Design of Automatic Warehouse and Inventory control under HMS concept

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Abstract: The objective of this paper is to develop the flexible manufacturing system (FMS), which is cooperated with the automatic warehouse and inventory control under holonic manufacturing system (HMS). The HMS is a next wave of manufacturing revolution to deal with dynamic changing. The architecture of HMS is developed for cooperation system between the automatic warehouse agents and the manufacturing agents. This research applies the concept of HMS to develop a distributed control system for automatic warehouse and FMS by industrial network. The parts of prototype manufacturing agents consist of the conveyer system and 3-axises robot that provide the variety patterns in order to work as punch process. Each order of productions depends on the reorder points(RP) of inventory levels. The computation results indicate an improvement by comparing with traditional centralized control.

Keywords: Flexible manufacturing system, Automatic warehouse, holonic, Centralized control.

1. INTRODUCTION

Presently, computer integrated manufacturing systems with their relatively hard-wired interconnection of 'flexible' manufacturing cells, are already obsolescent and bell be gradually phasing out. The reasons relate to rapidly changing markets, smaller batch sizes, and increased demands for customization of products. To respond with these requirements, production facilities will need to become reconfigurable based on increasingly intelligent autonomous modules that interact dynamically [1], [2].

Arthur Koestler [3] describes the nature of complex systems, such as the human brain, societies, and living beings as a holon. Every holon has a dual tendency to preserve and assert its individuality as a quasi-autonomous whole; and to function as an integrated part of an (existing or evolving) larger whole. A polarity between self-assertive and integrative tendencies is inherent in the concept of hierarchic order and a universal characteristic of life. The self-assertive tendencies are the dynamic expression of the holon's wholeness, the integrative tendencies of its partness. These two type of tendencies correspond to two vital characteristics of a holon:

- Autonomy: The self-assertive tendencies give the holon the required stability to act autonomously in case of unpredictable circumstances. It enables the holon to handle contingencies without requiring constant assistance from higher levels.
- Co-operation: The integrative tendencies make holons co-operate together. It transforms the individual holons into effective components instead of loose entities of bigger wholes.

An analogous polarity is found in the interplay of cohesive and separative forces in the stable inorganic systems, from atoms to galaxies. Examples of integrative tendencies are cohesive forces in insect states, colonial animals, flocks of birds. Self-assertiveness expresses itself in competition, individualism, nationalism, etc.

In the manufacturing context, the use of NC-code for the programming of machines is an example of a self-assertive tendency. Standardisation efforts and years of experience as well on vendor's as on user's side make that using NC-code is similar to a 'fixed action pattern' in behavioral science. Other, more obvious examples are found where equipment vendors try to enforce their own proprietary standards and protocols upon the users. Integrative tendencies are often initiated by market demand (users), which require the integration of multi-vendor equipment in an efficient bigger whole. For example, at this moment almost every NC machine has an Ethernet connection, next to the traditional RS232 connection, to allow easier/faster communication with a host computer.

It is interesting to note that this concept corresponds well to the theory of holonic systems, as developed by

Koestler [3]. He defined the word `holon', as a combination of the Greek word `holos' (that means whole) and the suffix *-on*, suggesting a particle or part, because of the following observations. First, he noticed that complex adaptive systems will evolve from simple systems much more rapidly if there are stable intermediate forms than if there are not; the resulting complex systems in the former case will be hierarchic. Secondly, while Koestler was analyzing hierarchies and stable intermediate forms in living organisms and social organization, he noticed that although it is easy to identify sub-wholes or parts –`wholes' and `parts' in an absolute sense do not exist anywhere. This made Koestler propose the word holon to describe the hybrid nature of sub-wholes/parts in real-life systems; holons simultaneously are self-contained wholes to their subordinated parts, and dependent parts when seen from the inverse direction. The sub-wholes/holons are autonomous self-reliant units, which have a degree of independence and handle contingencies without asking higher authorities for instructions. Simultaneously, holons are subject to control from (multiple) higher authorities. The first property ensures that holons are stable forms, which survive disturbances. The latter property signifies that they are intermediate forms, which provide the proper functionality for the bigger whole. Applying these concepts to manufacturing, a holonic control architecture is to comply with the concept of hierarchy in distributed systems [8].

This paper proposes the development of distributed control system for FMS and automatic warehouse on the CIM system using the HMS architecture. The HMS efficiency can improve the process management such a Just-In-Time System that has more important in industries nowadays. The computation results indicate an improvement by comparing with traditional centralized control.

2. HOLONIC MANUFACTURING SYSTEMS

Inspiration of by Koestler's concepts, a new research initiative for advanced manufacturing systems has emerged: HMS, Holonic Manufacturing Systems is the new term used to indicate research activities which are based on Koestler's observations. HMS is now known in manufacturing research laboratories all over the world that its paradigm is developed within the overall framework of the international Intelligent Manufacturing Systems (IMS) programme [4]. The goal of

IMS is the creation of a manufacturing science that can meet the needs of the next century.

The goal is to attain in manufacturing the benefits that holonic organization provides to living organisms and societies, i.e., stability in facing disturbances, adaptability and flexibility in facing changes, and efficient use of available resources. The new paradigm combines the natural concepts of hierarchical systems and the integration of autonomous elements in distributed systems. Whereas the architecture of conventional manufacturing systems are modelled along hierarchical lines with command-obey relationships, the HMS architecture is modelled using whole-part relationships.

The concepts of Koestler are developed for social organizations and living organisms into a set of appropriate concepts for manufacturing industries. Seidel and Mey [5] determines some definitions for a wide range of terminology to help understand and guide the translation of holonic concepts into a manufacturing setting. The key definitions consist of:

- **Holon**: An autonomous and co-operative building block of a manufacturing system for transforming, transporting, storing and/or validating information and physical objects. The holon consists of an information processing part and often a physical processing part. A holon can be part of another holon.
- **Autonomy**: The capability of an entity to create and control the execution of its own plans and/or strategies.
- **Co-operation**: A process whereby a set of entities develops mutually acceptable plans and executes these plans.
- **Holarchy**: A system of holons that can co-operate to achieve a goal or objective. The holarchy defines the basic rules for co-operation of the holons and thereby limits their autonomy.

The HMS integrates the entire range of production activities from order booking through design, manufacturing, and marketing to realize the agile manufacturing enterprise. It is organized as a holarchy, which defines the basic rules for co-operation of the holons and thereby limits their autonomy. Such holonic manufacturing system is, however, not organized in a fixed way, but organizes itself dynamically to meet its goals, and adapts itself to changes in its environment or itself. Thus it can also organize itself in temporary hierarchies [6].

3. INVENTORY CONTROL SYSTEMS

Almost of the realistic inventory situations does not exist certainly. There are two factors: demand and lead-time, usually fluctuate and cannot be completely predicted. In situations, these factors are relatively constant and known the earlier inventory models that will provide us an optimal solution. The assumption regarding the economic order quantities is not applicable to all inventory situations. Demand or usage of items can be greater or lesser than anticipated due to external and internal factors. Also, the acquisition lead-time can vary from favorable to unfavorable due to the supplier and /or transshipment difficulties [7]. The optimal solutions of inventory control aim to reduce backlog and lead-time as well as keeping materials enough for usage. The propose method can reduce operating time and lead-time by using the cooperative and autonomy under HMS concept.

4. CENTRALIZED CONTROL SYSTEM

Typically, a centralized control is the traditional hierarchical structure as we known in the given name "CIM or Computer Integrated Manufacturing System". The paradigm of CIM system structure is a Client-Server structure as shown in Fig. 1 (Business Management System, Production management, FMC, host computer and PLC network etc.) that the computers are linked together through an Ethernet Local Area Network and Internet gateway. The automatic warehouse system is used as the center of the distribution in the plant and inventory management system.

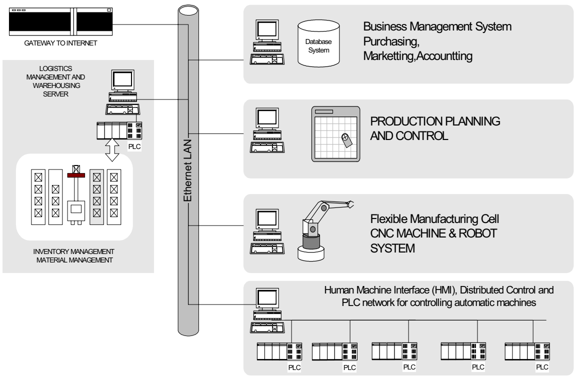


Fig. 1 CIM system structure.

In this paper, we focus on the interaction between automatic warehouse and flexible manufacturing cell by local area network. The cooperative procedure of hierarchy is only vertical interaction. The behavior likes a master and slave as shows in Fig.2.

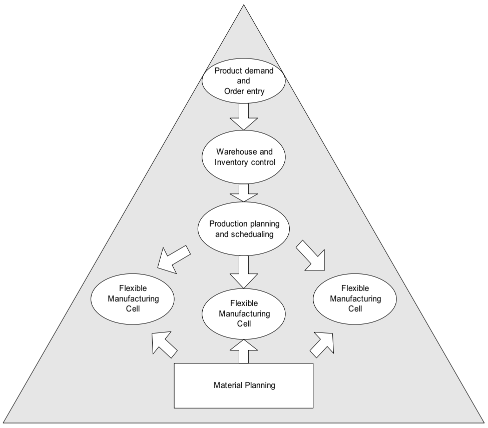


Fig. 2 Hierarchical control.

The hierarchical control is fixed structure that high efficiency and suitable for the mass production system; however, it cannot be re-configuration and it is difficult to re-scheduling when one part of manufacturing has failed.

5. HOLONIC CONTROL SYSTEM

Holonic control system approach whereby entities are provided with a degree of autonomy but are readily integrated with the rest of the operations through co-operative mechanisms [8]. One of the basic elements of the holonic manufacturing paradigm [9] is the incorporation of hierarchy in distributed systems to combine reactivity to disturbances with a high and predictable level of performance. As such, it claims to blend the best of both hierarchical and heterarchical control while avoiding their drawbacks.

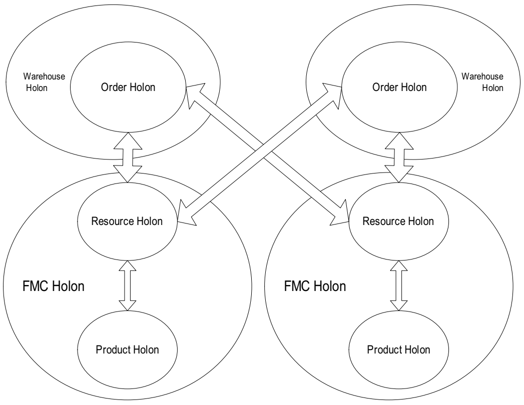


Fig.3 Interaction between basic holon.

5.1 Hierarchical control systems

The natural perception of hierarchy in the structure of complex systems is the motivation to build hierarchical control structures. A typical hierarchical control architecture contains several control modules arranged in a pyramidal structure, where each distinct level has its own purpose and function as seen in Fig. 2. The established hierarchy is used as the basis for structuring the system, as well as for controlling the system. In a hierarchical control system, the flow of commands is typically top-down, and the flow of feedback information bottom-up. The relationships between the modules are limited to master-slave relationships between parent and child nodes in a tree shaped hierarchy. Breaking down commands into subcommands for subordinates is often based both on technological (process oriented) and logistical considerations. More recently, the hierarchical control architecture has been improved in several ways, leading to modify hierarchical or distributed co-ordination/control architectures (Fig. 3).

There are many researchers, who design the architecture of holonic manufacturing system. In this paper, we interested the PROSA (Product Resource Order Staff Architecture) reference architecture, which was developed by Jo Wyns [10]. The PROSA reference architecture in holonic manufacturing system, describes three types of basic holons, which consist of product, resource, and order.

The resource holon consists of many parts: a physical part, a production resource in the HMS, and an information processing part that controls the resource. This paper given the physical FMS be conveyer system, robot arm system and its control system.

The product holon consists of the product knowledge and the manufacturing process, which provide to ensure the correct operation with sufficient quality. This holon contains the knowledge of the capacity of FMC.

The order holon represents a manufacturing order from inventory system when the product inventory is on the re-order level. This holon specifies the type of product (type A, type B, type C, type D) and quantity order.

The staff holon is optional holon to provide functionality that typically found in higher levels of hierarchical system. This holon provides advice but does not enforce its decisions to the other holons.

5.2 Distributed system

In a distributed co-ordination or control architecture [11], the strict master-slave relationships between supervisory and subordinate modules are relaxed to more interactive forms of co-ordination. Such forms are common, for example, within process industry control solutions where centralized control can be often impractical due to either the complexity of the individual units being controlled or the delays introduced by the physical separation of operations. Modified hierarchical architectures [12] also allow peer-to-peer communication between machine units. By this way, the lower levels can exchange data, better synchronize their progress, or react on specific disturbances.

To combine robustness against disturbances and unforeseen changes with performance optimization and predictability, we propose the incorporation of hierarchy in a distributed control system. The resulting control architecture has a basic structure of autonomous co-operating local agents, which are capable of negotiation with each other in order to achieve production targets (similar to heterarchical control). That basic structure is extended with central agents (for instance a scheduler agent) to co-ordinate the behavior of the local agents as seen in Fig. 4.

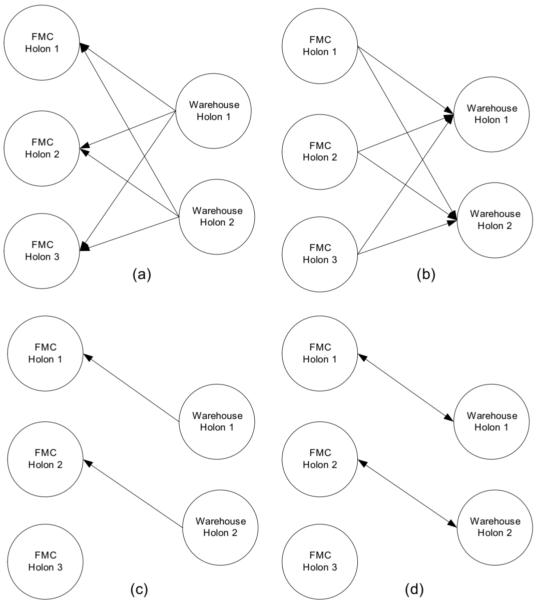


Fig. 4 Contract net protocol.

The process negotiation was developed by many protocols [7]; however, Contract Net Protocol is often employed. In this schem, the order holon concerns with the inventory level on the automatic warehouse database system, when the inventory level is on the re-order level state then the automatic warehouse control system will generate task for manufacturing process as follow in Fig 4a. All FMC holons cooperate to provide services. The information from order holon contains product type, amount for manufacturing, task time and priority. The cooperation of FMC holons provides to check their capacity of basic holon (resource holon and product holon) as bidding process: Fig.4b. The FMC holon that wins the bidding is the holon to manufacture. The tasks and contracts of the order holon are illustrated in Fig.4c and Fig.4d respectively.

6. COMPUTATIONAL RESULTS

The part of manufacturing process consists of the conveyer system and 3-axis robot has the variety patterns in order to work as the punch process that the process system is used to test the proposed scheme illustrating in Fig. 5. The system controller uses 2 PLCs that communicates by identify sensor--

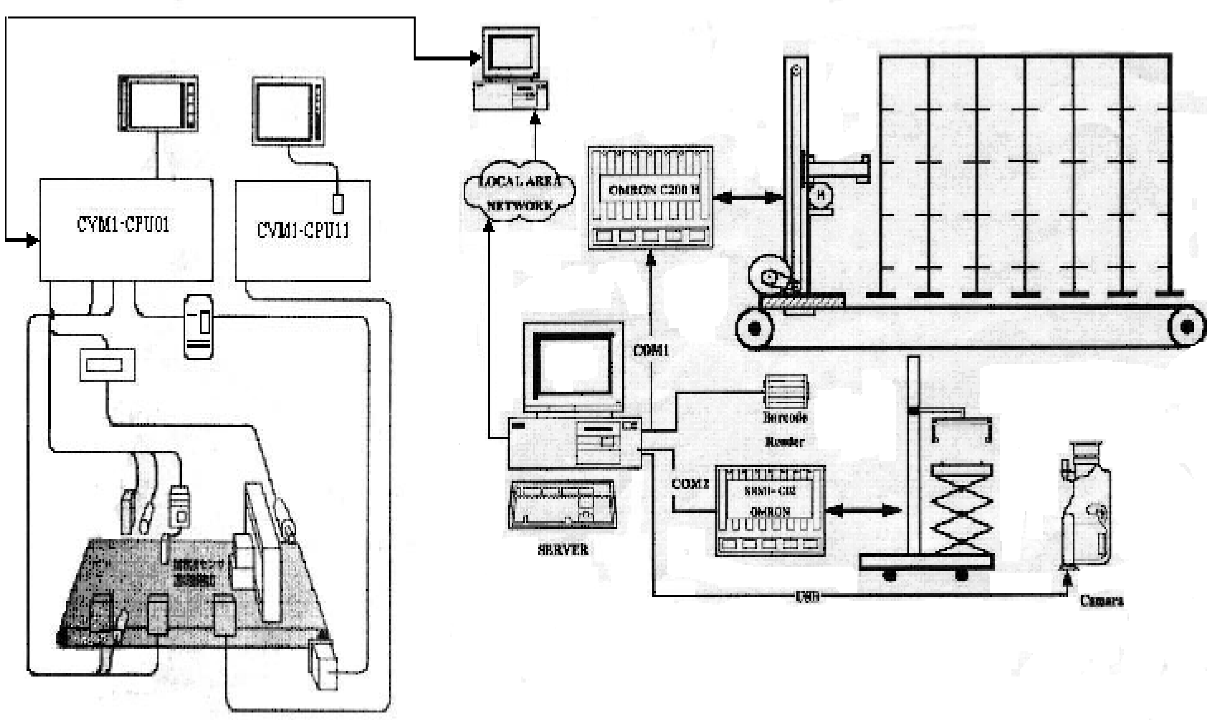


Fig. 5 The prototype of hardware structure.

with a magnetic data carrier. Moreover, FMS has developed to communicate with the automatic warehouse through local area network (LAN).

FMS in Fig. 5 can manufacture with 3 patterns of product. Each of patterns uses different time in each task that is pattern A uses the time 15 sec, pattern B uses the time 20 sec and pattern C uses the time 15 sec.

Supposedly, we have three FMSs that locate in the different areas. Therefore, the transportation time is different also. We assume the transportation time, which provides to communicate between the warehouse system and FMS that is 500 sec. for FMS1, 1000 sec. for FMS2 and 1500 sec. for FMS3. The total operating time for each task can be calculated as the following equation.

$$Ts = Tr + Tm \qquad (1)$$

Where

Ts: total service time
Tr: transportation time
Tm: manufacturing time

The total service time of FMS for each route can be classified in table1.

Table 1 The total service time of FMS.

Product type	FMS		
	1	2	3
Product A	515	1015	1515
Product B	520	1020	1520
Product C	515	1015	1515

Generally, the traditional centralize control system must be assigned the production planning and scheduling to provide the task assignment. The task scheduling can be optimized by assignment models in order to find the values of product for each FMS, which minimize the total time as the following equation.

$$\text{Minimize Total time} \quad T = T_{ij}X_{ij} \qquad (2)$$

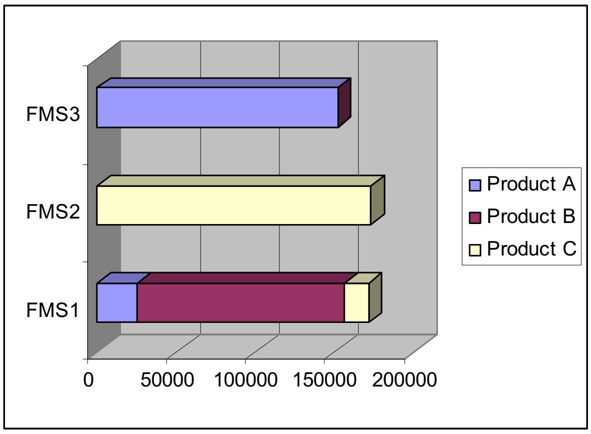
Where

i : product type A,B and C
j : FMS1,2 and 3
T : time
X : amount of product to manufacture

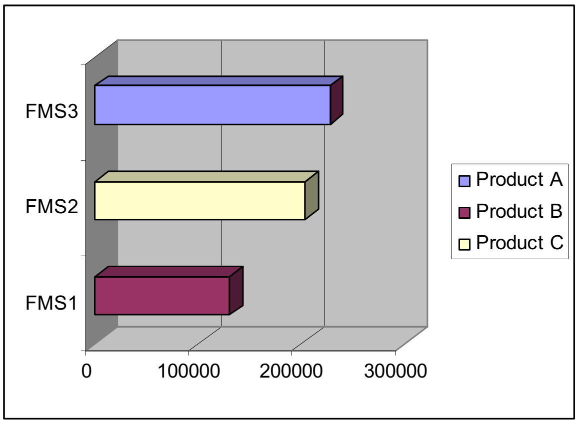
Assume, the time requirements to produce are: 150 for product A, 250 for product B and 200 for product C. The optimal solution of each FMSs is: FMS1 manufactures product B using 250 sec., FMS2 manufactures product C using 200 sec., FMS3 manufactures product A using 150 sec. and earliest total time are 227250 sec.

The disadvantage of traditional centralized system is difficult to rescheduling or reconfigurable. According to the computation results as seen in the figure 6(b), which the FMS1 have finished the process then it is idle although it can operate for the other tasks. In the holonic manufacturing system, each of FMSs will be communicated in horizontal; thus, they can form the cooperation and autonomy of operations that can be able to program on the programmable controller. The computation resource for the holonic manufacturing system is shown as the figure 6(a).

For the HMS production, the FMS1 manufactures product B using 250 sec., product A using 50 sec., and product C using 30 sec.; the FMS2 manufactures product C using 170 sec., FMS3 manufactures product A using 100 sec., and earliest total time are 172550 sec.



(a) Computational results of HMS.



(b) Computational results of the traditional system.

Fig. 6 Illustrating the computational results of the production process.

7. CONCLUSIONS

The automated warehouse and inventory control system by using holonic manufacturing system can combine the automatic machines in the flexible manufacturing systems together with the computer networks and the information technologies. The computation results was compared in the earliest total times between traditional centralized control system and holonic manufacturing system, which the comparison results were shown the HMS reducing the total task time of the system. In this article the operations and control of automation systems can be reducing mistake, manufacturing lead-time, and increasing performance as well as increasing the efficiency of production systems. Especially, the proposed system we aim to reduce the ordering costs, setup costs and also lead-time, which is effected to reduce the holding costs. This conceptual design of HMS suitable to support the JIT (Just-In-Times) system, Supply chains, and logistic management that has more important role for changing in industries.

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