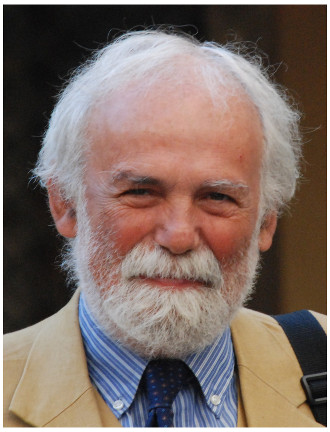
CELESTINO SODDU

Paper: **Generative Baroc Algorithms**

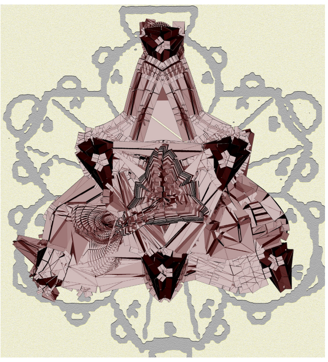


Topic: Architecture

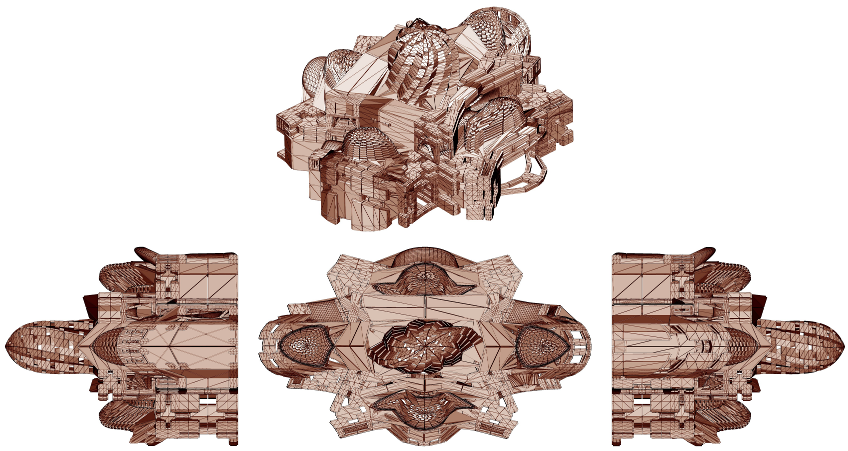
Celestino Soddu
1.Politecnico di Milano University, Generative Design Lab, Italy
2.Domus Argenia Center, Sardinia, Italy
www.argenia.it

References:

[1] Francesco Borromini, "*Opus architectonicum*" Il Polifilo, Milano 1998
[2] Bruno Zevi, "*barocco Illuminismo*", Newton & Compton, 1996
[3] H. Sedlmayr, "*L'architettura di Borromini*", Electa 1996
[4] Celestino Soddu, "*Citta' Aleatorie*", Masson, Milano, 1989
[4] generativeart.com



A constant of my generative operative research was to "abduct" by the Baroc a series of transformation logics that characterize my generative architectures. More specifically identifying and writing as algorithms my geometrical interpretations of the dynamics of the architectures of Francesco Borromini. The approach was to try to discover a possible interpretation from the complexity of Borromini architectures and not to analyze and copy them. Recently I have developed more in detail these potentialities by focusing these logical interpretations from Borromini dynamics that, for the first time, I try to render explicit in this paper telling how I designed "baroque" algorithms, a work that, as I already said, started from 1986.
Conceptually it was not difficult for me, since my interpretation is based on the possibility to read not only the existing forms but how these forms could spring from progressive transformations of pre-existing events. This is organized by the morpho-genetic process when it runs and performs the complexity. Following my approach, the Borromini architectures are like progressive tales of a creative thought able to generate complex and unique events based on progressive increases of three-dimensional geometric and topologic logics. And sometimes the third dimension, operating logical translations from the traditional bidimensional formal orders, unexpectedly finds again unthinkable and amazing fields of development. These are like progressive stories where each person could be able to find again a really unexpected, subjective and suggestive path of discovery and to follow his own increasing ability to appreciate the beauty, and to find out how to generate it. In other words, interpreting the Baroque structures as algorithms is surprisingly immediate. And it is what I have done in the last thirty years; increasing my generative approach starting from my vision of dynamic baroque architecture.
In this paper I use as example some logical-operational interpretations of mine, many times very "out of rules", as, after all, Borromini was; and I identify the logical-geometric structure of these algorithms and the use of them inside the progressive project Argenia, my generative software for artificial events.



Generated architecture designed with generative "baroque" algoritms.

Contact:*celestino.soddu@generativeart.com*

Keywords: Baroc, Borromini, Creative Evolution, Generative Algorithms, Identity, Complexity, Variations

Generative Baroque Algorithms

Celestino Soddu

Director of Generative Design Lab, Politecnico di Milano University

Director of Domus Argenia Center, Sardinia,

www.soddu.it

Figure 1: Generated baroque architecture inside an engrave of Piranesi. C.Soddu, 2011

Premise. Why Francesco Borromini and Baroc.

We are in Rome and I would like to point out my references to the Baroc of Borromini and the essential contribution that I have found in the work of this Master when I developped my generative approach to the architecture.

I didn't loved the Baroc for its decorative structure, of for the redundance of forms and I have never considered it as synonymous of decadence or synonymous of “female culture”, definition that was established by some philosophers to expressly identify a culture of the void, of the nothing, almost a not-project in which to lose themselves following empty metaphors without end. Such interpretation of the Baroc and of its architects is, for me, completely out of my experience. I started to appreciate the Baroc contemporarily to my passion for the geometry and mathematics and for the possibility to use them in the creative innovation. And I am interested, above all, of the architectures of Francesco Borromini, not only for his ability to read and use the classical geometric systems as dynamic structures in transformation, but, particularly, for his ability of invention, of going over the remixing, by tracing architectures that knew how to conjugate the unpredictabilty of the true innovation with the power of being surprisingly harmonic, as the architectures out of the time are.

I learned from this Master how it's possible to operate through logics of geometric transformation, moving from the orthogonality to concave-convex systems, from square to equilateral triangle, as Borromini developped in Sant'Ivo alla Sapienza, not losing the harmonic structure consolidated by the tradition but performing unthinkable creative processes. The progressive transforming rules can perform not only the geometrical basic matrices, but also each single events through progressions of orders that could be, as in Borromini, not only unpredictably harmonic but surprisingly carrying of a pleasure of possible variations.

In this field, the Baroque architectures of Francesco Borromini identify a creative logical thought which fulcrum is the increases of geometrical complexity by finding out fields of possible progressions developed without preclusions, neither the constrains of consolidated classical paradigms. If we reduce this approach only to metaphors, as some philosophers has done, we deny the deep sense of the pleasure of complex systems harmony, able to imitate the Nature through a deeply artificial approach.

The variations are fundamental for the Baroque approach, as they are for the Generative approach. The architectural variations of Borromini, as the variations in the Baroque music, succeed in increasing the appreciation of the subtended logics, of the identity and recognizability of the creative thought, of the pleasure of living the architecture, its creation and its fruition. As, centuries later, it's possible to find in Gaudi, other my great reference for establishing my Generative vision.

It's not easy to read the geometries subtended in these architectures. After all Francesco Borromini has carefully avoided to communicate the geometrical generative structures, particularly when, as in San Carlino, he introduces a complexity not easily readable through simple forms. This approach, typical of great masters in all cultural fields amplifies the need to operate through logical interpretations that must be a subjective interpretation, by rendering explicit, and at the same time stimulating, the vision of each people that look at these architectures. It's not casual that a lot of books and innumerable articles are full of different interpretations of the works of Borromini.

Abstract

A constant of my generative operative research was to "abduct" by the Baroc a series of transformation logics that characterize my generative architectures. More specifically identifying and writing as algorithms my geometrical interpretations of the dynamics of the architectures of Francesco Borromini. The approach was to try to discover a possible interpretation from the complexity of Borromini architectures and

not to analyze and copy them. Recently I have developed more in detail these potentialities by focusing these logical interpretations from Borromini dynamics that, for the first time, I try to render explicit in this paper telling how I designed "baroque" algorithms, a work that, as I already said, started from 1986.

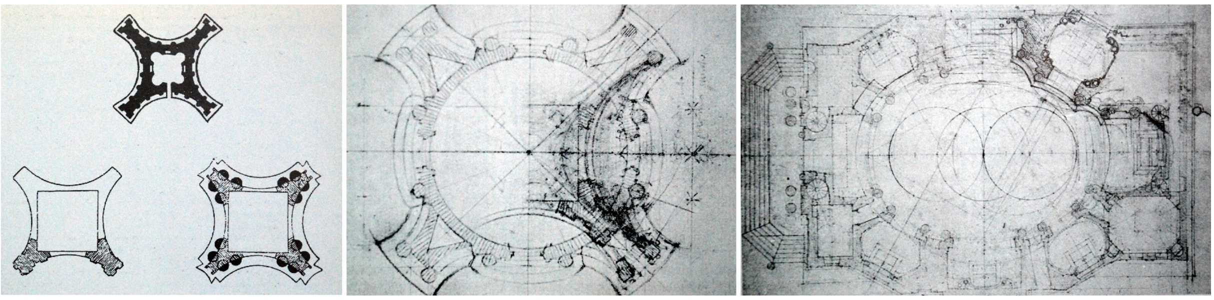


Figure 2: ancient grave, two geometries of F.Borromini, S.Andrea delle fratte and S.Carlino, from H.Sadlmayr, 2-3, original drawings of F.Borromini for S.Andrea delle Fratte and S.Carlino.

Conceptually it was not difficult for me, since my interpretation is based on the possibility to read not only the existing forms but how these forms could spring from progressive transformations of pre-existing events. This is organized by the morpho-genetic process when it runs and performs the complexity. Following my approach, the Borromini architectures are like progressive tales of a creative thought able to generate complex and unique events based on progressive increases of three-dimensional geometric and topologic logics. And sometimes the third dimension, operating logical translations from the traditional bidimensional formal orders, unexpectedly finds again unthinkable and amazing fields of development. These are like progressive stories where each person could be able to find again a really unexpected, subjective and suggestive path of discovery and to follow his own increasing ability to appreciate the beauty, and to find out how to generate it. In other words, interpreting the Baroque structures as algorithms is surprisingly immediate. And it is what I have done in the last thirty years; increasing my generative approach starting from my vision of dynamic baroque architecture.

In this paper I use as example some logical-operational interpretations of mine, many times very “out of rules”, like, after all, Borromini was; and I identify the logical-geometric structure of these algorithms and the use of them inside the progressive project Argenia, my generative software for artificial events.

Basic Structure of architectural events. The paradigm “27” and the paradigm “21”.

The reference to Borromini, in my project Argenia is constant. Both in the paradigmatic basic structure and in the progressive logics of transformation.

Borromini affirmed that the number 27 is at the base of his primary constructive structure of the architecture. This affirmation was not well specified. It mentions it in his only written work, the "opus architectonicum", by the way written by another people over his suggestions.

My approach is using the number 27 as definition of a space (1) surrounded by 26 interfaces that organize the relationships with the other surrounded spaces. If we verify this structure in the schematic constructive order of an architectural simple space like a parallelepiped, around the space we will have: a floor, four bases of columns, four beam-connections among the bases, four columns, four walls, four capitals, four beams, a coverage. In all 26 interface events + the inside space = 27.

I have directly used this systematic structure in my generative softwares of architecture. And I discovered that it is a geometrical extremely open and transformable system. Not only, it is able to guarantee the feasibility of the generated architectures and also their harmonic structure: once the relationships among these 27 elements are progressively defined, they mirrors a geometric logical approach. Results are recognizable as built following our cultural traditions and the specific progressive vision of our poetic. In fact, once that we apply progressive three-dimensional transformations to a so conformed system, by foldings it for fitting topological needs and by applying other geometrical transformation mirroring our architectural vision, our cultural tradition, as the Baroc is, we succeed in generatively easily managing the complexity of the architectural systems and the relationships among its events.

Thia adaptivity and ability to keep alive harmony happens also when we apply transforming rules able to capsize the topological system. A geometry, that we could identify as “not Euclidean” geometry, can be found by using algorithms able to transform the parallel straight lines by bending them in a way to converge them in two points. Other possible logics can be reached designing algorithms able to transform the orthogonality into hexagonal systems, into concave-convex systems, or in three-dimensional hyperbolic geometrical systems, or other. And into all multiple possible systems based on their mutual contaminations and convergences.

As examples: Euclidean – Not-Euclidean geometrical system, from rectangle to ellipse, the “flower” transformation, Orthogonal into Hexagonal System (Sant'Ivo), from orthogonal to convex systems. (S.Andrea delle Fratte, Sant'Ivo), from Rectangle to rounded Cross (Can Carlino), from Rectangle/Triangle to concave-convex sequence (Sant'Ivo).

The difference between working on forms and working on transformations is simply identified: the forms are hardly stratifiable, the transformations are easily usable one after/over the other. The forms are data (A=B), also if "parametrical" data A=function(B), the trasformations are algorithms that transform what was before in what will be A=A+1.

Reflecting on the quality inherent in the geometrical idea of Sant'Ivo, I have tried to move from the orthogonal structure to a triangular-hexagonal one, with the aim to enter into a system able to manage the generative progressive path to which this work of Borromini alludes. I have built therefore a geometrical system non based on 27 but on 21, that is an interior space based on the equilateral triangle surrounded by 20 interface. Running again the constructive schematic example used before, but with a based triangular prism, a floor, three columns, three beam-connections, three walls, three capitals, three beams, a dome. The number of all these interfaces are 20 + the inside space = 21.

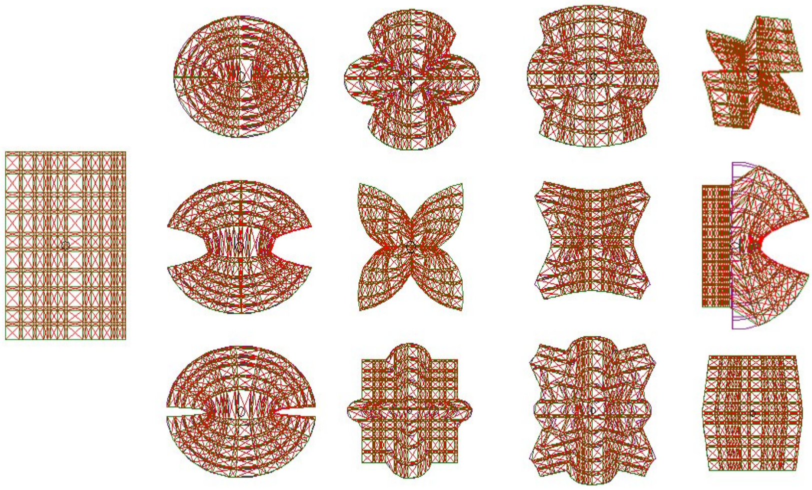


Figure 3: Starting from orthogonal system, possible transforming algorithms to fit Baroque geometrical systems.The used paradigm is "27".

I have realized that this paradigmatic system, also if similar to the one based on 27, don't has the same feasibility in being subsequently transformed since it is hardly able to maintain identity and harmony through transforming paths. May be that this is the reason why Sant'Ivo alla Sapienza is unique: it appears as a perfect architecture but hardly repeatable with variations.

However the based paradigmatic matrix on 21 is able to produce variations if directly used inside its geometric logical specification. In other words the initial order doesn't easily admit to be forgotten, as instead it happens for the based paradigm on 27 that is extremely adaptive and able to forget its own basic apparent order to strongly reach unpredictable and innovative orders.

This resistance to accept logical-geometric transformations is also due to its topological basic structure. While in the system 27 all the events have 26 interfaces, in the system 21 every event has a different number of interfaces. In the basic order the triangular event has 20 interface, the rectangular events, the "walls" surrounding the triangle, has 26 interfaces and the hexagonal "knot" 38 interfaces. This difference creates a hierarchical structure that forces the maintenance of some relationships and their basic structure of formalization and that is not able to accept

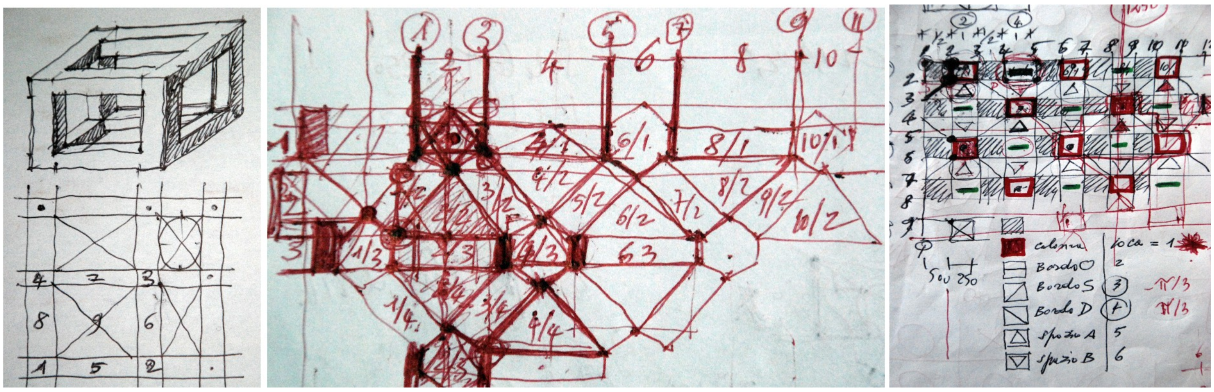


Figure 4: The 27 and 21 Paradigm. In the 3rd image the orthogonal system performed for managing Hexagonal systems.based on equilateral triangles and related interfaces.

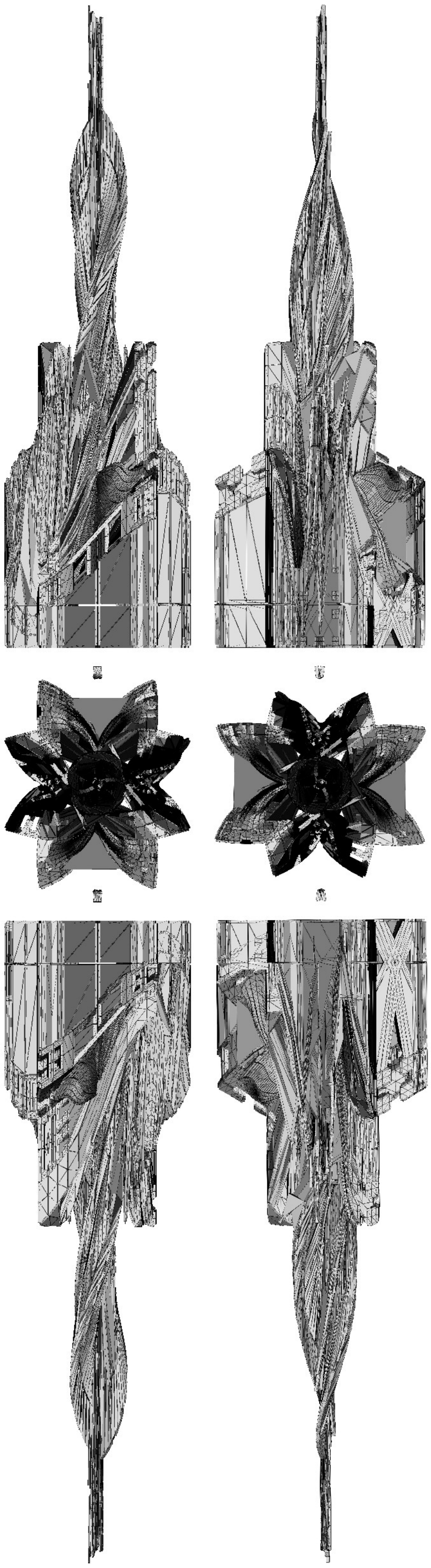


Figure 5: baroque architecture generated using transforming rules from orthogonality to curved spaces. C.Soddu 2011

transformations that modify these basic orders.

In other words, we can apply transforming rules if these logics are based on polar coordinates and not on cartesian coordinates. And the center of these coordinates must be located on the center of the main triangle and cannot be easily moved.

How to contaminate the orthogonal matrix and the hexagonal one in managing the generative processes? A purely geometric contamination was obviously impossible. I tried to follow a different approach. The main idea was to use a geometrical system based on orthogonality, and, when the system needs an exagonal plot, making "empty" 6 events of a the system 27 so that to reduce the operational events to 21, and defining some specifications of transformation and mutual correlation, in other terms defining the preliminary behavior that every event that "remains" must activate before being object of the following transformations.

The result is interesting, also because it is possible to make experiment already based on transformations around three Cartesian coordinates, and therefore based on the orthogonality, on the hexagonal system, not limiting it to the transformations based on the polar coordinates that, instead, directly appear operational on the hexagonal system.

The 3D models generated are amazing and imitates the innovation paths without prejudices that, for me, are proper of the work of the Borromini.

Progressive logics of transformation

The most Baroque of these logics of geometric transformation is, obviously, the algorithm able to turn a rectangle into an ellipse. Instead of progressively bending the sides until everything becomes "continuous" as a circle-ellipse, logic that I have used sometimes and that has, as possible result, the possibility to move from convex system to rectangle, to ellipse and to flower, I have preferred to imitate a possible path of transformation from the Euclidean geometry into Not-Euclidean geometry. In practice, in a rectangle, my algorithm operate in a way that the two opposite parallel sides meet themselves in two points, as it happens in the Not-Euclidean Geometry. The transformation acts progressively moving the vertexes of two parallels sides with the aim to bring them to coincide two to two: while the sides among the two vertexes that are going to coincide fold up itself toward the inside, the other two sides bend toward the outside, in a logic of concave-convex. (*Fig. 3, first column*)

Potentially the two vertexes have the tendency to form one of the fires of an ellipse through the point of progressive folding of the side, and they identify it if the side is completely folded up in two, abandoning its convexity. But it is not necessary to arrive till this final order, also because when it happens, the generated Not-Euclidean system apparently come back to Euclidean. The best "baroque" character appears during this process. Enlarging the transformation rule to the 3rd dimension is completely inside the Baroque character, as the images (*Fig. 8 and others*) can explain,

The interesting aspect of bending in this way the rectangle-pareallelepiped is that the system of the three-dimensional points insides the transforming space maintain their congruity and correlation also if them tend to perform a specific unpredictable complex "baroque" space. Congruity that also remains not only when transforming a single event but also when a connected net of events is globally transformed. Until a "city" system (*Fig. 6*). A concave-convex structure that, in a new curvilinear structure, surprisingly is able to maintains unchanged the initial topological connotations. More,

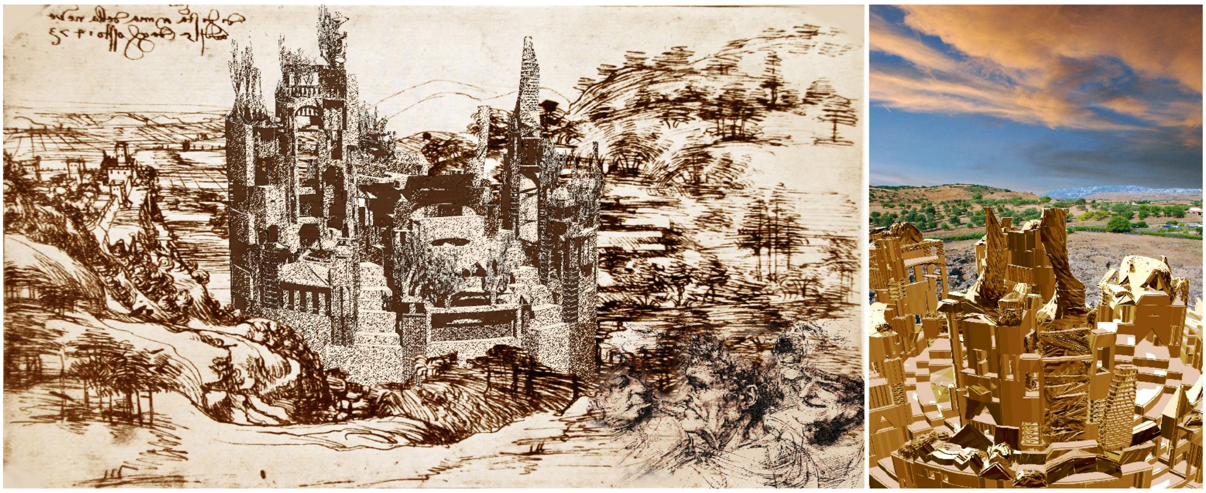


Figure 6: The bending process from Euclidean to Not-Euclidean system. A generated city with Not-Euclidean system performing the bidimensional plan inserted in a drawing of Leonardo da Vinci for Tuscany environment. In the other image a generated city in Sardinia. (C.Soddu 2009)

these transformations are able to increase the topological relationships by structuring new relationships (the contiguity of two vertexes that were before distant) not as change but as increase of complexity.

All these logics of transformation remain, however, very “axiomatic” if they are not used in series and if they are not contaminated one each other. The more satisfactory results, mainly from the point of view of the possibility to generate "baroque" architectures, is reached through the progressive use of different logics, and the application of these algorithms to the whole structure and to single parts.

The experimentations that I done by contaminating different algorithms of transformation are very complex and diversified. I try to show some meaningful examples always drawn by my interpretations of Borromini.

The algorithms interpreting the Baroque geometric dynamics are transformations applicable to the pre-existing form (even if already transformed) and they are finalizd to an increase of complexity and to a further stratification of identity and recognizability of the idea. They are dynamic tools for performing the vision. As we use tools for drawing, and we choose each tool following our singular vision, in the same way we use algorithms as possible tools for performing our subjective vision.

For instance the concave-convex algorithms, that are my interpretations of Borrominian architecture, are my tools for generating my architectures. In my experimentations this Borrominian character is reached using at least two different tools, two or more different algorithms able to perform, step by step, my baroque idea of architecture. (*Fig. 3, 2nd and 3rd column*)

Transform the sides of a square, or as in Sant'Ivo of an equilateral triangle, setting to the center a bending (a niche) and in the vertexes a convexity is not transferable in algorithms if not through a specific interpretation of the dynamics of these subsequent transformations.

One of my interpretations was based on exploding each internal virtual point from the center, according to a logic curve (the niches of Borromini in Sant'Ivo are not semi-circles). The whole three-dimensional space, not only event belonging to the sides, are pushed to the exterior when they are inside the angle focused on the middle part of each side. This because the aim was not to form a niche in a wall but to operate the spatial transformation of the whole space. In the same moment I performed the algorithm for lifting, with the same logic, the same points by harmonically increasing the Zs in relationship with the transformations on the other dimensions. The result is surprisingly very Baroque (Fig. 8 for the “27” paradigm and Fig. 9 for the “21”

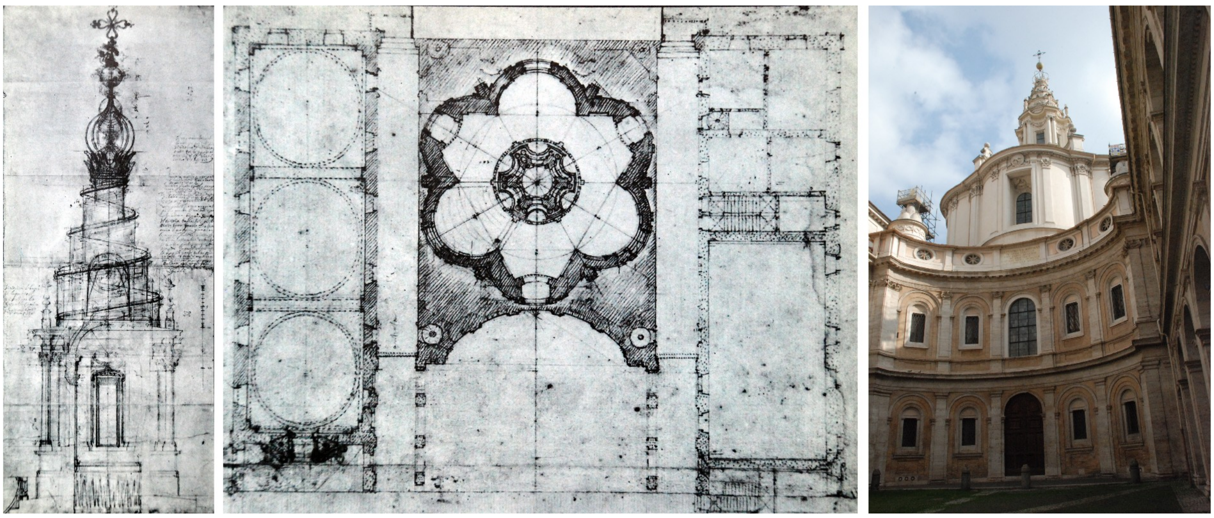


Figure 7: Sant'Ivo alla Sapienza by F. Borromini. Original Drawings and photo.

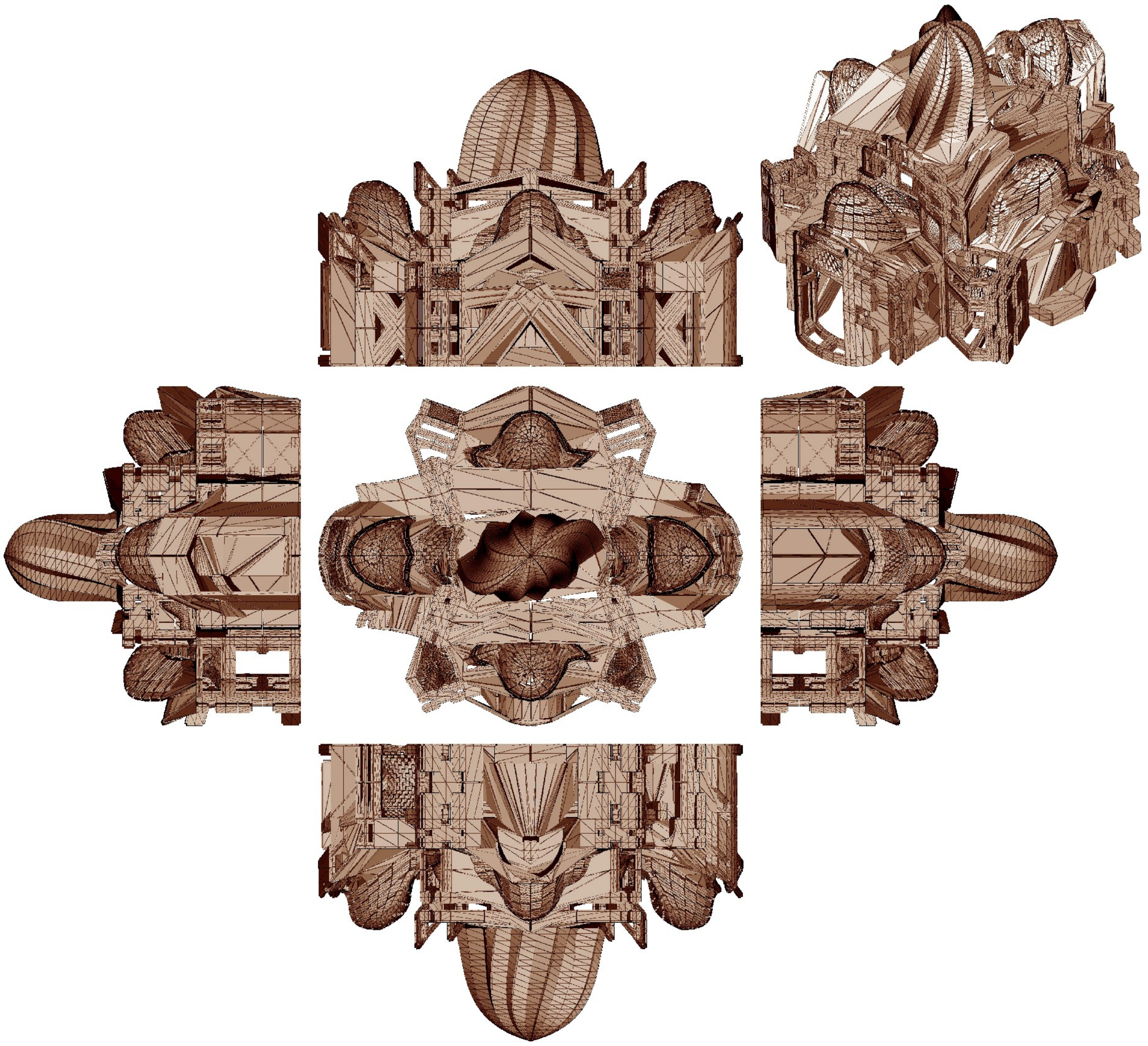


Figure 8: Generated architecture using different "baroque" algorithms with the paradigm 27. The contamination of two geometrical transforming logics: the Baroque niches and the orthogonal- convex system. In the following images, the generation is made using the 21 paradigm with the same transforming logics. (C.Soddu 2011)

paradigm). The harmonic transformation of the heights with a tied up progressive logic to the concave-convex one is inside the Baroque identity and recognizability.

Another algorithm of transformation, appliable and able to contaminate the first one, realizes the convexity of the angles. And the parallel use of these two algorithms produces the concave-convex geometrical system that we are looking for.

Progressive logics of transformation of the local events

First of all it is necessary to clarify that, inside each event, the structure of the relationships with the surrounding events (but not only) are primarily managed, at topological level, by the position of the event in the system 27 or 21.

Every single event has inside the possibility to refer to a series of spatial points,

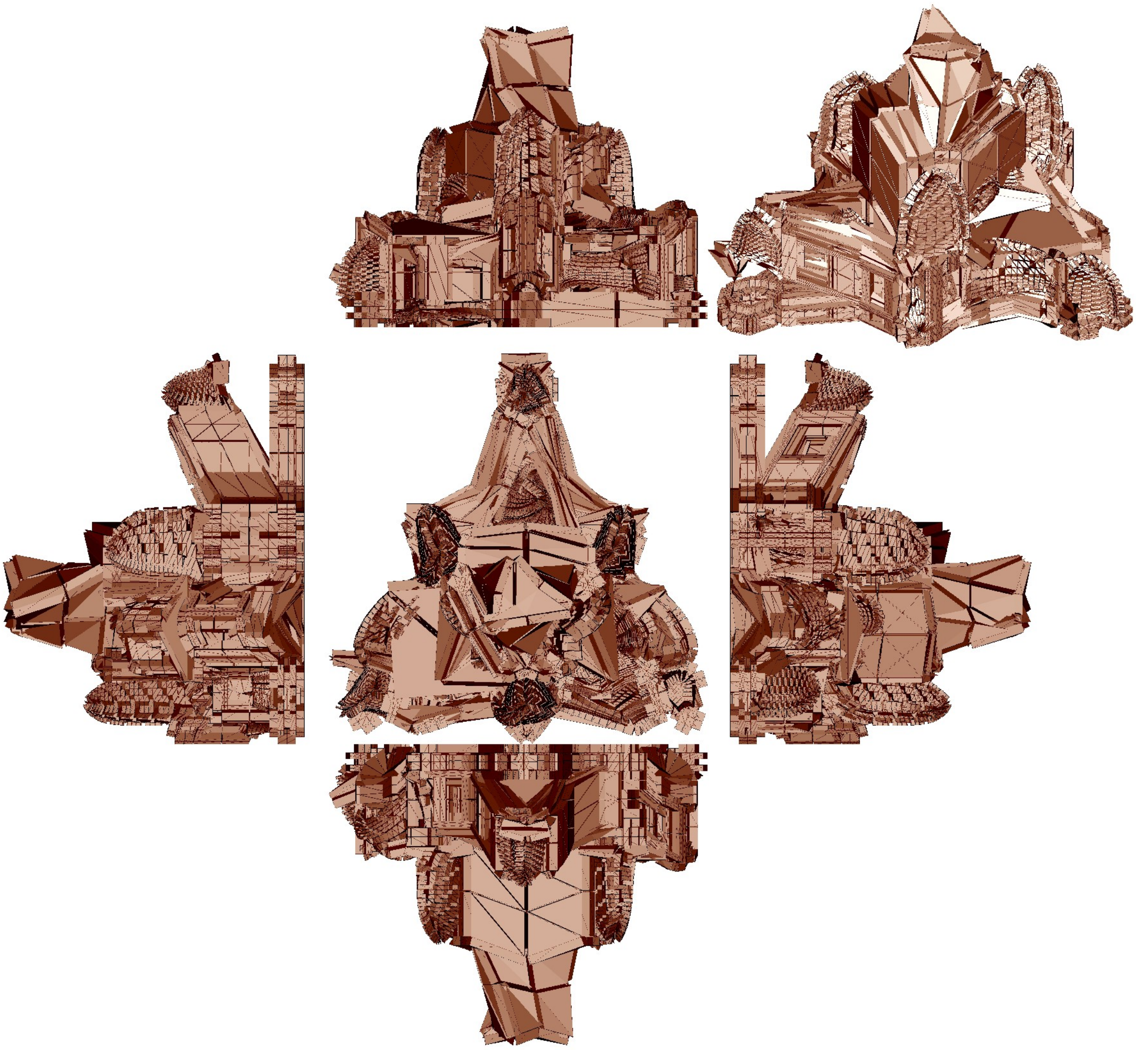
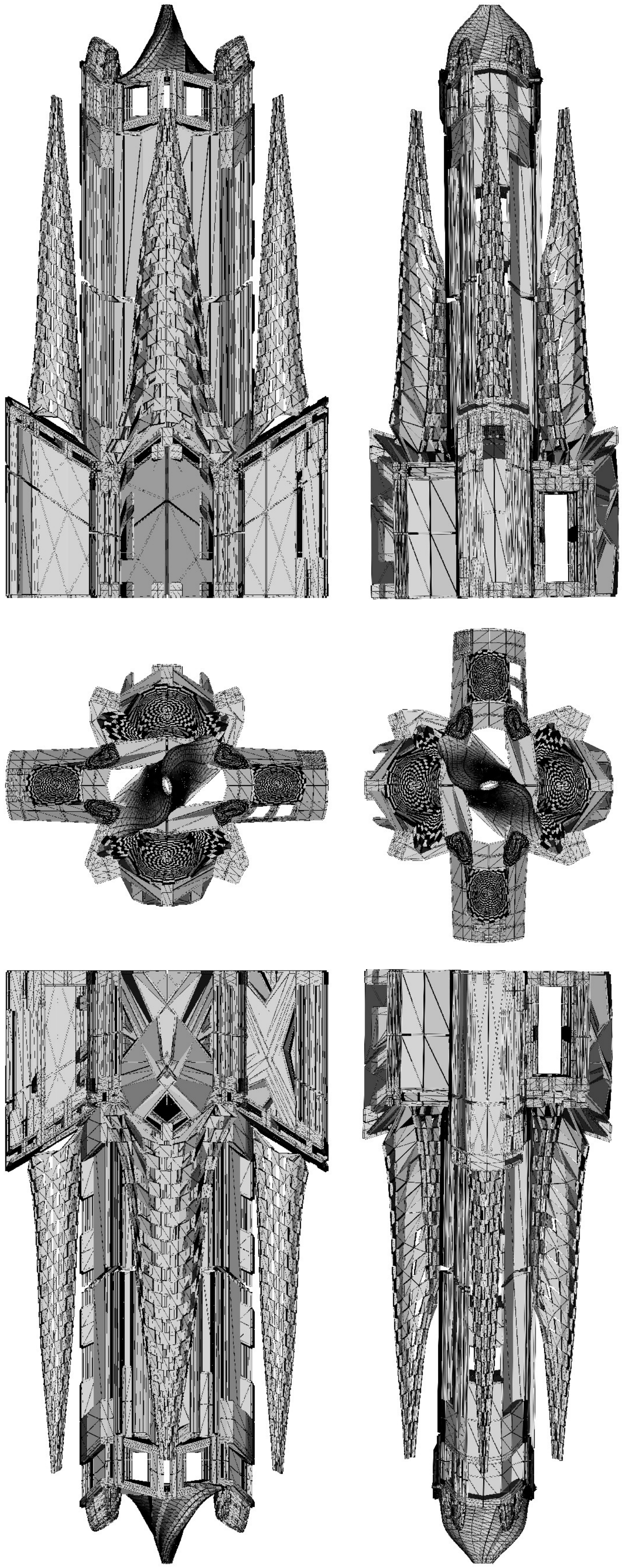


Figure 9: Generated architecture using different "baroque" algorithms with the paradigm 21. The contamination of two geometrical transforming logics: the Baroque niches and the convex system. (C.Soddu 2011)

around 2500 characterized 3D points), divided in A) parametric points, based on harmonic relationships and parametrically connected to the geometrical basic paradigm of the event, B) varying spatial points, based on progressive "topological" sliding of series of points. More, there are C) a series of just-generated points, generated in real time following polar coordinates and following nurbs surfaces in a way to fit the increasing complexity request by the complex system. In other terms the starting event, before subsequent transformations, springs through the contemporary use of parametrical, dynamical and realtime-generated coordinates. Each 3d event springs by varying dramatically its possible starting structure in relationship to the context in the moment of its birth; and such variations will not be casual but tightly in conformity with to the logic and subjective references of my architectural vision and peculiar aim of each projects.

Then each starting-event will vary following the subsequent geometrical transformations and the codes of congruence that define the relationship with surrounding events with which it has to be connected by respecting specific rules identified and defined by the topological structure. If, for instance, the event must be a “capital”, it will owe “to lean” on the column, a “wall” on a “beam”, and so on.



The generations and transformations of local events are managed by “matrixes” able to control the incoming transformations by using subjective interpretations of specific cultural references. In other terms all events, starting from their first generative step, are not static structures but dynamic events able to answer to each incoming algorithms, each interpretative dynamic code belonging to own subjective cultural, historical, constructive, geometrical and material references and preferences. These matrixes are, therefore the result of a further oriented reading of own cultural tradition through algorithms. In my generative work I didn't designed algorithms using only the references proper of my cultural tradition, but also of those with which I came in contact. Starting from late Seventies, in my experience of designing algorithms for the generation of architectures, I have tried to identify the characters of different environments and cultural contexts and I have tried to build progressive logics able to represent their identity and, obviously, my interpretation of their uniqueness.

All the environments where I had the occasion to interact by

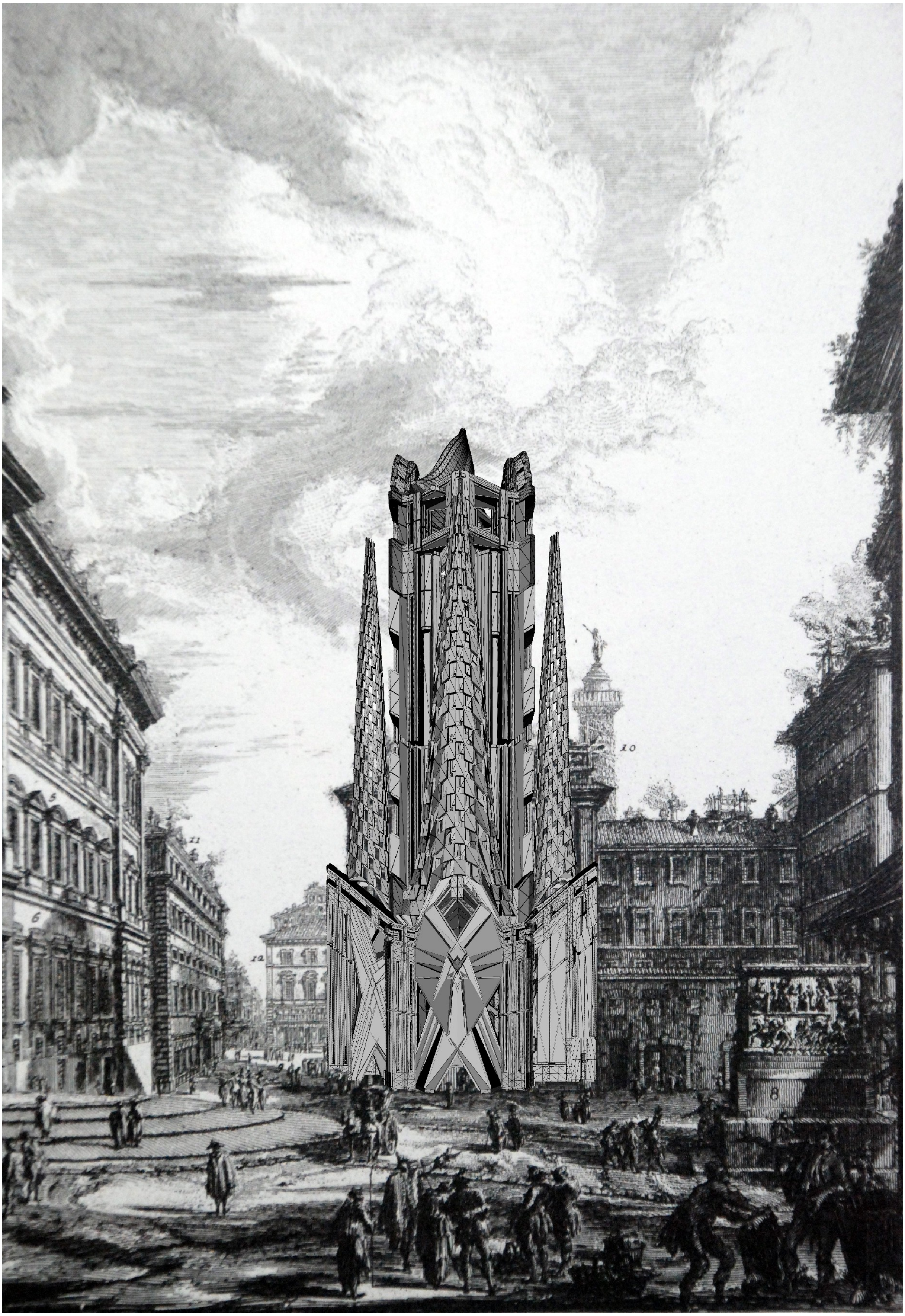


Figure 10: Generated Baroque Architecture inside an engrave of Piranesi representing Rome. In the previous figure plan and elevations. C.Soddu 2011

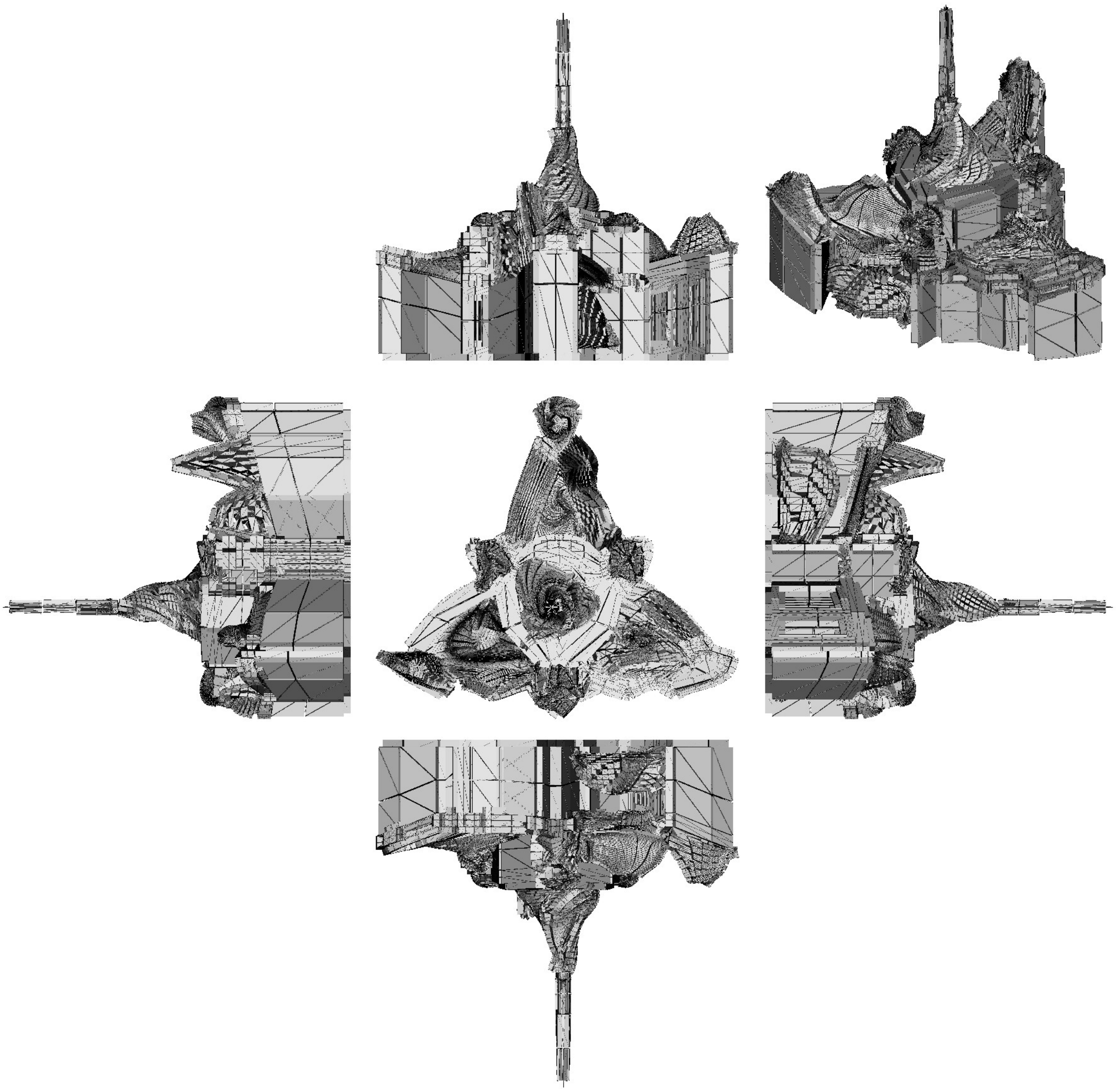


Figure 11: Another variation of generated architecture using the geometrical system based on paradigm 21, together with transforming rules based on polar coordinates and spiral development. C.Soddu 2011.

designing these generative architectures, were interpreted by me by building original algorithms based on each different local cultural identity. Through solo exhibitions and lectures, I tried to verify with the local people if these interpretations of their cultural identity were legible and pertinent to their vision of the genius loci, of their Ideal City. And this was the way to increase the complexity and to fit the possibility to reach each unique environmetal identity.

Nothing can be identified by a form. Designing with generative algorithms, every event belongs to a progressive tale springing from a creative approach to complexity. As, for me, the Baroc is.

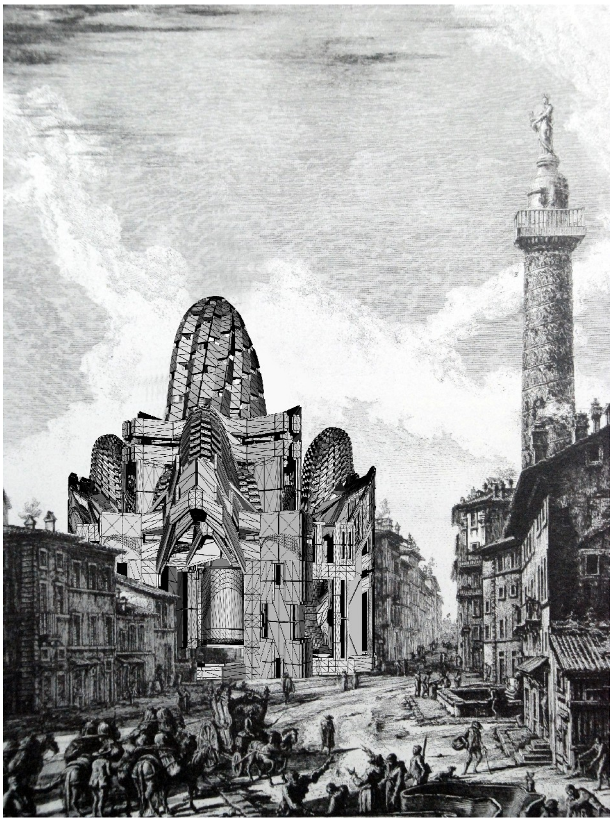


Figure 12: Two Roman Piranesi "locations" with generated baroque architectures. C.Soddu 2011

References

[1] Francesco Borromini, "*Opus architectonicum*", Il Polifilo, Milano 1998
[2] Bruno Zevi, "*barocco Illuminismo*", Newton & Compton, 1996
[3] H. Sedlmayr, "*L'architettura di Borromini*", Electa 1996
[4] Celestino Soddu, "*Citta' Aleatorie*", Masson, Milano, 1989
[5] www.generativeart.com
[6] www.soddu.it