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COMPUTER AIDS TO WORK ORGANIZATION IN HYBRID MANUFACTURING

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Abstract

The need for tools which aid the decider organize decisional latitude was identified in a study of task organization decisions in three different manufacturing workshops.

Hierarchical mechanisms in the decisional process were identified at both an organizational and an individual level. The hierarchy was found to be associated with different levels of detail relating to time, resources and work.

The model proposed is based on the notion of decision centers characterized by a specific type of decision associated with a particular level of detail in the factors relating to work, resources, and time. The decisional latitude or leeway in a lower center is thus governed by decisions made at the next higher level.

In a given center attention must be paid to : (1) coherence with higher level decisions, i.e. remaining within imposed decisional limits; (2) feasibility and decisional durability by allowing enough decisional leeway to the lower center.

The design of ergonomic computer aids can be reformulated as a problem in the presentation of latitudes in resources, time, and work loads designed to help the decider make coherent, feasible and durable decisions about task organization.

A prototype is described which presents latitudes in work load and time in a graphical way to aid task organization in hybrid manufacturing industries.

1. INTRODUCTION

Gains in productivity are a constant preoccupation in manufacturing industry. In large scale manufacturing (auto plants), high levels of productivity can be obtained due to the consistent nature of the assembled product which enables work stations on the production line to be harmonized thereby eliminating dead time. Further gains in productivity can be obtained by automation of elementary operations.

High productivity is less easily achieved, however, in small or medium scale production (or custom manufacture) due to the diversity of the products. Nevertheless, a more flexible automation suited to this type of manufacturing (numerical control machine tools, robots, etc.) has followed the recent advances in microelectronics and computerization. Flexible, completely automated workshops which can turn out a variety of products simultaneously are on the increase, although they are mainly encountered in the larger firms. Nevertheless, they tend to be rather less flexible than the more conventional, partially automated workshops.

In this situation, productivity can be increased by improving product flow through the workshop, which depends on the organization of:

- technical factors relating to the particular products (range, nomenclature, elementary operating processes, definition of new products);
- market factors, relating to orders and shipment schedules;
- materials, relating to the supply of raw materials, components and partially assembled products, as well as the control of stock of final products;
- work, in the organization of task durations and the appropriate allocation of resources (man, machines, raw materials and components).

Computer-Assisted Decision and Scheduling systems are now increasingly being used to organize the technical, market and material factors. However, with respect to the work-related factors, the design of suitable computer aided systems is based on a representation of their function which may not be realistic. This is reflected by the rather too common mismatch

between plans produced by computerized systems and the work effectively carried out. Our study is essentially concerned, therefore, with task organization within a workshop.

Most of the current computer aided task organization systems are based on heuristic rules, or local rules such as those relating to the control of queuing for use of a particular machine. Such systems can be set up without too much difficulty, but since they are based on local criteria they are based on highly restrictive hypotheses and may not fit in with overall objectives.

These systems sometimes contain a simulation function which enables the operator to test the choice of certain heuristic rules. The effectiveness of a given choice is evaluated, and the process is iterated until satisfactory results are obtained. It should be noted that these choices, which are in fact scheduling decisions, are made before or during the simulation. They neglect the possibility that decisions need to be made in real time during manufacture, especially those in response to unforeseen situations. The prescriptive nature of such plans leave little decisional leeway.

In an attempt to design a computer assisted system that was more suited to the real requirements of users, we studied the modes of organization of decisional leeway in workshops from an analysis of decision processes. The results of this study made us reconsider the problem of task organization in an attempt to design a more flexible system.

2. THE DECISIONAL PROCESS IN TASK ORGANIZATION

Modes of organization of decisional leeway were identified from studies carried out at three different sites. The first two studies characterized the decisional process from the structural point of view, while the third defined it functionally.

The results showed that the decisional process is essentially hierarchical on both an organizational and an individual dimension. On each dimension, decisions require processing of data at different levels of detail. These levels are not absolute and depend on the context, especially on the characteristics of the production process.

2.1. Organizational dimension of the process

The organizational dimension of the decisional process was identified in the machine shop of a company manufacturing heavy military equipment [1]. In this firm, we found that decisions on task organization could be distinguished on the basis of the level of detail in factors relating to work, resources and time. This decisional hierarchy also depended on the structure of the organization. As shown in Table 1, a particular level of decision was found to be attributed to a category of worker. It should be noted that this schematizes the actual decision taken. Since the responsibility for a decision is attributed to a particular category of worker, interactions between deciders will have important consequences within the same workshop. For example, in order to carry out an operation at a work station other than that planned, the workshop supervisor has to ask the opinion of the foremen and team leaders.

Table 1:
Level of detail in factors relating to the organizational dimension of decisions on task organization

Function	Workshop supervisor	Foreman	Team leader
Level of detail of factors			
Product	Operation phase	Operation phase	Operation
Resource	Work station	Work station and machine	Machine
Time	1 week to 2 months	1 day to 1 week	1 hour to 1 day
Examples of types of decision			
	Regulation of work load and capacity	Allocation of operations to machines and teams	Distribution of operations to workers
		Organization of tools, raw materials etc.	Definition of the order of operations

2.2. Individual dimension of the process

The individual dimension of the decisional process was identified in a study carried out in various machine shops of a company manufacturing jet engines. For a given individual, a decision was reached in several stages represented by sliding horizons. Each stage had a particular level of detail in the factors relating to a specific temporal horizon. For example, to decide on the allocation of operations to machines, the team leader constructed a weekly schedule which was then fine tuned to daily and half daily (team) schedules. The task schedule was continually refined as each task approached. Over a weekly horizon, the operations were classified on a daily basis, and the succession of operations was only defined over a half day horizon [2].

2.3. Alterations in decisional structure

A study in progress in various types of workshop (casting, machining, assembly) of a company making small electrical appliances has identified organizational and individual dimensions in decision making for task organization. They tended not to adhere to strict hierarchical levels, and were found to depend to a large extent on constraints of the on-going production process.

On the organization dimension, the relationship between decision levels and category of worker was found to depend on the characteristics of the workshop. In the casting and machine shops, decisions were centralized. The workshop supervisor made all the task organization decisions, while the other workers had a consultative role. In contrast, in the assembly shops, decisions were taken by various categories of worker in collaboration.

This diversity was also observed in the individual dimension. For some decisions, the temporal horizons were shorter at the end of the assembly line than at the start (casting and machining).

Study of the decision making process indicated that leeway in task organization fitted into a multi-dimensional hierarchical decision structure in which each level N (higher center of decision) defines the decisional latitude at level $N+1$ (lower decision center). The structure was not fixed, but varied in response to production constraints within a particular workshop.

3. MODEL FOR COMPUTER AIDED TASK ORGANIZATION SYSTEM

To make the system as compatible as possible with the real world decision making process in the workshop, we based our design on the constraints approach (time and resources) developed in the Automation and Systems Laboratory (L.A.A.S.) [3]. This model contains tools for analyzing inference and propagation of sets of time and resource constraints impinging on the decision making process. However, this model implemented in Prolog II [4] does not produce results that have direct application, and so we attempted to design an appropriate user interface.

3.1. Principle of constraints approach

In the constraints approach, the relationship between the higher and lower decisions centers can be schematized as follows (Fig.1):

Decisions taken at the higher center are transmitted in the form of time and resource constraints to be adhered to by the lower center. In other words, the constraints derived from decisions taken at the higher center define the decisional latitude of the lower center. Thus at each level, the decisional leeway depends on the limits (or degrees of flexibility) imposed by the next higher level.

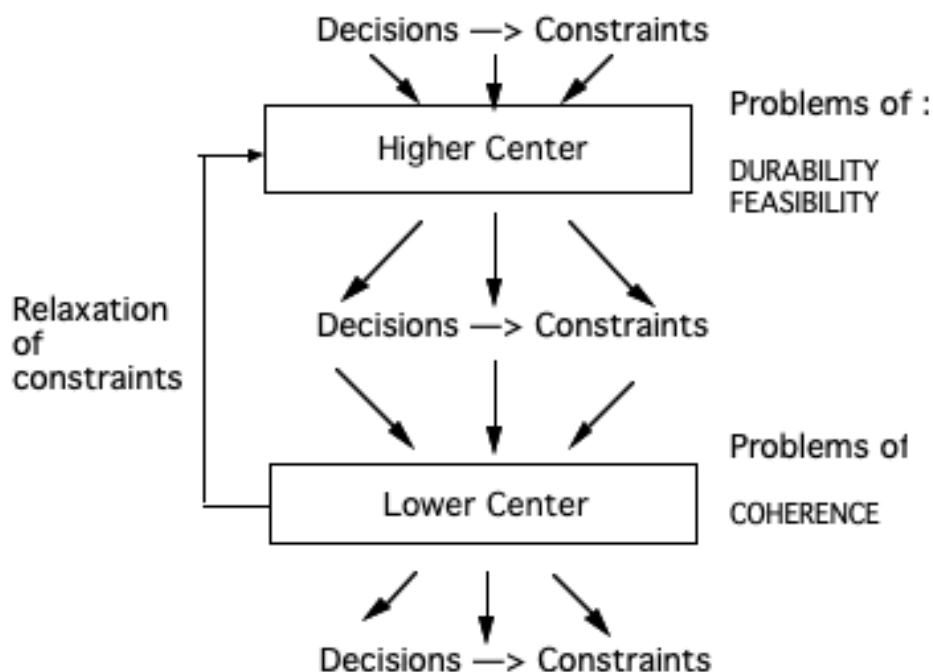


Figure 1. Principle of constraints approach

At the lower center, problems of coherence between decisions must be resolved, while at the higher center, the durability of the decision needs to be taken into account. The more durable the decision, the greater the scope for decision at the lower center. A decision taken at the higher center must be feasible. If the constraints (time and resources) imposed are not realistic or are incompatible with specific constraints at the lower center then the system will seize up. In this case, constraints have to be relaxed, which may conflict with decisions taken at the higher center. Although relaxation of constraints may lead to flexibility, it can turn out to be costly when used systematically. In this situation, feasibility is a crucial issue, and the more feasible the decision taken at the higher center, the less risk of error and backtracking.

Since decisions are taken by human operators, the feasibility criterion was incorporated in the user interface, which will be tested in future studies.

3.2. Model of interface: updating of decisional leeway

To improve the feasibility of decisions, the decider must be provided with information that is compatible with his cognitive system. This is seen at two levels. Firstly, the decider's internal representation of the data presented must be compatible with the objective, and secondly, the external representation of the data (nature and form) must be compatible with the decider's internal representation. The nature of the problem and the information required to solve it must therefore be carefully defined.

3.2.1. Nature of problem

One of the aims of task organization is to define a temporal sequence of operations. Current computer aided systems construct a solution, and all decisions are designed to conform to this overall objective. In this case, the objective is known, and all decisions converge towards this goal.

Our design approaches the problem differently. The objective is not predetermined, but is constructed by specification of leeways in response to the on-going situation. The previous

retrospective approach (goal to data) now becomes prospective (data to goal). Furthermore, the temporal sequence, a fundamental component of the traditional problem, now becomes a datum in the current problem, or one of the constraints to be considered at only the most detailed planning level in order to avoid backtracking [5].

Thus the problem of task organization, which is normally stated in terms of a schedule or temporal sequence, is now specified in terms of a specification of latitudes (time, resources, work).

3.2.2. Data presentation

Data presentation must help the decider in the higher center construct mental representations that are compatible with latitude specifications for the lower center. This mental representation should enable construction of a feasible decisional framework. The decider must therefore be given aids which enable him:

- to grasp the available latitudes
- to anticipate the impact of his decision on the latitudes imposed on the lower center.

The presentation of data must provide relevant information for processing of the organizational and individual dimensions of the task-related decisions. This must take account of interactions between and within decision centers during the different stages of decision making (cf. para. 1).

We paid particular attention to the 'succession of operations' constraint which must be introduced as late as possible. Two types of data presentation were devised, one detailed and the other more general, which were distinguished in terms of the perception of temporal proximity between operations (Appendix 1):

- a) Detailed presentation represents planned operations (duration, and temporal latitudes). The temporal proximity between operations is readily perceived, and so this presentation must be compatible with processing at lower levels of the decision making hierarchy.
- b) The general presentation represents the amount of work or tasks to accomplish for the operations planned. The detailed temporal latitudes are incorporated in terms of work latitudes. The temporal proximity between operations is not directly perceived, and so the

general presentation must be compatible with processing at the higher levels of the decision making hierarchy.

With respect to the decisional horizon for task organization on the individual dimension (within a center), the detailed and general plans are components of a temporal structure made up of time intervals defined by the decider.

4. CONCLUSION

One of the problems of workshop task organization is the specification of decisional latitude. The dynamic nature of production imposes a certain degree of decisional latitude for each center, and an overall coherence between decisions. A study carried out at different sites showed that a workshop resolved this by a distributed decision process. For certain types of decision, we also identified mechanisms for making hierarchical plans by successive levels of integration. Plans were progressively refined by a process of dynamic factoring.

This approach of prospective planning observed in workshops can be assisted by computer systems employing methods based on propagation of sets of constraints. However, since they only provide decision aids, a user interface is required which helps the decider make feasible decisions.

We devised an interface for displaying the temporal distribution of operations. Two modes of data presentation were used:

- the detailed mode presented the planned operations: for the processing of lower levels of planning, it steers the decider to consideration of temporal latitudes,
- the general mode presents levels of work: for the processing of higher levels of planning, it steers the decider to consideration of work latitudes (or work load latitudes).

The design of this interface raised several questions:

1. We have currently decided to use graphical presentation of data, although it is not clear whether this form is compatible with users' representations. There may be individual differences, and it may be more or less suited to particular problems (reasoning on time, work or resource latitudes).

2. Should the retrospective approach be included in the design of the interface since most of the current computer aided organization systems are based on it ? It may be that current users of such systems have developed habits that are not directly transposable to the prospective approach. The problem of upward compatibility or transfer of user experience will

need to be taken into account, and specific instructions or training maybe required for optimum use of the proposed system.

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6. APPENDICES

Presentation of detailed and general data

An operation is defined by (Fig.2):

- a time latitude bounded by an earliest date (Ci) and a latest date (Fi):
- a true start date (ti);
- a duration Di

The operations can be adjusted by shifting t_i within the time latitude or by reducing this latitude.

Temporal latitudes



Task



Operation

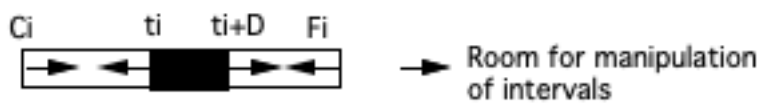
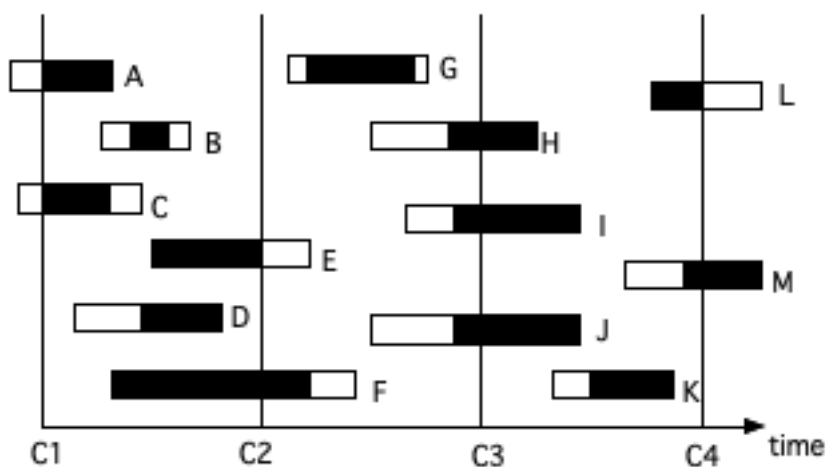


Figure 2.

Definition of operations and manipulation of time latitude

Relationships of temporal proximity between detailed operations are represented on a graph which is split up into intervals of decisional horizons (Fig.3):



Cn Dated boundaries of adjacent intervals

Figure 3.

Detailed levels, presentation of temporal proximity of operations

The same data can also be presented at a more general levels (schematic) which leaves out some of the proximity relationships, but emphasizes the range of amounts of work over the intervals (Fig.4). Any temporal shift in load will thus impinge on only two adjacent intervals.

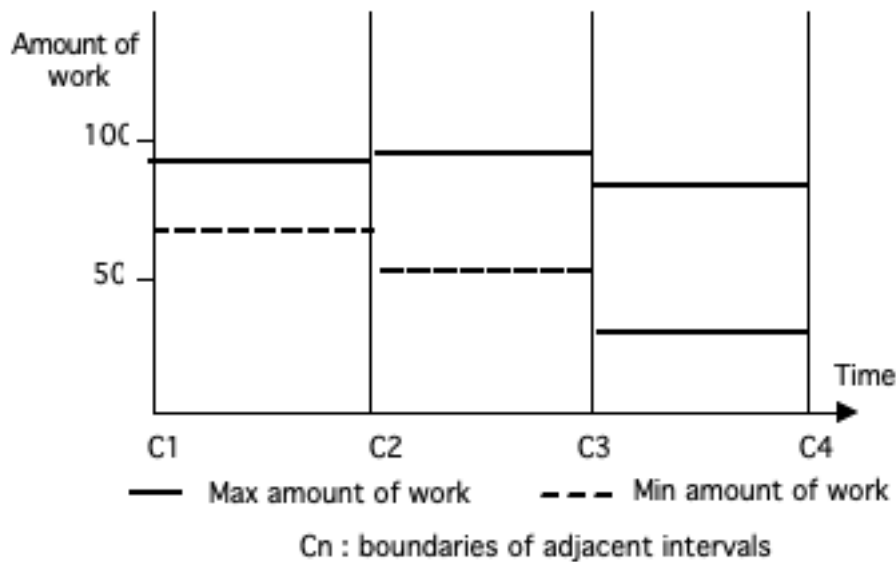


Figure 4:

General level, presentation of max and min amounts of work per interval.

This graph represents the max and min amounts of work for each interval and expresses the work latitudes taking account of the temporal constraints on the various operations. The amount of work is the cumulated energy, where energy is a unit of work relating time and resources required to carry out each operation in the interval. The max amount of work is calculated by centering the tasks (t_i, t_i+D_i) in the intervals (taking account of their time latitudes). The min amount of time is calculated by shifting the tasks (t_i, t_i+D_i) to adjacent intervals (taking account of their time latitudes). Manipulation of a work latitude is seen at the detailed level by a change in time latitude of operations included in that interval (on the detailed graph) and by extension, a change in work latitudes in adjacent intervals (on the general graph).

