Abstract:
HMS have emerged as an approach towards FMS to respond to the erratic market trends and consumer demands. To implement HMS, in control systems, is the Holonic Component Based Architecture (HCBA). It is a combined form of Component Based Development (CBD) and HMS. CBD is basically a programming approach in which a problem is solved by a solution that consists of many modules instead of a monolithic module. It very close to OOP, but is an improvement over it. This paper explains the approach of HMS and the concept of Holonic Component Based Architecture. Some variations have also been proposed in the existing structure of HCBA. Merits and de-merits of HMS in the present scenario have been discussed.

Keywords: HMS, FMS, HCBA, CBD, holon, OOP, holarchy

1. Introduction
The HMS combines the best features of a hierarchical and a heterarchical organizational structure as the situation dictates. This concept can preserve the stability of hierarchy while providing the dynamic flexibility of heterarchies. The idea “holon” is credited to Koestler, who examined hierarchical behavior within social and biological systems. He noted that complex situations or tasks can often be broken into a number of reasonably self contained subtasks, which in turn could be broken into further sub tasks, defining a complex functional hierarchy. He observed that these sub-elements followed the so called Janus Principle, whereby the element is at once both a co-operating sub-element contributing to a larger task and a relatively autonomous element achieving its own sub-goal.

2. Basic terms used in HMS

Holon: A Holon is an autonomous and cooperative building block of a system which interprets, executes & passes the information to the next level of operation.

Autonomy: The capability of an entity to strategize, plan and execute its tasks.

Cooperation: A process whereby a set of entities develops mutually acceptable plans and executes these plans.

Holarchy: A system of holons that can cooperate to achieve a goal or objective. Holonic Attributes: The attributes of an entity that make it a Holon. The minimum set is autonomy and cooperativeness.

3. Architecture of HMS

The basic architecture of a HMS consists of three types on holons, which are ordered out object oriented concepts like aggregation.

A Product Holon holds the product and process knowledge to ensure the correct fabrication of the product with correct quality. It works as a source of information to the other kinds of holons keeping them updated with information of product lifecycle user requirements, process plan etc.

A Resource Holon consists of a physical part, namely a production resource in the HMS and of an information processing part that controls the resource. It offers production capacity and functionality to the surrounding holons. It holds the methods to allocate the production resources and the knowledge and procedures to organize, use and control these production resources to drive production. An Order Holon epitomizes a manufacturing order and is responsible for performing the work correctly and on time.

4. Working of HMS system

Assume the use of a heterarchial control approach, products holons are created based on real or forecasted market demand. These product holons determine themselves how the product can be produced on the set of resource holons. They maintain all technical information needed for the fabrication of an instance of the product. When an order holon arrives in a system, it will first discover what it needs via the respective product holons. The order holon will negotiate with all relevant resource holons to have itself produced by them. As such, the order holon takes care of the logistical aspects.
The main contribution of this basic control architecture is to get everything manufactured in the face of disturbances. The exact mechanism of how a defect is diagnosed and dealt with, is adopted in working of HCBA as well, and will be discussed later.

5. HOLONIC COMPONENT BASED ARCHITECTURE (HCBA)

HCBA is basically, manufacturing control architecture, for a shop floor. Component Based Development (CBD) provides guidelines for HCBA when constructing a reconfigurable structure from the basic building block, and HMS identifies defines the attributes of those building blocks.

Component Based Development (CBD) focuses on the reusability and reconfigurability rather than the individual software modules. The concept of CBD is compared to Integrated circuits (IC), as it develops, packages software components for later use, just as the hardware components are packaged in an IC.

System Components of HCBA architecture are simply based upon HMS. resource holons, product holons and order holons all of these have a morphological, visible part and an invisible control part. Both parts are represented by software modules in the architecture.

5.1 Structure of HCBA

Due to the characteristics of the CBD and HMS, the HCBA code is also highly distributed. A pool of resource modules can be supplied by the equipment designers/machine providers. These components or modules have an analogy with their associated physical part in the factory. This stage is also called ‘static integration’ because there is no interaction among the holons at this stage. A new resource Holon can be added or removed at this stage without producing any effect. Similarly Product holons (software modules) can be supplied by the design department and the order Holon by the customers. These holons when start interacting, the stage is called ‘dynamic integration’. Once an order is processed again the state of static integration returns.

Fig. 1: working of HMS

Comparing the structure of HCBA to traditional hierarchal structure (Fig. 2), the traditional structure is comprised of different levels. The machine level performs real time control; the cell level performs execution and monitoring functions and the factory level performs planning and scheduling tasks. Devices like PLC networks for communication connect these levels to each other. Each level is supposed to be centralized and horizontally integrated.

In HCBA, each Holon represents a resource or a product or an order. It contains the control part and the physical part both within itself. So a traditional module for planning and scheduling (CIM etc.) does not exist in HCBA.

5.2 Operation of HCBA

The coordinator component of a product Holon (Fig. 3) coordinates this system, waiting for manufacturing orders. The coordinator manages the group behavior of each batch, while the WIP agent is product specific. The WIP agent negotiates with the resource holons in three ways:

Fig. 2: traditional manufacturing vs HCBA
1.) The agent sends request to the concerned resource Holon after each process, and waits for its approval

2.) The agent sends its request to all concerned resource holons and waits for their bid. It goes for the most suitable option then.

3.) The agent will send its request to all the resource holons, task by task, and will receive the bid of all resources before finally going with the most appropriate.

After the end of all negotiations i.e., once the product is guided through the chain, each WIP agent obtains an execution table. This table is a specification for the dynamic and virtual manufacturing line that was created when the product was being operated. Each agent has a different execution table due to different conditions of each physical part and its arrival time. The tables can be used for troubleshooting later. On the other hand, during the process, the resource holons also try to optimize their utilization according to the data in their control part.

5.3 Diagnostic Nature

The holons act in a cooperative manner and hence they can report their errors to other concerned holons. A few examples are discussed below to interpret the diagnostic mechanism:

1.) If an error occurs within a machine: The resource Holon sends the error information to the product holons and the WIP agent changes its path accordingly. The execution table has the record of the error and it can later be analyzed.

2.) A defect is found in a product Holon: The fault can be accesses directly from the WIP execution table or the associated resource holons which will be conveyed by the product Holon, of its error. The product Holon also sends the resource of previous operations (which may have caused the error) its error report, so they can analyze their own actions. Also, the resource holons ahead can request human intervention or skip its task itself (as programmed) instead of working on a faulty product.

6. Variations in structure of HCBA and their implementation in an assembly line

A few variations in the existing structure of HCBA have been proposed here. Some of the variations are specific to assembly line usage, but on the whole we have tried to give the existing structure a better managing and diagnostic capability. As seen in Fig. 4, an assembly line is a progression of operations, but the sequence of operations is not easy to change, the reason being, the bulky equipments and the rare need to change the sequence. The variations along with the implementation will be explained in the following points.

1.) There is no need for static and dynamic integration as there is no rearranging of resource holons. The process that has to be performed for the required flexibility is only skipping and inclusion of operations. For example in Fig 4, the operation sequence can be ABC, AC, BC and so on. This can be useful in production of different car engines from same assembly line, for all of them have almost same sequence of operations. This change would make the coordinator component work faster, as there would be no dissolving of chain after each task.
2.) The WIP agent gives feedback to resource holons, so that they may configure themselves for the process. For example if a process AC is to be conducted (Fig. 4), the resource for operation B, will perform accordingly. To explain, if B is a heating element it will move away from the line, or if it is a micro driller, it will stop. The physical actions will be made possible by d/a converters and PLC’s etc.

3.) Specifications of resources (physical specifications, like the wattage of a motor) should depend on the probability of it being used and the time it takes to complete its action on one WIP agent. According to the figure the characteristic of resource A, will be a function of \( \pi i \).

Also we propose that the number of units of resource (machine), for each operation, is the function of \( \pi i * T i \), subject to real world constrains like cost and availability.

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\text{i.e., Number of units of resource holon } = f(\pi i, T i),
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where:

\( \pi i \) – The probability of i’th resource being used in different operations.

\( T i \) – The time taken by i’th resource to complete action on one agent.

For example if a resource has a high probability of being used, the mechanisms governing it should be more robust, or if a resource takes too much time to perform a task its numbers can be increased to give WIP agents quick routes and eliminate queuing.

4.) The presence of a **recorder Holon** is seen in Fig. 4. This Holon interacts with each WIP agent and stores its execution table. This means it has the record of all the tasks performed in detail. This holon also has the capability to analyze this data. Basically this Holon monitors the system, and increases its diagnostic capability. The defects are analyzed after a fixed interval fixed by the program and the operators are notified of the problems, along with the possible solutions.

7. MERITS AND DEMERITS OF HOLONIC MANUFACTURING SYSTEMS IN THE PRESENT SCENARIO

1.) Holonic manufacturing shall address the problem of rising costs for the development and maintenance of complex software. It shall avoid the rigidity of hierarchical systems and shall fully support the system evolution to comply with changing requirements (e.g. new products, new or evolving technologies, unpredictable demands). Reuse of components shall reduce development costs and improve software quality. Consequently, reconfigurability of the HMS is an important aspect.

2.) To make a system self-configuring, learning and self-organizing is not a mean task and the increased flexibility, resulting from an agile and reconfigurable manufacturing system, may put a high load on the system operators. The holons in a HMS shall assist the operator to control the system. Holons shall autonomously select appropriate parameters settings, find their own strategies and build their own structure.

3.) Holonic manufacturing shall preserve a place for the human in the system, since he/she is the most flexible, and intelligent component in the system.

4.) Holonic manufacturing systems shall combine the high and predictable performance promised by hierarchical systems with the robustness against disturbances and the agility of heterarchical systems.

5.) The application of Holonic Manufacturing Systems with HCBA requires advanced control systems with a sound software end. So it requires a high initial investment.

6.) Due to the reason stated above, HMS may not be suitable for small and medium scale industries, and so, it may not gain much relevance, in India, in near future.

8. REFERENCES

