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Research and development of Multi-Agent System based agile collaborative design system for machining centre

F. Li*, N. Chen, L. Zhou
School of Mechanical Engineering, Southeast University, Nanjing, Jiangsu, China
* Corresponding author: E-mail address: lifangtju@yahoo.com.cn

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Analysis and modelling

ABSTRACT

Purpose: Today we face a demands always quickly varied market. For the machine tools manufacturers, reducing the development cycle of a product to be modified is much meaningful, and meanwhile, they have to improve (at least keep) the new machines performance. Consequently, an assistant-software has a certain degree of intelligent ability will have more advantages to improve the design quality and short design cycle simultaneously.
Design/methodology/approach: The development of machine tools is a typical work of a distributed cooperative process supported by CAX. MAS (Multi-Agent system) is now the mainstream of contemporary studies on distributed intelligent software system, and can provide a foundation for the establishment of such system.
Findings: In this paper, a MAS-based agile collaborative development system for MC (Machining Center) was set up using JADE (Java Agent DEvelopment framework). The whole system was divided into several functional modules that can carry out its typical mission. By taking the intelligent collaborative design module as an example, the configuration of Agents society was expatiated particularly. This module can provide intellectualized conceptual design help for MC designers.
Research limitations/implications: Whereas, the other modules of this system have not been established, so in order to make it more perfect, some interfaces are left for the next expansion of other modules.
Practical implications: A development process supported by this system for a customer ordered MC is taken to execute the prototype case study. According to the customer order information, three feasible proposals that have the greatest similarity are presented by the intelligent reasoning of CADDesignerAgents. By performing the parametric design and intelligent optimization, 3D dynamic MC model which is the customer satisfied is proposed and shown.
Originality/value: The platform supported with those intelligent abilities has shown that it is a powerful tool on the MC family design for shorten the development cycle and improve the design quality.
Keywords: Multi-Agent; JADE; Collaborative design; Machining Center

1. Introduction

Along with the emergence, development and maturation of advanced manufacturing technology, there are more and more design requirements to machine tools enterprise, which includes to short the development cycle and to improve the machines performance as much as possible, and so on. In order to enhance the compete ability and to win in the fierce market competition, it is of much significance to set up an assistant software system for the development and design of Numerical Control (NC) machine tools which has a certain degree of intelligent ability.

Considering that the development of machine tools is a typical work of distributed cooperative design which is supported by computer, further more, Multi-Agent System (MAS) is a mainstream of contemporary studies on distributed intelligent software system which can provide the most promising computer foundation for the design of such system, so the technology of Agent is chosen as the technic support in this paper. Now there have been large numbers of reports about MAS both at home and abroad and MAS is being used in an increasingly wide variety of application. Example of the application of MAS in industrial settings mainly include manufacturing[1], transportation logistics[2], network management[3], system diagnostics[4], and so on. Whereas, most of the reports are stayed on the phase of scientific research, and there is serious lack of key investigations in actualization of MAS application.

Owing to that there have been many researches about Machining Center (MC) structural optimization and topology optimization in our laboratory, MC is chosen as the study object in this paper. A rational framework of MC agile collaborative design system was founded by using MAS technology, which can make the customers, design engineers, CAE analysts and managers integrated in a uniform assistant environment with friendly interfaces. All members in this system can cooperate with each other conveniently, especially the design engineers can development a type of customer satisfied MC in a period as short as possible and perform parametric design and intelligent dynamic optimization under the guidance of corresponding webpage. Besides these, in the last process of a product development, all the correlative documents, 3D VRML drawings, BOM and dynamic optimization results can be provided for the engineers intelligently, so it can short the development cycle and reduce the design difficulties to a great degree. The next work of this project is to establish the intelligent virtual manufacturing module and process flow definition module which can integrate more multidisciplinary design teams and make this software system more perfect.

2. Establishment of the system framework

2.1. The technology of Agent and MAS

Lots of complicated problems in realm of engineering are solved under a distributed circumstance, accordingly more and more researchers are paying their attention to the study of distributed artificial intelligence. Especially the techniques of Agent and MAS have been the significant subjects of extensive discussion and investigation within the scientific community for several years.

The technology of Agent is a relatively new software paradigm that brings concepts from the theories of artificial intelligence into the mainstream of distributed systems. Now the most popular definition of Agent was proposed by Wooldridge in reference [5]: an Agent is essentially a special software and hardware component that has the characteristics of autonomy, sociality, reaction and proaction. It can provide different interaction interface for the outside, and even have the characteristics that only possessed of human beings, such as knowledge, belief, intention and so on. The greatest difference between Agent and traditional intelligent system is that Agent is autonomous, social, reactive and proactive[6], and that Agent has the abilities of interaction, harmonize, collaboration and communication with users, with system resources, and with each other by using some special communication languages.

Just as its name implies, MAS is a system that is consisted of multiple Agents which can model complex systems and introduce the possibility of Agents having common or conflicting goals. The technology of MAS provides a new suitable method to solve the distributed and uncertain problems, because it relaxes its centralized, planning and sequence control restrictions, and provides decentralized control, mission-critical response and the ability of parallel processing. The research about MAS is so extensive, including the system architecture, programming language and tools, development platform, Agent-oriented software programming, application of MAS in engineering, and so on. Rather than expecting developers to develop this core infrastructure themselves, it is convenient to build multi-agent system on top of an Agent-oriented middleware that provides the domain-independent infrastructure, allowing the developers to focus on the production of the key business logic. The most widespread Agent-oriented middleware in use today include Agent Development Kit (ADK), April Agent Platform, Comtec Agent Platform, FIPA-OS, Grasshooper, JACK Intelligent Agents, Java Agent DEvelopment platform (JADE), Java Agent Service API (JAS), LEAP, ZEUS, etc [7]. Along with the development of MAS, it is being used in an increasingly wide variety of applications, ranging from comparatively small systems for personal assistance to open, complex, mission-critical systems for industrial applications [8]. Examples of industrial domains where MAS have been fruitfully employed include process control, system diagnostics, manufacturing, transportation logistics and network management. The extensive applications of MAS speak volumes for its potential predominance.

2.2. Division of the System's Modules

According to the functional and performance demands analysis, as well as the former research fruits, the MC development system is divided into three parts: customer subsystem, manage subsystem, design and manufacture engineers subsystem, which are integrated in a web-based environment. In every subsystem, there are corresponding functional modules, in which different member can accomplish his mission or fulfill his task under the guidance of webpage.

A division of the whole system's functional modules is illustrated in Fig.1, which includes customer enquiry module, cooperative design module, CAPP module, virtual manufacture module, etc. In Fig. 1, the lowest layer of entire system is the data layer, in which all the former scientific researches such as MC model library, design repository, developing rules library, and so on, are embodied. Besides these, the customer order information can be stored in the global database by automotive persistent mapping. In the upper layer, JADE, which is one of the most popular agent-oriented middlewares that provide the domain-independent infrastructure for MAS, can make it convenient to develop the system framework and to found the Agents. Therefore, it is selected as the development tool of Agent and Agent societies in this system.

Among all the modules, the intelligent cooperative design module is the emphases of our project, which has multiple functions, such as MC conceptual design, confirm the feasible proposals as quickly as possible and help to perform parametric design, dynamic optimization intelligently, etc. It can assist engineers to provide a new feasible MC type and its dynamic 3D VRML drawings which satisfy most requirements of the customer, and all the functions are realized on top of Agent-based intelligent reasoning methods and original research productions. In order to ensure the security, Local Area Network (LAN) is adopted in the internal system, whereas the firewall technique is used to isolate customers from the LAN and confidential information of the enterprise.

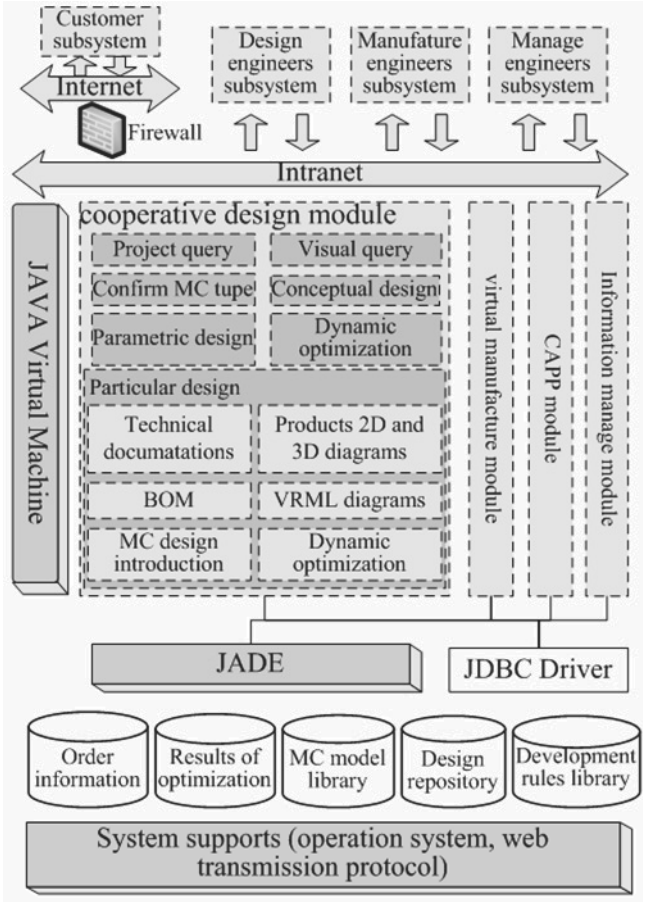

Fig. 1. Module Division of The Cooperative Development System for Machining Center

2.3. Classification of Agents and their structure in a PC

Based on the functional differences of Agents, all of them are divided into several types: Interface Agent, Information Service Agent, Communication Management Agent, Directory Factory Agent, Job Agent, Engineering Data Management Agent, and Problem Solving Agent, whose structure in a PC is illustrated in Fig.2.

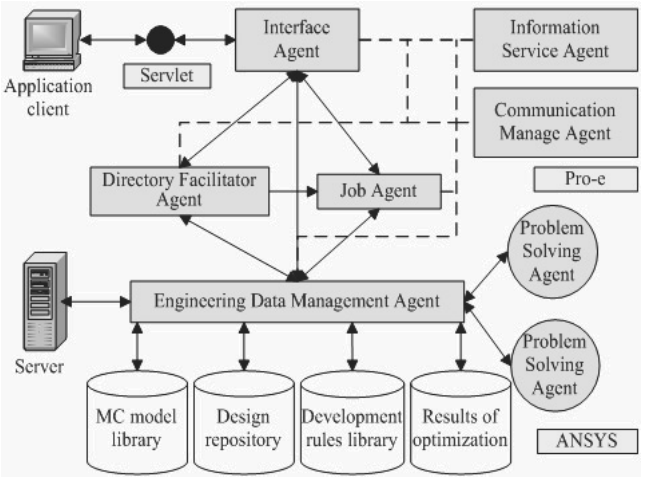

Fig. 2. Structure of Different Types Agent in a PC

The particular functional introduction of every type Agent is followed as below:

(1) The main function of Interface Agent is to form web-based user interface and transmit data to the back-end library via Servlet, which can facilitate the system's operation and ensure that all information could be stored in time.

(2) Information Service Agent lies in the web-supported layer, who is in charge of managing and providing service for the message transmission using Agent Communicate Language (ACL).

(3) Communication Manage Agent is responsible for the management of communications among different Agents or among Agents and human beings.

(4) Directory Facilitator Agent provides the registration service for other Agents residing in the system, and can inform other agents of the up-to-date registration information.

(5) In order to fulfill the task in different design phase, including MC intelligent conceptual design, parametric design, dynamic optimization, etc, Job Agent is in charge of searching for the matched Problem Solving Agent by communicating with Directory Facilitator Agent. It is the core part of the whole system, whose particular explanation and introduction is shown in Fig.3 and next section.

(6) Engineering Data Management Agent is in possession of the information about connection-configuration, database location, and engineering file directories, etc. It is in charge of providing operation service about database and documentations, such as updating design data and set correct data storage location for a new job.

(7) In this project, the CAD and CAE tools are Pro-e and ANSYS respectively, whose connection with the system web interface is realized by Problem Solving Agent. Considering Pro-e and ANSYS are all interactive 3D modeling and dynamic analysis software, which are difficult to be executed automatically by system and always are used by engineers only, the Problem Solving Agents are replaced by empty nodes.

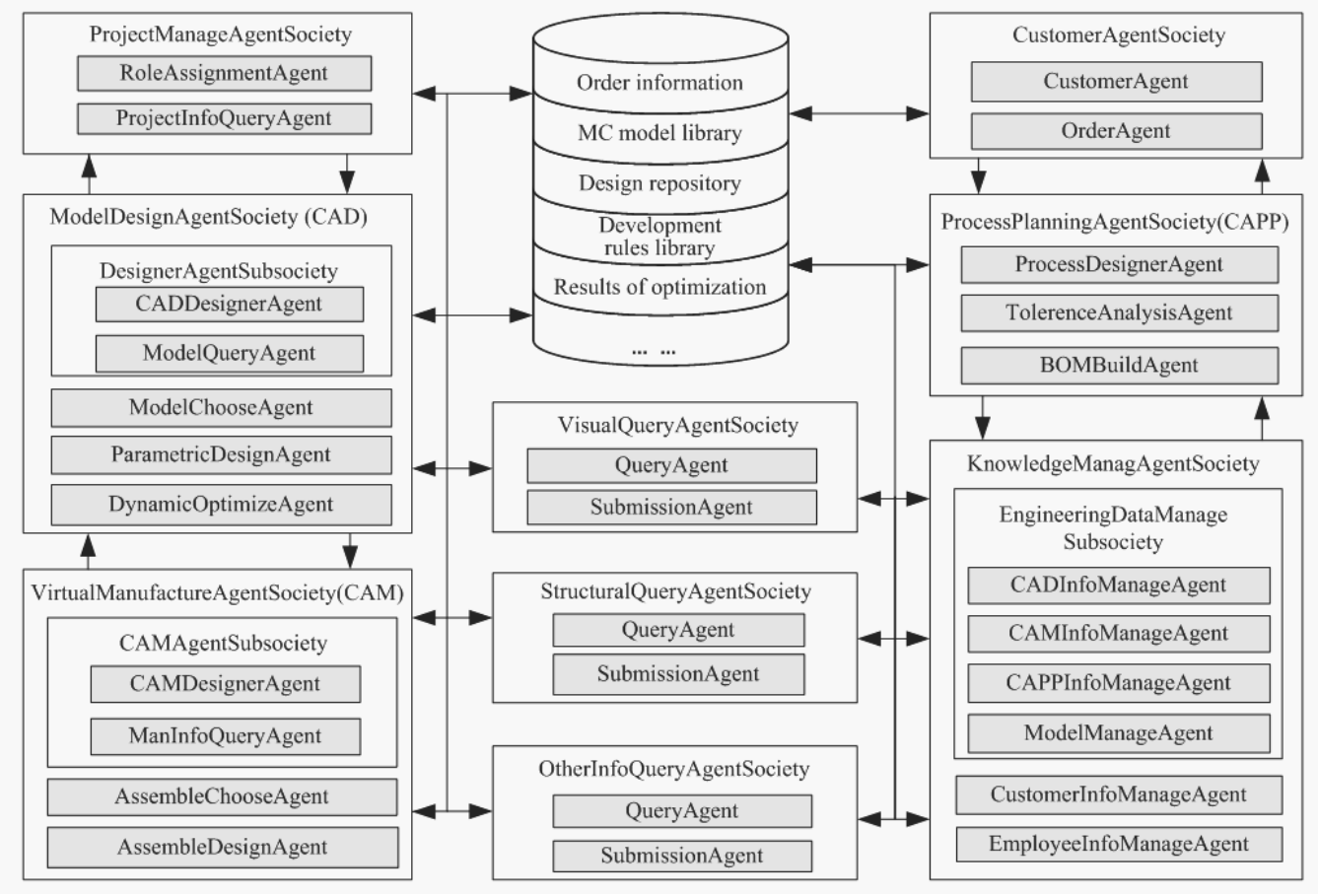

Fig. 3. Configuration of All Job Agents in This Development System

2.4. Foundation of Job Agents and their workflow in design module

It is evident that Job Agent is the core part of this intelligent development system according to the introduction above. In order to realize MC intelligent design and dynamic optimization, several Job Agents, which are encapsulated with corresponding reasoning methods and connected to related repository, are established in Fig.3. Besides this, several interfaces are left for the extension of other modules, such as virtual manufacturing module, intelligent CAPP module and so on. Fig.4 illustrates the MC development workflow by taking the MC design module as example. It can be seen that customers were introduced in the whole process of MC development, ranging from customers' submission of order information, to their participation in the design and manufacture, as far as to their satisfactoriness with the production. All the pursuits provide foundation for the realization of customer-oriented MC design, manufacture and maintenance.

After the confirmation of Job Agents' type and their functions, the next work is to establish every Agent in the JADE platform. In Fig. 5, it can be seen that every Agent in the intelligent design module were founded in the host computer by using JADE, which was encapsulated with special arithmetic to realize its respective function and cooperate with each other to fulfill the core task.

2.5. Interaction among different Agents

It is of great significance to confirm a rational interaction sequence and relationship among Agents, because that the goal of this system only can be arrived by a real-time and correct alternation and cooperation of Agents. Here, the MC design module is also selected to show the interaction sequence of Agents based on the production development workflow, whose Agents collaboration diagram is illustrated in Fig. 6. Similarly it can be seen that all members in a project, which includes customers, managers, CAD engineers, CAE analysts, etc, are integrated together to cooperate with each other. All the work is helpful to ensure that some problems, which are maybe encountered in the later phase, can be avoided in the early days of a production development, such as problems about assembly, process, cost, etc.

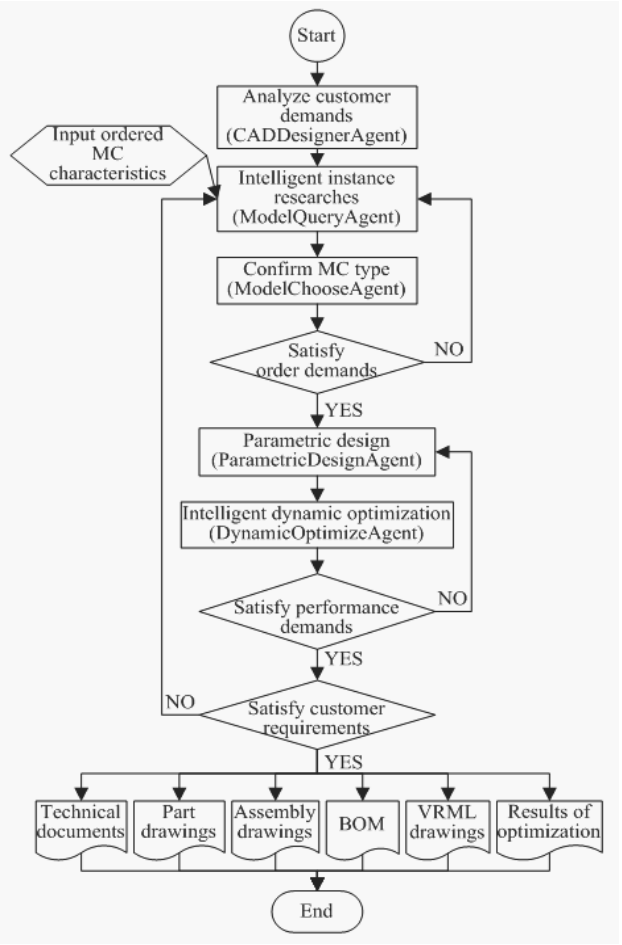

Fig. 4. Development Workflow of the MC Intelligent Design Module

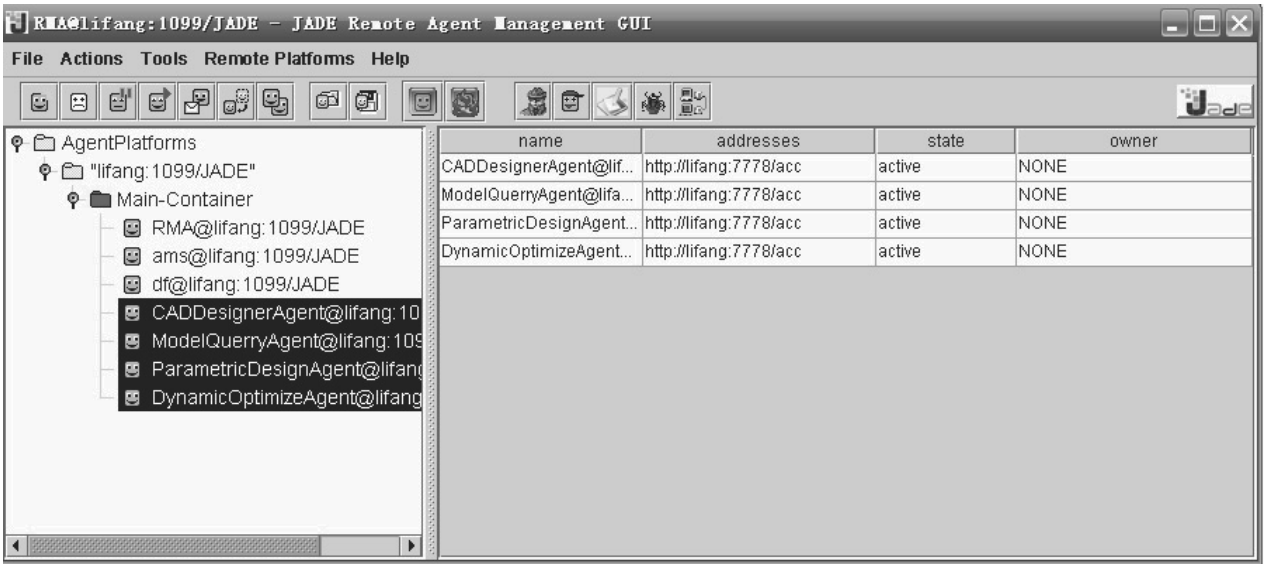

Fig. 5. Establishment of Agents in Design Module

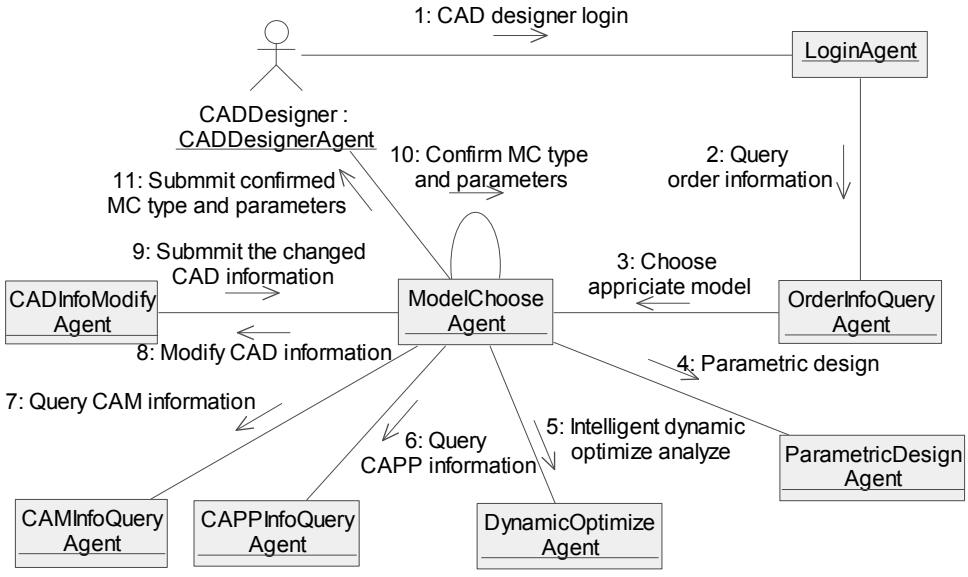

Fig. 6. The Collaboration Diagram of MC Design Module

3. A prototype case study

In order to show the actual application of this system, the development process of a customer ordered MC is taken as the prototype case study. According to the customer order information, three feasible proposals that have the greatest similarity are presented by the intelligent reasoning of CADDesignerAgents. And then by performing the parametric design and intelligent optimization, the 3D dynamic model of a customer satisfied MC is proposed and showed in a webpage. The screen shots of every step are illustrated in Fig. 7~Fig. 9.

From this case study, it can be seen that this system is very helpful for the intelligent collaborative design of MC according to the customer order information. Even a design engineer who is not experienced can accomplish a project by the assistant of this system in a shorter cycle, because that the application of Agent technology in this development platform makes it more intelligent.

Fig. 7. Screen Shot of Order Submission

最佳排名	与订单的相似度	序号	加工中心型号	加工中心类型	工作台长度	工作台宽度	工作行程X向	工作行程Y向	工作行程Z向	主电机功率	主轴最高转速	最大进给速度	X向进给速度	Y向进给速度	Z向进给速度	工作台承重	刀库容量	选刀方式	刀具最大直径	刀具最大长度	刀具最大重量	数控系统	定位精度	重复定位精度	机床总长	机总
	1	0	订单	立式	900	500	600	500	500	10.0	5000	5	10	10	10	500	10	固定	0	0	0	FANUC-0i	0.025	0.015	0	0
第1相似	0.8326809	7	TK7650A	立式	900	500	600	500	500	11.0	5000	5000	9	9	9	400	12	固定	80	300	6	FANUC-0i	0.025	0.015	2200	20
第2相似	0.81653124	6	TH7640A	立式	800	400	600	500	400	11.0	5000	5000	12	12	12	400	12	固定	80	300	6	FANUC-0i	0.025	0.015	2200	20
第3相似	0.7045936	5	XH715	立式	1200	500	1000	520	570	11.0	5000	10000	15	15	15	1500	24	任选	80	300	6	FANUC-0i	0.01	0.01	3380	23

Fig. 8. Screen Shot of The Similarity Calculation

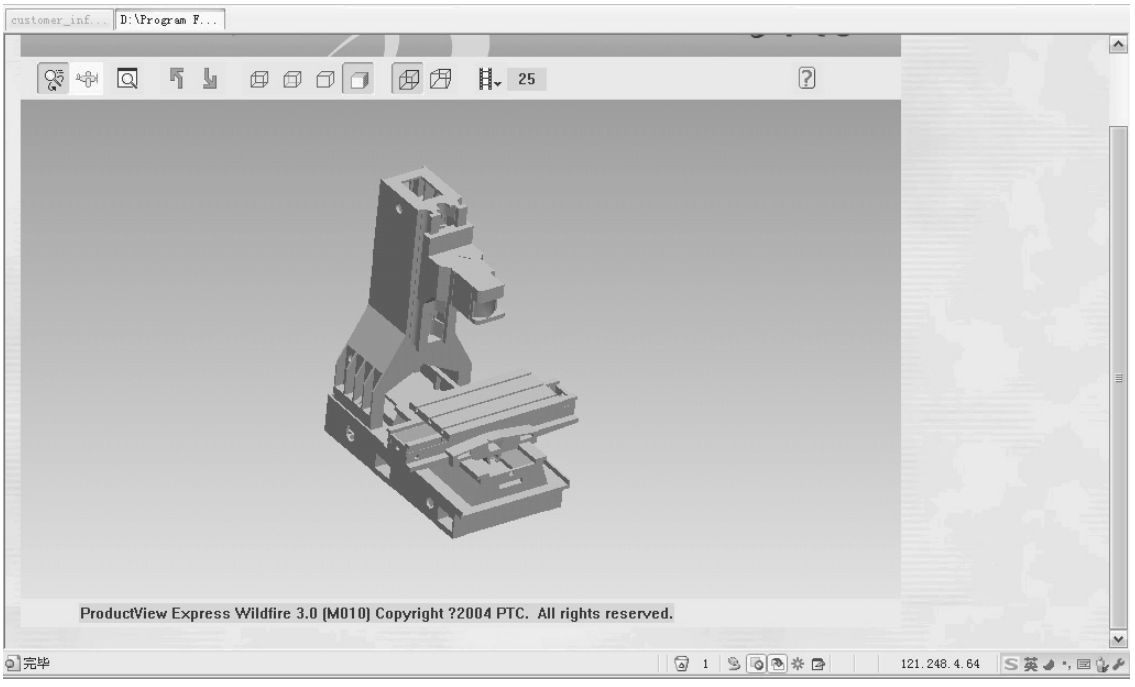

Fig. 9. The Optimized 3D Model of Customer-ordered MC

4. Conclusions

The only method to shorten MC design cycle is to establish a multi functional platform for the development of MC which integrates all engineer software and former experience together. In this paper, a framework of MAS-based agile collaborative design system for MC is founded using JADE, which takes full advantage of some popular technologies in engineering application, such as MAS, Agent software, Internet, firework, database, etc. In this platform, all resources, including experience,

software, managers, engineers and customers, are integrated in a harmonious, associated, distributed and friendship development environment. Besides these, the intelligent judgments, decision-makings and rational message communication are realized by some arithmetic which is encapsulated in corresponding Agent. The next work of this system development is to found an assistant virtual manufacturing and CAPP subsystem which is intelligent or half-intelligent, viz. it is the realization of the virtual manufacture module and CAPP module.

Acknowledgements

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