Cognitive Models for Parametric Design

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Abstract *Parametric models have different uses in architectural design, from design inception to design development, evaluation, performance, and fabrication. This paper introduces five (5) classes of parametric models which can be used in* ***parametric design*** *and presents one example of each class.*

Introduction Parametric models are geometrical representations of designs done in the computer where the models have attributes or properties that can vary and others that are fixed (Barrios, 2006). These attributes can be geometrical, numerical, positional, and relational. The attributes that vary are called parametric and they are parameterized with variables that can have multiple values. The attributes that do not vary are said to be explicit. The value of an attribute can be constrained to the value of another variable (explicit value), of it can have no value associated (implicit value). Attributes that are fixed or whose variables are constant are said to be constrained.

Contrary to some belief Parametric Design is not a specific modeling program or computer graphics language with geometrical components that can easily vary. Just like Computer Aided Design (CAD) is not a specific program or language. Although some scholars use parametric model and parametric design interchangeably, there is a fundamental difference between them. Parametric Design is the action of designing, and a Parametric Model is the medium used to design. In simple terms, Parametric Design is designing with the use of Parametric Models (Barrios, 2006).

Parametric Modeling The fundamental purpose of Parametric Modeling is to allow effortless variations of the geometrical components of a digital model at any stage of the design process. The idea of variation of geometrical components is natural in computer aided design (Monedero, 2000) where most geometrical operations, such as Euclidean transformations, are performed with ease. Figure 1 shows a parametric model of a single 3D geometrical shape and some of the possible variations of the original model. This kind of Parametric Model is also named Parametric Model of Variation Geometry, or simply Variation Geometry. In this case the parametric model allows the variation of the attributes of the parameterized geometrical components to create new configurations. As a result, new designs can emerge from the same initial model that does not require being erased and redrawn (Barrios, 2004).

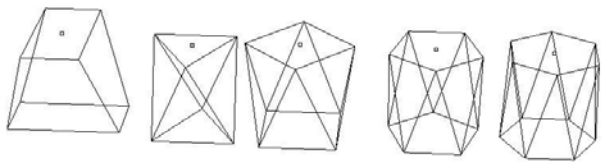

Figure 1. Parametric Variations of a Parametric Model.

There is however a limited range of operations that a single Parametric Model can do. The previous model, for example, can only make a single 3D closed shape. In addition to that, the previous model can only produce similar designs to the original parametric model, which are designs in the language of the parametric model. For more complex designs, a different type of parametric model can be created, like models for parametric combinations (Barrios, 2006).

In parametric combinations a number of components are joined to make complex designs and new spatial relations. These combinations are made by following specific rules of how to combine the geometrical components. Due to the finite number of primitive components and means of combination parametric models based on parametric combinations have also limited applications.

A limited number of possible designs will emerge, even though in some cases that limit can be a very large number. These are some of the major challenges to overcome when doing parametric design.

Cognitive Models for Parametric Design Due to the complexity of parametric models and the unpredictable nature of design, it is very difficult to predict all the possible scenarios that a designer might encounter when working with parametric models. The need for different cognitive models for Parametric Design offers the possibility to address different situations and aspects in the design process that would be very difficult to perform with a single parametric model. It very simple terms, it is the application of the divide and conquer principle.

Parametric Models For Exploratory Desing These models are mostly used in the initial stages of design to explore the design space or universe of possible solutions to a design problem. Models based on variation geometry are of this category. This models offer the ability to make transformations of designs with little effort. Figure 2 shows a family of shapes that where generated with the same parametric model. All shapes have in common the rules used to generate and the same topology. However the parametric model is able to generate different geometrical configurations allowing a simple and rapid exploration of the possible design solutions.

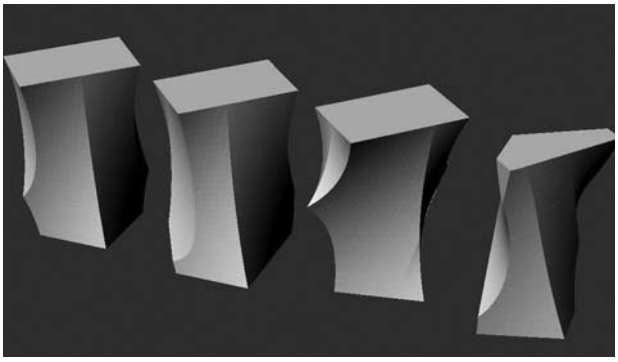

Figure 2. Parametric Model for Exploratory Design. Different design configurations are produced with a single parametric model.

Reusability Adaptability models, also known as design features, are based on the idea that a single model can be used in different scenarios, therefore allowing repetition with adaptation to local conditions. In some circumstances, these kinds of models have the capacity to detect changes in its environment and reconfigure to the new circumstances that emerge from the environment. Some others are able to be flexible enough to allow small changes locally and globally. Figure 3 shows an example of a complex geometrical shape that is reused with rules of symmetry to create a complex array of objects. Only one parametric model was created (indicated by wireframe geometry) and the rest was reused and adapted to a new condition based on the input rules.

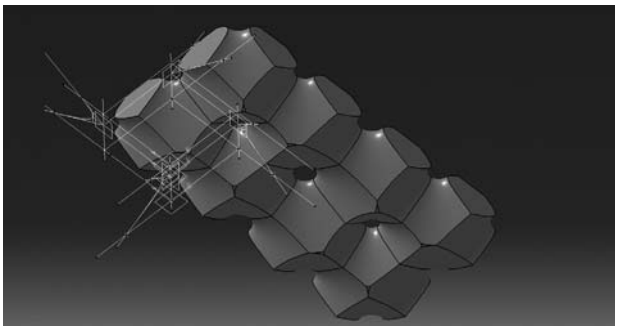

Figure 3. Reusability of a parametric model. One parametric model is used in different scenarios through duplication and local adaptability.

Parametric Models For Interactive Feedback Interactive feedback models are used when a set of the universe of solutions has been determined to contain candidates and it becomes necessary to explore such set in detail. An evaluation system works in conjunction with the parametric model which then provides immediate feedback to the designer when changes are performed. In this case the evaluation systems working with the parametric model help the designer assess the possible outcomes of the set of solutions that the designer is exploring. Figure 4 shows and example of this application, where a parametric model contains information on the properties of the surface that is constantly updated to inform the user whenever the parametric model changes.

These models can be used for performance based evaluation during the design process.

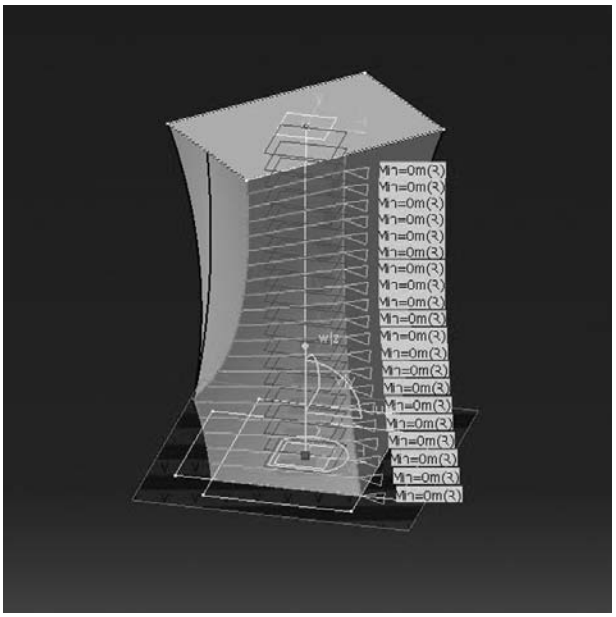

Figure 4. A parametric model that shows the properties of the surface curvature. The information on the curvature will be updated every time the design is changed allowing the designer immediate access to this information.

Parametric Models For Progressive Optimization This particular model expands on the model for interactive feedback in which helps the designer improve or refine at every step of the design process. Particular criteria will be set for the purpose of refining the selected design and progressively optimize it to arrive to a satisfactory solution. A parametric model for progressive optimization works in conjunction with a series of fitting functions that determine the best solution of a smaller universe of possibilities *(Figure 5, 6)*

Knowledge-BasedParametric Desing This type of parametric models serve for the purpose of helping the designer to make decisions based on the interaction of a parametric model with a knowledge-based system. The knowledge-based system will advice the designer on the decision making process on areas that the designer might not have expertise.

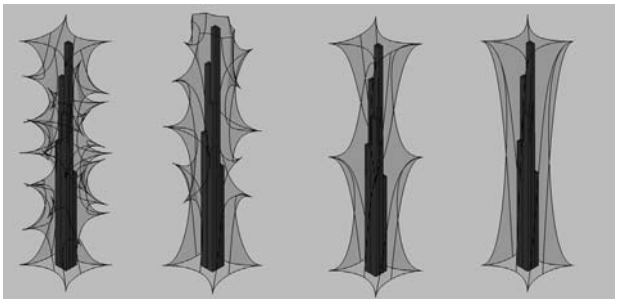

Figure 5

Figure 5,6. A parametric model that shows steps in the refinement of the geometry to minimize curvature cusps.

Conclusion The use of parametric models in design can be understood as a search problem in a very large space of possible solutions. Computationally, his can be a very expensive task even with the most advanced algorithms. Nevertheless, different tasks can be separated into individual parametric models for specific purposes. The presented cognitive models are not finite, but represent most of the tasks that a designer might encounter through the design process. This allows designers to effectively use parametric models through design encapsulation.

References **Barrios, C.**, 2006, ***Thinking Parametric Design: Introducing Parametric Gaudi.*** Design Studies 27, pp. 309-324. / **Barrios, C.**, 2004, ***Parametric Gaudi,*** in: VIII Congreso Sociedad Iberoamericana de Grafica Digital SIGraDi. Sao Leopoldo, Brazil, November 2004. pp 213-215. / **Monedero, J.**, 2000 ***Parametric design: a review and some experiences.*** Automation in Construction Vol 9 No 4 pp 369-377.

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