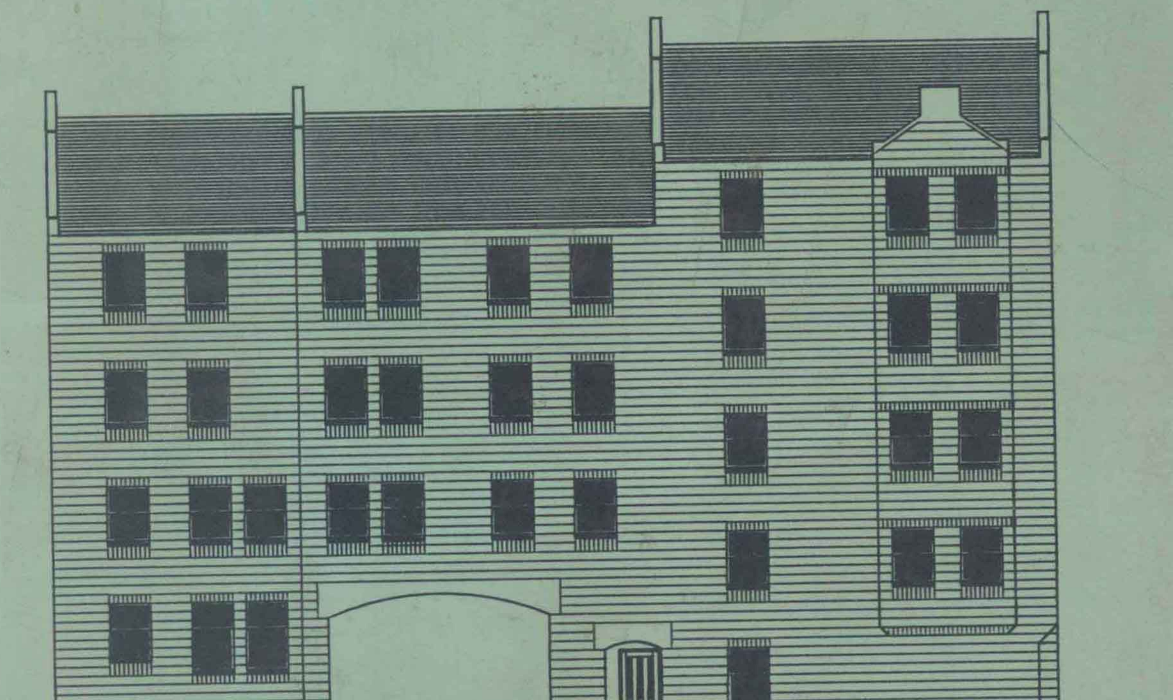
CAD84

Brighton Metropole Sussex UK
3–5 April 1984

Organized by the journal *Computer-Aided Design*



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6th international conference and exhibition on computers in design engineering

Organized by the journal *Computer-Aided Design*

Edited by Joanna Wexler

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FOREWORD

Welcome to CAD84, the sixth in the series of international conferences and exhibitions on computers in design engineering. The series, organized by the journal *Computer-Aided Design*, is an established international forum on the state-of-the-art in CAD and CADCAM.

This year's conference has two main streams. Two new sessions have been added, covering the important talking points of expert systems in CAD and process plant design. These join sessions on CAD in architecture, CADCAM, control, design techniques, drafting systems, electronics, geometric design, kinematics, mechanical engineering, solid modelling and structures. Also included are the Systems Purveyors presentations, where delegates may hear about commercial systems.

The exhibition, running alongside the conference, has again expanded enormously in size and numbers demonstrating that CAD has become part of the everyday working environment in many industries. Here you will find the hardware, software and services for your particular application.

I would like to thank the members of the conference planning panel for their efforts in refereeing the submitted papers, assembling the conference programme and chairing the sessions. Thanks are also due to the conference sponsors and co-operating bodies. I am grateful to the authors for responding to the call for papers to provide such a valuable state-of-the-art reference volume of CAD activity world-wide.

I hope that at the conference sessions, at the exhibition and during the social events you will develop new ideas and friendships that will ultimately help to increase the benefits of CAD to all.

Joanna Wexler
Conference Organizer

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CAD/CAM: Past, requirements, trends

Pierre E Bèzier

After briefly reviewing the major stages of CAD/CAM, the progress that has been made in hardware and software is described.

From these facts, are deduced some trends, giving a picture of the not too distant future.

* * *

Après un bref rappel des ètapes principales de l'evolution de la CFAO, on decrit les progres accomplis par les moyens matèriels et logiciels necessaires à son developpement.

De ces donnees, on essaie de dèduire quelle pourrait être l'èvolution dans les années prochaines.

1. RETROSPECT

Without any doubt, the advent of the computer is one of the major causes of the improvement in industrial practice. Moreover, numerical control and CAD/CAM are among the most important technical as well as sociological achievements.

This evolution has been so fast and so complete that we are liable to forget some important points, and it may be profitable to cast a glance over the past and briefly recall the most significant steps.

In 1942, the first computers appeared. One of them, probably ENIAC, was used to define the motion of a milling cutter manufacturing a camoid forming part of an aircraft engine automatic gas control system. A little later, BENDIX-AVIATION operated a special milling machine for cutting gas turbine foils.

This was not yet true CAD, but it was a great help for engineering the production of highly difficult parts.

In 1955, twenty numerically controlled machine-tools were displayed at the Chicago Machine Tool Show. Industry then began to play real attention to this technique.

In 1958, the APT program was intended to help engineering of production operations. It dealt with "conventional" geometry, lines, circles, sometimes parabolas, and a few polynomial curves.

At about the same time, the aircraft and automative industries began working on the problem of defining space curves and "twisted" surfaces, which are found in wings, fuselages and car bodies.

In 1964, James C Ferguson, of the Boeing Co., published a paper on "Multivariable Curve Interpolation" in the Journal for Automatic Computing Machinery. The polynomial expression was limited to degree 3x3.

In 1965, the SKETCHPAD project, by MIT and IBM, associated computing and drawing.

In 1967, Steven A Coons published project MAC from MIT: "Surfaces For Computer-Aided Design of Space Forms".

The objective was to describe completely four-sided patches whose boundary lines were given, ensuring at the same time slope or curvature continuity between adjacent patches.

In 1968, Doctor Robin A Forrest, now a professor at the University of East Anglia, was working in the Cambridge University Mathematical Laboratory of Professor Wilkes. After spending some time with Steven Coons, he wrote his Ph.D. dissertation on "Curves and Surfaces for Computer-Aided Design".

At about the same time research was being carried out in this area in Great Britain by Charles Lang, ARMIT, Malcolm Sabin, Flutter, etc. and even Mehlum in Norway.

A brief description of the principle of the UNISURF system appeared in the French technical press.

In 1969, William Gordon and Richard Riesenfeld's papers on Multivariate Approximation appeared in the Journal of the Society for Industrial Application of Mathematics, and in notes inside General Motors Co.

Since that time, a great amount of work has been performed around the world on this subject: USA, Canada, Western Europe, Japan and China. Little is known about the results of work carried in Eastern Europe.

Most systems, if not all, are based on the use of parametric polynomial functions with vector coefficients.

2. EVOLUTION

The progress of the means that are available largely reacts on the evolution of a system. Consequently, it seems advisable to briefly describe the changes that have taken place during the last twenty years, in both hardware and software.

2.1 Hardware

So great has been the improvement in the possibilities of computers that it seems difficult to describe it by figures for speed, power, cost or volume. Most of them should be expressed by two orders of magnitude, and sometimes three. Until about 1960, analogue and digital computers were still competing; the capacity of a memory was expressed, at the utmost, by a few kilo-octets, and the accepted idea was that a company should have a huge monster of a central computer working, simultaneously, for the benefit of every department.

Now, connecting together large, medium, mini and microcomputers has decreased the cost and the volume of a system, and it can be safely admitted that speed has been increased by a coefficient close to two or three orders of magnitude.

Designing an object entails displaying its image; a drawing is quickly obtained on a cathode ray tube (CRT) and it is easy and fast to rotate, expand or alter it; the accuracy is not very great, but this is seldom important. It is difficult to pass a final judgement regarding the aesthetic value of a project, even when it is displayed by a coloured and shaded image.

On the other hand, drawing board accuracy can be excellent, sometimes about 1/10,000, which is very useful when tracing maps, charts or templates. The speed of the tracer is commonly 300mm/s and sometimes 500, for motor driven machines, but magnetic control is even faster; the surface is flat, which makes aesthetic judgement easier; the total dimension can exceed ten meters and one of the major advantages is the ability to produce a full scale drawing on a plastic sheet that is very, if not perfectly, stable.

To obtain a true three-dimensional image, some drawing offices are equipped with specially designed milling machines intended to manufacture soft materials such as styrofoam, plaster, wood, resin and, sometimes, metal. They have a very fast feed, up to 200mm/s but the spindle power needs not be very great ie 1 or 2 kW.

2.2 SOFTWARE

CAD/CAM involves three major activities: computing, tracing and manufacturing models.

When an object has to fulfill some technical requirements, computation is first performed for determining a few basic dimensions related to physical phenomena such as stress, deflection, fluid dynamics, etc.; then, from these data, a rough sketch is drawn and then, iteratively computing and drawing, the final shape is defined.

The manufacturing process is first related to the definition of the surface and that of the cutting tool, and the program has much in common with the shape of the object itself, since it is important to avoid deflection, distortion and chatter.

Architectural drawings are mainly based on lines rather than curves, but the deletion of hidden lines is compulsory, as well as the use of a very complete database for standard components.

The tracing of the shape of an object raises a twofold problem: mechanical parts, for centuries, have been traced with compasses, T square and straightedge; some details such as fillets or draft, being left scantily defined, to be taken care of by craftsmen, highly skilled patternmakers, diesetters, etc.; some programs, e.g. APT, etc., have incorporated the properties of lines and circles, together with those of analytic simple curves, surfaces or volumes - mainly planes, cylinders, cones, spheres and toruses.

To deal with some physical phenomena and with aesthetics, a greater variety was required and, among many solutions developed the parametric curves are the only ones which have survived in practice.

Before the advent of CAD/CAM, the accepted practice for defining a surface was to trace cross-sections on a drawing, then to carve them in a block of material such as wood, plaster, resin or metal, finally leaving it up to craftsmen to interpolate between them and obtain the final shape of the model.

Steven A Coons was requested to devise a mathematical solution for a similar problem but, instead of cross sections, he was given a net of parametric curves entirely covering the surface; he built a complete definition of each mesh, ensuring slope and curvature continuity between them.

His system, based on tensor calculus, is considered a major milestone in CAD and gained him well deserved world-wide fame.

A little later, the possibilities of the COONS method were somewhat expanded with the help of characteristic polygons and nets. It seems that the improvement lies in the possibility to deal with degenerate patches and to make geometric properties easier to grasp and predict for the layman.

Then William Gordon and Richard Riesenfeld published in 1969, a solution also based on parametric spaces together with special interpolating functions; their system can be totally automatic, but the operator can also control it.

Since that time, solutions have appeared, by the name of CONSURF, B-splines, H-splines, K-splines, β-splines, etc. which apply mainly to cubics and which differ by the method for controlling the moduluses of the first end-derivatives.

Moreover, CAD/CAM has taken advantage directly or indirectly of the mathematical research carried throughout the world, by scientists such as Professors Cox, De Boor, Boehme, Sablonniere, Chang, Wu, etc. not to mention Malcolm Sabin who attacked, and solved, the problem of n-sided patches.

It can be broadly stated that, up to 1975, most of the work concentrated on the description of surfaces, since the main interest was focused on the definition and manufacture of experimental shapes, either technical or aesthetic: propellers, turbine foils, boat hulls, car bodies, aircraft, etc.

About that time, more attention was paid to mechanical parts, and the prospect changed: instead of connecting surfaces delimiting a volume, the shape of an object became a boolean combination of volumes: prisms, pyramids, cylinders, cones, spheres and toruses. This has been named "solid modelling"; the systems are many and include e.g. Applicon, Compac, Computervision, Datavision, Euclide (French), Euklid (Swiss), RA3D, etc.

Now it seems necessary to mix analytic and parametric surfaces and volumes; up till now, little has been published on that matter, though a large amount of work has been oriented towards the resolution of this problem.

The parametric surfaces and volumes have an evident advantage for the definition of parts that are submitted to finite elements computation for stress and vibration research.

3. FORECAST

From our present knowledge, can we imagine a future CAD/CAM?

First of all, it is certain that more and more will be expected from it.

Speed is a major value. Many an operator now complains that he has to wait for one or two minutes in front of a CRT before obtaining the result of an intersection or of a rotation; very likely, he has forgotten that, fifteen years ago, it took a couple of weeks to obtain the answer, which was sometimes not very accurate; maybe, he never knew. Anyhow, speed will have to be increased in order to comply with the request of most of the users.

Accuracy is only required at the final stage, for tracing a map, milling a template or sculpturing a die or a stamping tool. A slight distortion on the screen of a CRT or on a drawing table is not important since the vital data are exclusively carried by figures, the drawings and the models being nothing more than auxiliary information.

Possibly, large liquid crystals boards will compete with drawing machines, but the problem will remain to produce and keep good hard copies in the files.

For a stylist, it is vital to actually see and even touch a 3D object. Hence the importance of hidden line removal, perspective views, light reflection lines, colour and shading of CRT images. Possibly, holography will bring another solution but, very likely, it will need very powerful software.

Picking up 3D coordinates on a model is performed with the help of styling bridges or of photogrammetry. It is not unrealistic to consider that laser or sound telemetry would speed up this operation.

Inputting data for a 2D drawing via a keyboard, a joystick or a lightpen is easy and fast, and this leaves little to be desired. For a 3D figure, the "magic wand" of Evans & Sutherland gives good results and similar systems could use light or sound detectors.

For performing actual experiments, a 3D model is an absolute necessity. Some drawing offices and research departments are already equipped with fast milling machines; it seems predictable that this tendency will develop; maybe a laser will remove material faster than any cutter; it would help to have a fast curing material that would be spread with enough accuracy so as to minimise, or even nullify, the need for a subsequent machining.

Solid modelling will expand, and it seems compulsory to mix so-called "analytic" volumes and parametric entities, especially with a view to defining surfaces similar to variable radius fillets connecting patches. One hypothesis that should not be overlooked is that lines, circles and planes can be considered special cases of approximation by parametric curves and surfaces. Consequently, analytic entities could be included in parametric geometry rather than added to it.

Regarding the basic principle of CAD, two systems can be considered: translating an existing handmade shape or creating it directly with the help of figures.

The second method is simpler and faster, provided that the mathematical basis is easily understood and manipulated by designers and technicians without needing a special training in parametric geometry and tensor calculus. Its most evident advantage is that the definition of a shape is complete and indisputable, and that it can be transmitted completely distortion-free, without place for argument between people in charge of design and any other department dealing with production or inspection.

More and more companies are, or soon will be, using CAD/CAM. It is vital that the exchange of data between them and their associates or subcontractors be extremely easy. Geometric definitions and computers programs should be totally compatible. For the time being, this is far from being the case, but it is high time this point be seriously considered. This is perhaps, one of the major problems that specialists have to solve, and the International Standards Organisation (I.S.O.) has a vital part to play in such a task, one of the most urgent we are faced with.