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APPLICATION OF DISTRIBUTED KNOWLEDGE BASES IN INTELLIGENT MANUFACTURING

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ABSTRACT

The knowledge based systems developed as research or industrial prototypes recently are generally batch systems and they are built to be used in a sequential environment. Most of the manufacturing applications require the use of systems in parallel to represent the dynamics of the shop floor. This is possible either through independent knowledge bases operating on separate work stations networked together or implementation of these systems on parallel computers. This paper considers the former approach within the domain of knowledge based scheduling. The scheduling problem is addressed through distributed knowledge bases that have an ability to pass information back and forth between small knowledge bases functioning at different decision making levels.

INTRODUCTION

There is a big gap among the schedules generated using various planning systems and schedules actually used in the shop floor environment. This is basically due to fundamental characteristics of all scheduling difficulties. Effective scheduling is a knowledge intensive activity requiring a comprehensive model of the factory and its environment at all times in the schedule generation process [4]. Understanding the domain's constraints and their relative importance on the factory schedule and the relationships to one another can provide an effective foundation for schedule generation [5].

Knowledge based scheduling is still very much in its infancy. Few completed systems exist, but a number of research efforts are underway. Steffen [6] identifies artificial intelligence research into two broad categories: knowledge representation and control strategy. Most systems use a combination of artificial intelligent methods, although one method often tends to determine the system structure while others provide supplemental functions. Manufacturing processes are very dynamic and situations have a tendency to change rapidly. Expert systems, therefore, require extensive maintenance in order to keep them effective. Also, once developed and tested, expert systems could still fail to work in the intended operational environment because situations may have changed within the original environment [2]. Knowledge bases for a complex manufacturing environment have a tendency to be large and complex themselves. To revise or expand the knowledge base when new situations occur, it would have to rewritten to accommodate the new rules or facts. Revising these complex knowledge bases may create problem areas in other areas of manufacturing environment because of the interaction of the rules used.

A method that can be used to simplify the knowledge bases would be to develop smaller specific knowledge bases for specific areas within the manufacturing environment and link these knowledge bases together so not only will they be acting in parallel to each other but information derived from one knowledge base can be passed to another as well. This paper examines the feasibility of developing smaller knowledge bases for very specific purposes and linking them to another knowledge base to coordinate the flow of information and direct proper responses back to the smaller knowledge bases.

Knowledge bases are currently developed by one or a combination of four techniques:

(1) a domain expert interviewed by a knowledge engineer for facts and rules;

(2) operational data being reviewed by the knowledge engineer and converted to facts and rules;

(3) the domain expert interacting with an Intelligent Editing Expert System, or;

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(4) the domain expert can interface with an induction program which "learns" from examples and scenarios presented by the expert [1].

CONCEPT

A small manufacturing plant was conceptualized in order to experiment with this process. The general outline and areas of the manufacturing shop is shown in Figure 1. The domain specific area for the knowledge bases was to optimize the scheduling of work at each work station in order to meet a weekly quota.

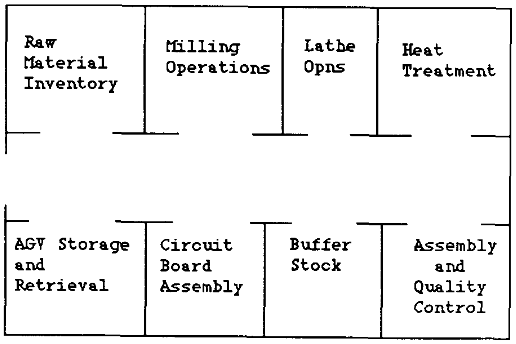

Figure 1. General Layout of Shop Floor for Experiment

Each specific work station in this layout will have a knowledge base optimizing the schedule of work through that particular work cell. In this experiment, each work cell was represented by an IBM 6152 work station. The knowledge bases that was used to coordinate the flow of information resided in another IBM 6152 work station. The work stations were linked to each other and the controlling knowledge base using a token ring network for the Local Area Network (LAN). Each particular knowledge base for each work station was designed to accomplish tasks particular to that work cell it represented. Some examples of these tasks are shown for selected work cells in the following sections.

AGV Work Cell

The Automated Guided Vehicle (AGV) knowledge base needed to schedule three AGV's to minimize idle time of the AGV's and ensure timely movement of raw materials, work-in-process, and finished goods. Some of the considerations needed by the knowledge base in scheduling the AGV's movements were:

- type and amount of raw materials needed at work cells
- type and location of products needing to be moved
- buffer stock needing storage and retrieval
- anticipation of job completion
- movement rates and times between the various work cells
- limitations of size and weight allowances per AGV

Circuit Board Assembly Work Cell

For the Circuit Board Assembly, a different set of objectives were needed to optimize the assembly schedule. Some of the considerations required were:

- actual sequencing of tasks to be performed
  - +normal job versus expedited job
  - +board fabrication
  - +circuit track
  - +solder mask
  - +component spacing
  - +component orientation
  - +composite selection
  - +general layout
- movement of the product or raw materials to and from the AGV's
- ordering new materials when short
- informing the controlling knowledge base when
  - +job is completed
  - +total jobs completed or late
  - +maintenance problems
  - +completion of repairs

Mill and Lathe Work Cells

The milling and lathe work cells consisting of *N* machines of each type would require scheduling of:

- jobs for both normal operations and expedited orders
- robotic arm movement to load and unload the AGV's
- tool control for
  - +replacement
  - +changeovers
- informing the controlling knowledge base of jobs completed and any late jobs
- informing the controlling knowledge base of maintenance problems or repairs needed.

Similarily, the other work cells, such as the raw material cell, heat treatment cell, assembly cell and quality control cell, will require knowledge bases developed to fulfill their requirements in optimizing the scheduling of jobs through them. The completion of jobs, need for movement of raw materials or products and the need for raw materials would be passed from one knowledge base to another for its use in scheduling and implementing.

The controlling knowledge base, in turn, must coordinate all the information being generated and direct the proper knowledge to the proper locations. Additionally, it must be able to handle routine challenges to everyday operations and must have a way of resolving new problems that arise. This may be a set of rules to use if a particular sequence of occurrences happen or it may mean contacting a human user to direct the solution of the problem. Some of the areas this controlling knowledge base must coordinate or information passed along are:

- display to the user the current status of:
  - +raw material inventory
  - +buffer stockage
  - +finished goods completed
  - +job status
  - +quality inspection results
  - +AGV status and locations
  - +late job data
  - +scheduling rules currently being used at work cells
- pass information to other knowledge bases needed to schedule jobs
- tie in with simulation/animation to display current shop status
- develop rules to handle changes in floor conditions and direct work cells of the implementations

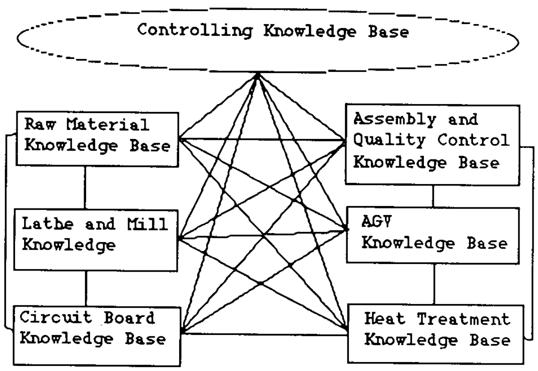

Figure 2. Knowledge Base Relationships

In order for the knowledge bases to be tested, background data needed to be generated on a number of jobs (i.e., the processes each job goes through, the process times for each process for each job, temperatures needed for heat treatment, AGV travel times between work cells, raw material required, and daily job requirements). This information can be placed in data files accessible to the various knowledge bases. The information can then be updated as changes occur and these changes passed on to the knowledge bases.

Some initial assumptions were made to simplify the process and get the experiment started. These assumptions were:

(1) to use a batch process in which all jobs were scheduled at the start of a particular time period rather than jobs continually arriving. For our purposes, all jobs were scheduled at the beginning of each day.

(2) that the system updates itself as to job status and revising schedules every two hours rather than real time. This was done in order to speed up the tests and because there were no actual machines to provide actual real-time feedback. Two hours was chosen arbitrarily to allow rapid progress over the daily interval but still allowed enough detail for analysis of ongoing operations.

REMARKS

Although the prototype system is not currently completed, there are expectations for usefulness in a manufacturing environment. Firstly, due to the knowledge bases being relatively small, they can be updated and revised more readily. Secondly, changes made in one knowledge base will not affect the operations of the other knowledge bases. Thirdly, this system will not only be able to handle structured problems; that is, problems that are well defined and already have solutions that are satisfactory and only require identification and implementation; but will also be able to begin solving unstructured problems as well [3]. The smaller domain specific knowledge bases will be able to resolve the structured problems using previously defined heuristics and optimizing algorithms. The controlling knowledge base in turn will have the ability to resolve structured problems affecting the overall system and will also have the ability to recognize unstructured problems, problems that have not occurred before or complex problems requiring more complex solutions than programmed for. This controlling knowledge base would have rules to narrow the problem down and direct the problem to the appropriate authority. This controlling knowledge base would then have the ability to update its rules to handle future problems of a similar nature as done with the induction programming discussed earlier.

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