INFORMATION SYSTEM FOR PARAMETRIC ARCHITECTURE, DEDICATED TO SPACES ALLOCATION

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Abstract. The parametric approach to architectural design is intended to help architects in the generation of complex types of shapes and of volumes, taking into account data on different areas affecting the architectural project. The tools of BIM technology (Building Information Modeling) are finding success in this digital approach. However, some projects require the mastery of a very large number of parameters but above all, the opportunity to change the values quickly and easily, according to the needs and to the arising of constraints. The spaces allocation in a project is a significant example as it requires massive data management and their combination. The solution would be an information system dedicated to the management of all project data, and which would be automatically linked to a computer assisted drawing tool. The aid system thus designed, gives flexibility and adaptability to the projects involving a large volume of information.

Key words: information system, parametric architecture, grid, computer assisted drawing, space planning.

1. Introduction

A major trend since the end of the last century is the exponential increase in the volume of stored data (Féraud *et al.*, 2008), whose management can suitably be done by means of an information system.

The domain of architecture is also experiencing strong growth in the number of parameters to be considered in a project. A trend accentuated by the advent of parametric architecture due to the possibility of its intuitive application to complex geometries (Turrin *et al.*, 2012), its ability to rapidly and automatically propose several solutions while taking into account standards and constraints already defined in advance, and its help to the designers for choose the optimum solution (Daher *et al.*, 2014).

This approach allow the formation of complex compositions, both formal and conceptual, through the implementation of a simple set of operations and parameters (Dino, 2012). The example is given by the latest BIM (Building Information Modeling) tools that include

Autodesk Revit, Gehry's Digital Technology Project, Geometric Component, Rhinoceros, Grasshopper, and ParaCloud (Chen *et al.*, 2015). BIM is a collaborative work methodology for the creation and management of a construction project. The objective is to centralize all the project information in a digital model, which conforms a big database that allows the management of all the elements of the infrastructure throughout its entire lifecycle. It is an evolution from the traditional design systems based on plans, incorporating geometric information, times, costs, environment and maintenance. One of the main goals of the BIM methodology is to work efficiently, trying to optimize all the activities that make up a project and then reduce the duration and increase the productivity (Troncoso-Pastoriza *et al.*, 2018).

The new modelling process is a great achievement and an improvement of the process for building simulations, allowing the architect to create and explore different design alternatives (Arayici *et al.*, 2018). Since it requires new ways of thinking and collaboration (Abaglo *et al.*, 2017). On the base of parametric model, architecture is always maintaining close ties with complicated logics (Ma, 2012) which is attenuated by the modeling capability of an almost infinite number of virtual possibilities, giving to the Architect an interesting potential of imaginations and suggestions of innovative spatial and constructive solutions (Silvestri, 2009).

Thus, digitalization of the design process enables designers to present their ideas more easily and leads to an increase in the complexity of architectural forms (Chen *et al.*, 2015). This approach leads to an adaptable design that is an approach to designing adaptable architectural products whose configurations and parameter values can be changed during an operational phase to meet the requirements of different customers (Zhang *et al.*, 2015). Changes can be made directly from a text file or a database (Wang *et al.*, 2008).

According to the nature of projects, this parametric approach of Architecture may require a very large number of parameters of which the management can easily be done through a dedicated information system. In addition, if the latter is connected to a computer assisted drawing tool, it allows automating the entire process of the architectural design.

The application of this approach to the allocation of informal spaces in a cultural building gives greater freedom to explore this idea though formality and informality which are fluid concepts (Ahlers *et al.*, 2014), All land everywhere and all structures on it are to some degree subject to informal use (Wu *et al.*, 2013). But theses types of spatial experiments, lacking a clear cut function, offer a wider range of possibilities, an unrestrained flexibility which facilitate the search, the research on a theoretical level and on the pratical level of design as well (Pop, 2015).

This work is also based on Toyo Ito's approach to the architectural project where boundaries are shifting and fuzzy. This jamming of limits has consequences for the way of apprehending the program of a building (Ito, 2011). The flexibility of the system we have developed makes it easier to take this approach into consideration. The control of a parametric model's flexibly have significant implications for the practice of architecture (Davis, 2013).

2. The developed methodology

The grid, because of its regularity, its neutrality and its expression of non choice, as privileged by Van Der Rohe, 1986, is used as a support for the architectural design by the developed application for managing and generating spaces data concerning the project.

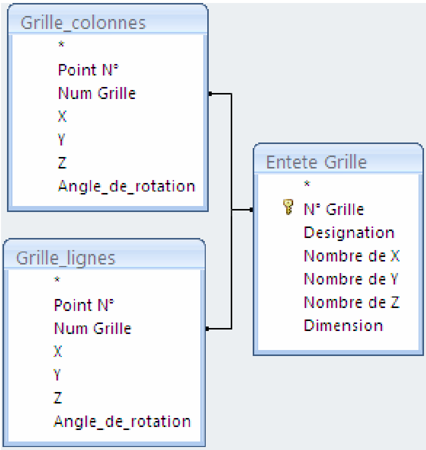


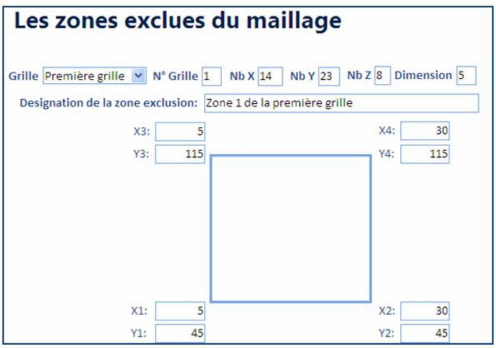
Fig. 1. The data scheme for the information system dedicated to the grid.

Fig. 1 shows data scheme of the information system for collecting the 3-dimensional coordinates of the constituent elements of each grid whose data is automatically generated according to basic information.

Whether in a building or in urban areas, the designed grids will be a support to the spaces allocation to a type of use.

The generation of these spaces, which consist of a set of meshes, and their assignments are done randomly in order to help the architect to explore all the possibilities offered by the chance which are constrained and shaped by external limitations due to the environment and leading to a new example of contingency as defined by Gould, 1991.

Therefore, the production of alternative space planning options require at the beginning to create constraints. First, by establishing exclusion zones in order to eliminate the not affected areas. Fig. 2 shows the algorithm in pseudo-code that determines whether a created mesh transgresses the exclusion zones or not.




```
WHILE Exclusion <> Fin
   IF X >= exclusion!X1 et X < exclusion!X2 AND
        Y >= Y1 AND Y < exclusion!Y3   AND rs!Y <
Nb_Y * Dimension AND rs!Y > 0 AND rs!X < Nb_X *
Dimension AND rs!X > 0 THEN
            Delete the first meshs of the space already
            generated
            Excluded = TRUE
            first_mesh = TRUE
            EXIT
   ELSE
            Excluded = FALSE
            Fisrt_mesh = FALSE
   Fin si
   GOTO NEXT Exclusion zone
END WHILE
```

Fig. 2. Form to determine exclusion zones and the pseudo-code algorithm for the taking into account of these areas in the spaces generation.

If this is the case, then all already generated space will be deleted. There may be as many excluded area as needed and which are entered in a form dedicated to this purpose.

The results of these constraints appear on the grid and also on the project as showed by Fig. 3. In our case these areas correspond to the location of the manually drawn part in the project, as well as that of the immediate environment.

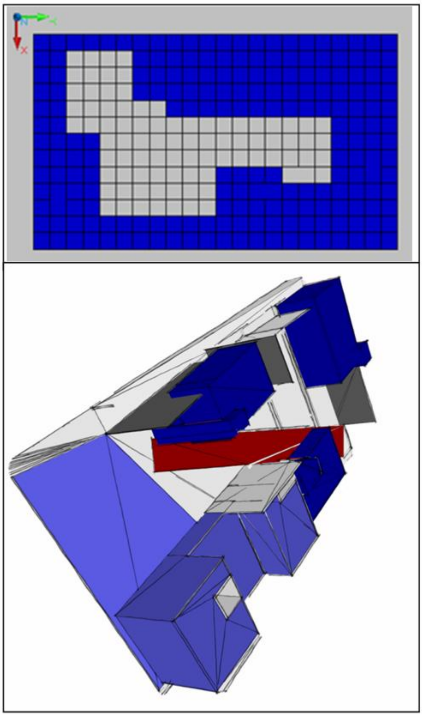


Fig. 3. Exclusion zones and their transcription on the grid and on the project.

It is possible to specifying the types of spaces with their minimum and maximum surfaces and also a percentage of free space. The assignment of a coefficient for each type of space makes it possible to promote compared ones to others, during their random generations. This allows the designer to explore different scenarios. The randomization of space's affectation is constrained by the following algorithm in pseudo-code:

```
READ type_of_the_luckiest_space
READ chance_number assigned to this space by its coefficient
Compteur_chance=0
WHILE chance_counter< chance_number
    Randomly generate a space_type
   IF  space_type=type_of_the_luckiest_space THEN
        Affecter le type d'espace à la nouvelle maille
        chance_counter = chance_number
   ELSE
        chance_counter = chance_counter + 1
    END_IF
 END_WHILE
```

The algorithm for data generation of the meshes sets representing spaces is based on the Archimedes' spiral principle. The first mesh of this space must be positioned randomly, on a free area of the grid. Then are drawn the other meshes according to a spiral whose center is the cell previously generated. The surface of this space is randomly generated between the minimum area and the maximum area set in advance by the designer. The generation of spaces takes into consideration the excluded areas, areas already occupied by other spaces and the areas outside the grid. The creation of mesh sets continues as long as there's a free area on the grid. The principle of Archimedes' spiral for the generation of spaces makes it possible to progressively occupy free spaces and generates fewer conflicts with the spaces already generated.

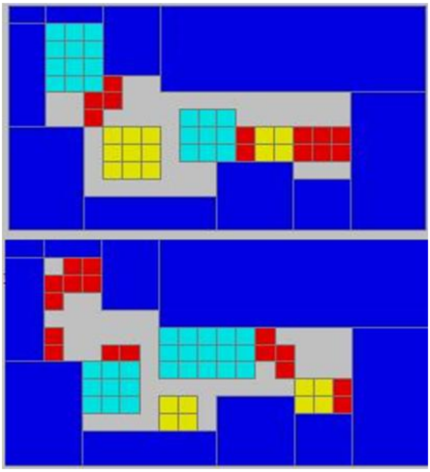


Fig. 4. The results of 2 attempts for the spaces generated randomly by the application designed according to the same constraints.

Using an information system for storing the data of grids, sets of meshes and constraints, facilitates their treatment, whether by programming according to predefined algorithms or by queries, written in SQL (Structured Query Language).

The designed application allow the random generation of meshes' sets, representing different spaces, control the drawing tool and materialize the solution generated by a constrained random. The designed application allows for as many attempts as needed to reach the ideal solution according to the vision of the designer. The selection criterion we considered in our project was to have a balance in the types of available spaces. Thus, the same constraints can lead to different results as shown by Fig. 4.

The spaces thus generated, it is now necessary to connect them with flux lines consistently. We added the constraint that the flow lines must connect two different types of spaces to reach the theoretical concept of the project which is to connect the opposing spaces, as shown in Fig. 5.

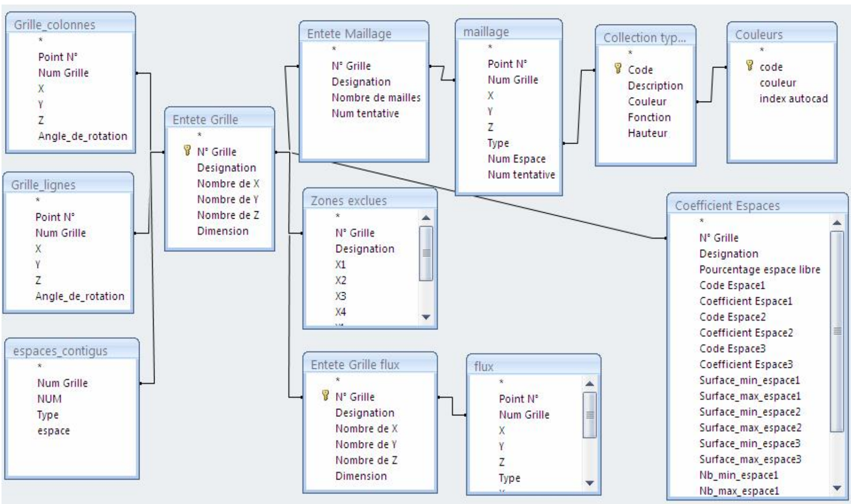


Fig. 6. The data scheme for the information system dedicated to the assignment of spaces and fluxes.

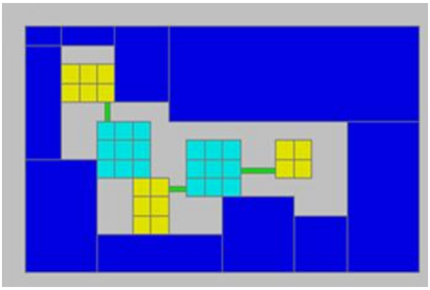


Fig. 5. The generated flow lines and the results preview in one of the attempts.

The information system thus manages all the necessary data to the spaces generation and their connections. Tables dedicated to each functionality are connected coherently as shown in Fig. 6.

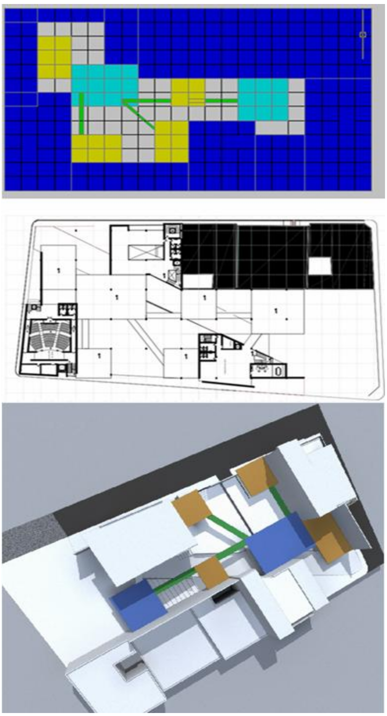


Fig. 7. Generated spaces and flows, architectural plan and volumes of the first grid.

3. Result and discussion

The application of the methodology previously developed for the design of a cultural center allows assessing its contribution to the architectural design. The first grid has collective spaces and public spaces that are randomly generated, but also non-generated spaces common to all cultural centers such as the auditorium, the exhibition gallery and the public library. Fig. 7 shows the generated spaces and flows as well as their transpositions in architectural plan and in volumes.

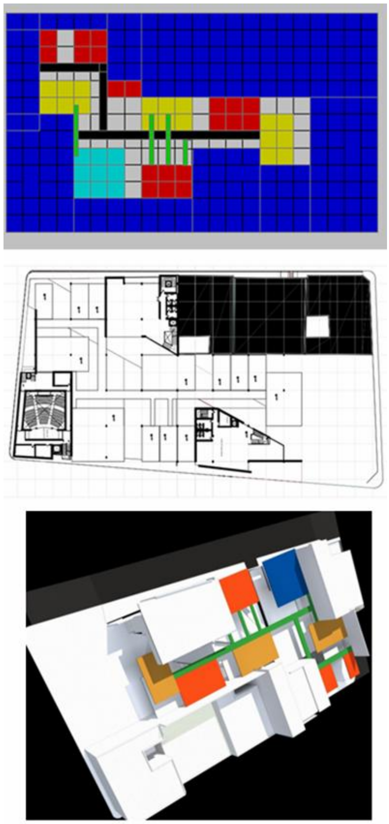


Fig. 8. Generated spaces and flows, architectural plan and volumes of the second grid.

The same approach is followed for the second grid except for this one; there is another type of space. These are the individual cells that are also randomly generated as is the case of public spaces and collective spaces. Fig. 8 shows the steps that allow achieve the project's volumes. It is necessary for the designer, to confront the randomly generated results against set targets. This confrontation is done by comparing the statistics generated and the pre-established constraints.

Tables, graphs and ratios automatically generated from the data of the information system, offers, to the Architect, analysis elements on the performed simulation. Table 1 shows statistics on one of the simulations.

Table 1. Statistics on the composition of the spaces types randomly generated during a simulation.

Description	Number of meshes	Area (m^2)	Percentage
Individual cell	25	625	8.33
Collective space	110	2750	36.67
Public space	165	4125	55
Total	**300**	**7500**	**100**

Constraints are imposed on parametric design by the designer himself to study a specific range of cases as shown in Fig. 9.

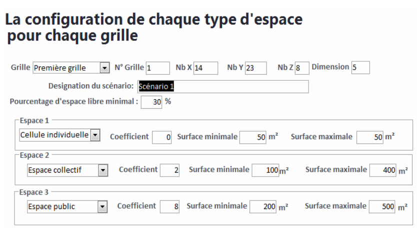


Fig. 9. Constraints for the configuration of each type of space for each project grid

Other environmental constraints can be applied (Taleb *et al.*, 2015). These new constraints can easily be taken into consideration by the information system designed which will thus become upgradeable. The generation of spaces, is indeed random in order to offer great combinations of solutions to the architect, but the existence of constraints, limits the effects of chance and shapes the overall (Brissaud *et al*, 2007).

The solution chosen by the Architect is based on the simulation results but may also, at a later stage, be readapted by others, thanks to the flexibility offered by the information system. Therefore, it will be possible to proceed with the reconversion and restructuring of spaces in accordance with the requirements of sustainable development.

The apply of information systems in the field of construction is taking more and more importance in order to seek to address the complex issues of creating a sustainable built environment (Farmer *et al.*, 2017).

The apply of information systems in the field of construction is taking more and more importance in order to seek to address the complex issues of creating a sustainable built environment (Farmer et al., 2017). This sustainable approach is accentuated by the use of parametric architecture (Saleh et al., 2012).

4. Conclusion

Addressing huge demand for built structures due to increasing population and progressing economies is not a normal task and is certainly cannot be done with the conventional approach (Sharma *et al.*, 2017). As our cognition about architectural generative mechanism changes, architecture design keeps changing (Zhu *et al.*, 2015).

Parametric architecture, as a way of thinking about buildings as a set of numerically coded aspects demonstrates the possibilities of using mathematical resources to improve functioning of the building (Czech *et al.*, 2016). Buildings cannot be reduced to their geometry alone; they also include knowledge. New lines of research are emerging to move from a purely geometric reasoning to a semantic level of digital representation of forms (De Luca *et al.*, 2005).

Accordingly, and given the complexity of decisions and diversity of data to manage, we propose a solution based on an information system that helps the Architect in the spaces allocation of its project. The developed system contribution to the project is above all the help given to a spaces design that complies with the architect's vision, even if it is complex. This solution could be used in other fields of architecture where the concept of grid is needed as support. This study was limited to an architectural project however, the use of the grid makes it possible to change scale and to be interested in urban projects.

The designed Generative System plays a key role in the production of a large number of solutions which themselves depend on a large number of parameters managed by the information system. The fact that a single application manages both the information system and the drawing tool facilitates the work of the designer and allows it to easily perform so many combinations as necessary to choose the most appropriate solution.

The developed application offers the possibility to parameterize the density of the architectural plan for each grid and the creation of programmatic diversity which allows reaching a certain architectural quality of the space. The information system can evolve to take into account other qualitative aspects of spaces such as light, ventilation or perception.

Finally, the networking of the information system will allow several actors to contribute as part of a large project. The designed application can, like BIM tools, provide a robust platform for communication and information sharing among all stakeholders (Akinade *et al.*, 2017), reduce design mistakes and increase the productivity (Miettinen *et al.*, 2014). Privileges can be assigned to different designers by field of intervention of each. The system would become collaborative, scalable and efficient for spaces generation and allocation in architectural buildings.

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