THE USE OF THE SMART GEOMETRY THROUGH VARIOUS DESIGN PROCESSES

Using the programming platform (parametric features) and generative components

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Abstract. The emergence of parametric generative design tools and prototyping manufacturing technolog led to radical changes in architectural morphologies. This change increased the opportunity to develop innovative smart geometries. Integrating these algorithms in the parametric softwares led to variations in building design concepts increasing alternatives and decreasing the repetitive work previously needed in conventional CAD software. The chosen software in this research is GenerativeComponents (GC). It is a software design tool for an associative and parametric design platform. It is tested for using Global Variables with associative functions during the concept creation and form GC comprises features. The results presented in this research may be considered an introduction to the smart geometry revolution. It deals with the generative design which applied in the design process from conceptual design phase, defining the problem, exploring design solutions, then how to develop the design phases. Office building is a building type which encourages new forms that needs computational processes to deal with repetitive functions and modular spaces and enclosed in a flexible creative structural skin. Generative design helps the office buildings to be arranged, analysed, and optimized using parameters in early stages in design process. By the end of the research, the use of the smart geometry in a high rise office building is defined and explained. The research is divided into three parts, first a summary of the basic theories of office buildings design and the sustainable requirements that affect it, and should be integrated.Secondly, the previous experiences in generating office buildings by Norman foster andSergio Araya. At last, a case study is proposed to test and evaluate the use of the parametric generative methodology in designing an office building with specific emphasis on the function, environmental aspects and form generation using Generative Components (GC) Software.

1. Smart Geometry

Computers enable us to calculate complex mathematical formulas, complicated equations introducing a whole new family of shapes, curved topologies, splines, and surfaces. Nevertheless, these tools offer relations and dependencies between points, curves and surfaces embedding fixed or variable parameters. Smart geometries are associated with parametric environment which has been developed in the car industry and Aeronautic industry ending by the aero architecture (Araya, 2006; Kilian, 2006).

The "Smart Geometry" organization was founded in 2005. It discussed the term smart geometry and the new methodologies to design some of the most radical buildings of our generation using Bentley's parametric Generative Components technology. Generative Components was developed by Dr. Robert Aish (Smartgeometry2008).

Aish explains, "With the advent of digitally controlled fabrication, the 'geometrically aware' and 'computationally enabled' designers are now as close to the materialization as in the original craft process, but with precision and control and the ability to explore variation which was previously unimaginable." (Day, The smart revolution, 2006). Programming therefore is becoming an important skill to create one's own, design-specific digital context (Kilian, 2006).

It was previously recognized in the architectural geometry that every design begins with the Basic Geometric shapes; points, lines, curves and surfaces, all of which are considered as entities in the geometric concept. But in parametric design, the designer can't work with these palettes of shapes. Parametric design has to be built bottom up from points, associated together with specific relations that enable the modifications in the form of the building easily without repeating all the procedures to build a model from the beginning. In addition, using simple or complex mathematical equations help to explore a new series of shapes and solids. Each designer can add his own new features which creates designs that are more innovative expressing his own character. Buildings with any form even being complex and double curved could be subdivided in wise small parts with approximate dimensions using iteration and replication in GenerativeComponents language to consider the fabrication process in early stages.

1.1. PARAMETRIC DESIGN

It is important to know how elements relate to each other, but it is not necessary to know their absolute dimensions. Parametric modeling has set the stage for the expression of elements as a set of relations that have variable dimensions. (Kilian, 2006; Araya, 2006; and Aish, 2006).

It is concluded that parametric design is defined as a design which is a rule based producing variations to maintain the dependencies and relations between them in order to introduce a fully organized controllable building forms.

Parametric generative design is considered the 5th phase of the design development as shown in the following diagram (Figure 1).

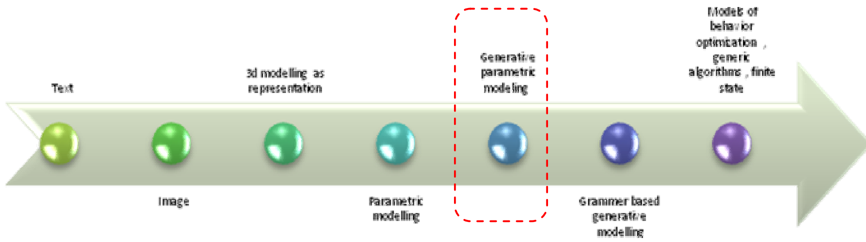

Figure 2 Parametric generative design phase through design movements

The parametric platform applied focuses on the assembly of components, functionality, computational and conceptual models within a design process. This program is called Generative Components.

1.2. GENERATIVECOMPONENTS (GC)

It is a design exploratory tool is defined as "a model-oriented end-user programming environment that combines direct interactive manipulation design methods based on feature modeling and constraints, with visual and traditional programming techniques" (Aish, 2006). In addition it turns user-defined geometric and behavioral design models into new classes (or types) of objects (or components). It is developed with Microsoft .NET technology.

Generative Components enable the designers to direct their creativity to wide range of exploration using "what-if" scenarios. Association and parametric relations can reduce time consumed evaluating different design proposals.

Generative components, in most cases, are used as an assistant system within some other software specialized in environmental, structural analysis, precise details and final presentation of the architectural projects.

A new version of Generative Components has been recently launched at the beginning of December 2008 introducing new features.

1.2.1. GenerativeComponents features

In general GC attracts the architects with its easy manipulation and emphasizes its uniqueness by a number of features.

- Geometric and algebraic programming, scripting and operations all create user defined components based on relationships and parameters.
- Fully association property which combines feature interactive design methods with constraints.
- Design alternatives exploration.
- Abstraction of design directs the manufacturing assembly from early stages in the design process.
- Replication speeds up the design iterations.
- Parallel representation (graphical, transactions, symbolic) as shown in Figure 2.

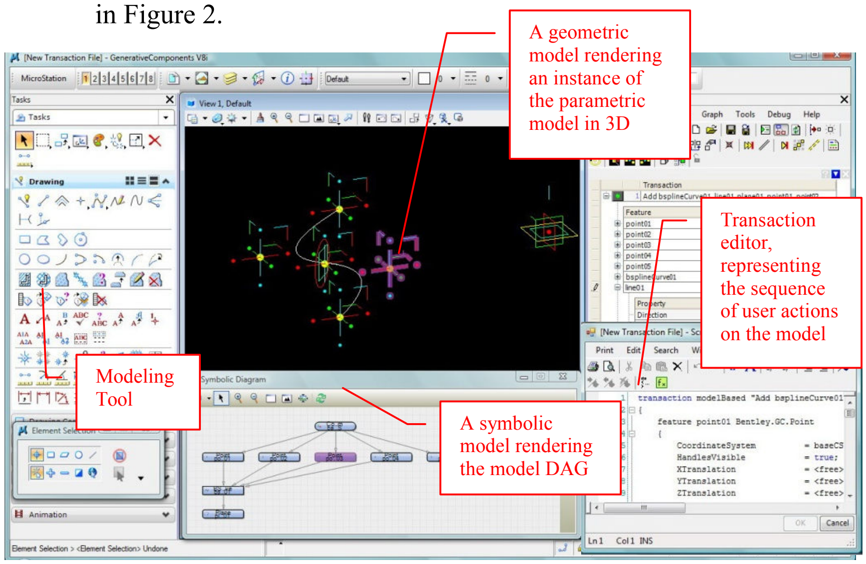

Figure 3 the interface of generative components showing the parallel representations and modeling tools (image by author)

All these features overcome the limitations of the previous CAAD software even the parametric ones.

1.2.2. Generative Components Limitations:

In spite of all these features, there are some complaints concerning the gap between the coding part and the design resulting of that particular script being executed (Araya, 2006). Architects still need a GC developer who can translate the designer's architectural concepts mathematically into the program. Architects could use Generative Components easily when mathematics and geometry courses are added to their studies. It needs large firms with wide markets as well which only use it in 5% of their projects because of cost effective experiments at the present time.[1]

2. Office building Design Process (generative approach)

To design an office building, many criteria should be taken into consideration:

- Number of storyes, proportion of plan aspect ratio and module,
- Form of circulation; loop, single, double corridor, radial, escape points,
- Environmental aspects; natural lighting, ventilation, sun motion, windows openings,
- Construction grid, position and number of cores, number of office units, atrium position, services floor, leisure functions in position with view (Graphic standards, 1996)[2].

In the design process,

- Start with defining the problem first with all its aspects in order to act as the design driver afterwards.
- Indicate the initial shapes that will pass through generating process or will be replicated under iteration process. This procedure is achieved by indicating the initial coordinates of the basic vertices in each section composing the overall form of office building, Figure 3.

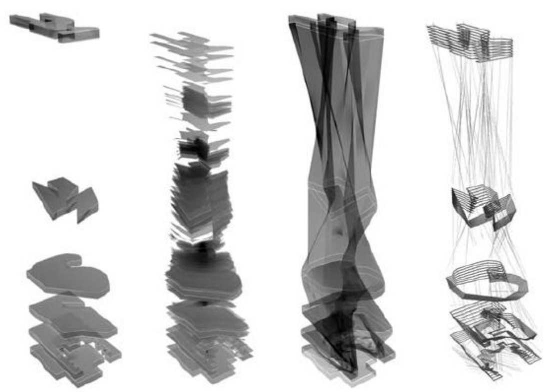

Figure4 Vertical transitions (class project by J. Paek and C. Santos for course GSD2311 taught by Kostas Terzidis *in fall 2005 at Harvard University)*

[1] http://www.stress-free.co.nz/internet_enabling_generative_components_for_a_new_breed_of_aec_consultant (27-1-09)

[2] This part is still in progress

- Derive the rule schemata "parametric shape grammar to allow the lengths of lines and the angles between lines to be varied in shapes. Values are assigned to the variables in these schemata to produce specific rule" as shown in Figure 4 (Stiny, 1985) which will be followed to generate the initial shapes.

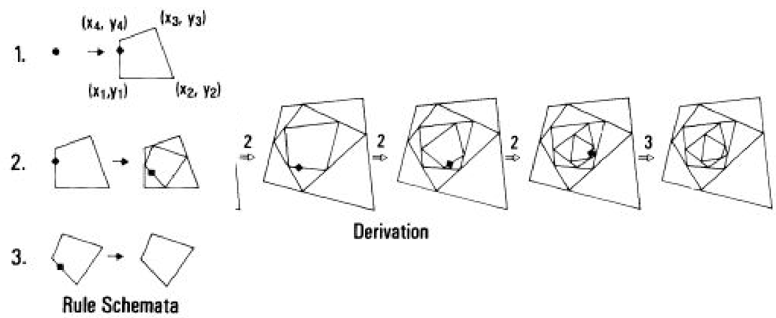

Figure 5 shape grammar using rule schemata generating derivation

- A matrix expressing the relation of functions is designed to indicate the degree of associative relationship between the functions and main components in addition to the environmental aspects.
- Consequently, design enters a phase of design solutions which is generated by the parametric software producing a number of alternatives that will be evaluated precisely to pick up the most suitable solution achieving the most perfect criteria.
- Design form and function is developed thus acquiring flexible formal progression with more uncertainty control, as shown in Figure 5.

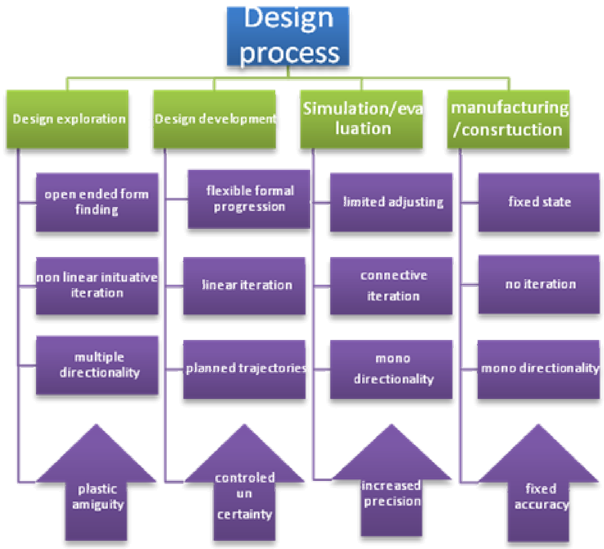

Figure 6 Design process gradients of flexibility, directionality, definition, accuracy and scale. (Araya, 2006)

- Finally, design reaches the manufacturing and assembly phase which was previously considered in the early stages of concept phase. At this stage, it is allowed to design double curve complex surface using different methods by cutting them in pieces , see fig (5).This will result in large collections of pieces, almost all equal, but every single one slightly different. In regular CAD this operation is extremely time-consuming. (Araya, 2006)

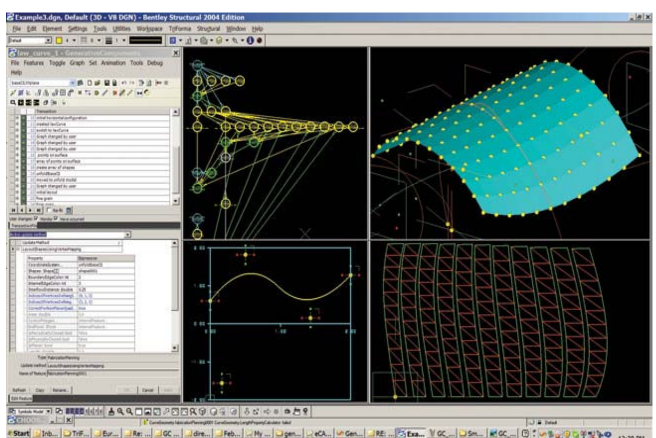

Figure 7 *showing how the parametric GenerativeComponents software can divide any shape to almost equal parts.*

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