OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

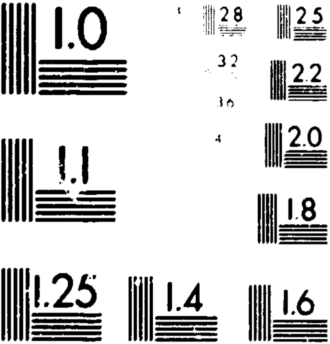
Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS

STANDARD REFERENCE MATERIAL 1010a

(ANSI and ISO TEST CHART No. 2)

RESTRICTED

14320

DP/ID/SER.A/560
10 January 1985
English

ADVANCED MANUFACTURING AND ENGINEERING METHODS

DP/BUL/81/009

BULGARIA.

Technical report: Computer Aided Design*

Prepared for the Government of Bulgaria
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of K. Shaw
Expert CAD Advisor

United Nations Industrial Development Organization
Vienna

* This document has been reproduced without formal editing.

REPORT BY EXPERT 11-02 SENIOR CAD ADVISOR, MR. KEITH SHAW

2.1 .84 - 16.10.84

1. Training

1.1 Project Training

During the period of the assignment, training was given to members of the project in the form of lectures on the following subjects:

1.1.1 Data-base management systems with special reference to graphics data-bases

I believe that within CAD systems different data structures need to be used for the storage of graphical and textual information. Graphical data bases should be designed for speed of access because response time is extremely important when carrying out graphics operations. Textual information should be stored using hierarchical or relational data structures for ease of interrogation.

1.1.2 Customers Graphics Interfaces

Advances in computer hardware happen far more quickly than advances in software. New computers and graphics terminals are announced frequently. It is therefore difficult for software to be kept up to date with available hardware. Since new hardware will either be cheaper or have more facilities (or both!) than existing hardware, it is important from the CAD users' point of view for the latest hardware to be supported. The only solution to this problem is the use of standards.

For driving graphics terminals, the international standard is GKS (The Graphics Kernel System). This standard has few implementations to date but has generated much interest in the industry. In my view, GKS has some limitations but hopefully these will be catered for in future versions of the standard. Standards are extremely necessary in this area and both suppliers and users should encourage implementations and development of GKS.

1.1.3 Two dimensional draughting systems

Two dimensional draughting systems are the basis and the starting point of CAD. They are the systems that most nearly replicate manual design methods and as such are more easily accepted by designers and integrated into the design process.

The parameters for design or choice of such systems are:

a) Ease of use

b) Cost effectiveness (i.e. price performance ratio)

c) Possible upgrade paths (staged development)

d) Ease of support.

The first of these is obviously very relevant to the design of the system and must be one of the first areas considered.

Cost effectiveness is usually dependent on the software's ability to take advantage of the latest advances in hardware technology. This is because hardware costs fall rapidly (32 bit Graphics Workstations can now cost less than $10000) whereas software costs remain approximately constant. It is therefore important for software systems designed, produced and supported by a small team to be as independent of hardware as possible and where possible to use international or ad-hoc standards (e.g. GKS, IGES, FORTRAN, UNIX).

Most CAD systems today are sold with one of; a micro-computer, a 32 bit graphics work-station or a super-mini computer. In respect to upgrade path, the micro systems are poor being difficult to organise into large networks to increase the number of users and also being unable to run 3D Design software to increase the functionality. For work-stations the upgrade path is clear, each new user needs a work-station which can usually be connected to existing work-stations by way of a LAN (e.g. Ethernet). The cost of doing this is, however, quite high, since the unit cost of work-stations is quite high. The upgrade path for super-mini based systems is stepped. This is because each machine can only support a certain number of terminals and then an expensive new machine must be obtained. I believe that the costs of 32 bit work-stations will rapidly fall to become equivalent to the cost of a graphics terminal. When this occurs, CAD systems will normally use work-stations unless there is a need for a large powerful CPU to carry out engineering analysis or other design calculations. In this case a hybrid system may emerge with the work-stations being connected to a super-mini computer via the LAN. The larger machine could then be used for archival storage, centralised printing and plotting as well as engineering analysis.

The ease of support of a CAD system is very much an organisational matter. Management must devise ways that customers software can easily be upgraded possibly without any direct action by support engineers. The well known concept of 'installation kits' is valid here.

When talking about two dimensional software, I think it is important to consider parametrisation. The major area for development of such software is in application areas. These appear more rapidly than any one organisation can possibly deal with. I believe that it must be made easy for users to produce their own application packages (i.e. to tailor CAD systems to their own needs). This is possible through the use of parametric symbols (macro languages) which must be designed to be easy to use, powerful and fast. Such a system would be a CAD Application Generator.

1.1.4 Three dimensional design systems

Three dimensional design systems are used for a variety of purposes:

a) Visualisation

b) Aesthetics design

c) Modelling

It is important to consider why the user requires such a system before deciding which of the five basic types of three dimensional design system is applicable. In fact, when carrying out this process it is often found that the user does not require a three dimensional system, a two dimensional system will be adequate.

The five types of system are:

a) Wire frame modellers which are cheap, fast, give reasonable visualisation (especially in colour) and can possibly be used in CAM.

b) Simple surface modellers which are a little more expensive, a little slower but give greatly enhanced colour visualisation and are better for CAM. They are, however, limited to simple shapes.

c) Sculptured surface modellers which are more expensive, are slower and more difficult to use, need a high degree of user ability, give very good visualisation and are also good for CAM. In fact for design of structures where aesthetics or aerodynamics are important, such modellers are essential.

d) Solid modellers which are probably more expensive and slower but give good visualisation, can be used for sectioning, volumetric calculation and can determine centres of gravity and moments of inertia. They also have good possibilities for use in CAM.

e) Combined systems which include all the above facilities. These obviously offer the user great benefits but are very expensive and require a large computer. Such a system may well have CAM integrated within it.

1.1.5 CAM and its connection to CAD

The most common area in which CAM and CAD are linked is in the production of NC or CNC tapes. The major deliberation in this area is whether three dimensional software is required.

Most NC machines are lathes and as such produce parts that can be classed as two and a half dimensional (i.e. A two dimensional profile plus rotation). Many milling operations can be considered similarly (a two dimensional outline plus depth). In many applications it may therefore be possible to use a two dimensional system.

The link between CAD and NC part programming is the transfer of the geometric data to describe the part.

Further software should allow the graphical verification of cutter paths (clash detection) and possibly even tape verification by the re-construction of the model from the machining instructions.

1.1.6 Engineering Analysis

The major area of engineering analysis centres on Finite Element Methods and such methods must be available in an integrated CAD system.

Available systems allow analysis in the areas of:

a) Stress analysis

b) Dynamic analysis - natural frequencies
- forces response

c) Thermal analysis - steady state
- transient

d) Non-linear analysis - Large displacements
- Plasticity
- Creep
- Buckling

e) Elasto hydrodynamics- Bearing analysis

f) Fracture mechanics

g) Multi-level substructuring

h) Cyclically Symmetric components

Finite Element Methods are CPU intensive and need large computers (a minimum is a super-mini). Future developments in this area are in applications where increases in computer power allow new areas to be explored. This is important to remember when building a CAD installation in which Finite Element Methods are an important part.

1.1.7 Computer Graphics Standardisation

It is becoming increasingly obvious that it is vitally important for users of CAD to be able to transfer data between different CAD systems. Obviously this could be done on an ad-hoc basis but, as the number of available CAD systems proliferate, it also becomes clear that a standard for this data transfer is necessary.

The only comprehensive standard for the transfer of CAD information is the Initial Graphical Exchange Specification (IGES) issued by the U.S. Federal Bureau of Standards and adopted by ANSI.

There are many problems associated with the use of IGES. It is slow and cumbersome. It is so large a standard that although most CAD system suppliers have implemented it, they have not implemented it in full. However, I believe that IGES is all that is available now and it will be imoroved (hopefully) to be a practical system.

1.1.8 Software Development

What CAD software should be developed? This is a difficult question. Software must be useful and used and therefore good sources for ideas for software development are existing or prospective users of CAD. However, it must be remembered that it is hardly ever worth developing software that is available elsewhere. It is more cost effective to buy in a package than to develop one. Another important consideration is the expertise of available staff.

I believe that software specification and development should be carried out by small compact teams with only three or four people working in any one area of a project. Specification work requires expertise and this expertise should reside in the team leader. I believe that the specification and implementation of software design should be carried out by the same team because:

a) The person producing the specification has control and responsibility for its implementation.

b) Having to see a project through to the end concentrates the mind of the producer of the specification on practicalities.

c) Modifications to the specification can be more easily catered for if they are found necessary during implementation.

d) Flexibility can be achieved in working practice with staff switching between specification and implementation as required by work loads and priorities.

I see software development as a series of steps:

a) Specification of the user interface and facilities. (NB. Ease of use is of primary importance).

b) Systems specification including flow diagrams. This should form the basis of systems documentation.

c) Preparation of a draft User Manual.

d) Coding.

e) Subroutine testing (independently if possible).

f) System testing and debug.

g) Integration (This stage is necessary if the software under development is part of a larger system).

h) Acceptance tests (to ensure that integration has not affected the main body of software).

i) Team testing (by members of the development team but not project members).

j) Alpha testing (in house independent testing)

k) Beta testing (by users on site)

l) Release

m) Maintenance

Failures in steps (h) to (k) result in a return to step (f).

If should be noted that this is not the much publicized 'Top down' approach to software desi For reasons of transportability, I recommend tha Fortran still be used for development and since Fortran is not a well structured language I find that this approach is best. If a structured language were to be used (e.g. Pascal, Ada) then it is possible that design and testing of the software will be better from the top and not start with individual bottom end routines as I have described.

Finally, on the subject of software development, I believe that Quality Assurance is of vital importance. The procedure described above should produce reliable well tested software, but additional techniques can be employed. Programming standards should be employed (even when using a standard language like Fortran) and structured walk throughs are a good method of getting the programmer to think more carefully about his work. It is said that over the life of a software system, half of the man time spent on the system is in testing and debugging. This should be spent before and not after release.

1.1.9 Object Analysis and Preparation of Prototypes for Application CAD Systems

We will now look at the steps that have to be taken when determining the specification of a CAD system to meet a particular customers needs and at the process of implementation of the system.

Probably the most difficult task is in deciding on the Customer's requirements. Extensive discussions are necessary and it is often the case that ustomers believe they need three-dimensional software when in fact they do not.

If three dimensional software is necessary then it is important to establish what type is required. This software together with two dimensional draughting software will form the basis of the system.

Having formulated the basis of the system, it is necessary to investigate application areas. Most users have a need for application software. It may be that such applications are a standard part of the basic systems. Alternatively, the basic systems may include application generators which can be used effectively. If not it is possible that separate applications programs may need to be obtained or produced and integrated with the basic system. Care must be taken to ensure that the timescales involved in this process are understood and are acceptable.

The next process is to determine the hardware configuration. This process needs to take into account the available hardware, any existing constraints on the customer, future expansion in terms of both software and hardware, cost, colour requirements, plotting requirements, digitising requirements, availability of maintenance etc.

Having determined the hardware and software requirements the next step is to put a proposal to the customer. Should he accept then we move into the implementation phase.

The first step in implementation is to order hardware and since this takes time to be delivered it is possible that some software development or integration can take place concurrently. I believe that as little software development and integration work as possible should take place on the users' site. This should be done in house or using the resources of the hardware supplier.

After installation or possibly concurrently with it, it is necessary to organise training. This can either be in a dedicated training centre or on the customers site. The first alternative is expensive to set up. The second precludes the possibility of concurrent training and installation.

Finally the work moves into a support or maintenance mode. As mentioned earlier, this is an area where good organisation is necessary to increase efficiency and keep the customer satisfied.

1.2 Other training

A two day seminar was organised and presented to invited delegates from Institutes and other UNDP projects.

The format was morning sessions of lectures followed by afternoon discussion periods.

The first day was dedicated to general CAD with a series of lectures entitled:

a) Introduction to CAD - what it is and what its benefits are:

b) Two dimensional draughting systems, their implementation on graphics work-stations and the use of GKS.

c) Three dimensional design systems.

d) Engineering Analysis.

e) The interchange of information between CAD systems.

The second day looked in detail at some specific packages:

a) The two dimensional draughting system DOGS.

b) Wire frame modelling system DOGS-3D.

c) Solid modelling system BOXER

d) The NC part programming system DOGS-NC

e) The finite element analysis system PAFEC.

2. A Universal CAD System

2.1 Universal or Integrated CAD?

A Universal CAD system is not a plausible concept. The great diversity within CAD means that such a system would require hundreds of sub-systems and be far too large to run on any available computer.

A possibility is for such a system to be developed in modular form and for only the required modules to be installed at any particular site. Such a system is plausible but the number of possible modules required is so great that no single organisation could ever produce them. Possibly this is the way to proceed. With the basic modules:

a) Three dimensional modelling

b) Two dimensional draughting

c) NC part programming

being developed first and other modules being added as required.

I would prefer to call such a system an Integrated CAD system since the term universal has implications that are not possible within CAD systems at the present time.

2.2 Data-base

For our Integrated CAD System we would prefer a common data-base structure. Probably the only way to achieve this is to develop the basic modules. It is unlikely that the three basic modules mentioned above will be available with a common data-base structure and be obtainable to form the basis of the system and allow extra modules to be added.

A second alternative is to obtain basic modules individually and to integrate them by means of the IGES standard (See Section 1.1.7). Although this will not lead to as good a solution, I consider it the more plausible alternative.

2.3 Additional modules

If the concept of integration of modules by means of IGES is adopted then it should be possible to either obtain additional modules from outside sources or to develop them in-house. I believe that the first of these is preferable because commercially available software is considerably cheaper than the equivalent cost of development.

3. Organisation of the CAD Laboratory

The CAD Laboratory has three primary functions:

a) Promotion of CAD

b) Development of CAD systems

c) Installation and support of CAD systems.

I would recommend the laboratory to be split into three groups, each dealing with one of these functions.

3.1 Promotion of CAD

In a country where CAD is not used in practical situations, it is necessary for any body concerned with CAD to be active in its promotion. This promotion needs to work on two levels:

a) General promotion work - the organisation of seminars, demonstrations etc.

b) Specific promotion - the discussion of the needs of a particular organisation leading to a proposal for a CAD system to be installed in that organisation. This aspect of the work may require more specific demonstrations in order to convince the client that the proposed solution is the best one.

3.2 Development of CAD

Although I recommend that CAD systems be bought in and not developed from scratch, I still feel that there is a need for a software development team within the laboratory. They will need to work on the integration of the systems and develop new modules which either cannot be bought in or which would not be cost effective to buy in.

3.3 Installation and Support of CAD

These two functions go hand in hand. They are the laboratories link with the clients hardware and software system.

This area needs staff who are familiar with both hardware and software though not necessarily experts in either. The staff must be flexible enough to work with a wide range of both hardware and software.

3.4 Handling a project

Once the client has accepted the proposed solution, a project team should be formed. This team should contain one member of each of the above groups and be chosen such that any appropriate available expertise is included in the team. The team will be responsible for the successful completion of the project but individual actions (such as development of software modules) would not be carried out by the project team but would be referred back to the appropriate group.

If the proposed solution is standard and does not require any new software modules or integration then it is possible for the project team to not contain a member from the software development group.

3.5 Flexibility

Within a small team, flexibility is extremely important. I would recommend that members of each group be familiar with the work of the other groups and for staff to change groups occasionally.

4. Co-operation with the UNDP funded machine tool project

Co-operation between these two projects would be very useful. A basic CAD system containing:

a) Solid Modelling

b) Draughting

c) NC

d) Finite Element Analysis

would be of great value to the machine tool project. Forming such a system would be of great value to the CAD laboratory as would watching the development and use of the system in a live situation.

5. Observations on CAD in Bulgaria

Bulgaria is ready to start with CAD. It has many engineers who are knowledgeable about CAD and the available systems. There is, however, a major drawback. As part of the Eastern Block, Bulgaria suffers from the United States' embargo on 32 bit hardware. In addition graphics terminals are difficult to import.

I consider there are three alternatives for CAD in Bulgaria at the present time. These are:

a) The use of micro systems for two dimensional draughting,

b) The use of main frame systems,

c) to wait for 32 bit technology to be available.

However, the need to at least get started with CAD is imperative and I would rule out option (c).

Option (a) has the advantages of letting organisations within Bulgaria experience CAD with the hope that when 32 bit hardware becomes available they will be ready to move ahead with practical systems.

Option (b) has the advantage that large scale systems could actually be used in earnest in the near future. Mainframe computers are available but problems may arise in attaching the available graphics terminals to them. I suggest that it may be possible to use a 16 bit mini computer as a link between the terminals and the main frame but the response of such a system may be poor.

6. Conclusion

Bulgaria needs CAD. It is restricted in that 32 bit computers are not available but must use whatever methods it can to begin the use of CAD in industrial organisations.