

# Agent-based workflow management in collaborative product development on the Internet

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## Abstract

Product development is collaborative, involving multi-disciplinary functions and heterogeneous tools. Teamwork is essential through seamless tool integration and better co-ordination of human activities. This paper proposes to use workflow management as a mechanism to facilitate the teamwork in a collaborative product development environment where remote Web-based Decision Support Systems (TeleDSS) are extensively used by team members who are geographically distributed. The workflow of a project is modelled as a network. Its nodes correspond to the work (packages), and its edges to flows of control and data. The concept of agents is introduced to define nodes and the concept of messages to define edges. As a sandwich layer, agents act as special-purpose application clients for the remote TeleDSS application servers. Agents are delegated to manipulate the corresponding TeleDSS on behalf of their human users. Details of the proceedings are recorded by agents as their properties for future references or shared uses by other team members. Through flow messages, agents are able to share input and output data and request for remote services. One of the major contributions is that agents, once defined, can be reused for different projects without any changes. © 2000 Elsevier Science Ltd. All rights reserved.

*Keywords:* Collaborative product development; Internet; Web; Agent; Workflow

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## 1. Introduction

A product development project consists of a set of work packages that in turn consist of activities and tasks. A team is established to conduct the project. Each team member may be responsible for one or more work package and/or activity. In addition, for each work package or activity, there may exist one computerised Decision Support System (TeleDSS) remotely available on the Internet accessible from Web browsers. Together with the corresponding TeleDSS, a team member is to accomplish his/her work package for which he or she is responsible. Project tasks and activities are interrelated. Therefore, team members must collaborate and corresponding TeleDSS must interact at some stage(s) of executing a project. The project team may be drawn from multiple corporations to form what is now called a Virtual Enterprise (VE). Alternatively, the team may be established within a single corporation but from different disciplines and functions. No matter, in a virtual or real enterprise paradigm, the team may well be distributed in the sense that they are geographically

dispersed, diverse applications are involved, and the tools and systems used operate on different platforms using different protocols with different user interfaces. These have created great difficulties and hindrances in teamwork and tool integration required for Collaborative Product Development (CPD). This has challenged both industrialists and researchers over the last decade or so.

Significant efforts have been made to develop computer supports to facilitate teamwork. Early developments and achievements in computer supported concurrent engineering had been reported in an American Society of Mechanical Engineers (ASME) workshop organised by Sriram, Logcher and Fukuda [24] and a special issue in the IEEE (Institution of Electrical and Electronic Engineers) Computer Journal (1993). Recent surveys by Huang and Mak [10] and Erkes et al. [6] indicate that the Internet/Web technology is playing increasing roles in developing and applying TeleDSS for CPD. Indeed, a number of major initiatives and projects, recently launched in America and Europe involving government, academic and industrial institutions, have adopted the Internet/Web technology as their development infrastructure. Examples include the Manufacturing Automation and Design Engineering (MADE) program and its follow-up *Rapid Design Exploration and Optimisation* (RaDEO) program [20], the Agile Infrastructure for

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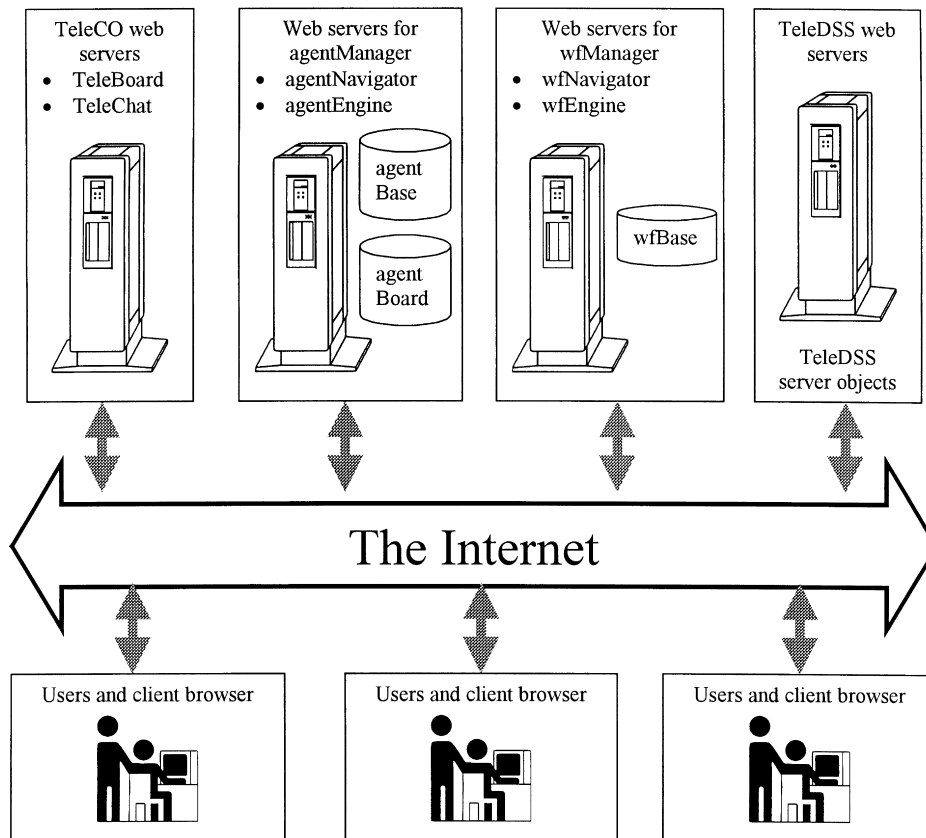


Fig. 1. The ActiveTeam architecture.

Manufacturing Systems (AIMS) project [1], the Technologies Enabling Agile Manufacturing (TEAM) program [25], the Global Engineering Networking (GEN) project [9], and Production Planning and Management in an Extended Enterprise (PRODNET) project [19]. More projects are emerging in other countries and regions. Demonstrative systems are being developed. CyberCut [23] and MADE-FAST [5] were two well-known early experiments. Roy et al. [22] have also presented experimental workbenches for Web-based design to production, including activities such as conceptual and detail product design, process planning, Design for Manufacture, NC (Numerical Control) programming and rapid prototyping.

Significant progress has been achieved in developing and applying Group or Team Decision Support Systems (GDSS). Web-based teamwork frameworks have emerged from two directions. One is from Computer Supported Collaborative Work (CSCW) and the other is from Workflow Management (WFM). The aim of applying the Web technology in CSCW is to develop Web-based framework or architecture to support teamwork or group decision-making. Participants are typically human users, rather than computer systems. One example of Web-based CSCW is the Web implementation of the GroupSystems methodology [21].

The Web technology has been applied for WFM. Resulting frameworks not only involve human participants

but also software systems. WebWork [14] is an example of Web-based WFM systems based on the METEOR WFM methodology.

In parallel, research on Distributed Artificial Intelligence (DAI) has resulted in Multiple Agent Systems (MAS) that can be used for enabling Web-based CPD [17].

On basis of the findings from the research into agent-based collaborative engineering, CSCW, WFM, and Web-based DSS in product design and manufacture, this research proposes a Web-based framework to facilitate, rather than automate, teamwork in CPD where TeleDSS are extensively used at geographically distributed locations. This paper focuses on the aspect of WFM, including defining, co-ordinating and monitoring the flows of work, information and control between multiple TeleDSS. The concept of agents is proposed and incorporated into the workflow network model. The project workflow integrates the tools and team members towards a common goal of the product development project. It plays significant roles in facilitating better teamwork for CPD in a Web-based environment.

## 2. Web-based collaborative product development

Fig. 1 shows a general Web-based architecture, Active-Team, proposed in the long term in this research to

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