Centralization and distribution of CAD/CAM systems

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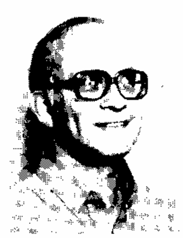

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The paper deals with planning and control of the development of CAD/CAM systems in an organization. The paper presents a descriptive technique that facilitates the analysis of centralization/distribution level of CAD/CAM and helps in establishing an organizational policy regarding this issue. The paper adapts a methodology which is used in the Management Information Systems (MIS) area. It defines what is distribution; it classifies degrees of distribution into various categories; it proposes a methodology to set a desired range for the degree of distribution; it distinguishes between the various activities along the system life cycle and suggests how an organization can assign a different degree of distribution to any of the life cycle activities.

Keywords: CAD/CAM, centralization/distribution, distribution policy.

1. Introduction

The early use of Computer-Aided-Design/Computer-Aided-Manufacturing (CAD/CAM) systems was mainly focused on installing *stand alone* working stations that facilitated the art of design on one hand, and partly automated the manufacturing on the other hand. Through the passage of time, CAD/CAM users have put a lot of effort in integration of CAD/CAM systems.

Integration of CAD/CAM is realized in two distinct directions. The first direction is toward automatic transfer of design outcomes to manufacturing processes. This may be called the *Design-to-Manufacturing dimension.* Its main benefits are in saving time and improving the accuracy of the process of converting design ideas to concrete products. Additional benefits are obtained in establishing more exact quality control measures, and fast constructing of prototypes. This trend has generated the term *Computer Aided Engineering* (CAE) [8].

The second direction of integration is towards connecting a number of working stations to a common mainframe computer by means of communications network. This may be called the *horizontal dimension.* The major merits of this type of integration lies in the common data base it generates. A common data base enables various designers to refer to design specifications that might be useful for different design task, and

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consequently to save time by sharing information. In addition to that, a commonly accessed data base allows for better control of managers on the progress and quality of projects under development.

The trend towards integration has risen the question of how far to centralize CAD/CAM systems. Present technology provides technical solutions to almost any desired degree of centralization or distribution (C/D). The C/D level should be, therefore, a result of a *managerial* decision rather than *technical* constraints. This paper proposes a systematic methodology to analyze and assess the level of distribution required for an integrated CAD/CAM system. The methodology is adapted from the field of Management Information Systems (MIS). It was first suggested by Buchanan and Linowes [3,4] and later refined by Ahituv and Sadan [2].

Before portraying the methodology we first have to indicate some similarities and distinctions between MIS and CAD/CAM systems. Both are considered to be high technology systems, based on interlacement of hardware and software features. MIS, however, are much more mature and have gained about 20 years of experience in practical use. CAD/CAM systems are relatively novice and tend to suffer from 'infancy' problems. Some of these problems can be remedied by learning from the MIS experience.

It seems that the variegation in data and in users is larger in CAD/CAM than in MIS. CAD/CAM systems are very useful to operational echelons in an organization and therefore its communication topology is typified by a network structure. MIS reflect the managerial structure of an organization, hence its communication topology tends to be more hierarchical. Nevertheless, the resemblance between the two seems greater than the disparities, so it is likely that the proposed methodology can be fruitful for policy making in CAD/CAM system deployment.

This paper proposes a tool to facilitate the analysis of the degree of C/D of CAD/CAM. The next section presents the basic concepts and definitions. Section 3 will lay out the CAD/CAM system life cycle and the elementary activities along it. Section 4 presents the concept of distribution spectrum. Sections 5 and 6 discuss the way management should apply the proposed methodology. Section 7 suggests criteria for deciding on distribution. The last section provides some concluding remarks.

2. Basic concepts and definitions

A conflict between desires to centralize and to distribute is inherent to a CAD/CAM system. On the one hand there is a large number of potential users, varied in professions (engineers, technicians, machine operators, supervisors), therefore generating different demands in terms of hardware features, software interfaces, technical jargon, working hours and location. All this may call for more distribution. On the other hand, the need to coordinate resources to efficiently produce well-designed, accurate manufactured products calls for more centralization. We will show that the conflict is indeed imaginary, since there are many aspects to C/D, and while some aspects can be centralized, others can be distributed.

Distribution is usually perceived in terms of hardware distribution, namely, deployment of hardware units in different locations. This definition is too narrow. We define distribution as '*delegating responsibility to end user*'. Consequently, one may discuss distribution in terms of software development, hardware selection, budgeting procurement of CAD/CAM equipment, etc. For instance, in a certain organization the selection of CAD/CAM hardware and software can be centralized, the deployment of mainframe computers can be distributed, the normal operation can be distributed, maintenance can be centralized, and budgeting can be distributed to departmental users.

We define a *distributed CAD/CAM* (DCC) as a CAD/CAM system containing some activities that are not centralized. The next section lists out the activities that can be considered for distribution.

3. CAD/CAM system life cycle

A cornerstone in MIS practices is the Information System Life Cycle (ISLC). The ISLC is a formal description of all the activities pertinent to the development and operation of an MIS (for details, see [1, ch. 7]). The activities delineated in the ISLC can be grouped into four categories [2]:

Table 1
CAD/CAM activities.

Life cycle category	Activity
Development	System definition
	Feasibility study
	System analysis
	Hardware selection
	Application software selection (or programming)
	Operating system software selection
	Hardware acquisition
	Software acquisition
	File definition
	System implementation
	Pilot run
	System documentation
	User training
Operation	Hardware operation
	Application software operation
	Communications operation
	Operating system software maintenance
	Application software maintenance
	Hardware location
	Input handling
	File handling
	Output distribution
Management	Priority setting
	Setting procedures and working methods
	Approval of changes
	Approval of operation scheduling
	Personnel management
	Pricing CAD/CAM services
	Budgeting
Control	Data security assurance
	Production process control
	Quality and reliability assurance
	Performance evaluation
	Setting improvement methods
	Improvement measurement

(1) Development,
(2) Operation,
(3) Management,
(4) Control.

Similar to MIS, CAD/CAM systems also undergo development and operation phases, and while doing so, they should be managed and controlled. Hence, the above four categories apply also for CAD/CAM.

Table 1 lists out the CAD/CAM life cycle activities, as they are grouped into the aforementioned categories.

In addition to detailing the activities, the ISLC formally distinguishes between the roles of three parties: MIS professionals, users of MIS, and managers.

Similar to MIS, CAD/CAM systems are developed by professional teams, but they should serve lay users and be controlled by ordinary managers. A policy regarding the distribution of CAD/CAM is, in fact, a clear definition of the role of each party. A tool to devise such policy is presented in the next section.

4. Centralization / distribution spectrum

As mentioned earlier, distribution pertains not only to hardware deployment but also to many activities related to human power and software development and maintenance. Buchanan and Linowes [3,4] suggested that for each MIS activity, a spectrum of feasible C/D levels be designated. A similar approach is presented here in table 2. For each activity, a C/D spectrum is proposed, where the left-hand side of the spectrum designates the most centralized possibility, and the right-hand side points out the most distributed case. In between the two extremities, some intermediate levels are put on a discrete scale. Note that the scale is absolutely an ordinal one and should not be perceived as a 'continuous function'.

5. Centralization / distribution profiles

The objective of the spectra provided in table 2 is threefold:

(a) Management can present a clear C/D policy by setting limits on each activity spectrum. In other words, management can decide that a certain activity shall never exceed beyond a desired degree of distribution. Such a decision is clearly expressed if the management marks on the spectrum table the acceptable range for each activity. The entire marked table becomes, then, a vehicle for management to convert 'vague' ideas into concrete and general C/D policy for *all* CAD/CAM systems.

(b) The table can also serve to plan the C/D level for a new CAD/CAM system. In such cases, the table is instrumental for designing individual systems. The designers will have to provide

Table 2
Centralization/distribution spectra.

Life cycle category	Activity	Fully centralized					Fully distributed
Development	System definition	User proposes, preliminary ideas	User defines requirement	User evaluates alternatives	User participates in the team	User performs the definition under professional team guidelines and control	User performs system definition
	Feasibility study	User is not involved	User reviews reports	User participates in selection of a solution	User participates in the team	User performs feasibility study under professional team guidelines and control	User performs feasibility study
	System analysis	User is not involved	User reviews reports	User determines detailed requirements	User participates in the team	User performs system analysis under professional team guidelines and control	User performs system analysis
	Hardware selection	User is not involved	User participates in requirements definition		User sets requirements	User participates in hardware selection	User selects hardware
	Application software selection (or programming)	User is not involved	User participates in requirements definition		User sets requirements	User participates in software selection or programming	User selects or programs the software
	Operating system software selection	User is not involved	User is informed on OS selection		User participates in OS selection and modification		User selects OS
	Hardware acquisition	User is not involved	User raises needs		User is informed on acquisition term	User initiates acquisition process and participates in negotiation	User negotiates and decides on hardware acquisition
	Software acquisition	User is not involved	User raises needs		User is informed on acquisition terms	User initiates acquisition process and participates in negotiation	User negotiates and decides on software acquisition
	File definition	User is not involved	User provides data requirements		User participates in file definition		User defines his/her own data base
	System implementation	User is passive	User is informed on implementation timetable		User participates in planning the implementation	User is involved in implementation steps	User is responsible for implementation
	Pilot run	User is not involved	User participates in pilot runs and acceptance tests		User runs the CAD/CAM system under professional guidelines		User is responsible for pilot run
	System documentation	User receives functional instructions	User writes operation guidelines		User participates in writing technical documentation		User prepares all the documentation
	User training	User receives training (user is passive)	User sets training requirements		User prepares training program and material	User performs training	User is responsible for training
Operation	Hardware operation	User operates only terminals	User operates local peripheral equipment		User operates local computer		User manages an independent computer installation
	Application software operation	Uses software operated by a professional team			User operates the software under professional team guidelines		User operates the software
	Communication operation	User receives communications services from professional team			User operates communications under central control		User is in charge of his/her communications operation
	Operating system software maintenance	User is using a given OS	User modifies application software due to OS requirements		User maintains the OS		User inserts changes into OS

	Application software maintenance	User reports on errors		User requires changes		User inserts changes and debugs application software
	Hardware location	Central site for hardware, including terminals	User receives terminals only	CAD/CAM stations deployed at user's site; computers in a central site		All the equipment is deployed at the user's site
	Input handling	User prepares only raw (source) data	User keys in data to a central computer	User operates all input facilities		User is in charge of input preparation and validity
	File handling	Central file	Central files with local responsibility	Local files shared by many users		Local and independent files
	Output distribution	Blueprints, drawings and other output are centrally produced	Combination of central and local output facilities	Local output facilities connected to a central computer		Local output reproducing and distribution
Management	Priority setting	Priorities are imposed by central management	User rank orders requirements	User proposes priorities		User sets priorities
	Setting procedures and working methods	Procedures and methods are centrally dictated	User suggests procedures and methods	User approves proposed procedures and methods		User sets procedures and methods
	Approval of changes	User cannot request changes	User request changes	User initiates engineering change request (ECR)	User approves ECR	User performs changes and distributes engineering change notices (ECN)
	Approval of operation scheduling	Operation scheduling is imposed by central management	User sets priorities	User proposes timetable for operation	User approves timetable for operation	User sets timetable for operation
	Personnel management	Management dictates employment policy	User provides personnel requirements	User evaluates personnel qualifications		User hires, fires and promotes professionel personnel
	Pricing CAD/CAM services	Pricing policy and rates are centrally imposed	User participates in setting pricing policy	User approves pricing policy		User sets his/her own pricing policy
	Budgeting	User presents needs in non-monetary terms		User presents budgetary requirements		User is reponsible for CAD/CAM budgeting
Control	Data security	Security arrangement are centrally dictated	User operates local security under central guidance	User approves local security arrangements		User is in charge of local security
	Production process control	Central responsibility		Central coordination of local process control efforts		Local responsibility for completeness and timeliness of process
	Quality and reliability assurance	User is passive	User devises Q & R assurance plans	User approves Q & R assurance programs		User is in charge of Q & R assurance
	Performance evaluation	User collects performance data	Users sets performance criteria	User controls performance measurement		User evaluates system performance
	Setting improvement methods	User is passive	User provides suggestions for improvements	User participates in the team that sets improvement methods	User approves improvement methods	User initiates and sets improvement methods
	Improvement measurement	User is not involved	User provides raw data	User collects data		User measures improvement

a C/D *profile,* based on the table, and to justify their proposal.

(c) The table is also a practical tool to document the status of C/D of existing CAD/CAM systems. If management wishes to conduct a survey on the C/D status of existing systems, the performers of the survey can be asked to use the spectrum table to mark the C/D profiles of the various systems. The survey results can be very helpful in establishing a global policy.

The next section suggests an approach to establish a global policy toward the distribution of CAD/CAM systems in an organization.

6. Establishing an organization policy to CAD/CAM distribution

The discussion in this section assumes that several CAD/CAM systems have already been installed in the organization, that the proliferation of CAD/CAM has not been systematically monitored through an imposed policy, and that management does wish to establish an organizational policy on this issue.

Before describing the steps towards devising a policy we would like to emphasize that an organizational policy does not necessarily contradict the notion of distribution, and does not necessarily imply centralization. On the contrary, an agreed policy can direct the organization toward distribution; such distribution will be, however, better controlled, whereas lack of policy will likely lead the organization to haphazard decentralization of its CAD/CAM rersources.

The establishing of a C/D policy undergoes through the following steps:

(1) Define the pertinent CAD/CAM activities (e.g., Table 1) and the relevant spectrum for each activity (e.g., Table 2).

(2) Survey existing CAD/CAM systems using the definitions provided in the previous step. The merit of the survey is two fold: first, it will check the feasibility of the definitions provided by the previous step (it is most likely that the spectrum table will undergo several iterations until it is finalized); second, the survey will provide up-to-date information on the status of existing CAD/CAM systems.

(3) Establish decision procedures regarding the C/D levels of new CAD/CAM systems. The term 'decision procedures' refers to points along the CAD/CAM system life cycle where a decision or a review of the C/D level should take place. On these milestones it should be clearly specified who participates in the decision making process, who prepares background information and analysis, what reports and forms should be submitted, etc.

(4) Set decision criteria regarding the C/D level of new CAD/CAM systems. There are many criteria that may help in deciding about the level of C/D. The list of criteria is presented in the next section. Management has to select those criteria that are most pertinent to the particular organization.

(5) Once all the above steps are completed, the entire policy proposal should be brought to top management for final approval. No need to mention that further to that, on-going control over the compliance of new CAD/CAM systems to the agreed policy is a must.

7. Centralization/distribution criteria

C/D profiles may vary among various organizations, and even among various departments within an organization. This in itself is not necessarily a negative phenomenon provided that it is based on calculated decisions and on well determined criteria. Following is a list of common criteria that may support a C/D decision:

(*1*) *Relationships to other systems:* when the data used by a CAD/CAM system is tightly related to other systems, degree of centralization should be higher. Examples:

- *PRINTED circuits layout design system.* The data serve many departments such as layout design, PRINTED circuit manufacturing and PRINTED circuit inspection. Naturally, such system will tend to more centralization.
- *VLSI design system.* This system helps in designing microelectronic very large integration chips. For other department, the chip is a 'black box' (an integrated circuit). Such a system will tend to be more distributed.

(2) *Data uniqueness:* when the data for a CAD/CAM system is unique to the particular system, a distributed solution is more favorable. Example:

- *Mechanic design sytem.* This system employs standard data which is useful to many departments; a centralized solution is, therefore, more considerable.

(3) *User diversification:* when the number of departmental users is large and variegated, the development of a centralized CAD/CAM system is more realistic; if only a few users need the system, development effort can be distributed. Examples:

- *VLSI design system* serves a few users, thus tends to distribution.
- *Digital components design and simulation system* is a multi-user system, hence its development should be centralized.

(4) *Existence of local hardware:* application software that is supposed to run on an existing local computer can be independently developed, maintained and modified. Examples:

- *Mechanic component production* is performed in the production shop and monitored by independent hardware equipment. This situation calls for distribution.
- *Digital circuit design and simulation system* is usually maintained by a central body.

(5) *Economic considerations:* very often, centralized and distributed solutions significantly differ in the cost of installing and running the system (e.g., economies of scale). The cost factor should certainly play an important role in the C/D decision.

(6) *Existing turn-key systems:* sometimes management has to comply to a solution proposed by a turn-key system, in order to refrain from in-house development.

(7) *Problem uniqueness:* when the CAD/CAM system is supposed to assist in problems that are very specific and unique to a certain department, it is better to let the particular department develop and maintain the system. Example:

- System definition of VLSI design for the microelectronics department.

(8) *Security:* System which is confidential and its security requirements are high, should be under the responsibility of the direct user.

(9) *Data availability requirements:* there are tradeoffs between the quality of the communication network and the distribution level. If instant availability of data is badly needed, then poor-quality communication system can be replaced (or backed up) by a distributed system.

(10) *Organizational and structural considerations:* a CAD/CAM system should reflect, as much as possible, the managerial style and the structural constraints of the organization. Since technology is very flexible nowadays, it is not advisable to impose centralized solutions on distributed units and vice versa.

(11) *Exogeneous factors:* sometimes, the need to interface a CAD/CAM system to external systems might impose constraints on the degree of distribution. Example:

- Installing a CAD/CAM system in a subsidiary firm which has to communicate data to other firms in the conglomerate.

(12) *Personnel qualifications:* the ability of local employees to develop and operate CAD/CAM systems is certainly a key factor in the C/D decision.

The above list of criteria is certainly not exhaustive, nor can it fit to all the organization under all circumstances. Each organization has to tailor a criteria list for itself. Yet most of the above criteria, may be with some variations, can be helpful in devising a C/D policy for CAD/CAM.

8. Concluding remarks

How far to go with CAD/CAM distribution is a critical problem to many organizations. Not only has it economic implication on an organization's profitability, but it can also have impact on employees' motivation and psychological climate. Misfit of CAD/CAM distribution level might hamper its adoption in the organization.

Similar problems have been encountered by MIS experts for many years. Many of the MIS infancy problems have been resolved, in particular, the analysis of centralization versus distrubition. This paper adjusts a methodology suggested for MIS analysis of C/D to CAD/CAM environment. The main thrust of the methodology is that a distribution problem should be decomposed into a number of aspects (activities) and each aspect should be analyzed in separate. Only after such an analysis, a comprehensive policy can be devised and implemented.

Based on some practical experience in a few cases, it is our belief that the methodology proposed here is indeed applicable.

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