Conceptual design with BIM

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SYNTHESIS

BIM has become the leading method for representation, interdisciplinary collaboration and management through all construction trades.

Several essays demonstrate the relevance of the BIM method in all project phases. In many countries BIM has become a mandatory practice for projects regarding the public sector. The presence of BIM has become unavoidable and undeniable.

However, the rigor, the accuracy, and the detail of BIM tools come at the expense of the flexible and abstract interface needed for form finding in the architectural sketch stage. This study aims to build a method for creative design with BIM. A BIM tool will be adapted for a more flexible interface tailored to the form finding and to the functional organization of an architectural project.

STATE OF LITERATURE

The drawing tools directly influence the way of drawing and consequently the architectural languages of a certain period. In the same way, the effort to frame architecture in an increasingly plural and heterogeneous context is intrinsically linked to the development and transformation of drawing tools and methods.

During the 90s the spread of digital tools and CAD[1] systems allowed architects to enter, manage, manipulate and save drawings in a digital interface. This change brought the added advantage of speed and rigor as opposed to hand drawings.

Today we are facing a generation of architects born in the digital age. Their immersion in software and hardware gives them an innate ability to adapt to digital technologies. For this CAD tools have become widely distributed in the field of architecture for the representation and documentation of projects. C.f. (PERBELINI & PROGRATZ, 2000)

During the 2000s, BIM[2] method gained a place in Architecture studies. Today BIM has become a mandatory practice in public sectors in some countries, such as Great Britain, since 2011, and France, since 2017. According to this data it is predictable that BIM tools will replace traditional CAD tools almost entirely for the building construction sector. The presence of BIM has become unavoidable and undeniable, due to the functions of interdisciplinary collaboration and project management through all construction trades.

These tools are based in the 3D modeling of architectural components. Unlike CAD tools, the features are not abstract, each element drawn belongs to a category that represents an architectural object (column, beam, wall, roof, floor, window, door ...). Each drawn entity is the source of a parametric[3] design. The parameters of a BIM object determine the geometry, the behavior and the analytical properties (surfaces, materials, energetic behavior, etc ...). These tools allow us to analyze, manage and manipulate in real time, the properties of drawn elements according its parameter values.

However, the rigor, the accuracy, and the detail of BIM tools come at the expense of the flexible, abstract interface needed for the architectural design phase. (AMC, 2015)

Despite the available 3D modeling functions, BIM tools are based on 2D projection drawings. All 3D geometries are modeled from their planar projections. Modeling on 3D space is limited and often impossible, 3D views are more oriented to visualization than they are for modeling. This concept seems contradictory and penalizes the use of BIM tools phase to other 3D CAD software, the latter being more adapted and intuitive to the form finding.

While BIM software allows to parameterize every building component (wall, roof, door, etc.) it lacks a component to represent and parameterize a building as a whole.

Such category must include all type of geometric and analytic parameters. Also, it must define rules for the interaction between each instance and other objects in its context. With this tool I aim to add an easy and intuitive way to sketch ideas and diagrams to a BIM interface.

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[1] CAD for Computer Aided Design
[2] BIM pour Building Information Modeling
[3] Parametric design generates geometries from an algorithm which defines an intention, values, relations and mathematical conditions.

OBJECTIVES AND METHODOLOGY

This study is being applied in the practice of Michel Rémon & Associés (MR&A) since 2016. Its development will be progressively tested and re-evaluated amongst architectural projects in sketch phase.

The MR&A it's a relevant case of study because it is teams are composed of architects who have followed the transformation of their working methods from manual drawing to the implementation of CAD and BIM, as well as architects with professional experience working on digital tools only.

Recognized for its functionality that follows many projects in the complex program, the MR&A has built a design process which is consistent and transversal to the tools (either manual drawing or CAD).

This study aims to build a method for creative design with BIM. A BIM tool will be adapted for a more flexible interface tailored to the form finding and to the functional organization of an architectural project.

In order to develop this tool, I choose Revit a BIM software developed by Autodesk, ranked world leader in BIM software by G2 Crowd in 2017[4]. The tools to be presented were developed with API, .NET and the samples found in the Software Development Toolkit (SDK)

To meet the established objectives this study has three phases:

1- The building category
   It will be presented and developed a new category of objects "building". This category will be quite abstract to simplify the sketching and schematization of an architectural concept.
   Geometric properties, identification data and principles of interaction with other Revit objects will be the fundamentals to the development of the building category.
2- The variables
   In a design phase is important to have a tool that allows the architect to draw, manage, manipulate and compare several volumetric solutions and spaces. With aim to speed up this process will be developed and put in place: a drawing method; project templates; and plugins as accessory tools.
3- The practice
   The tools developed for this study will be tested in ongoing sketch projects at MR & A. An analysis of the nature of each project and the feedback of users will be brought to determine the rest of this study. This analysis will be based on a project form and UEQ (Users Experience Questionnaire).

[4] The best Building Design and Building Information Modeling (BIM) Software products are determined by customer satisfaction (based on user reviews) and scale (based on market share, vendor size, and social impact) (www.g2crowd.com)

THE BUILDING CATEGORY

In REVIT, there is some hierarchy in component properties: construction objects are classified into categories, families, types and instances

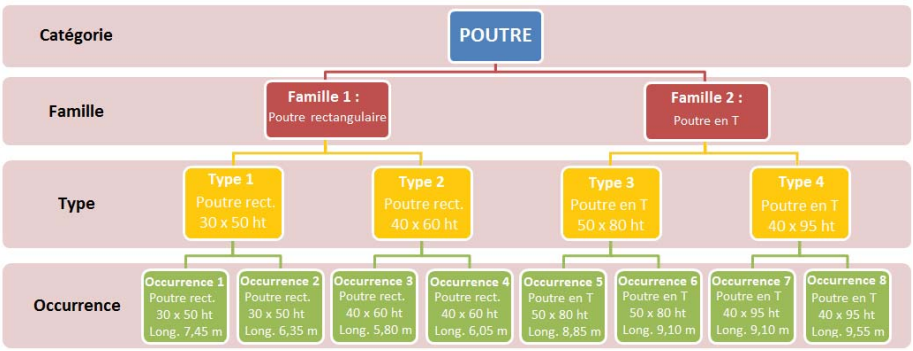
The categories are the classifications of construction objects: wall, post, beam, floor, staircase, door, window, ceiling, roof, ... Each category has an associated family template allowing the user to create the corresponding families.

Families are classes of objects of a category. Each family groups objects with a set of common properties and an associated graphical representation.

Types are family-based declinations based on family properties, called family-type parameters. A type may correspond to a role, a material, or to geometric characteristics determined by the user.

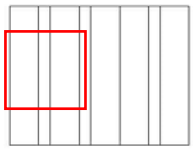
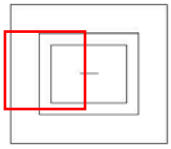
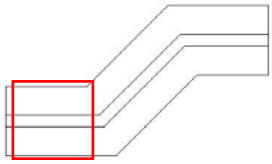
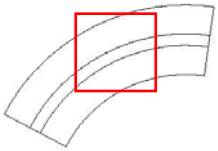
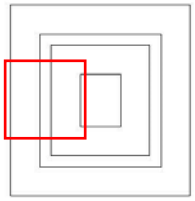
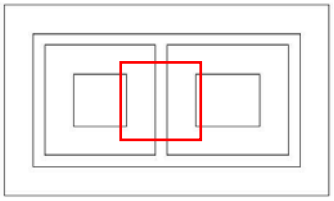
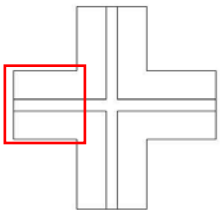
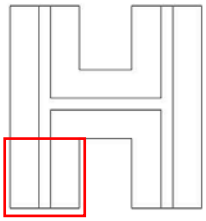
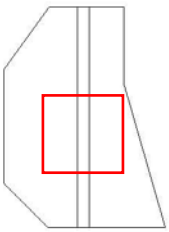
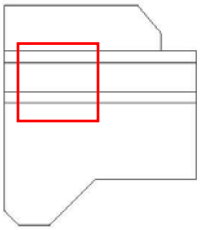
Instances are unique objects that are inserted into the project and located at a given location.

When the user inserts an object into a project using a specific family and family type, he creates an occurrence of that object. Each object has a set of properties, in which occurrence parameters independent of the family type parameters can be modified. These changes apply only to the instance of the object. On the other hand, any changes made to the family type parameters apply to all object instances associated with this type of family.



This hierarchy is fundamental to understand parametric drawing on REVIT. Each instance or element drawn on REVITs interface includes in itself all inherited information. This information, in the form of parameters, allows us to automate the quantification, analysis and representation and also to instantly change the properties of each object.

To develop a "Building" category I have carried a non-exhaustive research on building typologies, I have been inspired by projects in the following fields: office building; and medical building. For future essays, new typologies can be identified and justify a new family building. I have searched for the lowest common denominator to all typologies and then I isolate its proprieties. This element is the base for our first Building family, it will be called “Layer Building”.

Compact buildings		
Linear buildings		
Patio Buildings		
Crossed buildings		
Irregular buildings		

Red highlight in the table above I have isolated the lowest denominator common to all typologies, this element includes the geometric parameters necessary to facilitate the modeling of different solutions, such as: thickness, height, levels. The ground areas will be the basic analysis parameter for this study.

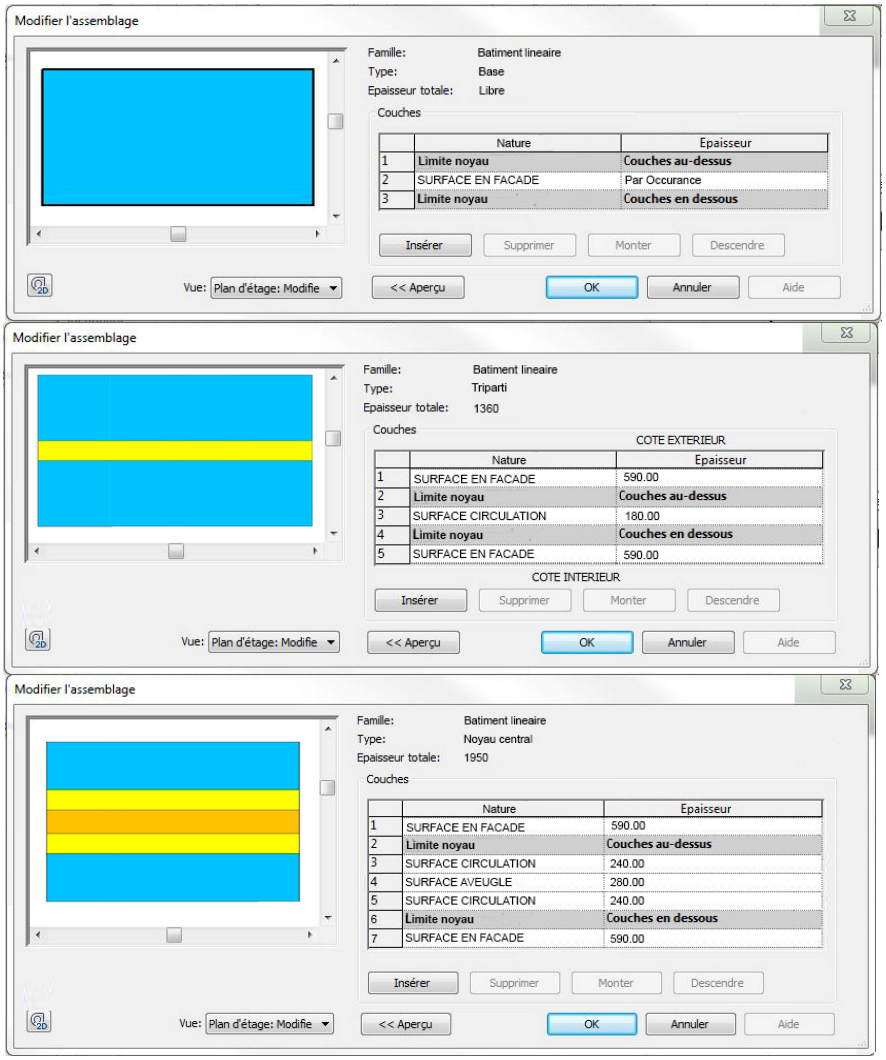
The"Layer Building" family is composed by vertical layers, each one contains three fundamental properties: use, illumination, function. Use determines whether it is a circulation area or a "useful" area. Illumination determines whether the zone is exposed diractly to sun light or not. The function determines for each sub-element the zone of the functional program it belongs to.

Each sketch becomes more than an abstract 2D/3D representation, it will also include all the information inherent to the "Layer Building" family to which it belongs.

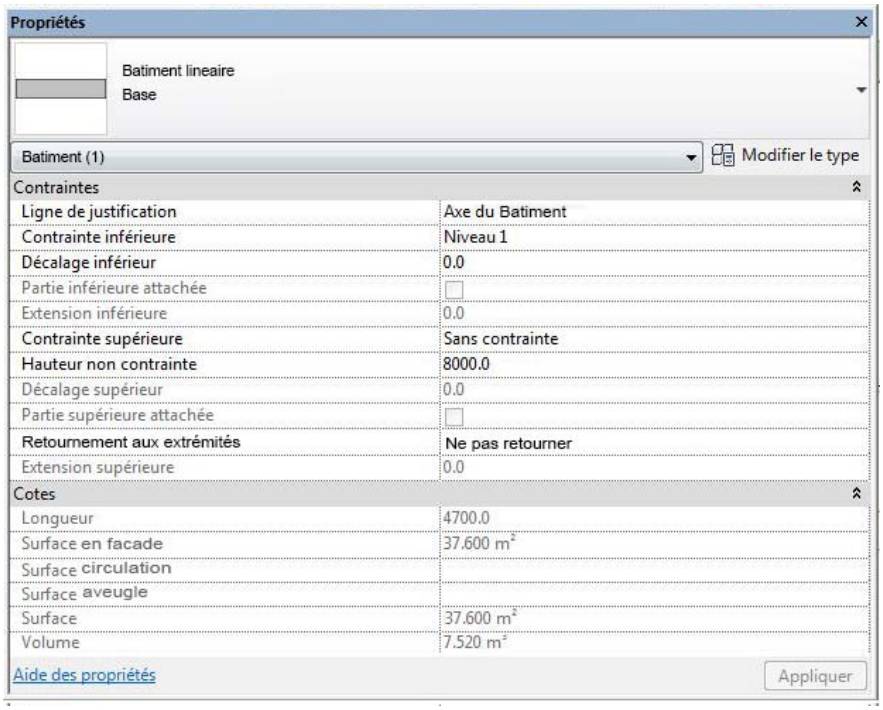
Types and Parameters

The "Linear building" family is defined by masses structured by the user.

The user has the possibility to edit and create types according to: the number of layers, the use of each layer, and their thickness.
The type of family 'linear building' will have to be chosen according to the configuration more adapted to the dedicated to the hosted function.



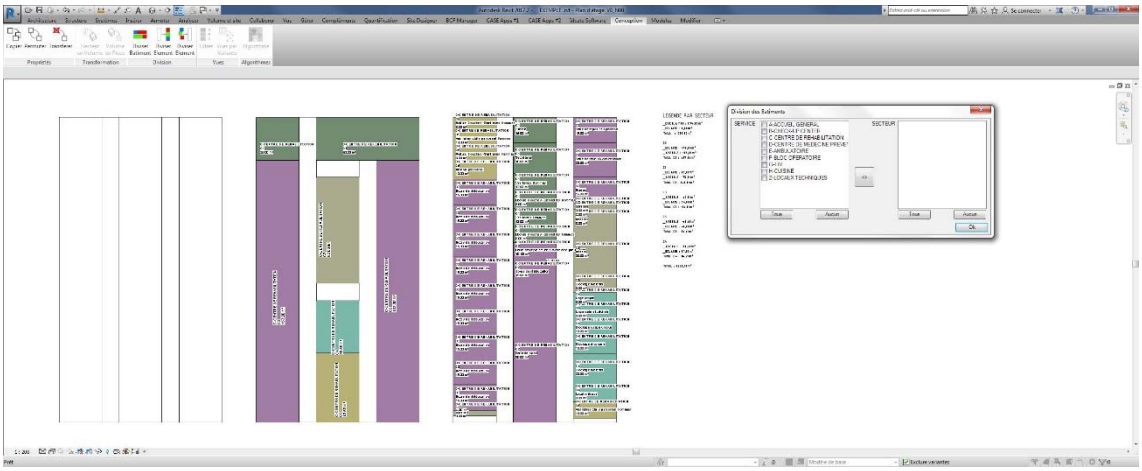
Each instance of the "Layer Building" family has instance parameters, such as height, level constraints, area and volume.



Building parts

The "Building" category is able to be separated into elements. This feature also exists on other Revit System families (floors, walls, roofs) and allows the user to divide an instance from the "Building" category as many times as necessary. Each element is defined by instance parameters (for example: zone name, room name, area, volume, depth, height, etc.) it also inherits the parameters nature, illumination and function from the parent family instance and layer.

The subdivision of elements can be manually or automatically calculated. In order to automate this step, I have developed one recursive algorithm that separates the instances of the building family according to the functional program of the building. This tool offers us different methods of subdivision according to the architect input: subdivision by zone or by room; random subdivision or according to an order of proximity given by a unique sequential code of each room.



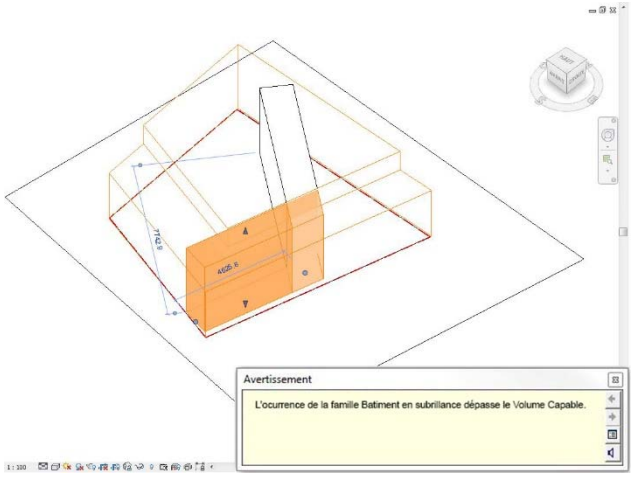
Each element result of a “Layer Building” family instance division can be transformed, however they will always be referenced and conditioned by the parent family instance and layer.

The whole is bigger than its parts. The object is analyzed as a whole so that the parts can be added, deleted or replaced according to the rules of the set[5]. (CONSIGLIERI, 1999, p. 55)

Interaction with the context

Each BIM category includes in its programming the rules that determine its behavior phase to other elements. For example, a door can only be applied to a wall; two walls cannot overlap; a room separator and a wall cannot overlap. When the designer forces an inconsistent action between two elements, the software displays a warning message and saves the warning in a report that is accessible to the user.

This principle has been applied to the building category. At first, I modeled an abstract mass that translates urban rules for the site, like a bounding box representing the space that the building can occupy. This mass will be called "Capable Volume". Secondly, the tool gives us warnings if the drawing is invalid, that is, when an instance of the Building category intersects the Capable Volume. This tool avoids going back and forth between the different projection views and 3D to check if the drawing respects the pre-established physical restraints.



THE VARIABLES

During the creative process it is essential to test several possible solutions. The users therefore need tools capable of facilitating the management, manipulation, analysis and comparison of different solutions. Revit makes available the design option set function which allows us to build several solutions in the same file and to filter each variant in the representation views and quantity schedules.

The global parameters, (tool available on Revit since 2017) help to parametrize the dimensions and proportions of the instances of the building family. Variables can be absolute values, or relative values in case this value results from a mathematical relationship to other parameters in the project. For example, parameter LENGTH = x (absolute value variable); Parameter WIDTH = LENGTH * 2 (relative value variable). Parameters can also be properties such as materials, energy coefficient, etc.

This tool allows us to quickly model variants of the solution under study. That is, when the values of the parameters are changed the model adapts instantly, therefore projection views and quantity schedules are updated.

[5] Gestalt concept

Revit offers us tools that allow us to represent more or less automatically objects drawn in the form of 3D view, 2D projection and quantity schedules. To reduce user intervention during this step, we've set up project templates and views templates.

At the same time, we have developed tools to create color legends by zone of the functional program, and to automatically multiply sets of views for printing with each new variant of the studied project.

Finally, to evaluate the solution, the architect has the schedules of quantities. To avoid back and forth between the drawing views and the schedules views, we have developed an area-by-view legend tool, this tool presents the surface area report of rooms in drawing; depending on its function (useful area / circulation) and its illumination (with or without natural light).

THE PRACTICE

This study is being applied in the practice of the studio Michel Rémon & Associés (MR&A) since 2016. The teams are often composed of a wide variety of profiles. We distinguished three types of users according to their Revit handling skills. Experienced: User with experience of more than 5 projects running on Revit and having total autonomy for handling Revit core tools; Novice: User with experience of less than 5 projects running on Revit and who does not have the autonomy to handle Revit based tools; Beginner: A user who has attended a Revit training and has no experience of handling Revit tools in a real project.

Lariboisière Hospital, June 2016:
Floor area: 51568 m²
Number of services: 8
Number of rooms: 2148 outside technical rooms and circulations
Rehabilitation and extension with two new buildings.
Complex urban rules, with different alignments, spacings and height ceilings constrained.
User: Amilcar Ferreira, an experienced Revit user and tool development manager.

Problems identified:
Due to the presence of rehabilitation in this project, the file preparation time before using the tools was long. The building family was used for the studies of the existing building, however in the rehabilitation it was not relevant because the influence of the building was already pre-established.

The urban rules contains a constraint that related the distance from a site boundary to the height of the new building. It is a dynamic constraint, which varies according to the variant in study, therefore this constraint can not appear in the modeling of the volume capable.

Time dedicated to volumetric research and distribution of the program in this project: more than a month.

American Hospital Project in Paris, January 2017:
Floor area: 17331 m²
Number of services: 8
Number of rooms: 303 off technical premises and circulations
Rehabilitation and extension for new building.
Complex urban rules with different alignments, spacings and height ceilings constrained.
User: Amilcar Ferreira, experienced Revit user and tool development manager, Géraldine

Maurice Novice user.

Problems identified:

See project for the new Lariboisière Hospital.
As for the Lariboisière Hospital project, the urban rules contains a constraint that related the distance from a site boundary to the height of the new building. The constraint has been fixed with a parametric variable of proportion: deviation = height of the Building / 2.
Time dedicated to volumetric research and distribution of the program in this project: 1 week.

FH Campus Vienna, December 2017:

Floor area: 20643 m²

Number of services: 5
Number of rooms: 250 off technical premises and circulations
New building in a new campus.
User: Emmanuelle Valersteinas, beginner user.
Problems identified:
Still in progress
Time dedicated to volumetric research and distribution of the program in this project: ongoing.

Presentation Sessions:
On December 15, 2017, an internal presentation and discussion session was held at MR & A's premises to broaden participation in this project to the entire MR & A team. This session allowed us to obtain feedback on the topics covered in this research project.

A questionnaire was set up to evaluate the advantages and disadvantages of the tools developed, as well as to determine the weak points and the functions to be added later in this study (See Appendix).

Subsequently the presentation sessions and discussions were scheduled per quarter, as well as internal training for the entire team of architects.

CONCLUSIONS AND PROGRESS ACHIEVED

We aim for the balance between a simple and rational process for the architectural design of complex program buildings, and for the flexibility to allow architects to introduce steps or sub-steps.

Work was carried out within MR & A for the development of digital tools. For technical difficulties, some of these tools today do not correspond to the interface presented in previous chapters. However, these tools had satisfactory operation to be applied in practical cases. Communication with Autodesk was initiated in 2016 but has yet to be completed.

The building category

The creation of a new category "Building" is currently blocked by Autodesk. Communication with Autodesk is essential for the future.

Today we have bypassed the technical problem using the "wall" category already present on Revit. For the good functioning of this tool we added the missing parameters (for example the ground area of each element, calculated from an application of the type *update*).

The disadvantages of using the "wall" category is mainly the impossibility of changing the behavior of the element facing other categories such as doors and windows. Despite the disadvantage of using an existing category the tool is suitable for use.

For the division of each instance in elements were developed several tools that allow an automatic division according to different criteria, a *wish list* of the parameters to be added or created was made during the presentation of the tools on December 15th, 2017.

As mentioned earlier in this study, the linear building family does not result from an exhaustive analysis of building typologies. Despite the versatility of the building family, the possible solutions are framed in the fields of Euclidean geometry. For further essays other 'building' families will be considered, a possible path is that to create a 'blob building' family, inspired in the work of Greg Lynn (LYNN, 1998), this family will allow us to expand the field of solutions to topological geometries or Anexact[6] as described by (HURSSEL, 1917).

The capable volume

The volume can be modeled with the "in-place mass" tool on Revit. Today this tool is not very intuitive and difficult to handle, geometrically more complicated urban rules can be very difficult, if not impossible to represent.

Subsequently, an algorithm for automatic volume modeling will be built. The modeling will be carried out according to the input parameter: property line, height ceilings, separation (function of the unit e = a + h / x, e = spacing at the limit of intervention, a = minimum spacing, h = height x = coefficient).

This step is operational, the 3D interface is sufficient to detect the inconsistencies between the building and the capable volume. However automatic warnings can be erroneous if the capable volume has not been correctly modeled, we plan to correct this problem with the development of the algorithm described above.

[6] Continuous and gestural geometries, are defined by relations and connections, can be exactly determined. However anexact geometries cannot be reduced to proportions and exact dimensions

Feedback from experiences

Despite the low use of these tools so far, the return has been satisfactory. The users were able to use all the features, the learning time was reduced, and the manipulation was considered by all the users, flexible and intuitive.

We have planned in-house training sessions for the MR & A team to apply these tools to more projects in the year of 2018.

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