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Eyesight Cartographies – unfolding the Visual Sphere

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Abstract. This paper addresses the relationships between the acknowledgement of different perspective concepts and its application in free-hand conceptual and observational drawings. A cartographical interpretation of perspective is pursued, by departing from the notion of *Visual Sphere* — a virtual perception spherical surface surrounding a viewer and upon which the entire set of visual data is laid. This work followed the developments of a research project where a computational tool was created aiming the reinforcement of the role of perspective in architectural design. The base for that research was the *Extended Perspective System* (EPS), a new geometrical perspective concept which was translated to an algorithm formulation and then written into a computer algorithm. After the development of the computational implementation, a role in the drawing learning process was envisaged and outlined in the form of a basic didactical strategy [4]. Therefore, we proceeded to the creation of a non-mandatory course, *Eyesight Cartographies*, where that strategy could be tested. Cylindrical and spherical perspective methods were introduced and practised as a different paradigm, regarding the prevalent classic perspective one. Also, recognizing that underneath each of these perspective systems is a single cartographic procedure, i.e., a particular method to map the Visual Sphere, students were challenged to scrutinize and inquire on the visual significance of several other methods found within Cartography, when used for perspective depiction purposes. We introduced theory in a first moment and promoted a hands-on in a second. The spectrum of the course goes from the practice of free-hand drawing to the writing of computational algorithms dedicated to the automation of perspective drawing.

Key Words: Perspective, curvilinear perspective, visual perception, free-hand drawing, extended perspective system, perspectograph.

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1. Introduction

The learning and the practice of free-hand perspective drawing in architectural design education promote the awareness of the place of the self in relation to space and its physical experience. By the exploration of the reversible variations of depth and spatial immersion, the process of perspective drawing consequently also conveys a consciousness of the architectural phenomenon and constitutes an important and critical means to clarify its visibility. Besides the features of direction, relative dimensioning and positioning (conceptually, attributes that altogether inform and perform representation, identification and construction of referents in visibility and spatiality), perspective symbolizes the experience of depth and place, by assigning distance and hence conveying time. The linear perspective code, although having established an important criterion of visual verisimilitude, intrinsically limits the reference to a panoramic, kinetic and haptic spatial experience.

The overcome of this paradoxical condition requires an inquiry into the conceptualization of the classical perspective. To rethink and re-equate the perspective representation, by congregating the linear and the curvilinear perspectives into a hybrid concept, seems to fit the contemporary consciousness of spatial fluidity, acknowledging the motional and visual dynamics of the observer. Consequently, the perspective representation should no longer be just static, with a motionless observer symbolized in the hierarchy established with the horizon line and the symmetrical vanishing points, as elements that bring order to the representation. This poses new challenges to the didactics of drawing in architectural courses, by requiring an increased knowledge of the conceptuality of geometry and of the formal abstractions which are the base of architectural design. However, free hand drawing remains an important asset, as a training from the visible and an effective 'representational epiphany' for the architectural becoming.

2. From the "real" to the "wide"

In the development of the perspective paradigm there is a decisive moment, whose importance is widely recognized, imposing perspective as the epistemological model of classical occidental thought. It corresponds to the period of the acknowledgement of the *costruzione legittima*, in the 15$^{\text{th}}$ century, with a special role from Brunelleschi, on account of his merit for the recognition of the identity between Point of View and Principal Vanishing Point. In this period the geometrical perspective codes were established and responded to the fundamental quest for the "real" representation, the mimesis, overcoming older intuitive and naive experiments in the field of perspective, such as the *fish bone* like attempts (see Figure 1).

Since then, the evolutionary process of representational drawings — previously confined by that fundamental question — diverged and new paradigms emerged, allowing for technical and conceptual drawings, scenography, *trompe l'oeil*, anamorphosis, stereotomy, axonometry, descriptive geometry, curvilinear perspective, *etc.* In this last example — curvilinear perspective — the corresponding fundamental question, was now the "wide" picture, i.e., the representation, not only of what the eye sees in a fixed direction but moreover the agglutination of a set of sequential views into one single drawing, allowing the understanding, exploration and representation of space in a completely new way. The power and consequences of this new regard are not yet fully understood, but there is a huge potential in several distinct fields as arts, architectural epistemology, aesthetics, philosophy, history, virtual reality, among others.

The development of the paradigm of the "wide" has been slow and also crossed trial and

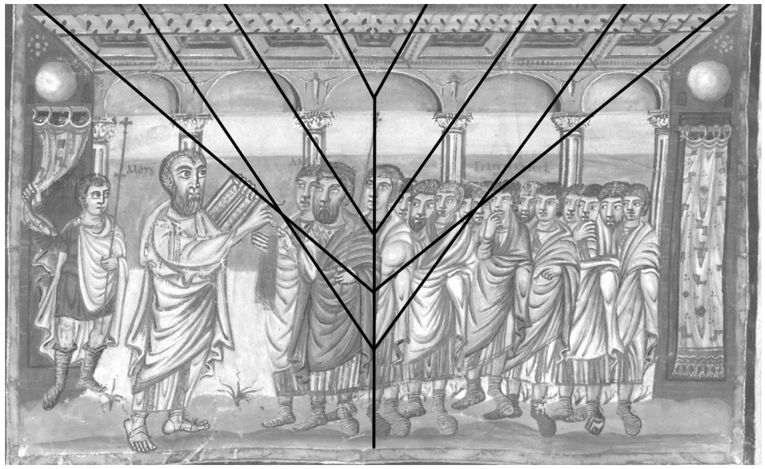

Figure 1: *Fish bone* structure in a decorative fragment, 9th century [7].

error, by adopting diverse curved projection surfaces, whose lines must, in some manner, be transferred to the picture plane. There are examples of an intuitive graphical strategy of bending lines dating from centuries ago, like the drawing (see Figure 2) by Jean Fouquet (1640), but the more scientific approaches appeared in the 20th century, being developed through the work of M.C. Escher, with his studies and the establishment of geometric cylindrical structural grids [5] for his remarkable drawings. Also, the work of Barre and Flocon, building the geometric codes for spherical perspective in the book *'La Perspective Curviligne'* [1] or the work of Gérard Michel, connecting the intuitive approach of the urban sketchers [8] with some pragmatic geometrical rules for the delineation of cylindrical and spherical perspectives [6].

However, the potential of bending lines goes beyond planar, cylindrical and spherical perspective, being possible to explore hybrid stages of the projection surface and its transfer into the representation surface. That is the overall capability of a new conceptual instrument — the *Extended Perspective System* (EPS in brief) [2], which congregates linear and curvilinear perspectives, from principles to practice and from automation to didactics, so fully exploring the "wide" paradigm.

3. A new synthesis

Linear perspective, with its convenient picture plane, is a well known and vastly applied representational system. Along with its historical count and broadness in modern visual culture, it really renders objects in a visually congruent manner, mainly by depicting all lines as graphic straight lines. Significantly, its conception and operativity are aimed at narrow fields of view, much below 180° miming the human eye.

Cylindrical perspective, by the use of a cylindrical projection surface (a simple curvature surface), allows an up to 360° panoramic delineation of the horizontal space surrounding the observer, but also restricts the field of view, vertically, to a value much below 180°. Generically, lines are turned into sinusoidal curves, with the exception of vertical lines, which remain straight.

Spherical perspective, by the use of a spherical projection surface (a double curvature surface), conveys a omnidirectional consistent view of the space surrounding the observer, only refrained by the progressive anamorphic character of the depiction when going towards

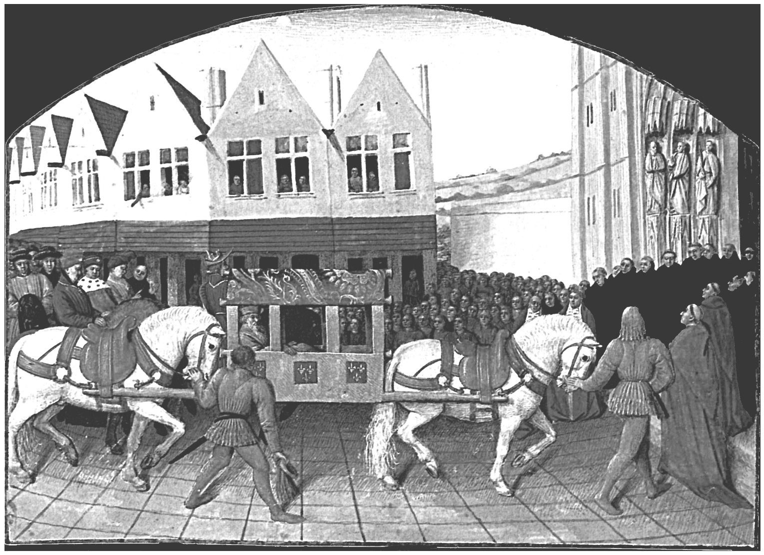

Figure 2: Cylindrical perspective attempt,
'The arrival of Emperor Charles IV at Saint Denis' [1].

the rear area of the global visual field. Nonetheless, this system of perspective has noticeable figurative capability till a 270° field of view. Generically, lines are turned into transcendental curves, with the exception of lines parallel to the visual axis, which remain straight.

The rectilinear graphical operativity of linear perspective has much practicability in free-hand drawing, by appealing to the common sense of a straight line. Nonetheless, that representational system is designed to convey spatial information that is mainly in front of the observer, within a restricted field of view. On the other hand, the curvilinear systems allow the translation of a sight in motion, targeting a broader or even complete field of view, which constitutes an important supplementary feature, regarding linear perspective capabilities. Nonetheless, those systems require the graphical management of mathematically specified curved lines, which turns their operativity more intricate and therefore less used in the didactics of free-hand drawing. Most of all, rectilinear and curvilinear approaches to perspective stand historically as alternatives or even rivalling propositions restraining overall complementary action as conceptual references of drawing.

In order to sustain a more inclusive and versatile method for the didactics of perspective in free-hand drawing, we took into account the formulation of the EPS, a broad theoretical concept of perspective that has been firstly presented in 2007 [2]. Since 2010, this concept was embraced by a multidisciplinary academic team, gathering skills in architecture, drawing, geometry, mathematics and computation, in a research project called NAADIR [3]. The main objective of the project was the making a computational implementation of the EPS, with the purpose of turning this representational system usable in architectural design, from conception stages to final presentation drawings. The computational approach was crucial to the operativeness of the EPS, since this concept stands mainly as a dynamic curvilinear model of perspective, strongly dependent on algebraic calculations that make feasible its intrinsically wide range of possible perspective depictions. A more detailed description of the EPS and the corresponding software tool that was created is already published [3].

Fundamentally, the EPS is established upon three principles.

- The first, inherited from the curvilinear perspectives conventions, is the dissociation of the projection surface and the representation surface (picture plane). The projection surface is the surface where primary projections of 3D points are set upon, while the representation surface is the planar surface where those projections are then transferred onto, in order to obtain the final perspective depiction to be visualized.

- The second principle is the mutability of the projection surface. Instead of the single static projection surface, the EPS determines the use of a parametric spheroidal projection surface. By means of homological procedures, this surface can be turned into the linear, cylindrical or spherical projection surfaces that are inherent to the former perspective systems but, principally, it can assume any transitory spheroidal state between those boundary configurations. Any particular state is defined by the combined numerical concretisation of two parameters: Radius (R) and Eccentricity (E) [2]. Therefore, this mutable projection surface continuously fills the gap between the autonomous and separated spherical, cylindrical and planar perspective systems.
- The third principle is the adaptability of the method for transferring the projected information from the projection surface to the representation surface. In classic perspective, the method is direct: projections become the depiction elements. In cylindrical perspective, the method is natural: the unrolling of the developable projection surface. In spherical perspective, the method is protocoled: a selected cartographic projection to render depiction elements onto the representation surface. In the EPS, since the projection surface is mutable, consequently the transferring method is reconfigured dynamically, adjusting either to each of the boundary states or to each of the transitory states of that surface, aiming visually optimized results.

Figure 3 shows an array of diverse EPS hybrid depictions that can be obtained by variations of the parameters R and E.

So, in general terms, the EPS is a unified concept of perspective representation, as it congregates and articulates the linear, cylindrical and spherical perspectives, as referential boundary systems, in a single theoretical build. The departing point for the formulation of the EPS was indeed the acknowledgement of the specific representational capabilities of each of those perspective systems, but mainly the envisioning of a truly complementary role to be fulfilled by them, as long as some particular changes in their overall geometric foundations take place. A role in the didactics of drawing can also be envisaged from here.

4. A didactical strategy for drawing

Although linear perspective shares many attributes that are identifiable in direct visual perception, it does not constitute an innate response in free-hand drawing. On the contrary, to draw what and how one sees is undeniably a difficult task to accomplish, without proper training and learning. Particularly, among architecture students this difficulty is sensed and requires much attention from Drawing and Geometry teachers. The didactics of linear perspective concepts and methods has a significant role in this process. In fact, it most frequently allows students to firstly get an objective comprehension and awareness of the vision process itself, before even the issue of drawing from it is tackled.

Traditionally, Geometry and Drawing disciplines follow different training methodologies. In geometry classes, priority is given to projection procedures and to its effects in the delineation of geometric figures. Here, standard exercises such as drafting cubes in space with 1, 2 and 3 main vanishing points (see Figure 4) effectively help students surpassing the natural naive stages of perspective drawing and to recognize the importance of a geometrically structured approach to representation. These exercises, in a unrestricted field of view (FoV)

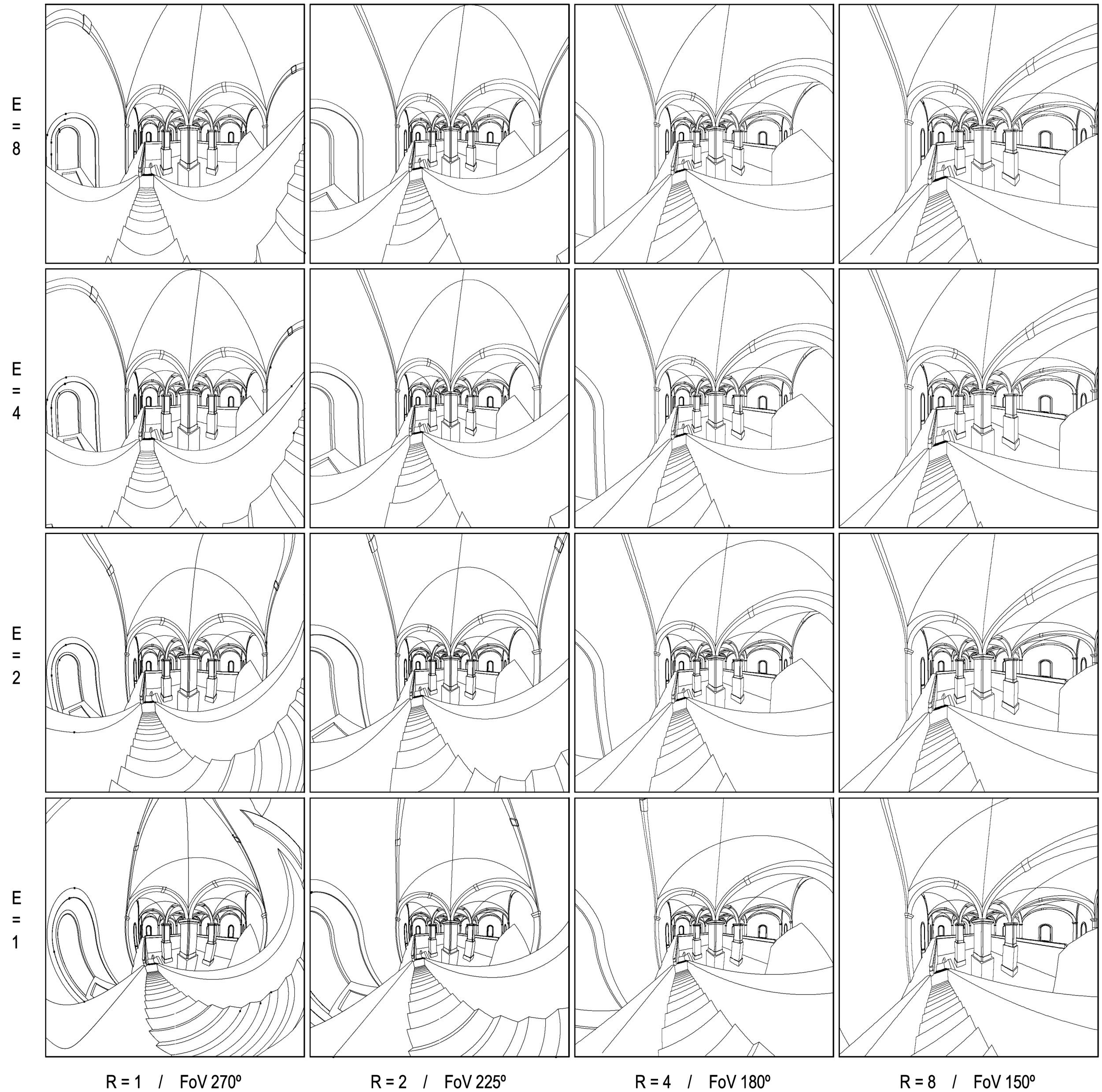

Figure 3: An array of images resulting from variations of the EPS parameters.

version (see Figure 5), also emphasize and turn apparent the conventional condition of linear perspective delineations — a code that, although rectilinear, may render less close to vision graphical representations. Counterpointing linear perspective, a supplementary consciousness of the available representational resources can be obtained by drafting in the cylindrical and spherical perspective systems, eventually with the help of grids to overcome the usual difficulties regarding mathematical curved lines (see Figure 6).

In drawing classes, a more heuristic approach is pursued, by favouring an intensive training in observational drawing from reality. It is here expected that individual visual intuition and reasoning take place, triggering student's improvement and differentiation in free-hand drawing skills.

With a wide visual framing, observational drawing of urban and architectural spaces,

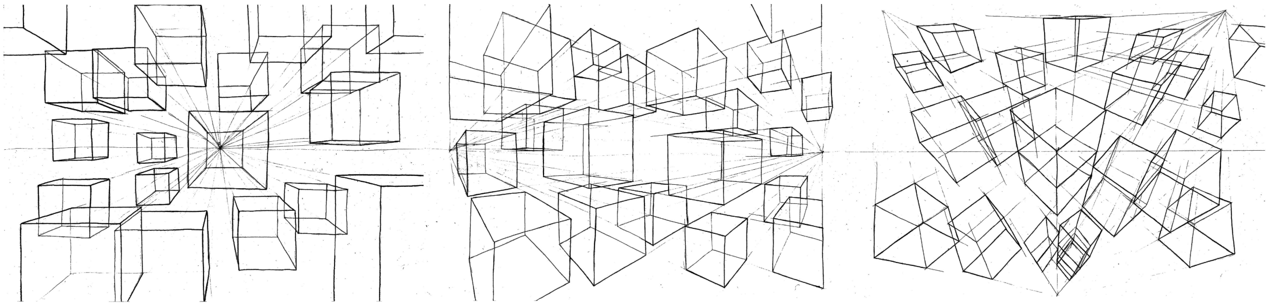

Figure 4: Perspective drawings with 1, 2 and 3 vanishing points, within a regular FoV.

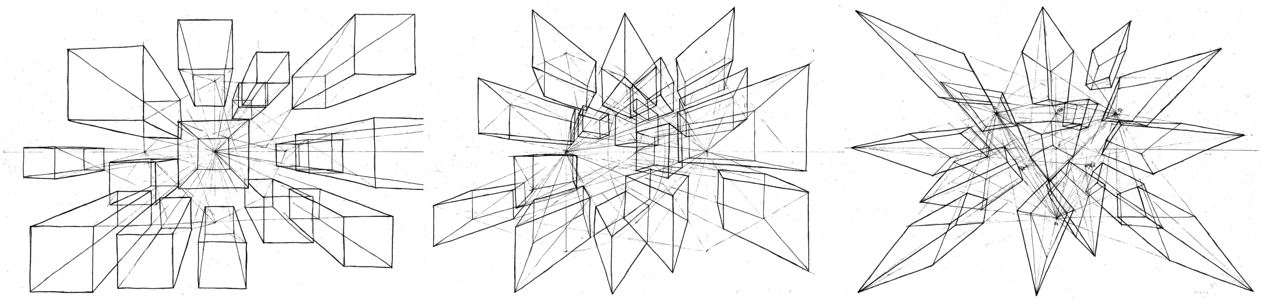

Figure 5: Perspective drawings with 1, 2 and 3 vanishing points, within a wide FoV.

as well as landscapes, favouring the insights for the subjective comprehension of the representational scale in a free-hand drawing. In fact, there are some situations where students understand that linear perspective is not adequate to dominate space representation. This gap requires a responsive versatility, between the representational scales and the sizes of the drawing supports, this way contributing to an intuitive research about alternative graphic solutions (curvilinear perspectives), more inclusive (and also more immersive), beyond the classic perspective paradigm, no more taken now as an unquestionable graphical paradigm. These supplementary resources become skills, and as so constitute an added value for the versatility of the graphical processes of design.

It is from the side of the results achieved in drawing lessons that we got the more interesting clues on the management of linearity when it comes to the visual approach to representation. Within the NAADIR project it was possible to collect several sets of observational drawings made by students under controlled circumstances, in order to reduce variables and turn their subsequent analysis more consistent. Generally, it was identified a correlation between the growth of student's skills in drawing and a more flexible use of the graphical

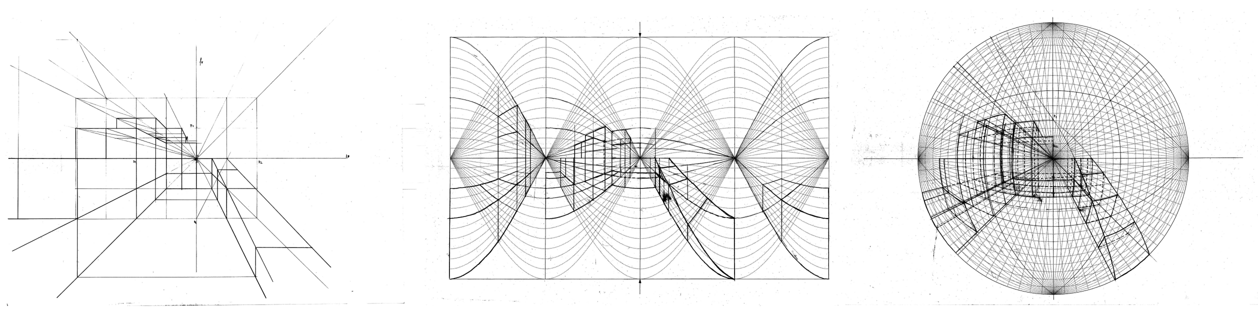

Figure 6: Drawings in linear, cylindrical and spherical perspectives, with the aid of lattices

Figure 7: A student's observational drawing of the *Mãe-de-Água building* in Lisbon.

rules of linear perspective. In fact, while students have shown the capability to pursuit thoroughly an explicit linear perspective lattice, that structural support becomes more implicit, many times even diffuse, when previously acquired geometric knowledge is confronted with the real time visual data that feeds the mind/gesture process of drawing. Plus, when students were asked to draw a surrounding architectural space, by allowing the sight to move freely in a wide field of view, targeting up, down, left and right in the scene, the linearity of the drawings noticeably deviates towards an implicit curvilinear lattice, although many times a scattered one. Intuitively, apprentices of drawing seek a graphical response to the experience of a dynamic observation of space (see Figure 7). Significantly, the bending of lines in these drawings is many times readable as a spontaneous deduction of the cylindrical and spherical graphical configurations of perspective, with their curved horizontal and vertical delineations. Amazingly, it resembles somewhat an EPS rendering.

These remarks lead us to interrogate on the sufficiency of the current perspective model as basis for the didactics of drawing, particularly in architectural courses where it is crucial that students become rapidly fluent in the use of the drawing resources to assist the learning and practice of architectural conception. We verify that the acknowledgement of linear perspective concept and method constitutes a gravitational reference for the embodiment of a structured and consistent way of drawing. In practice, this role means that a free-hand drawing's structure orbits that referential paradigm, getting closer or further from it as visual priorities and judgement take place. But we also see that enhanced drawings seem to deviate from a structural linear perspective grid towards a diffuse perspective model that someway resembles the alternative curvilinear systems. Therefore, we foresee a potential role of the spherical and cylindrical perspective systems also as gravitational references to be included in a more holistic perspective model for the didactics of drawing (see Figure 8). This would be the outcome of the EPS concept in this realm.

Alongside with the much valuable learning of the classic linear perspective system, students would additionally be trained in the particular boundary concepts of cylindrical and spherical perspectives and would become familiar with the overall possible hybridizations sustained by the EPS concept, through demonstrations and trial with the EPS computational tool. The expected result of this more diverse and extensive training would be the settlement

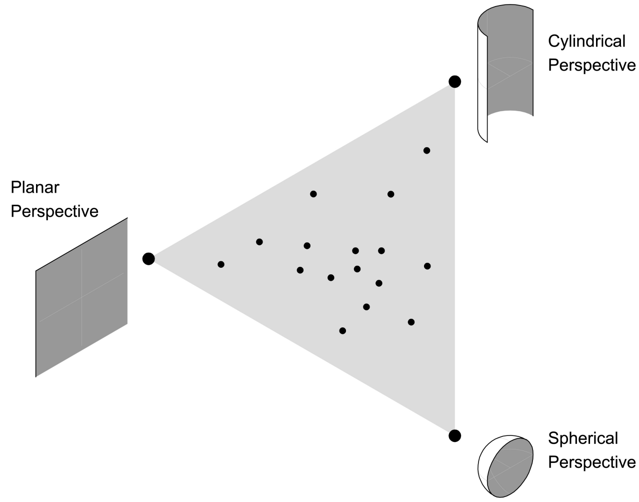

Figure 8: A schematic description of an extended perspective model for the didactics of drawing [4]

of an amplified referential framework for the individual process of growth and mastering in perspective free-hand drawing. We believe that, through this didactical strategy, an apprentice shall get a more acute comprehension of the subjectivity of the vision experience of space and find more efficiently his own personalized responsive way(s) of drawing. Therefore, we proceeded to create a non-mandatory course, *Eyesight Cartographies*, where that strategy could be tested. The departing point of the course would be the acknowledgement of the importance of linear perspective throughout the modern history of graphical representation but also of its conventional character and, therefore, the possibility of considering diverse alternative ways to translate visual perception into a perspective drawing, i.e., a graphical map of the visual data attained by an observer.

5. *Eyesight Cartographies* — a didactical experiment

The *Eyesight Cartographies* course was promoted in consequence and as corollary of our multidisciplinary research. It was therefore outlined as a congregative workshop with three sequential complementary modules, each putting emphasis on free-hand drawing, geometric hand drawing and computational drawing, taking into account mathematics, programming and cartography. The first edition of the course was addressed to students of the 3$^{\text{rd}}$ year of the Architecture and Urban Planning programmes.

In the first part of the course, the renaissance perspective was presented and commented. Aspects of *trompe l'oeil*, anamorphosis, curved frames, bicentral projections, stereoscopy, binocular vision and three-dimensionality and depth readings were discussed. Then, students were asked to do, at their own, some observational free-hand drawings from their workroom, taken from different points of view and making the representation of the scenario the most visually broad and comprehensive as possible (see Figure 9). These preliminary representations converged as an introduction to the acknowledgement of the ever new applications of perspectival representation and its uses, both symbolic and symptomatic of the contemporary. Peter Sloterdijk [9] states that all human experience of space — ancient or contemporary, intimate or collective — uses modes of representation where spherology is reflected. Cartog-

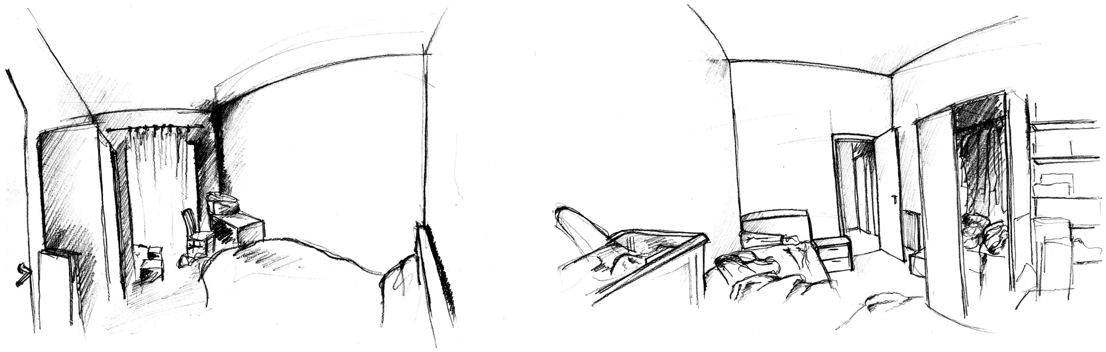

Figure 9: Intuitive approaches to panoramic observational drawing.

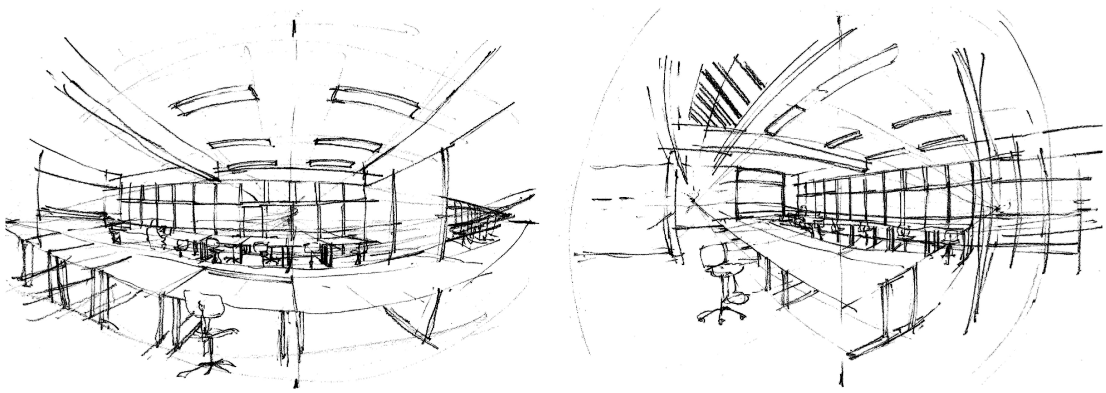

Figure 10: Geometrically structured approaches to panoramic observational drawing.

raphy and projections of curved character, cylindrical or spherical, can be better understood in this emergent context.

Following the first module, where the historical evolution of the “wide” paradigm of perspective was presented and its practice intuitively approached, the didactic structure of the course proceeded through the learning, comparison, synthesis and deeper understanding of the triangular boundary (see Figure 8) of the range of hybrid possible states of the new perspective depictions allowed by the EPS concept. That triangular boundary has, as vertices, the geometrical structures of planar, cylindrical and spherical perspectives. Assuming that the first vertex was a knowledge pre-requisite of the students, emphasis was given to the less known cylindrical and spherical structures, elucidating the concepts and methods for the control of direction (considering vanishing points and lines), dimension/proportion and space location, then put into practice in observational free-hand drawings (see Figure 10)).

After the first two parts of the course, where theory and practice where directed to analogue drawing, the third and last module was dedicated to the automation of drawing with digital means, namely by the use of computer graphics procedures. At this stage, geometrical, mathematical and programming knowledge were evoked and gathered in order to configure and produce new perspective depictions alternative to the conventional classic perspective system. To this purpose, a cartographic approach to perspective was pursued by establishing two main principles: first, the concept of the *Visual Sphere*, a virtual spherical surface surrounding a viewer and upon which the entire set of visual data is laid (see Figure 11); second, the notion of perspective as the result of transferring that set of visual data to a planar surface — a map — where the spatial representation can then be regarded as a perspective depiction.

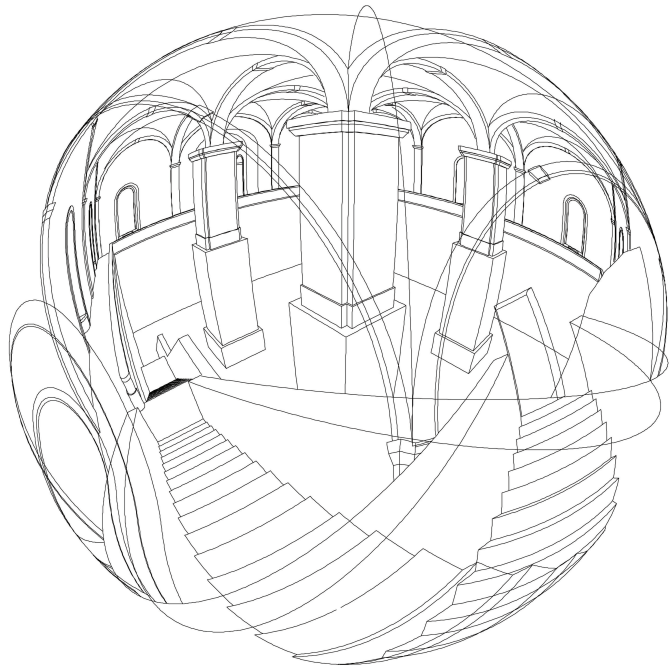

Figure 11: Visual dataset on a *Visual Sphere*

The concept of the *Visual Sphere* can be inferred from ancient optics studies and constitutes a way to rationalize geometrically the experience of a complete visual field, i.e., the whole set of visual data collected by an observer that fully rotates his eyes and head. Also, the enlarged concept of perspective sustained by the prior consideration of the *Visual Sphere* turns the perspective mechanics similar to the cartographic mechanics (considering the earth globe cartography). At this point, linear perspective and cylindrical and spherical perspectives can be regarded as just particular results of the application of specific cartographic methods, namely the gnomonic projection, the cylindrical central projection and the azimuthal equidistant projection. It must be emphasized that these three methods are among a group where approximately two hundred methods are currently catalogued. Therefore, a research on the use of several other methods to perspectival purposes seems to be pertinent, at least has a hypothesis to be investigated.

So, students were challenged to scrutinize and inquire on the visual significance of several other methods found in the cartography realm. Cartographic criteria of classification — equidistant, equivalence and conformality — become also relevant in perspective, as they determine the ability of a specific method to preserve the visual magnitudes along lines, the relative sizes of elements in the visual field and the local visual configuration of shapes. Also, other features of cartographic projections were considered, such as the ability to preserve curvature continuity (no swirling) or the ability to generate a uninterrupted mapping, avoiding gaps in the representation of the visual field.

For this first edition of the *Eyesight Cartographies* course, a set of twelve representative methods were then selected, among a classified groups of Cartography (see Figure 12). The student research work was made in groups and attended four stages.

- The first stage was the building and validation of a 3D digital architectural model to constitute the subject of the perspectives to be generated.
- The second stage was the computational implementation of the projection of the 3D

model in the surface of the *Visual Sphere*. From this moment on, this spherical projection was taken as the primary dataset for the calculations to be made in order to implement the cartographic method within each work group.

- The third stage was common to all the groups and regarded the computational implementation of the gnomonic azimuthal projection, which leads to linear perspective. This stage was important for students to get a cartographic perception of the conventional method of perspective and also to get an understanding of some basic procedures of computer graphics needed to tackle the research issue.
- Finally, the fourth stage was the overall computational implementation of the specific cartographic method that was chosen. The work involved the acknowledgement of the particular geometrical and/or analytical procedures, the algebraic translation and the writing of the computer program itself.

With this implementation graphical delineations became feasible (see Figure 13) and the work groups made a preliminary analysis of the visual properties of the perspective system that was configured. Besides intrinsic properties, each new system was compared to the prevalent linear perspective system (achieved with the azimuthal gnomonic projection), emphasizing the respective differences and visual qualities.

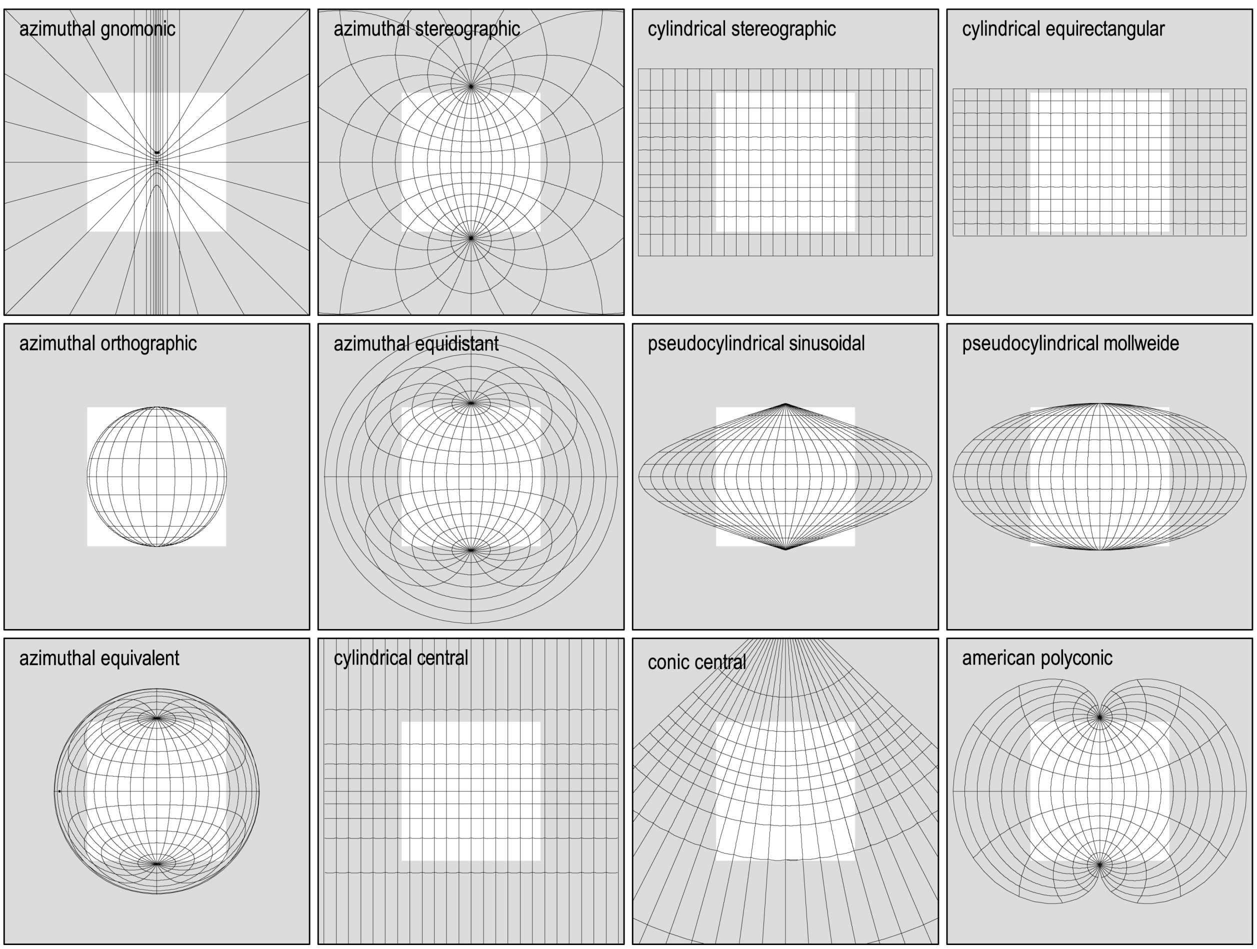

Figure 12: The selected cartographic methods: corresponding globe maps with graticule, with a highlight on a 170° horizontal FoV.

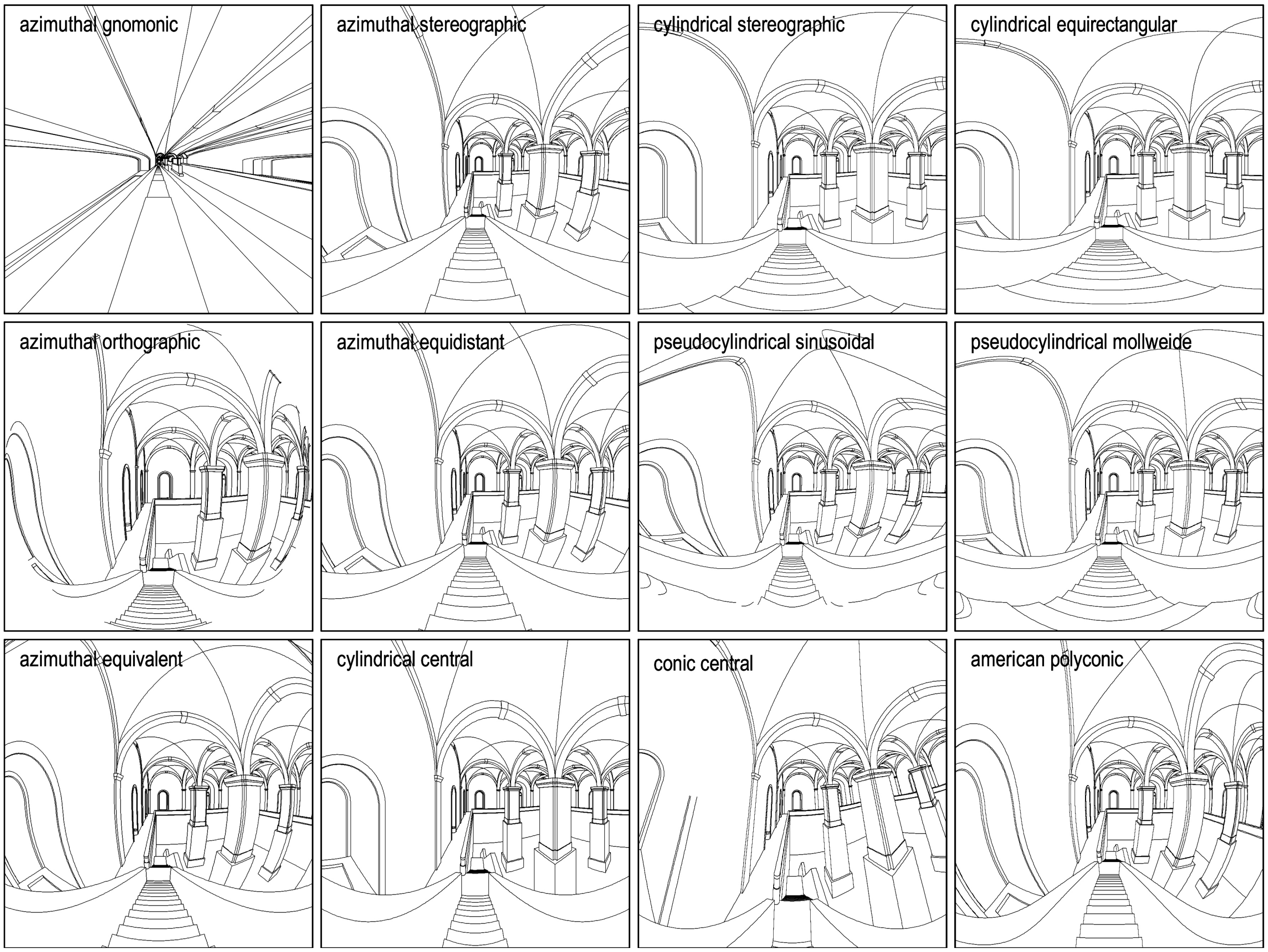

Figure 13: Equivalent perspective delineations with the use of the twelve cartographic projections, within the 170° horizontal FoV.

6. Conclusions

This paper described the foundations and the methodology of a new approach to the didactics of drawing in architectural courses, considering that the proficiency on free-hand perspective drawing is one of the fundamental objectives that an architecture student must pursue, in order to gradually let drafting be the easy and natural way to support and reveal the visual and spatial reasoning that is inherent to architectural conception. In this learning process, Drawing and Geometry disciplines together provide complementary methodologies, by the meeting of applied visual intuition with the rationale of perspective graphical codes. In its inherent plasticity, although, free-hand perspective drawing tends to develop graphical interpretations of visual perception that do not depend strictly on the observance of the graphical rules of a single perspective system, namely classic perspective. Instead, driven by real time visual judgement, it seems to gain an autonomy that strongly relies on a flexible use of the geometric principles of perspective.

A new formulation of perspective — the *Extended Perspective System* — develops a holistic approach by congregating and hybridizing linear and curvilinear perspectives, therefore building up an expanded and upgraded concept of perspective. After the development of a computational implementation, that firstly sustained the operativeness of this new perspective system, a role in the drawing learning process was envisaged and outlined in the form of a basic strategy, where the main concepts of the *Extended Perspective System* would inspire a renovated didactics of drawing in architecture courses. This motivation led to a new graduation course called *Eyesight Cartographies*, which is a multidisciplinary approach to perspective drawing that intends to provide students with a comprehensive understanding and a critic attitude towards the standards of space representation. By the meeting of cartographic methods with the purposes of perspective delineation, a diversified set of alternative depictions of visual data was achieved, thus assigning more versatility and responsiveness to the perspective graphical code(s) that supports drawing.

The noticeable students' interest and commitment in the *Eyesight Cartographies* course, as well as the results achieved, reinforced our perception of this didactic approach as a pertinent added value in the current teaching of drawing in the architecture graduation. As a major conclusion from this experiment, we understand that, in the next editions of the course, after the computational module, a return to the free-hand drawing practice should be promoted, in order to let it reveal eventual repercussions of the prior investigation and results. It should also be noticed the very recent inclusion of this course in the curriculum of the doctoral program of the Faculty of Architecture at the University of Lisbon.

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