps - such as the equirectangular, cubical, and the azimuthal equidistant maps - is computationally trivial [12, 15, 16], the setup was not arranged in the previous versions of the platform. Some further special adjustments were needed, such as delimitation, rotation, and calibration of the cubical map, due to the disposition of the cubical map's faces used by the authors being different from the default expected by TouchDesigner. Some of these steps could be avoided if the platform had been programmed independently

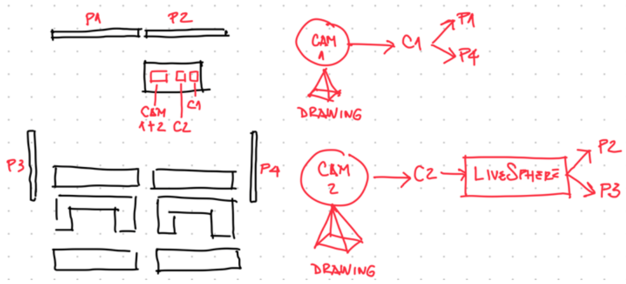

Figure 9: Setup during the workshop at Aalto University

rather than using TouchDesigner. This problem cropped up in several ways during the development and finally started to be solved with Spheri's latest version, which switched from TouchDesigner to JavaScript, Three.js and MediaPipe [23].

5 USING SPHERI FOR IMPROVING THE TEACHING EXPERIENCE

All the new functions of Spheri were tested for teaching purposes during the drawing workshops "How to Draw a Virtual Cubical Perspective Box", held in Helsinki, Finland [7], and "Drawing Handmade Virtual Reality panoramas", held in Faro, Portugal[4]. The first workshop focused cubical perspective while the latter in the equirectangular case.

The available time for the developments of the workshops were 1:30 hr. in Finland and 1:15 hr. in Portugal, a very short time even to transmit the most basic principles of spherical perspectives.

Time, as explained above, 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 us compare the results of both workshops analysing the following components:

1. classroom setup
2. use of Spheri
3. exercises performed
4. instructors
5. participants' background
6. results.

5.1 The experience in Finland

5.1.1 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 we arranged two cameras propped up over the main desk and pointing downwards, and two computers (Figure 9).

5.1.2 Spheri. The arrangement of the classroom was not prepared ad-hoc for the workshop; it was the standard room setup, the versatility of which enabled the use of Spheri at its best: the physical handmade flat drawing and its VR correspondent view were shown independently and in parallel during the lesson: camera 1 used computer 1 and broadcasted the physical drawing in projectors 1 and 4; camera 2 was connected to the computer 2, running Spheri, and broadcasting the VR viewport to projectors 2 and 3 (Figure 9, Figure 10, Figure 11). 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.

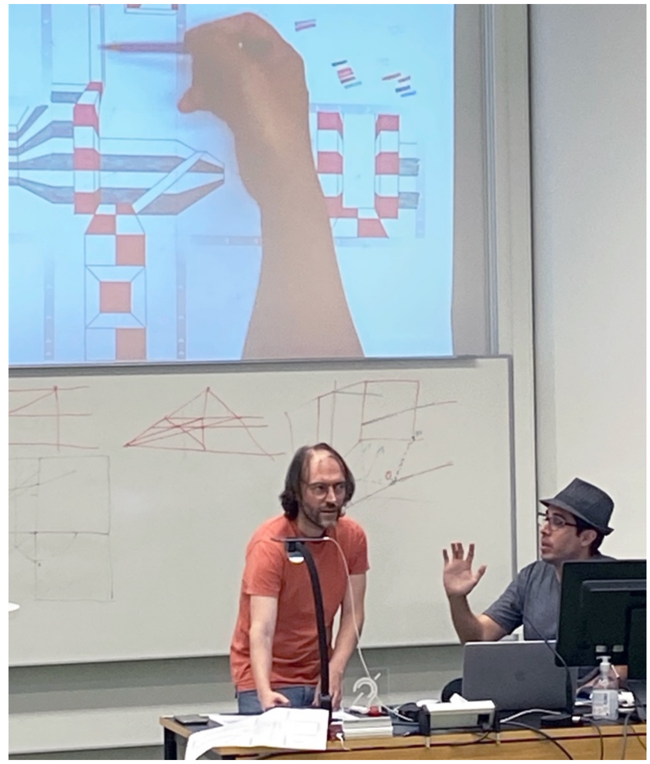

Figure 10: Using Spheri in Finland. In the background, screen 2 is projecting the flat drawing.

5.1.3 Exercises. Finland's workshop had a very well planned and previously prepared set of exercises: one whole and consistent cubical drawing should have to be completed after a limited number of steps with increasing complexity (Figure 12, Figure 13, Figure 14, Figure 15). In this way, 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 special frame of reference that used colours to help identify the connections between cubical faces. Participants were to draw on top of this reference. In short, the set of exercises to be performed included the construction of: squared tiles; a cube using one of those tiles as a base; the extensions of elements across the edges of the cubemap, such as the extension of a uniform tiling across cube faces, or the raising of a column from the front to the top face; a wall with given

[4]https://artsit.eai-conferences.org/2022/workshop-drawing-handmade-virtual-reality-panoramas/

Figure 11: Using Spheri in Finland. In the background, screen 1 is projecting the VR view.

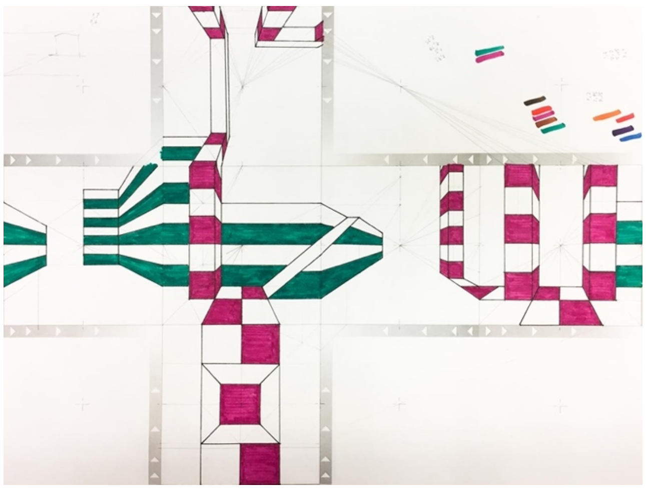

Figure 12: The final composition used for drawing a cubical perspective at Bridges 2022

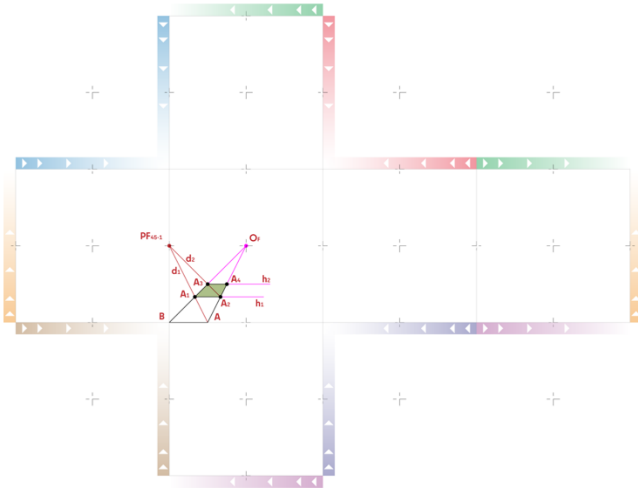

Figure 13: Construction of the first squared tiles

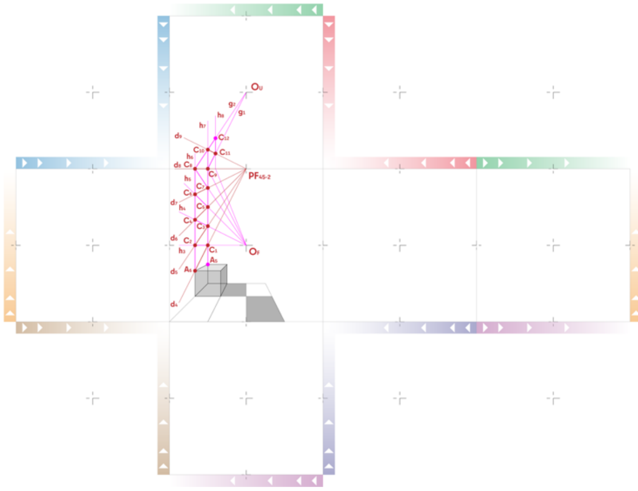

Figure 14: Raising a column in two different faces

proportions and its sub-division; a ramp connecting two given levels; and the extension of geometrical elements across faces with discontinuous gaps such as the top and the back faces.

5.1.4 Instructors. The lessons were given by the two authors. 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 of labour, it would have been very cumbersome and time-inefficient for a single person to operate Spheri and give the lesson at the same time. This characteristic of the platform was reconsidered within the current version, and it led to an improvement: now, the tracking follows the hand of whoever is drawing. This eliminates the need for a second person as operator of the virtual camera without requiring any further step or concern from the instructor.

5.1.5 Participants' background. The attendance in Bridges Finland was composed by a crowd with mixed backgrounds, including mathematicians, architects, designers, and artists. Regrettably, we missed the opportunity to conduct a survey to verify the composition of the specific attendance to our workshop. This and other important data, such as the motivation of the participants for attending the workshop cannot unfortunately be ascertained. The lack of such surveys in our work is a failing that we aim to correct shortly.

5.1.6 Results. Thanks to the combination of elements described above, the participants were able to follow every construction step-by-step, all of them reaching almost the same level of finishing

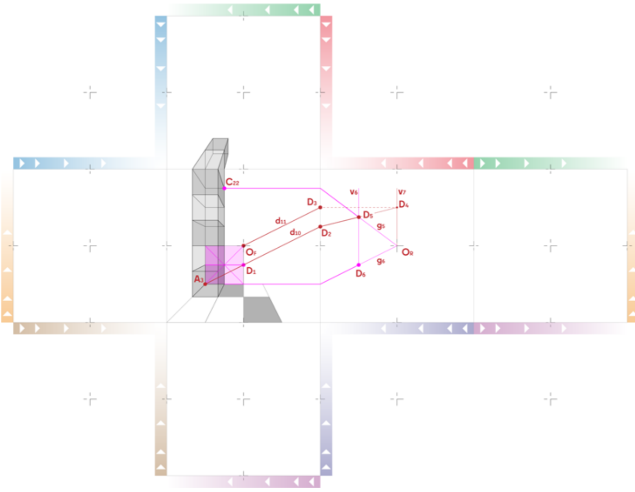

Figure 15: Drawing a wall with a given proportion

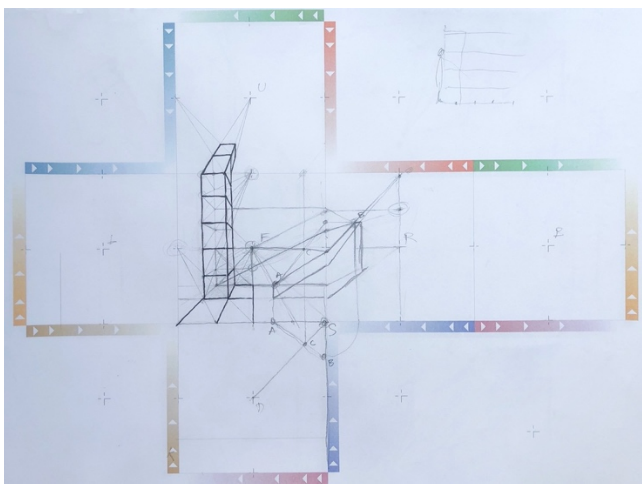

Figure 16: Results from participant A

(Figure 16, Figure 17). Some participants even managed to take the principles learned during the session to build by themselves some of the structures in the demo drawing that we had no expectation to develop during the session; for instance, one participant built the column on the extreme right of the back view and the arch connecting it to the frontal column.

All in all, judging by the regularity 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 the perspective's main concepts, and a considerable part of this came from the ease of communication and visualization that the Spheri platform enabled.

5.2 The experience in Portugal

5.2.1 Classroom setup. In contrast with the previous case, the workshop in Portugal was not held in a classroom but arranged

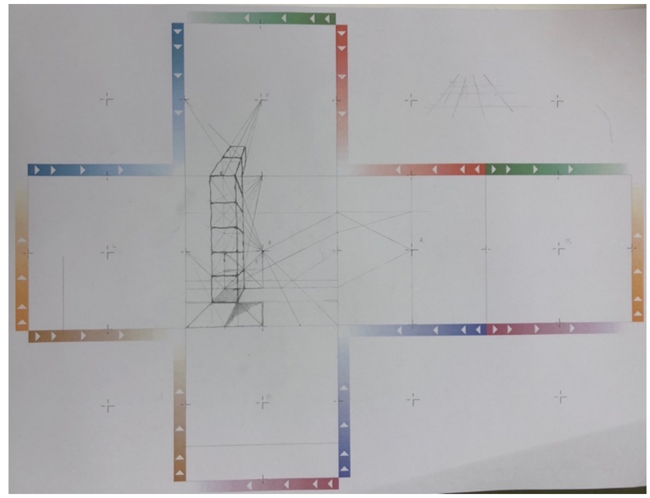

Figure 17: Results from participant B

in an open space between two conference rooms (Figure 18). This was much more of an informal workshop/event held in what was simultaneously the coffee break room, and the participants actually drawing were only seven, with a few more lookers on, some paying attention throughout the whole thing – seeing it more as a lecture or even a performance – some going in and out of the open room, some even posing questions or comments.

This arrangement presented several problems: 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; only one projector was available; neither the lighting conditions nor the quality of recording were optimal for the projected image (Figure 19); 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.

5.2.2 Spheri. Because only one projector and one camera were available, Spheri was forcibly adapted to be used in one screen. Hence, 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 screen showing the two views side-by-side (Figure 19).

5.2.3 Exercises. This time there was not a pre-established set of exercises. Instead, we intended to instruct the participants by drawing the workshop's room from direct observation. As the room was a simple and clean geometry it represented a good example for understanding the very basics of spherical perspective.

Contrary to Helsinki's case, participants did not receive any grid or frame to get oriented within the equirectangular map for this workshop. This was decided because under the conditions of the room it would have been hard to use dynamic grids, without proper support for the drawings. Instead, participants were instructed to create an ad-hoc system of reference by folding the paper in regular sections.

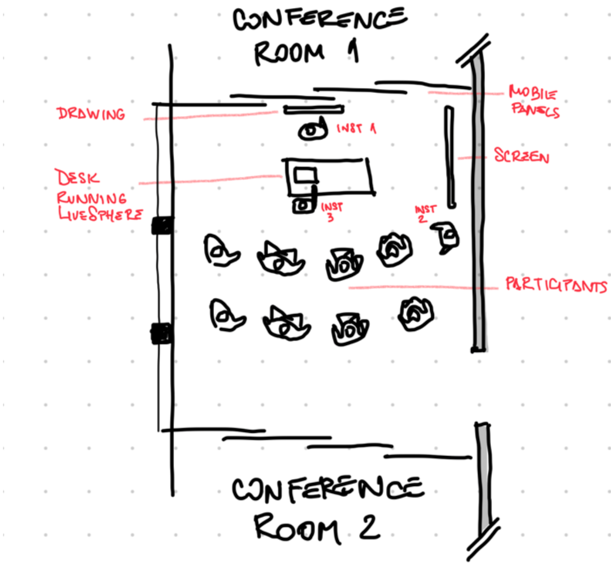

Figure 18: Setup during the workshop at the EVA Senses hotel, Faro, for the ArtsIT conference

Figure 19: A. B. Araújo performing the VR navigation of participant Mathilde Papillon's drawing

5.2.4 Instructors. The workshop was delivered by three persons, the authors and C. M. Sgrinzatto. Although the three trainers provided cross-knowledge and helped each other at each stage, the division of roles was: theory by A. B. Araújo, practice of basic guidelines by C. M. Sgrinzatto, and the flat drawing / VR view correspondence using Spheri by L. F. Olivero. During the whole session the three instructors helped the participants one by one (Figure 19, Figure 20, Figure 21)

5.2.5 Participants' background. Due to the nature of the congress and the instructors' networking during the talks, it is reasonable to assume the workshop was mainly attended by an audience specialised in IT and design careers, with artistic and technical background in the fields of Computer Sciences, UX/UI and Digital Media

Figure 20: L. F. Olivero helping the participants

Figure 21: C. M. Sgrinzatto helping the participants

Arts. Nevertheless, just as in the Helsinki case, we unfortunately did not conduct surveys that might confirm these assumptions.

5.2.6 Results. Compared to Helsinki, the results from Portugal were far more mixed, in graphical terms: while some participants clearly managed to grasp some of the basic principles conveyed and materialize them on paper, others did not manage to do so at all (Figure 22). Again, surveys might have been a clue in determining the reasons for such a disparity, but by analysing the graphical results we could venture that participants might have encountered more complications in translating the principles to 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.

In short, the workshop in Portugal was an excellent opportunity to apply Spheri to the equirectangular case, offering an interactive

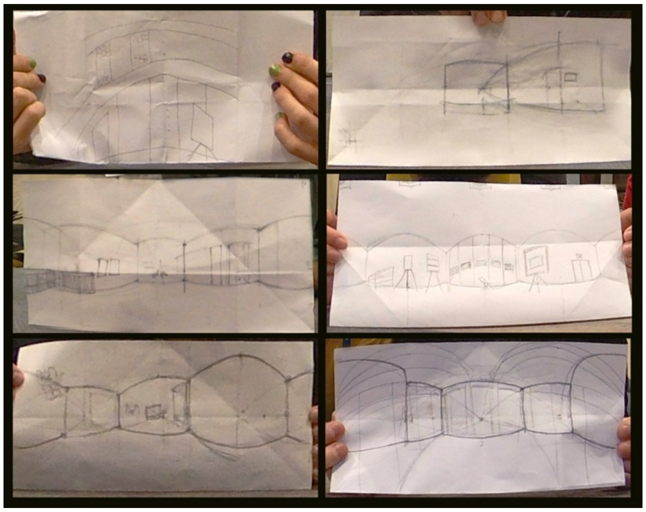

Figure 22: Results from some of the participants

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 cross-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.

6 THE FUTURE OF SPHERI

A further version of the platform is being developed thanks to the experience gathered from the two workshops [23]. This new version includes important improvements and new features, such as an illustrator-centred navigation system, smoother navigation, and enhanced stability (Figure 23, Figure 24). The illustrator-centred navigation allows the VR camera to be controlled by the hand of the person drawing. The stabilized navigation provides a smoother and more stable navigation experiences, enhancing user-friendliness. Furthermore, a hand gesture-based selection wheel provides a convenient method for users to choose among inputs.

A new and very important improvement of this new version is that it is the first independently coded version of Spheri as a web-based platform. With this opening, the platform is no longer dependent on TouchDesigner, which solves several problems: it no longer has limitations on the resolution of the output video, avoids compatibility issues between devices, and provides more accessibility. The new version, hosted at https://Spheri.art, is coded in JavaScript, uses Three.js for the geometry and MediaPipe for the body tracking functions.

The platform is expected to be presented publicly at a new workshop by the end of November 2023, and in a longform course in

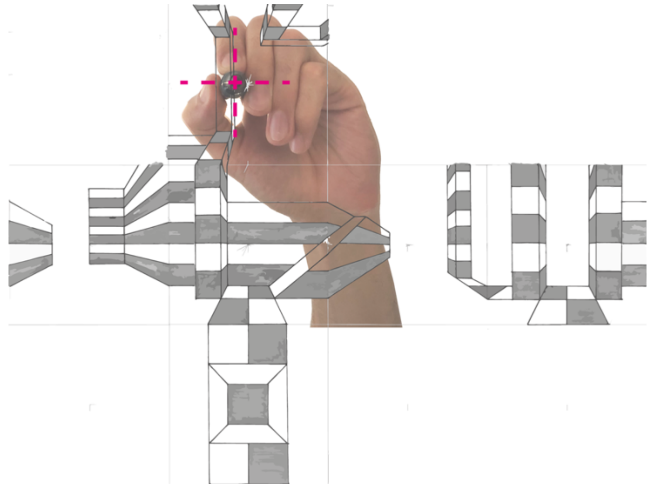

Figure 23: Drawing in the upper part of the cubical map

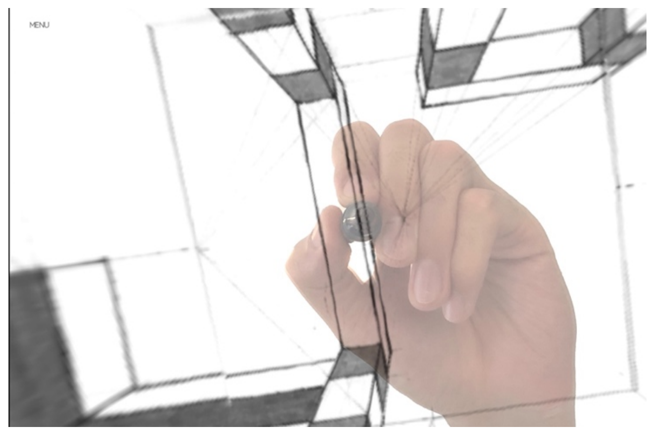

Figure 24: VR view of Figure 23

Macau in early 2024. If possible, authors will seek to gather user experiences' data, either through surveys or interviews. Furthermore, these surveys might also be conducted with past years students from the University of La Plata, in the framework of the abovementioned collaboration.

7 CONCLUSIONS

The digital platform Spheri, created to counterbalance the complexity of learning about spherical perspectives, enhances the use and understanding of spherical perspectives, easing their real-time interpretation. Spheri brings digital technology to the traditional handmade drawing practice, and it does so without sacrificing the transference of the knowledge to the illustrator, since it focuses on facilitating the intellectual task of constructing a spherical perspective step-by-step, empowering artists, designers, and illustrators to dynamically generate and witness the theoretical principles and not on replacing geometrical reasoning using a blind tool that might easily lead to black box thinking.

The new body gestures integrated into Spheri since its 3rd version seek to streamline and make interactions more intuitive, diminishing the reliance on mobile phones and computers, offering a unique experience of comparison between the flat drawing and its corresponding VR view. The live tests within the drawing workshops and the exhibitions, shed light on the strengths and intricacies of the platform. Nevertheless, we have also seen how external factors - such as the physical place's logistics - could have affected the results.

In conclusion, the varying audience sizes and workshop formats have provided valuable insights into Spheri's effectiveness. While surveys have not been conducted to date, some recurring trends emerge from the graphical analysis of the outcomes. It becomes evident that long-term and continuous courses yield better results in terms of knowledge retention and comprehension, whereas shorter formats often conclude as mere demonstrations due to limited time for absorbing new concepts. To help solving this issue, Spheri has proven to be a tool of significant value, effectively bridging the gap between theory and practice by offering real-time technological support that synchronizes VR rendering with flat drawing.

ACKNOWLEDGMENTS

The authors L. F. Olivero and A. B. Araújo were supported by FCT national funds though projects UI/BD/150851/2021 and UIDB/04019/2020 respectively.

REFERENCES

[1] Sara Antinozzi. 2023. *Appunti per l'infografia di modelli immersivi*. Libreria Universitaria Minerva, Fisciano (SA). Retrieved from https://www.researchgate.net/publication/373718864_Appunti_per_l'infografia_di_modelli_immersivi

[2] António Araújo. 2018. Let's Sketch in 360º: Spherical Perspectives for Virtual Reality Panoramas. In *Bridges 2018 Conference Proceedings*, Tessellations Publishing, 637–644. Retrieved from https://archive.bridgesmathart.org/2018/bridges2018-637.html

[3] António B. Araújo. 2019. Eq A Sketch 360, a Serious Toy for Drawing Equirectangular Spherical Perspectives. In *Proceedings of the 9th International Conference on Digital and Interactive Arts*, ACM, Braga Portugal, 1–8. DOI:https://doi.org/10.1145/3359852.3359893

[4] António Bandeira Araújo. 2018. Ruler, compass, and nail: constructing a total spherical perspective. *Journal of Mathematics and the Arts* 12, 2–3 (2018), 144–169. DOI:https://doi.org/10.1080/17513472.2018.1469378

[5] António Bandeira Araújo. 2018. Drawing equirectangular VR panoramas with ruler, compass, and protractor. *Journal of Science and Technology of the Arts* 10, 1 (2018), 2–15. DOI:https://doi.org/10.7559/citarj.v10i1.471

[6] António Bandeira Araújo. 2019. A fisheye gyrograph: Taking spherical perspective for a spin. In *Proceedings of bridges 2019: Mathematics, art, music, architecture, education, culture*, Tessellations Publishing, Phoenix, Arizona, 659–664.

[7] António Bandeira Araújo and Lucas Fabian Olivero. 2022. How to Draw a Virtual Cubical Perspective Box. In *Proceedings of Bridges 2022: Mathematics, Art, Music, Architecture, Culture*, Tessellations Publishing, Phoenix, Arizona, 475–480. Retrieved from http://archive.bridgesmathart.org/2022/bridges2022-475.html

[8] António Bandeira Araújo, Lucas Fabián Olivero, and Adriana Rossi. 2020. A Descriptive Geometry Construction of VR panoramas in Cubical Spherical Perspective. *diségno* 6 (June 2020), 35–46. DOI:https://doi.org/10.26375/disegno.6.2020.06

[9] A. Barre and A. Flocon. 1968. *La perspective curviligne*. Flammarion, Paris.

[10] A. Barre and A. Flocon. 1987. *Curvilinear Perspective: From Visual Space to the Constructed Image*. University of California Press.

[11] A. Barre, A. Flocon, and G. Bouligand. 1964. 'Etude comparée de différentes méthodes de perspective, une perspective curviligne. *Bulletin de la Classe des Sciences de La Académie Royale de Belgique* 5, L (1964).

[12] Aleksandar M. Dimitrijević, Martin Lambers, and Dejan Rančić. 2016. Comparison of shperical cube map projections used in planet-sized terrain rendering. *Facta Universitatis, Series: Mathematics and Informatics* 31, 2 (June 2016), 259–297.

[13] Manuel Flores. 2023. Anamorfose e realidade aumentada: uma proposta de itinerário para o estudo da geometria na disciplina de educação visual. doctoralThesis. Portuguese Open University, Lisbon. Retrieved September 7, 2023 from https://repositorioaberto.uab.pt/handle/10400.2/13638

[14] Manuel Flores and António Araújo. 2021. Applications of anamorphosis and mixed reality in a classroom setting. In *10th International Conference on Digital and Interactive Arts* (ARTECH 2021), Association for Computing Machinery, New York, NY, USA, 1–10. DOI:https://doi.org/10.1145/3483529.3483532

[15] Ned Greene. 1986. Environment Mapping and Other Applications of World Projections. *IEEE Computer Graphics and Applications* 6, 11 (November 1986), 21–29. DOI:https://doi.org/10.1109/MCG.1986.276658

[16] Cindy M. Grimm and Bill Niebruegge. 2007. Continuous Cube Mapping. *Journal of Graphics Tools* 12, 4 (January 2007), 25–34. DOI:https://doi.org/10.1080/2151237X.2007.10129250

[17] Massimo Leserri, Sara Morena, and Sara Antinozzi. 2022. Lapis Resiliency, through Analogic and Digital Drawing. In *Architectural Graphics*, Springer International Publishing, Cham, 126–136. DOI:https://doi.org/10.1007/978-3-031-04640-7_14

[18] Chiara Masiero Sgrinzatto. 2021. Venice Original: A spherical illustration of an imaginary environment. In *10th International Conference on Digital and Interactive Arts* (ARTECH 2021), Association for Computing Machinery, New York, NY, USA, 1–4. DOI:https://doi.org/10.1145/3483529.3483754

[19] Chiara Masiero Sgrinzatto. 2023. 2000 Eyes: Spherical View of La Fenice di Venezia. In *ArtsIT, Interactivity and Game Creation* (Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering), Springer Nature Switzerland, Cham, 22–35. DOI:https://doi.org/10.1007/978-3-031-28993-4_2

[20] Lucas Fabian Olivero. 2022. [IN]Musicality: a collection of VR drawings and music as an artistic application of Hybrid Immersive Models. In *ArtsIT 2022*, Springer International Publishing, Faro, Portugal. DOI:https://doi.org/10.1007/978-3-031-28993-4_1

[21] Lucas Fabian Olivero. 2022. [IN]Musicality v3 at CLB Berlin. In *Ubiquitous Music + [IN]Musicality at the CLB Space*. Berlin, Germany.

[22] Lucas Fabian Olivero. 2022. [IN]Musicality v3 at ArtsIT 2022. In *EAI ArtsIT 2022 - 11th EAI International Conference: ArtsIT, Interactivity & Game Creation*. Faro, Portugal.

[23] Lucas Fabian Olivero. 2023. Spheri v1. A body tracking artefact to interact with spherical perspective drawings made on-the-fly. In *Proceedings of ACM ARTECH conference (ARTECH2023)*, ACM Press, Faro Portugal.

[24] Lucas Fabian Olivero and António Bandeira Araújo. 2021. I'm watching you/me. Live drawing and VR visualization of spherical perspectives using TouchDesigner. In *Proceedings of ACM ARTECH conference (ARTECH2021)*, ACM Press, Aveiro Portugal. DOI:https://doi.org/10.1145/3483529.3483778

[25] Adriana Rossi, Lucas Fabián Olivero, and António Araújo. 2021. For Representation, a New Reality: Hybrid Immersive Models. In *Faces of Geometry* (2nd ed.). Springer International Publishing, 263–275. Retrieved from https://doi.org/10.1007/978-3-030-63702-6_20

[26] Julián Santoyo and Miguel A. Santoyo. 2021. The 360° Curvilinear Perspective: A Hybrid Hypercubic Angular Space Grid Based on the 1968 Barre and Flocon proposal. *Nexus Netw J* 23, 3 (September 2021), 717–735. DOI:https://doi.org/10.1007/s00004-021-00552-1

[27] M.S. Scherotter. 2018. Sketch360. *Microsoft Garage*. Retrieved from https://www.microsoft.com/en-us/garage/profiles/sketch-360

[28] David Swart. 2016. Drawing a Spherical Panorama. *D. M. Swart*. Retrieved October 12, 2020 from https://dmswart.com/2016/06/28/drawing-a-panorama/