A COMPUTER AIDED DESIGN TECHNIQUE FOR POTTERY PROFILES

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ABSTRACT

A method is discussed which allows 3-Dimensional curved solids of revolution to be effectively "drawn" on the screen of an interactive graphics terminal and thereby stored in a computer file.

The technique is based on the generation of "B-spline curves", and provides a means by which potentially quite complicated curved shapes can be defined by a relatively small number of co-ordinates. Since the storage requirements are minimal, the method may have advantages in applications that require large numbers of items to be catalogued for subsequent statistical analysis.

In particular, effort has been concentrated on providing a package intended for use in archaeology. Software has been developed which allows "drawings" of pottery profiles to be stored compactly in computer accessible form. The advantages of "computerising" such drawings extends beyond simple ease of access, since it provides the full power of the computer's ability to handle curve fitting and statistical calculations. Some of the implications of, and possible extensions to, this groundwork will be discussed in detail.

INTROUDUCTION

The general objective of this work was to develop highly interactive, "Computer Aided Design", (CAD) software which would facilitate the drawing or editing of curved shapes on a computer. The main incentive for doing this was to provide a package that would allow pottery profiles, which exhibit cylindrical symmetry to be conveniently manipulated and stored in computer accessible form.

The software, (discussed in detail in the project dissertation held in the department) was developed using a "DEC20" computer system via an "IMLAC Dynagraphics" vector refresh graphics device. Thus it was designed to be used in conjunction with similar high resolution graphics terminals that provide the facility of a light pen. In addition, all sections of the program that provide for hard copy graphical output have been developed using a "Hewlett-Packard HP7220T" flat bed plotter.

The final program, "NEWTST", is very much a compromise between all these functions that one would ideally like to provide, and those which it has been practical to implement in the time available.

The functions provided are explained in detail in the, "USER MANUAL" section of the dissertation and will only briefly be introduced here. The program has two ways by which it can display information, graphical output on the screen, or a plotter, and text information on the screen or plotter. In addition, there are two modes for the input of graphical data, (i.e. the information required to define a profile). A profile may be entered, (created), directly on the screen using the light pen. Alternatively, a profile may be read by the program from a previously prepared file and either displayed on the screen (e.g. to allow editing to be carried out), or plotted providing a hard copy. Only one profile may be displayed on the screen at any one time, however, up to 10 profiles may be plotted on the same sheet, each can be to any designated scale and position on the page.

Program "NEWTST", also provides the facilities for mapping surface pattern detail on to any surface of revolution defined by the profile. Both the profile's shape and surface pattern detail can be modified interactively using the light pen via a comprehensive curve and pattern editing facility.

A technique has been adopted which affords both interactive editing of curve profiles, and economy in the space required to store them. Curves have been defined by a relatively small set of co-ordinates, (here after referred to as control points). This positional information is used to calculate a 3rd order B-spline curve which has been constrained to pass through the first and last control points but not necessarily any of the intermediate ones. Curve editing is therefore achieved by modifying the position and number of control points and possibly by repeating them. Using B-spline curves has the advantage that altering the properties of a control point produces only a localized effect on the shape of the curve rather than a global change. This property makes it easier to anticipate the effect of moving the control points, and provides a means of intuitive editing. In addition, quite complicated curved shapes can be stored very compactly since only the defining control points have to be stored.

PROGRAM CAPABILITIES

The original specification called for software which would implement the following functions:-

(1) Allow pottery profiles to be displayed on the screen of the IMLAC vector refresh device, available in the computer centre at Bimingham.

(2) Allow pottery profiles to be plotted for hard copy on either of the plotters available.

(3) Allow pottery profiles to be "digitised" on the screen of the IMLAC terminal

(4) Allow pottery profiles to be edited, (i.e. modified), interactively on the screen of the IMLAC device.

(5) To allow pottery profiles to be stored in a user named file.

(6) To allow pottery profiles to be read from a named file and, either displayed on the IMLAC device or plotted for hard copy.

In addition to those items listed above, a facility has been provided which will permit surface pattern detail to be "digitized" and mapped to the surface of revolution defined by a profile. Naturally, a full set of editing commands has been provided to support the pattern facility. In this section, examples will be given which illustrate most of the graphical capabilities of this package.

Figure 1 shows a plot of an imaginary profile, (with surface patterning). This was "drawn" on the screen of the IMLAC by specifying control points with the light-pen.

The same profile has been drawn in figure 2 in this case however, for purposes of illustration, the control points which define the profile have also been plotted.

Figure 3 shows profiles which have been successively edited so as to modify the shape. All pattern detail was originally "drawn", (using the light pen), in a flat window. These items were then mapped by program "NEWTST to the surface. The diagrams also illustrate that any surface patterning present is automatically mapped to the new surface. It also illustrates the multiple plotting facility

Figure 4 is an example of a profile from which a 10 degree section has been sliced out of the right hand side. This option is included to give an impression of "3-dimensionality".

Figure 5 gives another illustration of the multiple plotting facility. Profiles may be drawn to any specified position and scale on a given plot.

CURVE GENERATION TECHNIQUE EMPLOYED

For the purpose of implementing a CAD package, some method is required which will provide a conventional means of generating and editing curves. There are a number of techniques available having varying degrees of applicability, among these are the "cubic spline", the "Bezier curve" and the B-spline curve.

The cubic spline method is one member of a family of curve fitting techniques in which the curve is constrained to pass through a given set of data points. These techniques suffer serious drawbacks which severely limit their usefullness to the field of interactive curve manipulation. One major disadvantage is that the effect of altering specific data points is not highly localised. This makes it extremely difficult to modify the shape of a curve, (for example by moving one of the data points), without

Figure 1

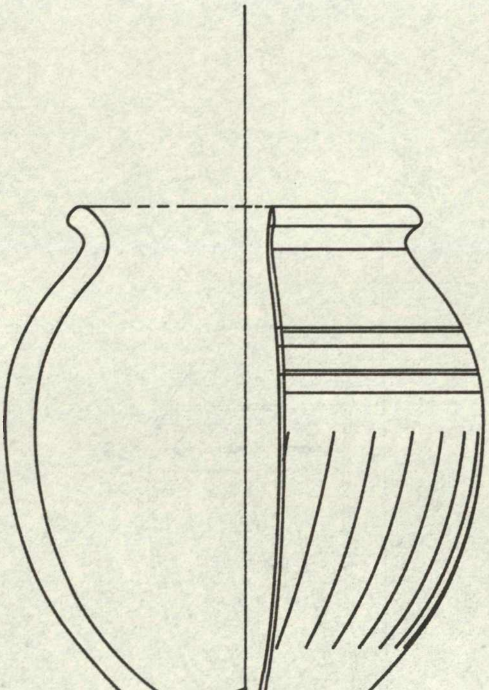


Figure 2

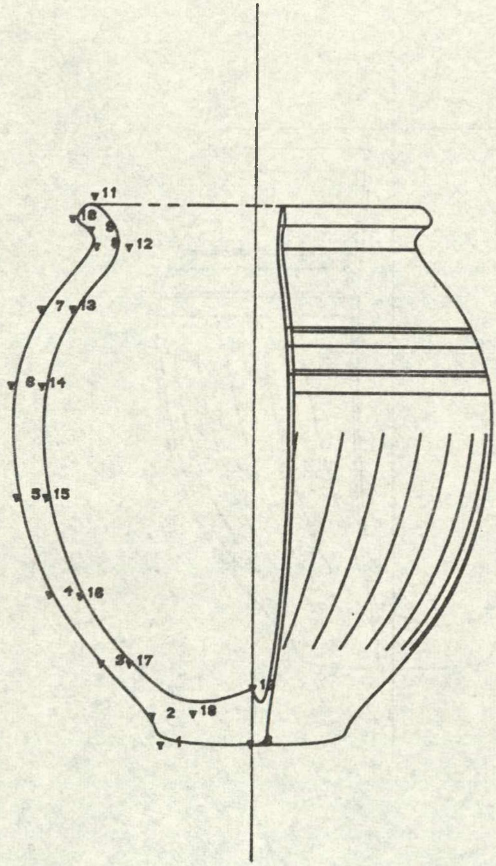


Figure 3

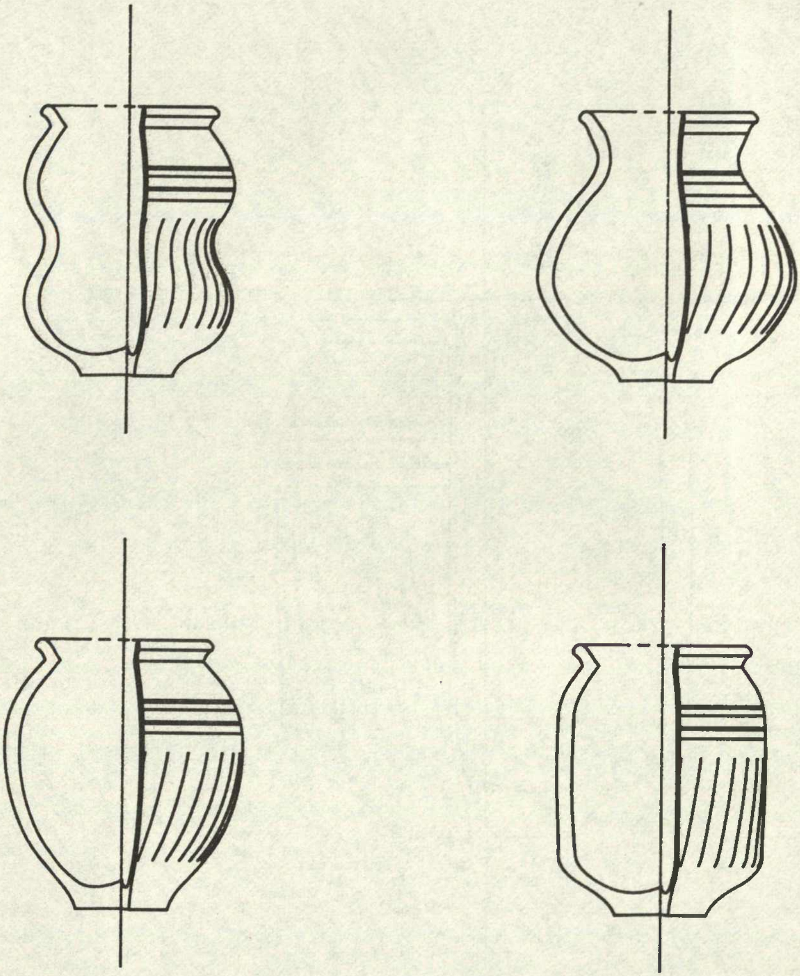


Figure 4

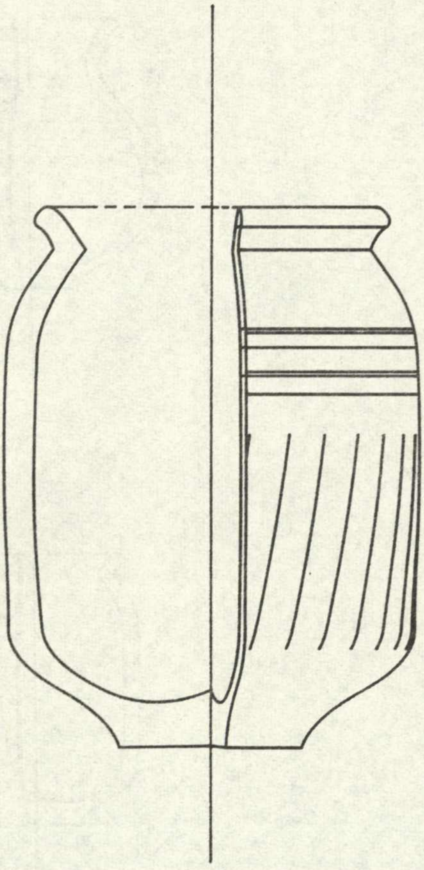
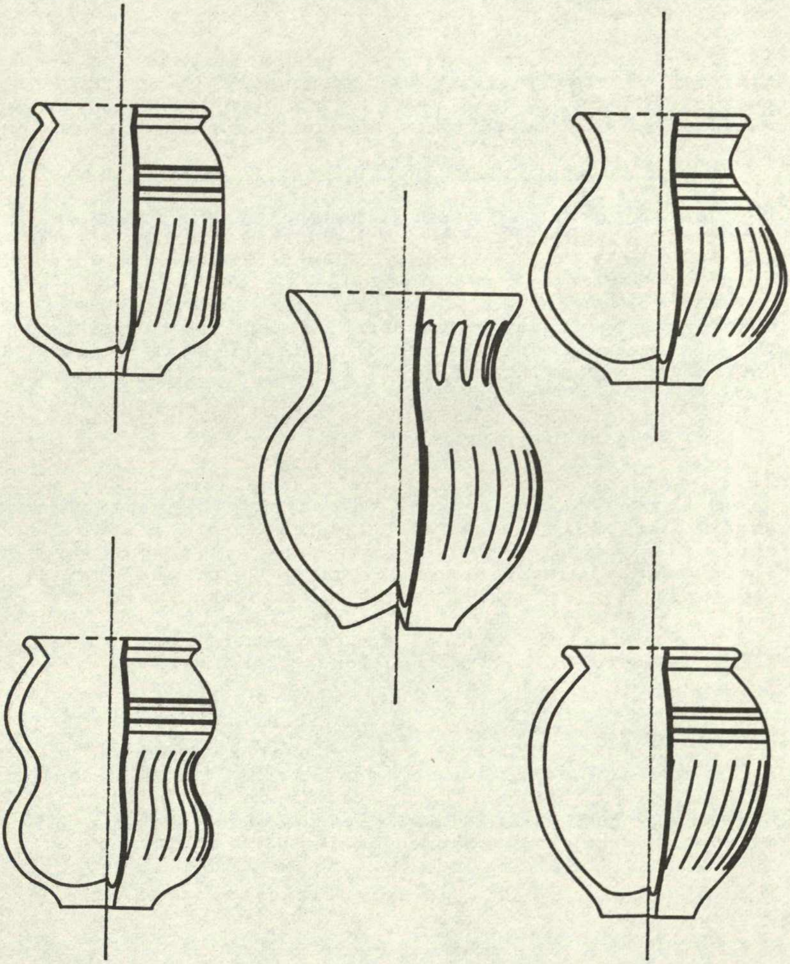


Figure 5



introducing unwanted changes in it's gradient.

A rather simpler technique for curve description was formulated by Bezier, (see the references cited in the text by Rogers and Adams, for a detailed account). This is not a curve fitting technique in that the shape of the curve is uniquely defined by the verticies of a polygon. In addition, the curve is only constrained to pass through the first and last points. Nevertheless, the intermediate vertices determine the order, shape, and derivatives of the curve. Since the curve tends to follow the shape of an open polygon, it provides quite an intuitive means of curve design and manipulation. In terms of flexibility, the Bezier technique offers considerable advantages over the cubic spline, but, it is less frequently used in CAD packages than the B-spline largely due to the lack of local control over the shape of the curve and hence the difficulties that arise when it is required to generate curves that contain regions of intricate detail.

The B-spline curve offers a good compromise between an intuitive editing facility and adequate local control over the curve, and for this reason, the B-spline technique has been adopted for the purpose of modelling pottery profiles.

Brief Description of the B-spline Technique

The objective of generating any spline is to provide some means by which a generally smooth curve may be defined by a relatively small number of co-ordinate points which may be imagined to be at the vertices of a polygon. The shape of this polygon in conjunction with the B-spline transformation function is used to determine the shape of a curve. Thus, a polynomial is defined whose terms are functionally dependent on:-

(a) The (x,y,z) co-ordinates of the control points, and,
(b) on some parameter "t".

The latter variable will specify displacement along the actual curve and can be used to control the separation of incremental positions on it. The degree of influence each vertex will exercise over the strength of various terms in the polynomial, (and hence on the shape of the curve), is determined by a so called basis or weighting function.

The parametric form of a curve generated using the B-spline basis or weighting function, N(t), is given by:-

$$P(t) = \quad P_i \; N_{ik}(t)$$

for all values of "t", from zero to some maximum value of t. The P_i are the position vectors of the defining polygon vertices. The index, "i", refers to the i'th polygon vertex, and ranges from, 0 to "n". The subscript, "k", is an integer and denotes the order of the B-spline curve.

The B-spline Basis or weighting functions $N_{ik}(t)$ are defined by the following recurrence relations:-

$$N_{i,1}(t) = 1 \text{ if } x_i < t < x_{i+1}$$
$$0 \text{ otherwise}$$

$$N_{ik}(t) = [(t-x_{k-i})N_{i-1,k-1}(t) + (x_k-t)N_{i-1,k}(t)]/(x_k-x_{k-i})$$

The x_i are members of the "knot vector" which contains integers indicating the maximum value of t and the number of times any control point is repeated. The end-points are always repeated to ensure that the curve passes through them.

CONCLUDING REMARKS

The software was orginally intended to allow drawings of pottery profiles to be entered into computer files so that subsequent retrieval and reproduction would be both quick and convenient. In most respects, program "NEWTST" meets these aims, however the subject of data entry requires some attention.

The number of scale profile drawings that have been published is highly extensive and it would therefore be an advantage to have some convenient method for digitising them. It certainly is possible to provide positional information using the light pen in conjunction with tracing paper. The current implementation is not very suitable for tracing profiles from drawings since it accepts control points and uses the B-spline technique to generate curves. Therefore, a curve will not in general pass through any but the first and last positions entered and so tracing a profile using a light pen is not as straightforwared as with a pencil! Ideally, a "trace mode" is required which would allow the user to put a curve through the points thereby providing a set of positions on the curve having a set incremental spacing. Finally, some transformation would have to be carried out, which given the curve, would yield it's corresponding B-spline control points. This would facilitate subsequent manipulation or storage in a file using existing software.

Program "NEWTST" provides no means by which a profile may conveniently be digitised from tne actual object. This is a hardware consideration and, although possible, it seems impractical to "draw" a profile from tne actual article directly on the screen. Rather, some method which directly digitises solid objects is required. As mentioned above in connection with tracing drawings, the measurements obtained would represent co-ordinates actually on the profile. Consequently, a transformation to yield the corresponding B-spline control points would need to be carried out. this would allow convenient data entry off the actual item and also provide for compact storage of that data.

Although quite a lot of work needs to be carried out in the aforementioned areas, there are many advantages of being able to enter profile data conveniently into a computer. It can readily be seen that given an appopriate filing system, retrieval of a profile drawing, and any related text information could be achieved conveniently and very quickly. Obviously, to facilitate this, a computer file indexing system would have to be designed and included. However, perhaps the most significant result of digistising pottery profiles is that the data is then readily available of numerical manipulation. A very extensive library of mathematical utilities has been developed, for example the NAG library for FORTRAN. Thus the profiles of a large number of items may be compared numerically using their defining control points this would allow profiles to be categorised statistically according to some derived critera. Doing this would in turn provide a means by which the likelihood of a single item belonging to a specific group or type could be quantified.

NOTES ON FUTURE WORK (SL)

The project described here was carried out during the summer of 1983 and was completed in the three months available. Since then the Imlac terminal has become very unreliable and is now due for replacement. The software described here is likely to need some editing before it can be run on the new system and is unlikely to be available before 1985.

Mean while the next group of projects will start with the RD Tracer on the Spectrum, with the intention of building up a collection of programs (probably on microdrive) which will fit a digitised outlined to a B-spline curve and continue to provide various types of analysis for such profiles. While the work described here can only be run on the DEC20 at Birmingham, the Spectrum software should be widely available at a very low price.

REFERENCES

The most recent textbook to describe this topic is:

"Computational Geometry for Design and Manuafacture"
I.D. Faux and M.J. Pratt ISBN 0 470 27069 1

The text referred to in the paper was:

"Mathematical Elements for Computer Graphics"
D.F. Rogers and J.A. Adams ISBN 0 07 053527 2