**INTERACTIVE GRAPHICS SOFTWARE FOR THE GENERATION OF CUBIC SPLINE AND POSTPROCESSOR FOR NC MACHINING**

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# INTERACTIVE GRAPHICS SOFTWARE FOR THE GENERATION OF CUBIC SPLINE AND POSTPROCESSOR FOR NC MACHINING

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PREVIEW

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IN LOVING MEMORY OF MY FATHER

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**ABSTRACT**

The 'CUBIC' software described in this thesis seeks to serve as a graphical tool to design a profile and determine the tool path for the same. The profile is basically a cubic curve drawn through the points described by the user. By generating the tool path on the screen, the user can check for any interference of the cutter with the curve profile in the narrow regions. Having confirmed the tool path, the G-codes are generated automatically and stored in a file. Using the kermit protocol, the G-codes file is transfered to a VAX main frame computer from where the punched tape is prepared. The punched tape is used as an input to the Bridgeport machine where the profile is milled. The package developed is menu driven and the command list is displayed throughout the interaction for the users benefit. The input functions used for defining the curve are simple with a fair degree of editing flexibility.

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# Chapter 1

## INTRODUCTION

In many industries, e.g, shipbuilding, automotive and aircraft, the full size of the part is determined by a process called lofting. Lofting is the process of preparing a full size drawing of the part contour (boundary of the part) and obtaining the blue print of the same. The blue print is pasted on the blank from which the part is produced. The blank is milled along the contour by manipulating the X-axis control and Y-axis control of the machine.

Early in the development of mathematical tools for computer aided geometric design there was considerable interest in developing a mathematical model of this process. As a result, the form of the mathematical spline is derived from its physical counterpart - the loftman's spline. A physical spline is a long, narrow strip of wood or plastic used to fit curves through specified data points. The splines are shaped by lead weights called `ducks'. By varying the number and position of the lead weights the spline is made to pass through the specified data such that the resulting curve appears `smooth', or `fair', and `pleasing to the eye'. Figure 1.1 illustrates the use of flexible spline and ducks.

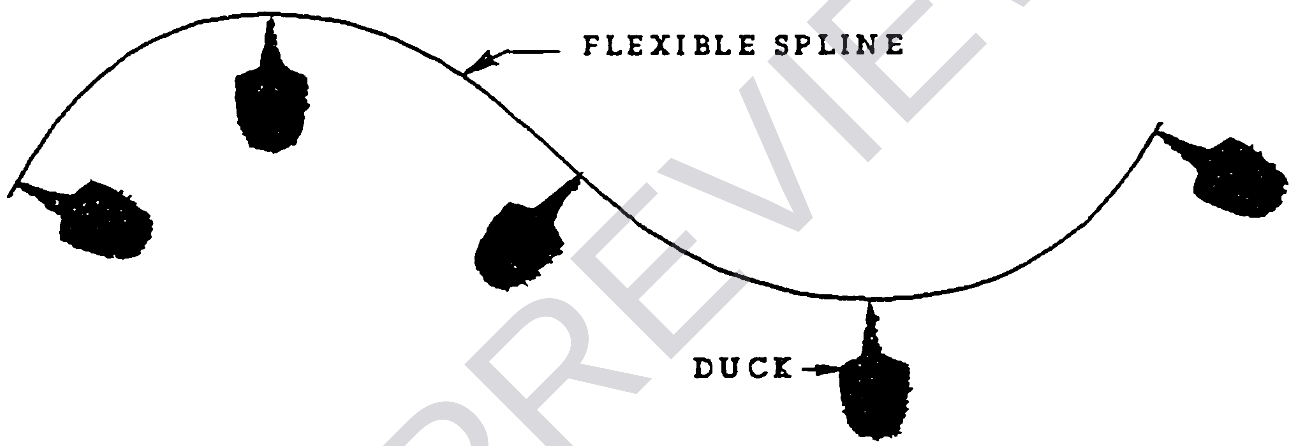


FIGURE 1.1 USE OF FLEXIBLE SPLINE AND DUCKS

REF(10)

### 1.1 APPLICATIONS

Curves are important in many areas of computer graphics. One example is animation. The animator draws key frames which must be linked together by many in-between frames, but these can be generated automatically by the computer. Points in these in-between frames that connect corresponding points of the key frames should not lie on a straight line, or else the motion of an object will be jerky and unnatural. What is wanted is a smooth curve that interpolates between the points on the key frames. The points of the in-between frames are created on that curve.

Another application of curves is to smooth an outline given approximately by a few points. In this case the curve itself is what we desire. It is usually created by an interactive process of specifying control points that shape the curve. If these control points can be interactively changed and if the resulting curve can be displayed rapidly, we can actually mold the curve to fit a desired outline. Such interactive modelling, done in real time on the screen, is easy and natural. This process is used in computer-aided design and manufacturing (CAD/CAM).

Still another application of curves is to create surfaces. This is usually achieved by specifying discrete points on the surface of an object which are then connected by interpolating or approximating surfaces. In case of

interpolating the surface, the surface passes through all the points obtained by interpolation. In case of approximating surface, the surface does not pass through all the specified points. Curves are involved because all surfaces can ultimately be derived from curves and exhibit the same characteristics of smoothness or roughness.

## 1.2 MATHEMATICS OF CUBIC SPLINES

Considering the physical spline as a thin elastic beam, the shape of the spline, corresponding to the deflection of the beam 'y', is obtained from Euler's equation for the bending moment M(x) along the length of the beam. Specifically,

$$M(x) = EI/R(x)$$

Where E is Young's modulus (determined by the material properties of the beam), I is the moment of inertia(determined by the cross-section of the beam), and R(x) is the radius of curvature of the beam (determined by load acting on the beam).

For small deflections, the slope of the beam is very much less than 1.

i.e., $dy/dx \ll 1$

Where 'dy/dx' is the derivative of 'y' with respect to 'x', 'y' represents the deflection of the beam, and 'x' represents the distance along the beam.

The radius of curvature is approximated by

$$1/R(x) = (d^2y/dx^2) / (1 + (dy/dx)^2)^{1.5} = d^2y/dx^2$$

Euler's equation then becomes

$$d^2y/dx^2 = M(x)/E*I$$

Assuming that the ducks act as simple supports, the bending moment M(x) = A*x + B, Eulers equation becomes

$$d^2y/dx^2 = (A*x + B)/(E*I)$$

Integrating twice yields

$$y = (A*x^3 + B*x^2 + C*x + D)/(E*I)$$

for the deflection of the beam. This result shows that the shape of the physical spline between ducks is mathemetically approximated by cubic polynomials. Thus we consider a mathemetical spline modeled using cubic polynomials.

In general, the mathematical spline is a piecewise polynomial of degree K with continuity of derivatives of order K-1 at the common joints between segments. Thus, the cubic spline has second-order or $c^2$ continuity at the joints. Piecewise splines of low degree polynomials are most useful for curve fitting because low degree polynomials both reduce the computational requirements and also reduce numerical instabilities that arise with higher degree curves. However, since low degree polynomial cannot span an arbitrary series of points, adjacent polynomial segments are used. Based on these considerations and the analogy with the physical spline, a common technique is to use a series of cubic spline segments with each segment spanning only two points. Further, the cubic spline is advantageous since it is the lowest degree

curve which allows a point of inflection and which has the ability to twist through space.

Cubic spline proves to be an efficient tool for approximation and interpolation. The mathematical spline thus possess the property that the cubics and their first and second derivatives are continuous.

**2.1 PARAMETRIC REPRESENTATION**

The concept of parametric representation is important before the discussion of curves in computer graphics.

The importance of parametric representation is that it allows us to derive curves for the 2-D plane; these can then be transferred without conceptual difficulties or any change in formalism to curves in three dimensions.

A curve in the 2-D plane can be represented by the relationship between two variables. There are basically two ways to do this. We can write it with either y or x as the independent variable:

$y = f(x) \quad \text{or} \quad x = g(y)$

Such representations lead to difficulties when there are infinite slopes and where there are loops in the curve that give repeated points. There is lack of symmetry in such representations since one variable must be designated as independent and the other as dependent. Writing in parametric form avoids these difficulties. We use a single new independent variable, u, called the parameter, to write

equations for both x and y:

$x = X(u), \qquad y = Y(u)$

The combination of x = X(u) and y = Y(u), for the same value of u, will be called the combined curve. The combined curve can loop and have infinite slopes in terms of x and y withpout having to have infinite slopes for the parametric equations. The slope of the combined curve is defined as the quotient of the derivatives written in terms of u:

$$dy/dx = (dy/du)/(dx/du)$$

It is easy to deal with a finite segment of the curve by limiting the range of the parameter to a finite interval. In computer graphics we deal with bounded curve segments only; therefore, the range of u will always be limited.

## 1.3 SOFTWARE DESCRIPTION

Whenever the coordinates of the points through which the spline is supposed to pass, are entered, those points are represented graphically on the screen. An interactive menu enables the designer to select one of these points as the control point so as to vary the position of this point and determine the shape of the curve. The tool path is determined by calculating the normal distance equal to the radius of the cutter from every point on the curve. Menu option permits the user to select the side of the contour to be milled. The milling sequence is graphically simulated on the screen. The points constituing the tool path curve are used to generate

the G-codes automatically by selecting the G-CODE option from the menu. The G-codes generated are stored in a file. Using Kermit protocol, the file containing G-codes is transferred to VAX main frame computer and the punched tape is prepared. Thus the appropriate contour can be milled.

This type of interactive software is applicable in aircraft and automobile industry for designing and fabricating the parts involving complicated contours.

## Chapter 2

## OVERVIEW OF COMPUTER AIDED DESIGN

### 2.1 INTRODUCTION

The computer has become essential in the operation of business, government, military, engineering, and research. In recent years it has proven to be a very powerful tool in design and manufacturing.

### 2.2 DEFINITION

Computer-aided design involves any type of design activity which makes use of the computer to develop, analyze, or modify an engineering design. Modern CAD systems (also often called CAD/CAM systems) are based on interactive computer graphics (ICG). Interactive computer graphics denotes a user-oriented system in which the computer is employed to create, transform, and display data in the form of pictures or symbols. The user in the computer graphics design system is the designer, who communicates data and commands to the computer through any of several input devices. The computer communicates with the user via a cathode ray tube (CRT). The designer creates the image on the CRT by entering commands to call the desired software subroutines stored in the computer. In most systems, the image is constructed of basic geometric elements-points, lines, circles, and so on. It can be modified according to the commands of the designer, Enlarged, reduced in size, moved to another location on the