计算机辅助设计系统的结构

CAD systems framework

edited by
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CAD SYSTEMS FRAMEWORK

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Røros, Norway, 15-17 June 1982

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PREFACE

CAD Systems Framework is focusing attention on the design of CAD Systems. CAD technology is still in its infancy regarding industrial exploitation. Accepting today as a rationalization tool, CAD systems of tomorrow must also offer industry other potential benefits such as: faster and improved tenders, customer tailored designs, production optimal design, allowing the incorporation of late design changes and extraction of production data to drive the scarcely-manned factory. CAD systems must be built to cover concept sketching, product structuring, spatial modelling and factory- and process-planning influences on design. It should be possible, without affecting the operational application system framework, to tailor the system to the particular user, to describe the product structures of any product, to parameterize the planar model, to control shape and proportions and to algorithmically model product specific geometries not commonly found as a primitive in a geometric modeller. Future systems should be built open-ended for ease of extension and alteration and to allow the inclusion of product specific calculation functions.

CAD systems hardware is rapidly developing. New techniques and configurations are demanding new software architectures. The networked CAD system forces improved system architecture and implementation quality. Presently, the state of the art in systems design and CAD software engineering quality – or rather the lack of quality – is, beside of the price, one of the dominant characteristics that prohibits CAD progress.

In IFIP WG 5.2 we have over the years been aware of the fact that new and improved systems would have to be developed. Thus we have worked towards standardization of building blocks to cover the most fundamental areas of CAD systems such as graphics and databases. Such building blocks will have to fit into frameworks of software, data-structures and modern hardware configurations to create modularly built, well balanced systems.

Since 1976, IFIP WG 5.2 has run working conferences and published books on ana-

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lyzing fundamental areas of CAD Systems such as: CAD Systems (1976), Artificial Intelligence and Pattern Recognition (1980) and Databases and Data-Structures (1981). The CAD Systems Framework is a synthesis based on the experience from other conferences.

The working conference in Røros, Norway, was decided upon as far back as 1978 and the theme CAD Systems Framework was thought appropriate. The conference attracted many interesting papers from all over the world, out of which 15 were selected for presentation. The contributions were organized in six major areas:

- Classification of CAD Systems;
- Framework Concepts;
- Geometric Modelling;
- The Designer/CAD Systems Interface;
- Conceptual Design of CAD Systems;
- Artificial Intelligence and Knowledge Databases in CAD.

Each of the presentations was followed by a discussion among international experts and are very useful for a deeper understanding of the problems. The conference was closed by a summing up session.

IFIP WG 5.2 has always made sure that their working conferences are well visited from all over the world. To Røros came 35 invited delegates from 13 countries. As program and organizing committee chairmen we would like to thank all of you who contributed to the conference, particularly the authors. We also express our thanks to those who sponsored the conference: IFIP, Braathen SAFE, several Norwegian computer companies and the Royal Norwegian Council for Scientific and Technical Research (NTNF). Special thanks are due to Rigmor Tilseth and Elin Ødegaard who have been of invaluable assistance with the typing and editing of the discussions.

Ketil Bø, Trondheim
Frank Lillehagen, Horten
December 1982

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SYSTEMS ARCHITECTURE, AUTOMATA AND CLASSIFICATION

E.A. WARMAN

In order to attempt to establish taxonomic relationships between computer systems - particularly CAD systems, the use of the automatic approach has been employed. This cannot be used solely as a basis for developing relationships but must be employed with other approaches to classification in order to show the particular features of CAD systems.

INTRODUCTION

The ability to classify events, artifacts or biological objects implies a degree of understanding of relationships and the interactions between these relationships.

Whenever a sector of scientific endeavour is faced with the impression of disorder, classification is one of the tools used for establishing the existence of relationships and their resulting patterns. Once patterns appear to exist, spaces in these patterns may be investigated, extensions postulated, theories formed and tested and mathematical analysis undertaken.

The industrial user of Computer Aided Design Systems may consider this approach to be of little or no value and certainly of no consequence to what is being undertaken today in industry.

Computer Aided Design is in its infancy and without the application of a methodology, possible developments, particularly those relating to the application of the theory of design, are highly speculative. Productive methodologies may thus be of considerable value in directing attention to particular lines of investigation.

Nor can Computer Aided Design be considered in isolation, developments in Robotics, Computer Aided Manufacture, Office Automation and Intelligent Systems will impact, open and merge with Computer Aided Design. The result will be integrated systems of a high degree of complexity and individuality. These integrated systems within each industrial organisation should be able to aid communication across organisational boundaries to other integrated systems. If an understanding between the total relationships that may exist between possible systems and system components can be achieved by means of methodologies developed from understandings revealed by the use of classification techniques; then developments should be able to be undertaken logically and objectively.

Models

The construction of a model is an essential step for commencing the analysis of systems. Computer Aided Design has been a fertile ground for this activity and a number of models have been produced to describe CAD systems or the CAD process.

These models may also be classified. Some are subjective in that they present a view of CAD from a particular viewpoint and application aspect. Others tend to be objective but of limited scope and context sensitivity. The ideal is a model that is objective but satisfies the various subjective viewpoints.

There are four key factors that are part of any CAD system:-

the computer
the program
the person
the environment

The computer embraces all the hardware. The term program has been used rather than software to allow for firmware. The person has been separated from the environment because they are different and have influences upon each other. Between each of these factors there also exists an interface.

These factors appear in various proportions in models presented by various authorities. Before yet another approach to modelling is presented let some of the existing categories of models be considered.

Data Base Centred Model

The Data Base oriented models that have appeared in several forms, (1, 2) relates the Computer Aided Design actively as a flow process where the design activity is a set of interactions upon a data base. A generic composite of such a model is illustrated in Figure 1. Such models tend to have a bias toward particular company methods of working and thus reflect instances of what may occur in the particular area of the model creator. The particular value of such models for classification purposes is for showing context sensitivities. It is however difficult to place values upon the parts of these models to aid any subsequent analysis process.

The System Flow Model

The system flow model is another approach that differs from the Data Base Centred Approach and also appears in many guises (3, 4). The value of this approach is showing, in some depth, the relationships between various blocks of computer and human activities in the Computer Aided Design process. Figure 2 illustrates such a diagram used by the author in a previous discussion. Again the approach - though more objective - does not lend itself directly to a conversion into an analytical form.

Pictograms

A third general class of model, that may be described as pictograms has been used to illustrate "abstract machine" topology (5). These models may be said to be pretty but do not lend themselves either to the development of analytical methods or taxonamic purposes and can in fact lead to arbitrary classifications.

The Automata Approach

The question therefore arises as to whether the study of automata, finite machines and computation is of any value in establishing a taxonomic foundation for the classification and study of Computer Aided Design Systems.

Adopting the top down approach, we have in Computer Aided Design, the classic case of a machine M coupled with an environment (Figure 3) where there is an input S and a response R.

Now S can have stages s_1, - - sm and produce responses R_1 - - Rm at each time t. Now this simple finite state model can lead into a wide variety of other models and their analytical description (6, 7, 8) at various steps of increased detail. At this stage there is however no difference between CAD or any other automata system.

If we now considered a further derived model based upon the Turing machine the particular features of a Computer Aided Design system start coming into play.

In its classical form a Turing machine is a finite-state machine associated with an external memory or storage medium that is usually envisaged as a sequence of "squares" marked on a linear tape. The machine is coupled to the tape through a head which is situated at each moment on some square of the tape. The head has three functions of Reading, Writing and Moving the tape.

Now the simple automata model with its inputs s - outputs R and a set of internal states Q

$$Q\ (t+1) = G\ (Q(t),\ S\ (t))$$

$$R\ (t+1) = F\ (Q(t),\ S\ (t))$$

is characterised by the above. The Turing model needs a third function D that tells the machine which way to move the tape.

Thus we have - $Q\ (t+1) = G\ (Q(t),\ S\ (t))$

- $R\ (t+1) = F\ (Q(t),\ S\ (t))$

- $D\ (t+1) = D\ (Q(t),\ S\ (t))$

Formal mathematical descriptions of Turing machines are presented in references (9, 10, 11).

This approach thus seems to indicate that an ordering may be shown to exist by using a formal approach using established methods relating to the analysis of automata. The next step is to extend the method so that the particular features of CAD systems may be incorporated. The first of these features is interaction.

Interaction

Interaction is one of the aspects that characterises Computer Aided Design from other non-interactive computer techniques. Interaction in the arguments that follow mean that the 'Person' is no longer part of the environment. Now there are many situations where interaction takes place without human intervention such as process control applications. The possibilities do tend to be pre-ordained in such circumstances with non computer based controls to shut down systems should the computer not be able to cope.

The interaction we are now concerned with is that interaction that makes:-

1. The tape on the Turing machine move how we want it to move;

2. It possible for the person to read and alter the contents of a square on that tape

The program must therefore allow for an interactive circle.

Interaction must therefore depend upon a machine state Q_1 and output R_1 and result in an input S_1 that produces a movement D_1.

Thus if the general interaction function is I having two forms IA and IB.

$D_1 (t + 1) = I_A (S_1(t), R_1 (t), Q_1 (t))$

movement depends upon input based on output and machine state subject to human choice, and

$S_1 (t) = I_B (R_1 (t), Q_1 (t))$

On general terms the interactive is dependent upon G, F and D.

Though this is not exclusively the CAD case it provides the extension to our simple device to allow for interaction and to develop the relationships between automata that allow for interaction that effects their subsequent program and actions.

Appendix 1 has been included to show the approach taken with process control automata.

The state so far reached in these arguments indicates that a relationship between the levels of automata, does exist and may be used for taxonomic purposes. A starting point has been prepared that will also enable extended work to be undertaken with respect to computability.

Now Turing's thesis is:-

> Any process which could notionally be called an effective procedure can be realised by a Turing machine.

This statement is also applicable to CAD considerations. One cannot prove this thesis but work over the years confirms its truth. The proposed extensions with respect to interaction have imposed two enviroments upon the Turing concept. The second enviroment being human choice.

Now this question of human choice is a key factor on the design process. It thus suggests that the Modified Turing machine is the conceptional computing device to be used in conjunction with work undertaken on the Theory of Design. The conjunction of these two approaches may thus arrive at results relating to the problem of "designability".

If attention is returned to the system flow diagram of Figure 2 it is apparent that the arguments so far developed are coarse in their approach. The question of interaction needs to be considered in more detail in order to further determine the differences that make a CAD system.

Interaction will be approached from the machine viewpoint. References: Ref: 13. provide a great deal of information on man -machine interaction and certain models are presented.

The approach that seems to fit best with the previous arguments is that of Hopgood (Ref: 12.) because it lends itself, at the fundamental level, to the automata approach.

The approach, based upon production systems, requires that in any time interval t, input stimulii S_h arrive in a short term memory and are acted upon by the central processing unit dependant upon the contents of a long term memory.

Now this approach helps us to deal more elegantly with the two results of interaction that could occur in our modified Turing machine - the tape movement aspect and the stimulus aspect that relates to changing tape contents.

It also suggests that this approach enables our model to be transformed into a pair of Turing machines - each having a different program. The human interacting with the outermost machine and the outermost machine interacting with the inner machine.

Several approaches to the use of production systems are given in Reference (Refs: 14 & 15).

These approaches may be subjected to the techniques of computational theory analysis by means of the Turing machine approach. Thus tools exist for the evaluation of the fundamental aspects of each of the approaches toward interaction.

Multi Dimensional Classification

The automata approach to classification is not a single isolated method for arriving at relationships between computer systems. It is merely one facit of a multi dimensional tree. Classification may also be undertaken on the basis - for example - of heirarchies of systems, or on software - firmware divisions for particular functions, or even on the physical tools of interaction.

Following up this approach, if actual drawing equipment is listed it may be tabulated into three classes :-

Class 1	Class 2	Class 3
Pencil	Pen & Ink	Chisel and block
Charcoal	Brush & Water Colour	of material
Crayon	Brush & Oil Colour	
Pastel	Finger & Oil Colour	
	Palette knife & Oil colour	

The difference between the Class 1 and Class 2 stylii is that the colour is an inherent part of the Class 1 stylii but has to be transferred to the Class 2 stylus. Class 3 systems when realised in computer terms are complete CAD systems. A Class 0 does exist, these are non marking stylii and may be envisaged as pointing and picking tools.

Now it is interesting to note that this method of classification leads us from parts of CAD systems to complete systems.

If the properties of the various stylii are considered and related to computer realisation the heirarchy becomes very apparent.

Class 1 Stylii

The drawing media of each pencil has a basic thickness and hardness. Pressure applied during use directly affects the line intensity and indirectly affects line width. With charcoal pressure is of even greater importance in obtaining desired effects. The range of thicknesses available is far greater than that of a pencil. Attitude of use (angle with paper) also affects greatly the line thickness produced when using charcoal, and to a lesser extent pencil.

Crayon and pastel have the added attribute of colour.

Thus in order to construct the electro-mechanical equivalent of a class 1 stylus, a device that is pressure sensitive and provides a pressure "feel" to the user is required. The stylus should also be able to sense attitude of use. When required the attribute of colour should also be given.

A class 1 stylus should be able to operate as a sketching input or as a constrained input. Constrained input implying line straightening and when required "tee square" control should also be available.

When using a "pencil" on paper a line ceases to be drawn the moment the pencil is lifted from the paper. This naturalness must be maintained in graphical interaction.

Solutions so far tend to be unnatural in that a light pen requires either an unnatural "wrist flick" or activation of a button to signify the end of an interaction step. When a conventional stylus and tablet is used, a momentary pressing of the stylus on to the tablet, (usually accompanied by a

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