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New Architecture for Intelligent Multi-Agents Paradigm in Decision Support System

Noor Maizura Mohamad Noor and Rosmayati Mohemad
Universiti Malaysia Terengganu
Malaysia

1. Introduction

In recent years, intelligent agent concepts have been applied in decision support systems (DSS) for business users (Bose & Sugumaran, 1999). Another research was done by Rahwan et al. (2004) where they used intelligent agents in one to many e-commerce negotiation to automate decisions making processes. Computer technology is increasingly being used to support executive decision-making in DSS environment (Moynihan et al., 2002). DSS are computer programs that aid users in a problem solving or decision-making environment. These systems employ data models, algorithms, knowledge bases, user interfaces, and control mechanisms to support a specific decision problem (Barkhi et al., 2005). Various researches have shown the uses of DSS in order to handle complex decision modeling and management process. Based on my readings so far, there are no literature discussing and applying intelligent multi-agent architecture in DSS especially for distributed environment.
In this research, intelligent multi-agent technology is proposed in developing DSS to enhance the system to be able to work in dynamic environments and support the adaptability of the system. Agent is defined as a software abstraction and logical model. The idea is that agents are not strictly invoked for a task, but activate themselves. Related and derived concepts include intelligent agents where they have the ability to adapt on the new situation with some aspect of learning and reasoning. Another derived concept is multi-agent systems that involve distributed agents that do not have the capabilities to achieve an objective alone and thus must communicate. In the environment of distributed system, agents play a major role in assisting a real user in making decisions where these agents are given the authority to communicate to each other in order to achieve the objective.

2. Motivation

Research that has been done by Parunak (2006) proposed multi-agent support system that can adapt to a user's resource constraints, resource priorities, and content priorities in a dynamic environment. Here, multi-agents that cooperates each other will consider the preferences and constraints of a user while gathering and assembling information.
The construction industry involves multiple parties such as clients, consultants and contractors. Project success relies heavily on the timely transfer of information among these parties (Kashiwagi, 2002). Projects involve a large number of organisations that may be geographically dispersed.

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The planning of a construction project is among the most challenging tasks faced by a project team (clients, consultants and constructors). Decisions made during this stage have a tremendous impact on the successful execution of the project from its early conceptual phases, through to project construction and completion. The construction industry is seen by many as being backward in its deployment and use of IT (Huang, 2001). Application of IT has been comparatively slow and only very few construction companies have a comprehensive and integrated IS to support its core business.

Many businesses use the Internet as a new technology platform to build a range of new products and services, and even to redesign their communication system and services (Ngai et al., 2003). With great advances in Internet and WWW technologies, various attempts have been made to implement Web-based DSSs for different applications in the areas of sales, design and manufacturing (Smith & Wright, 1996). However, very little has been reported on the use of the Web-based technologies for selecting the best alternative in the construction businesses.

The causes of time and cost problems in construction management projects can be traced back to poor coordination caused by inadequate, inappropriate, inaccurate, inconsistent, or late information, or a combination of them all (Deng et al., 2001). However, the physical distance between the parties further contributes to the communication barrier and thus a key factor in inhibiting information transfer. The availability of timely and accurate information is also important for all parties as it forms the basis on which decisions are made and such that concrete progress could be achieved.

The above issues arise despite the remarkable advancement in information management, handling, storage and exchange techniques. Improving communication among parties is thus a key factor that could lead to the success or failure of decision making processes. Furthermore, IT can be seen as having a mediating effect on communication, leading to new patterns of communication or changes in the content and quantity of existing kinds of communications. A coordination technology can encourage participants to control the way a decision is made, monitor results, improve productivity of meetings and support the team's decision-making process (Yazici, 2002).

With the advent of the Internet, collaborative e-business has been attracting more and more attention from both the academia and industry. Various technologies are being developed to support collaborative e-business, such as customer relationship management (Siebel, 2001), supply chain management (Indent, 2001, Commonce One, 2001), electronic market (Ariba, 2001), automated negotiation and auction systems (Huang, 2001, Kumar & Feldman, 1998, Su et al., 2001) and DSS in various applications (Mysiak et al., 2005).

3. Decision support system

Computer technology is increasingly being used to support executive decision-making (Moynihan et al., 2002). Nemati et al. (2002) explains that decision-making is the ability to make the 'right' decisions. The tendency is to focus on decision makers (DM's) moment of choice even though the process is complex (Simon, 1977). This focus is however not limited to a DM's preceding and subsequent decision-making processes as some DMs bear the responsibilities for decisions that were made even by their subordinates and groups. Simon (1977) identified three steps in a decision process: (a) *intelligence* as searching the environment for conditions requiring decision, (b) *design* as inventing, developing, and analysing possible course of action, and (c) *choice* as selecting a particular course of action.

A DM receives information in various formats such as printed materials, graphics, verbal and visual observation. While a computer can extend the memory of a human being, humans are often not very good information processors (Chen & Lee, 2003). The condition when information overload occurs can cause a rapid and severe degradation in the performance of decision-making. Good information is, therefore necessary but not sufficient for a good decision. A DSS can also be designed to support the creative and intuitive aspects of decision-making (Pearson & Shim, 1994, Phillips-Wren et al., 2004).

DSSs can also increase managerial effectiveness by improving personal efficiency, expediting problem solving, facilitating interpersonal communication, promoting learning, especially about how the system works, and increasing organisational control (Alter, 1980). These potential benefits lead many researchers and practitioners to believe that DSSs can be a powerful strategic weapon for organisations.

Bharati & Chauhury (2004) projected the organisational and individual impacts of DSSs and they categorised the impact and benefit into organisational and individual impacts as well. The former reflects on the structure, centralisation of authority, power and status. The latter reflects on productivity and job satisfaction. This factor constitutes the manager's satisfaction with the uses and benefits of its DSS for example in supporting decision making processes.

4. Intelligent agent technology

Intelligent agents are software or hardware entities that perform a set of tasks on behalf of a user with some degree of autonomy (Barley & Kasabov, 2005). Several applications in a variety of domains including: Internet-based information systems, adaptive (customizable) software systems, autonomous mobile and immobile robots, data mining and knowledge discovery, smart systems (smart homes, smart automobiles, etc.), decision support systems, intelligent design and manufacturing systems. Current research on intelligent agents and multi-agent systems builds on developments in several areas of computer science including: artificial intelligence (especially agent architectures, machine learning, planning, distributed problem-solving), information retrieval, database and knowledge-base systems, and distributed computing (Godoy et al., 2004).

Distributed intelligent multi-agent systems offer modular, flexible, scalable and generalisable algorithms and systems solutions for information retrieval, extraction, fusion, and data-driven knowledge discovery using heterogeneous, distributed data and knowledge sources in information rich, open environments (Parunak, 2006). Such systems consist of multiple interacting intelligent software agents. Such as reactive, proactive, anticipatory, goal-driven, adaptive, reflective, introspective, knowledge-seeking, autonomous, interactive, communicative, collaborative agents and multi-agent systems find applications in Internet-based information systems, adaptive (customizable) software systems, large scale data-driven knowledge discovery from heterogeneous, distributed data and knowledge sources, collaborative scientific discovery (e.g., in bioinformatics), intelligent decision support systems (e.g., monitoring and control of complex, distributed, dynamic systems) (Jennings et al., 1998).

Intelligent agents play the role of assistants by letting managers delegate work that they could have done to these agents. Agent technology is finding its way into many new systems, including DSS, where it performs many of the necessary decision support tasks formerly considered a uniquely human activity. Intelligent agents are useful in automating

repetitive tasks, finding and filtering information, intelligently summarizing complex data, and so on; but more importantly, just like their human counterparts, they have the capability to learn from the managers and even make recommendations to them regarding a particular course of action. Agents utilize several artificial intelligence techniques such as machine learning, and inductive and deductive reasoning to exhibit the "intelligent" behaviours.

There are many definitions of intelligent agents found in the literature. The definition, by Maes (1994), that "intelligent agents are software entities that carry out some set of operations on behalf of a user or another program with some degree of independence or autonomy, and in doing so, employ some knowledge or representation of the user's goals or desires," is the most appropriate for our purposes. Agents possess several common characteristics, such as their ability to communicate, cooperate, and coordinate with other agents in a multiple-agent system. Each agent is capable of acting autonomously, cooperatively, and collectively to achieve the collective goal of a system.

The coordination capability helps manage problem solving so that cooperating agents work together as a coherent team. The coordination is achieved, for example, by exchanging data, providing partial solution plans, and handling constraints among agents.

5. Objectives

The aim of the research is to propose a new architecture for a multi-agent based DSS in distributed environment.

The objectives of this research are:

1. To determine the characteristic of conventional DSS system.
2. To construct new architecture of an intelligent multi-agent of DSS.
3. To test and evaluate the applicability of the approach using a real-world scenario by using proof-of-concept and operational prototype system.

6. DSS design and functions

DSS consists of the following agents: a) contractors interface agent, b) client interface agent, c) coordinator agent, d) report agent, and d) database agent. The whole architecture is depicted in Figure 1. The overall DSS agent architecture consists of three high-level modules: a) interface module, b) process module, and c) knowledge module. The interface module deals with is publicly visible to other agents and users (consultants and clients). It provides mechanisms for interacting with the agent and supports inter-agent communication and collaboration. The process module and knowledge module are restricted only to the agent that is, other agents or users cannot directly manipulate the contents of these modules without access privileges.

The process module contains methods and heuristics that implement a variety of functions and processes using which the agent can respond to requests from other agents or users. Thus, the process module basically provides the services and computations that may be necessary in solving a particular problem. The knowledge module contains domain-specific and domain-independent knowledge relevant to problem solving. The detailed design of the three above-mentioned DSS agents, in terms of the three high level modules, is described section 8.

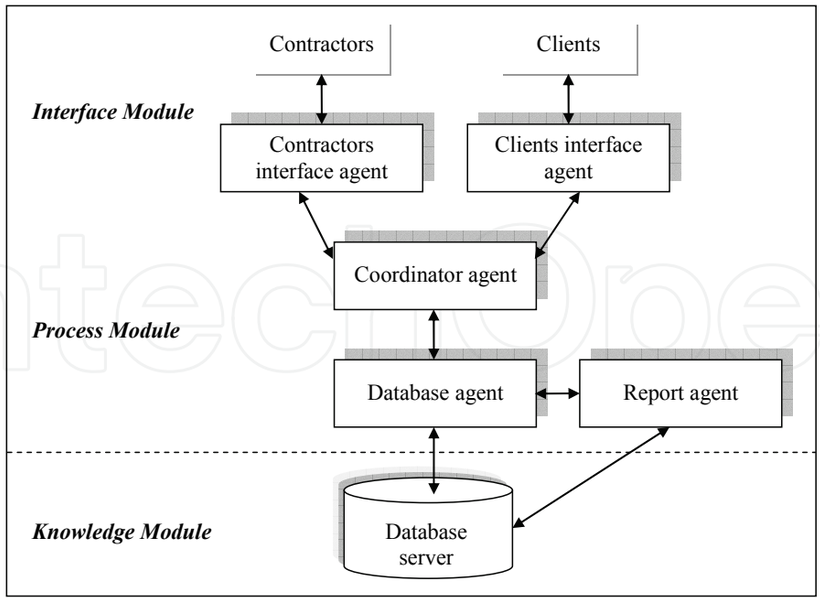

Fig. 1. DSS Based on Intelligent Multi-Agents Paradigm

7. Functions of each agent

There are several agents involved in this research such as user interface agent, coordinator agent, and database agent.

a. User interface agent

The user interface agent is divided into two types of user; a) contractors and, b) clients. Each of different users has their own interface agent. Generally, user interface agent provides a Web interface for the users to interact with DSS and to help him/her deal with several online forms, perform uploading/downloading related documents, and do data analysis activities. The user can provide a general description of the problem at hand in terms of high-level goals and objectives, or provide specific details about the data analysis or mining task to be performed. The user interface agent is responsible for receiving user specifications and delivering results. It also keeps track of user preferences.

The interface module of the user interface agent contains methods for inter-agent communication as well as getting input from the user. Its process module contains scripts and methods for capturing the user input and communicating it to the DSS coordinator agent.

The functions of the user interface agent are providing Web interface for user interaction, Web page for user input and problem description, provide parameters to use, Web page for status information - feedback providing states of various processes, Web page containing final results, dynamically creating HTML documents with special formatting needs, communicating the user input to the DSS coordinator agent, capturing user activities and preferences and create user profiles

b. Coordinator agent

The coordinator agent is responsible for coordinating the various tasks that need to be performed in cooperative problem solving. After receiving the user input from the interface

agent, the coordinator agent identifies the relevant criteria, determines the alternative that need to be evaluated and generates a plan of action such as ranking of the alternatives. These alternatives may include identifying the relevant data sources, requesting services from other agents, and generating reports. The interface module of the coordinator agent is responsible for inter-agent communication.

The process module contains methods for control and coordination of the various tasks as well as generating the task sequence. The sequence of tasks to be executed is created utilizing specific formula stored in the knowledge module using a rule-based approach. The knowledge module also contains meta-knowledge about the capabilities of other agents in the federation, available data sources and databases. The coordinator agent may seek the services of a group of agents and synthesize the final result.

The functions of the coordinator agent are from user input, identify high-level objectives based on these objectives, identify tasks, generate "task sequence" and delegate actions to corresponding agents, provide intermediate feedback to user, synthesize and generate final result, perform the calculation/evaluation of problem-specific information.

c. Database agent

The database agent is responsible for keeping track of what data are stored in database. It provides predefined and ad hoc retrieval capabilities. It is also responsible for retrieving the necessary data requested by the data mining agent in preparation for a specific data mining operation. The database agent takes into account the heterogeneity of the databases that may exist within the organization, and resolves conflicts in data definition and representation.

The interface module of the database agent provides not only the public interface for inter-agent communication, but also to existing databases. This improves inter-operability and enables users to gain access to a variety of data sources which otherwise might be inaccessible. The process module provides facilities for ad hoc and predefined data retrieval. Based on the user request, appropriate queries are generated and executed against the data warehouse. The results of these queries are communicated back to the user or other agents. The knowledge module contains meta-data information, including the local schemas and a global schema. These schemas are used in generating the necessary queries for data retrieval.

The functions of the database agent are inter-agent message communication, provide interface to databases, application program interface (API) to commercial database products, Ad hoc and predefined data retrieval, maintain local and global schema and formatting query outputs based on user needs.

8. Importance of our methodology

The proposed architecture for a multi-agent based DSS in distributed environment is organised around the decision-making model. Unlike other approaches, this architecture uses the multi-discipline concepts in computer science such as agent-programming, decision support system, distributed system and employs tendering processes as a case study in order to test the performance and usability of the framework. There are three development phases such as:

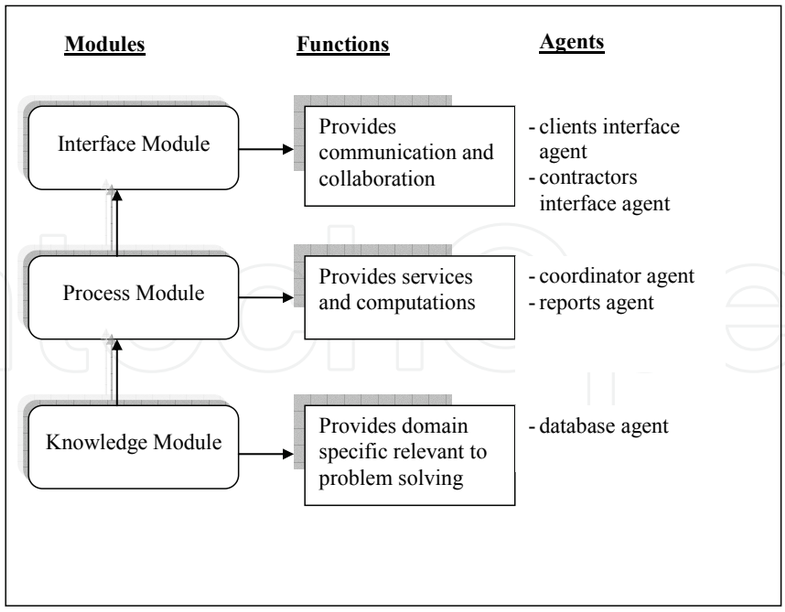

Fig. 2. Functions on Interface, Process and Knowledge Module

Phase 1: Construct architecture of a multi-agent based DSS in distributed environment. The architecture consists of two parts: the object (passive) and the agents (active). The major components of the architecture include: interface, data, models and agents. Interface provides interaction between users and the proposed application. The data and model are components containing data (collected online from other databases, or the users) and models relevant to decision making.
Phase 2: Design agent-programming in distributed environment by developing the three main agents: a) user interface agent, b) coordinator agent, c) database agent.
Phase 3: Evaluate the performance and usability of the approach, Web-based management system for the decision making process will be embedded as a research prototype.

9. Advantages

The government, construction industry and clients are all seeking to bring about some changes in the construction industry in order to improve quality, competitiveness and profitability and to increase value to clients and contractors.
The Web-based DSS has shown to have tremendous potential not only in adding value to registered clients and contractors in construction companies but also to the whole construction industry. The Web-based DSS is very much concerned with the display of information about a tender project and also the process of placing the tender. Many advantages can be achieved such as it enables a DM to accomplish a task more effectively, it reduces costs and time taken, and it can be customised to other applications.
The several Web-based DSS applications have been used in some countries and have proven to be effective in facilitating a faster and more efficient use of processes. However it is still a new research area in Malaysia where there are still many questions to be answered and challenges to be addressed. With the fast expansion of the Internet developing the Web-based DSS has gained more and more interest from many researchers all the over the world.

The Web-based DSS technologies will become an important management tool to enhance the performance of decision making processes. Although the development, deployment and thus the use of the Web-based DSS is still very much in its infancy in the construction industry, we expect to see a rapid increase in its functionality that will assist both clients and contractors in the electronic environments over the next few years.
The motivation for this architecture stems from the need to support the DMs in their task of solving complex problems such as those that exist in decision making processes. It emphasises ease of use, user friendliness, flexibility and adaptability. The DSS can be used in other contexts for example to be commercialised as a Web-based application for trading any goods or services in the world where a structured approach to supporting decision-making remain as the main concepts. Or in other words it can also be used as an e-commerce tool.

10. Expected outcomes

One of the major aims of this research is to provide quality decision support and performance assessments tools and services through the use of cutting edge techniques in decision sciences and computer technologies. We wish to see that DMs and decision-making processes in any field of human activities can be supported in a way that is systematic, rational, transparent, efficient and reliable.

i. A new documented architecture for a multi-agent based DSS in distributed environments.
ii. Robust prototype with a user-friendly environment. Users can come up with his/her own solutions, or modify solutions generated by the agents.
iii. The proper combination of agent-based technology for DSS in distributed environment will provide a powerful tool to support decision-making in distributed environment.

11. Conclusion

Decision-making for choosing the right alternatives for the right activities is immensely complex, involving various processes and communication mechanisms among them. We feel that the significant conclusions that can be drawn from our research are: (1) Building decision-support is much more complicated than merely applying a technical tool to solve a well-defined decision problem. The DSS is the application of the most potent forces in contributing to Web-based problem domain. Decision making problem that is based on the use of IT to achieve the primary principle of perfect competition for example to increase transparency of selecting alternatives. (2) Real time decision making process evaluation together with employing intelligent multi-agent will expected to provide a better way in order to make the processes more efficient, i.e. faster and lower cost.

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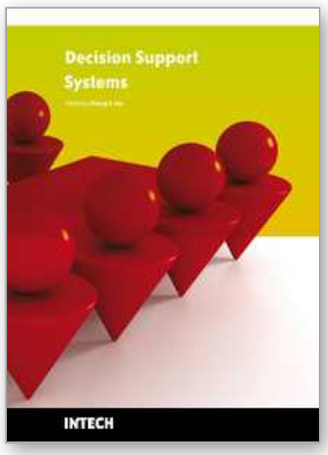

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Decision support systems (DSS) have evolved over the past four decades from theoretical concepts into real world computerized applications. DSS architecture contains three key components: knowledge base, computerized model, and user interface. DSS simulate cognitive decision-making functions of humans based on artificial intelligence methodologies (including expert systems, data mining, machine learning, connectionism, logistical reasoning, etc.) in order to perform decision support functions. The applications of DSS cover many domains, ranging from aviation monitoring, transportation safety, clinical diagnosis, weather forecast, business management to internet search strategy. By combining knowledge bases with inference rules, DSS are able to provide suggestions to end users to improve decisions and outcomes. This book is written as a textbook so that it can be used in formal courses examining decision support systems. It may be used by both undergraduate and graduate students from diverse computer-related fields. It will also be of value to established professionals as a text for self-study or for reference.

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