Available online at www.sciencedirect.com
ScienceDirect
Expert Systems with Applications 36 (2009) 2659–2669
Expert Systems with Applications
www.elsevier.com/locate/eswa

The design of a JADE-based autonomous workflow management system for collaborative SoC design

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Abstract

Given a fast changing electronics goods marketplace, designers of integrated circuits and components need to be more competitive, efficient, flexible, and use collaborative workflow to reduce time-to-market and a project's life cycle. In recent years, agent-based workflow management systems (WfMS) have been widely used to monitor and control business design processes. In this paper, intelligent agents are applied to the collaborative system-on-chip (SoC) design environment. The proposed JADE-based autonomous workflow management system (JAWMS) uses a workflow coordination mechanism and an agent integration mechanism to enable the analysis, management and interaction of automated design processes. The workflow coordination mechanism uses five domain specific agents to perform the workflow enactment services and a generic agent to control the system flow logic. The system kernel of JAWMS follows the specifications of the workflow reference model provided by the workflow management coalition (WfMC). The agent integration mechanism supports an agent to interact with other JADE-based agent platforms and to coordinate and monitor workflow coordination messages. All agents are written in the Java language using the JADE platform and work together to perform flexible, adaptive and dynamic design tasks in an autonomous and collaborative way. JAWMS facilitates SoC design and team interaction in a collaborative but distributed product development environment.

Keywords: Workflow management; Collaborative design; Intelligent agent technology; JADE

1. Introduction

In the past decade, workflow management systems (WfMSs) have been distinguished due to their significance and their impact on organizations (Cardoso, Sheth, Miller, Arnold, & Kochut, 2004). Workflow management is a promising technology that automates the business processes to improve the speed, efficiency and manageability of an organization's teamwork (Wang, Wang, & Xu, 2005). In order to reduce time-to-market and a project's life cycle, many organizations propose workflow management system as a mechanism to facilitate teamwork in a collaborative product development environment (Huang, Huang, & Mak, 2000; Huang, Trappey, & Yao, 2003). However, due to the lack of flexible and integrated mechanisms to deal with data exchange and application integration between heterogeneous systems, traditional workflow management is often too inflexible to meet the complex, dynamic situations in distributed, heterogeneous platforms. Recently, the use of agents for collaborative design has been demonstrated (Trappey, Trappey, Hou, & Chen, 2004). Researchers apply agent technology in the workflow system to achieve the benefits of autonomy, reactivity, pro-activeness, and mobility (Huang, Trappey, & Yao, 2006; Kuo, 2004; Xia & Li, 1999). There remain several issues with the use

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doi:10.1016/j.eswa.2008.01.064

of agent-based systems. The problem of coordination and communication between agents and agent-based platforms is often the central focus of the research (Xia & Li, 1999).

In this paper, an autonomous workflow management framework based on multi-agent technology for collaborative system-on-chip (SoC) design is proposed. The proposed framework, named as JADE-based autonomous workflow management system (JAWMS), follows the specifications of the workflow reference model defined by the workflow management coalition (WfMC, 1999). In order to enhance the cooperation and coordination between agents, workflow ontology is created and a standardized workflow metadata model is implemented. JAWMS use a workflow coordination mechanism and an agent integration mechanism, in which a society of intelligent agents work autonomously and collaboratively to perform design tasks. The workflow coordination mechanism uses five domain specific agents to perform the workflow enactment services and a generic agent to control the system flow logic. The agent integration mechanism supports an agent to interact with other agent platforms and to coordinate with workflow coordination mechanism. Further, the java agent development framework (JADE) (JADE, 2007) is used as the agent platform for linking the heterogeneous SoC design systems in a distributed environment.

The contributions of this paper are twofold. First, we adopt multi-agent technology to develop an autonomous workflow management system for collaborative system-on-chip (SoC) design. The proposed framework suits the heterogeneous environment of electronic component design firms. Second, the workflow ontology is enhanced and clarifies the relationship between workflow components. The goals of the proposed system include ease of construction, interoperability, and information transparency.

The remainder of this paper is organized as follows. Section 2 reviews the related literature in the areas of workflow management systems, agent technology, and JADE platforms. Section 3 describes the collaborative SoC design process and environment and provides a workflow diagram for SoC design. Section 4 illustrates our autonomous workflow system framework, the workflow ontology, and the agent communication model. Based on this framework, a prototype of an autonomous workflow management system for collaborative system-on-chip (SoC) design is developed. The last section summarizes the contributions and provides suggestions for future work.

2. Literature review

2.1. Workflow management systems

With the rapid development of Internet and information technologies, many organizations are faced with managing the workflow for collaborative design on heterogeneous platforms linked to a distributed computing infrastructure. A workflow is an ongoing process distributed among multi-participants that transfer information or tasks according to some previous defined rules or sequences (Huang et al., 2003). The workflow management coalition defines a workflow management system (WfMS) as a software application that supports the specification and execution of a workflow (WfMC, 1999). The system contains a set of tools and interfaces that provide support for the necessary services of workflow management, process definition, administrative and monitoring tasks, workflow client applications and other invoked applications (Georgakopoulos, Hornick, & Sheth, 1995; Hollingsworth, 1995). ARTech Consultores (2002) defines four types of workflows, i.e., administrative workflows, production workflows, collaborative workflows and ad hoc workflows. The main differences between these types are the workflow structure, repetitiveness, predictability, complexity and rules of flow logic (Cardoso et al., 2004). Kuo and Cheng (1999) identify three Rs, i.e., Roles, Routes and Rules, which a WfMS must provide for automating well-defined and structured workflow. However, the logical workflow, considering the combination of internal and external flows on heterogeneous platform in a distributed environment, is still a very challenging research area (Wang, Shen, & Hao, 2006).

2.2. Agent technology and agent-based workflow management systems

An agent is a software entity that can autonomously perform routine tasks with a degree of intelligence (Boudriga & Obaidat, 2004). Nwana (1996) divides agents into seven types, i.e., collaborative agents, interface agents, mobile agents, information/Internet agents, reactive agents, hybrid agents and smart agents. Goal driven agents typically possess three key characteristics, i.e., autonomy, cooperation and learning (Etzioni & Weld, 1995; Liang & Huang, 2002; Nwana, 1996). They are capable of acting autonomously, cooperatively, and collectively. The purposes of applying agent technology to develop applications are intended to exchange flexibility and reduce risks of concurrent, distributed and collaborative information processing, particularly for concurrent and distributed product design and manufacturing.

Using agents to perform WfMS functions is an emerging field where researchers are exploring the ability of agents to improve process integration, interoperability, reusability and adaptability (Huang et al., 2006; Trappey, Trappey, & Lin, 2006). More and more researchers believe that agent technology can provide coordinative architectures for integrating multiple heterogeneous workflow system (Kuo, 2007). An agent-based WfMS is a set of software agents that manage and coordinate the flow of work defined by a business process (Odgers, Shepherdson, & Thompson, 1999). The agent-based approach facilitates design process knowledge reuse while supporting distributed dynamic process management. From the system point of view, most WfMSs are multi-agent systems and can be classified as agent-enhanced workflow management and agent-based