Workflow Activity Task Controller: an Approach to Distribute Knowledge and Information in Collaborative Product Development

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1. Introduction

Historically, many manufacturing companies have concentrated on implementing information systems solutions in business processes. The integration of design and manufacturing information and knowledge management tools to support product development has often been neglected. The methodology proposed in this paper is to utilise workflow technology to improve integration and ease information exchange during product development processes. Traditionally, workflow technology is used to provide computer support for an organisation's business processes (Sayal et al. 2001), (Moore and Graham. 2002). However, until recently there has been little interest in making workflow systems more adaptive (Chang et al. 2001), (Narendra. 2001), (Van der Aalsta and Bastenb. 2002) or in using knowledge-based techniques to provide more flexible process management support than is possible by simply using current workflow systems (Stader. 1996), (Chung et al. 2003).

Companies are increasingly being aware of Product Data Management (PDM) systems and many of them are using such technology to store product-related information. Furthermore, the emerging technologies of PDM Systems encompass advanced web-based capabilities to distribute information across the World-Wide-Web (WWW). Inevitably, there is a need to make PDM workflow functions more adaptive to cope with agile manufacturing scenarios. Although one research area is the Task Based Process Management (TBPM) system architecture developed by Chung et al. (2003), the research does not specifically relate to PDM. The approach adopted by the project is common in workflow systems in which process models are actively used for supporting business processes. In addition, the project extends the scope of current workflow systems by not only using simple models of processes themselves, but also models incorporating knowledge about the application domain and the organizational context in which the processes are being enacted.

This paper presents a theoretical approach to workflow process management using well established PDM functions for controlling knowledge and information to support collaborative product development processes within the WWW. The new methodology is called Workflow Activity Task Controller (WATC) that can securely distribute design and manufacturing knowledge to support process planning with information exchange during the early stages of the product development phases. Most specifically, WATC uses the methods described herein to link the workflow management of a PDM system with a knowledge-based system and a process planning system. In addition, this framework is flexible and adaptive and can be extended to adapt to a specific company's needs. The objective and the intention of the development are to improve information flows, promote sharing of design and manufacturing knowledge and subsequently to maximise effectiveness of product development activities and task efficiency.

2. Background and Applications of Workflow

Workflow management theory dates back to the late 1980s when diagramming began to be used in a few pioneering organizations to support basic business processes (Beizer. 2002). Plesums (2002) states that "workflow is the automation of internal business processes or operations, in whole or part, during which documents, information or tasks are passed from one participant to another for action and tracking its progress according to a set of procedural rules."

Extensive literature reviews have shown that the majority of applications utilising workflow analysis techniques are mainly centred around providing computer support for an organisation's business processes (Sayal et al. 2001), (Moore and Graham. 2002). Such business processes include customer order processing, product support in marketing, stock taking and processing. However, little work has been done in applying the techniques enterprise wide in particular to support the design and manufacture and product development process which would benefit from these tools. Although research has been carried out on cooperating workflow and web-based technologies, the scope of the applications are narrowly focused and limited to business processes. For instance, (Abecker et al. 2000) demonstrated two approaches to utilizing web-based technologies and workflow techniques. The VirtualOffice scenario emphasized the use of workflow context information for improved document analysis and information extraction. The KnowMore approach supports a person working on some knowledge-intensive task by actively delivering context-sensitive and relevant information. Sayal, et al. (2001), describe how workflow technology and Business-to-Business (B2B) Standards such as RosettaNet, Common Business Library (CBL), Electronic Data Interchange (EDI), Open Buying on the Internet (OBI), and commerce eXtensible Markup Language (cXML) can be extended in order to support B2B interactions and to link them with the internal workflows. Cheung et al. (2003) examined the requirements of extending a workflow to the provision of e-services to fulfill predefined business processes and data requirements. The work proposed by Liu and Shen. (2003) is based on a process-view coordination model that can be extended to effectively address the issues of managing B2B workflows.

3. Workflow Methodology

3.1 Introduction to Workflow Methodology

Workflow is a methodology for analysis, modelling, assessment and reorganisation of working processes taking place within an organisation which involves the coordination and collaboration of different individuals as represented in Figure 1. The basic idea of Workflow is to describe the work and the activities taking place in an organisation as a business process, namely a "structured measured set of activities designed to produce a specified output for a particular customer or market" (Davenport. 1993). Another aspect of workflow is the improvement of working processes and its coordination through the introduction of Information and Communication Technology (ICT) and cooperation amongst individuals involved in the work processes.

Fig 1. Workflow System Characteristics

3.2 Different but Related Approaches in Utilising Workflow

This section describes different approaches to workflow which have been proposed and implemented in different areas other than business processes. Malamateniou and Vassilacopoulos. (2003) present a Virtual patient record (VPR) framework that allows the integration of geographically dispersed medical information within a health district and enhances collaboration and coordination of authorised workgroups by means of a web-based workflow system. VPR provides a means for integrated access to patient information that may be scattered around different healthcare settings. In this context, a VPR implementation enables autonomous healthcare providers to operate in a cooperative working environment and apply continuity of care. Workflow systems bring this collaboration and co-operation into effect by automatically routing the medical information needed by authorised actors in a healthcare process.

Tunnicliffe and Maropoulos. (2003), implemented a Cost Data Warehouse (CDW) strategy to share global cost reduction data for an automotive manufacturer. CDW allows cost reduction ideas to be effectively communicated and managed across departments such as design, purchasing and parts suppliers on a European and global scale to continually reduce the cost of manufacture throughout the vehicle life cycle. The system utilizes web-based technologies, business process re-engineering techniques and links to a mainframe system, which contains product design data of live part numbers to allow users to deal the issues in real-time. Huang et al. (2000) proposed to use workflow management as a mechanism to facilitate teamwork in a collaborative product development environment where Web-based Decision Support Systems are extensively used by geographically distributed team members. The concept used is workflow management supported by agent technology to prevent inconsistency and reduce redundant project activities. It can improve coordination and interaction of the engineers who work remotely in different locations.

Chung et al. (2003) investigated the use of ontologies, agents and knowledge-based planning techniques to provide support for adaptive workflow and flexible workflow management, especially in the area of new product development within the chemical industries. The work in this project uses a Task Based Process Management (TBPM) workflow engine, the Task Manager, to support heterogeneous agents (humans and software agents) in working together to achieve their tasks. The Task Manager includes a process modelling tool and an interactive process planner. The planner uses artificial intelligence techniques to assist in the planning of tasks, while permitting the user to participate in planning decisions. An agent-based architecture supports the execution and coordination of the planning process among multiple participants distributed across a computer network. TBPM also provides a process management framework that integrates with specialist third-party software systems such as simulation and analysis tools which are essential in chemical engineering.

None of the systems described, however, are currently exploited in the area of utilizing advanced tools such as a web-centric PDM system, which provides an easier and faster implementation of workflow modelling. PDM systems offer a Workflow function which enables the user to create a pattern of 'automation' to assign alternative tasks and eventful sequences as dictated by a company's operational procedures. Moreover, due to rapid advancement of Web-based technologies and data exchange formats such as XML, XML Data Interchange Format (XMI) and Resource Description Framework (RDF). In theory it should be possible to create a generic, ad-hoc model to capture the basic workflow patterns which are suitable for any PDM systems. Rather than capture internal operations within an organisation, it would be possible to use inter-enterprise operations. WATC attempts to achieve this integration with the application of internal and external sources through the native PDM's workflow function, the approach is explained in the following section.

4. The Technical Approach of WATC

This section describes the core of the proposal and the development of WATC which are based on the application of Windchill PDM system and its workflow functionality. The introduction of a PDM workflow and its capabilities are briefly discussed. The overall development of requirements and security measures creating a workflow are also highlighted. The ad-hoc workflow representations of the industrial collaborators are used to show how WATC can be integrated into the Windchill Workflow function to emphasise the usage of the WATC methodology in knowledge distribution to support product development.

4.1 Introduction of the PDM Workflow function

MatrixOne PLM, SmarTeam and Windchill (PDMs. 2003) are a few of the leading PDM systems available in the current market. All of these have common basic functionality. Their primary goal is to structure, control, make available and distribute product centric information throughout the whole of product life cycle. The PDM systems' workflow function serves the same purpose to streamline business workflow by linking people, information and processes together to improve productivity, efficiency and throughput.

The advancement of PDM technology and the development of user friendly graphical interfaces have had the effect of speeding up the time to customize such a system to suite the company's needs. The graphical user interfaces provide configurable and customizable support for workflow tasks through standard web browsers. It allows users to create new items such as activities to represent product development processes, predefined and user-defined tasks, automatic triggers and tracking and control over product life cycle reviews and approvals. Despite the effective support for business management and product development processes all these systems lack the capability of distributing and reusing of knowledge in product design and manufacturing processes to support product development. The purpose of WATC is a technical approach of creating a common Workflow which would bridge the gap of knowledge sharing. The algorithmic methodology can be adopted and embedded into different PDM systems' native workflow function.

4.2 Internal and External Integration Requirements and Security of Workflow Applications

Figure 2 illustrates the integration requirements for the design of a workflow, which can be differentiated into internal and external integration requirements (Becker et al. 2002). The role of networking allows all users to interact with the web services and the collaboration of external and internal applications.

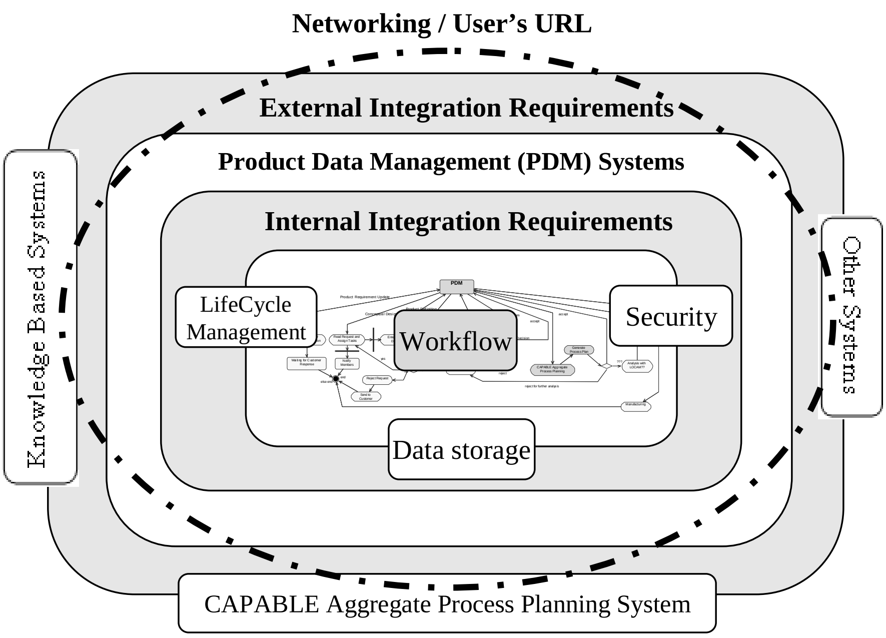

Fig 2. Design of PDM Workflow Requirements

Internal integration requirements concern those systems and functions which a workflow application needs to connect to. For example, the internal functionality of a PDM system is life-cycle management, data storage and security. External integration requirements exist with regard to systems that either invoke the workflow system from the outside (embedded usage) or systems that are invoked by the workflow application, for instance, the software systems such as the Knowledge-based system and the CAPABLE Aggregate Process Planning System (Bramall et al. 2003). Since work coordination involves external networks and external applications, another issue that must be addressed is security in the WWW. One major advantage of using PDM systems for Workflow is that, they automate information flows between individuals carrying out business processes and it has two major implications for security.

i. Firstly, since the description of a workflow process explicitly states when each function is to be performed and by whom, security specifications may be derived from such descriptions and translated into static role-based specifications.

ii. Secondly, since the Workflow functions are to be operated via Web-browsers, individual security rules must be enforced.

4.3 The Ad-Hoc Workflow Modelling

Figure 3 illustrates a Workflow Activity Task Controller in UML (Unified Modelling Language) activity diagram. The diagram defines a typical workflow for the product development processes. The core technologies behind WATC are methods to control the interactions of a PDM system, a Knowledge Based System and a Process Planning System. The implementation of WATC is centred on the workflow functionality within a PDM system. Hence, WATC sequences activities including design and development tasks such as knowledge sharing and automated process plan generation. Originally, workflow analysis techniques would only assign tasks during the product development processes. However, WATC aims to elaborate the techniques further by applying them into a network environment through the application of web-based technologies such as eXtensible Markup Language (XML) and a Java-based XML parser. Generally, WATC involves five stages as depicted in Figure 3:

i. Receive Customer Request and Adding Customer Historic Information
ii. Notify Product Development Team Members and Enter Conceptual Design Data
iii. Reviewing Conceptual Model and Adding New Knowledge
iv. Reviewing New Product Definition and Decision Making
v. Generate Aggregate Process Plans (Routing) for Capacity Planning

The workflow starts with the customer’s request for a new product or a change to an existing product. The initial stage is adding customer historical information such as previous product specifications, customer buying experience and relationships. This can be done by invoking a knowledge-based system. The knowledge-based system consists of two separate modules, one is for the design knowledge management system that captures information related to product design and design standards (Aziz et al. 2003), and the other is for manufacturing knowledge management to capture process and resource related knowledge (Cheung et al. 2003). The primary action of the workflow is to activate the process by assigning a task to make a connection with the KBS. All the information or relevant knowledge is stored or retrieved via a Windchill PDM Cabinet function. The Windchill Cabinet function is used to store product centric information and provides a method of locating information within the PDM system. The second stage of the workflow is to assign a concurrent task which involves notifying team members of the development team and issues requests to the appropriate personnel to enter conceptual design data. The third stage of the workflow is to review the conceptual design.

The fourth stage is an XML Parser mechanism which facilities the interaction of the CAPABLE Aggregate Process Planning System and the PDM Cabinet. The XML Parser is responsible for extracting manufacturing knowledge from the XML formatted knowledge file to be reused by the process planning engine. With the attachment of updated historic information and manufacturing knowledge, a new product definition will be generated. The product definition will be delivered to the CAPABLE Aggregate Process Planning to obtain preliminary process plans. The purpose of the CAPABLE Aggregate Process Planning System is to allow alternative process plans (or routings) for custom parts to be generated, evaluated and improved based upon estimated *manufacturability* before committing to a fully specified product model and supplier. The new process plans (routings) are then delivered to the PDM system for Plan/Review. The final stage involves capacity planning and implementation.

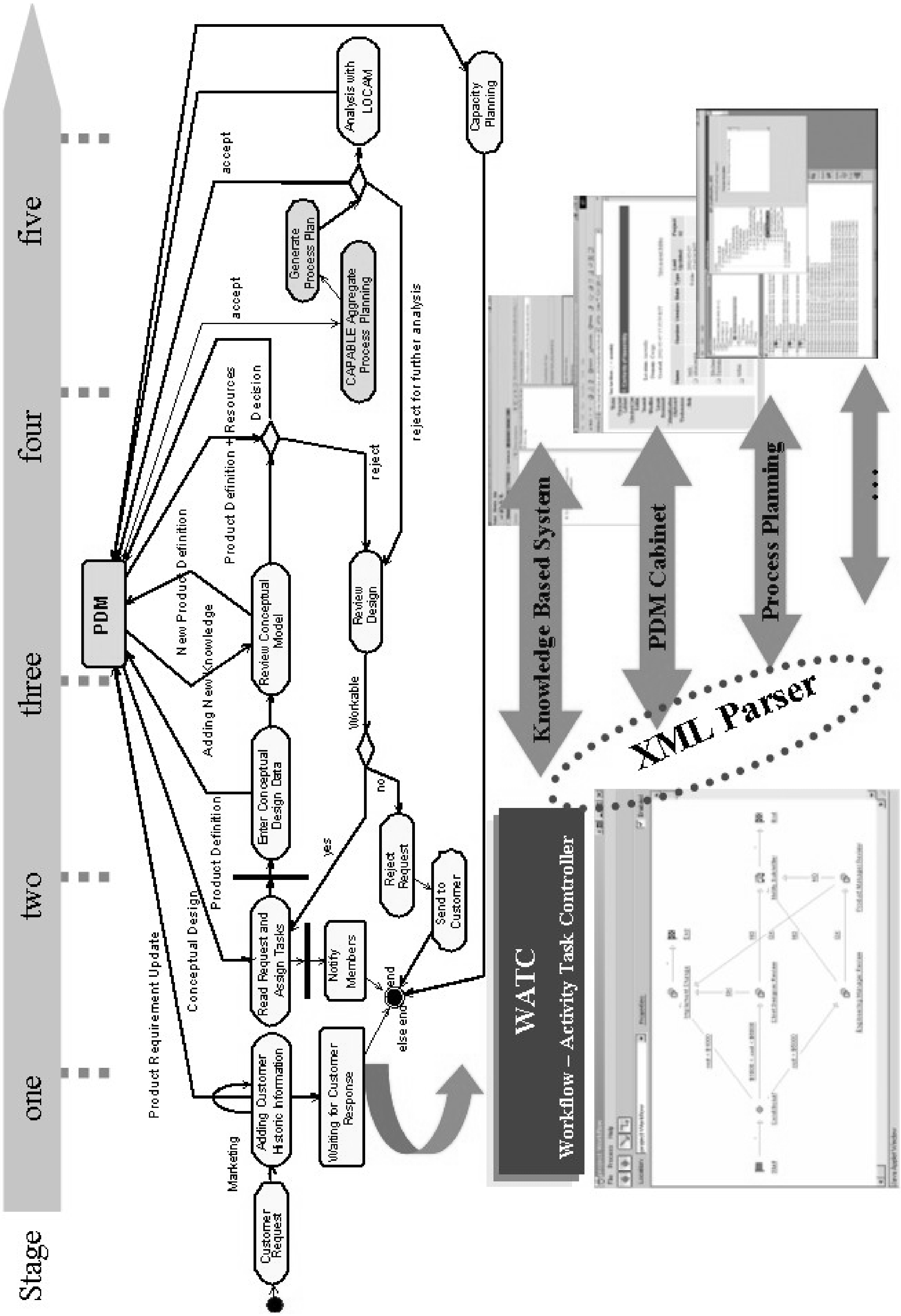

Fig 3. Representation of WATC

5. Conclusions and Further Work

This paper outlined a method for distributing the right kind of design information using PDM Workflow to support product development. The proposed WATC method leverages the capabilities of PDM systems through the application of web-based technologies. In particular, the framework facilitates effective access and reuse of manufacturing knowledge during the initial stages of the product development process. The overall idea of the development is to enhance and enable users of the PDM Workflow function to interact with external software systems and gain fast access to reusable knowledge about product design, manufacturing processes and resource requirements. Although the development of WATC focuses on the conceptual product development stages, it can be easily adapted for later stages such as product-review and product-submission by the application of the PDMs' Life-Cycle Management function. Further work is also underway on the XML parser which is part of the main element to demonstrate external integration within WATC.

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