GENERATIVE DESIGN FOR BIM

Its Influence in the Design Process

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Extended Abstract

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1. INTRODUCTION

The exploration of design efficiency is an old concern but the major developments in studies of this matter happened with the advances in computation. Until the late 60s, the paper-based approach was the main tool for the project development, being extremely laborious and non-efficient to handle changes.

The traditional paper-based design has been substituted by Computer Aided Design (CAD) by the end of the XX century, making the process of editing and revisions easier during the development. Nevertheless, conventional CAD tools do not support change efficiently, limiting the exploration of complex solutions.

The introduction of the Building Information Modelling (BIM) approach in the beginning of the XXI century, was a revolution in the design process, due to its capacity to handle change and to produce and mainly to produce and integrate in the model the whole design information. Still, it only worked well at a certain level of project complexity.

Generative Design (GD) was recently introduced in the design process as a disruptive approach that efficiently handles change and data complexity. However, it requires significant changes in the traditional workflow of the architect. This thesis's objective is to study these changes in the design process and also propose new methods that take better advantage of the GD approach.

Moreover, this thesis also includes an analysis of the current design process and also the impact of new technologies, with its main perspective towards Building Information Modeling (BIM). By taking advantage of BIM, we will propose new design computational methods and new workflows to achieve a better performance of the design process.

2. BACKGROUND

Historically, design was highly influenced by the drawing techniques of each era. Until the second half of the XX century, precise technical drawings, perspectives, and draw-by-hand techniques were the central points in the design process. Being labor intensive, modifications in design resulted in prolonged working hours.

The traditional paper-based design has been substituted by Computer Aided Design (CAD), facilitating the editing and revision over the process. The development of CAD software started by offering simple geometric elements such as straight lines and circles, and later advanced to the 3D modeling (Schoonmaker, 2002). Increasing the drawing efficiency and consistency, but still without any information regarding the design or construction. Moreover, CAD applications achieved a stable level of maturity and the improvements were very subtle. Therefore, designers felt the need for additional tools to accomplish their tasks with more efficiency.

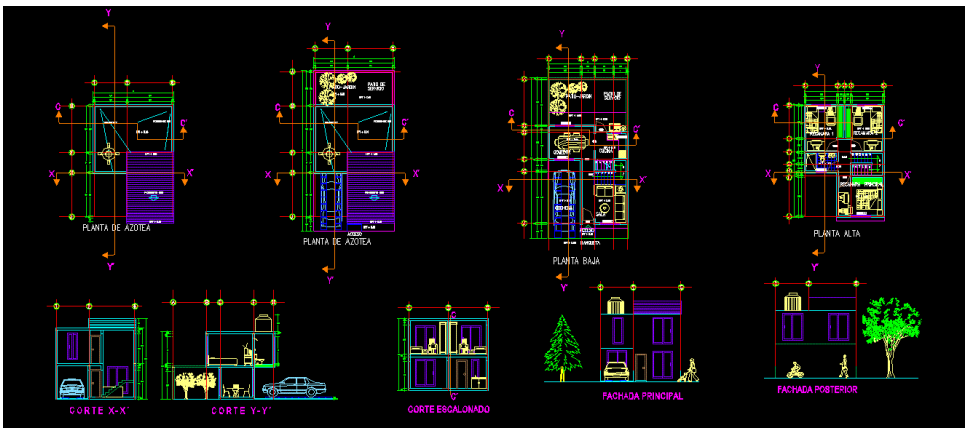

Figure 1. Project developed in AutoCAD, a well known software (source: www.bibliocad.com).

An answer to this need was provided by scripting languages, which allow the manipulation of CAD applications. They can access the underlying structure of existing CAD software and embed new functionality to it. In addition, they are usually used to assist the design by simplifying repetitive tasks, creating new features to the software, increasing the efficiency of complex tasks or also by manipulating large amounts of data.

```
;;; PROGRAM SHAPE1.LSP
;;; A SIMPLE MANUAL SHAPE MANIPULATOR WITH THREE RULES

;;; RULE 1 FUNCTION - PLACES THE INITIAL SQUARE
(defun rule1 ()
   (setq origin (getpoint "\nPlease enter origin: ")
       lowright (getpoint origin "\nEnter lower right corner of square: ")
       a (distance origin lowright) ;;; make sure lowright is on one
       )                            ;;; horizontal line with origin
   (command "INSERT" "square1" origin a "" "")
   (setq count 0
       mark (getpoint "\nPlease enter point on bottom side of square: ")
       c (- (car mark) (car origin))
       d (- a c)
       alpha (angle mark (list (car lowright) (+ c (cadr lowright))))
       b (sqrt (+ (* c c )(* d d)))
       reduction (/ b a)

   (command "CIRCLE" mark (/ b 10))
)  ;;; END DEFUN
```

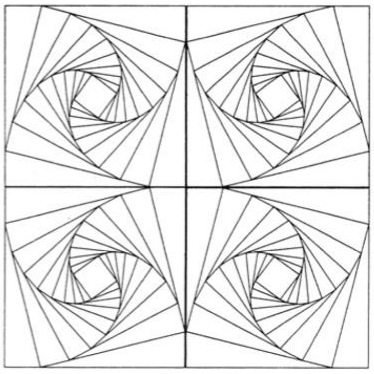

Figure 2. Autolisp - scripting language for AutoCAD (source: Celani, 2008)

Still, the user needs textual or visual scripting skills to execute them. Since most designers lack scripting knowledge, it becomes a barrier for them to use these tools. Additionally, these scripting languages are mostly

used with CAD applications and they have the same problem of producing only geometric entities without any design or construction information.

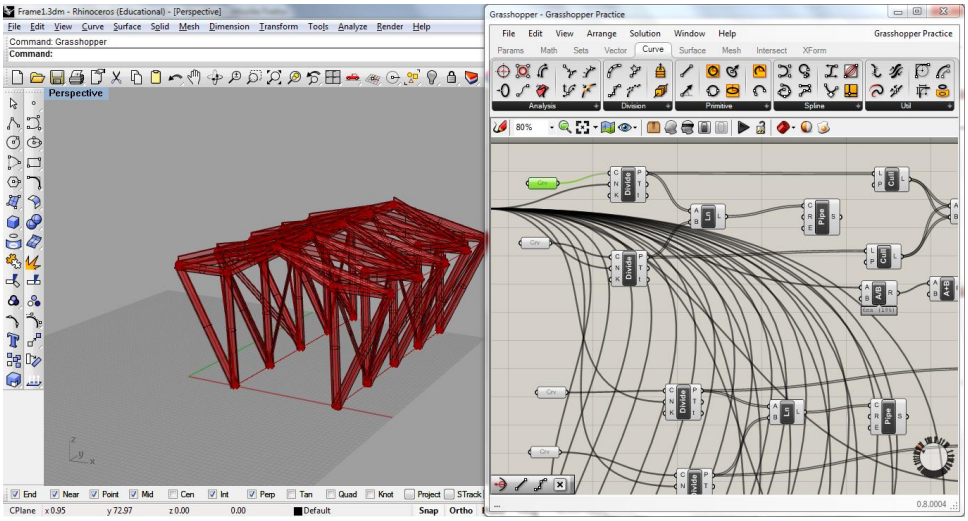

Figure 3. Grasshopper - A visual scripting approach for Rhinoceros (source: www.cameronwire.wordpress.com)

A promising approach that has the potential to address these problems is Building Information Modeling (BIM). The BIM approach offers the possibility to build virtually, simulating the construction environment with all the information needed for the construction (Azhar, 2011). Moreover, BIM tools generate plans, sections and views; simulate the structural details, external or internal interferences and performance analysis(Eastman, et al., 2008).

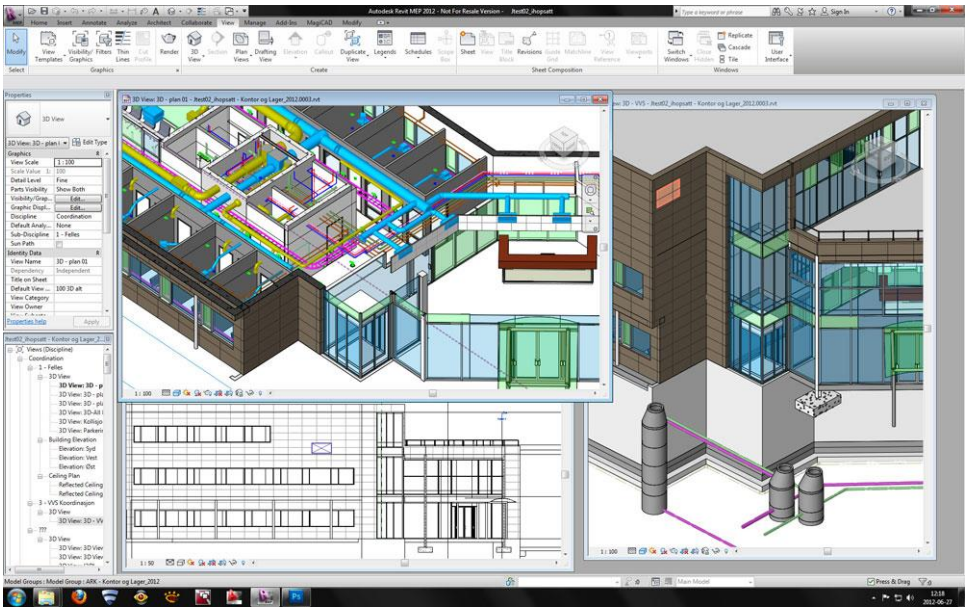

Figure 4. Revit Architecture - A well known BIM tool (source: www.magicad.com)

The two analyzed projects, Foundation Louis Vuitton and Beekman Tower, demonstrate that the use of BIM was essential for their success. BIM applications allow the project information to always be updated and used

at any time by different building agents, thus making it a significant advantage for the project because of their constant modification.

Figure 5 . **Foundation Louis Vuitton and Beekman Tower. Both projects developed in BIM technology. (source: www.letudiantautonome.fr; www.urbanfile.org)**

BIM improved the collaboration between the construction agents, allowing the participation of different team agents in the design process using the same BIM model. In addition, it also assisted in the process of fabrication, producing all the necessary data of each construction element.

However, when we deal with more complex projects, that involve a large amount of data and irregular geometries, BIM tools begin to show certain limitations. As a result, we need more advanced tools to assist the process.

The Generative Design (GD) approach offers a solution to these needs. This approach is defined as a process based on rules or algorithms, through which various elements and design possibilities can be created. These rules and algorithms are composed of parameters, which can be used systematically to generate various project solutions (Fasoulaki, 2008).

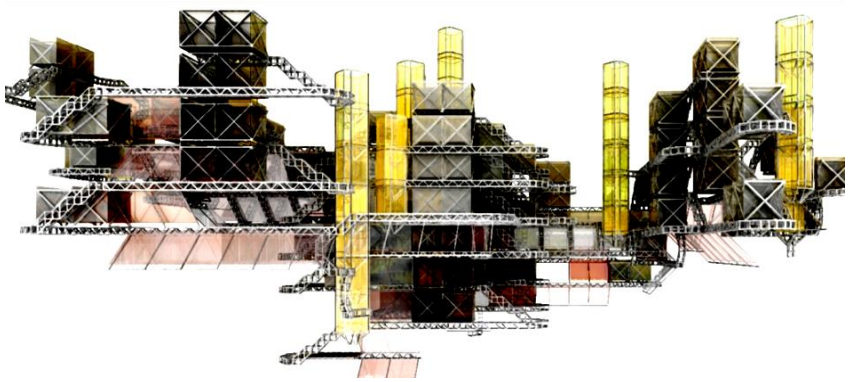

Figure 6. **L-System - a GD approach example (source: www.michael-hansmeyer.com)**

The GD approach has completely transformed the role of computation in the design process. Using GD methods, the computation is not limited to just record the design process, but can also be used as a creative and auxiliary tool in the design decision making.

The mentioned GD methods show that it is possible to create a large scope of solutions and design alternatives with a certain level of autonomy. The process of working in GD basically consist of data inputs and model generation. Still, these methods generate only geometric entities and still do not produce any construction or design information. Moreover, often the end results of the GD approach are impossible to be built with current technologies. That, happens because the GD methods are not connected with the limits of the current reality of building technology.

Combining GD with BIM is a way to address this problem. By doing this, the GD approach can take advantage of the BIM construction elements and information.

The Water Cube and Aviva Stadium projects showed that GD methods with BIM tools gives us the ability to create highly complex shapes with great efficiency. In addition, the use of BIM allowed the entire project information to be stored and consulted at any stage of the design process. BIM also assisted in the production of details generated in the GD model, for fabrication and analysis.

Figure 7. **Water Cube and Aviva Stadium. Both projects developed with BIM and GD methods (source: source: www.stylepark.com; www.info-stades.fr)**

Even though it is still at the beginning of its development, with the combination of GD methods and BIM technology, the AEC industry achieved the highest level of production, dealing with extremely complex data and shapes.

However, this combination is still not well defined. GD tools are usually being used only to solve problems and are not entirely integrated into the design process. They assist the traditional design process partially, but if they would be incorporated during the whole process, we would achieve much more sophisticated results. In order to solve this problem, we proposed a new conceptual workflow as well as the most suitable use of GD tools.

3. GENERATIVE BIM TOOLS IN THE DESIGN PROCESS

In the previous chapter, we described the development of digital tools and their influences in the AEC industry. In this section, we present a new conceptual workflow with the introduction of the GD approach in the design process, as well as its more suitable use, based on our investigation.

The GD methods are based on a programming approach and since most of designers do not know how to program yet, the design teams need to integrate or to collaborate with professionals that have programming knowledge. These professionals are software engineers or designers that know how to program. (Santos, Lopes, and Leitão, 2012).

For this collaboration to work we propose that both programming professionals and designers should have some knowledge of each other discipline to better understand the process. Furthermore, in this new reality, designers should have some basic knowledge of programming to be able to execute simple tasks for their own needs. If there is a complicated task, then they can invite the programming professional to solve it.

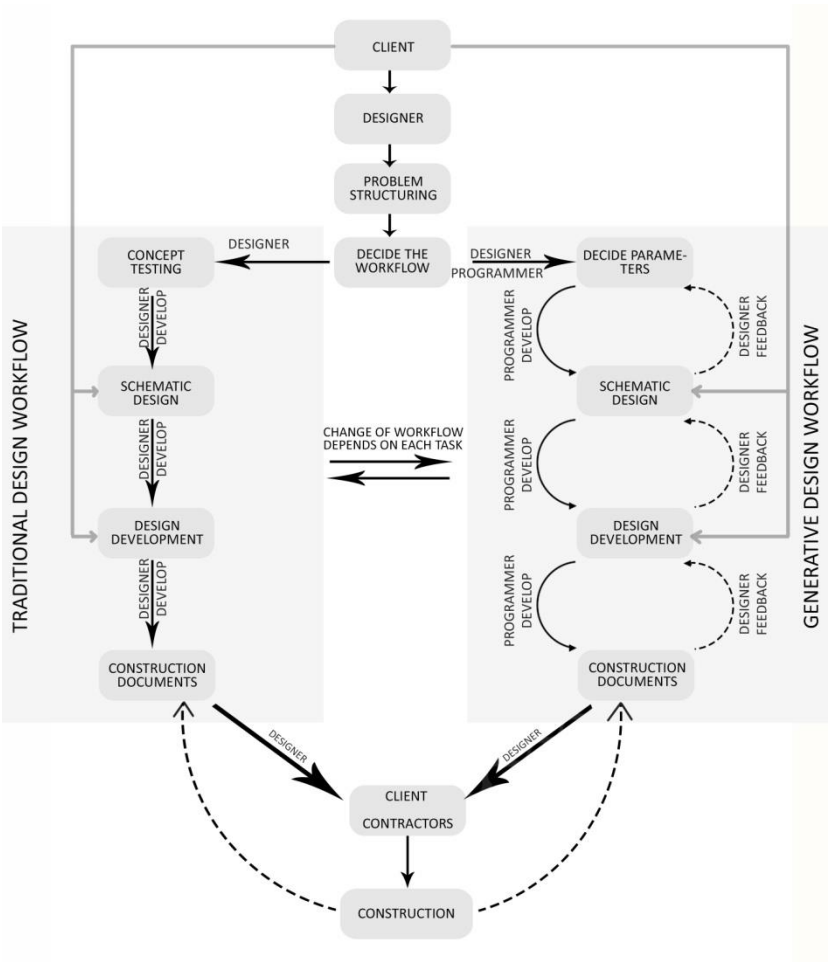

Figure 8 . Traditional and Generative Design Workflow.

As we can see in Figure 8, the Generative Design workflow is composed of designers and professionals of programming. Moreover, in this workflow we can observe that designers no longer interact directly with

drawing or modeling tools in the project, but via programming professionals. Thus, a good collaboration between architects and software engineers might be very useful (Santos, Lopes, and Leitão, 2012).

Furthermore, it is important to realize that Generative Design is not the tool that solves everything. Since GD methods requires massive effort of programming, there are projects where its use may not be beneficial. Some projects are easier to just design with the current BIM tools. Therefore, in order to select which project should involve GD methods, we propose a Table to identify the most appropriate tool for each project, based on the scale and data complexity factors.

	Small scale	Big scale
Non-complex	BIM	BIM+Macro
Complex	GD+BIM	GD+BIM

Table 1. **Proposal of the most suitable use of GD approach and BIM.**

To support the theory we mentioned above, we also develop a brief evaluation of two projects, Louvre Abu Dhabi and Absolute Towers. In the first project, we analyze the design process of Louvre Abu Dhabi, as a recent built project that heavily relied on GD methods to be developed (Imbert, et al., 2012). Then, in the second project, we make some simulations of project modeling based on the two approaches, BIM and Generative Design, to measure their impact in time and effort.

The results of the evaluation clearly favor the use of GD methods in the design process, due to their capability of handling change and complex data. Although modeling can be faster with just BIM tools in the initial stages, the usage of the GD methods proves to be a welcome addition when dealing with the amount of changes during the design process.

CONCLUSION

The development of drawing techniques has always influenced how designers think and the design process. The introduction of CAD technology facilitated the editing of projects and allowed a greater efficiency in the design process. The introduction of BIM technology exceeded the efficiency brought by CAD, allowing the modeling of virtual construction reality and the production of all the design information. Finally, with the introduction of GD methods, designers were able to explore a side of geometry and information complexity that could not be produced only with human capacity. Still, GD methods produced only geometric entities without any additional project information.

This problem was addressed using the GD paradigm within a BIM environment, by making use of BIM construction elements and also allowing the extraction of the project information. Moreover, this method already proved its success in several projects around the world, but still we lack a well-defined use of it. Therefore, this thesis discusses the influences and the introduction of the GD methods in the design process.

In this new reality, designers no longer interact directly with drawing or modeling tools in the project, but via GD methods. Since most of designers do not know how to program, we propose the integration of programming professionals within the design team.

Besides that, due to the great efforts required by a programming approach, GD approach is not always the right choice for the design process. Each project should be first evaluated, to find which is the most appropriate approach because, as we saw in the BIM case studies above, some of the tasks are just easier to do with the BIM technology. Therefore, we propose a table that evaluate projects, based on size and complexity of project data of to find the most suitable design tools.

Finally, to evaluate our solution, we made an analysis of a recently built project, Louvre Abu Dhabi, based on GD methods and BIM tools. In addition, we also simulated the modeling of another built project, The Absolute Towers, using the GD and BIM approach, to compare them in time and effort.

From the observation of the evaluation, we can confirm the main topic of this thesis: the GD approach can assist designers to efficiently handle changes and explore solutions. If the designers master the GD approach, they gain conceptual freedom to make changes, enhancing the project and the searching for a high performance design.

References

01. Azhar, S. (2011). ”Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry.” Leadership Manage. Eng., 11(3), 241–252.

02. Eastman, C. M., Sacks, R., Liston, K. and Teicholz, P. (2008) BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors. John Wiley & Sons. United Kingdom.

03. Imbert, F., Frost, K. S., Fisher, A., Witt, A., Tourre, V. and Koren, B. (2013) ‘Concurrent Geometric, Structural and Environmental Design: Louvre Abu Dhabi’, *Advances in Architectural Geometry 2012*, , pp. 77–90. doi: 10.1007/978-3-7091-1251-9_6.

04. Santos, L., Lopes, J. and Leitão, A. (2012) ‘Collaborative Digital Design: When the Architect Meets the Software Engineer’, Prague: ECAADE 2012. pp. 87–96.

05. Schoonmaker, S. J. (2002) The CAD Guidebook: A Basic Manual for Understanding and Improving Computer-Aided Design. Marcel Dekker. New York.