# Jean-Nicolas-Louis Durand's Clockwork: Computational Magnification of a 19th Century Procedural Design Mechanism

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## Abstract

This article investigates some antecedents of contemporary virtual design processes by translating into a digital procedural model the rules of the composition mechanism of 19th Century French architect Jean-Nicolas-Louis Durand (1760 – 1834).

Albeit the existing research, Durand's lessons and their original compositional techniques have not yet been regarded as a genuine research corpus. Durand centers his teaching on the instruction of what is commonly called the mécanisme – which is a generic and procedural design method articulated in a stepwise procedure directing the architect's hand in the composition of a project requiring whatever program.

This research will analyze and extend the application of the mécanisme. First, it will highlight the original representational setup. Secondly, the research will perform a translation of the mécanisme into a Python script generating 3D models. This allows an execution of the mécanisme in a new context and under (almost) unlimited conditions. The numerous situations generate actual models to confirm the virtual kernel of an analog design system. The research intends to elicit the abstract and generic in Durand's research object, expand it by pushing beyond what Durand could have imagined in order to suggest a historical background for some aspects of contemporary parametric architecture.

## Keywords

Jean-Nicolas-Louis Durand, parametric architecture, procedural model, instrument

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## 1. Introduction

Starting in 1796, with his nomination as lecturer at the newly-founded Parisian *École Polytechnique*, Jean-Nicolas-Louis Durand's work (1760-1834) engages in a pedagogical commitment towards the discipline of architecture, which in his own words is "the art of composing and executing all the public and particular buildings" (Durand, 1805: vol.1, 1). In this sense, his role as a teacher of architecture for a future generation of state engineers converges in theoretical research that develops and informs "a rational design method able to be applied indifferently to any kind of building" (Picon, 1992: 531). This design method, commonly called the *mécanisme*, is a core element of his teaching and is expressed in his widespread and numerously re-edited and translated manual *Précis des leçons d'architecture données à l'École Polytechnique (Précis of the Lectures on Architecture Given at the École Polytechnique*, 1802 – 1805), and subsequent complementary manual P*artie graphique des cours d'architecture faits à l'École Polytechnique (Graphic Section of the Lectures Given at the École Polytechnique*, 1821).

"Unfortunately, architecture is not the art of making a certain number of buildings; it is the art of making all the possible buildings, either public or private, and furthermore, to make them under any circumstance able to modify them" (Durand, 1821: 24).

Durand expresses with the clearest words his intention

to transmit to future civil servants the ability to realize any building the nation could require. Both the *Précis* and the *Partie graphique* are articulated around this method, firstly in the *Marche à suivre dans la composition d'un projet quelconque (Method to Be Adopted for the Composition of a Whatever Project)* in 1805, and then as the *Marche à suivre lorsque l'on compose — ou même — lorsque l'on copie (Method to Be Adopted When Composing or Copying)* in 1821. From a certain standpoint, the *mécanisme* can today be understood as an archaic application of a procedural design method. In other words, Durand establishes a virtual framework operated by a precise set of rules in order to fulfill the actual design of a given project. Thenceforth, this article establishes the same framework, by highlighting two important paradigms underlying the development of the mécanisme, firstly through the summary analysis of Durand's reference manual *Recueil et parallèle des edifices de tous genres, anciens et modernes (Collection and Parallel of Edifices of All Kinds, Ancient and Modern*, 1799 - 1801). Secondly the transformation of the *mécanisme* itself as well as its points of rupture highlighting a certain *virtualization* will be analyzed. This will be followed by an experimental implementation of Durand's composition method from 1821 into a procedural model in order to *actualize* the *mécanisme* in a new environment. Thus, it confronts Durand's set of rules with a more extensive application in order to further grasp the inherent conjectures of the *mécanisme*. The aim is then to explore the method itself, by pushing it way beyond what Durand could have imagined, as well as to suggest a historical background capable of engaging with contemporary methods of parametric architecture.

## 2. Teaching the Hand

### 2.1. Variation and Structure

The architectural drawing is the driving force behind the functioning of the *mécanisme*. Before putting in practice Durand's method, the students engage with architectural representation through the historical manual of their master. Put together between 1799 and 1801, the *Recueil* is a compilation of emblematic buildings, classified in different categories and represented on an identical scale predominantly through their plans, accompanied by a section or elevation. Every drawing of the *Recueil* is of a geometrical nature without any color, shadow or material expression. Architecture is deployed with the help of an abstract and flattened game of surfaces circumscribed by lines augmented with plain shapes for the plans. A curious gaze through the manual reveals some discrepancies between the drawing of a building and its actual built state, for example the town hall of Brussels or the Tower of Pisa. As Werner Szambien notes, "Durand bases his argumentation on *historic* examples reconstructed out of his own principles: he projects his ideal compositions onto history" (Szambien, 1984: 96). This ideal is namely the concept of *utility*, which is guaranteed through *convenience* and *economy*. Convenience is achieved through a rightful reasoning of the architect given the constraints of solidity, salubrity and commodity in the design process. Economy is imposed by the respectful use of symmetry, regularity and simplicity (Durand, 1805). As much as these concepts are prescriptive, Durand is nevertheless imposing the economic reasoning onto history. Thus, the *Recueil* bears in its architectural representations the traces of two concepts underlying the development of the *mécanisme*: variation and structure.

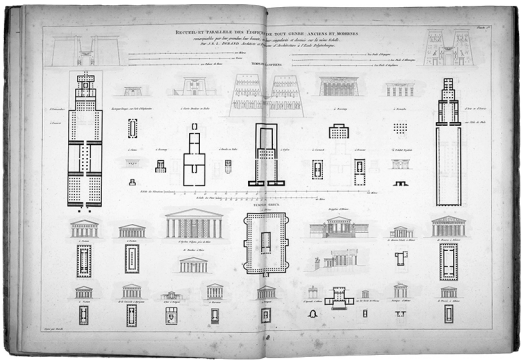

Figure 1. Study of temples in the Recueil et parallèle (1799-1801).

A first observation outlines the importance of the overall organization of the *Recueil*. The classification performed by Durand roughly consists of two main categories. The first part of the atlas contains historical buildings, like Egyptian temples and Roman palaces. The second part is a regrouping per plate of different buildings sharing the same function, like churches, town halls, hospitals and mostly other public building programs. These various juxtapositions establish precisely what Durand defines as *genres*, which are the incarnation of general characteristics and principles. Moreover, Durand is able by purifying his drawings to advance the idea that all these occurrences of different forms have in essence a common underlying irreducible geometric configuration (Lee, 2013). This concept of variation will later drive the practical exercises of Durand's classes and inevitably be assimilated by the future students.

The second observation condenses its intrinsic epistemological significance, conveyed through

representational methods. To do so, we establish a parallel between the Recueil and the plates of biologists from the 18th century studied by Michel Foucault in *The Order of Things*. Similarly to Durand's inquiry, the botanic observations limit themselves to the visual and are reject all other senses and hearsay, thereby positioning the drawing in an autonomous field of contemplation. Beyond the representation of a real object, the drawing's language comprises an internal logic. The *modus operandi* highlighted by Foucault articulates itself around a structure of four variables: the different elements' form, their quality, their relational distribution in space and the relative size of each. That same structure emerges also in the architectural representations of the *Recueil* which is embedded in the neoclassical spirit. Every building that the *Recueil* depicts is revealed as the outcome of a combination of different elements and parts and their reading relies on variables to which is allocated a quantity – numbered or measured – and a clear description by analogy or geometrical shapes (Foucault, 1966). At first glance, what resembled a historic account of our built past is in fact the definition of an articulated visual language with an operative capacity.

Durand has reconstructed the built past through its representation and was able to define architecture as an articulated visual – and drawn – language, with buildings as the various occurrence of a certain *genre* of building type.

## 2.2. The Mechanisms

At the beginning of both manuals, Durand introduces on a single plate different construction materials, exposed as the irreducible elements of architecture to which he refereed as "notes." Once the students are briefed, their preoccupations abandon the physical realm of construction and enter an abstract space where – similarly to music – all becomes dots and lines guiding the mind. It is the conceptual space – where architecture exists as a project deprived from building – which was previously formulated by Durand's master Étienne-Louis Boullée. If his conceptual separation between the conceived architectural project and the constructed building relies on a platonic ideal expressed in sensory paper architecture, Durand nevertheless conserved its principles though developing a practical methodology[1].

The outline of Durand's lessons follow a simple pedagogical approach: "combine together the different elements, turn then to the different parts of the building and from the parts to the whole, that is the way to follow in order to learn to compose; when composing, on contrary, begin with the whole, continue with the parts and finish with the details" (Durand, 1805: vol.1, 92). In other words, architecture can be understood as an iterative combination on different scales: the *elements* are mostly constructional and material, the *parts* are entities of the building – most of the time halls, vestibules and central pieces – and the *whole* is the building itself which, according to Durand, becomes again a part in when related to the city. Consequently, the two design manuals from 1805 and 1821 begin with a descriptive part exploring the combinations of parsed elements and parts in an absolute manner. Then, the following section of his lessons is the art of composing a building considered as a problem on its own. That part is prescriptive and consists of the training through apprehension and application of the here-studied *mécanisme.*

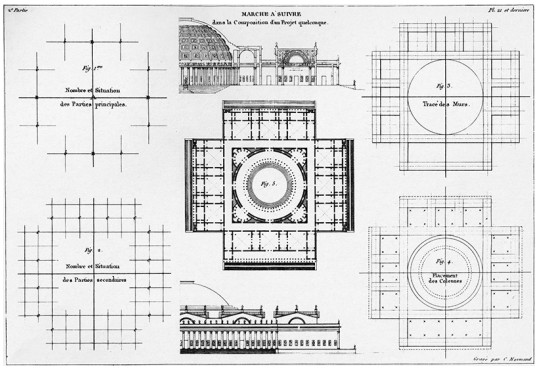


Figure 2. Method to Be Adopted for the Composition of a Whatever Project (1805).

Durand's *Method to Be Adopted for the Composition of a Whatever Project* is introduced at the end of the first volume of the *Précis* (1802 - 1805) after the aforementioned preliminary studies. It consists of a sequence of graphic operations which allow to compose a building for any given program. The work of the student starts with a sketch executed in four steps. First, by the help of axes, the number and the disposition of the building's main parts is outlined, followed by its secondary parts. In the third step of the sketch each secondary axis is doubled by an offset to become the building's walls. Then, each different part's size is evaluated in order to be completed, if necessary by columns. A cross is used for a single column, and a doted line for a row of columns. While executing the sketch, the student is not only following a graphic procedure, but also a precise set of choices outlined in the text of the *Précis*. Once the program of the building determined, the student has to examine a set of instructions starting with four binary questions: if the parts of the building are united

or separated, if the building is plain or with courtyards, if the building should be distanced from the streets, and if all the parts have a similar usage. These are then followed up by three resulting decisions to be made by the student: which are the main parts and which are the secondary ones, the number of these parts and their positioning, and the number of necessary floor levels. After having determined the outline of the building with the sketch, the student has to evaluate the size of it. The module of the building is the distance between columns, which is counted for each part and then summarized. The measure for one module is the division of the size of the building site by the number of counted modules. The last steps for a composition are of the highest simplicity: drawing the final floor-plan and extruding with the help of guidelines its section and elevation, which can be represented *pars pro toto* in a single drawing.

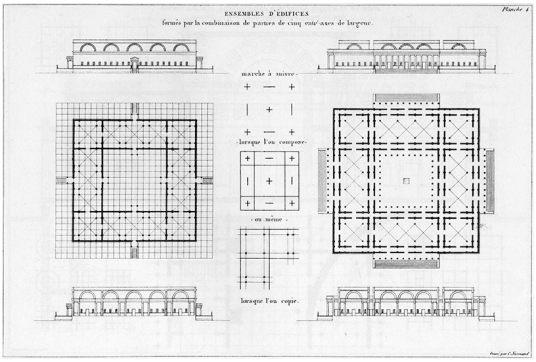


Figure 3. Method to Be Adopted When Composing or Copying (1821).

The *Method to Be Adopted When Composing or Copying* from the 1821 class manual simplifies the *mécanisme* by transforming the former linear procedures into a combinatory process of autonomous parts. By eliminating the necessity of the axes and their offset doubling, the student's sketch needs only to "express the situational relationships by a sign and the dimensional relationship by a number" (Durand, 1821: 18). In other words, the student manipulates coordinates augmented by qualifying and quantifying information, respectively, the type and the size of the parts. From here on, each type of part can be studied and drawn independently. The module still consists of the distance between two columns and Durand instructs in the textbook that the general width of a part should range between three, five or seven modules, which subsequently defines the order – i.e. the vertical proportions – of the whole building. Once the sketch of the dispositions is finished and the parts defined, the student clusters together the final floor-plan with the help of grid and tracing paper which was standardized in Durand's studio.

## 2.3. Virtualization

By focussing on the *mécanisme* itself, its preliminaries and on the way it was taught by Durand highlights how the compositional method is constituted of a virtual space with its own logic and includes a set of rules in order to both enhance its range of possible applications and to control its outcome. Exposing the evolution of the *mécanisme* highlights how Durand strengthens his intent to formalize the generic aspect of his method and how it becomes in the end an almost automated method, described as a "banal formalist approach" (Pérez-Gómez, 1983: 304).

After being introduced to the *mécanisme's* general principles with the help of an illustrated example, the students learn the method by applying it to various cases. For this purpose, the final section of both manuals are an oversight of different compositions. In this final part, present in both manuals, an interesting change occurred between 1805 and 1821. The early version of the manual disposes of a whole complementary volume dedicated to the large variety of public and private building programs of which each drawing is supported by a prescriptive text which outlines what the buildings' function requests. These examples by Durand are formal instances referring directly to the previously elicited general principles of each *genre* of building.

In the later manual, the *mécanisme* is similarly followed by design examples, but these represented buildings have no specific building program. Following their categorization by formal criteria – i.e. the number of axes and the specific characteristics of its parts – each composition is more a variation of variables

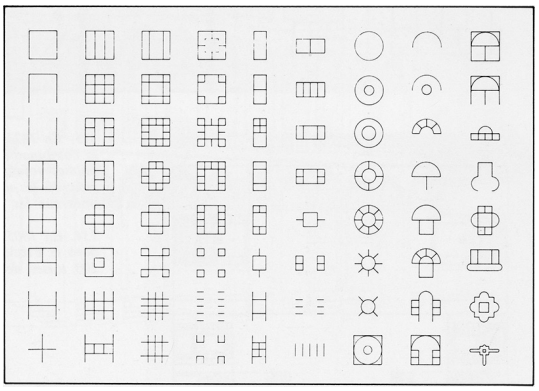

Figure 4. Divisions of the square combined with the circle (1805).

and their subsequent formal outcome by applying the *mécanisme*. Thus, it is more a pursuit of the ability to manipulate variation than to gain a specific knowledge related to a building's purpose. The titles of each composition, previously the buildings' program, is now a simple description[2]. This change between both manuals suggests that Durand finally adapts his exercise material to force his students to overcome the programatic needs of their time and instead extensively explore the largest variety of compositional configurations. Meanwhile, the *mécanisme* also alters the role of the sketch, which becomes a more and more abstract terrain for the exploration of various configurations as suggested in the previous manual.

A closer look at the *mécanisme* exposes what Durand implicitly articulates as the task of composing in two steps, solving each a problem of a different kind. First comes a geometric problem, incarnated by the sketch exploring possible configurations of the building in order to then access to an equational problem which will by the use of a module ultimately provide the measures of the building. What is striking is that this hinge alters between the two different methods. In the earlier method, the sketch is graphically evolving towards a point where it provides all the necessary information to accomplish the next step: the actual drawing. For the later method, the graphical qualities of the sketch are neglected and the main focus shifts to the second step because each part of a building is considered as an autonomous unit and therefore is independently subjected to design decisions. Thereby, Durand formalizes a practice from his predecessors Ledoux and Boullée, "characterized by the transformation of the relationship between the different parts and their relationship towards the whole, the essential outcome would be the disappearance of parts and the emergence of independent building units" (Kaufmann, 1981: 71). Durand also rejects the particularities of his first method, where a building's design was to a larger extent graphically explored by an abstract representation and therefore converts the *mécanisme* into a more cautious method of combining a limited, and to a certain extent, predefined number of parts.

## 3. Operating the Machine

### 3.1. Implementation

The highly formalist body of rules developed by Durand makes the *mécanisme* particularly suitable to be investigated by a computer script capable of automating the composition process. This experiment finds its inspiration in the existing research of shape grammars[3], a method eventually capable of re-investigating history of architecture. The procedural model developed in order to execute the *mécanisme* is an encoding in the programming language Python of a sequence of operations applied to various variables and executing different functions[4] – a process commonly termed as a script. In order to generate a visual outcome, the script interacts with the open-source 3D computer graphics software Blender, through which graphical primitives – or meshes – are created. The primarily goal of the script is to randomly generate a model of a building which fully respects Durand's prerogatives. It also aims to further grasp the *mécanisme's* internal logic by translating it into code.

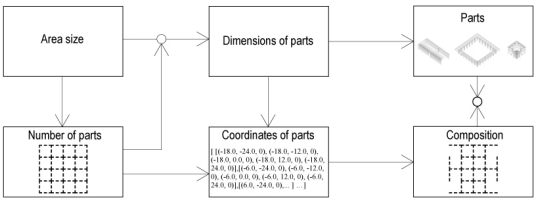


Figure 5. Schema of the script's execution.

The sequence of operations executed by the script imitates the 1821 version of the *mécanisme*. First, it calculates the coordinates of the different parts as well as their dimensions, then it generates a three-dimensional specimen of each part, and finally the respective parts are duplicated in their specific locations. In order to implement these steps of the *mécanisme*, an alteration occurs: the size of the terrain is now the starting point of the calculations and subsequently, the measure of the module – i.e. the space between the columns – is constant.

The execution of the script starts by generating a random number which is the width of a fictional area and which the procedural model tries to fully embrace. This first variable narrows down the two next variables: a possible high number of axes which implies the number of different parts and their respective size. Consequently, by combining the number of parts and their sizes, we can precisely determine and save the central coordinates of each of them in a matrix. At this point, the script will perform two separate tasks. On one side, and in order to randomize the compositional structure, some parts – solely existing in the form of coordinates in a matrix – are deleted (randomly) and automatically trigger the deletion of their symmetrical counterparts. At this level the building exists still in the abstract representation of a matrix but parsed and ruled by a central symmetry. The sketch of the building is, so to say, finished. On the other side, each part – hall, vestibule and central piece – is generated separately taking into account

their previously calculated sizes. The script finishes by duplicating each part in its specific position which is the coordinate in the matrix.

### 3.2. Actualization

The experimental approach of translating the *mécanisme* into a procedural model is in its simplest form an enhancement of its combinatorial logic. Furthermore, the interest of this study is situated on a formal level. In other words, it is to see what architecture this method, and its implementation by Durand, produces given a new context.

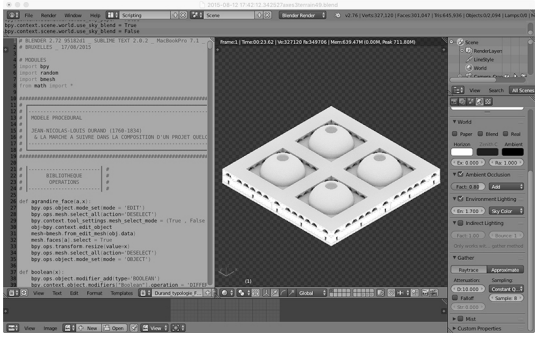

Figure 6. Blender UI wth script and generated model.

The translation into code of Durand's *mécanisme* establishes a symmetry between two coupled elements: the lessons' texts and their plates in relation to the script and the generated model. In the first case, the text is prescriptive and even culminates in a clear set of instructions and the corresponding plates are the given graphical toolset to perform these instructions. In the case of our implementation of the *mécanisme*, the script corresponds to a clear set of instructions generating an output, which is the model. So, the focus shifts from operating graphical means towards the completion of a design predefined through formal relationships, actualized by the script. It is, in other words, instruction and tool combined. Subsequently, it is only once our *mécanisme* has generated a configuration, that the floor-plan, the section and the elevation is extracted from this model. These representations are, in Durand's case fragmented, even if they are strictly correlated and therefore still operate in three-dimensional space (Evans, 1997). Furthermore, the fragmentation holds a certain sequence for the execution of the drawings in which the plan always comes first and the section and elevation are the result. By simply trying to perform Durand's *mécanisme* in a new context, the process of scripting actually enhances its evolution, which was already occurring between 1805 and 1821, further solidifying its tendency for automation. Imitation by computation inevitably becomes a silent optimization of the *mécanisme*.

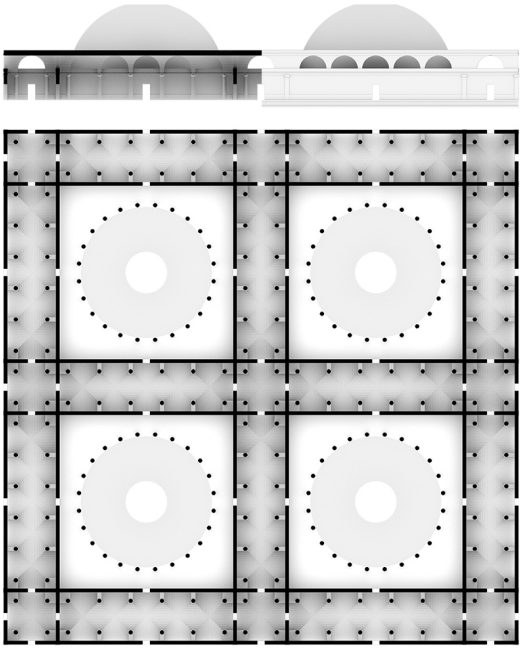

Figure 7. Rendering of a 3D procedural model. 3 axes and 49 modules.

When the procedural model is deployed on an area of important size, the script consequently generates a model of a bigger size, either by augmenting the number of parts or by dilating drastically a reduced number of parts. Even when it tends towards an extreme, Durand's system is in a certain sense presenting a form of resistance: it can unfold into the unmeasurable but stays nevertheless confined by certain constants – precisely, the halls being only of the size of three, five or seven modules – and the neoclassical language. The explanation of this phenomena can be found through different factors, as much present in Durand's reasoning than inside the script itself. It is important to highlight that the *mécanisme* bases itself on a preliminary study which underlines the formulation of the achieved applications. The small and middle scaled compositions performed during the architectural lessons in Durand's classroom are thereby nothing but unpredictable. Another major element to be considered is the strict codification of neoclassical architecture as a coherent formal grammar. The orders – incarnation and symbol of geometry and

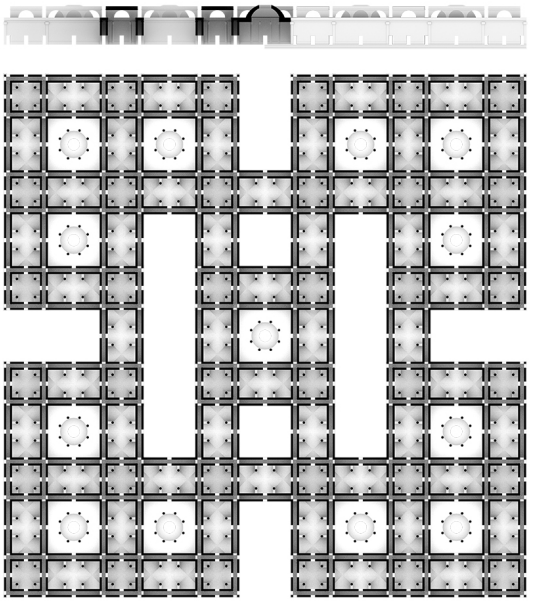

Figure 8. Rendering of a 3D procedural model. 6 axes and 87 modules.

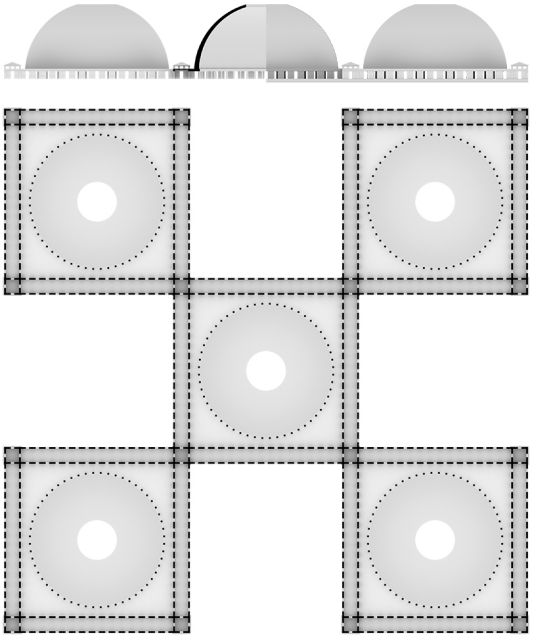

Figure 9. Rendering of a 3D procedural model. 4 axes and 105 modules.

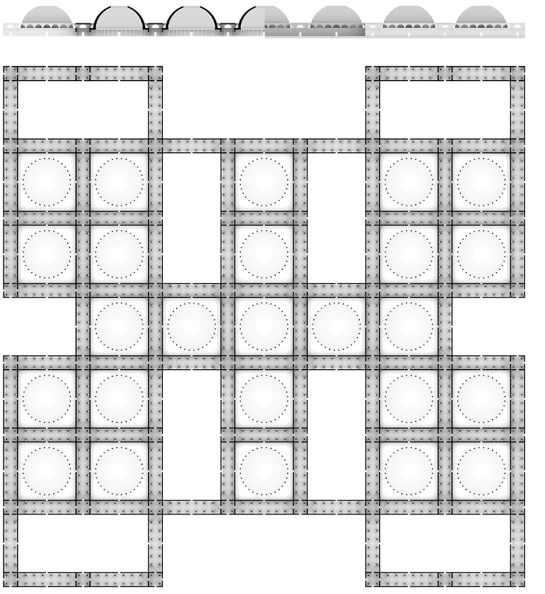

Figure 10. Rendering of a 3D procedural model. 8 axes and 109 modules.

numbers – are relegated by Durand to a proportional system which guarantees a certain efficiency during the conceptual process (Pérez-Gómez, 1983). In that sense, the script processes at its beginning all the calculations necessary to define the vertical measurements. And during all of its subsequent execution, these measurements become unchanged parameters necessary for different independent functions like the ones generating each different part of the building (hall, vestibules, etc.). By being constant once calculated, theses values are the guarantors of the building's unity. Every operation is autonomous in its procedure, but still equally subjected to a general norm.

## 4. Conclusion

The critique formulated by Antoine Picon towards the projects of Durand's students highlights two consequences of its method. Durand's teaching is insufficient to convert the polytechnic students into enlightened men of arts. The highly schematic character of his approach does not permit to the students to familiarize themselves with programmatic details of the studied building. Similarly, the drawings show a lack of knowledge about construction materials and the common construction processes (Picon, 1992). Nevertheless, Durand's architecture course is inscribed in an engineer's curriculum and taught in the formalistic context of the *École Polytechnique*. Therefore, the

goal of his teaching is the capacity to think about the compositional problem itself, whereas the more pragmatic questions will ultimately be confronted in the field. Furthermore, a second point of contention concerns the direct consequence of the instrumentation of architectural representation necessary for Durand's procedural approach. The practice of drawing, once standing on a philosophical ground and incorporating myths and beliefs, is by Durand replaced by an auto-referential setting of scientific and exclusively operational value (Pérez-Gómez, 1983). The recent developments in numeric architecture, and in particular its algorithmic turn, can be regarded as positioning itself in that same tendency.

A more nuanced position of Durand's method has been highlighted through this study. With the development of the *mécanisme*, Durand incepted a method defined by rigor but nevertheless also positions the architect in a unique role still today proclaimed by the discipline5 (Huet, 1984). An absolute realm – abstract and detached from construction preoccupations – where the architect's role is to speculate of what he thinks – or got taught – is the essence of the project. For this unique task, Durand conceived of a genuine graphic artifact: the sketch. The subsequent training in class would sharpen the students' intuitive manipulation of this tool. Durand's *dispositif* has a simple goal: once the virtual speculation is concluded its actual outcome would be assured by a formalized process. By interpreting the evolution of the *mécanisme* from 1805 to 1821, we can observe that the graphical support of the sketch seems to dematerialize: what remains is an immutable set of rules. The hands got automated but the minds lost their support. Concentration moved from an abstract and ambiguous graphical mean of conceptualizing the project to the rational and automated rules used to execute the drawing of a composition.

To finally transpose the research into the present and open the debate, we need to consider Durand's *mécanisme* not as a way of making architecture *per se* but as a way of articulating graphical representation and automated processes. In that sense, by adapting Durand's position, we can question contemporary CAD tools and in a higher extent BIM models. These instruments work because they are constantly automating the invisible task of manipulating a high amount of data, thus putting the architect in the position of a blind spectator in front of his drawing, which is the rendered data on screen. By their design and capacity, these computer tools impose the amount of precision, which for the practitioners results in the obligation to be more and more precise and accurate in their design decisions. The *mécanisme's* transformations can be of use by bearing the capacity to imagine not a further quest for efficiency, but to take it in an opposite direction, as an inspiration to disintegrate and fragment our contemporary design tools.

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