On Design Continuity with Smart Cloud of Points

Eyal Nir[1]*, Guedi Capeluto*[2]
[1]*Shenkar College of Engineering and Design*
[2]*Technion – Israel Institute of Technology*

The continuity of the design process is not well supported by the widespread available CAD systems that mainly focus on specific design stages overlooking the transition between them, where some of the design information is lost or duplicated. The growing use of complex geometries in architectural design projects led to the adoption of constraint-based parametric modeling techniques in the construction industry. Applying these techniques and tools requires rationalizing the design solution and fixing its geometry at an early design stage. When done prematurely, it can result in design fixation and restrain the design creativity, putting it within constraints. In this paper we explore the use of Smart Cloud of Points (SmCP) as an adaptive design media supporting the continuity of the design process.

Keywords: *Parametric Design: point-clouds; performance driven design.*

Introduction

Technological and cultural developments supported the growing use of complex geometry and free-form shapes by architects in recent years (Vollers, 2001). The ease of use and availability of advanced 3-dimensional CAD tools have brought greater freedom of shape to the design, enriching the preliminary conceptual stage (Burry & Murray, 1997). The transition from concept to form in the conceptual stage of a design has a major impact on both the definitive design stage and the performance of the built design. In many cases there is a gap between the first idea which express the designer's original intent and the constructed building while generally the tools available during the design process do not allow the designer to bridge this gap. Moreover, sometimes these tools are unable to help in the transition from the three-dimensional idea to a build-able form (Turk, 2001). The continuity of the design process is not well supported by the widespread available CAD systems, one example for that is the document exchange process that takes place when more than one CAD tool is used in a design project. In this process, information may be lost or duplicated and therefore create set backs in the design process.

The Design Process Continuity

The design process is a multi-stage and multi-participant process and can be divided into five phases: briefing, conceptual design, schematic design, detailed design and execution design. A typical design process, following the five stages mentioned above, is generally performed in a linear fashion. Each phase defines and manages the design information independently, communicating its results and information to the following phase (Asanowicz, 2001). This linear design strategy has been supported by the development of specific digital design tools for every design phase. Digital sketching tools were developed to support the conceptual phases and precise drafting applications for detailed design phases. The need for continuity in the design process rise as the design is more complex involving multiple tools and multiple designers. To achieve this continuity we suggest separating the design logic from its visual representation. This separation is the foundation for Smart Cloud of Points (SmCP), a parametric point-cloud design model that supports the transition between the design stages as an adaptive design model (Nir, 2005; Nir & Capeluto, 2005). Smart Cloud of Points provides a representation of the design logic and intent that can be applied directly to CAD software using generative modeling techniques. The design logic is represented as an adaptive model that supports the clarification process of design information as it progress and develops throughout the various design stages. As the design progress and clarifies, it wears an appearance which best fit the design stage. Keeping the logic model in an abstract numeric form, allows communicating and developing it along the design process, hence maintaining the information flow and continuity of the design process, as will be explained in the next section.

Case Study: Albion Riverside

In this section we explore how SmCP can support the design continuity using the Albion Riverside project as a case study. Albion Riverside development is located on the south bank of the River Thames in London. The building is an eleven storey curvilinear structure with glass and aluminum cladding designed by architects Foster and Partners using generative modeling techniques. The roof and wall continuous section sweeps along the spiral plan following a sine wave to accommodate the building cores. The development of the building geometry employed parametric design tools to generate design alternatives and achieve an optimized design solution. The use of SmCP in this example starts with digitizing the building form by sampling 22 points along a curve drawn to its section profile. The section profile includes the wall and roof sections that

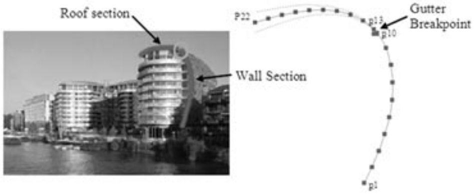

Figure 1
Section profile setting out.

are separated by a gutter channel (Figure 1). The gutter channel provides a break-point for two topological surfaces. The wall section is used to generate a sweep surface along the plan curve and the roof section is used for generating a sinusoidal sweep surface where the section profile rocks up and down as it sweeps along the plan curve resulting in a doubly curved sinusoidal surface.

The SmCP model data structure of a point consists of four coordinates describing its X, Y and Z position and a numeric pointer to an algorithmic behavior pattern that generates a spatial point-cloud geometry when applied (Nir, 2005, Nir & Capeluto, 2005). A multi-layered parametric control interface is provided for the designer allowing the generation of design alternatives while maintaining the design logic. The first layer refers to the design geometry and allows introducing both typological and topological transformation. Using point-cloud to define the design geometry provides a flexible representation. This parametric point-cloud model is explored as an alternative to the parametric constraint-based system which was used by the project architects. The SmCP model does not require rationalizing the design into a fixed number of arcs and lines, as required when using a constraint-based model which eventually determine the design topology and therefore restrict the designer only to typological transformations. With SmCP, by altering the parametric values of a behavior pattern various design alternatives can be generated within the behavior topology. Moreover, topological changes can be easily introduced by assigning a different behavior pattern represented in the forth coordinate of each point (Figure 2). Any transformation applied to the design model maintains the continuous surface of the building en-

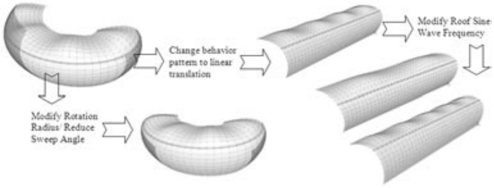

Figure 2
Typological and topological transformation using SmCP behaviour patterns.

velope that was expressed in the design intent described by the architects.

The second layer of parametric control of the SmCP model manages the population of the point cloud geometry with parametric components. A library of components created in CAD software is linked to the design geometry using a schematic layout table as an unfolded representation of the design surface. Each cell of the table contains the name or code of a component the designer chooses from the library. The component population algorithm acquires the orientation, location and size from the point-cloud geometry and attaches the component specified in the schematic layout table. This allows for exploring various design alternatives for the development of the building façade components. The multi-layered control allows altering the design geometry and regenerating the detailed design model with no draw backs in the design process (Figure 3).

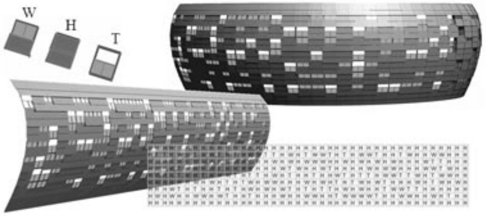

Figure 3
Generative façade components populated on different point-cloud geometries according to a schematic layout table.

Applying performance analysis algorithms to the design model allows maintaining the performative aspects of the design within a desired boundary that satisfies the requirements expressed in the design intent. For example, an accumulative solar radiation study of the façade can be used to define the components layout according to their solar performance (window size, glazing type, PV panels, etc). To demonstrate it, a set of parametric components named by a numeric value that indicate their opening factor is created. These components populate the façade point-cloud geometry based on the radiation study results by attaching the tabular form containing the results as a schematic layout for the component-population algorithm. This allows for a performance driven design process where the geometry of each design alternative is evaluated and populated with façade components according to the performance study (Figure 4).

Conclusions

The paper presented the Smart Cloud of Points as an adaptive design media for supporting the continuity of the design process. The use of SmCP shows how the development of conceptual-schematic ideas on one side and detailed design aspects on the other is kept while introducing typological and topological transformation to the design geometry. The multi-layered data structure allows handling every design aspect separately and overlay it at any given time to form the complete design model. Assigning relationships between various design aspects such as performance issues and façade components layout establish logical order within the design model. Therefore it assures that the alterations of the design model yield design alternatives according the requirements stated in the design intent and design logic.

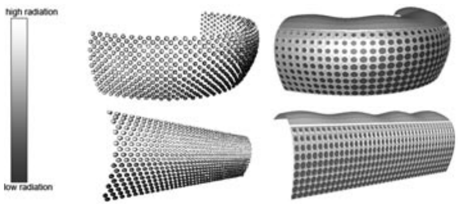

Figure 4
Performance-based generative components. Accumulative solar radiation over the façade (left) and opening factor (right).

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