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A Knowledge Based Distributed Control Architecture (KBDCA) in Flexible Manufacturing System

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Abstract

In this paper, we present Knowledge Based Distributed Control Architecture (KBDCA) for the real time controlling of Flexible manufacturing system with multi cells. The proposed architecture integrates the hierarchical and heterarchical control architecture to provide the local information for rapid control and information globalization for supervisory control. The prominent literature review provides an insight the use of knowledge base with the controller to make the decision easily. The proposed distributed control architecture makes the system more responsive and robust to the changes of real world FMS and it also gleans the exquisiteness of knowledge base simultaneously.

Key words: *Flexible Manufacturing System, Control Architecture, Knowledge Base, Knowledge Based Distributed Control Architecture*

1. Introduction:

Owing to the globalization of the market, increasing demands of the customized products and rapidly changing needs of customers, the manufacturers are facing a problem of customer satisfaction and survival in the market among the various competitors. Therefore, they are searching such a manufacturing system, which fulfill the demand of the market within due dates and it should be available on lower cost. Thus, they can continue to exist in the global market. Among all the existing manufacturing system, they require a manufacturing system, which is having the flexibility to make the customized product with medium volume. Therefore, they are allured to the flexible manufacturing system (FMS), which is a compromise between job shop manufacturing system and batch manufacturing system. Flexible manufacturing system is the system, which is equipped with the several computer-controlled machines, having the facility of automatic changing of tools and parts. The machines are interconnected by Automatic Guided Vehicles (AGVs), pallets and several storage buffers. These components are connected and governed by computer using the local area network. The exquisiteness of this system is that it gleaned the ideas both from the flow shop and batch shop manufacturing system. The prominent literature has the several definitions of the flexible manufacturing system which is given by the many a researchers like Carlson (1989), Upton (1994), Wadhwa and Aggarwal (2000) Wadhwa et al. (2005) etc. Wadhwa and Rao (2000) have defined the flexibility as the ability to deal with change by judiciously providing and exploiting controllable options dynamically. Due to the inherent complexity of flexible manufacturing systems (FMSs) and rapidly changing production environment (tools and technology), the controlling of FMS is a Himalayan task at the cell level or in the operating state. Therefore to run the system efficiently, the judicious combination of flexibility and information based real time control is crucial (Wadhwa et al. 1997). For an FMS controller, it is very difficult to make the decisions which are not systematize, because of dynamism of the system and unexpected production disruptions. The aspect of real time decision making and control of system is always neglected in the design of the control command framework of manufacturing systems (Tawegoum et.al., 1995). There are two types of distributed control architecture (Hierarchical and Heterarchical) regularly used by many a researchers (Bongaerts et. al., 2000; Maione and Naso, 2003; Leitao and Restivo, 2008).

In the hierarchical control architecture, the decision making has been done by the supervisory controller whereas each controller is in-charge of controlling the good execution of the decision based on the local information available in the heterarchical control architecture. The researchers are also motivated to develop the classical control architectures with some new philosophy to overcome the intricacy of real time decision making by the controllers. Taking this into the consideration, in the present paper, a Knowledge Based Distributed Control Architecture (KBDCA) for FMS controlling has been proposed. The novelty of the proposed architecture is that it gleans the ideas both from the hierarchical and heterarchical architecture (vertical and horizontal information flow) for distributed control of FMS. In KBDCA, the partial autonomy is used for fast decision making and the hierarchy is embedded to avoid some contradictions in decision making by controllers of the same level. The KBDCA leads to fast and coherent decision making concerning the real time execution of the operations with the aim of achieving production goals.

The remainder of the paper has been arranged in the following manner: the distributed control of FMS has been described in section 2 while section 3 presents the background of knowledge management. The proposed distributed control architecture of FMS has been delineated in section 4. The paper has been concluded in section 5.

2. Distributed Control of FMS

Today’s Flexible Manufacturing Systems (FMSs) have become extremely complex and difficult to control. Therefore a ‘control system’ may be designed as a loop that enables a system or a process to be controlled through sensors and actuators. This control system paradigm creating a loop is controlled by a single centralized controller which consequently be implemented to control the FMS (Baker, 1998). Single central factory controllers are incapable to deal with the complex nature of flexible manufacturing systems which includes data management, uncertainty related to demand and resource accessibility, information delay along with real-time constraints. Researchers resolved the associated problems of such centralized controllers by distributing decisional capabilities to various decisional entities within a system, moving towards non-centralized control systems (Bongaerts, L. et.al. 2000, Bussmann, S., and Schild, K., 2001, Takahashi, K., and Nakamura, N., 2002). Distribution of decisional capabilities in a system evolved in a new paradigm called distributed control system. Distributed control is defined as the division of a global control process into various decisional sub-activities that are assigned to sub-systems; these are known as decisional entities. Decisional entities cumulatively support a decision process by initiating a triggering activity. This triggering activity is estimated by the distance between desired control objectives and present state of the system. Consequently the objective of decentralized control is to resolve the centralized control or global control in to local control activities.

2.1 Hierarchical and Heterarchical Approaches

The initial approach of distributed control was fully hierarchical and derived by resolving the global control problem into hierarchy based sub-problems. Decreasing hierarchical levels like strategic, tactic and operational were assigned to dependent decisional entities resulting in to a Master/Slave behavior (figure 1(A)). These decisional entities were permitted to have long term optimization (global optimality) rather than to have short term optimization (e.g. agility, reactivity). The term ‘‘distributed’’ in hierarchical approach is sometimes used to refer the distribution of resources (Chung, S.H., et.al. 2009).

After two decades of the evolution of hierarchical control, other kind of distribution, particularly based on the distribution of control decision was developed. This approach was adopted due to the rising need for local reactivity. The key rationale behind this new approach was that, in hierarchical control, the time spent to find and inform the upper level controller (upward), to decide and apply the decision (downward) cannot be ignored. The new scheme was designed to assign more autonomy by providing real decision control powers at local level and therefore by the use of real time cooperative control of systems, the delay in taking decisions was completely removed. This approach was distributed, cooperative and heterachical in nature (figure 1 (B)).

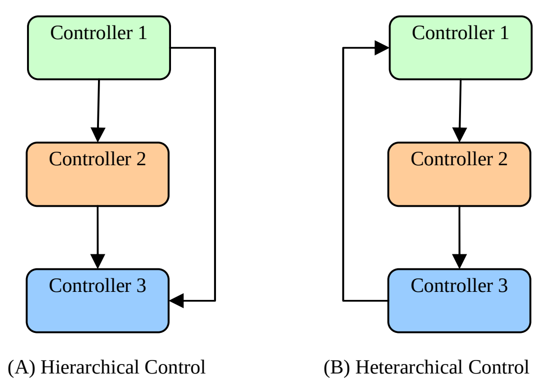

Figure1. Digraph representations of FM cell controllers

3. Background of KM

As Francis Bacon said, “Knowledge is power”. According to Nonka (1994), Knowledge has been defined as ‘‘justified true belief’’ that increases an organization’s capacity for effective action. It has two dimensions: explicit and tacit knowledge. Davenport and Prusak (1998) define knowledge as a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. Knowledge Management (KM) provides processes to capture a part of tactic knowledge through informal methods and pointers and fairly high percentage of explicit knowledge, reducing the loss of organizational knowledge (Nonaka and Takeuchi, 1995).

“KM is the formalization of and access to experience, knowledge and expertise that create new capabilities, enable superior performance, encourage innovation and enhance customer value” (Beckman, 1997). According to Taiwana (2000), Knowledge Management is the ability to create and retain greater value from core business competencies. Whereas, Tiwana and Balasubramanyam (2001) feels that knowledge management addresses business problems particular to business- whether it’s creating and delivering innovative products or services or managing and enhancing relationship with existing and new customers, partners, and suppliers, or administrating and improving work practices and processes. Nietok (2003) examines that knowledge has a connotation of ‘potential for action ’and is different from information in terms of its more immediate link with performance.

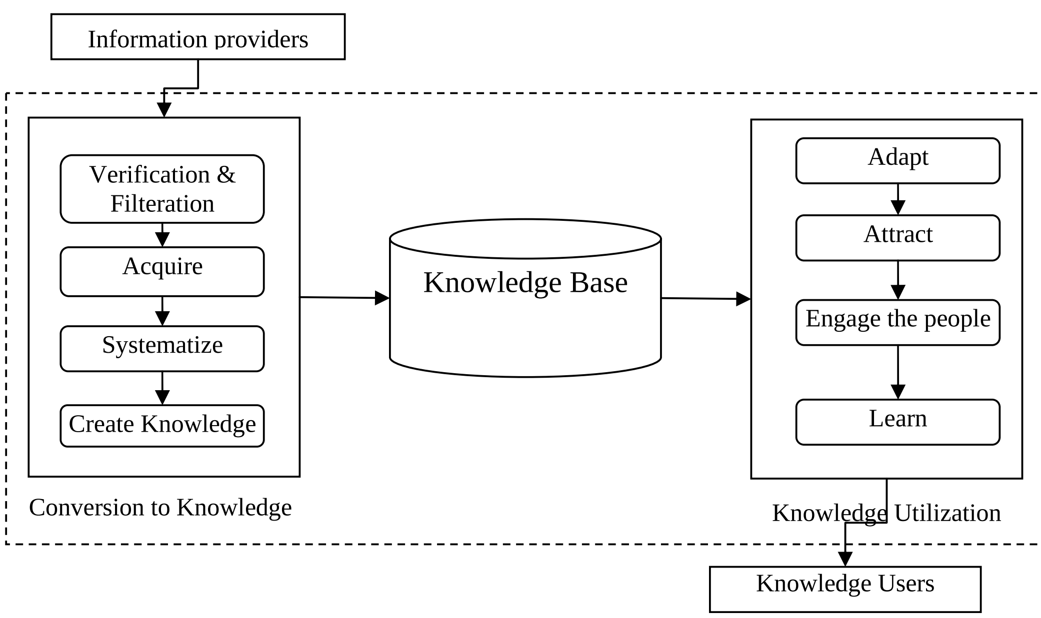

Figure 2. An Integrated Framework of Knowledge Management (Wadhwa et al. 2009)

An integrated framework of KM has been shown in the figure 2, which is adapted from Wadhwa et.al., (2009). It shows the conversion of information to knowledge and integration of knowledge base with knowledge utilization. To convert the information to knowledge, the process follows the various activities as verification, acquiring the filtered information, classification and creation of the knowledge from this information. All the acquired knowledge is stored in the knowledge base. After accumulation, the knowledge has been distributed to the knowledge users by following the steps like adaptation, attraction, engaging the people and learn them how to use this knowledge.

4. Knowledge Based Distributed Control Architecture (KBDCA)

The real time distributed hierarchical type controller for FMS is based on a hierarchical structure in which the FMS is decomposed into several levels of decision making from machine level to highest level of the system. The hierarchical approach is more suitable for system reconfiguration but it can become prohibitively complex with the increasing size and complexity of the manufacturing system. In contrast to the hierarchical decision architecture, the heterarchically controlled architecture consists of cooperation of autonomous entities which act on local information available to achieve their individual goals or the system goals as well. The independence of the system entities makes the system naturally modular. The heterarchical control architecture must present a high level of intelligence of the system entities to permit autonomous decision making.

In the present paper, a mixed type of control architecture has been proposed for FMS with the ease of decision making by using the knowledge base. The proposed architecture has the magnificence of both conventional architectures and simultaneously it provides a knowledge base for taking the decision straightforwardly. The proposed architecture of KBDCA, for an FMS with *n* numbers of FMCs with individual cell controller and supported by different knowledge bases, has been depicted in figure 3. The distribution of the authority of control allows the system to reduce the complexity of the control and to make decisions more quickly to control the lower level of hierarchy to achieve the system goal. This provides a partial independence to the controller in decision making.

From the figure, it is clearly shown that the physical devices are controlled in heterarchical manner e.g. each machine has its own controller and each AGV also has the individual controller. This approach of controlling includes the choice of an operation to perform among products in machine queues, the product routing between workstations etc. all these individual controller has a horizontal type of communication among all the controllers. In this context, a direct communication between adjacent local controllers is allowed. To avoid the conflicts among the decisions of individual controllers, a cell controller also takes action on the just upper level in the hierarchy thereby reducing the chances of deterioration of system performance. The The lower level has to request the upper decision centre to which it belongs, and so on, until the tipper decision centre in charge of controlling remaining operations is reached. The cell controller is also supported by a knowledge base which receives the information from the cells (machine information, part information, AGV information, pallet information, robot information) and provides it to the cell controller as knowledge. This knowledge base has the information of all cells, therefore all the cells controllers has the prior knowledge about the other cells. Thus it can also lessen the conflicts among the decisions of cell controller and protect the system performance from deterioration. There is also a horizontal communication among all the cell controllers to make the rapid decision to accomplish the objective of cell and system.

All the cell controllers are connected to a supervisory controller, which is known as FMS controller, in the hierarchical manner. This controller sends the control signal to the entire cell controller to avoid the conflict among cell controllers and improves the performance of the system. This type of the communication is known as vertical communication. In the vertical communication, the lower level has to request the upper controller to which it belongs, and so on, until the tipper in-charge of controlling remaining operations is reached. This controller is also supported by another knowledge base, which is enriched by the information of market, resources, finance, system capability etc. This knowledge base provides the ease of decision making to FMS controller.

5. Conclusion

This paper provides a new approach to control the multi cell flexible manufacturing system in real time manner. This approach is also strengthening by the exquisiteness of knowledge base. This approach integrates both types of control: supervisory as well as independent entities. Hierarchical or supervisory control permits coordination of distributed controllers whereas heterarchical control gives a partial autonomy in decision making to lower level controllers. The decisional flexibility and the robustness of the system of the real time control level protect the system from decline. The knowledge base also provides the ease of decision making to the controllers by offering the relevant information. A knowledge-based view of the architecture is necessary to understand the requirement of the real world FMS and the potential of control architectures.

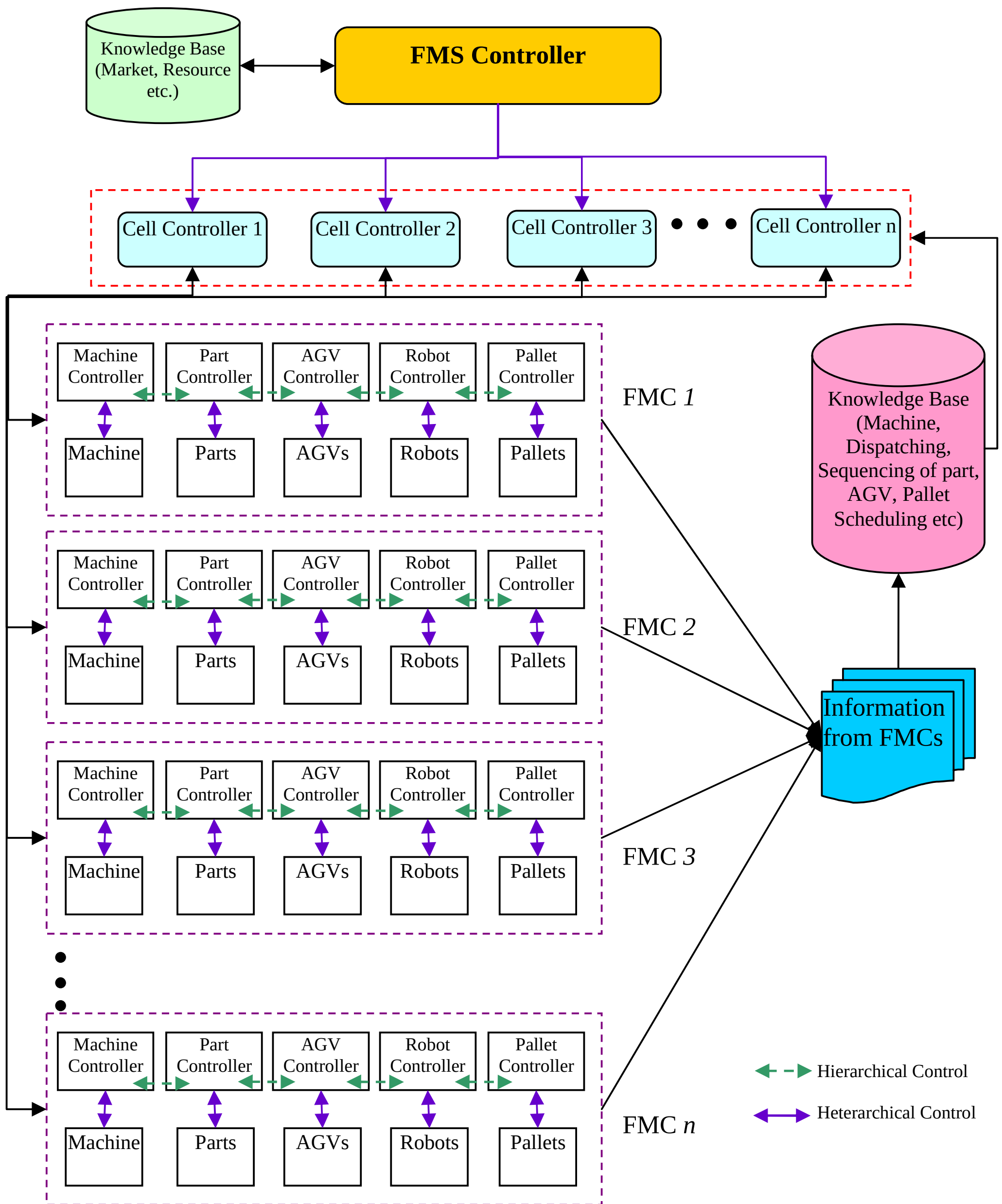

Figure 3. Proposed Distributed Control Framework for Flexible Manufacturing Cell

References

Baker, A.D., (1998), "A Survey of Factory Control Algorithms that can be Implemented in A Multi-Agent Heterarchy: Dispatching, Scheduling, and Pull" *Journal of Manf. Systems* 17 (4), 297–320.

Beckman, T. (1997), "A methodology for knowledge management", in Harmza, M.H. (Eds),*Proceedings of the IASTED Int. Conf. on AI and Soft Computing, ASC '97*, Banff, IASTED ACT Press, 29-32

Bongaerts, L., Monostori, L., McFarlane, D., Kadar, B., (2000), "Hierarchy in Distributed Shop Floor Control" *Computers in Industry*, 43, 123–137.

Bussmann, S., Schild, K., (2001), "An Agent-Based Approach to the Control of Flexible Production Systems", *8th IEEE Int. Conference on Emerging Technologies and Factory Automation*, 2, 481–488

Carlsson, B., (1989), "Flexibility and the Theory of the Firm," *Int J. of Ind. Organization*, 7, 179–203

Chung, S.H., Chan, F.T.S., Chan, H.K., (2009), "A Modified Genetic Algorithm Approach for Scheduling of Perfect Maintenance in Distributed Production Scheduling" E*ngg Applications of AI*, Article in Press

Davenport, T., Prusak, L. (1998), "Working Knowledge: How Organizations Manage What They Know", Harvard Business School Press, Boston, MA.

Leita˜o, P. Restivo,F.,(2008), "A Holonic Approach to Dynamic Manufacturing Scheduling", *Robotics and Computer-Integrated Manufacturing*, 24, 625–634.

Maione, G.,Naso,D., (2003), "A Soft Computing Approach for Task Contracting in Multi-Agent Manufacturing Control" *Computers in Industry*, 52, 199–219.

Marık, V., Lazansky, J., (2007), "Industrial Applications of Agent Technologies", *Control Engineering Practice*, 15, 1364–1380.

Nietok, M. (2003). "From R&D management to knowledge management An overview of studies of innovation management", *Technological Forecasting & Social Change*, 70, 135–161.

Nonaka, I. (1994), "A Dynamic Theory of Organizational Knowledge Creation" Org. Sc., (5) 1, 14-37.

Nonaka, I., Takeuchi, H. (1995), "The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation", *Oxford University Press*, New York, NY.

Takahashi, K., Nakamura, N., (2002), "Decentralized Reactive Kanban System", *European Journal of Operational Research*, 139, 262–276.

Tawegoum R., Castelain E. And Gentina J.C. (1994), "Hierarchical and Dynamic Production Control in Flexible Manufacturing Systems", *Robotics & Computer-Integrated Manufacturing, 11(4), 327-334*

Tiwana, A., (2000). "The knowledge Management toolkit", Prantice hall.

Tiwana, A., Balasubramaniam Ramesh. (2001), "A design knowledge management system to support collaborative information product evolution", *Decision Support Systems*, 31, 241–262

Upton, D., (1994). "The Management of Manufacturing Flexibility", *California Mgmt Rev.*, 36(2), 72-89

Wadhwa, S., Aggarwal A. (2000) "Synergism of Flexibility, Integration and Automation in Computer Integrated Manufacturing (CIM) Systems", *Studies in Informatics and Control*, April.

Wadhwa, S., Prakash, A., and Deshmukh, S.G., (2009), "A Knowledge Based GA Approach for FMS Scheduling", *The 2009 IAENG-INCINDE*, 18-20 March, Hong-Kong, 1715-1719

Wadhwa, S., Rao, K. S. (2000) "Flexibility: An Emerging Meta-Competence for Managing High Technology", *International Journal of Technology Management*, 19(7/8)

Wadhwa, S., Rao, K. S., Chan, F. T. S., (2005) "Flexibility-Enabled Lead-Time Reduction in Flexible System", *International Journal of Production Research*, 43(15), 3131-3163.