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GENERATING THE ARTISTIC SHAPES USING SUPERFORMULA

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ABSTRACT

Geometric modelling has been used in designing various artistic shapes since year 1940. Most of the Computer Aided Design (CAD) and Computer Aided Geometric Design (CAGD) used spline, B-spline, Beta-spline, Hermite and Bezier in the designing process. This paper presents an alternative way to generate the artistic shapes with free form surface by using superformula namely Gielis formula in bipolar cylindrical coordinate. In Gielis formula, there are six parameters that can be changed to get different design. Random values for the parameters have been chosen. Mathematical software namely Maple has been used to design the artistic shapes. The equation and method that will be discussed in this paper can be used as a guideline in designing new potential design in manufacturing industry.

Keywords: Gielis formula; superformula; shapes design; free form surface; Maple.

1. INTRODUCTION

Geometric modelling has been used in designing various artistic shapes since year 1940. Most of the Computer Aided Design (CAD) and Computer Aided Geometric Design (CAGD) used spline, B-spline, Beta-spline, Hermite and Bezier in generating 2D and 3D shapes. In this paper, we used superformula or Gielis formula as an equation for designing a free form surface of artistic shapes.

The Gielis formula was introduced by Dr Ir Johan Gielis in year 1997. According to him, the formula can be used to describe many complex shapes and curves that are found in nature (Gielis, 1999). In the last two decades Gielis formula has benefited extensive researches in retreving parameters from various data types, such as range images, 2D and 3D point clouds, etc (Gielis, 2003a). In this paper, the Gielis formula has been used to generate the artistic shapes with free form surface.

2. GIELIS FORMULA EQUATION

One of the most fundamental aims of science and mathematics is to find better and elegant ways to describe and represent shapes and patterns in our nonlinear world (Chac, 2008). This paper focuses on Gielis formula. It is a simple formula that can be used to describe many

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complex shapes and curves found in nature (Gielis, 2003a). Gielis (2003b) in his paper discussed the potential of Gielis formula in designing 3D object for CAD/CAM purpose. By using the Gielis formula in developing 2D and 3D CAD/CAM, more products inspired by natural shapes can be designed. Gielis formula, will enable products or shapes that have been generated to be evolved into a new design which meets the innovation criteria (Preen & Bull, 2012).

The study on natural shape design is important in various fields such as in architecture, mechanical design, manufacture design, arts and design and others creative works. Nowadays, under the discipline of biomimicry, many innovation tools or equipments have been designed based on the natural shape (Arnarson, 2011). Gielis formula describe unlimited nature shapes, threfore, it is suitable to use in designing any tools that are based on the discipline of biomimicry. Furthermore, this formula is easy and simple to be applied in the designing process.

Gielis formula starts with a set of shapes called superellipses:

$$\left|\frac{x}{a}\right|^{n} + \left|\frac{y}{b}\right|^{n} = 1 \qquad (1)$$

The formula can be expressed in polar coordinate:

$$x = r\cos\theta \quad , \quad y = r\sin\theta \qquad (2)$$

Johan Gielis generalized the superellipses equation and came out with a new formula called Gielis formula. The following equation is the Gielis formula in terms of trigonometric functions.

$$r(\theta) = \left[\left|\frac{1}{a}\cos\left(\frac{1}{4}m\theta\right)\right|^{n_2} + \left|\frac{1}{b}\sin\left(\frac{1}{4}m\theta\right)\right|^{n_3}\right]^{-1/n_1} \qquad (3)$$

Where a and b are positive real numbers but not zero, m, n_1, n_2 and n_3 are real numbers.The modification of the parameters in Gielis formula shows a large variety of shapes. Figure 1 shows the sample of motifs that have been created in 2-dimension, while Figure 2 shows the sample of shapes that have been created in 3-dimension.

Figure 1 : Motif in 2-dimension.

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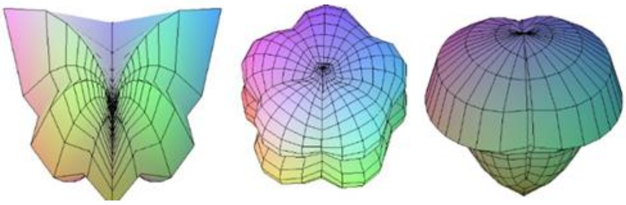

Figure 2 : Shapes in 3-dimension.

3. GENERATING THE ARTISTIC SHAPES

Stefan & Mihai (2010a, 2010b) in their papers have discussed the variety of coordinates system to produce 2D and 3D shapes. With reference to their results, this paper will discuss the generating of 3D using bipolar cylindrical coordinates which is a built in function in Maple application. Bipolar cylindrical coordinate is a three-dimensional orthogonal coordinate system. These coordinates are produced by projecting the two-dimensional bipolar coordinate system in the perpendicular z-direction (Rafizah, 2013). Parameters a, b, m, n_1, n_2 and n_3 in equation 3 can be changed to get a different pattern.

In designing a 3-dimension object, the following equation for x, y and z axes are used.

$$x = r_1(\theta)\cos\theta \bullet r_2(\phi)\sin\phi \quad (4)$$

$$y = r_1(\theta)\sin\theta \bullet r_2(\phi)\cos\phi \quad (5)$$

$$z = r_2(\phi)\sin\phi \quad (6)$$

Where $-\pi \le \theta \le \pi$ and $-\frac{\pi}{2} \le \phi \le \frac{\pi}{2}$

By using the values a=1, b=1, m=0, n_1=1, n_2=1, n_3=1 and bipolar cylindrical parameter, the round pole shape as shown in Figure 3 can be obtained.

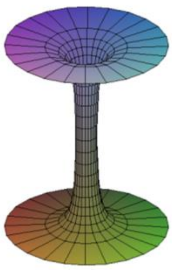

Figure 3 : Shape of a round pole.

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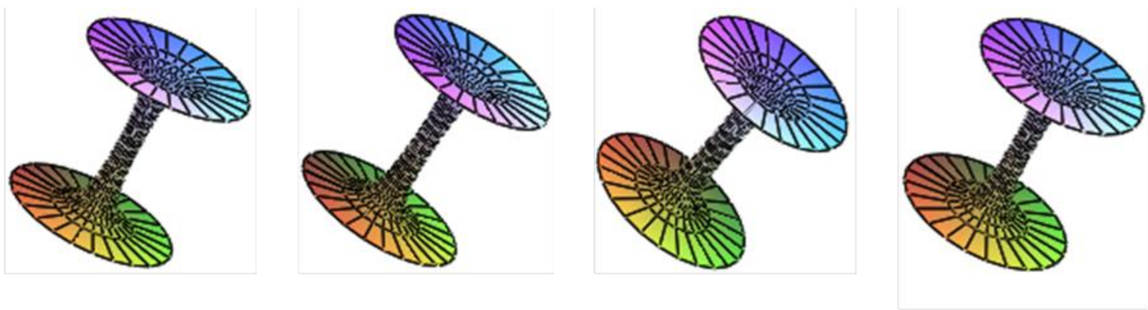
4. EFFECT OF CHANGING THE PARAMETERS

The round pole shape will change according to the value of parameter a. Figure 4 shows that the round pole shape as shown in Figure 3 will change from smooth surface to rough surface. A bigger value of parameter a will produce a rougher surface.

a=2 a=5 a=6 a=8

Figure 4 : Effect of changing of parameter a.

Figure 5 shows that the shape does not change even though the value of parameter b has been changed.



b=1 b=5 b=6 b=8

Figure 5 : Effect of changing of parameter b.

The top and bottom of the round pole shape will change according to the value of parameter m. From Figure 6, the top and bottom shape will produce a smooth circle one round shape if the value of m is equal to one. If the value of m is equal to two, the top and bottom shape will split into two corners. If the value of m is equal to seven, the top and bottom shape will split into seven corners. This shows that the number of corners that will be produced depends on the number of parameter m.

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m=2 m=5 m=6 m=7

Figure 6 : Effect of changing of parameter m.

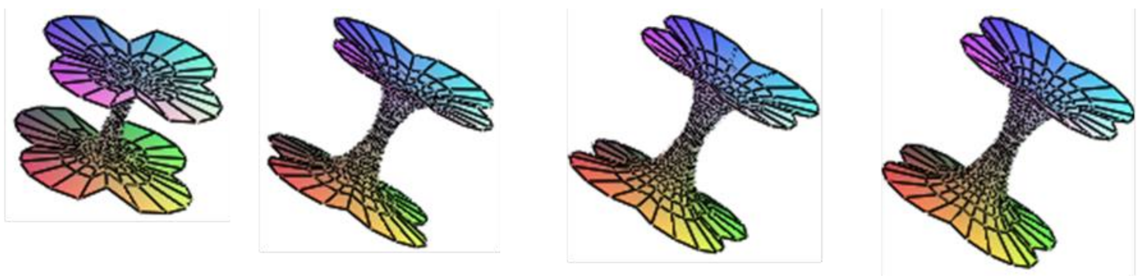
Figure 7, 8 and 9 shows the effect of the round pole shape when parameter m is fixed at four while parameter n_1, n_2 and $n_3$have been changed.

Figure 7 shows that if the value of n_1 is increase, the rod will be longer and the top and bottom of the round pole shape will be smoother.

m= 4, n_1=0.2 m= 4, n_1=0.5 m= 4, n_1=0.7 m= 4, n_1=1

Figure 7 : Effect of changing of parameter n_1

In Figure 8, if the value of n_2 is increase, the top and bottom of the round pole shape remain the same whereas the rod becomes longer.



m= 4, n_2=0.2 m= 4, n_2=0.5 m= 4, n_2=0.7 m= 4, n_2=1

Figure 8 : Effect of changing of parameter n_2.

In Figure 9, if the value of n_3 is decrease, the top and bottom of the round pole shape remain the same whereas the rod will split into two.

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m= 4, n_3=0.2 | m= 4, n_3=0.5 | m= 4, n_3=0.7 | m= 4, n_3=1

Figure 9 : Effect of changing of parameter n_3

In Figure 10, it shows that the shape will change in various shape and surface if random values are given to all parameters.

a=2, b=3, m=9,

n1=7, n2=8, n3=9

a=2, b=3, m=5,

n1=0.5, n2=0.5, n3=0.5

a=2, b=3, m=10,

n1=0.7, n2=0.8, n3=0.9

Figure 10 : Effect of changing of parameter randomly.

5. CONCLUSION

The superformula that has been used in this paper is easy and simple to be applied in any design process. User only needs to change the parameter to get various shapes. This will help designer to think creatively and produce better tools and equipments as we need more innovative products. The design of innovative products needs to be creative, stylish and attractive to impress potential buyers.

The design of the artistic shape which has been discussed in this paper can be used as a guideline in designing new potential design in manufacturing industries. Artistic shapes have commercial value in décor industries. Suitable parameter values are needed to make sure that the artistic shapes that have been generated by using Gielis formula is practical to produce a physical objects.

More research should be done to find the best fitting parameters of Gielis formula in order to design a target shape. The results can be used in developing 2D and 3D CAD software in designing shapes inspired by natural shapes.

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