A Multi-agent Framework for a Web-based Decision Support System Applied to Manufacturing System

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Abstract. The Combination between Web services and software agents provides a promising computing paradigm for efficient service selection and integration of inter-organizational business processes. This paper proposes an agent-based Web DSS; the main contribution of our study is to provide an efficient tool that helps users find information resources available as an online service within Intranet. The decision-making is not only guided by the information provided by DSS but rather than the Web technology, the process is entirely based on communication between ISP Agents and Web agent. While negotiating compromises for conflict solving to share common resources, decision centres use Web service to conduct various complementary tasks. To illustrate the idea, a simple case study is given.

Keywords: Decision Support System (DSS), Integrated Station of Production (ISP), Software agents, Web-based DSS.

1 Introduction

Computer technology progress has led to widespread use of computerized support in various activities. Particularly, traditional decision support systems (DSS) focus on computerized support for making decision with respect to managerial problems. There is an emerging and fast growing interest in computerized support systems in many other domains such as information retrieval support systems, research support systems, teaching and learning support systems, computerized medical support systems, knowledge management support systems, and many more. The recent development of the Web generates further momentum to the design and implementation of support systems.

Obviously enough, there is a strong trend for studying computerized support systems especially on Web platforms. Research on information retrieval support systems, research support systems, teaching and learning support systems, decision support systems, computerized medical support systems, and knowledge management support systems are just some of their representatives.

This paper will focus on one of the important research topics of Web- based DSS and provides an efficient tool that helps users find information resources available as an online service within an Intranet. The organization of this paper is as follows. We introduce the concept of Decision Support System and Web-based support systems in the next section. Section 3 discusses issues of recent research in Web-based decision

support. In section 4 we propose our contribution. In section 5 we explain our proposed model. Section 6 shows a sample application for the Web-based DSS. Finally, a conclusion and future work are given in Section 7.

2 Decision Support System and Web Based Decision Support System

2.1 Decision Support System

Before we start with detailed aspects of the issue, it is important to tackle the definition of decision support systems.

Decision Support Systems can be defined as computer technology solutions that can be used to support complex decision making and problem solving (see Shim *et al.* [17]). To account decision problems complexity and uncertainty, we understand the DSS as a set of computer-based tools that provide decision maker with interactive capabilities. It aims to enhance his understanding and information basis about considered decision problem through usage of models and data processing. The latter, in turn, allows reaching decisions by combining personal judgment with information provided by these tools. The classic DSS tool design is comprised of the components for:

- Database management capabilities with access to internal and external data, information and knowledge;
- Powerful modelling functions accessed by a model management system; and
- User interfaces that enable interactive communication between the user and system.

Decision Support Systems (DSSs) are interactive computer-based systems intended to help decision makers utilize data and models to identify and solve problems and make decisions. The "system must aid a decision maker in solving unprogrammed, unstructured (or 'semistructured') problems...the system must possess an interactive query facility, with a query language that ...is ...easy to learn and use" [2]. DSSs help managers/decision makers use and manipulate data, apply checklists and heuristics, and build and use mathematical models.

According to Turban [21], a DSS has four major characteristics: it incorporates both data and models; it is designed to assist managers in their decision processes in semistructured (or unstructured) tasks; it supports, rather than replaces, managerial judgment; and its objective is to improve the effectiveness of decisions, not the efficiency with which decisions are being made.

According to [8], decision support systems fall into five categories:

- Communications-Driven DSS – uses network and communications technologies to facilitate collaboration and communication;
- Data-Driven DSS – emphasizes access to and manipulation of a time-series of internal company data and sometimes external data;
- Document-Driven DSS – integrates a variety of storage and processing technologies to provide complete document retrieval and analysis;

- Knowledge-Driven - intended to suggest or recommend actions to managers. These DSSs are personal computer systems with specialized problem-solving expertise;
- Model-Driven DSS or Model-oriented DSS – emphasizes access to and manipulation of a model, e.g. statistical, financial, optimization and/or simulation. Simple statistical and analytical tools provide the most elementary level of functionality.

2.2 Web-based Decision Support System

Web used technologies are employed to improve the capacity of decision support systems through decision models, On-line Analysis Processing (OLAP) and data mining tools that allow "standardized" publishing and sharing of decision resources on the Internet. In a web-based decision support system, all decision support related operations are performed on a network server n order to benefit from platform independence, shorter learning curves for already familiar users with the Web tools and web navigation, lower software distribution costs, ease of performing system updates and “reusability” of decision modules and information on the Internet through standardized protocols and formats [8].

According to [5], the importance of using Web-based DSS originates from the growing amount of available information that should be identified, controlled and accessed remotely using web based tools to support reusability of integrated decision modules. Using such systems, an enterprise can create survey software, Web based forms, build document-driven DSS for requests and approvals. They help global enterprises manage and improve decision processes through improved efficiency, better process control, improved customer service, more flexible re-design, and streamlining and simplification of business processes.

Using Web-based DSS, decision-makers can share open decision modules on the Internet using standardized protocols such as HTTP, and a standardized format like XML or DAML.

According to [16], Web-based systems are regarded as «platforms of choice” for delivering decision support while taking into account many technical, economic and social considerations. The migration towards web based DSS denotes a shift from DSS generators (that allow users to develop specific applications characterized by limited deployment, inflexibility) to integrated cross application orientations that emphasize the reuse of applications and components. By deploying Web capabilities, multiple knowledge bases and knowledge processing techniques can be used. The design of decision support systems has been affected by the availability of a wide range of web based tools, techniques and technologies. The use of web tools are reshaping the description of relations between information components and decision modules in a way that affects both the physical and logical design of the DSS, model visualization, sharability of decision modules and the development life cycle of DSS. As a result, the underlying architecture for Web-based DSS has moved from mainframes, to client–server systems, to Web and network technology based distributed systems that enable the integration of large amounts of data and decisions support tools originating from heterogeneous multidisciplinary sources for the

provision of value-added information using knowledge discovery and data mining tools.

3 Recent research in Web-based Decision Support System

This section reviews and summarizes the state of Web-based DSS research in two areas: (a) architectures and technologies and (b) applications and implementations. A number of articles have reviewed more specific topics related to Web-based DSS. For example, Kuljis and Paul [12] reviewed Web-based simulation and Kersten and Noronba [10] reviewed Webbased negotiation support.

3.1 Architectures and technologies

A number of articles discuss architectural issues, frameworks, usability, and other technology topics that are generally applicable to Web-based DSS.

Gregg et al. [6] developed a DSS metadata model for distributing decision support systems on the Web. Bharati and Chaudhury [1] conducted an empirical study to investigate customers' satisfaction with a Web-based decision support system. Iyer et al. [9] studied model management for decision support in a computing environment where enterprise data and models are distributed. Guntzer et al. [7] proposed Structured Service Models that use a variant of structured modeling. This proposed approach can help users find information resources available as an online service withinin Intranet. Zhang and Goddard [22] applied Software Architectures to the design of Web-based DSS. Mitra and Valente [13] provided an overview of Web-based optimization for model-driven decision support, discussed two paradigms (ASP and e-Services), and articulated technology issues for an e-Services model.

3.2 Applications and implementations

Many researchers and vendors have reported Web based DSS case studies and the development of prototype applications. Kohli et al. [11] reported a case study of a Web-based DSS for hospital management called Physician Profiling System (PPS).

Ngai and Wat [14] developed and implemented a Web-based DSS that used a model based on fuzzy set theory to perform risk analysis for e-commerce development. Dong et al. [4] developed a Web-based DSS framework for portfolio selection. Sundarraj [19] identified key issues in managing service contracts and developed a prototype that can support a manager's planning process. Ray [15] reported a case study that demonstrates the implementation of Web-based decision support technologies. Delen et al. [3] developed a Web-based DSS, called Movie Forecast Guru, to help decision makers in the movie industry.

There are many additional case studies related to deploying Web-based decision support systems. For example, Sugumaran and Meyer [18] report the development of a Spatial DSS prototype for the City of Columbia, Missouri.

4 Contribution

Given the multidisciplinary data sources and related decision support tools, the design, specification, and implementation of a Web-based DSS often in a distributed environment is still an open research problem [22]. Firstly, a Web-based DSS often consists of the data and related tools, which come from multidisciplinary areas. Those data and related tools originally are not designed to work together. Traditional DSS design methods lack the ability to help organize them in a hierarchical view and specify the software architectures of a Web-based DSS in a formal way. Secondly, with the assistance of Web and network technology, the data and decision support tools from multidisciplinary areas can be located on computers distributed over a network. In such a distributed environment, a Web-based DSS needs a distributed framework to manage and integrate the data and tools in a seamless way.

Furthermore, the work reported in [20] concerns a novel approach for decision making. In her paper, she addressed an agent architecture-based model in order to present a multicriteria DSS which can be applied to solve some uncertainty problems in dynamic production system scheduling. The established negotiation contract thus deals with certain exceptions; it is based on the agent approach. The major advantage with this modeling paradigm consists in facilitating access to the executed tasks carried out by Integrated Stations of Production (ISP) agents.

This paper proposes an agent-based Web DSS, its principle is to help users solve the problems of failure of their resources in an industrial estate on a web service using online within an intranet. In addition to the Web Service in our contribution we will use negotiation between ISP Agent and other agents on the web **(Fig.1)**. The ISP Agent will check the resources of a workshop at the resource failure, it will contact the agents based Web that will help for decision making to resolve the failure. To illustrate the feasibility of the idea, an AUML diagram is given in **Fig.2.**

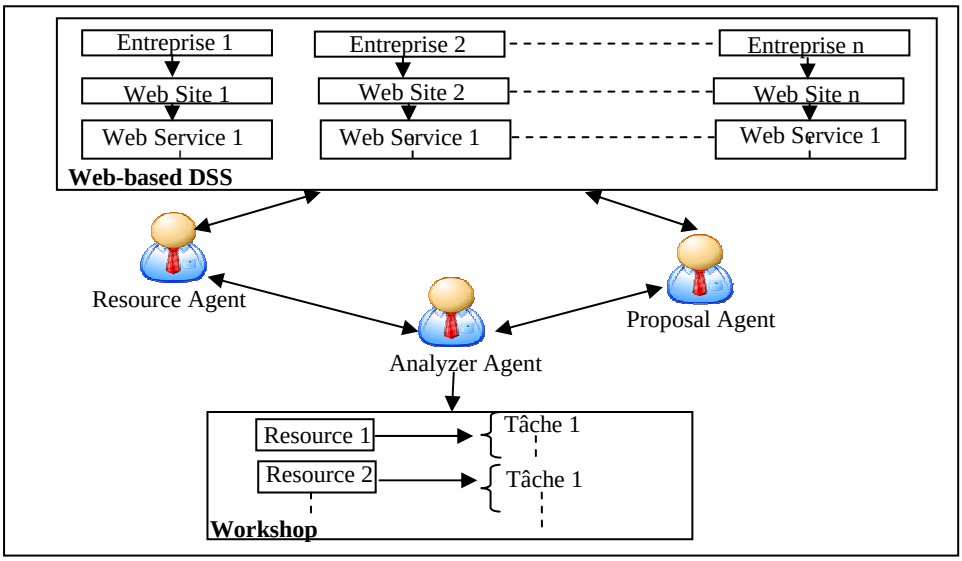

Fig.1. General architecture

5 Scenario for Proposed Model

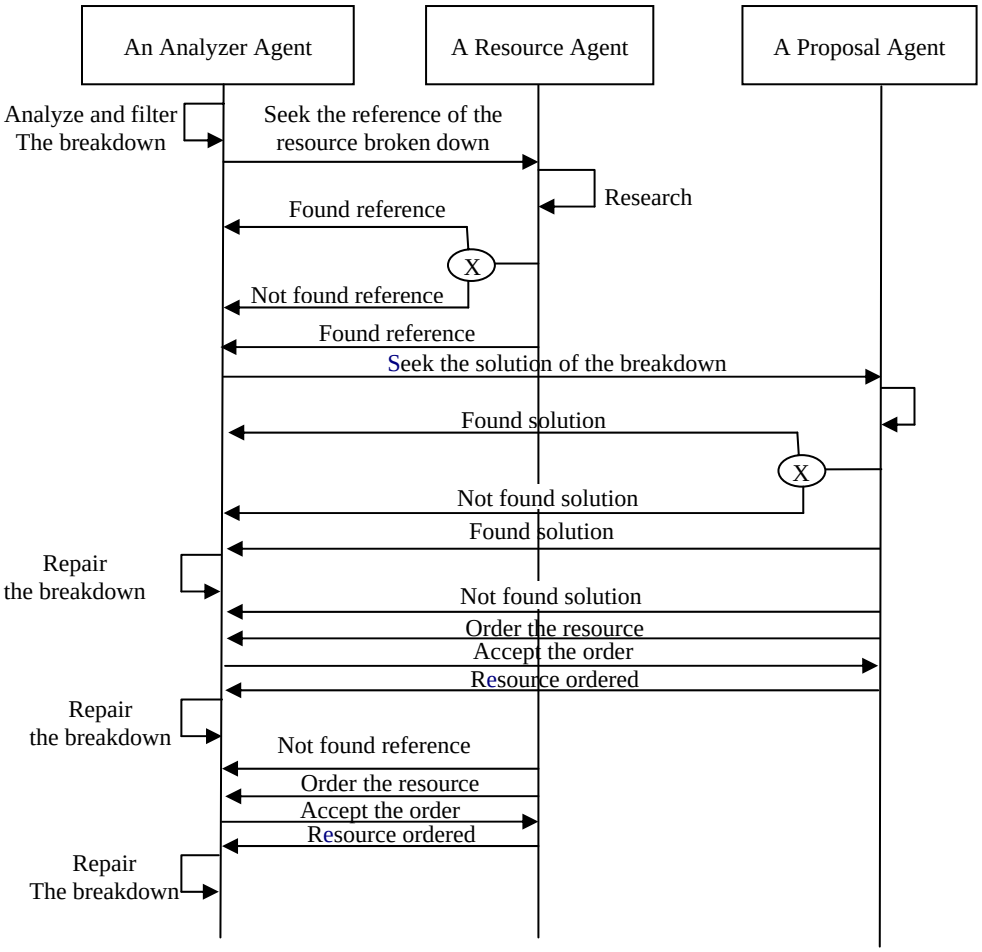

Fig. 2. Communication between Agents (Diagram of Sequence)

5.1 The Analyzer Agent Structure

The analyzer agent includes several types of functional modules such as: analysis module, proposal generator module, a database, a knowledge base, rules base, a filter and an interface. The analysis module is the core of this architecture; its role is to use the data input which is stored in database, knowledge which is stored in knowledge base and the rules which are stored in rules base. This is to analyze and filter the breakdowns, and produce like exit a generator of proposal of analyzed and filtered

breakdowns. The interface module manages the information exchanges between the agent analyzer and the other agents.
During the problem resolution, the analyzer agent will require the resource agent to seek the resource reference on the Web.

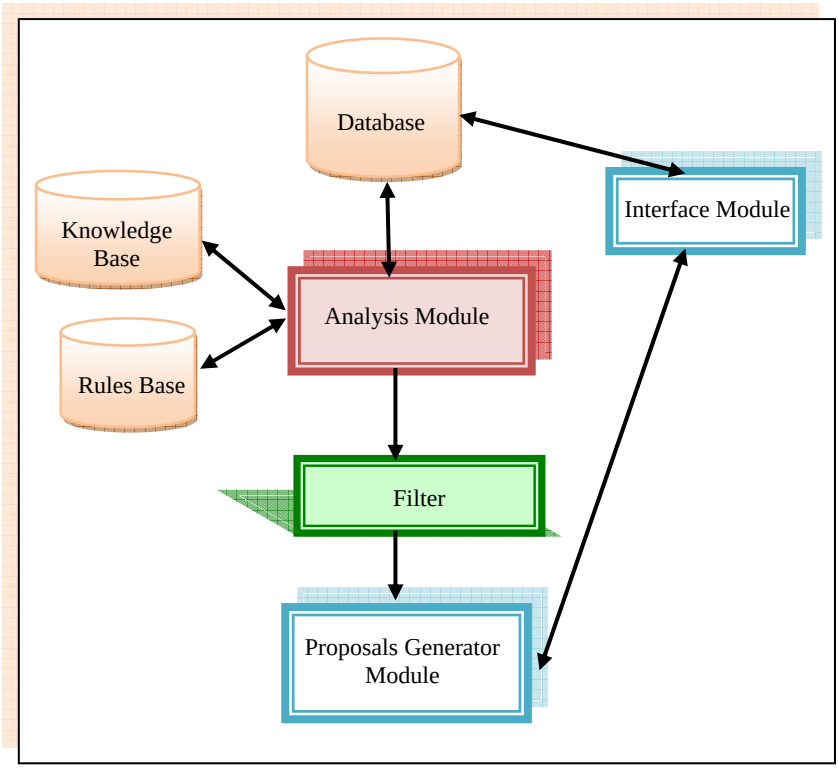

Fig. 3. The analyzer agent structure

5.2 The proposal agent structure

After having to find the reference of the resource broken down on the Web, the agent analyzer will require the proposal agent (see **Fig. 4**) to launch an advanced research on the Web concerning the breakdown envisaged for this resource.

The proposal agent includes several types of functional modules such as: research module, solutions generator module, a data base, a knowledge base, rules base, web data base and an interface. The research module is the core of this architecture; its role is launching an advanced research on the Web (in the Web Database) as for the breakdown of the resource. At this time there, it will generate several solutions. The interface module manages the information exchanges between the agent proposal and the other agents.

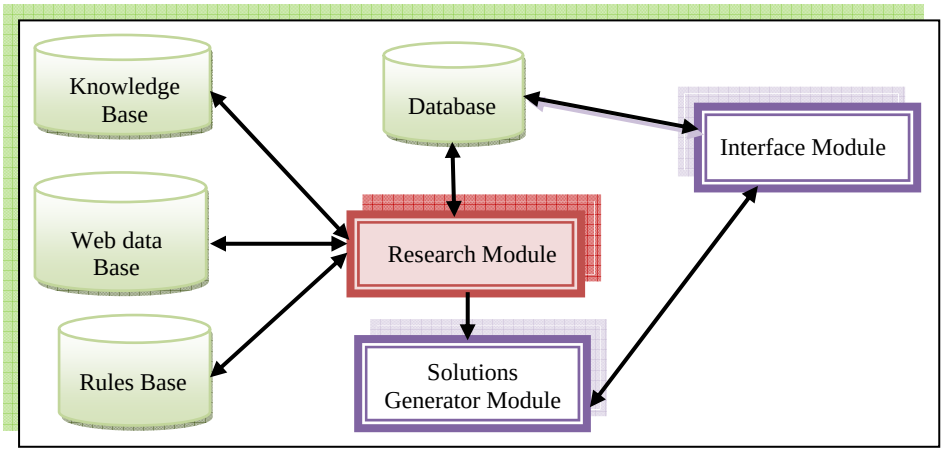

Fig.4. The proposal agent structure

6 Sample Application for the Web-DSS

We use the resource allocation problem to demonstrate how the agents solve problems by interactions among agents. A company wishes to produce a special computer installation with its own hardware and software for a customer. The following print screens given in both (**Fig.5**) and (**Fig.6**) show a practical situation when decision-making is necessary.

Fig.5. Simulation Function

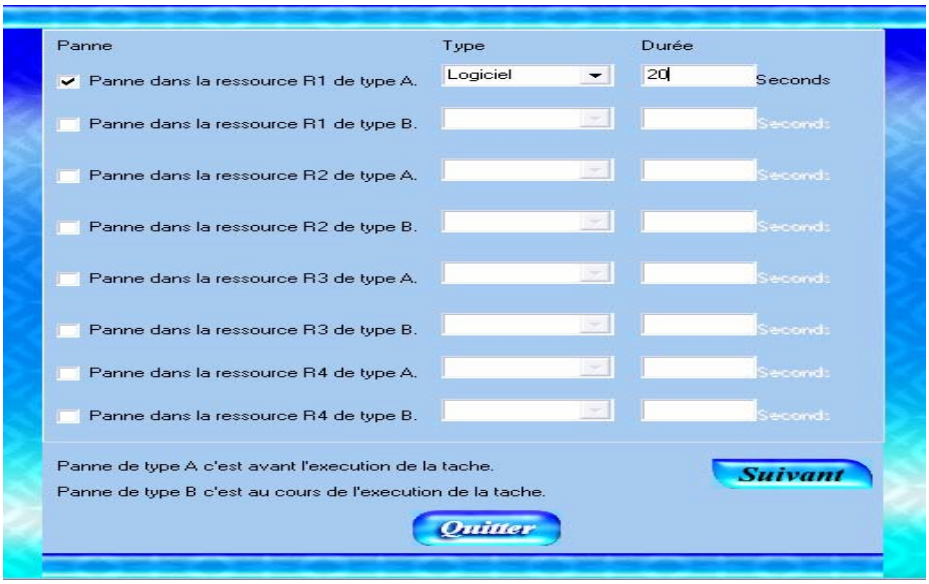

Fig.6. Simulation of a Breakdown in the Resource

7 Conclusion

A Web-based DSS uses the Web as a portal to the underlying DSS. It lets interested users access and make use of the underlying DSS through the Web. Moreover, we believe a distributed implementation of the underlying DSS is also important for a Web-based DSS presents a challenge, which needs the combination of a DSS with distributed computing technology. Our proposed multi-agent approach provides a practical way to implement a Web-based DSS.

More precisely, we have integrated agents into Web-based DSS for the purpose of automating more tasks for the decision maker, enabling more indirect management, and requiring less direct manipulation of the DSS. In particular, agents were used to collect information and generate alternatives that would allow the user to focus on solutions found to be significant. Based on this, and considering that communication capabilities play an essential role in Web-based DSS to enable 'any-time, any-place" operation mode of the system. Further work based on coordination protocols between agents needs to be done. Particularly, the context information domain included in the software tool will be extended in order to improve the support for decision making and the coordination activities.

The proposed architecture of the Web-based DSS is under development. One of our perspectives is to completely implement it, test it in a manufacturing industry in order to obtain feedback on the usability of the developed system.

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