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Development of 3D cartoon by using B-spline and sweep surface method

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A B S T R A C T

B-splines are one of important tools for Computer-Aided Geometric Design (CAGD). CAGD is a new field that initially developed to bring the advantages of computers to industries such as automotive, aerospace and shipbuilding. CAGD is based on the creation of curves and surfaces and is accurately described as curve and surface modelling. This paper will study about uniform quadratic and cubic B-spline curves. Two dimensional curves are formed yang using same value of knot and control points for uniform quadratic and cubic B-spline curves. Furthermore, three-dimensional cartoons are formed by transform two dimensional cartoons by using sweep surface method such as revolution and translation techniques. Result shows quadratic B-spline cartoons are the best curve after comparing between quadratic and cubic B-Spline cartoons. This research will give an alternative to designer in order to form three dimensional cartoons or get the curve needed. Besides that, it also gives an idea and knowledge to reader on how to design three dimensional cartoons and obtain the best curve. All processes will be done by using Mathematica software.

1. Introduction

Nowadays, Computer Aided Design (CAD) and Computer Aided Geometric Design (CAGD) have been widely used to explore design ideas, visualize concepts through animations, renderings and simulate how a design will perform in the real world (Yassin et al., 2017). B-spline is one of the popular surfaces that widely apply CAD and CAGD besides Bezier surfaces, Extended Cubic Uniform B-Spline and Non Uniform Rational B-Spline (Gang and Zhao, 2008; Hamid et al., 2010). Surface generated by a CAD and CAGD program provides a very accurate, smooth surface and can be easily modified (Jung and Kim, 2011; Salomon, 2007). One of the common forms of shape description is sculptured surface. Sculptured surface is a set of curves that connect design point of the surface and usually used in geometric modelling to describe variable shape surface such as airplane wings, car bodies and so on (Al-Fnzi et al., 2009; Neacsu and Daniels, 2006). B-spline curve is used to overcome the main disadvantages of the B´ezier curve, which are the degree of the B´ezier curve depends on the number of control points. It offers only global control and individual segments are easy to connect with C^1 continuity, but C^2 is difficult to obtain (Salomon, 2007). This research only focuses on Quadratic Uniform B-Spline and Cubic Uniform B-Spline curve. Then, the two dimensional Quadratic Uniform B-Spline and Cubic Uniform B-Spline curve will be plotted. Besides that, a three dimensional cartoon will be developed by combining all the segmentation of two dimensional curve and will transform by using sweep surface method such as revolution and translation techniques.

Sweep surface method is an important issue and powerful in order to determine the object in three-

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dimensional (Bronsvoort et al., 1989; Coquillart, 1987; Lee et al., 2000; Marhl et al., 1996). It is practical, simple and efficient to be used. Sweep surface also called as generalized cylinder and can be defined as enveloped formed (Elber, 1997). Curve and surface that are produced in CAD and CAGD must be smooth and form the accurate shape (Al-Fnzi et al., 2009; Choi and Lee, 1990).

2. Methodology

2.1. Quadratic and cubic uniform B-spline

In this phase will study about B-spline such as quadratic and cubic uniform B-spline curve. The following equations of B-spline will be used (Jung and Kim, 2011) (Eq. 1).

$$B_{i,k}(u) = \frac{u-u_i}{u_{i+k-1}-u_i}B_{i,k-1}(u) + \frac{u_{i+k}-u}{u_{i+k}-u_{i+1}}B_{i+1,\ k-1}(u) \quad (1)$$

$i = 0, 1, \dots, n$

$$B_{i,1}(u) = \begin{cases} 1 & u_i \le u \le u_{i+1} \\ 0 & otherwise \end{cases}$$

where $B_{i,1}$= ith B-spline basis function of order k, μ = the knot sequence and u = parameter variable.

The obvious defining feature of the basis function is the knot sequence. The knot sequence is a set of non-decreasing real numbers. The variable u represents the active area of the real number line that defines the B-spline basis. It takes k+1 knots or k intervals to define a basis function. Since the basic functions are based on knot differences, the shape of the basic functions is only dependent on the knot spacing.

The two-dimensional quadratic and cubic uniform B-spline curve will be plotted by using the selected control point. The following equation will be used to plot the two-dimensional quadratic and cubic B-spline curve (Salomon, 2007) (Eq. 2):

$$P(u) = \sum_{i=0}^{n} P_i B_{i,k}(u) \quad (2)$$

$i = 0,1, \dots, n$

where P_i = the control points and $B_{i,k}$= ith B-spline basis function of order k.

Fig. 1 shows the quadratic uniform B-spline is plotted by using three control points, and Fig. 2 shows the cubic uniform B-spline is plotted by using four control points.

2.2. Revolution

Revolution is used to generate the symmetric surface. Surface of revolution is created by rotating a two dimensional cross-section curve about an axis in space. A surface of revolution can simply be formulated as a matrix operation, where a two dimensional cross-section curve rotates about an axis in space. Example of resulting surface of revolution are bottle shape, vase shape and handless of mug (Lai and Ueng, 2000).

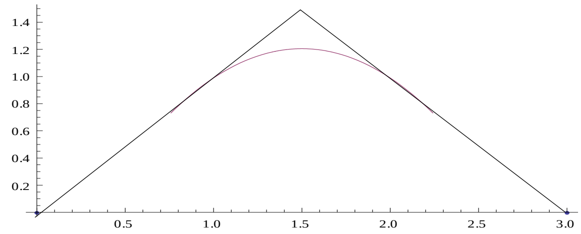

Fig. 1: The quadratic curve with control polygon

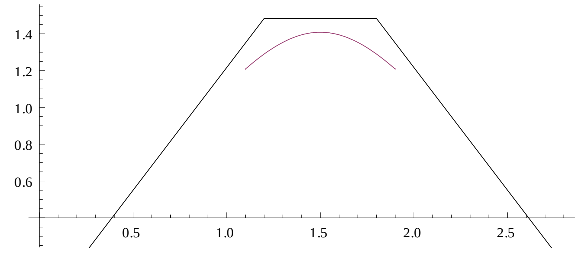

Fig. 2: The cubic curve with control polygon

If angle of revolution is W and revolve about r axis r = (r_x,r_y,r_z), then matrix revolution T(W) is (Salomon, 2006)

For z-axis

$$T(w) = \begin{bmatrix} \cos w & \sin w & 0 \\ -\sin w & \cos w & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

For y-axis

$$T(w) = \begin{bmatrix} \cos w & 0 & \sin w \\ 0 & 1 & 0 \\ -\sin w & 0 & \cos w \end{bmatrix}$$

For x-axis

$$T(w) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos w & \sin w \\ 0 & -\sin w & \cos w \end{bmatrix}$$

The surface is produce by using the equation below.

$$P(t, W) = P(t) \bullet T(W) \quad (3)$$

where P(t, W) = surface revolution, P(t) = cross section and T(W) = matrix revolution.

Figs. 3 and 4 shows that the surface was produced when the quadratic and cubic uniform B-spline curve with different degree is revolved about y-axis

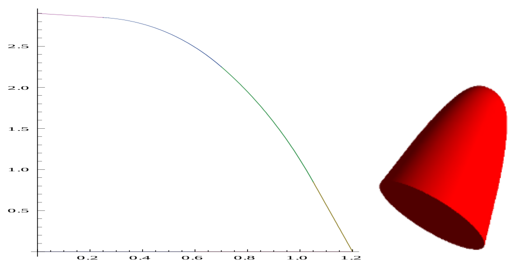

Fig. 3: Quadratic curve revolution

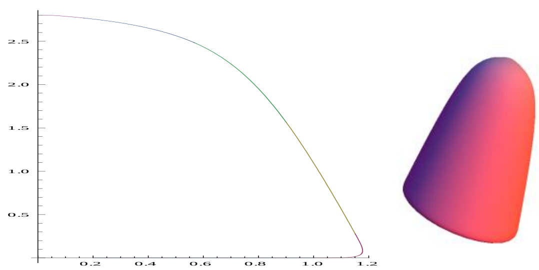

Fig. 4: Cubic curve revolution

2.3. Translation

Translation surface is a sweeping transition in which the contour moves perpendicularly from one end of the line segment to another line segment. A translation is transformation in three-dimensional spaces that move in any direction. In other word, surface of translation is rotational sweep where the contour rotates on axis of rotation and the general sweep where the contour moves along an arbitrary three-dimensional trajectory curve (Tai and Loe, 1996; Pocock and Rosebush, 2002).

The following equation of translation technique that will be used in this research is (Salomon, 2007) (Eq. 4):

$$S(u,t) = R(t) + Cx(u,t)n(t) + Cy(u,t)b(t) \quad (4)$$

where S(u, t) = B-spline surface as a function of two variables, C(u, t) = contour blended, R(t) = the trajectory, n(t) = determined with the minimum rotation scheme (x-axis), b(t) = determined with the minimum rotation scheme (y-axis) and t(t) = the unit tangent vector of the trajectory.

Figs. 5 and 6 show a surface was produced when a circle moves along the quadratic and cubic uniform curves.

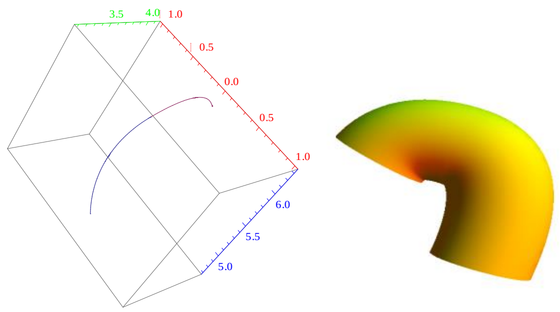

Fig. 5: Quadratic curve translation

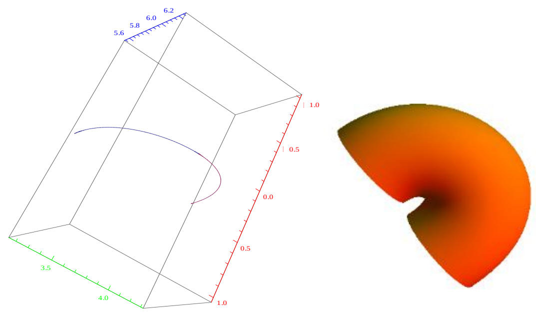

Fig. 6: Cubic curve translation

3. Results and discussion

This research focused on designing the three dimensional cartoon using uniform B-spline. Before designing three dimensional, quadratic and cubic B-spline of two dimensional cartoons must be designed first and then applied to three dimensional cartoon using sweep surface methods such as revolution and translation technique. Modification or changing the control points was made in order to develop the best shape of the cartoon. Figs. 7 and 8 show three dimensional cartoons were developed by using quadratic and cubic uniformed B-spline curves. The three dimensional cartoons used the same values of knot and control points. Head of the cartoon are formed by revolve quadratic and cubic uniform b-spline curve about y-axis at 360^0 angle of revolution. Eyes, mouth and moustache are formed by translate a circle along the quadratic and cubic uniform b-spline curves. Then, head, eyes, mouth and moustache are combined in a space.

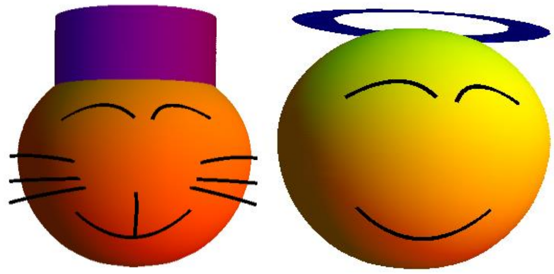

Fig. 7: The quadratic uniform B-spline cartoon

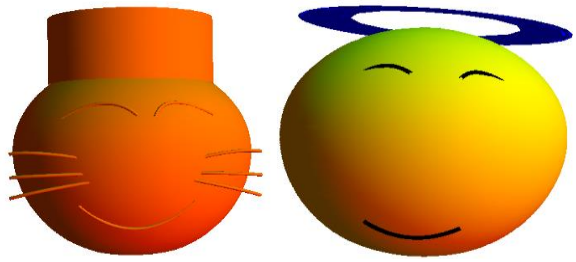

Fig. 8: The cubic uniform B-spline cartoon

4. Conclusion

This research studies about quadratic and cubic B-Spline curve. Quadratic and cubic B-spline curve will be plotted. Sweep surface method such as revolution and translation techniques will be used to transform two dimensional curves to three dimensional objects. Three dimensional cartoons will be formed by combining all the segmentations of quadratic and cubic uniform B-spline curves. As result obtained shows that quadratic uniform B-spline curve is more accurate to the real cartoon.

All the process will be done by using Mathematica software. This research will give an alternative to designer in order to form three dimensional objects or get the curve needed. Besides that, it also gives an idea and knowledge to reader on how to design 3 dimensional objects.

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