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Distributed and centralised material handling scheduling: Comparison and results of a simulation study ☆

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ABSTRACT

Part of a larger research that employs decentralized holonic modelling techniques in manufacturing planning and control, this work proposes a holonic-based material handling system and contrasts the centralized and distributed scheduling approaches for the allocation of material handling operations to the available system resources. To justify the use of the decentralized holonic approach and assess its performance compared to conventional scheduling systems, a series of evaluation tests and a simulation study are carried out. As illustrated by the results obtained from the simulation study, the decentralized holonic approach is capable of delivering competitive feasible solutions in, practically, real-time.

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1. Introduction

The increasing influence of global economy is changing the conventional approach to managing manufacturing companies. Real-time reaction to changes in shop-floor operations, quick and quality response in satisfying customer requests, and reconfigurability in both hardware equipment and software modules are already viewed as essential characteristics for next generation manufacturing systems. The decentralized modular architecture, the cooperation and coordination mechanisms, and the real-time response capabilities of holonic systems make them a viable solution to achieve the above-mentioned characteristics [1]. An overview of the literature in holonic manufacturing scheduling showed that there are several approaches for designing the mechanisms for cooperation and coordination among the entities in the holonic architecture.

Considering multiple manufacturing cells, Gou et al. [2] presented a coordination solution based on the pricing concept of market economy using a Lagrangian relaxation methodology with results reported as near-optimal in a timely fashion. Using a holonic decomposition framework for an entire supply chain, Walker et al. [3] developed a job-shop scheduling approach based on the formation of dynamic virtual clusters around a resource-scheduling dynamic mediator agent, the particular order and the potential resources to perform the order tasks. When compared to results given by scheduling heuristics and benchmark solutions, the holonic scheduling performance is encouraging. By combining evolutionary computation and dynamic programming, Sugimura et al. [4] proposed a real-time scheduling procedure to determine machining schedules through autonomous decision-making and cooperation among part holons and equipment holons. The solution provided a method to integrate process planning and scheduling system while providing both sequencing and scheduling of machines in the manufacturing system studied. A real-time control architecture viewed from the system, software, and functional architectures points of view is presented by Wang et al. [5,6], followed by an event driven real-time distributed control system developed via using a combination of intelligent agents and IEC 61499 function blocks.

This work is part of a larger research that employs decentralized holonic modelling techniques in manufacturing planning and control for the purpose of obtaining better system performance [7–11]. The main objective of the research so far, is to develop real-time feasible schedules for material handling (MH) resources working in stochastic manufacturing environments. Because of their rigid architecture, the existing MH systems are difficult to respond to the requirements set on future manufacturing. In this research, the holonic modelling framework is employed in the design of a decentralized control system used for scheduling MH operations in manufacturing cell environments. The designed Holonic-Material Handling System (H-MHS) uses specific internal holon evaluation and allocation procedures and inter-holon coordination mechanisms.

To justify the use of decentralized holonic approaches for manufacturing control and assess the performance of the H-MHS in comparison to conventional systems, a series of evaluation tests

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and a simulation study are carried out. Optimal and heuristic search algorithms that serve as the basis for the MH conventional control approach are developed for this purpose. Section 2 gives a brief description of the H-MHS and its operation, and contrasts the two scheduling approaches that are the subject of this study. Section 3 depicts the characteristics and the design of experiments for the simulation study, while Section 4 presents the results obtained from the software implementation of the scheduling and simulation algorithms. Finally, Section 5 provides the conclusions coming from this study and future research directions. The characteristics tested in the experimental part comprise: the quality of the solution delivered, the real-time scheduling ability, which includes the real-time response to changes in production orders. By comparing the results given by the two alternative system configurations, the performance of the proposed decentralized holonic system can be evaluated.

2. Holonic material handling system operation

The proposed holonic architecture, presented in Fig. 1, is formed by the physical MH resources all of them having their own control unit, called Material Handling Holons (MHH), a computing unit having a global perspective, called Global View Holon (GVH), and a System Monitor module having an associated Database (SMD). Software modules, in the form of Order Holons (OH), are assigned for each new order that enters the system.

2.1. Scheduling material handling operations

In manufacturing planning and control systems, once the schedule of processing operations is developed, to correctly find the total processing time of the orders released to the shop-floor, it is necessary to insert the MH operation times between processing operation times and recalculate the schedule make-span based on this new information. All the algorithms developed for the MH job evaluation, allocation and execution processes, and for the computation needs of the GVH take into consideration the precedence constraints of the jobs on each machine, the precedence constraints of the operations of each job, and the MH resource constraint, that states that, at each particular time, there should not be scheduled more MH operations than the number of available MH resources.

2.1.1. Decentralized holonic control approach

The holonic MH resource allocation process considers information exchanged among all the entities in the system. Except for the SMD module, all other software entities have internal evaluation algorithms embedded in their structure, based on which they make the allocation decisions corresponding to their functions in the decentralized architecture.

Due to the distributed decision-making existing in the system, the algorithms used for MH job evaluation and allocation are simple and not characterized by combinatorial explosiveness. Each MH resource allocation process has as output an individual schedule (IS) which is sent to the GVH by the active OH in the system. Using its system perspective, the GVH combines all the ISs received into a system level schedule (SLS) which is then distributed to all the entities in the architecture. No complex algorithm is required for obtaining this emergent schedule. From the algorithmic point of view, a common personal computer (PC) is powerful enough to handle the needs for any entity in the proposed H-MHS. These reactive scheduling mechanisms used for MH resource assignments only require re-arrangements of jobs along one dimension based on specific steps needed to be executed. The functions of the entities working in the holonic architecture related to the development of the global schedule are presented on both sides of Fig. 1. As shown from the figure, not only are there several types of entities involved in the decision-making process, but an individual decision type is also distributed among entities of the same category. A detailed description of the holonic decision-making process and the algorithms used by the holonic entities can be found in Refs. [7,8], respectively.

2.1.2. Conventional control approach

In the conventional control, or global scheduling approach, all possible combinations of MH resource assignments lead to a tree-search type of problem, for which optimal solving algorithms are usually accompanied by combinatorial explosion. The system is working using the centralized control approach in which the GVH acts as the central computer which makes all the decisions regarding the assignment of MH operations to the existing resources in the system. One optimal and three heuristic algorithms are developed for the scheduling needs of the GVH. A detailed description of the four algorithms can be found in Ref. [11]. The optimal algorithm, called Enhanced Best-First Search (EBFS) uses the best-first search technique coming from the artificial intelligence (AI) field presented by Russell and Norvig

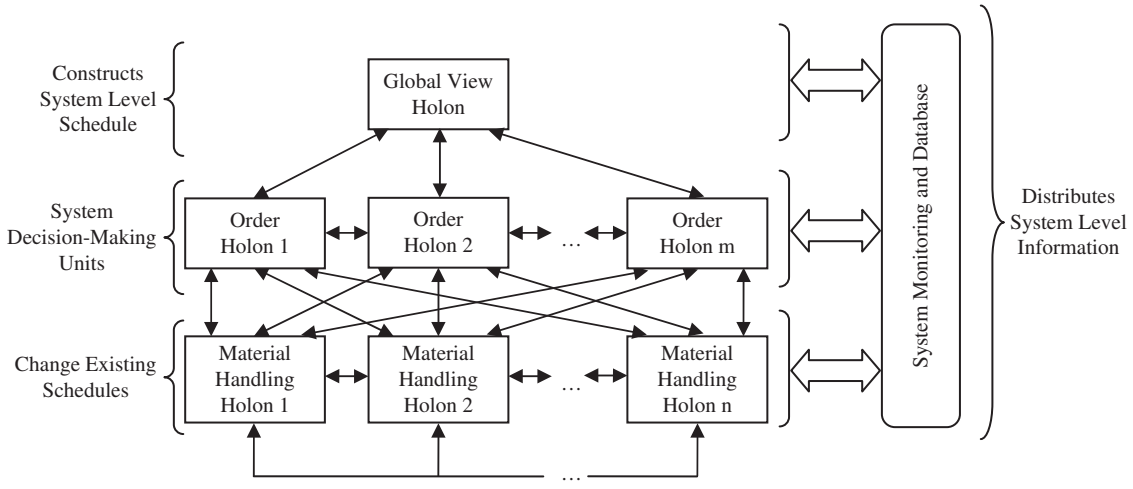

Fig. 1. Holonic-Material Handling System Architecture.

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