Design and Implementation of an Integrating Infrastructure for CIM Systems*

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Abstract: Integrating infrastructure is the basic supporting environment for CIM (computer integrated manufacturing) systems. This paper introduces the design and implementation of an opening distributed CIM integrating infrastructure, HIT-IIS.2, developed by HIT (Harbin Institute of Technology). The HIT-IIS.2 prototype includes the following service functions for CIM systems: business process control, enterprise activity control, resource management, definition and description, system information, communication management and front-end interface. Each service function is described in the paper.

Key words: computer integrated manufacturing (CIM); CIM integrating infrastructure; distributed processing system; interface; architecture

Through integrating human, organization, technology, resources, business management and information of enterprises, CIM (computer integrated manufacturing) systems can greatly improve the productivity of industrial factories and the economic benefit of enterprises. Since the CIM systems are usually distributed over the whole enterprise, the integration of functions and information should be supported by an opening distributed integrating infrastructure or platform. Just like an operating system in an enterprise, integrating infrastructure can provide various services for building and operation of CIM system, e.g. business process, activity management, resource management, enterprise modeling, information exchange and management, man-machine/CIM system interface, communication, system performance evaluation, etc. And integrating infrastructures or platforms also plays an important role in the open CIM architecture describing the principle and methodology for integrating each part of CIM system in industrial enterprises. In recent ten years, several CIM integrating infrastructures or platforms have been presented and developed[1], such as CIM-OSA[2], SAA[3], CIM-BIOSYS[4], PERA[5], and so on. As an open CIM systems architecture, CIM-OSA, developed by European ESPRIT projects, is a life-cycle-oriented CIM integrating infrastructure, not only provides a CIM modeling framework, but also provides planning of CIM

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integrating infrastructure. With its functional completeness, open architecture, standardized framework and formalized representation, CIM-OSA becomes one of the best CIM architectures and integrating infrastructures. Based on CIM-OSA reference architecture, on the one hand, different CIM systems can do some modifications oriented to different application fields, on the other hand, CIM application system can reduce the complexity of the implementation by using some mature technologies such as IDEF-X, CORBA, Internet, and so on.

In order to support the modeling and building of CIM system, we have developed two prototype systems of distributed CIM integrating infrastructure. Since they are developed at HIT (Harbin Institute of Technology), we called them as HIT-IIS (HIT Integrating Infra-Structure for CIM)[6], and the second version of the HIT-IIS is called HIT-IIS. 2. The function of HIT-IIS. 2 is designed based on the CIM-OSA framework, but some details have been updated. The distributed processing form of the HIT-IIS. 2 is based on the client/server architecture, and the implementation method of the HIT-IIS. 2 prototype is based on the object oriented programming technique.

The remainder of this paper is organized as follows. In Section 1 we present the overall functional structure of the HIT-IIS. 2 and describe all components in detail. Section 2 gives out the distributed architecture of HIT-IIS. 2 based on Client/Server. Section 3 contains the working procedure and a case study used to evaluate the performance of HIT-IIS. 2, and Section 4 is with conclusion and a short outlook.

1 Functional Structure of the HIT-IIS. 2

As a CIM integrating infrastructure, the HIT-IIS. 2 should support the activities in each phase of the CIM system's life-cycle. In order to provide various services for function integration and information integration in the CIM enterprises, it is necessary for the HIT-IIS. 2 to make use of CIM architecture and enterprise modeling framework to define its functions. And CIM-OSA is just a good CIM reference architecture and modeling framework. CIM-OSA describes an enterprise from four views: function view, information view, resource view, and organization view. It can support the CIM modeling process and the life-cycle of a CIM enterprise through a cube modeling framework, and an integrating infrastructure[7]. HIT-IIS. 2 supports the CIM-OSA modeling framework.

According to the analysis of requirements for providing the services for building and operation of CIM systems, the HIT-IIS. 2 should support the following functions:

- controlling business processes and activities in each phase of building and operation of CIM system;
- representing information of CIM system in the form of above four views;
- providing various information for CIM system, such as data, knowledge, and so on;
- providing communication services for distributed processing of CIM system;
- defining the model and parameters for a specific CIM system;
- providing a user-friendly, unified front-end interface;

Based on the above function analysis and the reference of CIM-OSA framework, we propose the functional structure of the HIT-IIS. 2 system as shown in Fig. 1.

There are six classes of services in the HIT-IIS. 2 system, i.e. FI (front-end interface), control, RM (Resource Manegement), DD (Definition and Description), SI (System Information) and CM (Communication Management). The following will depict them in detail.

1.1 FI (Front-end Interface)

This class of services performs the interaction between HIT-IIS. 2 and various functional entities in the enterprise, provides service of the capability resources, and performs mechanism of the enterprise behaviors and processing. FI server provides a global consistent service interface for HIT-IIS. 2 application environment. FI service class consists of three services, i.e. human front-end service (HF) which provides a consistent man-machine user interface, machine front-end service (MF) which handles all of the machines in a CIM system to perform the ma-

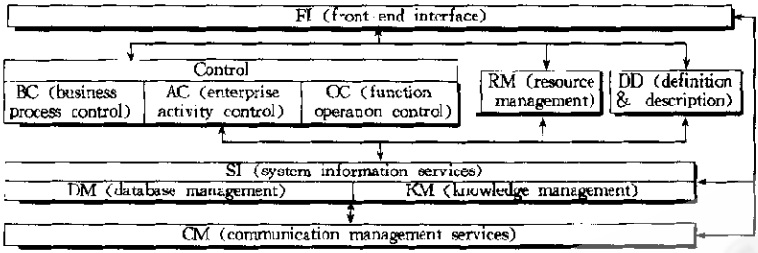

Fig. 1 Functional structure of HIT-IIS. 2

chine-specific functional operations and applications, and application service (AF) which handles all of the application functional entities in a CIM system.

1.2 Control

This class of services supports the function view in the CIM-OSA framework, through providing the processing and controlling services for execution of the enterprise business processes. Three services are included in this class, i.e. business process control service (BC), enterprise activity control service (AC) and function operation control service (OC).

• BC

Business process control service (BC) controls execution and distribution of business processes, which is the most important part of HIT-IIS. 2. Through explaining the business process rule set (PRS) and constraint rules, BC server controls the global distribution, scheduling and execution of enterprise business processes (BPs) in order to control the behaviors and procedures of the enterprise.

• AC

Enterprise activity control service (AC) controls execution of enterprise activities (EAs) by dispatching functional operations in order to organize and control the function operations of enterprises.

• OC

Functional operation control service (OC) is responsible for the execution of all function entities, which is the atomic unit operation in CIM system.

1.3 RM (Resource Management)

This class of services supports the resource view in the CIM-OSA framework. RM server controls global optimization, scheduling and allocation of all resources in the enterprise to support executions of business processes and enterprise activities, monitors the statuses of resources, updates resources, and so on.

1.4 DD (Definition and Description)

Definition and description service class supports the building and maintenance of CIM model. There are two servers in this class, one is Function Definition and Description (FDD) to describe and maintain the functional model of CIM enterprise, the other is Resource Definition and Description (RDD) for describing and maintaining of the resource model in CIM enterprise.

1.5 SI (System Information)

This class of services supports the information view and organization view in CIM-OSA modeling framework, and provides system-wide consistent information for the modeling, implementation and running of the CIM system. Two services are included in this service class: Database Management (DM) and Knowledge Management (KM).

• Database Management (DM)

In a CIM system, there are many kinds of information including text, data, table, graphic and engineering

data, model, method and procedure, with the development of manufacturing technology. Additionally, information is processed in a distributed environment built on the heterogeneous computer networks. It is necessary for DM to provide the modeling and running of a CIM system with system-wide consistent information management and services including the description and management mechanism of an enterprise model, the building and maintenance of global data dictionary/directory, schema converting, information integrity, consistency and security, transparent access of local and remote data management system, and so on.

Considering that many different distributed heterogeneous DBMSs coexist in the CIM system, all these DBMSs maybe differ in data model, schema, syntax, semantic, etc., we also have planned and are developing a multidatabase mid-ware named MDBI (Multidatabase Integrator) to integrate all kinds of DBMSs in spite of their difference. In this way, HIT-IIS. 2 system presents the users and applications a standard data format.

• Knowledge Management (KM)

KM stores, retrieves and manages the knowledge in a CIM system through the knowledge base system or the expert system. KM handles knowledge accessing and processing requests which come from applications, maps these requests to the external knowledge management system, and then returns the results to applications. Additionally, KM is able to convert the knowledge representation scheme from one to another in order to provide the knowledge sharing and transformation function among different servers (maybe in different nodes). Therefore, KM contains the following functional units: knowledge representation, knowledge schema converting, knowledge access mapping, knowledge access control, knowledge updating, etc.

1.6 CM (Communication Management)

CM server is responsible for the system-wide data transportation and communication service including the controlling of communication channel, the transparent access of special network system, communication controls of remote function entities and the realization of HIT-IIS. 2 communication protocols. Owing to these, the system-wide distributed processing and controls can be achieved.

The interactions among these services and among the HIT-IIS. 2 service systems running in different network nodes are performed by means of communication protocols. There are four types of protocols in HIT-IIS. 2 including server protocol, access protocol, agent protocol and external protocol. The different services in the different nodes interact with each other through server protocol. The same types of services in different nodes cooperate through the agent protocol. The different types of services in the same node interact with each other through the access protocol. The interaction between function entities and the HIT-IIS. 2 services is achieved by the external protocol. The external protocols are the object-oriented, programmable service interface at which function entities access the HIT-IIS. 2 services. All the HIT-IIS. 2 protocols are achieved by special communication system supported by CM service entity.

2 Distributed Architecture of the HIT-IIS. 2

HIT-IIS. 2 is implemented in a distributed processing environment. In logic it is a unified and integrated system, but physically it is distributed in a CIM network. In each node of the CIM network there should be a complete set of services of HIT-IIS. 2. And the HIT-IIS. 2 system adopts client/server technology as its system architecture to provide flexibility of the system configuration and more powerful information processing mechanism. Figure 2 shows the distributed architecture of the HIT-IIS. 2 system.

The HIT-IIS. 2 system running on the network nodes can be classified into a number of service-cells according to the system configuration and function allocation. Every service-cell consists of a server-node and some client-nodes. The node having the full service ability and containing all six services is called a server-node. The node containing the front-end services and the communication services is called a client-node. Client is a HIT-IIS. 2 service

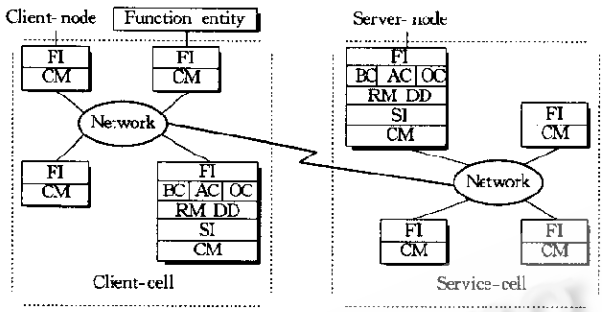

Fig. 2 The distributed architecture of HIT-IIS. 2

system to which a service request is submitted by a function entity. Server is a HIT-IIS. 2 service system providing services for its clients. One server-node can provide services for many client-nodes and one client-node can obtain services from many services through many server-nodes. Client-node accesses services from server-nodes in other service-cells through the server-node in its own service-cell. Server-nodes in the different service-cells interact with each other in the same way. The HIT-IIS. 2 service system running on the server-node can be also a client if it asks other server-nodes to provide services for it. So a client-node is always a client, but a server-node may be either server or client. Additionally, service requests in a service-cell can be decomposed and/or be transmitted to other service-cells via its server-node, thus the distributed control and service of the HIT-IIS. 2 system can be achieved.

The client-node receives service requests coming from function entities. However, client-node is unable to process those service requests because of the lack of the business process services and the information services, so client-node must pass requests to its server-node in the same service-cell by means of the protocols between client-node and server-node, then the control service entity on the server-node executes the controlling, resource and information services, at last passes the results returned by server-node back to the function entities which submit the request.

3 Working Procedure and Case Study

The working procedure of the HIT-IIS. 2 system is described briefly as follows. When a function entity issues a service request by means of external protocol, the front-end service of the client receives the request, passes it to the BC in its server-node within the same service-cell. The BC of the server analyses the request, triggers relevant BP(s), and creates the Business Process Occurrence (BP-O). Then the BC calls RM service to schedule and reserve resource for it. As soon as resources needed by BP-O are obtained, the BC will schedule the BP-O and start executing it. In the procedure of BP-O execution, the BC releases Enterprise Activities (EAs) to the AC orderly through processing PRS (Process Rule Set). In order to evaluate the performance of the HIT-IIS. 2, we adopt a case named shopfloor domain developed by PRC/CEC (P. R. China/Commission of European Community) Collaboration. In the shopfloor domain, there are four domain processes, i. e. Shopfloor Planning and Management (DP1), Shopfloor Manufacturing (DP2), Shopfloor Storage and Transportation (DP3), and Shopfloor Support (DP4). The relationship among them can be showed as Fig. 4.

When receiving manufacturing orders, the first thing to be done is to make plans according to those orders. This is accomplished by coordinating the availability of material, resources and by allocating tasks to manufacturing cells. Then all cells of the shopfloor can work under the management of the Shopfloor Planning and Management domain process. The Shopfloor Manufacturing domain process covers the manufacturing of the parts by the

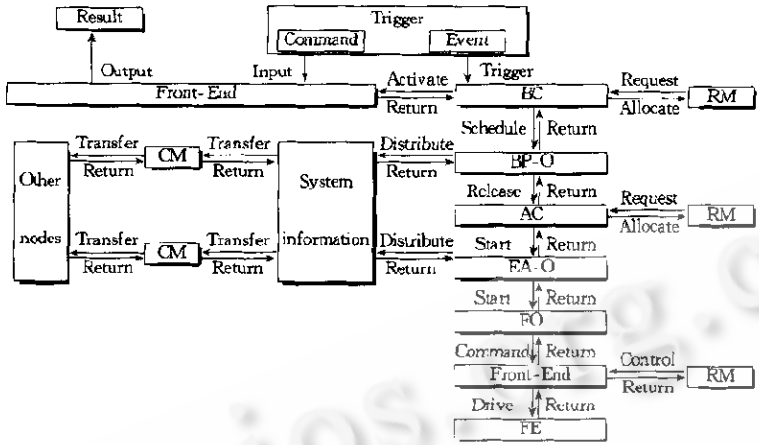

Fig. 3 Working procedure of the HIT-IIS. 2

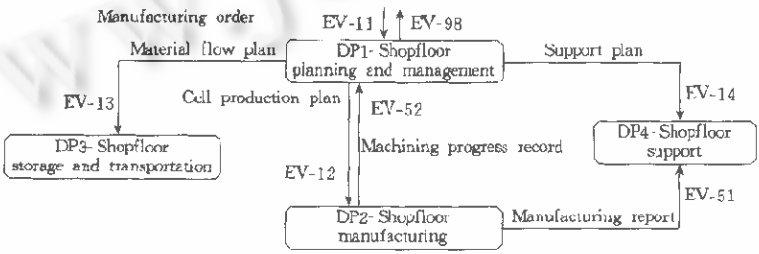

Fig. 4 The four domain processes in shopfloor domain

cells responsible for realizing the cell production plans. The Shopfloor Storage and Transportation domain process is responsible for providing raw material and fixtures. And the Shopfloor Support domain process is responsible for providing auxiliary support, such as tools, equipment maintenance, and so on.

Because the executing process of all the domain processes is similar, we take (Shopfloor Planning and Management) DP1 as an example. Fig. 5 shows the function decomposition of DP1.

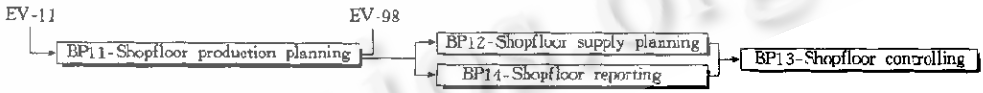

Fig. 5 The function decomposition of DP1-Shopfloor planning and management

When a production order event named EV-11 comes, the BC of the Control Server in HIT-IIS. 2 system analyses EV-11, and BP11-Shopfloor production planning is triggered, meanwhile an occurrence of BP11 named BP11-O is created. Then BC calls RM server to schedule and reserve resources for BP11-O. According to the location and requirement of resources needed by BP11-O, the RM server decides whether to distribute BP11-O or not. If BP11-O cannot be completed in the local node, it can be transmitted to other BCs in different nodes through CM and corresponding protocols. In case resources are obtained, the BC will schedule BP11-O and start executing it. As soon as BP11-O is completed, HIT-IIS. 2 decides either to send an event named EV-98 or intercurrently trigger BP12 and BP13 according to DP1's PRS and the end-state of BP11-O. In this way, DP1 can be executed step by step until it completes.

For the similarity among BPs and with working procedure above, the execution of other BPs in DP1 and all EAs in them can be easily deduced.

By running on the HIT-IIS. 2 through a local network, the production process of machine shopfloor domain can be vitally demonstrated. And through the demonstration, some merits of HIT-IIS. 2 system also can be found as following:

(1) The HIT-IIS. 2 system can do well in supporting the simulation running and property evaluation of CIM enterprise model.

(2) Through the network, and according to the dynamic allocation of resources and the loading of system, HIT-IIS. 2 can really run on a distributed environment.

(3) By using an algorithm, HIT-IIS. 2 system can evaluate the execution performance of every business process and enterprise activity.

(4) By adopting an cost model, HIT-IIS. 2 system can calculate the material cost of a specific business process or enterprise activity.

(5) According to a priority strategy, HIT-IIS. 2 system can select a desirable business process and enterprise activity to be triggered.

4 Conclusion

CIM Integrated Infrastructure is one of key technologies in the research and implementation of CIM System. A few universities and institutes in China have also taken steps in this research field. ShenYang Automation Institute does some theoretical researches. Tsinghua University does most researches in the application system, but their studies do not involve the enterprise models. NorthEast University pays more attentions to the Information Integrated Platform, especially on the heterogeneous databases among the enterprises, but their prototype system can not support the processes of enterprise modeling and enterprise implementation.

The HIT-IIS. 2 system is an opening and distributed CIM integrating infrastructure prototype based on the CIM-OSA standard framework developed by Harbin Institute of Technology. From the view of system implementation, we make some modification, improvement and appropriate simplification on the CIM-OSA, design and implement a prototype system with the kernel functions including business process control services, enterprise activity control services, etc. At the same time, we research deeply on the implementation technology, especially on the implementation mechanism of business process distributed controlling. The HIT-IIS. 2 system can do well in supporting the simulation running and property evaluation of CIM enterprise model, and its principle will also be very important and useful for the enterprise CIM engineering. Considering the development of relevant technology such as intelligent manufacturing, knowledge engineering, virtual manufacturing, etc., we will make further research to improve and extend the HIT-IIS. 2 system functions. Our aim is to develop a new type of integrating infrastructure to support more information types, support agile manufacturing and virtual organization.

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一种 CIM 集成基础结构的设计与实现

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摘要: 在计算机集成制造系统中,CIM(computer integrated manufacturing)集成基础结构是最主要的支撑环境之一.介绍了由哈尔滨工业大学设计和开发的开放式 CIM 集成基础结构 HIT-IIS.2.该原型系统为 CIM 系统提供了以下一些服务功能:经营过程控制、企业活动控制、资源管理、定义描述与维护、全局系统信息服务、通信管理以及系统前端接口等.详细描述其中的每一服务功能.

关键词: 计算机集成制造;CIM(computer integrated manufacturing)集成基础结构;分布式处理系统;接口;体系结构

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