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Research

Perspective, a Visionary Process: The Main Generative Road for Crossing Dimensions

Abstract. Perspective is the only tool able to create subjective links between human beings and art spaces. Each perspective representation can be drawn only by identifying a subjective point of view, which varies from individual to individual. This represents a subjective way of interpreting the hidden logical structure of the world. By interpreting the "perspective" representations of the artists of our past we can approach their cultural visions through a possible re-constructing of their represented spaces, a non-linear process that opens a creative-generative path from past to future, teaching us that "dolce" perspective is the main road for our logical interpretation of art. Starting in 1979 I designed original software for space representations. My investigations concerned perspective and, in general, representations crossing multiple dimensions.

1 Visionary crossing by moving from a dimension to another

The field of investigation of this paper is the relationship between the three-dimensional form and its two-dimensional image in its manifold variations. But we could consider also the image and its possible 2D forms, in its manifold interpretative variations. The "generative" reciprocity between the form and the image of the form, where every form "produces" a plurality of images and where each image "produces" a plurality of forms in an endless spiral, is one of the principal fields of construction of Generative Art. This art was born from expressing ideas as a morphogenetic logical process.

First of all, a difference of dimension can exist between the form and its image. Often this difference consists in considering the form as a three-dimension event and its image as a two-dimension representation, but this is only one of the possibilities. We can get a 3D representation from an event having many dimensions, or we can increase the dimensions of the representation in comparison to the dimensions of the event, as, for instance, when we try to represent the image of a jewel pending from the neck of a noblewoman in a seventeenth-century portrait by building a three-dimensional object that interprets the image of the painting. In this case only one of the possible two-dimensional representations of the constructed 3D event will fit the original image.

In order for the result of this moving through different dimensions to be considered totally acceptable, it is necessary that each point of the form correspond to one point of the image and that the structure of the form-system will have the same topological logic then the image-system. This is obviously not possible in the passage from one dimension to another. The *perspectiva artificialis* of Piero della Francesca is only one of the possible two-dimensional representations of three-dimensional events. With this approach much information is lost. The inverse run, from the perspective representation to the three-

dimensional event is, in fact, only a reasonable hypothesis. This passage can be considered as acceptable only if we build this three-dimensional event on the basis of important additional knowledge that we cannot find in the image, i.e., the location of the point of view used in the representation. If we don't know this, it can only be identified through a subjective interpretation; every interpretation therefore "produces" different forms.

Further, we can reconstruct only what we see and not what is behind or inside the represented events. As Florenskij said, the perspective image represents only the skin of the three-dimensional event linking the three-dimensional event to the two-dimensional representation. But, even in light of this consideration, the bending of the skin will never be sufficiently represented in the 2D sheet of the sketch. The relationship between bending of the skin and the 2D sheet is comparable to the relationships between Euclidean geometry and not-Euclidean geometries.

But we also have to perform a further interpretation choosing among the different techniques of perspective representation that we presume could have been used to produce the two-dimensional images. These techniques are manifold and can be synthesized into three types, each of which can link the form to its image in a different way.

2 Perspective tools

2.1 Perspective – 1 to 1. One point of view to one target

Starting Dimension: 3 (x, y, z of object and viewer)
Representation Dimension: 2 (x, y)
Each bundle of parallel straight lines converges into one point representing infinity

Perspective with only one point of view and only one direction of the gaze. The observer and the represented event are in front of one another and the interface is a plane screen.

This is the *perspectiva artificialis* of Piero della Francesca: only a single point of view (and therefore only one eye and not two), and only a single direction are considered. This direction also becomes the central vanishing point in the geometric construction of the image.

In this case the ambiguities of the correspondence that must be clarified as we move back from the 2D representation to the 3D even are:

1. The location of the point of view. Moving the location higher and lower in the 3D scene changes the horizontal order; for example, the floor will be sloped to a greater or lesser degree.

2. The distance of the point of view from the scene. In the image by Piero della Francesca (fig. 1a), the 3D reconstruction of the image results in a very long space. This is because the distance used in the representation is not congruent with the first impression and with the hypothesis that the floor is composed of square elements, as can be seen by looking at the details.

Fig. 1a. Piero della Francesca, *Flagellazione*. A reconstruction of the space represented
results in a very long space, very different from what might be expected

Fig. 1b. Image of a medieval city by Simone Martini. It seems to be a *perspectiva artificialis*
but the vanishing point moves across the image referring to a further dimension: it
represents the dynamic moving of the observer

These parameters, together with other ambiguities inside the structure of the 2D image, make it possible to arrive at an endless number of different interpretations of the image when we can try to reconstruct the 3D object. This is one of the main fields where it's possible to "generate" many different 3D objects starting from a 2D representation. This because we need to use our "interpretation"; we need to go through a "creative generative logical process".

Further, starting from Simone Martini's depictions of Italian medieval cities (fig. 1b) it was possible to generate endless variations of these cities while maintaining their unique identities (fig. 2). This work, which I developed and published in 1986 and 1989,

was based on the possibility to identify, in each image of Simone Martini and Giotto, many stratified perspective representations belonging to the movement of the point of view. Often this movement goes from exterior to interior of these cities generating a complex representation that can be interpreted as 2D representation of 4D events, interpreting as further dimension the sliding position of the observer.
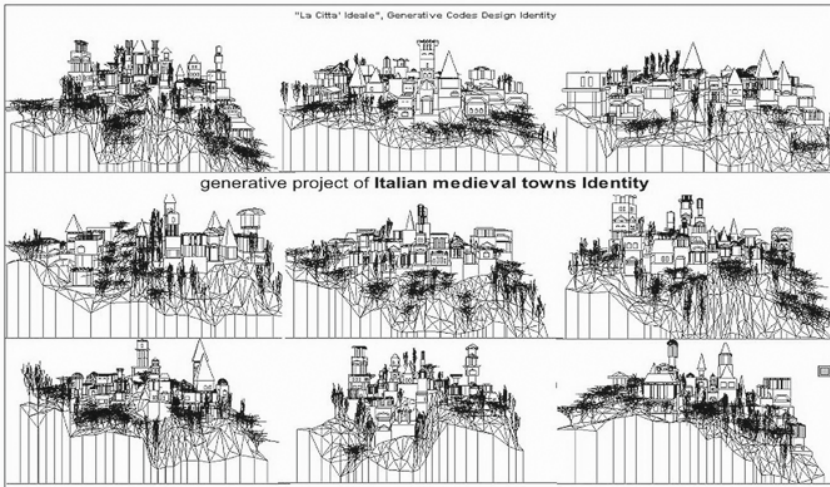

Fig. 2. 3D models of medieval Italian cities generated by the author in 1988. This project was based on the perspective interpretation of Simone Martini's images of cities

2.2 Perspective – 1 to Infinity

One point of view to endless targets.

Starting Dimension: X, Y and Z of object and viewer. There are also the polar coordinates X and Y of targets referred to the motion of sight all around the viewer.

Representation Dimension: 2 (x, y). The 2D representation can be done on a Euclidean (2D sheet) or a non-Euclidean (sphere) interface.

Each bundle of parallel straight lines converges into two points (non-Euclidean geometry)

Spherical total perspective: this perspective technique considers only a single point of view but manifold directions of sight, covering up to 360° in the horizontal (cylindrical perspective with heights in *perspectiva artificialis*) as well as in the vertical (spherical perspective). The observer is at the center of the system.

As we know, in *perspectiva artificialis* only the represented point that is intersected by the direction of sight is not distorted. Every other point of the perspective image is distorted compared to the "view". The distortion is proportional to the distance of the represented point from the point where the gaze crosses the sheet. Spherical total perspective cancels all these distortions. It is constructed by using a sphere as the interface and tracing all the points of the perspective image with the intersection of the gaze in the spherical interface. In this way only undistorted points are used.

After that we have the problem of how to represent this spherical total perspective on a 2D sheet. This can be done by projecting the spherical image onto a sheet rolled into a cylinder. For checking and representing the heights on a non-infinite sheet I use a logarithmic scale. The result is closer to our vision.
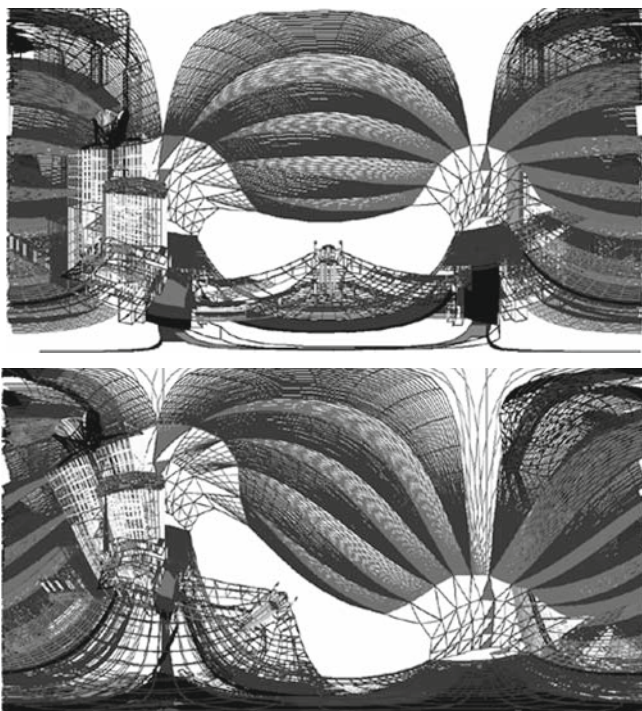
Fig. 3a-b. *Generated Castle* by the author represented in total spherical non-Euclidean perspective in two different views, the first one with horizontal sight (above) and the second inclined (below). Images produced using the software designed by the author.

In any case the curved perspectives seem to follow the naturalness of our vision. In fact, if we are inside a space, for instance inside a rectangular room with parallel walls and with a flat ceiling, and we look toward a side, we will see that all the parallel sides of the mentally-constructed image converge toward a point (the vanishing point). Then, if we turn and look at the opposite wall, we see that the same lines converge toward another point opposite the first one. Quickly turning our gaze from one side to the other, we realize that these parallel lines converge in two points of the image that we are building in our mind. Only a non-Euclidean geometry system makes it possible for a bundle of parallel straight lines to converge in two points. The amazing thing is that if we pass from a perspective constructed within a Euclidean geometric system to a perspective constructed within a non-Euclidean geometry, such as spherical geometry, the mathematical representation of the transformation – that is, the algorithm that represents the passage from 3D into 2D – becomes very beautiful mathematically, because it makes it possible to represent everything through the measurement of the angle. I began experimenting on these non-Euclidean total perspectives twenty years ago. These experimentations and the algorithms that I wrote to build the software capable of representing "total perspective" form the basis of my generative software. They constitute a generative engine capable of generating endless possible results starting from a single image [Soddu 1987].

Following this approach, I proved that all perspective events – that is all "subjective" geometrical representations of events going from a very large number of dimensions to dimension two, or, vice versa, going from a very large number of dimension to a very

small one – are, when we interpret them in order to go back to the original dimension, "generative engines" very well suited to fitting and communicating our subjective view. Their function of generating endless variations expresses our poetics. It is, in other words, a "logical interpretative engine" capable of representing and managing the complexity of our work. We must remember that perspective, which represents a subjective vision, is the only representation capable of representing infinity on a single sheet.

Further, in practice, if we represent an event with *perspectiva artificialis* and reconstruct the 3D event using a total perspective we can generate an endless number of unpredictable results according to our creative vision.
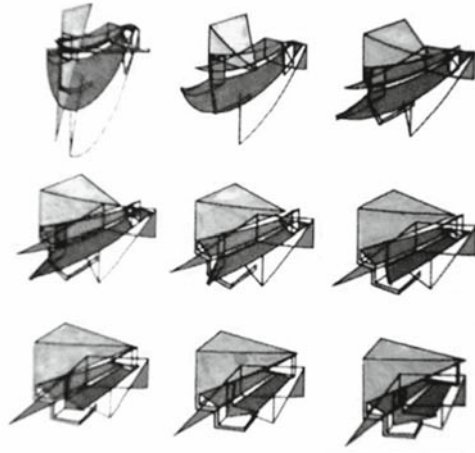

Fig. 4. Moving from Euclidean to non-Euclidean perspective in a reconstruction of the possible 3D objects resulting from an interpretation of a futuristic artwork of Balla [Soddu 1988]

There are some interesting reasons for using this total perspective in architecture. With *perspectiva artificialis* we cannot represent the whole interior space from a point of view inside the space. Thus we cannot control the entire interior system with its relationships and complexity. With total perspective we can do it easily and once we become accustomed to this unusual representation, we discover that this perspective representation is so much closer to our mental approach that we can use it without problems.

There are many different "total" perspectives, depending on the many possible different interfaces that we can use.

The cylinder is the easiest interface, also because it is a "plane" interface curved in one direction only, and allows us to use a normal sheet for our representation, folding it when we want to look at the representation.

We can also use a spherical interface, which is closer to real vision but which requires us to represent a curved surface on a 2D sheet; the alternative is to make our drawing on the surface of a sphere.

There is also a really interesting approach to representing the total environment from its interior. We can use a mirrored cylindrical or conic interface. This system, which we can call anamorphic perspective, was a Flemish and Chinese invention of the sixteenth century (fig. 5).
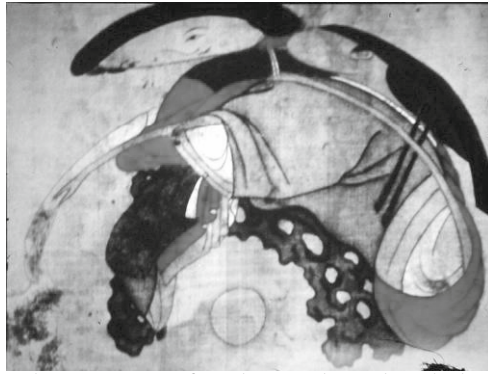
Fig. 5. Chinese anamorphic perspective of two lovers. The circle is the location of the cylindrical mirror

I tried to design the rules for the algorithmic transformation that make it possible to represent in 2D the 3D environment in such a way that it can be viewed by putting a cylindrical mirror in the center of this (circular) drawing (figs. 6, 7, 8, 9).
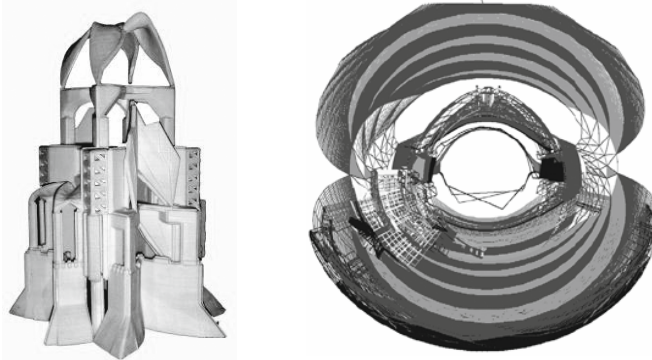

Fig. 6. (above, left). Generated Castle realized with rapid prototyping using 3D STL model directly generated by Argenia, the generative software designed by the author

Fig. 7. (above, right). The Castle represented with anamorphic total perspective using the software designed by the author. The location of the cylindrical mirror is in the middle

2.3. Perspective – Infinity to 1. Infinite points of view to one target

Starting Dimension: X, Y and Z of object and target together with polar X and Y of endless viewers

Representation Dimension: 2 (x, y)

Each bundle of parallel straight lines converges into two points (non-Euclidean geometry)

If we succeed in representing the total interior space with a spherical total perspective, we can think that it is possible to represent a total object from the exterior, looking at the same moment at all the exterior events, not only at the part that we are facing. We could see, together in the same drawing, the front and the rear, the right, the left, above and below. A "primitive" representation of an animal (such as the representations of elephants or lions that I have seen made by people in Somalia) is really similar to this type of perspective. It represents the animal as a carpet-skin and it is possible to look at the top, the right and the left at a single glance.
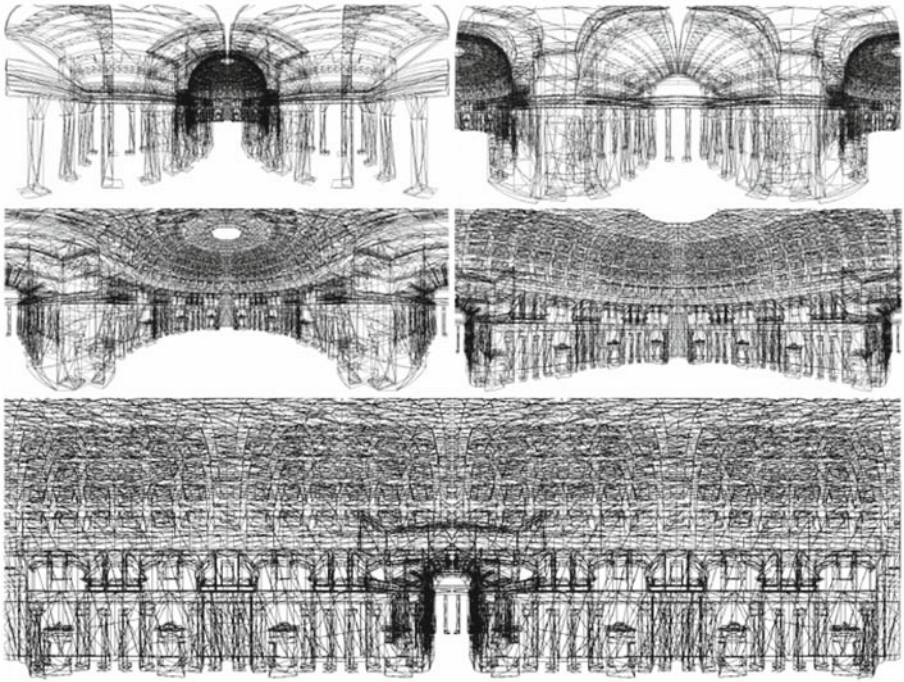
Fig. 8. Spherical total perspectives of Pantheon in a sequence going from outside to the center. The last perspective is from the center of Pantheon that is the center of the half-sphere of its dome and of its cylinder. This coincidence generates a particular perspective representation. Images made with the author's total/anamorphic perspective software [Soddu 1986]
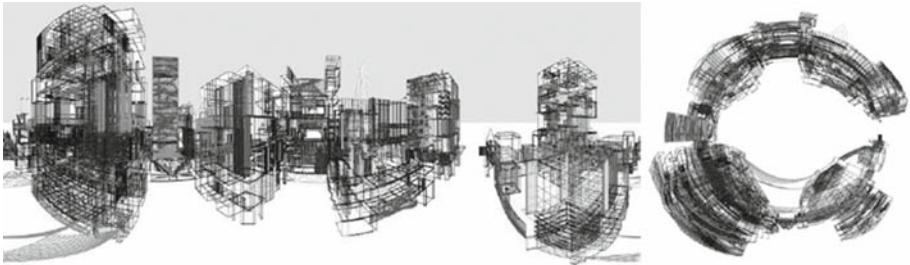

Fig. 9. Image of generated city with spherical and anamorphic perspective realized with the Flemish/Chinese system. In this case, I used, as interface of the anamorphic image, a conic mirror for projecting in the inside of a large cylinder the image of the city, during its generation, viewed by its center. From an exhibition of the author's generative architectures at the Milan Fair in 1998

This is the reverse perspective of Pavel Florenskij [1983]. This approach considers a multiplicity of points of view, the two eyes and their various possible motions, and only one target of the gaze. The represented event is the center of the system. This perspective aims at encompassing the multiplicity of different visions in a single two-dimensional image. This approach tries to represent, in a single 2D drawing, the mental image we form when we look at a 3D object with both eyes, particularly when the object is small and it is very close to our nose. "Reverse" perspective, amplifying this kind of vision, can increase the number of "eyes" up to an infinite number.

The practical construction of this kind of perspective can be created through an interesting conceptual reversal that I have created with my algorithms. If the target of the gaze is unique and the points of view are different we can reverse the total perspective, which has only one point of view and different targets, by setting the point of view in the target and the directions of the gaze in many "eyes". The images thus created could be likened to a representation of the skin of the object seen from the interior but represented as exterior. The reverse perspective has been identified and explained by Pavel Florenskij in relation to Russian icons. Because these are sacred representations, the fundamental choice is setting the represented event as center of manifold views (fig. 10a). In these two-dimensional images the representation of the face of the Saint is, according to my hypothesis, represented as seen from the inside of its head (fig. 10b). Since, as Florenskij affirms, we represent only the "skin" of the physical event we can reverse the face. Its projection on a sheet will turn out to be similar to the representation in reverse perspective of the Russian icons. In other words, it is my belief that the reverse perspective is the reversal of spherical total perspective and not only a reversal of Piero's *perspectiva artificialis*. Also, the Russian icons are only a part of the total reverse perspective, which could represent the back of the Saint's face as well.
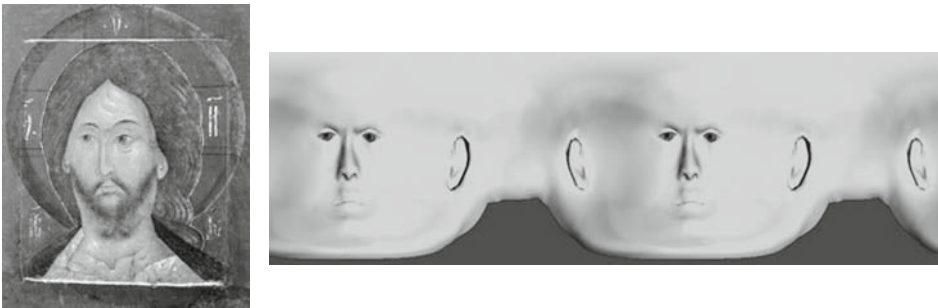

Fig. 10. a, left) Russian icon with Christ represented in "reverse" perspective; b, right) A human head represented in "reverse" perspective. The image is repeated two times (360°+360°) in order to clarify the external representation of the head as a whole. It is made by swapping the 360° interior total perspective, made with the point of view inside the head, into an exterior representation. This swap interchanges the point of view with the target of sight. In the end we have endless points of view and only one sight target. The head is the center of endless subjective points of view. The image is clearly similar to the Russian icons

3 Creative moving across dimensions

The passage from one dimension to another, and particularly from 3D to 2D events through different perspective methods, but above all the reconstruction of the 3D object using different perspective-visual methods introduces fields of variation owing to different factors inherent in the dimensional transformation and in the type of representation used. These fields of variation belong to the subjective interpretation of the image, or better, to the interpretative reconstruction of the parameters that could be used for the production of the image, and of the reconstruction of the parts that are not represented because they are not visible, being either behind or inside the volume of which the skin is represented.

The hypothesis of reading an image by decoding it through the *perspectiva artificialis* when instead it had been constructed using Florenskij's reverse perspective can produce unpredictable forms. For instance a cube could be reconstructed as a pentagonal prism.

This happens because, in reverse perspective, the two opposite sides of a cube are represented as "in sight" along with the side that is facing the observer. The reverse perspective of a cube is capable of showing three faces in sequence because the cube is seen from both left and right. This is what happens when we look at a very small cube and we bring it very close to our eyes: one eye sees the right side, and the other left side; the resulting image is the synthesis of the two views. Our mental image is a reconstruction of the cube representing three consecutive faces. If we look at this representation with a canonical Euclidean perspective approach, we must presume that it is something different from a cube. The space "behind" appears too much ample and the re-constructive interpretation of the 3D form can lead us to imagine more than a single hidden face, for instance two, and therefore to generate an acceptable reconstruction of a prism with five or more consecutive sides. The cube, as a result of these successive passages from dimension to dimension (3D - 2D - 3D) is turned into a pentagonal prism.

These transformations are born of our interpretations: they are a "natural" construction of generative motors that mirror our creative identity, our cultural references.

The idea of an architect isn't based on forms but on transformations. This is a transforming approach that sees the existing world as dynamic, and is capable of generating visionary scenarios and their endless variations. The generative engines are the structure of the designer's idea. They work on morphogenetic codes fitting the uniqueness of the approach; they are the anamorphic logic that allow the designer to generate endless visionary worlds by mirroring, in their multiplicity, the design idea.
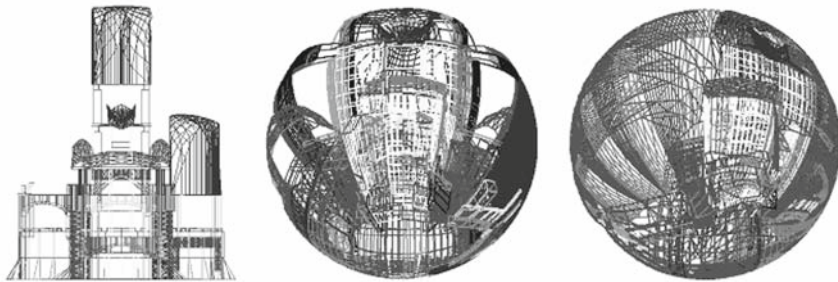

Fig. 11. Generated castle by C. Soddu, represented in elevation and in two different "reverse" perspectives drawn on a sphere, using the software designed by the author for investigating Florenskij's approach

4   Construction of generative morphogenetic processes with perspective approach: identity, subjectivity and variations

The identity of an artwork exists if people can recognize it as belonging to a species. All possible 3D interpretations of a perspective image are recognizable because they belong to the 2D image. In these reconstructed 3D models we can find the particular view that fits the original image; all the other views are different but, at the same time, they are recognizable as belonging to the same species. In reconstructing the 3D space, we constructed an anamorphic object capable of changing according to different

subjective views. Each perspective image can be likened to an artificial DNA strand capable of generating a species of 3D events.

When we want to construct the identity of our artworks, we can identify its species and execute it by designing an artificial DNA strand. This approach is Generative Art: building a series of logical rules of transformation capable of generating an endless number of possible results recognizable thanks to the morphogenetic paths used for their creation and to the reference to possible anamorphical rules of logic belonging to our creative and cultural identities.

The results, in terms of quality and extended appreciation, are best where the anamorphic logics produce answers pertinent to different subjectivities, therefore where the generated complex system doesn't provide only the possibility of being understood as axiomatic structure of a shape or of a function but its complexity makes it suitable for subjective and unpredictable uses. This usability is performed and appreciated when the suggestions, the logical rules of use and the aesthetical appreciation of each user are related to the complexity of the designed system and to the potential anamorphic interpretations that this complexity makes possible.

Further, the identity has to belong to a species, not in denial of, but as a reinforcement of the identity as individual, as *unicum*. This leads to the consideration that the design of morphogenetic paths rather than of shapes doesn't take anything away from the final results in terms of identity but rather strengthens them, especially because of the parallel presence of "variations", as occurs in music, from Bach to Mozart and to jazz. Variations are constructed by consolidating different forms at different moments, but these results are reciprocally congruent because of the common morphogenetic paths that, from the detail to the whole, lie at the basis of an idea. These "endless" variations might seem aesthetically less strong and functional, less recognizable than the single result chosen because, at the end of the optimisation of the form-function relationship, it was considered the best, but this approach is misleading. The affiliation to a species, with the possibility of mirroring each result in an infinity of parallel variations, creates two congruent layers of recognizability and identity that are mutually reinforcing: the identity of the species and that of individuals.

The fascination of perspective images are strongly related to the possibility of multiple subjective interpretations: each image is a possible mirror of a different observer's subjectivity.

On the left the rendering of normal perspective; in the center the 360° spherical perspective; on the right the anamorphic perspective with a conic mirror interface. The inclination of the 360° spherical perspectives follows and represents the helical geometric structure of the 3D models.

5 *Different perspective views together in the same image*

As we can see in the art of Simone Martini, many artists identified in the perspective view a possibility of representing the fourth dimension, that of time. The aim is to achieve the complexity, the quality that belongs to the multi-significance, full-of-sense works of art.

The *Carceri d'invenzione*, the most interesting series of engravings by Piranesi, were made by stratifying, in subsequent moments, further objects and, in the meantime, also further perspective points of view in the same artwork.
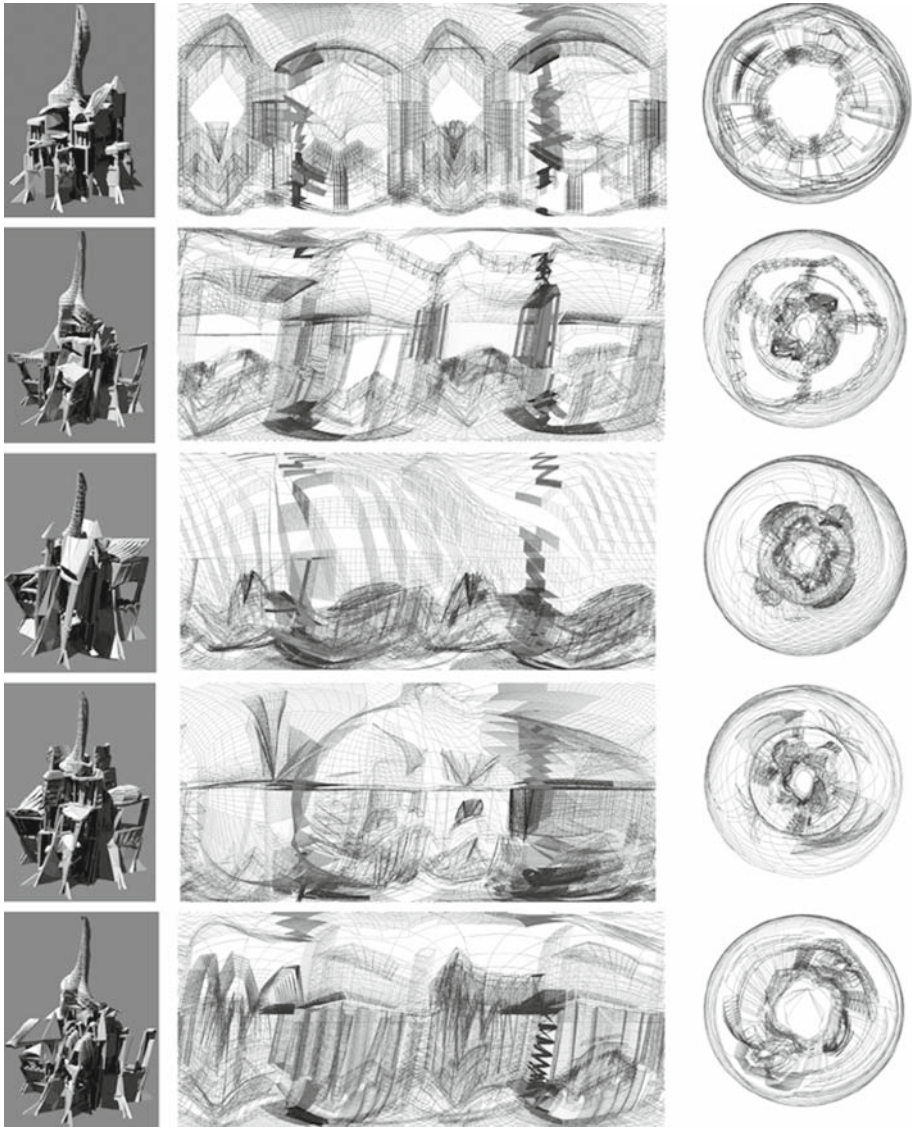
Fig. 12. Variations of the *Babel* project by the author. All these 3D models are completely generated and represented with the author's software

Sergei Eisenstein, in *Oppositions* 11 [1977], describes the increasing complexity of Piranesi's engraves through the addition of new stratified layers. Piranesi used different points of view for these "new" perspectives in a way such that these new layers perform jumps in scale and in space geometries. Eisenstein argues that this method is similar to the vertical sequences in Japanese Kakemono paintings, with the difference that Piranesi unpredictably magnified the subsequent layers instead of reducing them in accordance with the rules of perspective (fig. 13).
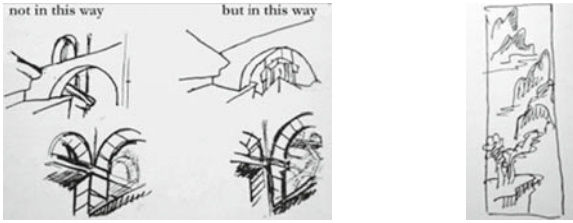
Fig. 13. Sergej M. Ejzenstein, about Piranesi perspective and Japanese Kakemono [1977]

I tried to go on with this increasing complexity approach, with this creative path, by stratifying into the Piranesi engraves subsequent objects using a perspective point of view that is not exactly the same, but somewhat changed. And I have created this increasing complexity by generating, with my Basilica software, fifty different variations of the same Tower of Babel and using them to create another layer in an engraving of Piranesi, pushing in depth the existing layers. These fifty variations were a gift to the fifty participants of the 2008 Generative Art conference in Milan (fig. 14).

Fig. 14. Fifteen different variations of the Babel Tower, the after-Piranesi generative artwork

In conclusion, Perspective is a "logical interpretation" of reality that is able to generate endless "logical interpretations" fitting different subjective observers.

The availability of different perspective tools creates the possibility to cross dimensions, going from a perspective representation to its 3D space and back to different perspective representations by interpreting the perspective images with our creativity. This possibility is one of the more interesting ways to connect our past, our cultural heritage, to our vision of the future. It increases our creativity.

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Celestino Soddu Celestino Soddu obtained his Master's Degree at Università di Roma "La Sapienza" in 1970. In the same year he passed the State Examination for the Register of Professional Architects and Engineers. He has taught Architectural Representation, Composition and Technology in Italian universities since 1971. He is now professor of Architectural Generative Design at the Politecnico di Milano in the Faculty of Engineering-Architecture. In 1997 he founded and is presently director of the Generative Design Lab at the Department of Architecture and Planning of the Politecnico di Milano. Beginning in 1998 he has organized and directed the annual International Generative Art Conference. He has presented his generative projects and artworks in many personal exhibitions, including exhibits at the Hong Kong Museum, Visual Art Centre, MF Gallery in Los Angeles, IDB Cultural Center in Washington DC, the Pacific Design Center, Los Angeles, the Italian Embassy in Beijing, the International Finance Center of Hong Kong and the Commerce Chamber in Milan. He is the author of numerous books in Italian and English. Video interviews and programs for international televisions were created about his architectural research activity in Italy, China, US and Spain. More information can be found in his website http://www.soddu.it