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The application of workflow management technology in Web-based collaborative produce development

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Abstract

This paper mainly addresses the integration of engineering processes of enterprises performing collaborative product development in the form of virtual enterprise. The virtual enterprise support system with three-tier architecture is proposed first. The workflow process modelling and execution services are located in the business tier as service components. The implementation of information integration and application integration is discussed as the basis for business process integration. The characteristics of Web-based collaborative product development process are analysed, and the corresponding solution for process modelling and integration is proposed. The organization model is build up for assembling a product development team. On these bases, the main steps of implementing the collaborative product development supported with workflow management technology are presented.

Keywords: Workflow; Virtual Manufacturing; Collaborative Product Development

1. Introduction

Product development is complex system engineering. The development of product as a whole involves partners working in various industrial sectors. The manufacturer usually adopts the strategy of collaborative product development in order to produce high quality product with lower cost and short development period. The booming Internet and e-commerce technology enable distributed enterprises to develop product collaboratively in the form of virtual enterprise or supply chain, which is becoming the main manufacturing paradigm.

Comparing to the operation and management of traditional enterprise, it needs more efforts in coordinating the partners in a virtual enterprise. Therefore, there are strong demands for the integrated management of collaborative product development process. As an information technology for integrated managing and automating business processes, workflow management system can instantiate process instances according to pre-defined workflow process model, and control the execution of them. In the course of execution process instances, application and/or services are invoked to process the relevant documents and information. The work items are added to the work-list of workflow participants, or the performers are notified about the work to be done.

The application of workflow management technology in the area of product development or manufacturing is focused on collaborative product development[1][2][3], distributed product data management[4][5], engineering change management[6]. This paper mainly addresses the integration of engineering processes of enterprises participating collaborative product development in the form of virtual enterprise. In section 2, the structure of virtual enterprise support system is proposed first. The workflow process modelling and execution services are located in the business tier of the virtual enterprise support system as service components. The implementation of information integration and application integration, which are the bases of business process integration, is discussed in section 3. In section 4, the characteristics of collaborative product development process are analysed, and the strategy for modelling and integrating business processes in collaborative product development is proposed first, then the building up of organization model is given. The main steps of implementing the collaborative product development supported with workflow management technology are presented in section 5. Finally, concluding remarks are given in section 6.

2. Virtual enterprise support system

Virtual enterprise support system supports the collaboration of geographically distributed enterprises, which have distinct organization border. Therefore, it is a typical Web application with three-tier architecture as shown in Figure 1. The first tier includes application clients, which are usually standard Web browsers. In some cases the application client can be proprietary for accessing certain business services located in the middle tier. The middle tier includes the Web servers and application servers. The Web server processes the HTTP requests from the application clients, returning the Web pages for presentation, while the application server performs computation according to business logic, returning the results to the Web server and then to the application clients. The third tier provides data service for the Web serve and application serve to access data sources.

The process definition and workflow execution service are located in the middle tier of the virtual enterprise support system. The middle tier can also provide other business services that are needed by the operation of virtual enterprise, such as product/service information publication service, partner selection

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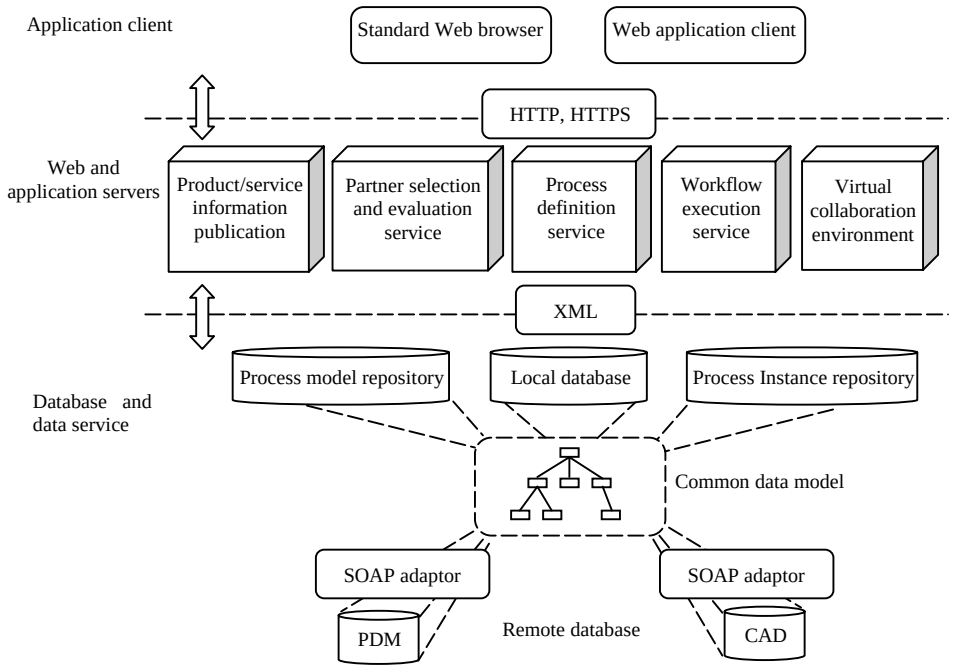

Figure 1. Virtual enterprise support system

and evaluation service and virtual collaboration environment etc. The process definition and workflow execution service mainly include process definition component, workflow engine component and workflow execution monitor. Process definition component are used to plan the execution of business process, finally producing workflow process model that can be instantiated and executed by the workflow engine. Process definition service provides visualized user interface as well as sufficient and straightforward modelling elements for usual enterprise users.

A workflow process definition defines the objects in a business process, such as activity (representing a process step or a work item to be accomplished), process participants, the invoked applications and the relevant data object for the execution of the business process. A workflow process definition also defines the attributes of the objects in a business process and the relationships between these objects, such as the transition between the activities and the logical relationship of these transitions (AND, OR, XOR etc.). The finished workflow process definition of a business process is stored in process model repository and released for initiation.

The main functionalities of workflow execution service are to create process instances, controlling the execution of existing processes instances according to pre-defined rules, assigning the task of manual activities to the work-list of the proper user or notifying the user. Workflow execution service is implemented by a workflow engine or a group of cooperative workflow engines. Each workflow engine is composed of a server accomplishing certain functionality and a communication module. The communication module is responsible for accessing process model repository or communicating with other workflow engines. A user can access workflow execution service to initiate the process instances of a process model that the user has the right to do so. The accomplished tasks are submitted to the workflow engine for the subsequent execution.

The progress and the execution status of the process instances are the important information for the managers of collaborative product development to make decision. Workflow execution monitor provides visualized presentation of the execution status of the process instances that is initiated by an end user. In order to realize the supervision of the execution of process instances, the modelling elements representing the execution status of a business process are introduced in the workflow process definition. In the run-time, the workflow execution monitor acquires the information on the execution status of the concerned process instances or activity instances, showing their execution progress to the end user in visualization form.

3. The integration of information and application

A product or one of its parts is described by data from various sources, which are distributed among and maintained by the involved application systems of the collaboration partners, for example, the CAD, CAM or PDM systems. These data are in heterogeneous format and are difficult to be exchanged. However, the necessary and sufficient engineering data have to be shared and exchanged in order to develop product collaboratively. The sharing and exchanging of heterogeneous information in networked manufacturing can be implemented through Web-based information integration. Thus the engineering data concerning a product are physically heterogeneous and distributed, but logically are integrated as a whole. The information shared or exchanged by collaboration partners are also shared and exchanged by their internal engineering processes. As the basis of business process integration, these information are defined as the common data objects that are referred by the internal process definition of each collaboration partners.

In virtual manufacturing environments, the OEM collaborates with partners from various industrial sectors. The openness and extensibility of XML enables the OEM and each of its partners to create the XML documents with elements, their attributes and relationships pertaining to a industrial sector, which will

drastically facilitate the information sharing and exchange between the OEM and the corresponding partner.

Most of the CAx systems and PDM systems support the standard for product information exchange, i.e. STEP (Standard for the Exchange of Product Model Data). However, an application cannot obtain the needed data from a STEP file through the Web. The mapping mechanism of the entities in the STEP file to the elements in the XML document has to be built up for sharing and exchange product data from various application systems based on the Web.

The application integration means the interoperability of the applications. The implementation of the interoperability of applications requires the support of distributed computing environment, such as the remote procedure call (PRC), Web application programming interface (WAPI) and communication middleware. The communication middleware includes message-oriented middleware (MOM), the object request broker (ORB) of Object Management Group and Java 2 platform enterprise edition (J2EE) of Sun Microsystems etc. In case of representing data with XML, the Web service technology can provide open and standard inter-enterprise application integration. Web service utilizes the Simple Object Access Protocol (SOAP), which is built on the top of the widely used HTTP protocol, providing a mechanism for exchanging structured complex data objects in the form of XML. The execution of business process needs the interoperability between the workflow management system and the involved applications, which can be implemented with these distributed computing technologies.

4. Strategy for modeling and integrating product development process

Virtual enterprise is loosely coupled actual enterprises with common objectives. Collaborative product development involves the internal design process of partners, in which the trade experiences, know-how and business knowledge of the participated enterprises are embodied. On the one hand, the enterprises need to collaborate with each other; on the other hand, they required protecting their competitive know-how. Actually, in order to enable collaborative product development, the product or service providers need only to know the requirements model of the component defined by the OEM, to share and exchange the necessary and sufficient engineering information and to submit the development results to the OEM. They do not need to expose the internal structures of their product development process. Under these process-modeling requirements, the integration of business processes can be implemented in the following way:

- The process models of the internal product development process and engineering change process are built up by the collaboration enterprises themselves.
- The internal product development process of a partner is modeled either as a workflow process that can be interpreted and execute by the specified workflow execution service, or as manually executed block activity in case of no workflow execution service deployed inside the partner.

For the manufacturer that needs to integrate its business process with the internal business process of its collaboration partner, the latter is modeled as a black box and implemented as a sub-flow. The specification of the interface between the main workflow and the sub-flow should be defined as well. In the run-time, the workflow execution service interoperates with the workflow execution service of the sub-flow, thus the whole product development are integratedly executed.

Under the loosely coupled organization relationships, an enterprise can neither expect nor require that workflow management system be deployed in its collaboration partners. Therefore, the strategy of combining the centralized and decentralized process modeling and execution should be adopted, i.e. all the collaboration enterprises that have not deployed workflow management system use the workflow process modeling and execution service provided by virtual enterprise support system. The collaboration enterprise that has deployed workflow

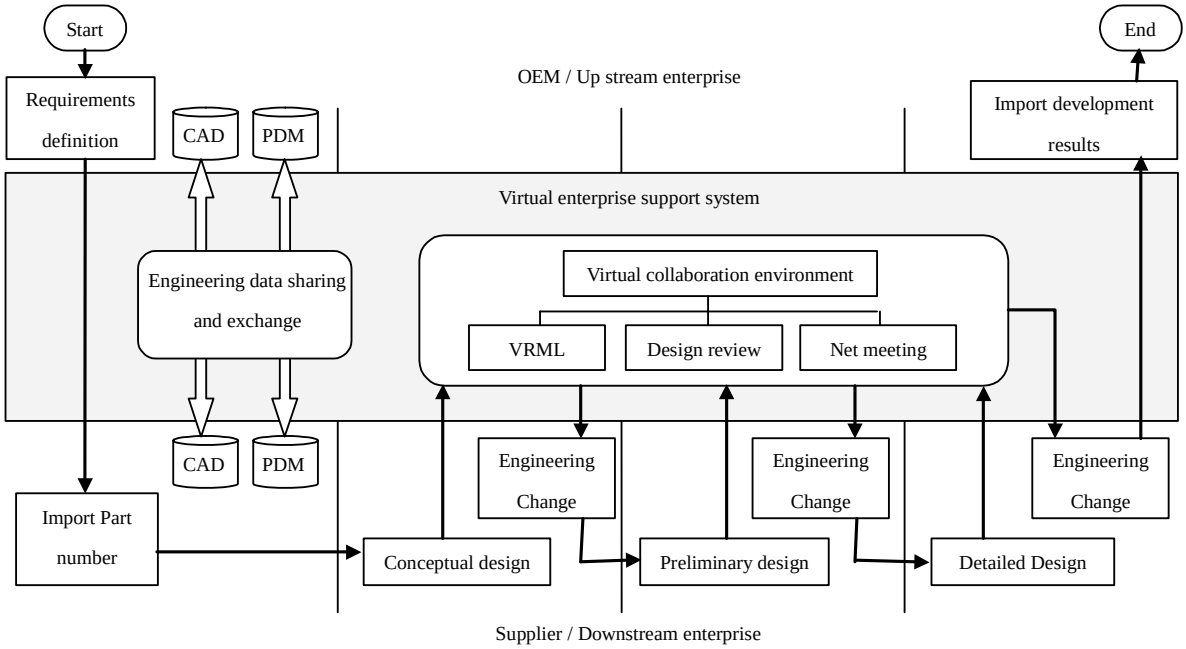

Figure 2. Collaborative product development process and its modeling granularity

management system still uses the process modeling and execution service of its own. Two kinds of workflow execution services are bound in the run-time and interoperate to execute distributed process instances.

4.1 The characteristics of product development process

The distinct characteristics of product development process that distinguish it from other business processes are that product development process usually lasts long period, covering from several weeks, several months to several years. Product development is also an innovative process since the intelligences of the developers are necessary. As the product development process undergoes the requirements modeling, conceptual design, preliminary design and detailed design phase, frequent engineering change process will inevitably occur so as to meet the increasingly manifested product requirements. Comparing to the business processes, such as order processing process and loan process etc., which have relatively stable process structure, the dependencies and relationships between the activities in product development process are very complicated. The execution of product development process is high dynamic.

These characteristics of product development process make it difficult to build up the product development process model exactly at the beginning of product development. It is also required that the workflow modeling and execution services also have high flexibility so as to adapt to the dynamic product development process. Considering the requirements and the characteristics of collaborative product development process comprehensively, the strategy of modeling collaborative product development process with large granular process steps is proposed in this paper. Only the major engineering steps as well as the milestones for checking development results are modeled, as shown in Figure 2. The internal product development process and engineering change process are modeled as one process step in the collaborative product development process and implemented as sub-flows. Thus, on the one hand, the requirements of protecting the know-how of each partner are met; On the other hand, the dependencies between large granular process steps are relatively simple and stable. The dependency on the flexibility of workflow process modeling and execution is also drastically decoupled.

4.2 The organization model of product development team

When coordinating product development process with workflow management technology, not only the aspects such as activities, the logical dependencies between these activities, the conditions to execute each activity, the documents and information, and the applications to deal with the documents and information should be modelled, but the workflow participants and the policies to assign tasks should be defined in the process model as well. If the tasks are directly assigned to the users, or the organization model is defined within the workflow process model, the process model will be lack of flexibility because the workflow process need to be redefined when the organization structure or the members of the project team of each collaboration partner are changed. In the virtual manufacturing environments, the member and its role in the product development team of a partner are assigned by the partner itself. It is difficult for the process modeller to obtain and maintain the information inside an organization.

In order to enhance the run-time flexibility of workflow management functionality, organization model is separately defined, which will be referred to by the relevant workflow process model and will be implemented through a database maintained by

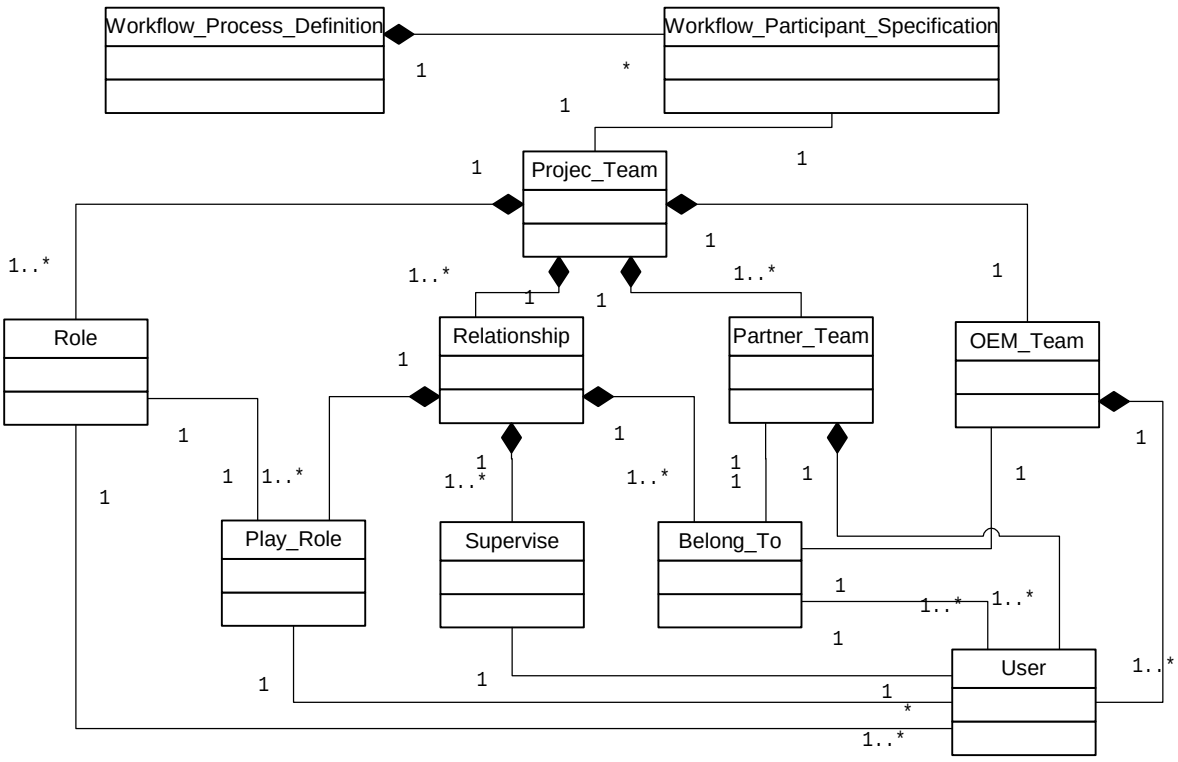

Figure 3 The organization model of collaborative product develepment team

virtual enterprise support system. Each collaboration partner is responsible for registering and maintaining its organization information. In the workflow process model, tasks are assigned to abstract organization objects, such as role or workgroup. These abstract performers are instantiated in run-time. For example, the actual performer, as well as the way of assigning tasks (e-mail or work-list) and the coordination mechanism between the performers with same role or in the same workgroup, is extracted from the organization database.

The organization model of collaborative product development defines the objects, their attributes and relationships concerning the collaborative product development team. The main objects of the organization model are OEM team, partner team, department, workgroup, user and role etc. A role is a collection of users capable of accomplishing certain organization functionalities, while department and workgroup groups the users according to their subordination relationship. The relationships between organization objects include 'Play Role', 'Belong To' and 'Supervise' etc. Both the objects and their relationships have attributes. For example, user has the 'Name', 'E-mail' and 'Post Address' attributes; Role has 'Name', 'Responsibility' attributes; Play-Role has the 'User Name' and 'Role Name' attributes etc. An organization model of a collaborative product development team is shown in Figure 3. In this figure, the organization object 'Project_Team' is associated to workflow process definition through 'workflow participant specification'.

5. The implementation of collaborative product development process

Collaborative product development process is started after the collaboration relationship is established. The enterprise users have to register in virtual enterprise support system for accessing to the services. In order to highlight the support for collaborative product development process, the concept of project management is adopted. The development of each product corresponds to a project folder in virtual enterprise support system. All the information that concern the development of a product, such as project management, project team, the relevant process model, the product structure and its attributes, are grouped in its project folder.

At the beginning of collaborative product development process, the OEM creates a project folder and shares it with its collaboration partners. Then each collaboration partner registers its users under the project team entry of the project folder using service of virtual enterprise support system, which is based on the organization model shown in Figure 3. The OEM is responsible for defining product structure and assigning the part numbers, and associating each part or component to be outsourced with a collaboration partner according to its responsibility.

In the next steps, the OEM and each of its collaboration partner determine the necessary and sufficient information that has to be exchanged between them in the product development process, creating corresponding data objects according to the data model, defining the interface specification between their internal engineering processes. The involved application systems such as PDM and CAD systems should also be determined. The adaptor between these application systems and the virtual enterprise support system should be developed too. Finally, the process model of collaborative product development process can be defined based on the results obtained in the previous steps.

The collaborative product development process is coordinated with workflow execution service of virtual enterprise support system. After the collaborative product development process model is built up, it is assigned to the users who have rights to initiate the process instances, for example the project leader or the coordinator of OEM. Then the workflow engine submits the tasks to the work list of relevant users, providing right information to right the people at right time, navigating the execution of collaborative product development process from one step to the next.

6. Conclusions

With the support of Web and e-commerce technology, it is a growing trend that the enterprises with common goals participate collaborative product development in the form of virtual enterprise or supply chains. Collaborative product development is complex system engineering. In this paper, the XML based information integration and the Web services based application integration are addressed as the basis of business process integration. The requirements for protecting the competitive know-how and for the flexibility of workflow execution service are analysed. Then the strategy of modelling business process with large granular process steps is adopted. This paper also proposes the strategy of separating the organization model of collaborative product development team from the workflow process definition. These strategies reduce the dependency on the flexibility of workflow execution service.

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