Massey University
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A Distributed Shop Floor Control System Based on the Principles of Heterarchical Control and Multi Agent Paradigm

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Preface

In progressive firms, major efforts are underway to reduce the time to design, manufacture, and deliver products. The programs have a variety of objectives, from reducing lead-time to increasing product quality. The process of improvement starts with customer requirements, which in turn lead to customer-driven manufacturing, incorporating customer requirements more directly into the manufacturing processes. Forecasting customer requirements has not become any easier, in fact, just the contrary. The implication is clear: that if demands cannot be forecast, the manufacturing function must be designed to respond to these demands. To do this rapidly, more and more of the manufacturing decisions are being delegated to the factory floor. To paraphrase; the customer is saying what is to be made, the due date is now, and the work force is figuring out how to do it online. As the manufacturing world moves toward the "zero everything" vision of the future (zero inventory, zero set-up time, zero defects, zero waste), fundamental changes will take place in the factory. These changes will necessitate changes in manufacturing planning and control systems and particularly changes in planning and control on the shop floor level. This dissertation addresses the possible direction that some of these changes might take on the shop floor.

The starting preamble of this research is that forecasting in certain type of manufacturing systems is not possible. An example might be systems in which product orders arrive randomly, such as manufacturing facilities involved in production of replacement spare parts). Additionally, in many other manufacturing systems, forecasting generates results that are of a very low level of certainty. In many occasions they are practically useless, since they are applicable only for short time horizons. As an example, small-quantity batch manufacturing systems usually operate under conditions where frequent disturbances make this production unstable at all times. Therefore, addressing these systems, the main idea embodied in this dissertation could be expressed as follows: *"Instead of focusing efforts on how to improve the old, or develop new methods for controlling material flows in manufacturing systems, methods that are solely based on the main premise of predicting the future circumstances, this research takes another course. It considers an alternative approach – developing of manufacturing control mechanisms that are "more reactive" to the changes in the systems and "less dependant on prediction" of future events.*

It is believed that the modern job shop manufacturing facilities, such as mentioned above, can further increase their competitiveness by adopting approaches for shop floor control systems that are discussed in this research study. This is because the proposed system is capable, both dynamically and in real time, of promptly responding to frequent changes in production conditions, always attempting to find the best possible solution for given circumstances.

The embodied philosophy in this project for resolving computationally difficult and complex scheduling problems in manufacturing systems is not new. However, it introduces a concept and methodology that makes development of a distributed multi-agent system a reality. It does so by using common hardware, computer operating and network systems, and programming languages and technologies. A developed test-bed application that can run on theoretically unlimited number of computers connected into a local area network (LAN), demonstrates the work of distributed multi agent systems, and proves that such a system can be developed using common computer hardware and software technologies, in a very affordable, and inexpensive way.

This dissertation represents yet another effort in the vast research endeavour directed towards the building of competitive manufacturing facilities. If any part of this work is going to be used for these purposes in the future and serve as a small contribution to this endeavour, the author will consider this study successful.

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Abstract

This practically oriented research study concerns the design and implementation of the core part of a distributed heterarchical shop floor control (SFC) system based on the multi-agent paradigm. The system has been designed and developed with the primary aim of supporting production operations in discrete part manufacturing systems of a job-shop type. The "modus operandi" of the system is envisaged to be beneficial, and of a particular value, for job shop manufacturing systems that are characterised with:

- A large number of machine tools (manually operated or fully automated CNC machines);
- Low volume - high variety batch production (that is, in which products are fabricated in small quantities and many different product types); and
- Random arrival of production orders of different product types and quantities, (order rates, types, and sizes are not known in advance and are hard to predict).

A classical example of an appropriate manufacturing system is one that produces spare parts as single items or in small batches.

The project used multi-agent system theory and recent developments in software technology to solve the problems that concern modelling, design, development, and implementation of a proposed heterarchical SFC system. The project demonstrated (by using integrated simulation) how difficult and complex scheduling and resource allocation problems in job shop manufacturing systems could be successfully resolved in an on-line and real time manner.

Basic production and control units in the proposed approach were organised around workstations. Manufacturing operations inside workstations were simulated while the interaction among workstations (including communication and negotiation processes) was conducted in the same manner, as it would be in the real-life systems. These simulated activities as well as the "testing capabilities" of a workstation agent were integrated seamlessly into a single software package – a workstation agent. (The term "testing capabilities" refers to the feature that enables a user, for example, to capture a message that is sent to the workstation agent and then to postpone the message processing, to change the content of the message, or even to reject the entire message to see what effect this has on the total operation.)

The dissertation describes the structure for both the proposed manufacturing system resource model, which is based on *manufacturing workstations* as basic production units, and the heterarchical shop floor control system model, which is based on *workstation agents* as the basic control units. The heterarchical control system was demonstrated on a test-bed network application that was created with the objective of validating the concepts, and verifying the feasibility of the proposed concept. The dissertation outlines the main design aspects of the application (it describes basic modules of the production workstation agents) and describes the way in which the system operates, using an example of a simple workpart travelling through the system.