Agent-Based Intelligence Infrastructure

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INTRODUCTION

Today's enterprises must go beyond traditional goals of efficiency and effectiveness; they need to be intelligent in order to adapt and survive in a continuously changing environment (Liebowitz, 1999). An intelligent organization is a living organism, where all components and subsystems work coherently to enable the enterprise to maximize its potential in its goal-driven endeavors. Stonier (1991) suggested that intelligent organizations must have not only intelligent individuals, but also "collective intelligence" that is created through integration of intelligence from sub-units of the organization. Researchers have developed frameworks for building organizations around intelligence, as opposed to traditional approaches that focus on products, processes, or functions (e.g., McMaster, 1996; Liang, 2002). Analogous to intelligent biological life, an intelligent organization has a life of its own. An intelligent enterprise understands its internal structure and activities, as well as external forces such as market, competition, technology, and customers. It learns and adapts continuously to the changing environment. The learning and adaptation are achieved through real-time monitoring of operations, listening to customers, watching the markets, gathering and analyzing data, creating and disseminating knowledge, and making intelligent decisions.

Building an intelligent enterprise requires an intelligent foundation that supports intelligent reasoning and behavior at all levels of the organization. Modern information and communications technologies, combined with artificial intelligence (AI) research, provide necessary tools to create and sustain intelligence in the organizational infrastructure. Artificial intelligence has found wide applications in business, ranging from production planning and scheduling to data mining and customer relationship management. However, traditional AI systems have focused on domain-specific problem solving. Simple job shop scheduling and product malfunction diagnosis do not lend themselves well to enterprise-wide management. A more recent branch of artificial intelligence research is distributed artificial intelligence (DAI). DAI helps "far-flung, often stand-alone, application components work toward a common goal" (Chaib-draa, 1998, p. 31). Another development in AI research is the study of agent-based systems, in which autonomous software agents are deployed to carry out various tasks that are traditionally performed by humans (Jennings & Wooldridge, 1998). Recent advancements in distributed artificial intelligence, multi-agent systems, and networking technology have laid the foundation for real-world deployment of intelligent agents (Martin, Cheyer & Moran, 1999; Moukas, Zacharia & Maes, 2000).

BACKGROUND

Intelligent agents go by various names such as software agents, softbots, autonomous agents, or simply, agents (Huhns & Singh, 1998). Russell and Norvig (1995, p. 33) defined an agent as "anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors." An intelligent agent is, according to Franklin and Graesser (1996), "a system situated within and a part of an environment that senses that environment and acts on it, over time, in pursuit of its own agenda and so as to effect what it senses in the future." In practical applications, intelligent agents are named according to their main functions. Examples include news agents, e-mail agents, shopping agents, search agents, information brokering agents, personal assistant agents, collaborative agents, negotiation agents, transaction agents, security agents, and so on.

Intelligence infrastructures have not been well studied. However, many successful businesses have already built intelligence infrastructures, enabling them to become intelligent enterprises. Broadly speaking, an intelligence infrastructure includes all basic facilities, services, and installations needed for the functioning of an intelligent enterprise. Intelligence infrastructure is defined as information technology-based facilities, systems, and services that support holistic intelligent behaviors

throughout an organization. In the 1970s and 1980s, the information infrastructure of a business consisted of database and database management systems that supported various business processes. During the 1990s, businesses began the move from information age organizations to learning organizations, characterized by an information infrastructure based on data mining and knowledge management systems. Intelligent agents have emerged in recent years as key components in the organizational information infrastructure.

The evolution of modern organizations and their information infrastructure can be classified into three distinctive phases, as depicted in Figure 1. Information age organizations emphasize data and information processing. Transaction processing systems (TPSs), management information systems (MISs), decision support systems (DSSs), and executive information systems (EISs) are traditional business information systems used at different managerial levels. Database (DB) management and knowledge management (KM) provide the infrastructure support for learning organizations. A learning organization emphasizes knowledge creation, sharing, and dissemination. Supply chain management (SCM), enterprise resource planning (ERP), business process redesign (BPR), and total quality management (TQM) are commonly used in learning organizations. Multi-agent systems (MASs) can be designed to create dynamic connections to various information systems. MASs, DBs, and KM provide the foundation for distributed intelligence. Intelligence infrastructure (II), global resource management (GRM), and customer relationship management (CRM) are indispensable components of an intelligent enterprise.

Intelligent organizations require seamless integration of all systems in the organization through the intelligence infrastructure. Global resource management systems allow the intelligent organization to scan, analyze, and integrate global resources. The existence of advanced information and communication systems such as MASs, IIs, and GRMs does not automatically guarantee the success of the organization. It is a necessary condition for intelligent enterprises. Success of those enterprises depends on the assimilation of advanced information technologies into their organizational design.

A key feature of the intelligence infrastructure is the integration of all components and subsystems within the enterprise. Those components and subsystems include not only various information and knowledge systems, but also management control, human resource management, and environment management. Intelligent agents automate key operational processes, monitor operations, schedule activities, coordinate tasks, process data, anticipate needs, deliver proactive information and services, negotiate and collaborate with other agents, and intimate with their masters—the knowledge users. What distinguishes intelligence infrastructure from other types of systems is its ability to continuously capture and integrate business process knowledge, hence improving the organization's ability to learn and adapt while the changes occur, not after.

Although intelligent agents have found many successful applications, the research on integrating intelligent agents with traditional systems to create intelligence infrastructure is limited. Much of the research on intelligent agents has focused on technology issues and spe-

Figure 1. Evolution of organizations and their information infrastructure