Of the $18 in dues collected for each member, $4 goes to ACM to support the costs of maintaining membership lists and other headquarters services directly related to membership. The remaining $14 almost pays for the cost of printing and mailing the four issues of the newsletter. We actually have a net loss on each member! Added to this is the lower registration fees paid by the 15% of our membership who attend the conference each year and you get quite a deal when you belong to ACM SIGGRAPH.

It should come as no surprise, then, that the executive committee is considering an increase in the dues to take effect in Fiscal 88 (this means new or renewal memberships after June 30, 1987). We are currently looking at a $2 increase with the expectation of a similar increase in two years (roughly a 5% annual increase to cover inflation).

Publication

This issue of the newsletter is a bit unique. The third issue each year has usually been the proceedings of the annual conference. This year the proceedings will appear as the fourth issue, with a new fifth issue appearing as the October 1, 1986 issue.

This change has been made to provide more timely information on a regular basis to the membership. The previous publication schedule had a six-month gap between the second and fourth issues during which vital information such as conference announcements and submission deadlines frequently went unreported. John Beatty (SIGGRAPH editor-in-chief) has established a new publication schedule that will see four full issues of the newsletter in addition to the conference issue. Refinements to the schedule may be made in the near future to adjust the publication dates.

In the coming year I hope to continue supporting the improvements in quality that have occurred in the newsletter and to be able to carry more material such as the GKS report that was published as an issue of the newsletter in 1984.

I hope that you will agree with me that *Computer Graphics* is a valuable part of ACM SIGGRAPH and that it should perform a vital link to timely information in the field of computer graphics.

Local groups

The recent explosion in local SIGGRAPH groups has been quite impressive. Like any new activity, there is a learning period during which we will have to adjust our views on the appropriate balance between local activities and those of the large organization. Maxine Brown (vice-chair for operations) has assumed primary responsibility on the executive committee for coordinating local group activity. She has reported in the newsletter on the efforts that she and Steve Keith (SIGGRAPH local groups coordinator) have been making to set up guidelines for chartering local SIGGRAPH groups.

One aspect of this that was not anticipated is the desire by some members to form local groups that cover fairly large geographical areas. Requests have been made to charter "SIGGRAPH X," where "X" has been one or more countries (though we have yet to receive a request for an entire continent). At the present time we are moving cautiously in this area, preferring to charter only truly local groups that have geographic homogeneity.

ACM by-laws require that local SIGGRAPH groups exist within the framework of a local ACM chapter. In most cases this works well. ACM has developed policies for dealing with local groups when there is no local chapter, but the expected mechanism is to work through the chapter.

An issue that has been raised a number of times is the financial obligations of local SIGGRAPH groups. As with ACM local chapters, local SIGGRAPH groups are designed to be self-supporting. The annual dues paid to ACM SIGGRAPH cover membership expenses in the parent organization. Most local groups will have a dues structure of their own to provide additional member services tailored to their own needs and complementing the services provided by ACM SIGGRAPH.

Every effort is being made to assist local SIGGRAPH groups in obtaining SIGGRAPH materials (such as the video review and slide sets), but the mushrooming number of local groups precludes any significant financial involvement by ACM SIGGRAPH in this area.

The outlook for next year

I look forward to continuing my role as SIGGRAPH chair next year and to active participation from SIGGRAPH members in the activities of ACM SIGGRAPH in the years to come.

A Personal View of Progress in Computer Aided Design

by Pierre E. Bézier

An earlier version of this paper was presented by Dr. Bézier at the SIGGRAPH '85 Conference, in accepting the 1985 Steven A. Coons Award for Outstanding Creative Contributions to Computer Graphics.

1.0 Introduction

Industrial progress occurs in two ways. One is a slow and continuous scheme, comprised of small day-to-day steps. For example, one recalls that the machining of cylinder-block bores had, circa 1930, a range of 20 microns; by 1980 it had shrunk to about five microns. Thus the improvement in honing accuracy has been about 15 microns in a half century, and this seems to be a good case of gradual progress. The other mechanism can be described as a succession of large and fundamental changes. A biologist would think of the latter as Mendelian mutation, as opposed to Darwinian evolution.

For such a change to happen, there are three essential factors:

1) a scientific discovery or technical invention;
2) the possibility of economic advantage;
3) a sufficient number of people who can be trained to take advantage of (1).

Obviously, the advent of computers triggered a fundamental change in industry, especially in automobile companies.

As I have worked in this field for more than 40 years, I will try to discuss this specific example, particularly the production of car bodies and sometimes at a very fundamental level, though of course many other industries have known a similar evolution.

Figure 1

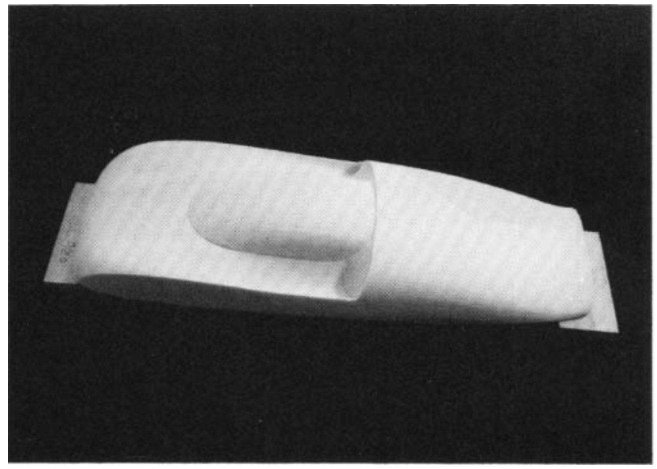

Figure 2

It should be recalled that CAD/CAM requires some rather expensive equipment, in terms of both hardware and software. Hence it was originally predicted that it would only be available to large and wealthy companies. This is no longer true, as is evident from its appearance in industries of medium and sometimes small size.

2.0 Previous Solutions

It seems advisable to recall first how car bodies were designed and tooled before the advent of CAD.

First, stylists built a few small-scale clay models, about 1/5 or 1/8 of full size, from which top management selected two or three for further development. From offsets, measured with a coarse "bridge," a full scale drawing was then obtained, representing the exterior shape or "skin" of the future car. This contained cross sections 10 centimeters (4″) apart, used for bandsawing plywood ribbings for a full scale "clay model." This model was in fact made of plaster, lacquered and equipped with wheels, chrome trim, windshield, etc. (Figure 1). When the final clay model had been accepted after a few modifications, or many, offsets were measured so as to produce a final drawing containing every detail: inner panels, locks, the frame, hinges, handles, glass plates, gaskets, the brackets for holding mechanical components, etc. Next came the important step of carving the master. Between cross sections, derived from the drawing, highly skilled patternmakers were responsible for interpolating to obtain a "fair" or "smooth" appearance. Again, after some modification, the master became the only and absolute standard, for as long as the car remained in production. Replicas, made of plaster or fiberglass and resin, were used for copy-mill stamping tools. Other replicas were substitutes for the master for hand finishing and die-spotting, and for adjusting assembly and inspection jigs.

Not only was this a difficult, long and costly process, but the major drawback was that each step could involve alterations, either for aesthetic purposes or to facilitate production, and no one person could be held responsible for a loss of accuracy. Then, too, the fitting together of parts involved adjustments, and the stylist could always complain that his basic concept had not been properly translated.

That loss of accuracy was cause for argument between stylists, the drawing office, production engineering departments, the tool shop and inspectors, as well as with subcontractors, licencees, etc. This added to expenses and resulted in delays.

With the help of a computer, it became possible to do away with this hinderance. Transmitting digital information is accurate, fast, permanent and indisputable. Moreover, a gain in accuracy means cutting the time required to make modifications, as well as for fitting and, consequently, cost.

It should be noted that, information being represented by numbers and not by drawings, templates or replicas, the accuracy of the final product depends only on that of the machine-tool, lathe, milling machine, grinder, etc., and not on the accuracy of the drawings, which display information to people but play no part whatsoever in the accuracy of the product.

3. Conditions

A system built to take full advantage of the power of a computer should at least comply with the following basic requirements:

1) The system, and especially its mathematical basis, should be usable by people such as designers, stylists, production engineers, machine-tool operators, etc. They should not need a knowledge of mathematics beyond that typical of their profession, which is mainly geometric. The system should rely on instinct rather than pure science.
2) The curves available should not be limited to lines, circles and parabolas; they should include space curves, and offer a large variety of shapes.
3) In the styling and drawing phase, a drawing, or better yet, a 3-D object, should be obtainable in a very short time: minutes for a drawing and a few hours for a solid object (Figure 2). The aim is to correct any errors rapidly and reach the desired result by iteration.
4) The cost of data processing should be kept within sound limits. As a consequence, the amount of data to be stored and processed should not be too large.

4. Facilities

After nearly 20 years, the tools are available to accomplish these goals.

4.1. Software

Twenty odd years ago, different techniques were used for defining curves and surfaces. Some made use of polynomials expressed in Cartesian space, which seemed

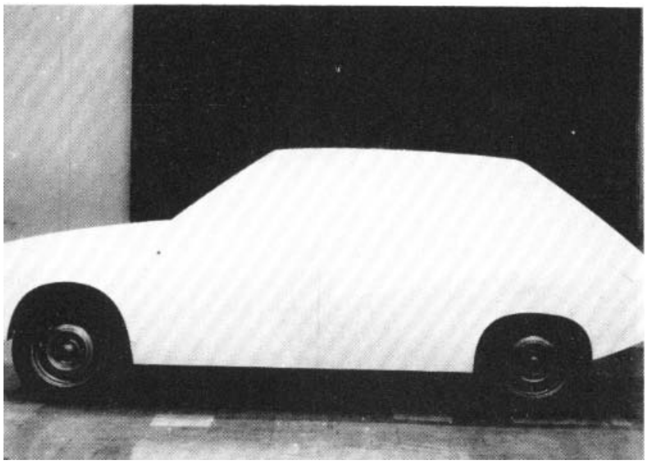

Figure 3

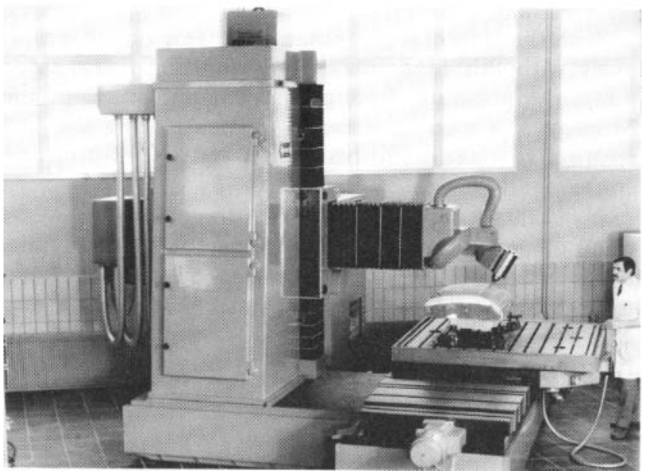

Figure 4

logical owing to the nature and architecture of the machine tools. Another, at about the same time, quite successfully took advantage of the double harmonic function used in aerodynamics and was well suited for analog computing. Since 1965, parametric polynomials or rationals have become practically the only solution for free-form surfaces. Nevertheless, analytic functions are well adapted to the description of mechanical parts which were, by tradition, traced with the help of straightedge and compass.

Mathematicians pay close attention to parametric spaces; week after week, indeed day after day, results are published in technical and scientific magazines that describe recently discovered properties or new ways of extending the capabilities of already existing systems or software: triangular patches and the finite element method are among the most promising improvements in recent years, but one must admit that up to now, many of the geometric discoveries have not yet been implemented in software.

The systems available now are rather powerful. The definition of curves and patches is obtained on line via cathode ray tubes, as are the computation and display of intersections, rotations, scaling and mirror images. The removal of hidden lines, color, shading and reflections add to the quality of CRT images and styling takes great advantage of these techniques.

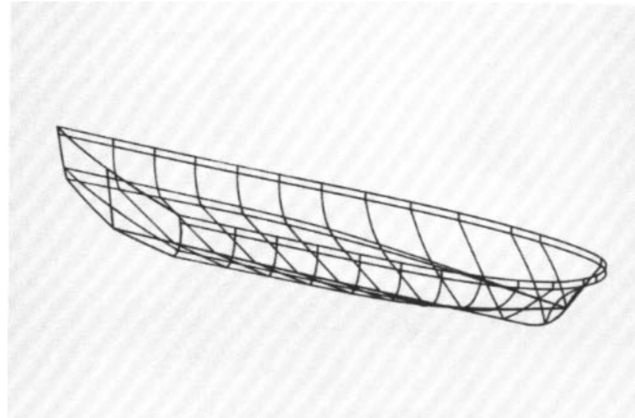

Figure 5

4.2. Hardware

CRT's are used for the preliminary definition of shapes and for additional computation such as finite element analysis, determining the dynamics of fluids, etc. Large machines produce final drawings, which are still and will remain required. It should be remarked that their accuracy need not be very high, since the actual definition is made of numbers and not from tracings, as has been previously explained.

Since it is vital to give stylists or designers the possibility to see and touch without delay a 3-D rendering of the object they have conceived, it is necessary to provide them with machines able to carve very rapidly a large part of a car or, even better, a complete one (Figure 3). These are special milling machines (Figure 4) or robots able to deal with parts made of styrofoam or resin. The spindle is revolving very fast—up to 30,000 rpm. Its power seldom exceeds one or two kilowatts, but the feed can reach 150 to 200 mm/sec (30 to 40 feet/min). The accuracy need not be better than 0.25 mm (.01 in.), except when the machine is used to manufacture aircraft models for wind-tunnel test, in which case 0.1 mm (4 thousandths of an inch) is the maximum limit for a part about 1.4 meters (5 feet) long.

In the stamping tool shop, heavy milling machines are directly controlled by computer. The reason is that with such a system, the quantity of basic data that is required to define a part is limited to the vector coefficients of the patches. Tool offset, parameter increment, feed and the choice of scale or coordinates are left to the operator and input via the workstation keyboard. Consequently, the same small amount of data suffices for controlling the roughing, semi-finish and finish cuts, whatever the dimensions of the cutting tool, as well as for manufacturing a part or its counterpart, i.e., a punch and die. This point is important, especially when subcontractors are involved, or when factories are distant from each other.

5. Use of Systems

In a design process, drawing and computing, except for aesthetic objects, are performed alternately and iteratively. Drawing comes first since computing must take shape into account, even though it be provisional.

Regarding a shape to be obtained, three different types can be named:

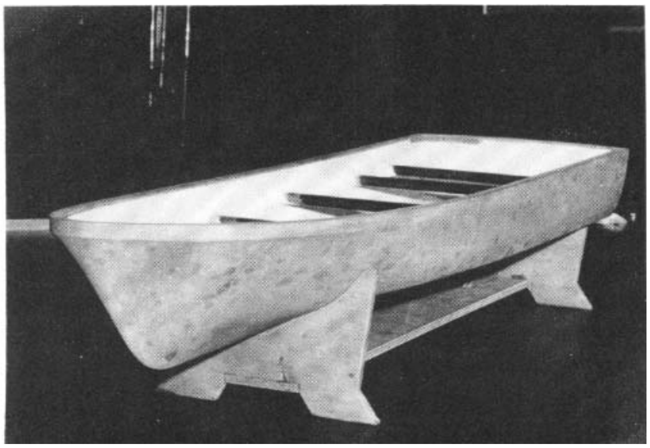

Figure 6

Figure 7

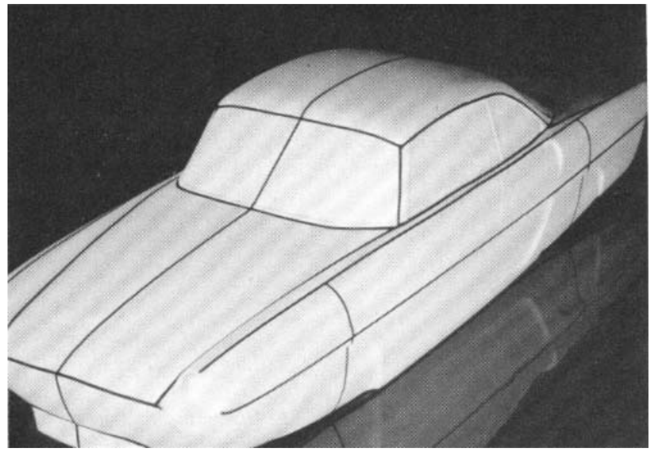

Figure 8

Figure 9

1) Parts that have basically technical function, the shape of which is directly related to the efficiency of the mechanism in which they take part. Obvious examples are, for instance, turbine blades, propellors, aircraft wings, boat hulls, etc. (Figures 5 and 6).

   In such a case, the final shape is obtained by adjustments made after tests, and it must be produced with great accuracy, e.g., one part in 10^4.
2) Parts that have a purely aesthetic function. The accuracy is less vital than in the previous case, but the mathematical definition can improve the continuity of the hand-made model.

   Some people have endeavored to relate the beauty of a curve or of a surface with the rate of variation of slope or curvature, but, up until now, the final judgment is the stylist's responsibility.
3) Parts without aesthetic function but which must contain, at least approximately, some points while not colliding with neighboring objects. Inner panels of a car body are a good example of this class.

To define the shape of an object by a set of vector-coefficients, three approaches may be taken:

1) The first is appropriate for technical products that must be expressed with great accuracy. Offsets are measured, either with an appropriate gauging instrument (Figure 7) or by photogrammetry, at many points, most commonly on cross sections. The curves interpolated between these points bound an ensemble of patches that are dealt with by a quasi-automatic process. The best known and most used bears the names of Coons.
2) In the second approach one defines first, either on a drawing or, better, on a 3-D model, a set of free-form or plane curves considered as principal or "character" lines, on which the rest of the shape is built (Figure 8). The points inside the patches are computed in the same manner as in the preceding solution. This is, for instance, the prevailing process when the styling and drawing offices work in the traditional way—that is, don't use the computer, and CAD is applied from the production engineering step on.
3) In the third solution, a numerical definition is built directly at the beginning of the process, that is by the stylist or, at least by the designer. Feeding the computer with numbers via lightpen, keyboard, joystick, tablet, etc., results first in a sketch on a CRT, then in a real drawing on a large drawing machine, and, finally, in a 3-D object carved by a milling machine or by a robot (Figure 9). Drawing and sculpture are liable to be modified in a very short time.

In the automobile industry, most stylists still prefer to produce small scale mockups by hand, and then have full-scale clay models built, under their supervision, by professional plasterers. But there are cases of young stylists who define and produce directly small and full-

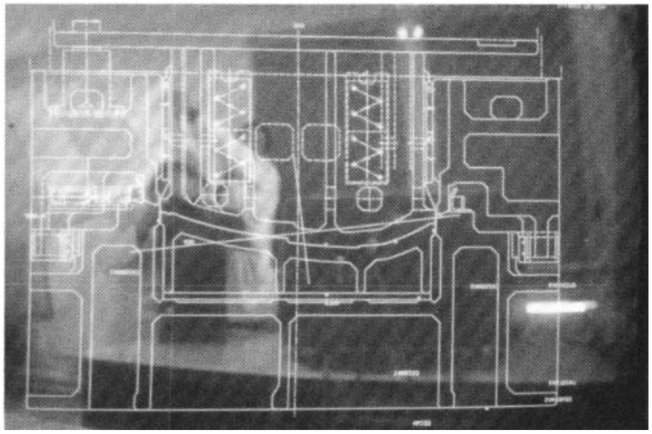

Figure 10

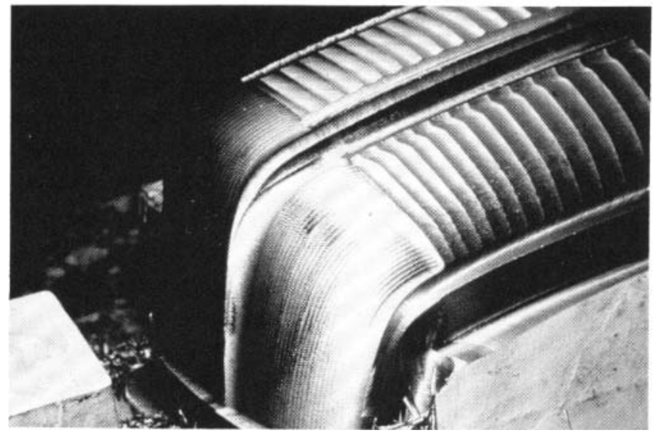

Figure 11

scale models, milled in styrofoam blocks by a plano-miller, or a robot, controlled by computer. The advantage is obvious, as information is then transmitted to every department, drawing office, production engineering, pattern shop, tool shop and inspection, completely free from distortion or error.

Style defines only the outer shape of a car body. It is the task of the drawing office to convert that information into complete drawings of each part, door, top, fender, hood, trunk, etc., and to define the parts to which style is irrelevant (i.e., inner panels, frame, hinges, brackets, locks, etc.).

Perhaps the greatest advantage of numerical definition by style is to let R&D engineers be free to simulate stress, distortion and vibration as soon as style can give an approximate definition. Some sensitive points, such as windshield pillars or rear glass housings, can be evaluated long before an actual prototype is built and ready for testing on a torsion and vibration bench. This point is considered important because it reduces the design time and spares the cost of some prototypes.

The methods drawing office is in charge of tracing stamping tools (Figure 10), assembly jigs and some inspection fixtures. Because of the springback effect, there should be a difference between the shape of a part and that of the corresponding press tool. It is also the duty of the tool drawing office to choose the convenient tipping (or tilting) angle in order to facilitate the stamping operation, and to define the surface on which the blank is clamped prior to pressing.

The shape of the consumable patterns must include some allowance for machining, and compensation for pressing.

In the tool shop, the trajectory of the cutting tool is simulated on a CRT. The finishing cuts are close enough to leave a very small amount of material, i.e., 0.02 to 0.05 mm (1 to 2 thousandths of an inch) to be removed (Figure 11) or, rather, polished, by hand. Tool setting and spotfacing are no longer required.

6. Use of the Systems

CAD/CAM has now been in use — in actual use — for 10 years, and significant results can be safely stated.

The delays have been nearly halved for obtaining a final definition of a clay model as well as for starting the production of a new car body. This is as a result of the speed of the tracing operation, and to the improvement of the accuracy, which is at least one order of magnitude. Consequently, the matching of adjacent parts has been practically obtained without setting. Moreover, the accuracy of the patterns and the speed of milling operations have cut the manufacturing time.

The tool cost has been reduced by 40 percent and sometimes by 60 percent. The final setting of punches and dies has been replaced by mere polishing, and the delay and cost for this phase has been cut by 90 percent.

The data representing the shape of an object, which have to be carried between departments and workshops, are limited to coefficients defining each patch, as the coordinates of each point of the trajectory of the tool, including offset, are computed on line.

With very few exceptions, the whole system has been easily accepted and understood by people of every rank: designers, operators, production engineering specialists and maintenance people; a few stylists are even beginning to pay attention to it.

One thing is now granted: CAD/CAM has reached the point of no return and it is admittedly irreplaceable, especially when finite element calculations are involved.

7. Conclusion

Regarding a technique that is only 10 years old and still in active development, it seems risky to make long-term predictions. Nevertheless, some conclusions can be offered.

Today there is a choice between different CAD/CAM mathematical definition systems, and very few problems remain unsolved. Nevertheless, some improvement is still desireable, and there remain practical problems for the specialist. For instance, the shape of an object can be defined either by so-called "analytic" functions or by parametric expressions. It happens that when both are used for different parts of the same object, e.g., a stamping tool or a forging die, it is possible to compute intersections and fillets, but it may require processing and storing rather large quantities of numbers. I, personally, wonder whether expressing analytic shapes with parametric functions could make things simpler.

Blending patches together is, most of the time, reasonably easy, but in some cases, a totally automatic system would be a great help — at least for objects which have no aesthetic function to perform.

One of the most vital problems is still to unify the mathematical solutions and, most important, to make different software easy to implement in most types of computers. The problem is especially crucial for subcontractors working for different companies. The case of the stamping tool industry is one of the most striking.

Drawing and, especially, styling services need a system for obtaining, in a very short time, a 3-D representation of an object. Milling a foamy material is, for the time being, the fastest method. Perhaps physicists will contribute by making it possible to replace milling cutters with laser beams, and so speed up the process. One could also dream of holograms generated by a computer, or of a fast curing resin dispensed by a robot holding a gun. Perhaps such dreams will be realized in the not too distant future.

"Expert systems" are much spoken of. They are supposed to sum up or to accrete the knowledge and experience built up by people, and to become capable of solving most of the problems that engineers could be faced with. But it would be too optimistic—or should I say pessimistic?—to imagine that man could be totally replaced by a computer in activities such as styling, design and manufacturing techniques.

The future of CAD/CAM can mainly, but not only, be limited by the availability of people able, at every level, to be trained to use it. Another point is that some financial advantages are difficult to assess, as, for example, the reduction of lagtime. This is likely to hinder acceptance by top managers.

In January, 1968, a paper was presented at the Detroit S.A.E. meeting, dealing with "the use of NC for car body design and tooling."

Reviewing this text at the request of a large company a specialist concluded that:

> "...computer methods for surface definition can and will be used more and more widely as time goes on, and maintenance of a healthy competitive position in the industry can be insured only by adopting similar methods and putting them in use as early in the design cycle as human personalities will allow."

The name of the specialist? Steven Anson Coons.

SIGGRAPH Awards Committee

by Maxine D. Brown
SIGGRAPH Vice Chair for Operations

Awards: What are they?

SIGGRAPH works because it is a collection of personalities, and no one is too good (or too bad) to volunteer their efforts for a common goal. Several years ago, however, the executive committee came to grips with the fact that there are some outstanding personalities that deserve recognition for their significant contributions to the advancement of state-of-the-art computer graphics. In 1981, the SIGGRAPH executive committee appointed one of their directors, Pat Cole, to propose a computer graphics awards program and submit it to ACM for approval. And so began SIGGRAPH's formal recognition of some of the outstanding members of the computer graphics community.

SIGGRAPH currently has two awards. The *Steven Anson Coons Award for Outstanding Creative Contributions to Computer Graphics*, awarded during odd-number years, recognizes individuals who have made a long-term creative impact on the field of computer graphics; it is accompanied by a $1,500 honorarium. The *Computer Graphics Achievement Award* is presented annually to individuals who have made significant recent accomplishments in computer graphics; it carries an honorarium of $500.

The scope of accomplishments for award recipients encompasses both theory and application. This includes, but is not limited to, works of art, development of algorithms, hardware design and innovative applications of computer graphics. Neither award is based on service to SIGGRAPH.

The recipients of these awards, who need not be members of ACM or SIGGRAPH, are the guests of SIGGRAPH at its annual conference. The award presentations are held during the opening session of the technical program.

Awards: Who selects?

The SIGGRAPH awards committee consists of an administrative chair, selected by the SIGGRAPH executive committee, and five selection committee members, appointed by the awards chair with the approval of the executive committee. The chair is responsible for soliciting nominations, administrating the selection process and making the presentation. The selection committee members are responsible for evaluating the contributions of individuals being considered and for selecting the recipients. Approval of the recommended recipients by the executive committee is required.

Until recently, Jon Meads served as awards chair; he is succeeded by Bert Herzog. The SIGGRAPH executive committee wishes to express its warm appreciation for Jon's outstanding efforts initiating and maintaining a very professional and prestigious awards program. The executive committee is pleased that Bert has agreed to be his successor, as he will continue Jon's excellent job with his own form of panache.

The selection committee members are appointed for five year terms; the terms are staggered so that only one committee member is appointed per year. Selection committee members meet once a year at the annual SIGGRAPH conference to discuss the program and procedures. Nominations are reviewed and recipients are selected during a teleconference meeting several months before the conference date.

Current members of the selection committee are Nelson Max, Loren Carpenter, Jeff Posdamer, Martin Newell and George Michael. Dave Evans and Carl Machover are past members, and their early efforts contributed significantly to helping the awards program become established.

Awards: Who's won?

To date, the *Steven Anson Coons Award* has been presented twice. The recipient of the first award was Dr. Ivan E. Sutherland, the developer of SKETCHPAD—which provided the vision of what computer graphics could be when made available interactively to engineers. In addition, Dr. Sutherland personally inspired numerous individuals who have made major contributions to computer graphics over the past 20 years.

The second recipient of the *Steven Anson Coons Award* was Dr. Pierre Bézier who developed the technique of specifying free-form curves and surfaces through the use of control points. Dr. Bézier has been a major