# Parametric Affordances What, When, How

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Parametric Affordances presents a theoretical framework for development, use and implementation of parametric models in a design setting. This paper presents fundamental background theoretical concepts and proposes an approach to separate tasks and actions of the design process in different kinds of parametric models to take advantage of them.

## Introduction

The use of flexible geometry in computer graphics dates from the very first inceptions of computer modeling software such as Ivan Sutherland's *sketchpad,* a computer program he developed at MIT in 1963. Among the many features of sketchpad was that geometrical figures could be moved, copied, rotated or resized (scaled) while retaining their original properties, which allow under some cases to create *duplicates* (identical clones) or instances of the *master geometry* while transformations propagate to the instances without additional editing. Although powerful, sketchpad's features were somewhat cumbersome and limited by the computer power of the time. This idea of flexible geometry became the holy grail of computer graphics software that was pursed in many cases with the implementation of the history stack, tools like the "undo" and "oops" commands, or the hierarchy tree, but once again limited by the memory and processing capability of the computer hardware.

However, it is only until recently that efficient forms of flexible tools for editing geometrical models have become available as standards in most mainstream computer graphics software. Different software packages have implemented their own flavors for variable and flexible geometry, and today there are a myriad of *variable geometry gizmos* grouped under the umbrella term *Parametric Design*. Parametric Design remains as the customary name given to computational procedures that allow flexible editing of geometrical entities without erasing and redrawing. But, what exactly is *parametric design*?

## Fundamental Concepts: WHAT

Before defining what is Parametric Design (PD) let's take a quick step back and define some fundamental concepts. First and foremost is the distinction between *Parametric Model*s or *Parametric Modeling* (PM) and *Parametric Design* (PD), two different terms that are very often confused or used interchangeably.

In generic terms, a Parametric Model (PM) is defined as a group or cluster of geometrical components that have attributes (properties) that can vary and other attributes that are fixed. The fixed attributes can be of two kinds, *static*, when the value does not change (fixed value) or *constrained*, when the attribute is associated with a fixed location or position. In this last case, if the value of the parameter can change, then it is not a considered a fixed attribute.

The variable attributes are called *parameters* and they can be of several types. Generally speaking, a parameter is a placeholder for variables to exist allowing different values within certain possible limits (range), hence allowing variation to take place. Parameters (variable attributes) can be of different kinds, but most can be grouped in the following six categories:

1. Independent: those attributes that can take any allowable value that is valid within the range of possibilities.
2. Dependent: are those attributes that vary but with respect to the value of other attributes or parameters. They can take the form of mathematical equations or numerical relations. For example, the value of the parameter can be the result of the solution to a mathematical function. The value of the dependant parameters can be the result of a linear or non-linear dependency.
3. Relational: Parameters that depend on a relation or sets of relations with respect to other attributes. Examples of this kind are relations between geometrical components (perpendicularity, parallel, concentricity, etc), adjacency or location.
4. Boolean: parameters that, based on a specific condition can take values that are usually opposite, by either being "on" or "off", or in an "active" or "inactive" state.
5. Conditional: are those parameters that will take the value depending on the evaluation of an initial conditional state. If a condition is met, then the parameter will have a specific value, or allow values within a specific set. If the condition is not met, then the parameter will either have a different value or allow values of a different set.
6. Temporary: is a parameter which value is constrained, or dependent of a condition that might be temporary, or will have a value or set of values that will be valid as long as the condition is still valid.

In this context, Parametric Design is defined as a design process where parametric models are used, thus making a clear distinction between the process and the tools used for the process.

## Fundamental Uses: WHEN

In the context of architectural design, and in particular in academic environments, PM have been used primarily for three pusposes: exploration of formal design ideas, refinement, and integration through building information modeling.

Design exploration refers to the process of initial design ideas or *Design Discovery* (DD) during the initial phases of the design process. Through variations in the generic geometrical arrangement of geometrical components, a Parametric Model (PM) will allow flexible exploration of a design idea when some of the geometrical components are not fixed. This is particular useful in the early stages of the design process when a generic idea might be defined, but there is a high degree of uncertainty in the final geometrical and formal configuration of the design. During this stage a high degree of flexibility is desireable in a parametric model, at least until some decisions of the overall building configuraion are made. Parametric Models for Variational Geometry (Barrios, 2005) are the most comon used in this initial stages of the design process. These are PMs with geometrical components that have a high degree of freedom and where hierarchies and dependencies are built with ease. These kinds of models have the ability to resemble rubberband-like behavior where geometrical components are easily adaptable.

Models for *Design Refinement* (DR) are used in an intermediate stage after the initial ideas in Desgin Discovery have been determined, but right before design development stages. In this stage a generic form has been found or determined, but certain configurations are still under exploration. A level of feedback is sometimes implemented at this stage through performance or aethetic evaluations that can occur within the model or with an external based measuring criteria. Design is progresively refined through an itterative process of variations and evaluations to indicate optimal results, or tradeoffs beteen the different design solution candidates. It is very often that in these kinds of models the geometry is accompanied by the use of spreadsheets, tables or other kinds of figurative elements that will inform the designer of the consequences of the actions when varying the model, thus indicating when a specific action will yield closer solutions to the desired results. Designers will use this data to make informed decisions when evaluating possible candidates for the design solution.

The last form of PMs used is for coordination towards building a complete and realist ic geometrical model with attributes that contain data and information about architectural elements in a building. In this case, a successful model will have a minimun set of flexible geometry that will be independently variable, while the rest of the geometrical components will necessary become dependent parametric entities. A typical scenario is a *Parametric Skeleton©* with a few points and lines that controls a surface as independent parameters (as few as possible) and a large array of geometrical objects dependent on the surface configuration that will respond to any changes occuring in the underlying geometry. Another typical scenario is the where complex surface and solid geometry is dependent on lower level entities either as basic point-data, or numerical values that control geometrical configurations which can be input in spreadsheets. In both cases serveral higly complex geometrical objects or collections of objects are attached to the simple geometry as dependent entities in the *parametric infrastructure©*. In this kinds of PMs, and for the most part, the objects are created as parameterized and dependent entities of the uderlying parametric infrastructure. Ussually this models are very complex in their structure, and seldomly varied as they demand extensive use of computing resources with frequent unpredictable results when geometry is changed. In some cases forcing designers to freeze the parameters to avoid undesired changes. This is perhaps one of the most difficult challenges in current modeling systems.

## Alternative Uses: HOW

Traditionally a parametric modeling software serves for the purpose of creating geometrical entities that allow the designer the exploration of different design alternatives by making variations on the geometrical components of the model and responding to them. This affords the designer to navigate through possible design solutions without much effort. However there are far more possible applications that a parametric model can be used for.

In 2007, the author published a paper and proposed five different cognitive models for parametric design to aid the designer in different phases of the design process. In that paper, it was clearly identefied that different stages of the design process would require a different kind of parametric model. In just a few years later, new developments in computer programs have incorporated some of the features proposed in the paper, such as reusability of parametric features, such like the ones existing in BIM modeling programs. The proposed model aimed to provide a robust structure in which changes in geometry would be related to other features in the model. Although the flexibility of reusing parametric geometry in different models has existed in Feature-Based Design modeling software, this did not existed in the context of architectural design as stand alone integrated package.

A second model proposed that has catched up very quickly is flexible interactivity between variable geometry and properties associated with it. This particular class of PM is referred to the *Interactive Feedback Model* (Barrios,2007) In an interactive feedback model, the geometry has a level of intelligence associated with evaluators that will inform the designer the consequences of their actions in real time at the moment of performing parametric variations. Although computers have had the capacity to perform in this manner, it is still not necessarily integrated in current software platforms. Therefore it is up to the designer to build the geometry containing the appropriate links, attributes and evaluators to create a model with such behavior. It is clear that such enterprise might represent a challenge since it is very difficult to predict what a desing will look like and how it will behave until a model is done. The default solution from most parametric modeling software is to provide generic tools to allow the designer customization at will and for each case, although some effort and progress has been made in recent developments to make this seamless.

is defined as a geometrical entity composed of geomtrical elemnets that have attributes (propoerties) that are variable and other attributes that are fixed. The fixed attributes are called static when they have a fixed value, or constrained when they have a fixed location. The variable atributes are called variables, or parameters and can be independent or dependent. The dependent attributes will take their value from another external parameter creating a dependency relation. The independent attributes are free to take any value that the designer assigns.

## Affordances

One of the most important questions to ask is what is the purpose of using a parametric model, in other words: WHAT kind of parametric model or parameterization scheme to use; WHEN to use it for the purpose of helping the designer and the design process; and HOW to take advantage of the parametric model to better suit the needs of the designer. The fundamental premise that a PM can and should help the designer create a multitude of candidates for design solutions, evaluate, sort and rank them, inform the designer of possible outcomes or warn him of posible conflicts, and finally allow the proper management of data contained in the geometry seems a rather straight forward task for a computer to perform, but experience shows otherwise. On one hand, as design develops and the complexity increases, models require inmense resources to handle enhanced amounts of data, while at the same time become more intricate and difficult to manage efficiently. On the other, as the design develops and decisions are made, there seems to be less need for flexibility and more for interconnectivity among the geometrical components of the model.

In general a parametric model if used for a specific purpose it should be tailored to suit that purpose. This calls for a redefition of a parametric model as a universal container of all geometrical components with multiple layers of relations that can control all aspects of the model, geometrical or not.

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