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Tall Building Form Generation by Parametric Design Process

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Abstract
Historically, the development of the tall building has been dependent on technological advancements. As the continuous advancements of technology impacted tall building design and planning, the architectural profession also changed to keep up with the rapid technological progress. One of the recent remarkable technologies is the use of the computer to analyze complex structural systems and its ability to produce construction documents. However, digital tools to assist in architectural design to generate innovative tall building forms have not progressed at a comparable rate. This paper will discuss the generative concepts of a tall building forms and an innovative design process using digital tools that are based on a parametric design approach. The paper will discuss a series of transformations based on architectural as well as geometrical properties that can be used to define tall building forms and the development of a process to generate representations needed for visualization and study model making. The intention of the paper is to inspire continued interest in new concepts of tall building forms and to investigate a design process that integrates architecture with digital methods.

Keywords: Tall building form, Design process, Digital tool

1. Introduction
The symbolic value of a tall building is very powerful in a urban landscape. To architects and the public, the form of a tall building is primary concern, and the attitude is critical toward the outcome of the design. The approach to designing evolutionary tall buildings is an open subject of professional debate, and the role of the architect in designing them is very important, particularly from the point of view of form generation. Recently, a few architects have presented building forms that exhibit a more complex geometry. With the introduction of digital tools, generative design possibilities can be more fully explored with these geometries.

In the development of tall buildings, the overall building form should be one of the major elements that impacts building aesthetics and behavior. However, architecturally, structurally and aesthetically, it is a complex task to develop an optimal form for tall buildings due to the interrelations of large numbers of components. The attempt to combine more than one major function in a building or complex presents the designer with several problems. Each function has different planning considerations for optimum and habitable space. Due to the inter-related functional requirements within a building, one change can affect many other factors that must be considered when developing a project.

The use of digital tools in the schematic design phase of tall building design is still quite limited. The computer-aided design includes using a computer not only for visualization, analysis, and evaluation, but also for the generation of designs or, more accurately, for the rapid generation of computable design representations describing conceptual design alternatives. Potential design alternatives are generated and evaluated in order to obtain the most promising solution.

The advantage of parametric design in this research is to plan and synthesize the overall requirements and relationships of many design elements into one form (see Figure 1). This process allows the designer to investigate variety of possible solutions quickly.

This research is concerned with tall building forms generated by digital tools based on the architectural and structural criteria. It explores potential generative
forms, and also suggests an innovative design process using digital methods. The following objectives have been identified for this:

- Define the relationships between design criteria and overall tall building form
- Explore the various geometries and transformations for tall building form
- Suggest an innovative digitally based design process for tall building design
- Suggest generative forms and concepts of tall building that meet the design criteria
- Develop an architectural design methodology using digital tools

However, the selection is complex to arrive at the best alternatives since tall building forms include a large number of disciplines that sometimes conflict with design requirements. Once the proposed scheme has been accepted the building design is progresses into the design development stage.

In parametric design, it is the elements of a particular design that are declared, not its shape. By assigning different values to the parameters, different configurations can be created. The proposed design process in this paper is based on parametric input (see Figure 2). Parametric design consists of a set of variables and a series of relations to define a form. The overall form can be manipulated by altering specific parameters that are able to automatically adjust building data such as total gross area, total building height, total number of floors, and aspect ratio.

2. Proposed Design Process

The design of a tall building involves professionals from several disciplines, starting from the conceptual design to final design documents. The entire process is rather complex in that it requires experts from different disciplines. In the schematic design phase, architects and engineers create a set of alternative possible tall building forms. The output of conceptual design can lead to design concepts that can be used as a basis for embodiment and detail design. Although schematic design phase only occupies fifteen percent of the total design fee, this stage is more important than the other stages because about eighty percent of the resources required to build a structure are committed by decisions made during the conceptual design stage. This early phase of design is the most crucial part of the entire process.

Potential design alternatives are generated and evaluated in order to obtain the most promising solution. Ordinarily, several alternative solutions are proposed to the client for consideration or approval.
Parameters are expressed as numeric and geometrical relationships. To design with these relationships requires the establishment of a series of parametric principles. Development of tall buildings could be determined by design factors; these factors have several parameters such as user needs, functional requirements and structural demands (see Figure 3). These design parameters are dependent upon planning considerations. Items related to planning considerations are building functions, core planning, lease spans, and floor-to-floor height. These considerations are interdependent with each other and they affect the overall building design. In this research, all of these considerations are the design parameters to achieve an appropriate solution.

Before selecting a building geometry, it is necessary to set the appropriate spatial requirements. These areas must include base and top floor areas and appropriate core areas with proper lease span by function. The core area is determined by total number of elevators and elevator zoning. The number of elevators can be calculated by given gross area of each function and design guidelines. The base and top floor area calculation worksheet consists of these complex relationships (see Figure 4). By using the worksheet, appropriate core area, proper base and top area, and number of floors each function will be set quickly before form generation. This process establishes the architectural requirements for the project.

3. Geometry and Transformation

Geometry plays a critical roll in the generation of building form and structure. Geometry in the schematic design helps to explore design ideas. This paper explores potential geometries and new concepts of vertical transformation to create an overall spatial form using non-conventional concepts. A geometric shape has own architectural and structural characteristics. Tall building forms can be designed based on geometric shape. The explored geometries in this paper are focused on symmetry. One polygon’s corner can be another polygon’s center. These combinations generate many symmetrical forms usable for tall building form as shown in the geometry table (see Figure 5). Same side distances and same bay corner columns characterize these symmetry geometries.

Conventional building form along its height can be described as prismatic, tapered, and setback. This paper presents non-conventional vertical transformations such as setback, section morph, twist, and curvilinear. This investigation covers the development of a series of starting and ending floor plate shapes for a set of floors. Figure 6 shows the combinations of starting and ending geometries. According to each combination, different number of control point will be decided to create a form. Throughout this process, numerous new concepts of tall building form can be explored. Digital procedures are developed to transform starting floor plate shape to the ending shape. Operations such as rotation, scaling, and morphing are demonstrated for a variety of basic shapes. Embedded in the generative process are architectural and structural criteria that limit the resulting form.
Fig. 5. Examples of Explored Symmetry Geometries

Fig. 6. Examples of Combinations of Base and Top Geometries
4. Form Generation

In the conceptual design phase, creativity and exploration are very important. With appropriate input parameters, the form generation program is executed. In this process, forms can be generated with any combinations of the explored geometry and the defined vertical transformation (see Figure 7). The form generation program consists of four groups, which are section morph, setback, twist, and curvilinear group. Each group has different architectural and structural characteristics and different parameters to create a form.

Figure 8 shows four example forms with different vertical transformations of same combinations of base and top geometries. After the combination of base and top geometries from the geometry table is selected, each geometry’s area and dimension are set based on the area calculation worksheet. Examples were generated with 2,000,000 sq ft office, 400 units hotel, and 400 units apartments. The area calculation worksheet shows approximately 400,000 sq ft for base and 12,100 sq ft for top. Figure 9 shows the selected geometries and dimensions.

Fig. 7. Exploration of Generative Forms

Fig. 8. Examples of Generated Forms

Fig. 9. Example of Selected Base and Top Geometries
After base and top geometries are set, the form generation program can be operated with several parameter inputs to get total number of floors and forms. Automatically, each form’s building data and structural layout data that are members and joins read for any of structural analysis program are created. The Parameters of each group:

• **Section Morph:** The number of control point depends on the combination of geometry. Parameters; base and top geometries, location and number of control points, number of floors by function, and floor-to-floor height by function.

• **Setback:** The number of setback will be determined by architectural and structural design criteria. Parameters; base and top geometries, location and number of control points, floor-to-floor height by function, number of setbacks, rate of each setback, and number of floors of each step.

• **Twist:** The angle of twist will be determined by architectural and structural design criteria. Parameters; base geometry, location and number of control points, floor-to-floor height by function, and angle of twist.

• **Curvilinear:** The line factor of curvilinear line will be determined by architectural and structural design criteria. Parameters; base and top geometries, location and number of control points, number of floors by function, floor-to-floor height by function, line factors of each line, and curve factors of each line.

5. Evaluations

In this phase, explored potential tall building forms can be evaluated in more detail against architectural and structural design criteria. The three-dimensional model is one of the manifestations of the computer model. The forms are developed completely with digital models from the very beginning. As an outcome of this research, three-dimensional generated building forms can be constructed as three-dimensional surfaces for rendering and three-dimensional model for structural analysis (see Figure 10). To check architectural building properties automatically a spreadsheet can be generated in the Microsoft Excel format (see Figure 11), and input data file can be created for direct analysis by structural analysis program.

Finally, to physically compare alternative forms, study models can be made by the laser cut process. With given scale of model, the material and its thickness for laser cutting will be decided. The laser cut program generates every floors plate configurations and register slots at a given scale (see Figure 12). Once every floor plate is cut with a laser cutter, they are assembled with the register slot. As shown in the Figure 15, the study models in this paper are made at 1 to 600 scale. Additionally, more-detailed model can be made showing columns, floor slabs, core shape, and envelop.
In the schematic design phase, parametric design can generate a series of designs quickly, which consider a series of architectural and structural design criteria. The proposed design process has the advantage that procedures perform set of inter-related all necessary tasks in the schematic design phase such as planning and design, visualization, analysis, and model making (see Figure 13).

6. Conclusions

The intention of this research is to inspire more interest in a innovative concept of tall building forms through integration of architecture and digital technology. The focus of this research is to suggest the generative forms as applicable to architecture by means of architectural and structural evaluations and also form generation process. This research will contribute to the Form Development of Tall Buildings.

Technology can be used as an architectural tool to produce not only the better performance design but also generative and innovative concepts. The improvement of design quality and design process using advance technology is more practical and challenging task for the professional development. By integrating digital tools based on design criteria rule and design requirements with new concept tall building form, the generative potential forms can be determined. Development of such a method enables the designer to uniquely apply their design concepts easily and evaluate a variety of alternatives.

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