“Improvising” Architecture: A Fractal Based Approach

Özgür Ediz
Uludağ University, Department of Architecture, Bursa / Turkey
http://www.ozgurediz.com
ozgurediz@gmail.com

Abstract: In this study, a computational, generative design model is investigated in the context of an approach based on improvising in architectural design. This approach asks the question: “How can fractals be used in the architectural design process?” The initial focus is the similarity between the architectural design process and musical improvisation. This is informative because improvisation in the design process can aid in developing numerous design alternatives. An understanding of improvisation in jazz music is particularly relevant for the architectural design process.

Keywords: Generative design; fractal-based design; computational architectural design; improvisation; jazz music.

Introduction

Computers have been used as tools for representing human-conceptualized shapes in the past few decades, replacing tracing paper and pen as the de facto drawing utensils. However, the potential of computers has been truly unlocked with the introduction of computational architectural design.

Negroponte (1970) in essence summarizing the recent utilization of computers where forms are generated somewhat outside of the control of the designer states that “computers are intellectual machines that allow us to simulate human behavior”. The designer is often required to define design parameters, or identify an algorithm, which ultimately is responsible for the resultant shape. Thus, the designer’s new role is to provide the “intelligence” that is the core of a set of design rules, while the computer provides for calculating power and randomness. Therefore, computers are bound to become an indispensable pre-design tool for generating multiple alternatives, from which a designer can pick and further his proposal. This process has been referred to as the computer’s potential to become “an active creative partner in design” (Shea, 2004).

The starting point of the theory behind computing in architectural design is based on Aristotle’s concept of a generative system that can provide a variety of potential solutions to a problem (Mitchell, 1990). Systematic use of generative systems in architectural design is not only a function of the computer age, as it was applied by Leonardo Da Vinci in the design of central plan churches. Similarly, Durand used this systematic approach to generate plans and elevations from different combinations of building elements.

The lexicon of the computer age refers to this principle as shape grammar or design grammar. It is based on the generation of shapes according to a parametric shape rule schemata. Applications of shape grammars and other grammatical formalisms in architectural and engineering design have been growing steadily and impressively in the last decade.
This paper presents an innovative method to produce alternative forms using digital technologies in the conceptual design phase of an architectural problem. The concept of fractal-based computational design is introduced at the onset, followed by a description of CADaFED (Computational Architectural Design approach based on Fractals at the Early Design stage). Briefly stated, CADaFED is software developed for the specific purpose of generating parametric architectural models to provide a digital medium for designers to extend their imagination.

**The computer as an improvising machine**

**Improvisation**

Improvisation is the practice of acting, singing, talking and reacting, of making and creating, at a given moment and in response to the stimulus of one’s immediate environment. This can result in the invention of new thought patterns, new practices, new structures or symbols, and new ways to act. This invention cycle occurs most effectively when the practitioner has a thorough intuitive and/or technical understanding of the necessary skills and concerns within the improvised domain.

The skills of improvisation can apply to many different contexts; artistic, scientific, physical, cognitive, academic and non-academic, as well as various disciplines, such as music, cooking, business, sports, and the arts.

**Improvisation in jazz music**

This is the spontaneous creation of music in the course of extemporaneous performance. There is, however, always a model or framework that determines the scope within which a musician may create. In the case of jazz, the model may be a series of harmonies that determine pitches to be selected for a melody; or a melody that is subjected to variation; or a set of motives from which a selection is made (http://www.music.princeton.edu/~jeffery/Ellingtonvocab.html: February, 2009).

**Generative design**

The concept of computational design is related to a number of overlapping fields including, generative design, parametric design, algorithmic design, and computational creativity.

Generative design methods have been identified as having two unique sources:
1. Natural analogy and
2. Logical basis (Knight 2002, in Shea 2004).

Shea (2004) identifies neural networks, cellular automata, genetic algorithms, genetic programming, particle swarm optimization and self-organizing systems as generative computational processes having their roots in nature. The logical basis, on the other hand, necessitates an understanding of the “underlying logic of objects and systems of objects to form rules that generate a language of valid objects” (Shea, 2004).

Generative computational design has been explored in computer science and linguistic research, as well as aerospace and nautical engineering. Earliest examples can be found in Chomsky’s work on generative grammars, which eventually led to advanced computer languages being built. Parallels can be established with architecture by replacing Chomsky’s symbols with shapes. Chomsky’s generative grammars were developed from his initial work on well-formed strings of parentheses. These generative grammars are now integral to computer languages and compilers (Stiny and Gips, 1972). In architecture and design it would be more natural to compute with shape directly rather than symbols. This idea prompted the creation of shape grammars (Stiny, 1980) and has been applied in architecture to produce languages of architectural form, often to recreate and extend the style of a particular architect (Shea, 2004). Recent examples of the shape grammars include, Traditional Turkish Houses (Çağdaş, 1996), The Prairie Houses of F. L. Wright (Konig and Eizenberg, 1981) and Alvaro Siza’s Houses (Duarte, 2005).
Design approach

“Let us build machines that can learn, can grope, and can fumble, machines that will be architecture partners, architecture machines” (Negroponte, 1970).

Bernard Bell applied formal languages to the representation of musical processes. The initial interest of this research was the structure of improvisation in “North Indian tabla drum music”. Experiments were conducted in the field as far back as 1983 with an “expert” system called the Bol Processor, BP1. In this system, the computer was used to generate and analyze drumming patterns represented as strings of onomatopoeic syllables, bols, by manipulating formal grammars. Material was then submitted to musicians who assessed its accuracy and increasingly more elaborate and sophisticated rule bases emerged to represent the musical idiom (Bel, 1992).

Just as in Bel’s approach, if we know the language-grammar of a settlement, we can improvise similar patterns in the architectural design process. In this paper, a method based on fractal dimensions is used for defining local architectural characteristics. This is akin to improvising a tune in jazz music. This method has been termed as CADaFED (A Computational Architectural Design approach based on Fractals at the Early Design stage) (Ediz, 2003). This method can be applied to both settlements and patterns. The concept of fractals is utilized to analyze the characteristics of architectural patterns formed by sociological, cultural and environmental factors.

Fractal dimension in architectural design

The fractal dimension, which is obtained by a calculation process applied to a selected settlement’s patterns at different scales, are used for creating new forms. This can be considered as a form of improvisation in the architectural design process. This calculation process has been described in previous work (Ediz, 2003), and will be briefly described in this paper.

The fractal characteristic of an object is determined by a mathematical parameter called fractal dimension. Fractal dimension is usually represented with a number between 1- 2. As the number approaches 1, Euclidian geometries emerge, a shift towards 2, results in the generation of more complex shapes.

With the new design approaches based on computer generated design systems, fractals have begun to be used consciously in computer generated architectural design. Fractals are used in the area of computational architectural design by means of generative models to support creative design processes. The fractal dimension takes its place in this process as an input for creating new architectural objects.

Generative algorithms can be used for creating new form alternatives in the area of computational architectural design.

This study utilizes a three-staged design model based on the fractal approach for generating new form alternatives. The chosen settlement, which possesses a unique architectural grammar, has been examined for the purposes of this study. It is intended to produce a new pattern for a building, where the existing architectural patterns are reflected in the outcome.

Key

The jazz musician X, described improvisation as a “spontaneous invention within the context of a given key; creating a new melody while performing; spontaneous composition” (www.jazzinamerica.org/l_glossary.asp: February, 2009)

In Jazz music, it is important that the spontaneous creation of melodies or patterns is not entirely rootless, but takes key changes into account. A key is the reference point for improvising. It is like a structure or DNA code. One has to be at least intuitively aware of the individual notes within a key to construct melodic patterns within that key. In generative design, the fractal dimension is the “key” that determines the potential variations of a specific shape or pattern.
Once an appropriate fractal dimension is chosen, it is used to determine the number of guide lines on x-, y-, and z-axes of the initial block in order to aid in subtracting pieces from the mass. In this way, new form alternatives are generated.

If the fractal dimension is increased, the number of subtracted initial shape masses is increased as well, and a more complex form emerges (Figure 2).

Through using fractal dimensions, CADaFED can also create 2D patterns, such as settlement layouts (Figure 3).

Conclusion

Analogic theories and approaches are used in a number of fields such as linguistics, music and geometry to aid in creativity. These theories are based on either (1) natural analogies, or (2) have a logical
basis (Knight 2002, in Shea 2004). The theories of generative design that have a logical basis are dependent on mathematics and algorithms.

In architecture, generative design approaches use algorithms similar to those in Jazz music. In essence, the fractal dimension refers to the characteristics of the context akin to a “key” in musical terms. Just as a fractal dimension aids in expeditious creation of multiple alternative forms, a key provides the musician with a basis to improvise an infinite number of tunes.

In architecture, fractal dimensions can be selected based on ones calculated for local architecture, as well as ones that are in contrast to the context. This decision is entirely up to the designer. It must be taken into account that the forms defined by the fractal dimensions are not only dependent on shape, but also on the sociological, cultural and environmental factors of the specific project site.

If functional necessities can also be implemented in a computer algorithm, environments that are not only harmonious as 3 dimensional shapes, but also architecturally meaningful can be created. This remains the next avenue to be explored in computational architectural design.

Acknowledgements

The author would like to thank Philip Smith, Yavuz Taneli, Ian Kaplan, and Gizem Kaya for their assistance in editing the final manuscript.

References
