



# Enterprise integration using the agent paradigm: foundations of multi-agent-based integrative business information systems

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## Abstract

Enterprise integration through integrated business information systems (IBIS) is necessary to achieve agility in the current age of hyper-competition. Multi-agent systems (MAS) provide a new paradigm for IBIS development. In this paper, we review the IBIS modeling and MAS literatures and find that the MAS paradigm provides an excellent approach for modeling and implementing IBIS systems. We synthesize these two bodies of literature and propose a conceptual framework for multi-agent-based integrative business information systems (MIBIS) and a unified set of eight orthogonal ontological constructs that are minimally required for any conceptual modeling grammar for the MIBIS bounded universe of discourse.

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## 1. Introduction

To thrive in the current hypercompetitive environment, businesses not only need to integrate their internal stovepipe applications, they also need to

integrate their application systems with their supply chain partners' systems. Both the practitioner publications and academic literature have noted the significant benefits that information systems integration both within and across the enterprise can bring about for businesses in terms of improved planning, timely deliveries, reduced inventories, reduced costs, improved product line in tune with market needs, and responsive and improved customer service.

Information systems (IS) reengineering and integration became one of the most important IS issues in the early 1990s, driven by the call for business process

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simplification and cross-functional process integration, the key tenets in Hammer and Champy's [54] landmark work on business process reengineering (BPR). In fact, the top four IS issues that emerged from a 1994–1995 Delphi study of senior IT executives [12], pertain directly to the notions of IS responsiveness, reengineering, and integration.<sup>2</sup> Work in these inter-related areas has continued since the early 1990s in both the information technology (IT) industry and the academia under a variety of labels including enterprise resource planning (ERP), enterprise application integration (EAI), integrated supply chains, and workflow management.

Most of the enterprise and IS integration efforts have utilized the object-oriented (OO) paradigm and component-based architectures as the technological solution for the integration problem (e.g., Refs. [4,34–36,67,81,115–117]). However, some researchers have focused on the intelligent agent and multi-agent systems (MAS) approaches as more suitable alternatives for e-business and enterprise integration applications, and have developed and utilized agent approaches and technologies in e-business applications [66,70,72,124,142], business process management [63,65,102], supply chain management [60,118,143], enterprise integration [82,101,110,111], and manufacturing [76,109].

While the popularity and application of the agent technology in the business domain has grown over the recent years, the field is currently marked by unique and innovative approaches and architectures for solving the business and IS integration problem. There is currently a lack of a unifying framework that not only synthesizes literatures in the two pertinent streams—business/IS integration (e.g., BPR, ERP, workflow, etc.) and the MAS paradigm—but also provides a foundation for conceptual analysis and modeling of integrative business information systems based on the multi-agent systems paradigm. The goal of the present paper is to fill this void. We review relevant literature in these two key major areas and find that the MAS paradigm indeed provides an excellent approach and suitable mecha-

nisms for developing integrative business information systems to achieve the goal of creating an integrated enterprise. We also synthesize the two bodies of literature and propose a conceptual framework for multi-agent-based integrative business information systems (MIBIS).<sup>3</sup> We also identify a minimal set of orthogonal ontological constructs [15,73,114] that are central to the MIBIS bounded discourse universe [74].<sup>4</sup> We take the approach of minimal ontological commitment [51] in our synthesis as we wish to identify only those ontological constructs that are absolutely essential for conceptual analysis and modeling of MIBIS systems.

The paper is organized as follows. In Section 2, we discuss the role of information systems in business integration, define the concept of Integrative Business Information Systems (IBIS), and review a number of approaches authors have taken for conceptual analysis and modeling of such systems. In Section 3, we discuss the notion of agents, agent communication, multi-agent systems, and how multi-agent systems provide an appropriate architecture for IBIS using various coordination mechanisms. In Section 4, we synthesize the IBIS and MAS literatures, and develop a unifying multi-agent-based integrative business information systems (MIBIS) framework as a means for achieving business integration. In Section 5, we discuss why the constructs are necessary for the analysis and design of MIBIS systems and how they will help enterprise integration modeling. Finally, Section 6 concludes the paper.

<sup>3</sup> While the acronym MIBIS contains the letter S for the term system, we use the phrase MIBIS system for ease of reading. We also use the phrase MIBIS entity in this paper to refer to a multi-agent-based integrative business information system.

<sup>4</sup> A universe of discourse comprises the realm of the phenomenon of interest and of the logically possible propositions within that realm. A bounded discourse universe delineates a narrower realm of interest. If information systems is treated as an unbounded universe (because it will deal with concepts from every imaginable perspective), the MIBIS universe is a bounded universe because we are only interested in concepts pertaining to a particular type of information system, one which is an integrative business information system and is based on the multi-agent systems paradigm.

<sup>2</sup> The top four issues in this study include: (1) building a responsive IT infrastructure, (2) facilitating and managing business process redesign, (3) developing and managing distributed systems, and (4) developing and implementing an information architecture.

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