Case Study: Modeling the Interior Structure of Seashells

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Abstract

This case study describes the process undertaken to a create digital mode of a seashell that includes its interior structure. The ultimate purpose of creating these models was to study their structural properties. This was part of a larger architectural study of natural forms. The resulting model was used to visually display the internal structure of a seashell and also as input to structural analysis software. The case study includes the steps taken to complete the software for the model.

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 shells. Our interest centers on an investigation of natural forms as possible starting points to generate architectural forms. For this particular study the seashell was selected. For this study 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 of the interiors of shells was conducted by Conklin [9] using x-rays.

2. Seashell Geometry

As documented by Raup the seashell geometry can be expressed by four basic parameters. As shown in Figure 1, part 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.
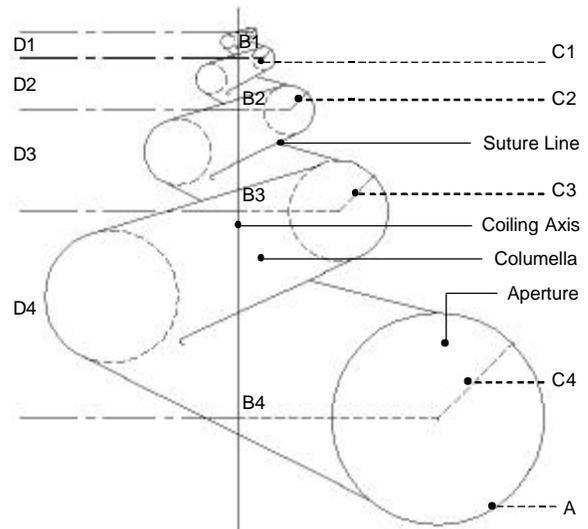

Figure 1: Seashell geometry

3. Preparing the Seashell Data

For this research the coiling shells of the gastropods class in the mollusk classification was selected for its simplicity of form and its traditional spiraling quality. 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 2 shows the selected shell cut and Figure 3 the results of the scan.

The scanned image was processed by Adobe Streamline to extract the edges of the image and then convert them into line segments. These line segments were then imported into AutoDesk's AutoCAD package. 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. These equations then became the basis for the generation of a three-dimensional mesh model.

Figure 2: Cut seashell

Figure 3: Scanned seashell section

4. Seashell Model

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 4 displays the first part of the model generation. For visualization purposes only, these sections could be 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. Figure 5 displays these results. 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 6 displays the final mesh model.
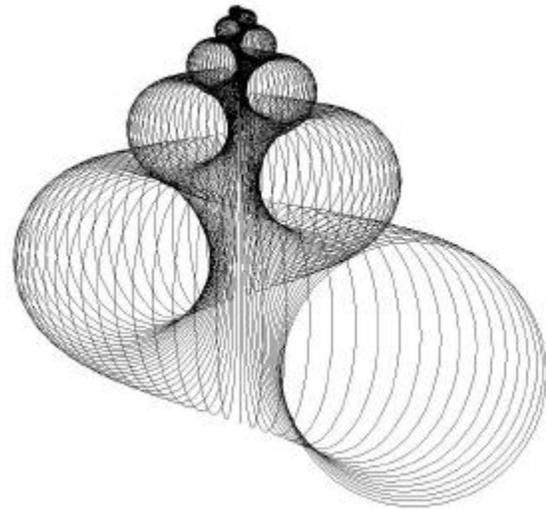

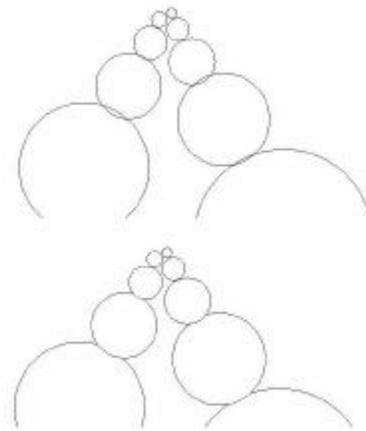Figure 4: Wireframe of shell sections
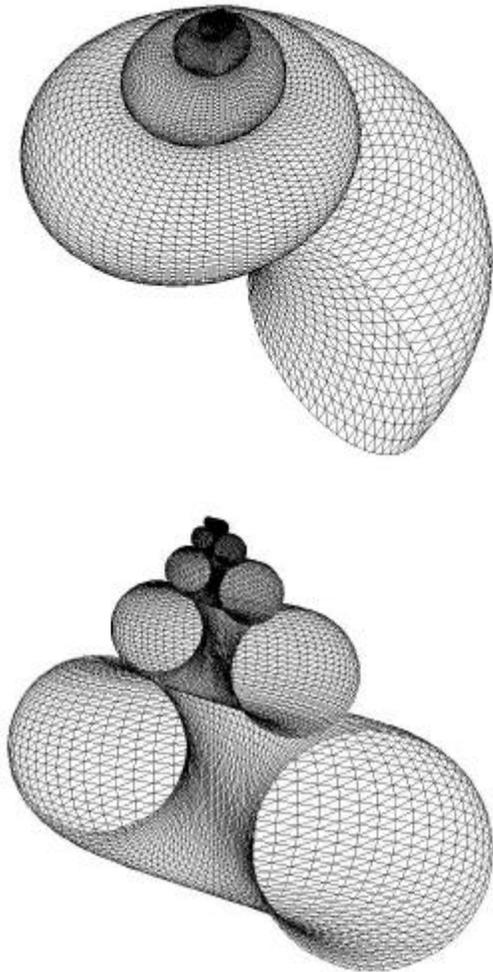

Figure 5: Shell section intersections

Figure 6: Final mesh model

6. Observations

Using the method of intersecting sections produces a fairly accurate version of the actual interior structure of a shell. The same model that was used in the rendering was also used successfully for structural analysis. The glass-blown quality of the resulting shell expresses the perfection of the outer surface, as well as, displays the hidden inner beauty of the shell.

7. References

[1] D'Arcy Wentworth Thompson, *On Growth and Form*, Dover Publications, Inc., 1992

[2] David M. Raup, "The Geometry of Coiling in Gastropods", Proceedings of the National Academy of Sciences of the United States of America, Volume 47, 1961

[3] David M. Raup," Computer as Aid in Describing Form in Gastropod Shells", Science, July-September 1962

[4] M. B. Cortie, "Models for Mollusc Shell Shape, South African", Journal of Science, 1989

[5] Chris Illert, *Foundations of Theoretical Conchology*, Hadronic Press, Inc., 1992

[6] Richard Dawkins, *Climbing Mount Improbable*, W. W. Norton & Company, 1997

[7] Hans Meinhardt, *The Algorithmic Beauty of Sea Shells*, Springer, 1998

[8] Deborah R. Fowler, Hans Meinhardt and Przemyslaw Prusinkiewicz, "Modeling Seashells", Computer Graphics, July 1992

[9] William A. Conklin, *Nature's Art: The Inner and Outer Dimensions of the Shell*, University of South Carolina Press, 1985

5. Visualization

Once the three-dimensional mesh model was created, it could be rendered. Discreet's 3D Studio MAX was used for the renderings. The renderings were developed to exhibit two major properties that were part of this study. The first was that the equations used to develop the final geometry generated a perfect shell, not one that had the normal irregularities found in nature. The second goal was to show the internal structure of the shell. To be able to express these properties, a transparent glass-like material was selected. To it a reflective map was added to bring out the surface highlights. Figure 8 displays the rendered shell in a top view, side view, and in cross-section.
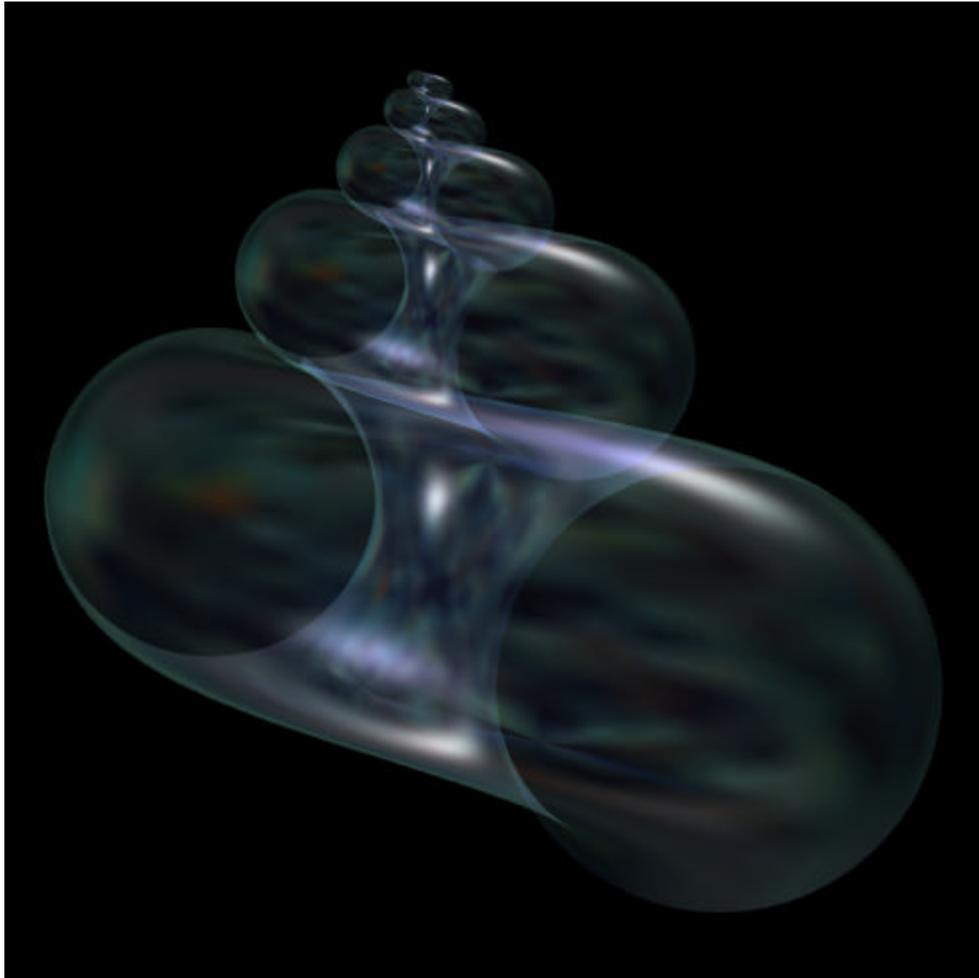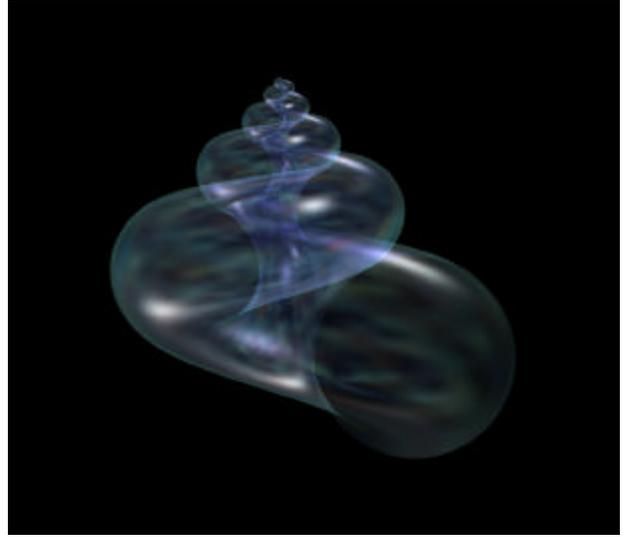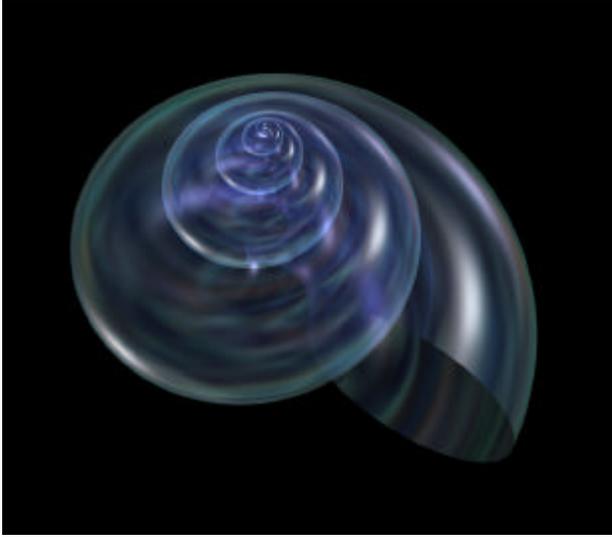
Figure 8: Rendered shell; top, side, and cross-section views