Successful Applications of AI in Manufacturing Industry

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1 Introduction

Over the past few years, manufacturing industry has exploited the use of AI technology, and in particular knowledge-based systems, throughout the manufacturing lifecycle. This has been motivated by the competitive challenge of improving quality while at the same time decreasing costs and reducing design and production time. Just-in-time manufacturing and simultaneous engineering have further required companies to focus on exploiting technology to improve manufacture planning and coordination, and on providing more intelligent processing in all aspects of manufacturing.

This paper looks at five examples of the use of this technology in various stages of the manufacturing lifecycle. In each case the goal is to improve quality, to reduce costs, and to speed up the design and manufacturing process. Three of these case studies have been selected recipients of the prestigious Innovative Applications of Artificial Intelligence award given to the best commercial AI successes each year.

2 Nippon Steel's Quality Design Expert System (QDES)

Nippon Steel is the largest steel supplier in the world. It constantly receives customer requests for new steel products varying in material, size, and shape. Although the number of new requests continually grows, the quality design experts are required to design in shorter and shorter times. To meet this challenge, Nippon Steel has built an expert system to help with the development of new high-quality steel products.

The principal technical approach of QDES is the use of 'case-based reasoning' to find a previous design that is most similar to a new customer request. The retrieved design is then customized to the particular needs of the new request. In addition to case-based reasoning, QDES uses hypothetical reasoning to explore various combinations of design features and find the best alternative. It also uses neural net technology to provide initial intuitive judgements on design feasibility, fuzzy logic for categorizing ambiguous knowledge, and learning to store new steel designs.

This ambitious system took 18 calendar months to build and involved 350 person-months of development. QDES consists of about 3,000 ART rules and about 500,000 lines of code. It has been deployed since May 1990 and has resulted in significant business benefits. QDES has reduced the design cycle time by 85% and has improved the accuracy of steel designs by 30%. This improvement in accuracy is attributed to the use of hypothetical reasoning to optimise the combinations of ingredients in the new material, thereby reducing the cost of the ingredients used.

The more QDES designs, the better the designs it produces, largely due to the learning and accumulation of new and better designs within its case base. QDES has also been used to provide training to new and novice designers. It serves as a resident expert, on hand 24 hours a day, 7 days a week.

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3 Ford's Technical Information Engineering System (TIES)

Product quality and design cycle time are two critical factors in achieving customer satisfaction and market share in the automotive industry. Ford Motor Company has successfully integrated these factors with knowledge-based system techniques to help improve its design time and product quality. TIES builds upon, and extends, a Japanese developed technique called Quality Function Deployment (QFD), a systematic method of ensuring that customer demands are accurately translated into appropriate technical requirements and actions.

TIES is a design tool and provides a framework for product and process design teams to collect and store relevant engineering information, experience, and knowledge. For example, TIES can analyse marketing information on customer preferences for a car's instrument panel and link it to the group responsible for designing the panel. The common framework allows separate groups to design components while maintaining consistency with designs of other groups.

The system provides a sophisticated graphical interface that relieves users from the formerly tedious and difficult process of manually creating, depicting and analysing the many kinds of objects and relationships involved in automobile design. Through various TIES operations of filtering, focusing and hierarchical decomposition, users can quickly examine the trade-offs between customer desires,technical solutions, and competitive factors at varying levels of detail.

Having been in production use since December 1989, Ford cites as benefits from using TIES: the system documents, preserves and distributes expert knowledge about design choices, engineering trade-offs and customer concerns; it provides consistency and coordination of vehicle development; it reduces development time for new vehicle programs; and it accelerates training of new engineers.

4 Trailer configurer

In the manufacture of semi-articulated lorry trailers, there are a great many possible variations on the basic parameters of body type, chassis and axles. One manufacturer found that these variations were not well understood by many of its sales force, and ambiguities and mistakes in the detail of orders was all to frequent. This caused delay to manufacturing, since problems were frequently not identified until the trailer was actually being built.

There may be nothing especially novel about using an expert system to configure a complex product, to ensure that an order both meets the needs of the customer and is correct from a technical standpoint. However, what is novel in this particular case is that the approach that was taken to configuring was also designed to assist manufacturing.

A typical configuration system leads the user through a sequence of choice making stages, from which the specification for a correctly configured product is produced. In the case of the trailer configurer, Inference effectively reversed this process. A 'standard' trailer is defined from the answers to a very few basic questions - typically only 5 questions are needed. The full specification of the 'standard' trailer is then displayed, at which point the customer is able to alter any aspect of the trailer's specification until completely satisfied. Throughout this second phase, the alterations are supervised by the configuring rules to insure that the changes being made are both valid and consistent with other options chosen.

As well as the obvious benefit of correctly configured orders, the initial step of offering a 'standard' configuration avoids a long sequence of questions before any tangible results appear. Then allowing the customer to alter any aspect of the specification enables him to order precisely the trailer he wants, even to experiment with alternatives. At the same time, it avoids wasting time over aspects of the specification that do not concern the particular customer, leaving the defaults of the standard trailer unchanged.

Once the customer is satisfied with the specification of the trailer, the system prints out the order form with the details of the order. The overall result is much quicker and more accurate specification of orders, with significantly less variation between orders being passed in to manufacturing.

5 Vibration Analysis in Rotating Machines

There are many manufacturing processes that operate 24 hours/day, 7 days/week, with periodic shutdowns for maintenance. Once such process in the food industry suffered from occasional breakdowns on three production critical hammer mills, disrupting production and with consequential damage resulting from the failures.

The UK's Industrial Noise and Vibration Centre were consulted and recommended that sophisticated vibration monitoring was the technique most likely to provide early detection of faults. This would enable maintenance to be scheduled and costly breakdowns avoided. A wide range of fault conditions can be diagnosed by an experienced vibration engineer by studying machine vibration signatures. The more sophisticated the monitoring and diagnosis, the earlier a wider range of faults can be detected.

To provide round the clock monitoring of the hammer mills, an expert system was developed that incorporated this specialised vibration engineering expertise. Transducers mounted on the hammer mills are connected to spectrum analysis hardware fitted inside a PC, with the analysis software being controlled by the expert system running on the PC.

The expert system is responsible for capturing vibration signatures using the built-in analyser, with different parameters being used for different machines and load conditions. The expert system processes the data using various analysis techniques to identify signature features associated with machine components. Sophisticated data validation checks are applied to protect the system from the effects of transients, transducer failure, etc. A combination of historical data and expertise stored within the system are used to provide a detailed diagnosis of any faults, and to make recommendations for maintenance. Fault information is presented in both text and graphic forms, and fault reports can be exported into a separate maintenance management system.

Use of an expert system means that the machine operators need have no knowledge at all of vibration measurement and analysis. Operationally, the system has demonstrated its worth with early diagnosis of several potentially very costly faults, including bearing faults, motor misalignment, and bearing lubrication problems.

6 Ford's Expert System for Claims Authorisation and Processing (ESCAPE)

Every night, Ford Motor Company in the US processes a large number of warranty claims submitted by dealerships. Each claim is a request from a Ford dealer for reimbursement of the cost of the parts and labour needed to repair a vehicle under warranty.

The processing of claims is handled by a suite of COBOL programs known as ACES (Automated Claims Entry System) which runs on an IBM 3090 mainframe. However, the maintenance of part of this existing warranty system became increasingly difficult, and the maintenance group had problems implementing changes in Ford's warranty policy with sufficient speed to respond to changing market needs.

Written using ART-IM, the ESCAPE expert system replaced the part of one of these existing COBOL programs that was concerned the validation of warranty claims. It verifies that the vehicle type, production date, mileage, parts and labour costs, and other data are appropriate for the warranty cover of the vehicle. Claims that fail to meet the appropriate criteria, for instance if the mileage is too high, are rejected with an appropriate message explaining why.

The ESCAPE went into production use in October 1989, and has been used nightly ever since for processing claims. Since it became operational, the maintenance of the validation program has been dramatically reduced due to the way that the ART-IM rules so closely mirror the arranty rules.

7 Summary

This paper has presented just five examples of the use of knowledge-based systems technology within various stages of the manufacturing process. It is to be anticipated that within another few years the more technically advanced companies will have produced sequences of expert systems to handle the full range of manufacturing tasks, from the initial concept development, to design, to process planning, to production and assembly, to distribution, and to maintenance.

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