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Automatisation of Drawing-Office Activities

Automatisation des activités d'un bureau de dessin

Automatisierung im Entwurfsbüro

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SUMMARY
After a short introduction of CIAD, the paper presents the findings of two CIAD projectgroups on the subject of automation of drawing office activities and the experiences gained during the testing of twenty CAD turnkey and software packages. It ends with recommendations for requirements to be met by systems for technical draughting.

RESUME
Après un bref aperçu des activités du CIAD (Association pour les applications de l'ordinateur dans la pratique des ingénieurs), cette publication présente les résultats de deux projets de groupes du CIAD, réalisés sur le thème de l'automatisation des bureaux de dessin, notamment les expériences tirées des tests d'une vingtaine de postes de travail et de systèmes logiciels CAO. Les conclusions mettent en évidence les exigences principales auxquelles devraient répondre ces systèmes.

ZUSAMMENFASSUNG
Der Bericht behandelt die Ergebnisse zweier CIAD-Projektgruppen, die sich mit der Automatisierung im Entwurfsbüro befasst haben. Zwanzig «turnkey» CAD-Systeme wurden untersucht und die dabei gemachten Erfahrungen werden erläutert.

1. CIAD
1.1 Association for computer applications in applied engineering

CIAD is a Netherlands independent non-profit-making organisation devoted to the effective use of computer applications in applied engineering. It has been active since 1968.
The members of CIAD are consulting engineers, contracting companies, government departments, educational and research establishments, computer centres and software houses.
In the Association the members find common interests and aims. By mutual discussion and collaboration they tackle problems that they would otherwise have to face alone.
The activities undertaken by CIAD for its members include:

- The collection and arranged distribution of information concerning computer programming, existing and new techniques, hardware and various matters supporting the efficient use of the computer.
- To establish and maintain contacts with national and international organizations and public services with similar interests and take part in their activities, thus forming a communication channel and voice for all CIAD members.
- To stimulate, co-ordinate and accompany direct project groups formed by its members, providing them with a framework for purposeful co-operation for studies, program development and promotion of other common interests within the overall objectives.
- To conduct consultations with the general and specialised education institutes and to contribute to an adequate education in the field of informatics, which plays a large role in engineering practice.

One of the most active project groups that CIAD ever had is the project group on Automation of Draughting Office Activities.
This group is a good example of co-ordination between the members of the organisation; a rather expensive investigation that could hardly be paid by a single concern, is being financed by 23 firms now. The group started in 1979.

A small work group formed itself and put forward a proposal for the project group on the automation of draughting office activities.
Fourteen members subscribed to the first. Two meetings were required to draw up the work plan for the project group. Nineteen CIAD members reacted positively.
The overall objective is:

- To promote knowledge and understanding of the potentialities and limitations of the automation of draughting-office activities for draftsmen/ designers in architectural and civil engineering.

From this, the following specific objectives have been derived:

- to gain knowledge in the field of existing hardware and software
- To make a compilation of wishes and needs with the help of present and future users.
- To make recommendations for methods and procedures in the use of systems for the automation of draughting processes.
- To investigate the social consequences of automated draughting and to formulate recommendations about procedures in introducing such systems.
- To try out the recommendations by means of a test.
- To draw conclusions and to report on the group's activities.

In 1980 a number of extensions took place as a result of the enormous interest which the project has aroused. One reflection of this was the increase in the number of participants to twenty-three, which meant that plenary meetings were attended by some thirty-five people. Partly because of the size of the project group, it was decided at a fairly early stage that the actual work would be

done by working parties, which would receive intensive assistance from the CIAD-secretariat.
Recently the project group finished its final report.
In this report conclusions and recommendations are formulated concerning the introduction of CAD-systems at the building and engineering offices. The report also gives a discription of eighteen CAD-systems. Besides this, fiftheen systems were tested on aspects concerning 2D-draughting facilities and the possibility and quality of features as linking graphical and alphanumerical programs.
It is a comprehensive report that is of use for all the participants including the suppliers of CAD-systems, who all received a free copy.
We learned many lessons by this project. One of the most important is mentioned here:

> The one who is thinking about doing all, or part of his draughting work by computer, cannot just listen to vendors. This does not mean that one cannot trust them, but the big problem is that they don't understand what, in this case an architect, is doing, they haven't the slightest idea what that job implies. It is absolutely necessary to play a very active part.
> At the same time the next problem is indicated: users and of course future users are not able to formulate their wishes in a manageable way. In this field associations like CIAD can be able to bridge the gaps.

2 PROCEDURE FOR ASSESSING REQUIREMENTS

There are a number of stages to be gone through before a new working method or new equipment is introduced at a firm or in a department. Having heard of the new idea, and having come into contact with it several times, possibly only fleetingly, a potential user has to investigate whether it is suitable for his firm or department.
In other words the need for it must be determined.
There are two aspects of the need. In the first we have to find out whether the need exists in general terms, and if so we have to investigate how this need can best be met, in other words which system or equipment is best suited for the firm or department in question. There is nothing new about this, but for the automation of draughting office activities the relevant CIAD project group considered that it would be useful to set up a procedure which could be followed to determine the need, as mentioned above. This procedure is divided into a number of stages, and the content of each stage is described briefly below.

2.1 Nine stages

The first stage of course has to give an answer to some general questions and is a brief investigation within the company to find out whether there is any point in a more detailed study of the need for automation of draughting office activities and to make the user of the procedure aware of the aspects that are linked to these activities.

- Is the type of draughting work suitable to apply computers?
- Is enough workload available for it?
- How many draughtsmen are in the firm and what will be the influence on their number and the quality of their working atmosphere?
- What will be the organisational effect anyway?
- How much money can be spend and what will be the productions costs after the investment has been made?

It is quite possible that an organisation never reaches step two.

In the second stage firms will have to realize what draughting with the use of a computer exactly means. This is a more fundamental orientation, a logic step after the first one.
In this stage we will learn about the differences between turnkey-systems and software packages.
What is the interactive way of working, the only type of working we want to talk about in this study.
Applying software packages, what does this mean for other applications that run on the already existing computer.
Probably the firm is in this the phase already, they might know the differences between storage tubes, raster- and vector-scan-tubes, plotter types etcetera.
Some of the people inside an organisation are already familiar to all those aspects, than it will be necessary that they formulate all this to help other people within that organisation.
It will soon appaer that most of them don't have the faintest idea of all the possibilities and consequences, sometimes step two will be a continuous story that runs simultaneous during the total process.
In order to judge which part of the existing amount of draughting work can be handled by computers one needs to analyse the existing situation (stage three).
An extra difficulty here is that working in a new way opens new possibilities.
For instance there is no need to make draughtings on different scales any more, one is enough, or it might be possible that the savings in the organisation don't effect the draughting work, but the more economic way of storing draughtings, because this firm is involved in very complex projects for instance. This are just some possibilities, there are plenty more.
On the basis of a survey of the quantity of draughting work for each kind of work, an estimate can be made of the capacity that the firm, or department, currently uses to carry out draughting activities.
The study gives a tool by offering a checklist and a method to measure the activities.
For every activity one has to find out which possibilities he wants a draughting system to posess. This is step four.
From the matrix we build up this way the specific demands can be read.
We can also make a kind of advanced matrix by using some weight-ratio, which could be the result of an internal questionnaire, in such a way that everyone involved can give his own accents. After all not everyone is making the same products.
Designers working on a small scale will show specific demands, that will differ from demands shown by designers that have to handle large dimensions or high accuracy.
Stage five that comes next, is testing the facilities of the various systems against the specific requirements.
Within the frame work the project group made an investigation of some 20 CAD-systems. The experiences on this test will come up for discription later on.
When the possibilities found out in step five are combined with the specific demands formulated in step four, we have a soft tool that tells us about the productivity ratio of each specific system to our specific demands.
It is realized that this procedure gives a result that is a little bit academical, but it gives an impression that is based on a realistic situation.
Besides this it will make sense to combine the result with running a bench mark on two or three selected systems.
Stage seven is a special one called social aspects.
It has everything to do with ergonomics, division of labour, working atmosphere, older draugthsmen and new technics, and how to introduce these modern tools in an organisation.

A special working group with specialists in it was formed. They visited several firms in the Netherlands, where these modern tools are already in use. They spoke with managers, draughtsmen and operators and what they got out of it was very confusing.
Here some (cautious) conclusions:

- The learning period before users feel familiar with the system is between a few months and six months.
- Correct lighting of the workroom to prevent reflections is highly important.
- Long response times are extremely annoying.
- Working with the system is not felt to be routine. It calls for more concentration, but is not seen as making the job difficult.
- A lot of attention must be paid to preparing the drawing work, but this is not regarded as inconvenient.
- The quality of the draughting work is more constant and is generally more highly regarded.
- Draughting becomes more effective as use can be made of previous elements, i.e. standards.

Some of the most demotivating aspects pointed out were:

- Hardware and software problems in the most general way.
- Supplier promises that are not kept.
- The 'speed' of a slow plotter.

A difficult phase too is step eight, the making of an economic analysis.
We are now trying to compare the decrease of production costs by working in a more efficient way to the increase of those costs by the purchase of an expensive system. The comparison is difficult to make, for we must realize that a draughtsman is only making draughtings for about half of his time.
The costs of the system are to be shared over initial and periodic costs. In principle this doesn't differ from procedures on other buyings, but there are some striking differences one should considerate.
Just mentioned were the high initial costs for training and the time that must be bridged between the date that the equipment is carried into the premises and the date that all runs smoothly. Mostly this will take more than half a year.
Maybe one gets a new kind of organisation, more uniform and flexible, but also more complex and vulnerable.
Besides all these aspects the computer might or will also have its influence on the design process itself, and we have to be honest to ourself if we want to.
It is realized that sometimes this paper is not very optimistic.
Well, step nine might be the most frustrating: the conclusions from all we did and the decision we propose to our management.
Perhaps we started with five systems, we ended our evaluation with three and propose one or two.
A problem seen in many organisations is the difference in approach between technicians and management. Very expensive evaluations, mostly carried out by a technical team, suddenly seem to be of interest no longer, when the stage of decision is reached, the stage where the commercial games are played.
Suddenly strange things happen.
Suppliers start sending cable grams during board meetings, in which they propose all kind of new possibilities, cheaper workstations, proposals to co-operate etcetera.
Suddenly all those technical evaluations seem to be of no interest any more; we came into a rather agressive network of commercial tricks. This game might be very frustrating for technical people involved in the selecting, and they must be prepared for it.

3. TESTING THE FACILITIES OF VARIOUS CAD-SYSTEMS

As mentioned already at stage five of the previous procedure, it is necessary to test the facilities of the various systems against the specific requirements. A special 'CIAD-test for electronic draughting' was designed for this purpose.
This test is in three parts:

1 A general draughting
2 Test of response time and disc capacity
3 Making a menu.

The test was send to the suppliers concerned well in advance of being carried out.

3.1 General draughting

In order to arrive at a general test draughting by means of which draughting operations could be tested, the existing working method was analysed. It transpired that there is a heavy emphasis on corrections and alterations. Starting with the basic draughting a variety of additions and corrections are made.
The various operations are described step-by-step in the test.
Obviously every user or future user can decide for himself the importance of the various subjects, such as mirroring, rotating, reducing and scaling. The test shows whether these operations are possible or not, and if so the standard to which they are performed.
Other features covered are:

- How lines are built up internally (hardware- and/or software-generated)
- Draughting in layers
- Draughting to scale
- Lettering
- Dimensioning
- Hatching
- Splines

In the last stage of this test the time taken for a total projection is measured.

3.2 Test of response time and disc capacity

To find out in a simple manner how quickly the system can project a draughting and how much space such a draughting occupies on disc, a simple standard draughting has been designed; this draughting is built up in four stages:

1 500 horizontal lines
2 500 vertical dashed lines
3 500 times the lettering 'ABC'
4 500 circles with a diameter of 10 mm.

In terms of information quantity, the final result is equivalent to a simple standard draughting as prepared in civil engineering and structural engineering firms.
The accuracy of the systems is then tested with the aid of a triangle with sides in the proportion 3-4-5.
Starting with sides of 3333 and 4444 units at right-angles to each other, the triangle must be dimensioned; the sloping side must then be 5555 units. If this is the case, the number of 3s and 4s is continually increased untill the accuracy limits of the system in question are exeeded. The readings achieved are an indication of the accuracy.

3.3 Making a menu

The project group attached particular importance to the facilities for linking graphic and alphanumeric information. The purpose of the third part of the test is to establish the possibilities and qualities of the various systems in this respect. The test involves draughting a small ground plan in which reinforcement must be laid.
The program to be linked must then present a sorted bill of materials for the reinforcement.

3.4 The test in retrospect

While carrying out the various tests it became apparent that there are in fact three aspects to testing:

1 Testing whether the basis for making the draughtings is indeed correct
2 Testing the person operating the equipment
3 (finally) Testing the draughting system.

It emerged that compiling a good test is a difficult matter. On close inspection various questions were not clearly answered, but on the other hand information sometimes emerged that no one had thought of at the outset.

3.4.1 Projection speed test

Taking as a reference a draughting consisting of the above mentioned 500 lines, lettering and circles, we find that sometimes more than one minute may be needed to project the draughting. Obviously this is too long for the operator. Usually, however, it need not take so long. Often all that is required is an indication of the draughting on the screen, so that 'a window' can be defined in which the eventual draughting work will be done. For the above reasons it may be important to be able to terminate projection of the draughting before it is complete.

3.4.2 Storage on disc

People were generally badly informed about the characteristics of the equipment. Nevertheless it was found that the data occupies much more space than might be expected.

3.4.3 Line thicknesses and line types

It emerged that a distinction must be made between line thicknesses and line types on the screen and the plotter, and between hardware-generated lines and software-generated lines.
For example, a Tektronix 4014 screen has five hardware line types and two line thicknesses. The draugting system may or may not make use of this hardware option.
What are the advantages and disadvantages of using the hardware-generated lines?
Suppose a dashed line is to be displayed on the screen. If the draughting system uses hardware lines, the computer need only send the start and end coordinates with line type and line thickness. The Tektronix then projects these as a dashed line. In terms of time it is immaterial whether a solid or dashed line is being drawn.
The draughting system may also generate the lines itself (software lines). In that case the coordinates of all short dashes must be transmitted, together with line thickness. This results in a long projection response time.

In the projection response test it is usually important to know, for the projection of the 500 dashed lines, the number of dashes that go to make up a dashed line. However, the test made no provision for this.
Various suppliers projected the dashed line in the form of only a few short lines.
A disadvantage of using the Tektronix hardware lines is that there is a limit of five line types. This applies to the screen. For the plotter the lines are usually generated by the draughting program. Often more line types are then possible on the screen.
To make the whole matter even more complex, even more techniques are in use for the above facilities. The draughting program may generate everything but the projection time may nevertheless be short. In this case the draughting station is usually extensive, with seperate facilities.
If the draughting station has its own (local) intelligence, the computer need only send supplementary and/or altered data to the draughting station. The work is projected on the screen from the draughting station itself, and the projection time may be very short.

3.4.4 Layers

It is not sufficient to ask whether a system can draw in several layers; the subject turns out not to be so simple. All the systems so far tested offer a large number of layers, but it is important to establish what function the user can give to the various layers. It is also important to establish whether the draughting system has already assigned functions to the layers, and if so, which. Some systems for example use the layers to place the various line thickness in.

It is also customary, and practical as a means of switching off a layer during intermediate projection on the screen, to use a layer for the following, for example:

- Normal lines
- Lettering
- Dimensioning
- Hatching
- and so on.

Users often wish to use layers to draw the following by layers, for example:

- Shape of a floor
- Reinforcement in the floor
- Drains in the floor
- and so on.

After this summing up it will be clear that not every draughting system offers the layer technique required.

3.4.5 Rotation and Mirroring

At some systems lettering appears upside down, at other systems all text will disappear completely after a rotation or mirroring action.

3.4.6 Scaling

Two methods are used for locking up the coordinates:

- All coordinates are locked up in actual size
- All coordinates are locked up to scale.

For the draughtsman everything appears to be the same. In both cases a dimension of, for instance, 1000 mm must be stated as '1000'. However, practice shows that the differences in results can be very great. In systems that use actual-size storage, draughting with several scales on one draughting is usually impossible, or only possible in a fairly roundabout manner. When working with actual-size storage the height of the lettering must be taken into account. If lettering 5 mm high is to be used on a draughting to be plotted on a scale of 1:100, the draughtsman must enter the lettering height as 5 x 100 = 500 mm.

The above comments on the use of several scales on one draughting generally also applies to scaling. In draughting systems with actual-size storage, scaling itself is often possible, but afterwards it is usually no longer possible to dimension automatically.

3.4.7 Interfacing own programs

If a draughting system is to be used in the CAD (computer-aided design) field, it should be possible to interface user programs to the draughting program. It must be possible to transfer information from the draughting to the user program and to add information to the draughting from the user program. In order to try out all these features, a test was designed for making a program (menu) for interactive draughting of concrete reinforcement.
According to the survey, user program can be interfaced to the draughting program of all draughting systems. As our findings show, things are somewhat different in practice.
Beside this point the group found out that this matter is more complex.
It appeared that there are two principles of doing computations during draughting work.
1 Linking (Fortran) programs
2 Using a so called macro language
When a system works according to the last mentioned principle, it is not certain that one can connect already existing programs to one's draughting.
This complexity of this issue had been underestimated.
For this reason a second CIAD projectgroup added a part to the test they developed.

4. A SECOND PROJECTGROUP

The line of approach of the previous mentioned projectgroup was architecture and civil engineering.
A second CIAD projectgroup on the subject of draughting office automation has its origin in mechanical design. It is obvious that many experiences of this group are very useful in the field of structural design as well.
The test program that this group developed can be seen as a completion of the first.
The final report of this projectgroup is published in september 1982.

<u>4.1 The test program</u>

The test program covers three important issues:
1 Three dimensional capabilities
   - Definition of elements, library facilities, wire, plane and solid models.
   - Combination and separation of elements
   - Manipulation of elements: move, rotate, copy, mirror, replace, change

- Views and sections, perspective, hidden lines removal.
- Computation: spacings, radii of curves, centres of gravity, volumes, moments of inertia.

2 Linking facilities for (own) Fortran programs.
- Call-up program from graphic workstation
- direct processing by this program of graphic data displayed on the screen
- Direct display op program output as graphic data on the screen
  The program to be called is given. This program should be defined as a Fortran main program and is not just a Fortran sub-routine, unless this figures out to be the only way to handle the problem.

3 System diagrams and database management.
- Production of drawings using basic elements
- Linking of attributes to elements
- Definition of alpfanummeric files
- Data input into alphanummeric files
- Production of various listings with input from graphic database
- Production of various listings with input from alphanummeric database
- Additions to alphanummeric database
- Production of report using 'report writer'

	system	test 1	test 2
1	AD-2000-CDC	X	X
2	Anvil 4000-L	X	X
3	Applicon	X	X
4	Autotrol GS-1000	X	
5	Cablos-VM 1	X	
6	Cablos-VM 1/Medusa		X
7	Cadam	X	
8	Cadam/Catia		X
9	Calma	X	
10	Computervision	X	X
11	Desikon	X	
12	EIDS		X
13	Euclid		X
14	G.D.S.	X	
15	Gerber	X	
16	Gri-2D	X	
17	IGS-Siemens	X	
18	Intergraph	X	X
19	Kongsberg CDM 100		X
20	Mc Auto Unigraphics	X	X

The systems tested by the two CIAD project groups.

4.2 The second test in retrospect

The projectgroup that ran the second test was formed by seven organisations. All of them stated that their main goal in joining the group was to get an instrument in making a decision in chosing a CAD-system for their own organisation.
After the closing of the test program one of the main conclusions was that they all overestimated the possibilities of the systems tested.
Especially the possibilities of 3D-modelling are much more modest than expected to be.

4.2.1 3D Modelling

Constructing and working with 3D computermodels turned out to be much more complex than expected.
The best results have been achieved with surface models combined with a hidden line algorithm.

4.2.2 3D Manipulations

Manipulations on so called solid models are simple to execute but claim an enormous amount of computertime.
The test is build up with a very simple design. Nevertheless took some operations more than thirty minutes on a big mini-computer, in spite of the fact that the test was the sole activity at that moment.
On wire or surface models all kind of operations operate much faster. Here problems might occur when a user zooms in at particular details and looses clarity.
All the lines have the same intensity and it is not possible to get a good judgement on which lines are in the front or at the backside of the model. This problem can partly be solved by using colour or automatic hidden lines removal.

4.2.3 Different principles

Several different principles can be found when studying the way how 3D models are build up in the several systems. Sometimes manipulations can only be carried out in one certain plane, e.g. the X-Y plane.
In other systems one can only work in the 2D projections of the model. Problems might mainly occur when a user wants to build up double curved surfaces.

4.2.4 Linking Fortran programs

One should pay attention to the fact that linking (Fortran) programs to the graphical database is not selfevident possible. Some systems offer very simple procedures, other very complicated. In this case only very advanced programmers can use this facility.

4.2.5 Database management

In this part of the test a small project consisting of several draughtings is simulated. If figured uot that only a few systems were able to produce the requested listings. Most systems only have facilities to make so called connector lists.
Some could run this part of the test rather efficiently but for most of this group comprehensive programming work had to be carried out.
Later was found out that problems might occur when elements in the draughting have been copied or mirrored. Mostly all the connected alpha numerical data is lost after such an operation.

5. BASIC REQUIREMENTS TO BE MET BY SYSTEMS FOR TECHNICAL DRAUGHTING

To formulate basic requirements to be met by systems for technical draughting is probably just as difficult as developing such a system. During the many contacts that took place as the project group carried out its activities it became abundantly clear that the suppliers had no idea of the sort of draughting work carried out by CIAD members. In this case CIAD members means the members of the project group, the majority of whom are active in the architectural, civil engineering and geodetic fields.

It must be pointed out at the same moment that the members of the project group have little experience of computer draughting. The exchange of information between the two parties was therefore laborious. The problem was acknowledged by both parties. Without wishing to go into undie detail, the purpose of this chapter is to attempt on behalf of (future) users to formulate the basic requirements that draughting equipment must meet. Some of the points mentioned in the CIAD report are listed below.

5.1 Entry of dimensions and dimensioning

Almost everything is drawn to dimensions, and the entry of the dimensions is therefore highly important. Automatic dimensioning is essential. Generally the end of the dimension lines is indicated by points and sometimes by dashes or arrows. It must be possible for the user to specify the length and termination of the auxiliary lines. If a dimension will not fit between the auxiliary lines, it must be possible to displace it easily.

5.2 Line types

Several line types with associated line thicknesses are necessary. For architectural draughting, five line types are normally sufficient. For surveying work as many as 20 types may be needed, and it is important that the user can design the lines himself, and that the lines may also consist of symbols.

5.3 Lettering

Several lettering heights with associated line thicknesses, upper and lower case must be possible.

5.4 Layering

Layering as a two-dimensional technique. An example of this is given below.

Example of layer numbering

	Lines	Lettering	Dimensioning	Miscellaneous
Drawing of the floor	0	1	2	3
Drains of the floor	10	11	12	13
Electrics in the floor	20	21	22	23
Miscellaneous	30	31	32	33

5.5 Coordinate size and accuracy

For architectural draughting work, systems should allow for a largest coordinate of 1000 m with an accuracy of 1 mm. For surveying draughting work the largest coordinate may amount to hundreds of kilometres to an accuracy of 1 mm.

5.6 Hatching

Hatching must be possible, with line type, distance and angle to be chosen by the user. It must also be possible to draw hatching with symbols developed by the user.

5.7 Repetition

It must be possible to make repetitions in drawing elements easily by means of a repetition factor.

5.8 Mirroring and rotation

This must be possible about any axis. This applies also to lettering and dimensioning, but these must not appear in mirrored form. The text must remain in the imaginary mirrored rectangle that surrounds it. After mirroring, numbers in the dimensioning must remain on the same side of the dimension line as before mirroring. In other words they must stay on the dimension line.

Rotation through any angle must be possible, and it must also be possible for rotation to be determined by the draughtsman or from the database. This applies also to the lettering and dimensions, but these must not appear upside down. On the drawing, it must be possible to read the lettering and dimensions from the bottom upwards and from left to right.

5.9 Several scales on one drawing

It must be possible to work with several scales on one drawing, and the digital data must remain intact.
It must also be possible to scale (make larger or smaller) an existing drawing, and to choose whether the scaling is to include lettering and dimensions.

5.10 Response times

The response times are a function of the size of the drawing and the number of active work stations. The 500 lines, letterings and circles as processed in the second part of test one test drawing one should be taken as a standard for drawing size. Response times are divided into search time and display time. Long response times cause the draughtsman to lose concentration.
It is difficult to specify how long it should take for a drawing to be displayed on the screen. A display time of a mimute or more for the above drawing is too long for the draughtsman and is economically unattractive. As a general rule it can be stated that it should not take longer than 10 seconds for the primary information of the drawing to be displayed on the screen.
Among the features that contribute to a short display time are:

- fast hardware and software
- the ability to interrupt display
- the ability to suppress lettering, dimensioning and hatching
- schematic representation of circles, splines and cells (symbols)
- displaying software-generated lines as hardware lines.

5.11 Security

In the event of breakdowns, no results, or only very few results, may be lost. There must be protection against unauthorised use of the drawing data.

5.12 Ergonomics

The following points ought to be considered:

- clear arrangement of working space
- distance from eye to screen
- lighting
- working in daylight
- space to spread out drawings
- posture
- screen brightness
- and so on.

5.13 Interchangeability

Since drawings are usually made, used and processed by persons from several disciplines, it is essential that it should be possible for drawings to be transferred from one system to another.

Information (digital data) must be stored with an unambigious dimension unit, so that interchange is possible. The digital data is a mathematical model of an object consisting of coordinates of angle points, interconnected by metrological constructions.

5.14 File management

It must be possible for several work stations to work simultaneously on the same project, and for the results thus obtained to be recombined to form a single entry. It must be possible to increase or reduce the file size as required.

5.15 Temporary enclosures

It must be possible to mark out areas within which any lines can be removed up to the boundary of the area, or displaced as whole.

5.16 Speed of manual operation

It must be possible to combine several commands and parameters into one command.
Example: the following parameters are usually needed to position lettering:

- lettering type
- lettering height
- lettering width - line thickness
- lettering justification
- layer number.

It must be possible for the user to combine several combinations that occur in his work into a number of individual commands so that it is not necessary to specify parameters.

5.17 Linking programs

It must be possible, and easy to manage, to link excisting (Fortran) programs to the graphical database.
Besides this a so called macro language can be very useful.

5.18 Database management

It must be possible to link alphanumerical data to graphic elements. This data must be protected when a user excecutes certain manipulations. Various listings must be possible from graphical and alphanumerical database. It must be possible to connect pointers to the graphical elements.

6. A CLOSING REMARK

Selecting CAD-systems that can be used in a structural engineering environment is more complicated than expected at first sight. This also turns out to be the experience of existing users declaring that sometimes it lasted more than a year before all the features of their systems were known.
The execution of comprehensive investigations in joint effort as described in this paper can be very useful for the parties involved.
It illustrates the benifit of user-associations like CIAD.

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