A Distributed VIPD Architecture with Central Coordinator

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Abstract: The paper illustrates what is related between VIPD (Virtual enterprise oriented Integrated Product Development) and information fusion, discusses some limitations of the distributed architecture, proposes a distributed VIPD infrastructure with central coordinator, and demonstrates its central coordinator and global database. By avoiding end-to-end communication and enhancing system security, the architecture will be a good attempt for manufacturing enterprises to unite and reorganize dynamically. On the other side, it will provide a lot of experiences and inspirations in applying multi-source information fusion technologies into complex systems.

Keywords: VIPD (Virtual enterprise oriented Integrated Product Development), information fusion, central coordinator, global database, PDM (Product Data Management)

1. Introduction

1.1 Background

The paper is supported by a research project called “Mode and technologies on VIPD”, which is sponsored by Chinese National High-tech Plan/CIMS topic, and deserves to work on the theories, technologies, and modes for implementing VIPD (Virtual enterprise oriented Integrated Product Development). In the project, a digital product model, with multi-sources information including design history, assembly data, market information, and so on to be built-in, will be constructed [4]. And some advisable experiences and a reference mode for mid-scale and small enterprises to implement dynamic organization, and collaborate from remote locations, will be proposed [1]. The infrastructure, which is described in the paper, will be the basic architecture to integrate engineering environments of the project.

1.2 Arrangement

The paper proposes and illustrates an integrated infrastructure for VIPD, which makes advantages of both central management and distributed computation, and can integrate various polymorphous information derived from all the members of virtual enterprise and their subject product. With its central coordinator, it is more secure for member enterprises to exchange and share their data involved in product development. Moreover, the central coordinator will provide a facility for integrated product teams to collaborate their engineering transaction [10].

It is by seven sections that the paper illustrates the architecture for VIPD. In the next section, we will give an introduction to virtual enterprise and VIPD, which is helpful for readers to understand the infrastructure in the paper. In the third section, we will discuss information fusion in VIPD, which will do readers a favor to get clear for how VIPD will benefit information fusion theory. A simple development history of integrated modes will be given and the infrastructure for VIPD will be introduced in the forth section. After that, the theory and global database of the integrated architecture will be illustrated, and its features and advantages will be concluded. Finally, the paper will be ended with a conclusion and the references.
2. Virtual Enterprise and VIPD

2.1 Virtual Enterprise

With the shorter and shorter product life span, enterprises are required to be enough flexible and agile to meet with smaller and smaller batch of orders. On the other side, however, it is very difficult for a single enterprise to get all the necessary technologies and resources for that. As a result, virtual enterprise (or virtual organization) emerges [2]. Virtual enterprise is one of the perfect styles for agile manufacturing. And what identifies its idea is as follows: in order to develop a new aborative product and win a market battle, some enterprises, which possess necessary resources and technologies for designing, manufacturing, and marketing the product, will make up a occasional union to cope with their rivals together. They select what they are good at and organize them to be a new enterprise, and make it as their behalf for profits [1].

All the components of a virtual enterprise are independent, self-determined, self-organized, and self-optimized, and they generally collaborate with each other and perform as coordinates. Besides, the members are often distributed in different locations, and can take part in more than a single virtual enterprise in the same time [2]. Another standout feature of a virtual enterprise is that a product opportunity determines its presence: when the opportunity occurs, it will be organized quickly; and when the opportunity fades away, it will be disjoint in the same speed.

It is due to their independent feature that many members of a virtual enterprise would be using various product development subsystems, which are usually polymorphous with each other. However, in order to have consistent and common product data so that they can collaborate in development, the subsystems are urgent to get integrated and harmonized [8].

2.2 VIPD

As we know, traditional CIMS (Computer Integrated Manufacturing System) and CE (Concurrent Engineering) have contributed a lot to information and process integration [5][9]. However, in product development, with more and more enterprises becoming dynamic organizations, many new problems, especially those about integration among multi-enterprises, have appeared and expected to be worked out [7]. As a result, VIPD is paid attention to and expected to benefit the problems [1].

VIPD is one of the key technologies for implementing virtual enterprise, which attempts to integrate both the utilities and product development processes into a uniform computer integrated engineering environment. And by drafting, designing, manufacturing, testing, and analyzing the product in a consistent environment, concurrent design and global integration among enterprises can be achieved based on information integration, function integration, and process integration. As a result, development will become faster and performances for concurrent and manufacturability in design can be fulfilled better [2].

Some objectives of VIPD are concluded as follow. Firstly, VIPD will expand its subjects from a part to a complete product, which will pay emphasis on constructing 3-D product model that merging assembly information into [4]. In the second place, VIPD will take up with developing the technologies to support remote collaboration among members of the product development teams, all of which are based on the distributed databases and network systems. Thirdly, VIPD will benefit integrating distributed PDMs (Product Data Management) on the condition of the wide-area network. Finally, as we know, when virtual enterprises get changed, the related supporting environments and technologies should be adjusted accordingly, and which in turn requires those technologies in VIPD to be open and standardized.
3. Information fusion in VIPD

3.1 Information fusion in CIMS

As we know, CIMS is one of the typical complex systems, in which many kinds of data or information, such as those about administration, enterprise, organization, product, financial affairs, etc. will be dealt with. Considering their different features, formats, and sources into, not only different utilities, media, and devices will be used to edit, collect, or store them, but also different methods will be required to tackle with them. All of them, as we know, will resort to the theories and methods about information fusion. As a conclusion, the fusion (integration) of multi-source information will be one of the basic research topics, and will run through CIMS.

3.2 Information fusion in VIPD

VIPD is an advanced technology in CIMS and a landmark in integration. Fundamentally, VIPD results from the rapid progress in information and communication technologies. And when constructing its integrated environments, both the strategies of remote collaborative development, and the features of the product data in open, generality, and interchangeability between engineering fields or developing phases, including market decision, policies making, design, manufacturing, and maintenance, will be emphasized on. As a result, the information sources and supporting technologies in VIPD will be much more complex than those in integrating a single enterprise will. In the next paragraphs, six aspects will sum up several kinds of information multiformity in VIPD, together with their advisable solutions.

(1) The members are different in location. As we know, there are not any limits in position for the components of a virtual enterprise. Generally, by remote communication based on Internet, information exchange and sharing can be conveniently achieved between them.

(2) There exists an evident unconformity between the structures for member enterprises, especially in their resource organizations. One of the main causes for the unconformity is that these enterprises are specialized in different phases of making product, and they are often particular to each other. Consequently, it is necessary for VIPD to consider all the characters of different organizations in establishing security mechanisms and charts for examining, approving, and releasing the changes and proposals.

(3) There are often inconsistencies in rules for the members to instruct their engineers how to design products and by which standards and criterions to constrain their designs.

(4) There are many differences in the carriers of product data. As we know, product data can be stored by the data files (for example, documents and CAD/CAPP/NC files), databases (for example, metadata), and even hard copies. Moreover, there is severe unconformity in the database systems (for example, object-oriented database systems and relational database systems) and data editors (for example, MS Word contrast to VI, PRO/E contrast to UG, etc.). Therefore, in order to exchange and transform between them, it is necessary for engineers to develop various interfaces and front-ends.

(5) Product structures, BOM (Bill Of Material) reports, product management data, and flow charts for developing product, which will be dealt with in VIPD, are polymorphous. A popular resolution for the problem is to develop the corresponding transform forms.

(6) The supporting environments, including networks and database management systems, are polymorphous in a virtual enterprise. Owing to the different history of development environments and different enterprise backgrounds, software and hardware of the networks and database management systems are usually different and even non-compatible. Fortunately, many providers of PDMs (Product Data Management system) have paid a lot attention to the problem and provided many commercial PDM systems, which are packed
together with WWW servers, and can support across-platform navigation and operation [10].

All of the above make an indubitable conclusion that VIPD can be studied as a typical technology and practice for multiple-source information fusion, and the technologies and theories for information fusion are also basic supporting elements for implementing VIPD. In another words, research on information fusion will benefit VIPD a lot; and on the other side, study on VIPD will become one of the important branches and tendencies of information fusion. As will be illustrated in the next sections, the infrastructure for implementing VIPD can’t only settle how to share and exchange polymorphous product data securely between the components of a virtual enterprise, but also support across-platform interoperation by WWW technologies [10]. Accordingly, we can declare that it isn’t only a good resolution for information exchanging and sharing, but also a practical reference mode for information fusion of multiple-source polymorphous.

4. Limitations of the distributed systems and its solution

4.1 The history of integration structure

In the case of traditional central control, a failure from the master would make the entire system to break down, and which can often cause a terrible loss. As a result, distributed control systems appear and get used extensively. It is very evident that the distributed environments possess many advantages over the central control systems. For example, in the former case, each subsystem is independent of each other, and in the event that one of them goes wrong, there isn’t any impact on other systems. As a result, distributed structures have got popular rapidly, and many of their modes, such as those based on agents, have been devised in the last decade.

4.2 Limitations of the distributed systems

As we have seen, distributed structures have been dominant in the last decade. However, with rapid growth in commercial hardware and software for information and communication, limitations of the distributed structure are becoming more and more evident. And in the event of collaborative development in a virtual enterprise, the conclusion is especially true. The next paragraphs will give some details for it.

Firstly, security is one of the critical difficulties in a distributed structure. As we know, all the components of a virtual enterprise are independent of each other, and it’s only for commercial profits that they would get united. Generally speaking, because they often engage in some similar businesses, there are undoubted competitions between them. However, when product data are exchanged in VIPD, some protocols are inevitably required by a distributed system to get correct information. Therefore, it is a popular method to construct agents in all sites of the virtual enterprise. And in order to communicate and inter-operate with other components, it is required that every agent be aware of information in all the other subsystems. However, on the other side, the agent is usually fully accessible to the local administrator. Consequently, component enterprises can’t be assured that their product data are enough secure. As a conclusion, the VIPD environment can’t be established smoothly without an active participation of the components.

Additionally, to a distributed environment, there are many disadvantages in online updating between its subsystems. For example, when one of them gets changed or omitted, or a new one takes part in, it can’t be assured that others be updated in time. Especially in the cases that servers with the agents built in are started and shut up frequently, it’s difficult for them to keep pace with. In such a condition, product data can never keep consistent between the member enterprises.
4.3 Prospects for the structure with central coordinator

In the case of central management to a virtual enterprise, because supporting systems for information exchange and sharing are based on Internet and independent collaborative subsystems, a centralized control architecture can seldom lead to a tragedy. An argument is that the integrated system is an enhanced environment, which is specialization and reorganization for random and anarchy data exchange and sharing, and one of its key functions is for collaboration between remote engineers. And in the event of central server failure, most of engineering activities can be continued in individual sites. After all, communication is not a continuous operation.

Just for the above consideration, most people are turning their attention around central systems once again. In fact, under the condition of a virtual enterprise, because there is always a master member to head the union, which generally goes ahead and have an excellent leading power, it’s probable and feasible to establish a single powerful server to control and coordinate all the communications between members.

Besides, with more advanced technologies and more reliable devices, disadvantages and risks from central control are lessened quickly. Accordingly, in our research project, by probing into the existing development environments, analyzing the motives and uniting modes for implementing virtual enterprise, and considering into the requirements and impacts of a virtual enterprise on the establishments, enterprise cultures and social settings, we conclude a integrated infrastructure for VIPD. The structure is based on commercial PDM systems [10], Internet, browser/server, and central coordinator, makes advantage of both central management and distributed computation, and is helpful to improve the competitive capacity of Chinese manufacturing industry.

5. The infrastructure for VIPD
and its coordinator

5.1 PDMS in VIPD

As has been approved, involved with basic and complex development technologies and terrible workloads, it is acknowledged as a poor way to construct integrated architecture for product development by the foundational network and database systems. Fortunately, with Internet, object-oriented, and digitized technologies developed rapidly, PDM systems have been provided and used for integrating product development supporting subsystems.

PDM is one of the leading supporting technologies for concurrent engineering, which can be used to manage what are related to products (including information for components and parts, product structure configuration, documents and archives, resource organization, and security) and workflow for changing and releasing of item revisions. By taking product structures, development processes, and designers into a uniform platform, PDM can avoid those problems about versions, privileges, and data redundancy [6]. Its essential goal is to make a right person to receive right data and achieve a right task in a right way, right time, and a right location.

Current practices have showed that it’s just a right way to apply PDM systems into VIPD. Moreover, to make use of PDMs’ WWW servers and their client/server architectures and take it as a foundational supporting platform, can quicken and simplify the process for implementing VIPD. Moreover, the practice will show PDMs an improving way in the same time.

5.2 Introduction to the infrastructure

As is illustrated by figure 1, to construct an integrated environment for VIPD, every component of virtual enterprise is firstly required to possess an integrated subsystem for their
developments. All of the subsystems are based on PDM systems and customized with WWW server and communication interfaces, so that any valid users can navigate and operate product data and applications by the allocated privileges in their browsers. In addition, a logical central server will be specified, with its global database and WWW server built in. In such an environment, product data, rules, and descriptions of subsystems can be stored and maintained in a global database, and bi-directional transformation and communication services from a global product structure model to various data views can be provided. Moreover, any valid user, wherever he comes from and locates at, can access the central server by his privileges from his sites.

In such a mode, the central server can provide a powerful coordinator for integrated product development in virtual enterprise, with global databases and file systems in it. And a local WWW servers in a member enterprise can’t only deal with its local transactions normally, but also update in time with central server. In this case, there are explicit links between the local product data and items in global databases, and the other data in a subsystem won’t be impacted at all.

With the architecture, self-determination of a member enterprise can’t be disturbed anyway, and its distributed transaction can also function as well as anywhere. In addition, one of its most important advantages is that the communication functions of a commercial WWW platform can be inherited by using a local WWW server. As a consequence, workloads in developing communication interfaces will be reduced a lot, and the generality, modularization, and standardization of a subsystem will benefit.

5.3 Global database and coordinator

It is a general global product database that describes the subject product of a virtual enterprise in all ways and is used as an essential facility for exchanging and sharing between the subsystems. And status, configuration, and site information for the member subsystems are all stored in the global database by standardized forms. By the database, some necessary services can be provided during the interactive activities between the members. These services include name service, query service, schedule service, transform service, and add and cancel service.

Generally speaking, by name service, a subsystem can call for the others with their names or IDs, instead of knowing their correct addresses. And by query service, a subsystem can ask the central server for what the other members can provide. In such a case, the server will search for the tables for related members and their features and services, and once an item to match with the query conditions is found out, a response message will be sent back to the request. As for the schedule service, in the case that no member can provide any facilities for the request, it can generate an item in a space called “blackboard” to record the requirements. Taking into account that the other members can access the blackboard for the current requirements, when there is a member can provide a requirement, a response will be made and informs the corresponding member.
Another service, which will enhance the VIPD architecture, is transformation performance of the global database. It is by transitional forms that the service can assist different subsystems to achieve an exchange for their polymorphous product data, such as BOM reports, etc.

Finally, by add and cancel service, when a virtual enterprise wants to get a new member or cancel an existent one, what it will have to do is to change the lists in the global database.

5.4 Features

In the architecture, the WWW servers and their customized services are very similar in all members, so a central server with its global database is the only key facility for VIPD. With ODBC and across-platform programming languages, all components can be standardized easily. As a conclusion, the architecture is good at compatibility and practical in implementing.

Under presence of the central server, subsystems can contact the central server directly for a communication, instead of communicating with their destinations in point-to-point mode. Besides, by the infrastructure, when an enterprise want to join, what it is required is to customize a little for its PDM system and publish information to the central server by the procedures, so that the latter can update its status, rules, security and privilege tables in time. Because its description lists can be updated online, items can be added or changed at any time. As a result, it is more convenient to add or cancel a new member or applications and change meta-information for a product.

Accounting that the members can communicate with each other by only contacting with the central server, end-to-end interaction can be avoided and the system will become more secure and practical. To sum up, we can declare that such a system is open and compatible, and can take full advantages of both the distributed computation and the central management.

6. Conclusion

The paper identifies virtual enterprise, VIPD, and PDM, illustrates how VIPD and information fusion theories impact each other in their system architecture. Additionally, the limitations of both the central and the distributed architecture are discussed. Afterwards, an open and compatible infrastructure for implementing VIPD is proposed and its coordinator is demonstrated. Based on commercial PDM systems and browser (client)/server, the architecture can take full advantages of the distributed computation and the central management. Moreover, by avoiding end-to-end communication between the members of a virtual enterprise, the integrating mode based on the architecture can reduce what to do for configuring subsystems, enhance system security, lessen data transfer, benefit information sharing and exchange in a virtual enterprise. As a conclusion, it will be a good way for Chinese manufacturing enterprises to unite and implement virtual enterprise. And on the other side, the architecture will provide many useful experiences and inspirations for applying multi-source information fusion technologies into complex systems.

7. References


