CIM.REFLEX - using expert system technology to achieve real time shop floor scheduling

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ABSTRACT

If European manufacturing organisations, particularly SMEs, are to thrive and expand in the future, it is increasingly necessary for them to carefully examine their information technology strategies and the software systems which they employ to aid in the management and decision making process. In particular competition from the USA and Japan means that European manufacturing must be efficient, flexible and dynamic in its approach.

Of course many European manufacturers are utilising software systems which now implement traditional approaches such as CAD/CAM, Just In Time, MRP and Total Quality methodologies. However, both the USA and Japan continue to undertake research in these areas to refine systems and thus increase productivity and efficiency (and hence competition).

It is, therefore, vital that practical research is undertaken within Europe to ensure a healthy future for its manufacturing base. In particular, the need for SMEs to refine their efficiency is urgent if they are to be able to continue operation in such a competitive climate. It is, therefore, for these reasons that there is a vital and urgent need for such research.

The CIM.REFLEX project (ESPRIT 2 Project 6304) takes a novel approach to the production planning process in order to enable manufacturing
companies to respond in a much more flexible and dynamic manner. The goal of the project is to specify, develop, implement and evaluate an intelligent production planning system which will also address the tasks of product configuration and cost assessment.

The major objective of CIM.REFLEX is to develop an advanced software system which will enable manufacturing organisations to manage, plan and control their shop floor operations and resource requirements (and how these are met), in a more effective and efficient manner.

This paper describes the CIM.REFLEX approach and the structure of the system. In particular, the paper draws on the experience gained by the consortium in developing the CIM.REFLEX system for the needs of the two very different user sites involved in the project.

1 INTRODUCTION

Production planning and scheduling is an extremely complex process for which many solutions have been proposed. To date, however, none of these solutions have succeeded in adequately solving all the problems of the production process.

This is particularly true in the case of smaller manufacturing organisations who have to respond effectively and rapidly to the current dynamic market-place. Such organisations often do not possess the resources to invest in appropriate software tools and, even if they were to do so, the software tools which do exist would not adequately address their needs.

Current production planning and control systems are based upon rather inflexible and unrealistic models of the production planning process. Generally, they implement traditional operational research algorithms in order to produce and update production plans. Such algorithms are not, however, able to represent the inherent complexity of the many constraints placed upon production planning or the true dynamics of the process in real time.

In recent years attempts have been made both in Europe and the USA to produce systems which are more effective. These [1,2,3] have, in general, taken the approach of refining the algorithmic approach by adding heuristic [4,5,6] or simulation technologies.

Although such approaches do represent a major advance in production planning technology, they have not, as yet, attempted to attack the very heart of the problem, which is that they are not modelling the totality of the problem domain.
CIM.REFLEX SYSTEM OVERVIEW

CIM.REFLEX (see Figure 1) aims to provide a powerful multi-user, multi-site knowledge-based production planning tool designed specifically to address the needs of the SME manufacturing community. It will consist of an open environment to allow third party software support. Each of its three major modules (CAPS, CONFIG and COST) are designed to be used independently if required or in conjunction with either or both of the other modules. The complete system will allow the establishment of knowledge based decision support at the time of sale with real time data reflecting the situation on the shop floor.

A combination of Prolog and the DECIBAC expert system shell is being used to develop the CIM.REFLEX system. This approach offers flexibility, and makes the maintenance of the rule base and knowledge base straightforward. The project also uses XVT, a virtual graphics tool kit (supporting Microsoft
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Windows, OS/2, Presentation Manager, Motif, and Open Look for UNIX), to interface to graphical user interfaces.

The three system modules have the following global functionality:

2.1 CAPS (Computer Aided Production Scheduling)

CAPS accepts data on planned orders and the bill of process for those orders from either an existing MRP system or equivalent. Shop floor status information can be entered manually or via an existing shop floor data acquisition system based on rules and constraints for materials and resources. CAPS is able, with the information on planned orders and shop floor status, to generate a production plan. Multiple users are able to access individual parts of the plan for updating, view the whole plan at several levels of detail and perform 'what if' simulations on part of, or the whole, plan.

2.2 CONFIG (Configuration)

CONFIG is designed to help the sales department to evaluate a customer order in terms of its capability of manufacture (i.e. product configuration). This will be achieved by comparing the customer order with a known set of process sequences derived from an MRP system or equivalent (e.g. design and assembly drawings). The module will handle variants and options of existing products and also required changes to a product currently in production.

2.3 COST (Cost Estimation)

The COST module has two significant features, as it does cost assessment and pricing of a configured product. For a product composed of standard sub-assemblies the cost estimation can be based on look up tables but more complex products will require AI techniques. For example a product in a partially assembled state may need modification to accommodate a specification change. This will usually require partial disassembly, some rework, the generation of scrap and salvageable parts. The evaluation of the cost implications at various stages of assembly is the prime task of the COST module.

The next section of this paper focuses upon the CAPS module which is the core of the system.

3.0 INTELLIGENT SCHEDULING IN CAPS

Current MRP systems produce production plans at a high level; however, these can not be dynamically updated as production progresses. Furthermore these systems do not take into account special constraints or planning criteria, used within individual production departments.
In the CAPS system the server database is fed with the production data, and other relevant information (see Figure 2). The execution of production orders is the responsibility of the shop floor manager, and CAPS is his/her planning tool. As an option, data acquisition equipment could be used to report changes in production status to the CAPS system. This could include "production started", "machine not ready" and similar status updates.

The user interface of the CAPS system is based on three windows: Assigned Processes Window (APW), Unassigned Processes Window (UPW) and Summary Load Window (SLW). Production orders are initially shown in the UPW. The orders are then either manually, or automatically planned and moved to the APW. The manpower needed to execute the plan is displayed in the SLW. The user interface is keyboard or mouse driven. It enables the user to move processes, access underlying processes, and move machine information, and hence create or edit the production plan.

A user is thus able to simulate a schedule. A simulation could be an intermediate result in generating the actual plan, or one of several "what-if" copies for considering alternative schedules. A simulated schedule is represented by a plan view in a given state, optionally being stored in a file for later recall, but not being used for updating the actual schedule.
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A unique feature of the CAPS system is that the rule base is specific to each department, or production site. Based on rules and constraints the automatic planning engine is able to present qualified plan proposals. Furthermore, the system generates a warning if the manual reallocation of resources leads to a violation of the rules or constraints.

3.1 SCENARIOS

In the following a number of user scenarios are outlined. Each scenario represents a typical user situation:

Scenario 1

In this scenario, the user monitors a part of the actual schedule, e.g.:
- To see a day's activities on a machine, or a group of machines.
- To monitor the execution of today's schedule, with processes changing status, including real-time rescheduling performed by another user.
- To get an overview of a week's schedule, with machine utilisation, operator load, etc.

Monitoring could be relevant for machine operators, sales people and executives. The user will be able to:
- Set up the system as desired, selecting charts, time scale, colours, etc.
- Open the desired plan view, i.e. import it from the server.
- Open displays with relevant data.
- Select batch or on-line update of the plan view from the server.

Scenario 2

In this scenario, the user simulates a schedule, without affecting the actual schedule on the server, e.g.:
- To try out the consequences of inserting a rush order.
- To try out the feasibility of changing resources, e.g. adding work hours or machines.
- To get a general overview of resource requirements in a future, not yet scheduled, plan period.

Simulation could be relevant for planners at any level, operational as well as executive. The user will also be able to:
- Perform scheduling operations in the plan view.
Scenario 3

In this scenario, the user works with the actual schedule, authorising it for execution:

- To schedule next week's production in a factory shop.
- To adjust today's schedule to minor irregularities on the shop floor.
- To reschedule today's production radically due to machine breakdown.

Scheduling is relevant for any operational planners, shop managers, etc. The user should further be able to:

- Log on to the server.
- Lock (parts of) the plan view on the server.
- Select batch or on-line mode for sending updates from the plan view to the server.

4.1 USER TEST SITES

4.1 ARTIX

ARTIX Limited is a private owned company. It manufactures articulated dump trucks exclusively for Caterpillar Incorporated, the world's largest international construction equipment manufacturers. Articulated dump trucks (ADTs) are spoil carriers and are most commonly found in the construction, forestry and mining industries. These ADTs come in two forms: one with two axles (four wheels) and one with three axles (six wheels). Both types have a range of vehicles which can take payloads of between 18 tonnes (20 tons) and 36.3 tonnes (40 tons). All vehicles have extensive standard equipment as well as a wide selection of optional equipment such as air conditioning, extra body work for protection, sound suppression, spare tyre and rim, tool kit, vandalism protection, and wiper/washer for the rear window.

The Dispatch area is the most suitable area to initially implement CIM.REFLEX. This is the area where the final finish and reworking take place. Final finish involves the putting in of optional equipment and painting. Reworking involves bringing the vehicle up to new specifications. The Dispatch area is a key function within the plant. It both prepares the trucks for delivery (paint, optional extras, etc.), and acts as a final buffer for any remaining defects.
in the vehicles, before they reach the customer. The area has traditionally been a problem area. It often does not meet scheduling requirements and is viewed as a bottleneck. The length of time a vehicle will spend in this area is very variable, and almost impossible to determine in advance. The amount of manpower and physical space available is also limited. These problems combine to make scheduling very difficult. The area is a bottleneck because of the frequent requirement to rework vehicles from stock (fitting of optional extras) at short notice as well as handling current production.

4.2 DANFOSS STRECON© TECHNOLOGY

Strecon Technology©, an organisational unit within Danfoss, is the world-wide manufacturer of "pre-stressed containers" (Strecon©). Strecon© containers are used by other manufacturers to hold and support their tools used in cold-forging production. The business concept includes a patented technology (to pre-stress the containers) which makes the containers stronger than normal containers. Using the Strecon© products to hold a cold-forging tool gives a number of benefits compared with using a normal one. They include an extended die life, and allowing for higher cold-forging pressure, which enables the production of more advanced components. (The higher pressure is used to fill out smaller detailed parts of the die).

Strecon's© customers include many Danfoss "factories". But a number of customers are spread across the world - such as the automobile industry. The activities include development, design, production and sales of these products. Strecon© employs a total of 15 staff. So, Strecon© can be considered to be an SME (Small and Medium Sized Enterprise).

5 CONCLUSION

Although the project has only completed its first six months, a great deal has been achieved. REFLEX.CAPS is an available product and the multi-site/multi-user functionality is close to realisation. The functional design of REFLEX.COST and REFLEX.CONFIG is complete and detailed design and implementation using the DECIBAC expert system shell is under way. Initial system installations have been made at the two test sites.

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REFERENCES


