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Architectural Forms by Abstracting Nature

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Abstract

The structures in nature are great lessons for human study. Having been in development for several billion years, only the most successful structural forms have survived. The resourcefulness of material use, the underlying structural systems and the profound capacity to respond to a variety of climatic and environmental forces make natural form tremendous exemplars to human architectures. The wholeness of natural form indicates that the form and forces are always in some sense of equilibrium. In most of natural forms, the quality of equilibrium may be difficult to recognize. However, seashells are one of the natural forms whose functions are simple enough to be approximated by a simple mathematical relationship. The focus of this study was to understand the seashell form as applicable to human architectures. Digital methods are the language to analyze, create, and simulate seashell forms, as well as, suggest a variety of possible architectural forms.

1. The Study of Natural Forms

The study of seashells has a long history, starting with Henry Moseley in 1838 [1] and followed by many researchers such as Thompson [2], Raup [3, 4], Cortie [5], and Dawkins [6]. These researchers have outlined in a number of mathematical relationships that control the overall geometry of shells. Our interest centers on an investigation of natural forms as a starting point to generate architectural forms.

As documented by prior researchers, the seashell geometry can be expressed by four basic parameters. Figure 1 indicates these parameters that influence the shell forms.

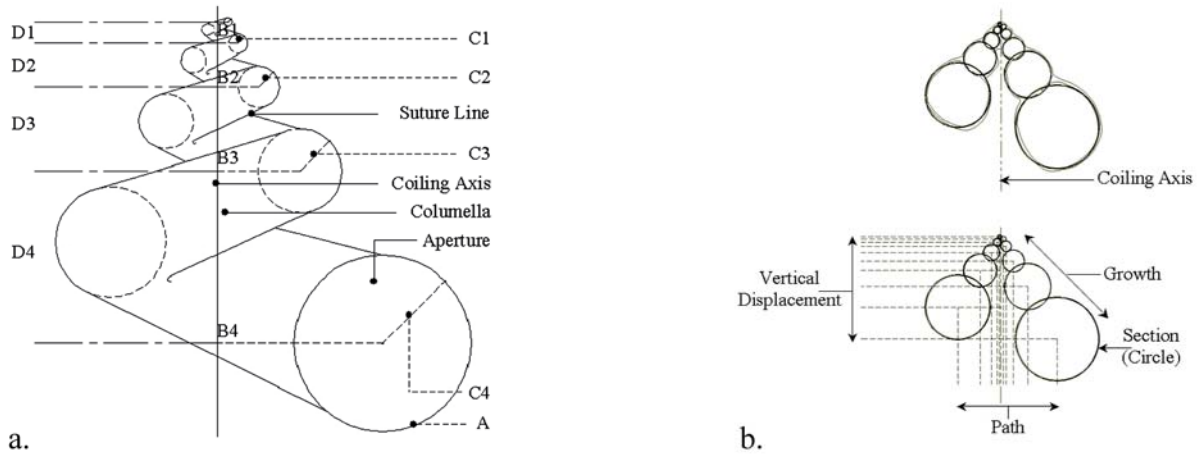

Figure 1. The four parameters.

As shown in Figure 1a, A is the shape of the aperture or the shape of shell section, B is the distance from the coiling axis to the center of the shell section, C is the section radius, and D is the vertical distance between sections. To understand the mathematical relationship of these four parameters, Figure 1b illustrates the measuring concept of one coiling shell of the gastropods class and Figure 2 illustrates its digital geometry reconstruction.

Figure 2. The wire frame and mesh model of selected seashell.

Each seashell can be reconstructed in a digital form with variations of the mathematical relationships among the four parameters. The result of a specific mathematical combination reflects the shell form for a specific seashell specie. In this study, the concept of creating architectural form originating from seashell geometry can be accomplished by applying these parameters to an architectural form interpretive exploring process.

Using mathematics as a tool of investigation in both the natural and architectural forms gives us an advantage of exploring multiple forms easily and allows us to implement new parameters into the mathematical framework. Architecture, which exists in a dramatically different environment from the seashell, has other parameters to be integrated during the architectural design process concerning its form. These parameters are designed to accommodate the practical requirements of architectural forms.

2. Abstracting Nature

The abstracting process combines three major components that influence the final result of an architectural form. These components are the seashell geometry properties, seashell structural properties and architectural properties.

2.1 Seashell Geometry Properties

There are four known parameters in the study of seashell geometry; path, section, growth and vertical displacement. Each parameter is represented by a specific mathematical curve in which it can be replaced with series of different mathematical curves to develop an architectural form. In the seashell form these mathematical curves are limited to those that appeared in the actual geometry of shell such as logarithmic spiral, circle and ellipse. In the architectural form the limitations are less, however, only mathematically defined curves are chosen in this investigation according to the fact that seashell form always exhibits a curvature. For a clearer understanding in replacing seashell parameters with other mathematical functions, the mathematical curves are divided in to two simple groups based on their mathematical properties; closed curves and open curves. Figure 3 illustrates the sample of closed and open curves and diagram indicates the use of each group.

2.2 Seashell Structural Properties

The actual shell geometry responses to any load outside by redirecting forces within a very thin section of shell structure along its natural multiple curvatures. Finally those forces are transferred to the supported area such as ground, rock or sand depending upon how the seashell positions itself in the environment. By acknowledging this structural phenomenon and understanding its weakness against tension forces, the compressive shell form suggests the possible structure of the architectural form beyond the existing forms of man-made shell

structure. Its structural properties applied to architectural interpretations are included the shape of section, the overlapping section, and the support condition.

2.3 Architectural Properties

In architecture, there are some basic design criteria that architects and engineers have to take into consideration when developing building forms. In this investigation those criteria are treated as architectural parameters. These parameters emerge from architectural design principles that make architectural forms inhabitable. Without a specific requirement of an actual site and functions, the architectural parameters for this study can be set as ground condition, orientation, human scale and enclosure.

As architectural forms are developed the interpretation of these three major components yield the resultant of architectural form that contains the qualities of the seashell.

The architectural form generating concept adopts the four parameters from the seashell geometry and implements additional conditions based on architectural and structural properties into one mathematical framework. This mathematical framework then generates the result of the architectural form. Figure 3 illustrates the diagram of related parameters in various combinations that enable architectural form to be generated.

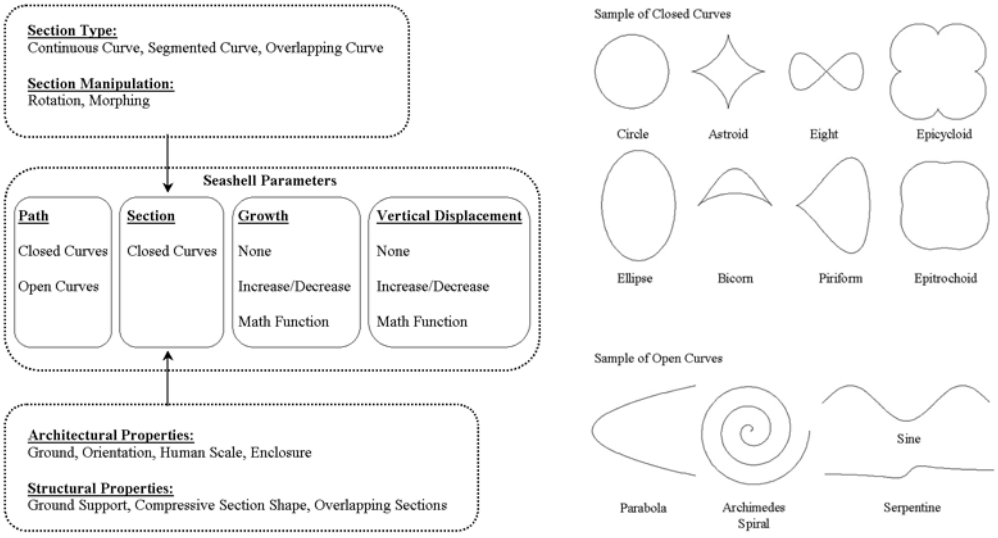

Figure 3. Architectural form generating diagram and mathematical curves.

To illustrate the possibilities of architectural forms generated in this process, samples of conventional and unconventional architectural forms are presented in Figure 4.

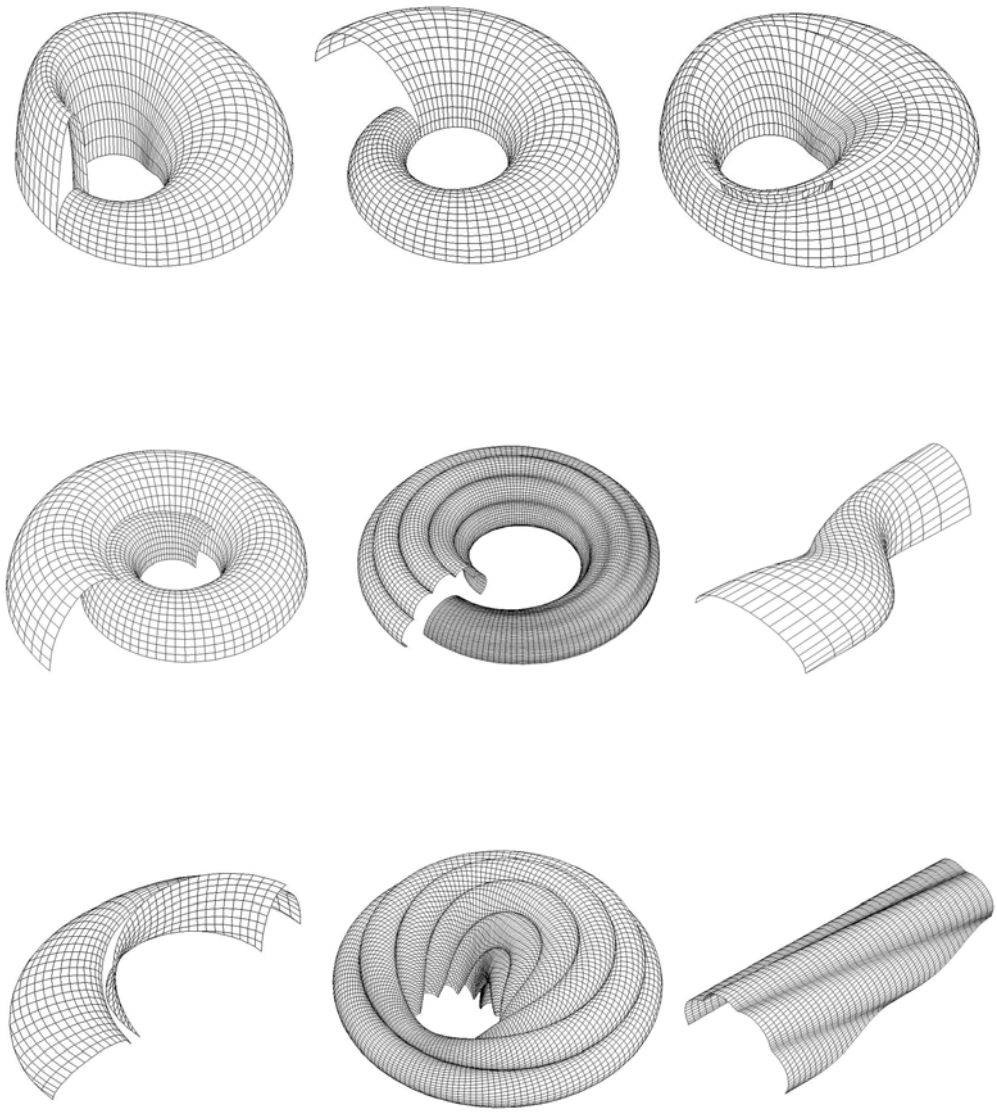

Figure 4. Sample of generating forms.

3. Architectural Applications

The result of forms developed by this process can be applied for specific architectural functions. Figures 5 exhibit the idea of how these forms can be used as architectural applications. Each form displays a virtual quality of architecture and is ready to be developed further to a real architecture with proper material and structural system selection.

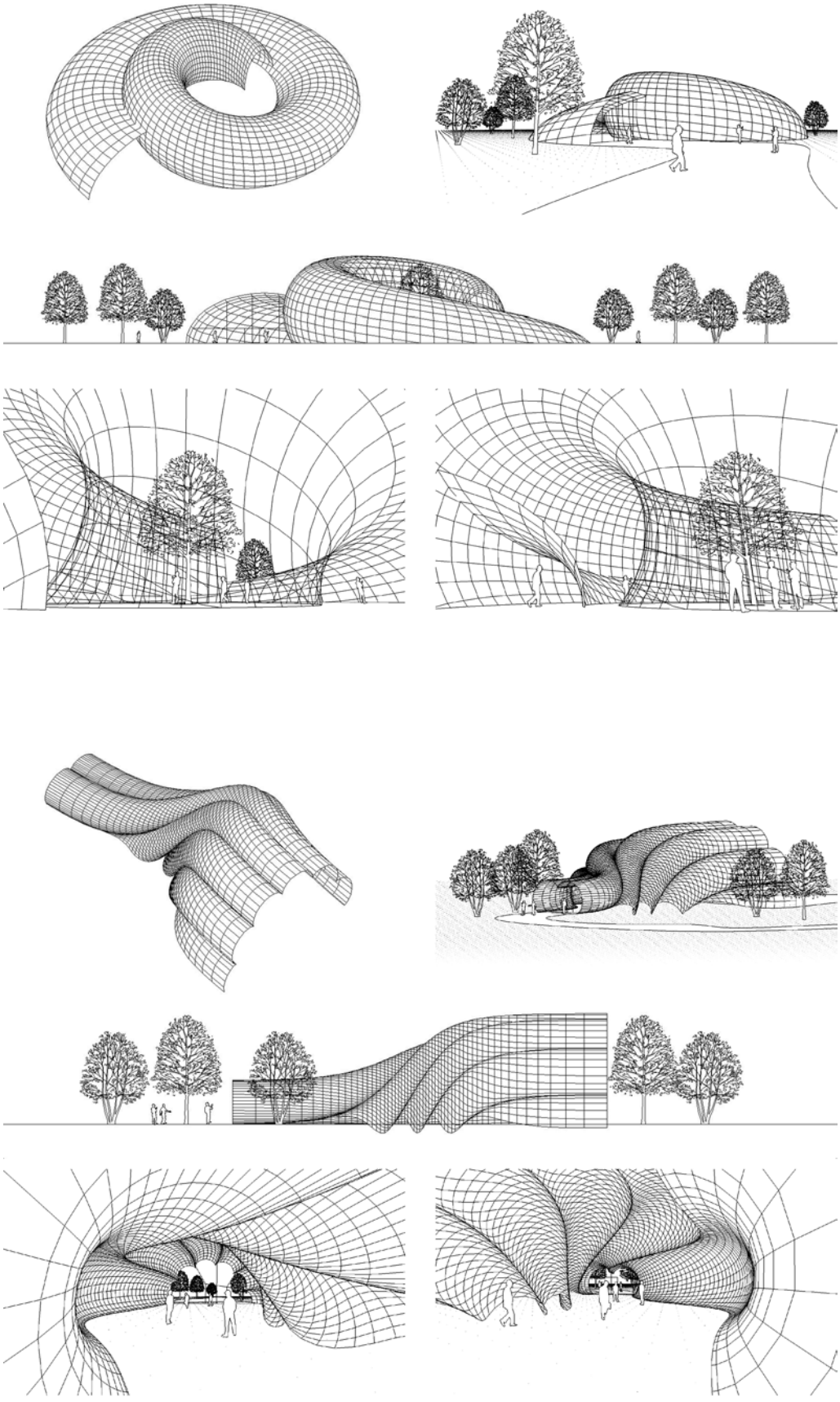

Figure 5. Sample of the architectural applications.

4. Observation and Conclusion

This research concluded that the value of the study of nature is not only for its power of inspiration and influence, but also for its abstract geometric properties. If the abstract properties can be described by the mathematical relationship, they can then be developed into a built form. The translation of abstracted nature in conjunction in concrete mathematical terms and by applying prerequisite architectural considerations is the fundamental concept of this form development.

The value of this research is the process of developing mathematically definable models into an architectural form. The process is flexible enough to be adjusted to a variety of parameters according to the specific requirements of each architectural project. The results are a family of architectural forms based on one simple mathematical comprehensive relationship.

5. References

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