Design by Algorithms: A Generative Design System for Modular Housing Arrangement

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Abstract. *This Paper explores the applicability of algorithmic design in a real-world architectural context; through the creation of a generative system for modular housing arrangements (MHAS). It is a user interface in Autodesk Maya based on stochastic search to produce various alternatives for the modular housing arrangements. Through the UI, the designer can enter parameters and rules, and then the MHAS will produce 3D alternatives according to the specified frame conditions and renders a selected view. This generative system is expected to facilitate the design process, generate unexpected solutions for well specified rules, and save time consumption in the early design process.*

Keywords. *Generative design, Algorithmic design, stochastic search, Modular housing*

Introduction

Due to the availability of complex software and its reliant hardware technologies architectural design has changed radically by the start of the new century. These technologies have produced a fast, accurate and globally transferable design culture and community (spiller, 2008).

Until very recently the architectural design process always depended on the decision of what the architect would like to have as a final result. In order to achieve a specific final result the architect would have to specify from the beginning all design rules and methods, which should be followed and carried out until the last project was actually realized.

By taking advantage of computer's processing power, an unlimited number of variations in both the form and function can be provided while following the same set of constraints. Through the use of Algorithmic strategies, a relationship can be created between the machine and the human mind. And a new approach appears as architecture discovers Programming, as programming techniques became now one of the digital designers tool to create various solutions under constrained unpredictability.

Algorithmic scripting techniques involve the articulation of a strategy for solving problems whose target is known, as well as to address problems whose target cannot be defined. Within the realm of computer graphics, solutions can be built for almost any problem whose complexity, amount, or type of work justifies the use of a computer (Terzidis, 2006).

The breaking through technology in prefabricated construction made Modular housing a fast, cost-efficient, higher performance housing. It needs less labor, fewer mistakes and less waste of materials than any ordinary housing construction. Prefabrication by its nature is also considered green sustainable housing. The process itself reflects transparency for all the teams involved in the construction as well as its future user. On the other hand, the modular housing arrangements lacks Variety. A good example for variety is Habitat 67 by Moshie safadie.

Algorithmic Design

In 1990, Novak introduced architectonic propositions that are liquid, algorithmic and transmissible. He means by "algorithm" that the forms are never manipulated through manual corrections, but the mathematical formulas that generate them are adjusted to produce different results (Novak, 2001). Kotnik (2006) introduced a digital design frame work, which is based on the Turing machine as an abstract model for the computer and it results in an algorithmic description of every task performed by the machine. Terzidis (2006) also states that algorithmic processes are not necessarily based on computers. He also focuses on the comparative analysis between tool makers and tool users in the field of design. Algorithmic architecture involves the designation of software programs to generate space and form from the rule-based logic inherent in architectural programs, typologies, building code, and language itself.

There are complex algorithms that have a high potential value in design; those algorithms are Boolean operations, stochastic search, fractals, cellular automata, and morphing (Terzidis, 2006; El-Khaldi, 2007).

As an example for the stochastic search, Cardoso (2006) took a program and site for a residential tower, and he creates a rule building process and implementation of these rules in stochastic search program written in MELscript.

Stochastic search

In this Paper, stochastic search method is chosen in order to be applied in the created generative system. It is a form of heuristic search that use the following generic algorithm: First, Construct a set of random candidate solutions. Second, keep searching until some condition is reached according to the specified rules.

Modular Housing Arrangement System (MHAS)

In this paper a generative system for modular housing arrangements (MHAS) is presented. It is a user interface in Autodesk Maya based on stochastic search to produce various alternatives for the modular housing arrangements. Through the UI, the designer can enter parameters and rules, and then the MHAS will produce 3D alternatives according to the specified frame conditions and renders a selected view. This generative system is expected to facilitate the design process, generate unexpected solutions for well specified rules, and save time consumption in the early design process. As the arrangements are produced according to some frame conditions related to the urban context and the modular unit itself, the system lacks both environmental and functional frame conditions. So, the system should be used in the early design stages, the designer can choose from the produced alternatives, or even change the inputs if he is not satisfied with the results to get different ones under the same specified rules. Afterwards, he finalizes the design putting into consideration the environmental and functional aspects.

MHAS: Concept

We have to put into consideration that MHAS is a rule based system which doesn't substitute the human mind in the design process, but rather acts as a parallel thinking to the designer's mind. This generative system is sabe as a plug-in and then designer will just load it as a shelve and use it whenever he wants.

Using stochastic search as a process in which building elements are placed at random locations in space that are then evaluated against a set of constraints to be accepted if there is a satisfying fit. The random search space can be adjusted to match the zoning envelope and the constraints can match structural, circulation, or programmatic requirements. So, first rules and their algorithms should be written, and then translated into a script in Mel. Afterwards, the designer can start adjusting the parameters and initiating the Process (Figure 1).

MHAS: Implementation

The designer have to enter the inputs for each of the each frame conditions starting by the units dimensions, site and envelope Parameters, optional court, optional core, a view to be rendered and number of alternatives needed and finally initiating the process by pressing apply(Figure 2).

The Parameters and frame conditions can be explained as follows (Figure 3):

Unit Parameters: According to the modular unit provided by the designer, the unit's 3 dimensions can be entered through this part in the UI. This unit can be a modular room or an entire modular house depending on the designer's need. The Parameters include: unit's length, width and height in meters.

Units' arrangement in site: Here the designer can enter the parameters of the land specified for this arrangement, or in other words he can define the skin constraints of the arrangement, this includes the number of units, the starting point and ending point of site's length, the starting point and ending point of the site's width, and the starting point and ending point of height in meters. In this part the designer has the option to make his arrangement in either 1 or 2 stages. In the first option the units will be only arranged without any change in a cuboid skin constraint. On the other hand, the second option will give some variety to design. The arrangement can be divided into two stages the first could be with a broader area within a certain height, and the second with smaller area starting from the previous height and ending with a specified height or vice versa or any case depending on the designer's creativity.

Court: It contains the option of inserting a court or not, and if a court is required by the designer, its parameters and location can be specified.

Core: This usually contains the stairs and any required services. This input is also optional, and the designer can also control its parameters and location.

Render view: The application renders a selected view for the provided alternatives. The views are plan view, side view, front view and perspective view.

Alternatives: Specifies the number of alternatives for the above mentioned constraints.

MHAS: Application

In order to demonstrate the program's abilities, some cases created by the program are introduced. It also shows that by changing the UI's parameters different results are being created.

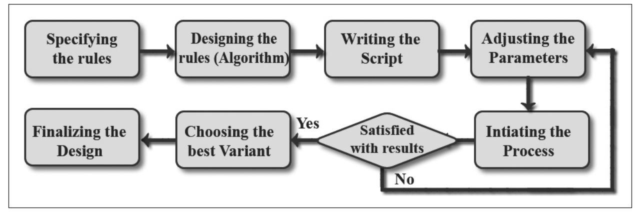

Figure 1. The process steps in creating the system.

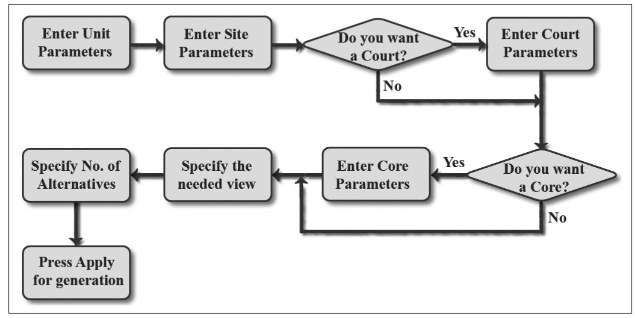

Figure 2. Rule-based sequence of the system's design process.

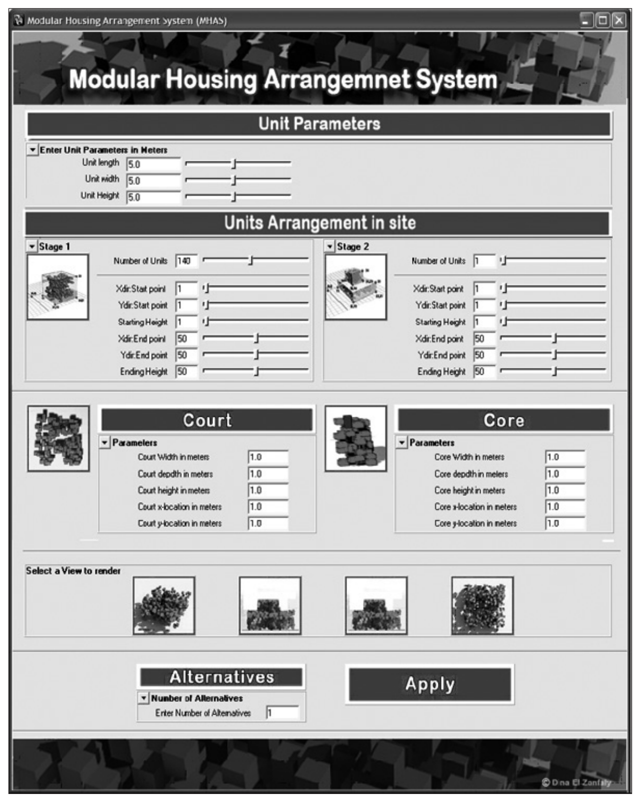

Figure 3. All the MHAS UI Parameters.

First case: Terraced residential building

Required program: a modular complex building the arrangement included a total of 270 residential units in two building envelope stages, 20 and 25 meters height and an inner core. The unit dimensions are: length 5.5 meters, Width 12 meters, and Height
3 meters. The site plan is 100 x 100 meters (Figure 4).

After initiating the process the 3 dimensional results are obtained (figure 5).

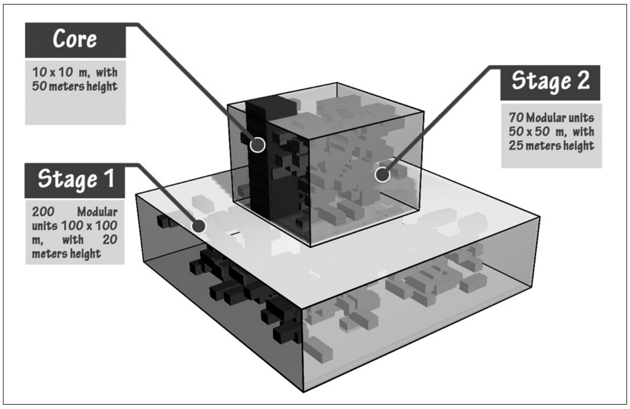

Figure 4. The Case's parameters.

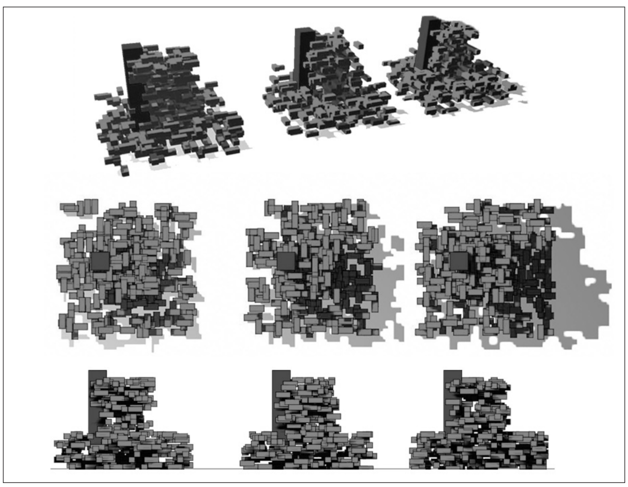

Figure 5. Resulted Perspectives, site plans and Front views.

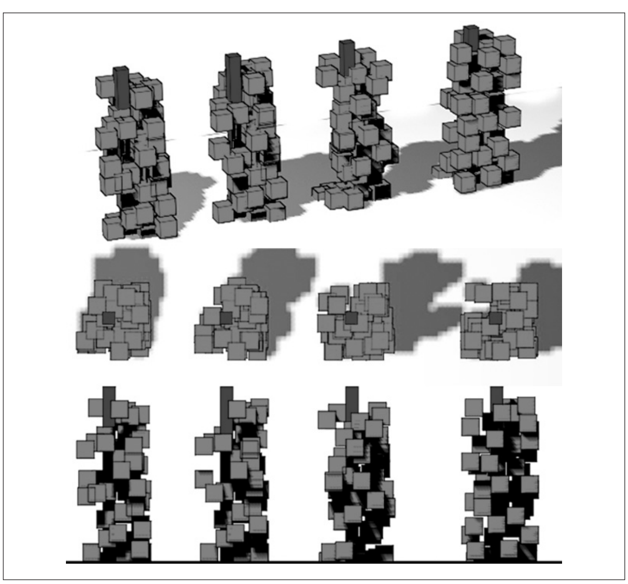

Figure 6. Resulted Perspectives, site plans and Front views.

Second case: Capsule Tower

Required program: a Tower with randomly located capsule units. The program requires a total of 70 residential units in two stages and an inner core. The unit dimensions are: length 5.5 meters, Width 12 meters, and Height 3 meters. The site plan is 35 x 35 meters.

By exploring the program's abilities further, by entering the program parameters in the UI and specifying that 4 alternatives are needed, the program presents 4 arrangements meeting the same specified parameters (Figure 6).

Conclusion

The difference between scripting and manual design is in the complexity and unpredictability of the actions. The human designer may be constrained by quantitative complexity. End user programming languages have allowed designers to take advantage of the potential of the computer's processor to perform a very large number of calculations manipulating complex geometry through scripting, this new kind of interaction with the computer is still new for most practicing designers, yet has proved to provide an extended field for design exploration.

As shown, the designer can build his own tool to meet the program's parameters (tool maker) instead of using previously made tool which may not meet all his design needs (tool user).

Future work

The Program created is a Generative model, which can be used in an early design process but not a final one. For example it lacks the environmental and orientation parameter. Future work will include not a generative model but a compound model, like a generative performative design. Compound models are based on integrated processes including formation, generation, evaluation and performance.

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