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Seashell Architectures

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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 measurable mathematical relationships. 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. Introduction

The study of seashells has a long history, starting with Henry Moseley in 1838 and followed by many researchers such as Thompson [1], Raup [2,3], Cortie [4], Illert [5], Dawkins [6], Meinhardt [7], and Fowler, Meinhardt and Prusinkiewicz [8] . These researchers have outlined in a number of forms the mathematical relationships that control the overall geometry of a shell. Our interest centers on an investigation of natural forms as possible starting points to generate architectural forms.

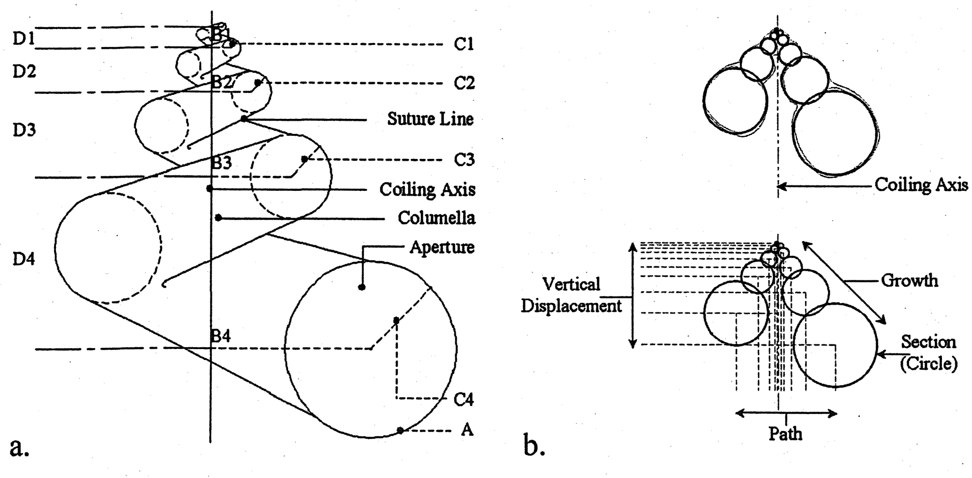


Figure 1. *The four parameters*

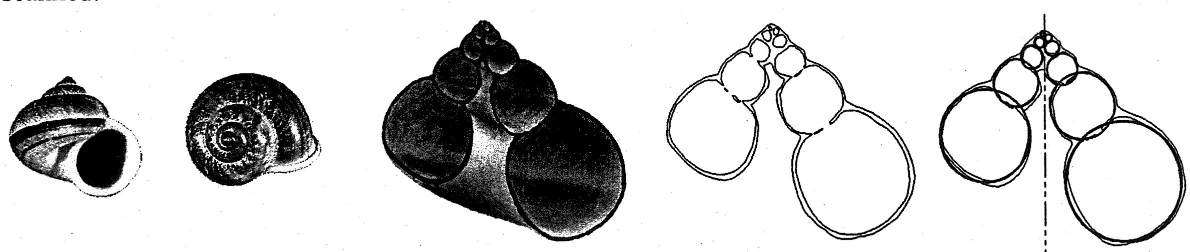
To study the shell, digital models had to be created that display the exterior surface of a seashell, as well as, its interior geometry. The interior geometry was needed so that an additional study could be made using traditional structural analysis software. Previous research only concerned itself with the modeling of the exterior surface of the seashell. The primary goal was to demonstrate the geometry and secondarily to have a surface which could be used to develop methods of creating patterns of markings. The only study found of the interiors of shells was conducted by Conklin [9] using x-rays.

As documented by prior researchers, the seashell geometry can be expressed by four basic parameters; 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. The columella is the elongated cone around the coiling axis, the internal structural support of the shell. The suture line is the intersection of the sections vertically. The columella and the suture line are the result of the spiral growth of the seashell.

To better understand the mathematical relationship of these four parameters, a number of shells of the gastropods class in the mollusk classification was selected for measurement and reconstruction. They were selected for their simplicity of form and their traditional spiraling quality. Their general geometry is illustrated in Figure 1b.

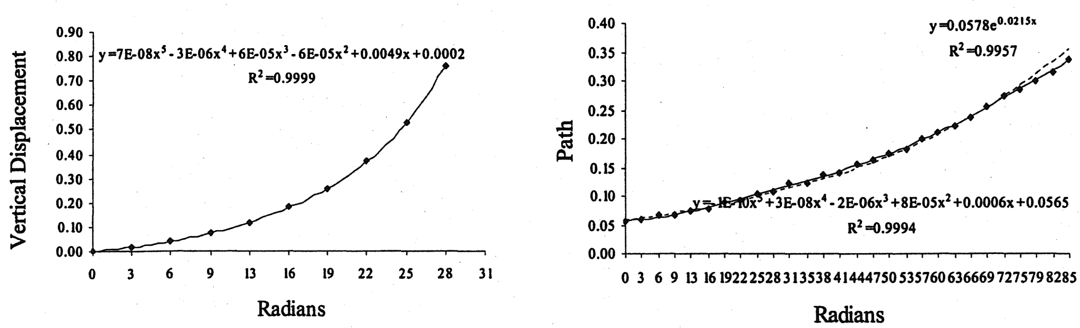
2. Preparing the Seashell Data

One such shell selected was the Tapestry Turbin. Even though the literature outlines the parameters for this class of seashell geometry, none was found that included specific values for a particular species. To be able to accurately model a specific species of seashell, one was selected and cut in half and then placed on a scanner to record its profile. Figure 2a. displays the selected shell, and 2b. the cut shell as it was scanned.



a. *b.* *c.* *d.*

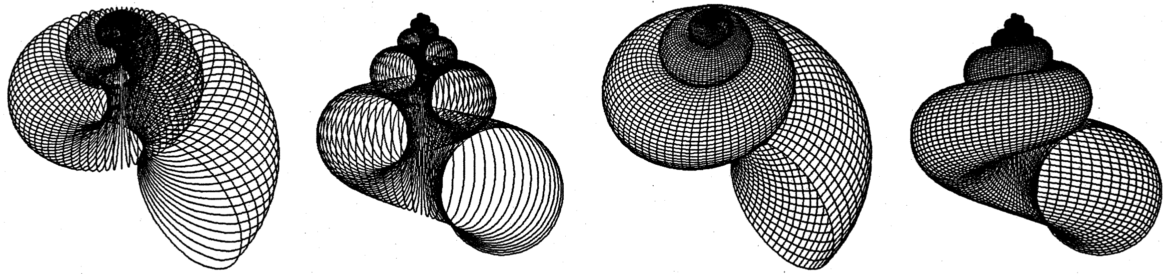
Figure 2. *Steps in preparing the shell.*



a. *b.*

Figure 3. *Relationship of vertical and path displacement.*

The scanned image was processed by Adobe Streamline to extract the edges of the image and to convert them into line segments, Figure 2c. These line segments were then imported into AutoDesk's AutoCAD package, Figure 2d.. Once the section became a traditional line drawing, a series of measurements were made to determine the section growth, offset from the vertical axis, offset from the top of the shell, its vertical drop, and the shape of the section itself. These parameters were then entered into an Microsoft Excel spreadsheet and curve fitting functions were applied to developed a set of best fit curve equations. Figure 3a. displays the results of vertical displacement and 3b. the radius offset of the horizontal path. Figure 3b. confirmed that these shells were based on the logarithmic spiral. A similar analysis from measured data was completed for section growth, the radius of the section. Other shells required the growth to be analyzed separately along the vertical and horizontal axis. These equations then became the basis for the generation of a three-dimensional mesh model. Since these equations were the result of curve fitting, all the shells we were able to reconstruct were a perfect version of the measured ones. Imperfections were not accounted for.



a. *b.*

Figure 4. *Digital version of the measured shell.*

Using AutoCAD's AutoLISP programming language a series of procedures were written to create a three-dimensional mesh model of the seashell. The equations obtained from the analysis of the shell measurements were the basis to construct a series of wireframe sections by computed spherical coordinates. Figure 4a. displays the first part of the model generation. For visualization purposes only, these sections could have been converted to patches or faces and rendered. Since an accurate model of the shell was required along with its internal structure, the intersection of these sections had to be computed. A second procedure compared these section to each other and modified them according to intersections. A few conditions had to be addressed. When sections overlapped, the overlapping portion had to be removed and the section profile modified. Depending on the vertical and horizontal offset, this overlapping could occur in a number of areas on any two sections. The overlapping section also required that additional nodes to be computed so that the connecting plates or faces accurately represent the actual shell and model the natural rigidity adequately. Once the nodes in the section were modified and added to, the section profile definition had to be reordered so the nodes in successive sections would align and so faces could be created between them. A final procedure was written to create triangular faces between adjoining sections. These faces form the exterior and interior surfaces of the shell. As these faces were created, each had to be checked for its size. The structural analysis software is sensitive to the aspect ratio of the length and width of these faces or plates. These had to be modified to conform to a specific range of sizes. Figure 4b. displays the final mesh model.

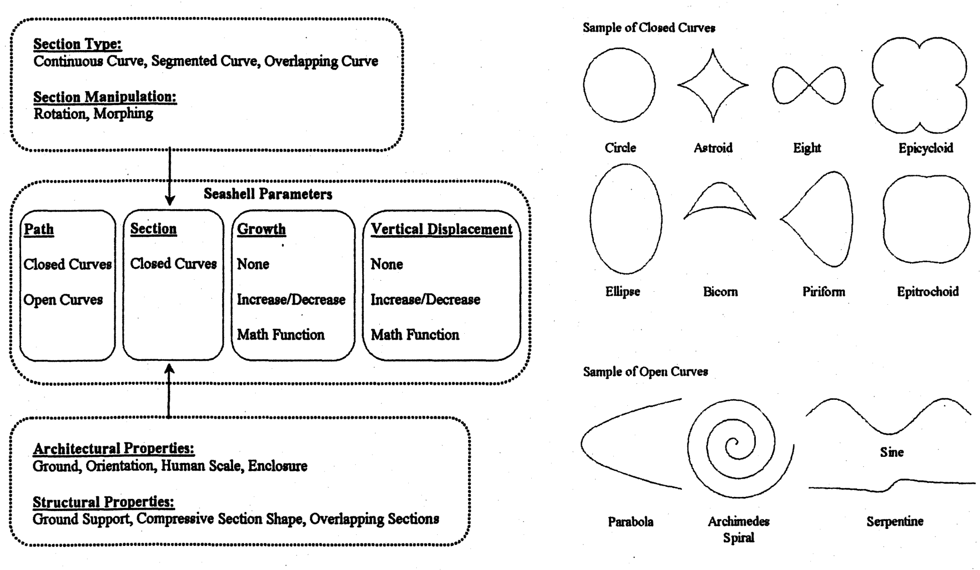
The final step was to render each of the shells measured. Renderings were produced of exterior views of the shells, as well as, an interior cut section. The material selected gave the shells a glass-blown quality which expressed the perfection of the outer surface modeled and which could display the hidden inner beauty of the shell structure.

3. Architectural Interpretation

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 same parameters in 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, such as, scale and orientation.

The method of generating architectural forms is developed by substituting each seashell parameter with other possible mathematical curves. Each selected mathematical curve represents a mathematical abstraction of a specific seashell parameter as it occurs in nature. This enables the exploring of new mathematical relationships to generate a variety of architectural forms. Figure 5. illustrates the architectural form generating concept and displays examples of other possible mathematical curves.



a. *b.*

Figure 5. *Architectural form generating diagram and mathematical curves*

Figure 6 displays one such example using a spiral path with increasing or decreasing section growth. Others that were included were first separated into three main categories: spiral, circular and linear path. Each of these were then examined with a linear increased or decreased section growth, vertical or horizontal axis or both at the same time; use of a mathematical function as the growth parameter; linear increased or decreased vertical displacement; use of a mathematical function as the vertical displacement parameter; rotated section; morphing section; segmented section; and overlapping section. An unconventional series was also developed that used a combination of the aforementioned parameters in a single form.

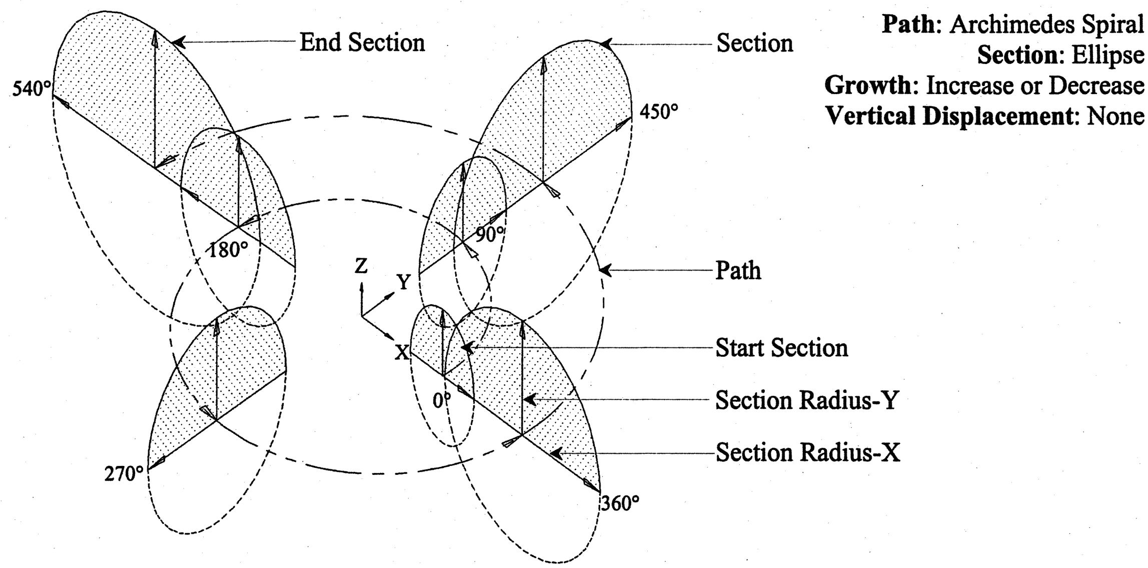


Figure 6. *Spiral Path Diagram – Increased or Decreased Growth*

To illustrate the possibilities of architectural forms generated in this process, samples of basic and unconventional architectural forms are presented in Figure 7. Figures 8 and 9 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.

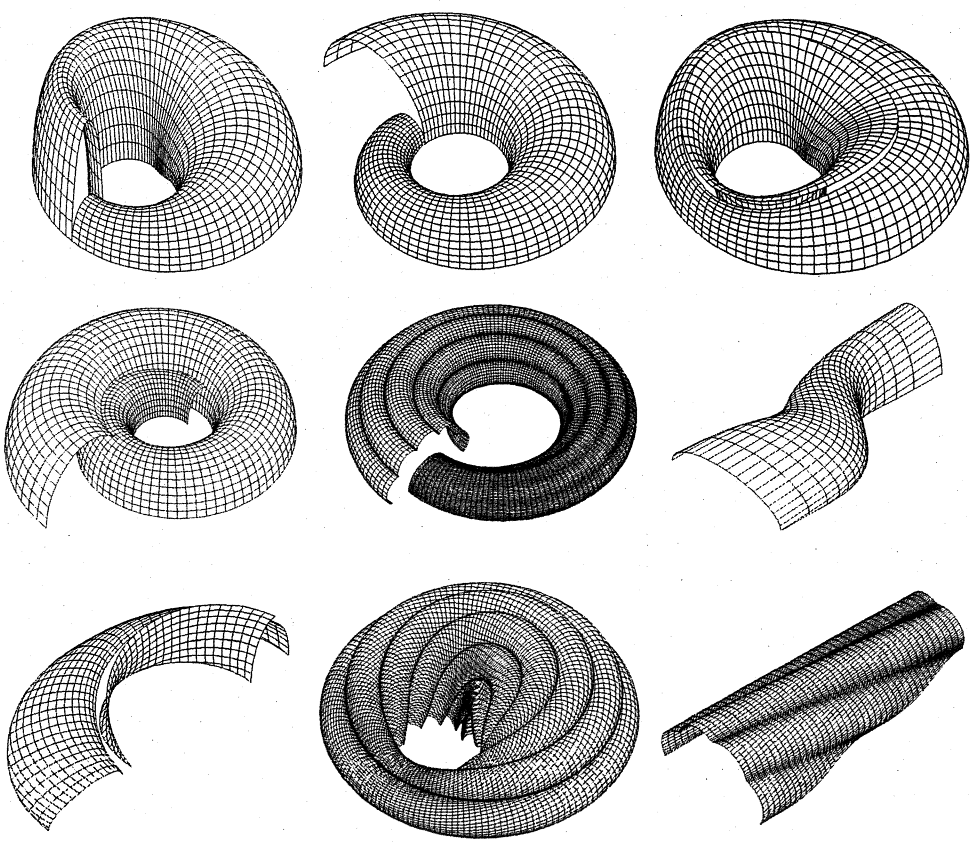


Figure 7. *Sample of preliminary results*

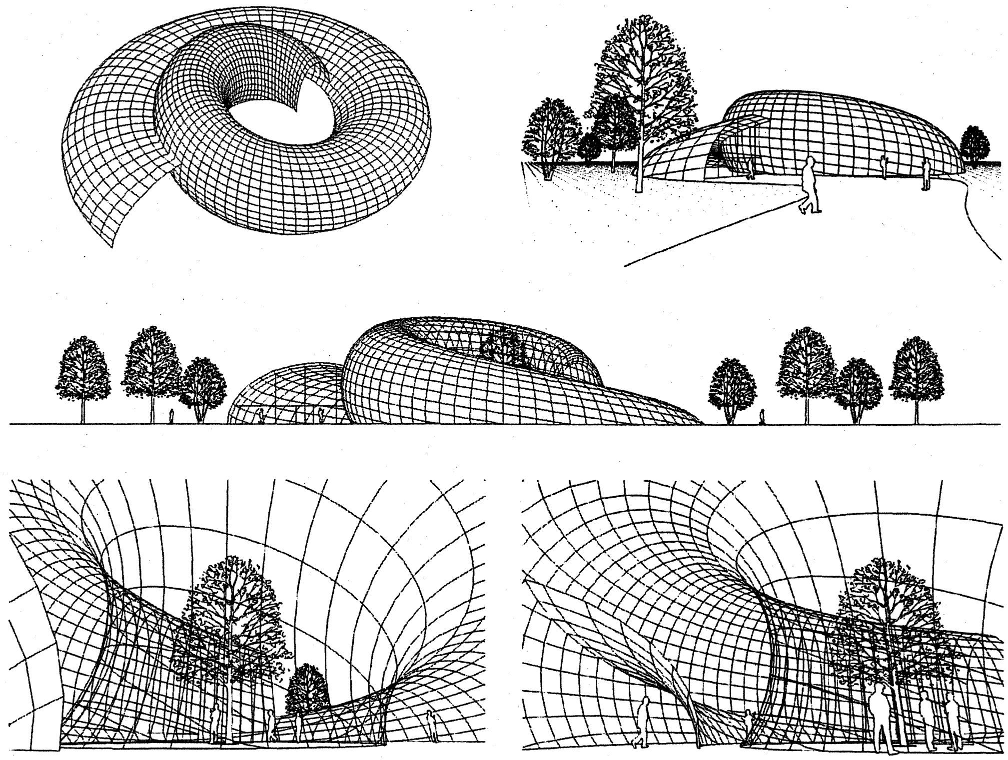


Figure 8. *Form as a virtual architecture, example 1*

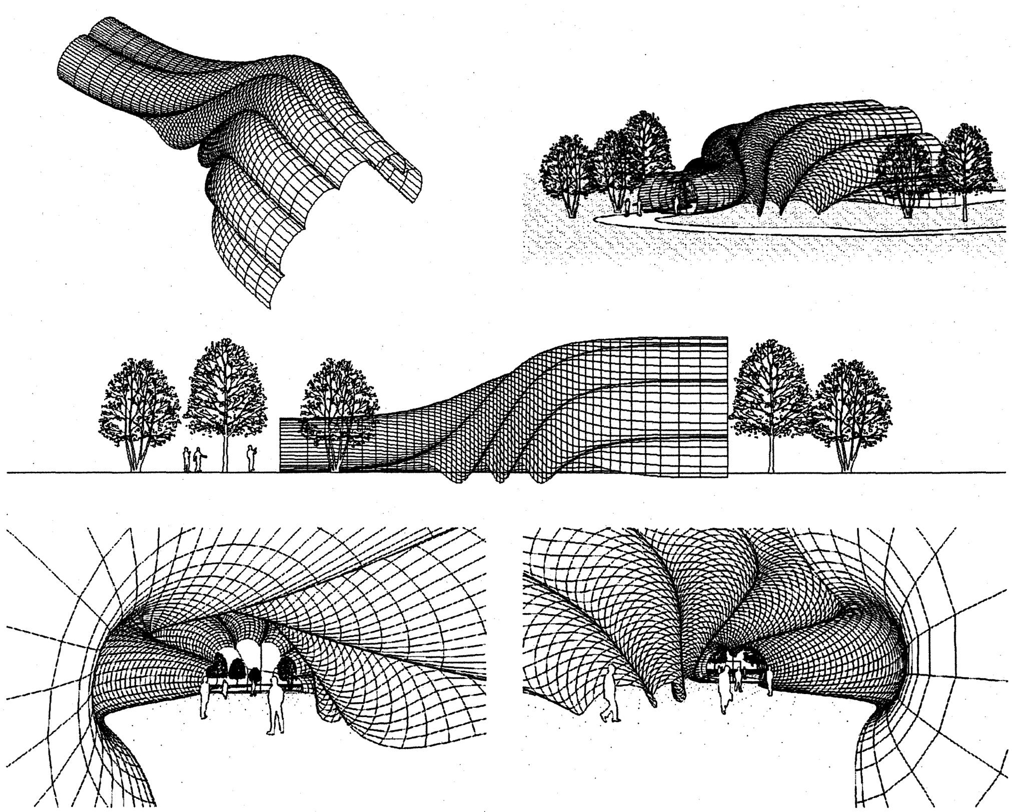


Figure 9. *Form as a virtual architecture, example 2*

4. Observations and Conclusions

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 as 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.

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