Multi-agent-Based Control Model of Laser Welding Flexible Manufacturing System

Shiyi Gao[1,2], Mingyang Zhao[1], Lei Zhang[1,2], and Yuanyuan Zou[1,2]

[1] Shenyang Institute of Automation, Chinese Academy of Science, Shenyang 110016, P.R. China
[2] Graduate School of the Chinese Academy of Sciences, Beijing 100049, P.R. China
gshiyi@sia.cn

Abstract. Existing modeling frameworks for manufacturing control can be classified into hierarchical framework and heterarchical framework. The two modeling frameworks have some drawbacks which can't be overcome only depending on them. In this paper, in order to improve the performance of the laser welding flexible manufacturing system (LWFMS) we have developed a hybrid modeling framework which has the features of the hierarchical and the heterarchical framework. The LWFMS contains several robots and many workstations which work together to realize a common goal. There exists coordination and cooperation among the different robots and workstations so the multi-agent technology is adopted in the LWFMS. In the end, the simulation result of the hybrid control framework in the LWFMS testifies the validity of the model.

1 Introduction

In recent years, with the development of the computer science and technology, the intelligence manufacturing based on the multi-agent system is proposed. The multi-agent system is composed of heterogeneous agent types with distinct agent properties, such as adaptation, mobility, collaboration and learning [1~3]. It is also a distributed artificial intelligence system which embodies a number of autonomous agents to achieve common goals [4]. The agents in the multi-agent system can take specific role within an organizational structure. The multi-agent system provides a novel approach to address complex problems where decisions should be based on the processing of information from various sources of diverse nature[5]. Each agent represents a source and the MAS stands for the overall manufacturing from management, planning to execution. In FMS, the agent may be designed to represent various information units, the types of which reflect the capabilities of different departments of the enterprise.

Many researchers have engaged in various researches on applying agent technology in developing manufacturing control systems. The view of original implementation of MAS in manufacturing was proposed by Yams [6~7] who assigned an agent to each node in the control hierarchy (factory, workstation, machine.). Carlos Ramos [8] has developed the architecture for dynamic monitoring in flexible manufacturing system (FMS) which assigned an agent to each resource. He has also proposed a new negotiation protocol for rescheduling, which is able to deal with faults. Warnecke and Huser [9] adopted the metaphor of fractals to describe a model for a FMS in which self-contained entities can organize themselves without the power of an external. Maturana et al propose MetaMorph, a multi-agent architecture, for distributed manufacturing system [10]. Two

T.-J. Tarn et al. (Eds.): Robot. Weld., Intellige. & Automation, LNCIS 362, pp. 243–248, 2007.
springerlink.com

types of agents: resource agents for representing physical resources and mediator agents for coordination were adopted in their built control framework. Laws et al. proposed a viable reference architecture for a multi-agent supported holonic manufacturing system [11]; and Kotak et al. introduced an agent-based holonic design and operations environment for distributed manufacturing [12]. Leitao et al. proposed a collaborative production automation and control architecture. The architecture provided a catalog of elements that simplifies the development of agent-based control systems for flexible manufacturing from design to operation [13]. Parunak and Baker [14] described a type of agent architecture for shop floor control and scheduling. Manufacturing resources, managers, part types, and unit processes are modeled as intelligent agents in their architecture. Among these research issues, the agent technologies are still immature and few true agent-based systems have been realized for manufacturing systems. The potential of the agent technologies has not been released completely. So the research about the application of the multi-agent into manufacturing will be necessary.

2 The Laser Welding Flexible Manufacturing System

The integrated laser tailored welding manufacturing system (LWFMS) has the ability to joint different thickness and different material metal plates together by using the advanced laser welding technology. The automobile bodies manufactured by LWFMS can reduce in weight and maximize the structural stiffness in modern automobile

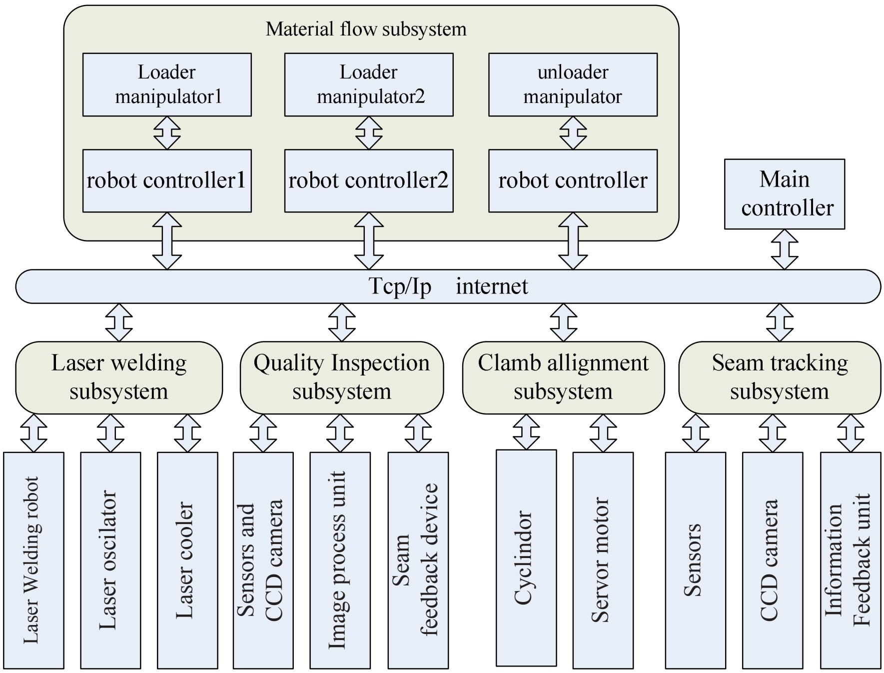

Fig. 1. The hardware configuration of the LWFMS

design. So using the LWFMS in welding automation manufacturing has become a necessary trend in order to improve the welding quality. The LWFMS consists mainly of a material flow subsystem, a laser welding subsystem, an on-line quality inspection subsystem, an alignment and clamp subsystem and a seam tracking subsystem. The material flow subsystem contains three robots, two loader robots and an unloader robot. The LWFMS is a typical integrated flexible manufacturing system. The Fig1 shows the hardware configuration of the LWFMS.

3 The Hybrid Framework of the LWMFS Based on MAS

The LWFMS consists of five subsystems and each subsystem is autonomous and independent in function. So each subsystem can be considered as an agent. In order to improve the performance of the LWFMS, we have built a hybrid control framework for the LWFMS which can be seen from Fig 2. In this framework, all agents are divided into three levels: high level agent, middle level agent and low level agent. The high level agent, which has a global perspective, generates a global optimized schedule. The middle level agents dominate and monitor the low level agents. The low level agents may autonomously make their negotiation with the high level agents according to the rules planned previously.

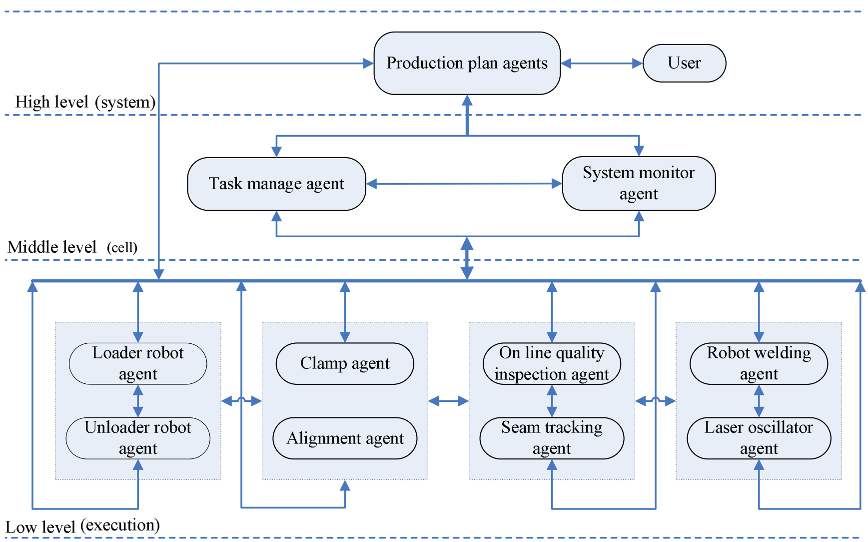

Fig. 2. The hybrid framework of LWFMS based on multi-agent system

The production supervisory agent in high level is the highest controlling body and it aims to satisfy the goals defined by the user. The classical functions –administration of client orders, data management, material management and global control management are fulfilled at high level. This agent has a broad view and is thus able to make decisions to prevent unstable behaviors. For example, if no low agent is willing to execute the task, the high agent has the power to force an agent to accept a specific assignment. The high level can also dominate the middle agent for stable solutions by declining permission to middle agents on a specific assignment.

The middle layer consists of task management agent and system monitor agent. The task management agent can be classified as a reactive scheduler. It maintains updated aggregate planning information, for example, the welding sequence of blanks is assigned to each resource. When it gets a request to change the original assignment, it examines the projected workload of resources in its control area and grants the request only if the assignment change is necessary or desirable. For instance, a loader robot conveys a blank that may be an unqualified one, at the same time the welding robot and the system have been ready for welding, so the loader robot must convey a quality blank again. In the return process of the loader robot, a message is submitted to the task management agent and a new assignment is done in the agent. Notice that the massage is submit to other agent of high level and low level because the control design framework is interaction among levels. The major functions of monitor agent are error detection, error diagnosis and error handling. Each resource, including all robots, machines, tools, devices in the LWFMS are under the responsibility of the monitor agent. In this model, the monitor functions are realized by the control mode which is a distributed system between the low agents and the monitor agents.

Just as upper agents must take into consideration interests of the lower level agents, lower level agents must also contribute toward achievement of upper level agents' objectives [17]. Thus, the lower agents must satisfy up level agents' objectives while attempting to satisfy their personal objectives. The low agents share with common databases and can communicate massages each other by blackboard modes. For example, after the blank is ready for welding, the massage is reported in the blackboard and the welding robot can receive the news, and subsequently accomplishes the welding task. In the LWFMS, these low agents stand for certain components and controllers by which the complex production task can be realized. The low agents that are autonomous are managed commonly by the middle level and the higher level. So the level control is a distribute mode which offers robustness and agility with respect to uncertainties.

From the above analysis about the architecture of LWFMS a new control model is built up based on the multi-agent technology. This model is a hybrid framework because it incorporates elements of the hierarchical and heterarchical frameworks. A negotiation mechanism for real time task allocation is used in order to overcome the structural rigidity and the lack of flexibility.

4 The Simulation

In order to verify the presented framework, this section describes the implementation and the testing results of the LWFMS control systems based on multi-agent system. Those agents are developed using java language based on the Java Agent Development Framework (JADE) which is a software framework to develop multi-agent systems in compliance with the FIPA specification. One of the important features that JADE agents provided is the asynchronous message passing. Each agent has a sort of mailbox where the JADE runtime posts messages sent by other agents. Whenever a message is posted in the message queue the receiving agent is notified. The Fig 3 is the JADE asynchronous message passing paradigm.

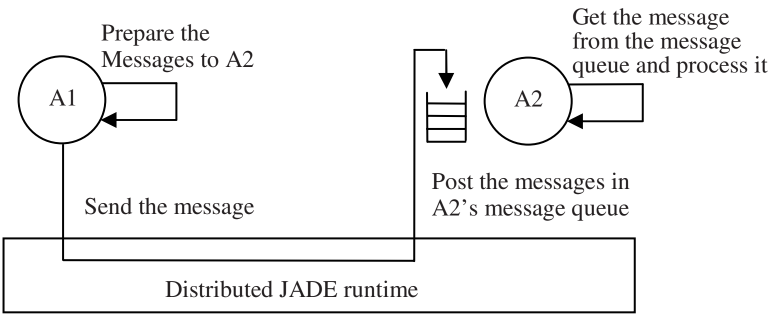

Fig. 3. The JADE asynchronous message passing paradigm

A number of tests and evaluation have been done on the basis of the hybrid control framework thought the JADE platform. In those tests fifty blanks was welded continuously and the abnormal run state probability can be computed. From the tests result we get the following graph shown as Fig 4. We can summarize that the result of the test of the hybrid control framework is better than the conventional framework From Fig 4. The reason is the agents interact with on another independently. When some agent of WFMS control system breaks down, although the whole performance of the system may drop, the WFMS can run continuously. In a word, by adopting the MAS based the hybrid control framework, the disadvantages of the traditional WFMS, such as insufficient configuration, low capability of fault-tolerance and difficult maintenance can be resolved.

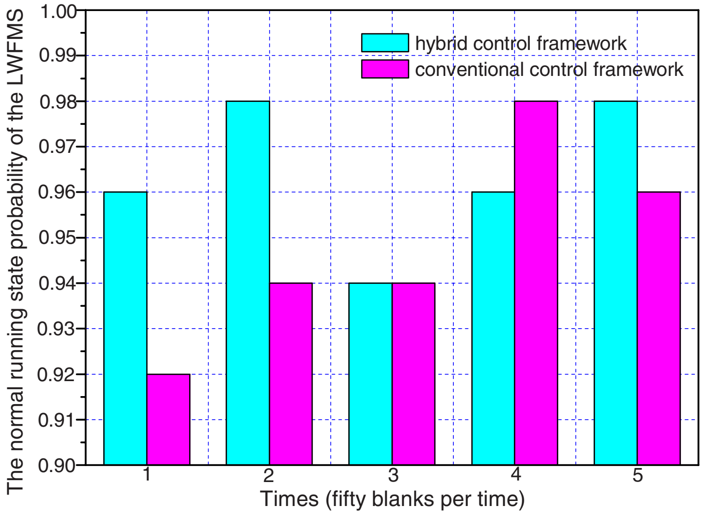

Fig. 4. The normal running state probability of two different control framework

5 Conclusions

In this paper, we developed a hybrid control model for LWFMS based on the multi-agent system. In the model, all agents are divided into three levels: higher level, middle level, and lower level. Each agent in a different level can communicate according to programming rules. The simulation test for the LWFMS demonstrates that the hybrid control architecture is an effective and appropriate approach.

References

1. Alessandro Garcia, Uirá Kulesza, and Carlos Lucena Aspectizing, " Multi-agent Systems: From Architecture to Implementation," Lecture Notes in Computer Science, Vol. 3390, PP121-143, 2005
2. A. Garcia et al, "Separation of Concerns in Multi-Agent Systems: An Empirical Study," Software Engineering for Multi-Agent Systems II., Springer, LNCS 2940, April 2004.
3. A. Pace et al, "Assisting the Development of Aspect-based MAS using the SmartWeaver Approach," Software Engineering for Large-Scale MASs., LNCS 2603, March 2003.
4. W.B. Lee, H.C.W. Lau, "Multi-agent modeling of dispersed manufacturing networks," expert systems with applications, vol. 16, no 3,pp 297-306, 1999
5. N.K. Krothapalli, A.V.Deshmukh, "Design of negotiation protocols for multi-agent manufacturing," int, J . Prod. Res, vol. 37, no. 7, pp 1601-1624, 1999
6. H. Van Parunak, "Distributed A.1 and Manufacturing Control: some issues and insights," Y. Demazeau and J.Muller, eds., Decentralized A.1, North-Holland, pp. 81-104, 1990.
7. H.Van Parunak, "Industrial applications of multi agent systems," Actes de MFAUTOM'93, du traitementreparti aux systemes multi-agents et a l'autonomie dessystemes., pp. 18-19, Toulouse, 1993.
8. Carlos Ramos, "An architecture and a negotiation protocol for the dynamic scheduling of manufacturing systems," IEEE International Conference on Robotics and Automation, Vol. 4, pp. 8-13, 1994.
9. H.-J. Wamecke, M. Hiiser, The Fractal Company – A Revolution in Corporate Culture, Springer, Berlin, 1995.
10. F. Maturana, W. Shen, and D. H. Norrie, "Metamorph: An adaptiveagent-based architecture for intelligent manufacturing," Int. J. Prod.Res., vol. 37, no. 10, pp. 2159–2173, 1999.
11. Laws AG, Taleb-Bendiab A, Wade SJ, "Towards a viable reference architecture for multi-agent supported holonic manufacturing systems," J Appl Syst Stud 2(1):61–81, 2001
12. Kotak D, Wu S, Fleetwoood M et al, "Agent-based holonic design and operations environment for distributed manufacturing," Comp Ind 52(1):95–108, 2003
13. Bellifemine F, Poggi A, Rimassa G, "JADE a FIPA2000 compliant agent development environment," Proceedings of the international conference of autonomous agents, Montreal, pp 216–217, 2001
14. A. D. Baker, H. V. D. Parunak, and K. Krol, "Manufacturing over the internet and into your living room: Perspectives from the AARIA Project," ECECS Dept., Univ. Cincinnati, Cincinnati, OH, Tech. Rep.TR208-08-27, 1997.
15. N. R. Jennings, M. j. Wooldridge, "Applications of intelligent Agents. In "Agent Technology : Foundations, Applications and Market" Springer, pp. 3-28.1998
16. W. Cao, C.G. Bian, O.O. Ugwu, L. Newnbam, A. Thorpe, "Collaborative design of structures using intelligent agents," Automation in construction, vol. 1, pp. 89-103, 2002
17. Sunderesh S. HERAGU, Robert J. Graves, Byung-In Kim, Art, St. Onge, "Intelligent Agent Based Framework for Manufacturing Systems Control," IEEE transactions on systems, man and cybernetics pp560-573 , Sept. 2002