Web-based Decision Support System for Industrial Operations Management

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ABSTRACT

To maintain sustainability in today's' global economy industrial companies must have well managed systems and operations to keep up with competition. For this they can take advantage of using Web and Internet based technologies. Such can be achieved by accessing good management resources and methods through the Internet which otherwise would not be available and, at the same time, take advantageous of collaboration provided by networks of partners and users. Due to operations management complexity when a company does not have access to good algorithms it usually draws upon simple and empirical procedures whose quality of solutions provided tends to be poor. This is a situation that can be avoided if companies have easy access to good operations management algorithms or services. This can be possible because a pool of knowledge on industrial operations management, which has been developed by academia and industry over the years, can be made available, through the Internet, to a large community of users. This idea is explored towards development of a web-based system for Industrial Operation Management, based on a P2P network of operations management algorithms providers and users. Thus, the paper describes a web system for aiding the resolution of Operations Management problems through collaboration based on a network of distributed resources and users, web services and other Internet technology. The system adopts a P2P network architecture to create and enable a decentralized and global industrial operations management environment. It includes a set of functionalities accessed through the P2P network, which holds algorithms for solving different types of Operations Management problems. The algorithms are selected through a user-friendly interface, which is automatically generated for each specific problem context, including loading existing XML problem data documents, and searching and running algorithms on the peers belonging to the P2P network.

INTRODUCTION

The Internet increasingly performs an important role in the success of companies. In particular, it enhances collaboration among different companies or partners helping to improve operations and everyday decision-making processes in different areas of activity and knowledge. This enhancement results from taking advantage of the features and resources that are or can be made available through the Internet to all company stakeholders. This means that a greater impact on companies' performance can be achieved ensuring better use of manufacturing and management resources and better customer service, namely through reliable and timely deliveries. Therefore, providing decision support systems based on Internet technology can make the difference between success and failure and highly contribute to the competitive ability of industrial companies.

In this paper, work is reported towards providing companies with improved decision making abilities on managing industrial operations with the aid of the Internet.

Due to operations management complexity when a company does not have access to good algorithms it usually draws upon simple and empirical procedures whose quality of solutions provided tends to be poor. This is a situation that can be avoided if companies have easy access to good operations management algorithms or services. By exploring the Internet facilities in a network of industrial operation management (IOM) service providers, users can ensure better management of their industrial operations. This is because a pool of valuable knowledge on IOM, which has been developed by academia and industry over the years, can be made available to virtually any company or user.

The idea, of easily providing required IOM knowledge to any company that needs to improve operations, is explored in this paper through the development of a web-based decision support system (WB-DSS) for IOM based on a P2P network of operations management algorithms providers. At this stage the system is focused on scheduling problems and based on a problems ontology developed by Varela and Carmo-Silva [1]. This paper describes such a web-based system and is organized as follows: The next section briefly reviews the literature on IOM solvers available through the Internet. After, there is a brief description of the WB-DSS architecture, focusing on its P2P structure and components. The subsequent section, summarizes the main system functionalities, and illustrates them through a practical example. Finally, the conclusion section is presented.

LITERATURE REVIEW

With the evolution Internet technologies web-based industrial management applications can now be easily made available, implemented and become a valuable resource for the success of modern manufacturing companies. Traditional IOM applications, running locally on PCs have been gradually substituted by more dynamic and worldwide available applications running on the Internet. An application example to the control of manufacturing cells is presented by Ming Tsai and James Lin [2]. They describe a application architecture for a web-based distributed manufacturing control system based on co-operative mechanisms and contract net protocols. The control system uses a web based controller that in coordination works with the local manufacturing cell controllers for carrying out manufacturing control decisions on production orders. Typical information used by the Web controller includes due date, quantity, process plans and priority parameters of production orders. The system is responsible for selecting a specific process plan or routing, allocating resources, scheduling work, downloading processing instructions, monitoring the progress of activities, detecting and recovering from errors and preparing reports based on system status data.

In the literature we can find reference to a variety of several solvers that can be of great use for IOM. Two well known solvers are the Lekin system (http://www.stern.nyu.edu/om/software/lekin/index.htm), oriented to flexible job shop IOM, and the Lisa Library of IOM algorithms (http://lisa.math.uni-magdeburg.de/).The NEOS Server [3], developed by the Northwestern University and the Argonne National Laboratory, is another example of a web application for solving optimization problems, including IOM ones (http://www-neos.mcs.anl.gov/). NEOS Server accesses nearly 50 solvers, through several different interfaces, for remotely solving problems. Another novel application, relevant to IOM, is the ForthMP (http://www.brunel.ac.uk/ depts/ma/research/com), a system for mathematical programming running on the web, developed by the Mitra's Group of the Brunel University. The Test Bench Assistant being developed under the IMS-NoE umbrella is another example running on the Internet (http://www.ims-noe.org/BENCHMARK/ TBA.asp). Other solvers which can be accessed through the Internet include VISHNU (http://vishnu.bbn.com), OCEA (http://www.ocea.li.univ-tours.fr/eocea/index.jsp) and RIOT (http://riot.ieor.berkeley.edu/riot/Applications/Scheduling/index.html) specifically oriented to scheduling.

Although useful and powerful these solvers may be, in general, they are mostly centralized, based on a number of available algorithms and procedures provided for user access, either though download or for direct use on the remote server though the Internet. In this paper a different approach is explored, namely the development of a dynamically updatable IOM application, based on algorithms globally available through a P2P network, and selectively chosen for solving industrial operations management problems. This extends previous work carried out by Varela, Carmo-Silva et al. [4, 5].

WEB TECHNOLOGY AND SYSTEM ARCHITECTURE

Collaborative manufacturing is emerging as a norm for manufacturing in distributed environments. This is largely due to the global business decentralization and global manufacturing outsourcing. To stay competitive in the dynamic global market of today, companies with distributed factories or divisions require new ways of effective collaboration among all production units and stakeholders including suppliers and outsourced service providers. Among many other factors, flexibility, timeliness, and adaptability are identified as the major characteristics to bring dynamism to collaborative manufacturing environments.

Manufacturing processes, including distributed ones are quite complex, especially at job shop like systems where a large variety of products, usually in small batch sizes, are handled dynamically. Therefore, there is a need for using IOM applications enabling the use of a wide range of knowledge and algorithms for easing decision-making. This is particularly required in dynamic manufacturing environments. These needs, purpose and environments are probably better accomplished and dealt with an adaptive application architecture that enables effectiveness and efficiency of important functions such as distributed planning, dynamic scheduling, real-time monitoring and remote control. Moreover, the application should be responsive to both varying collaboration needs and unpredictable changes of distributed production capacity and functionality. An ideal shop floor should be the one that uses real-time manufacturing intelligence to achieve the best overall performance with the least unscheduled downtime. However, traditional methods are based on off-line processing that is normally performed in advance, and thus, are impractical if applied directly to this dynamic collaborative environment. In response to the requirements and to coordinate the dynamic activities in collaborative manufacturing, a web-based IOM approach can greatly turn these everday decision-making processes much easier for manufacturing companies to achieve dynamism, even in distributed manufacturing environments.

Developing an IOM applications using web-based technology becomes a promising strategy. In fact, by migrating from conventional applications to a web-based application, the following improvements are expected:

1. Automate the data transactions and eliminate human errors, by enabling direct XML data transferring.
2. Sharing IOM resources and services, regardless of distance between peers.
3. Structuring the application in a decentralized and distributed manner, e.g. including several modules replicable and running on different machines.

In order to make a contribution in this direction, an application architecture is proposed and designed to use a Peer-to-Peer (P2P) structure for effective IOM algorithms and information sharing. We may define a P2P network as a network of several computers, i.e. peers, which do not possess a permanent client or server nature but, instead, work dynamically as both, depending on a transaction or service being received from or supplied to the network [6]. P2P technology enables distributing information in a network of peers by providing any user with direct or indirect access to peers in the network. The peers collaborate forming a virtual network for communication and data transfer and for solving problems in a collaborative manner.

Peer-to-peer technology and appropriate networks suit well the increasingly decentralized nature of modern companies and their industrial and business processes. Characteristics of P2P networks are explored in the design of the IOM WB-DSS, of which a prototype was developed and is described in this paper. The IOM WB-DSS follows a P2P network and is based on XML and related technologies [7]. In this web system a set of peers, each one contributing with a local knowledge base component, compose a Distributed Knowledge Base (DKB) and form the P2P network of the system. The P2P network has the capability of allowing a direct-interaction between the peers, which turns the computing environment decentralized, namely in terms of storage, computations, messaging, security and distribution. One of the greatest benefits of a P2P network, in the context of this work, is to easily support the concept of community. Consequently, it is possible for users to organize themselves into groups that can collaborate with each other in order to achieve certain goals.

One of the main goals in this work is the collaborative improvement of the resolution of IOM problems. This is possible through a DKB for IOM by easily accessing different algorithms spread through a P2P network, integrating several algorithms' servers. It is achieved by providing a mechanism that allows the members of the P2P network to share their IOM knowledge and respective solving algorithms.

Figure 1 shows a general outline of the P2P IOM WB-DSS architecture. The system is able to quickly assign algorithms to problems that occur in real world industrial environments and solve them through the execution of one or more appropriate implemented algorithms which are local or remotely available and accessible through the Internet through the P2P network. The selection of one or more specific algorithm for solving a given problem is made through a searching process on the DKB. Therefore, one of the most important goals of the system is to be able to facilitate the access to web services and to share them.

The P2P networks make an important contribution because they allow systems to run in a decentralized and distributed environment and allow individuals and communities to participate more actively in the network. The P2P networks allow direct collaboration between users without them having to rely on central services and allow sharing processing capabilities of the resources that are interacting on the network. Moreover, all network resources may communicate directly without having to have an intermediary.

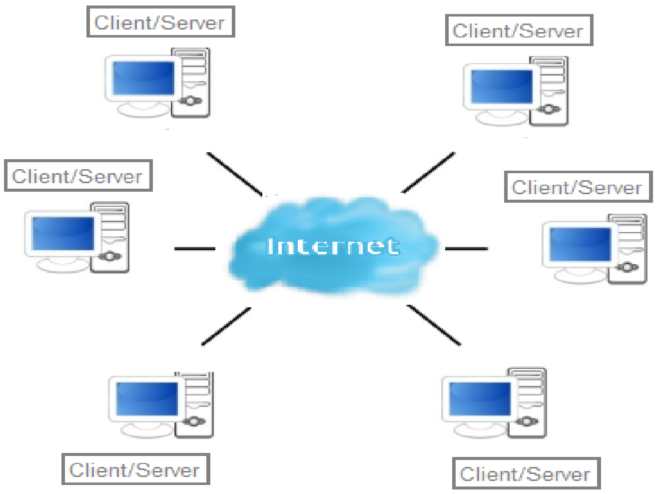

Figure 1: P2P system network.

An application deployed to operate in a P2P network context must have three types of layers: 1) One layer for enabling to discover and communicate with all network participants; 2) a middleware layer for system integration with other systems or applications and 3) a layer capable of providing a user interface to exploit the full functionality of applications [8].

The IOM WBDSS is structured around this three layer framework, as describe in the next section together with main system features.

The system is intended to bring systems' users together in order to enable sharing all the resources involved in the network as well as important information, enabling a collaborative work between all actors in the network.

SYSTEM FUNCTIONALITIES

The IOM WB-DSS inherited generic functionalities from web based framework, such as standard user interfaces, ubiquitous networks and web-based programming capability including web-services technologies.

The IOM WB-DSS possesses a set of specific functionalities. The algorithms, available in the P2P network are selected through a user-friendly interface, which is automatically generated for each specific algorithm. XML documents of IOM problems available in the network may be accessed for easing the user's task of problem instance specification. Once this is carried out, one or a set of algorithms can be selected for obtaining solutions to each IOM problem. Solution can be stored and presented to users in several formats, including tables, Gantt charts and XML e PDF files. Input data, in addition to direct introduction through the browser interface referred, can also be input through XML files. Some important functionalities are illustrated in Figure 2.

The system is able to search for information and existing services, mainly IOM procedures and algorithms, in the network to support IOM problem solving in several different production environments. It selects appropriate problem solving algorithms, available on the different peers belonging to the network and having its own local data and knowledge bases. Searches can be filtered according given manufacturing environment scenarios or by choosing server communities capable of providing the required services, as illustrated in Figure 3.

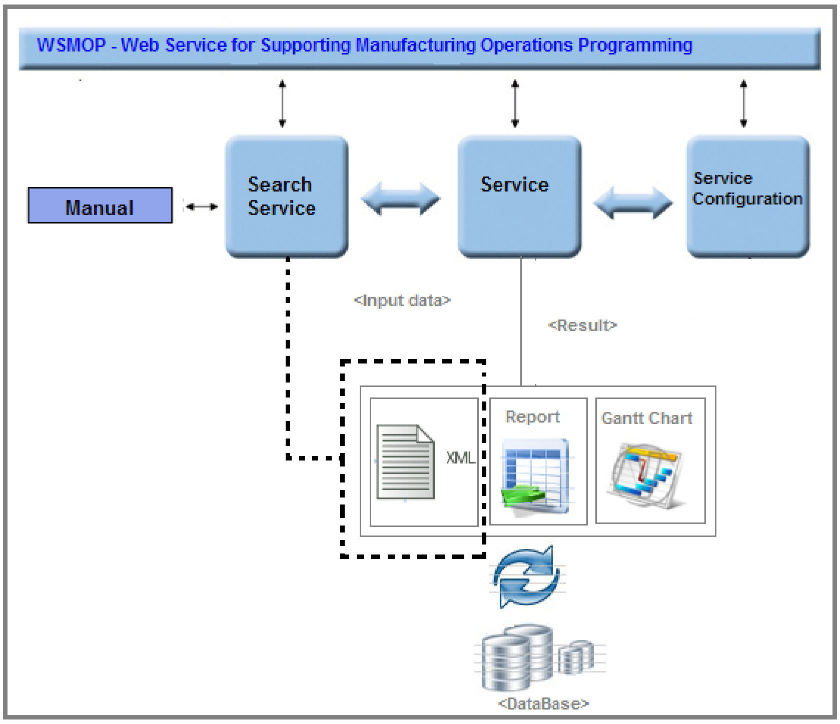

Figure 2: Application functionalities.

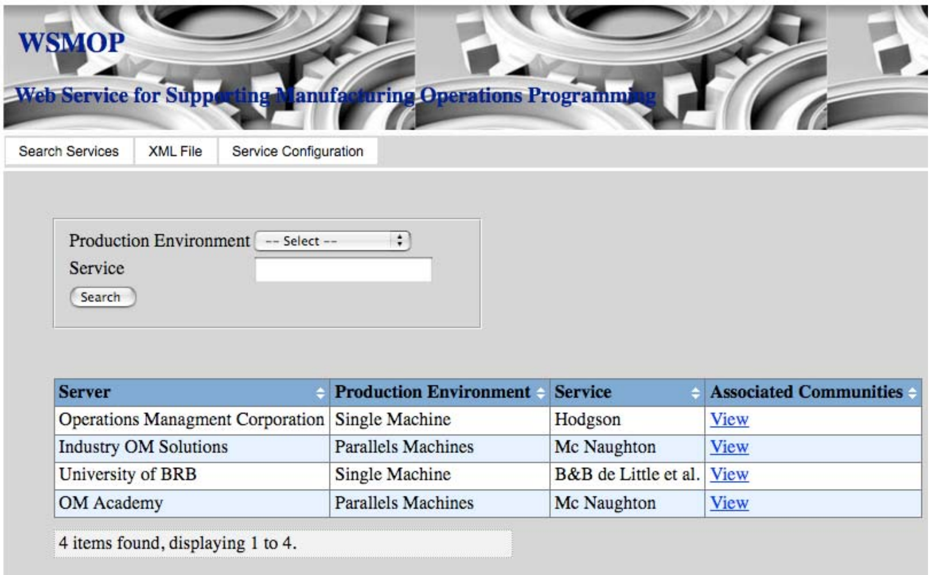

Figure 3: Network search functionality

The application also allows the association of individuals or communities to work with a common purpose, thereby catalyzing and increasing the collaboration among them.

After a given algorithm is selected, from the ones available in the P2P network, it is remotely executed for solving a problem instance specified, as illustrated on Figure 4.

Once a service is selected it is invoked for solving the specific IOM problem instance under consideration. An example could be for the resolution of a single machine operation scheduling problem using the Hodgson's algorithm [9]. This finds a solution that minimizes the total number of tardy jobs in a set of jobs to be processed on a single machine manufacturing environment.

Figure 4: Machine/ algorithm selection interface.

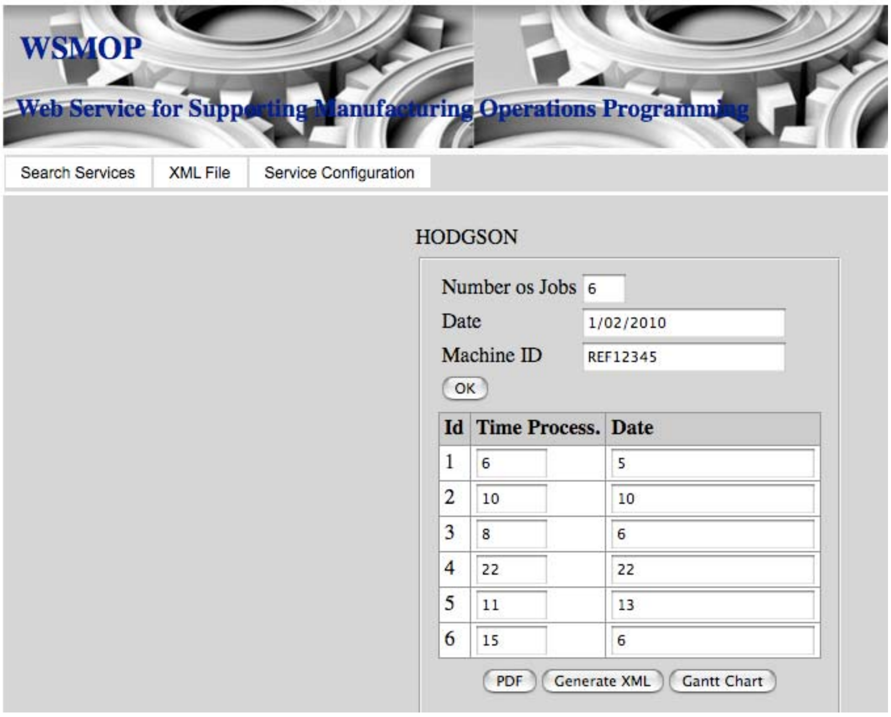

Figure 5: Hodgson's algorithm interface.

The problem instances data are given either directly through XML files or through the automatically generated system interface, as illustrated in Figure 5. The XML file contains all data concerning to the web service, such as the problem input parameters for running the IOM service on a peer.

The way information about problems' solutions results is reported is very important regarding to the need of its interpretation and understanding by the user for decision-making. Therefore, in order to enable a better decision-making process, the IOM WB-DSS presents and store results in several alternative formats. These include Gantt charts, tables, XML documents and PDF files. These documents can be saved and locally stored for a later reuse if necessary.

Gantt charts are very effective for visualizing, analyzing and understanding IOM scheduling solutions and for providing an easy perception of job processing priorities and starting and finishing events. It is also very suitable for comparing the quality of different problem solutions provided by alternative solving algorithms. Figure 6 shows a Gantt chart example, which is automatically generated by the IOM WB-DSS, based on the results represented as a XML document.

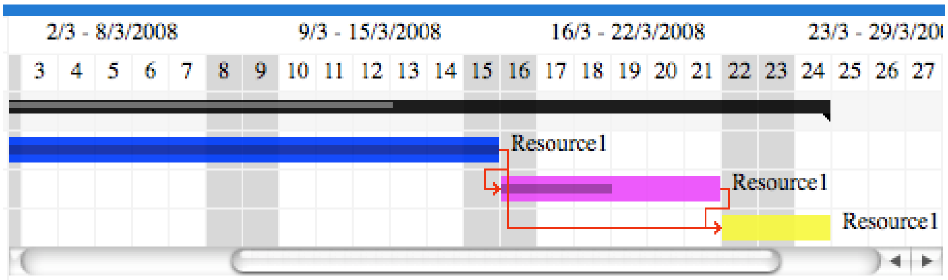

Figure 6: Gantt chart interface.

One of the advantages of storing XML files of problems data is that it enables performing further IOM services execution by repeatedly submitting it to other web service without having to repetitively inserting the same problem data. This storage procedure also enables an ease and fast way of reusing documents for specifying similar problems or different problems instances.

Figure 7: XML document loading interface

Figure 7 illustrates the application interface for Gantt chart generation based on searching XML files, over the P2P network, of problem solutions.

CONCLUSION

A web-based application for aiding IOM problem solving can be based on the concept of a distributed knowledge base available on computers or peers, integrating a P2P network. Thus, a very large knowledge base, on the form of IOM algorithms and mechanisms, can be made available and accessed by users by means of adequate platforms.

In this paper this idea is explored through the concept of a P2P web-based application for solving IOM problems or tasks, based on a network of computers. In this network each peer may supply and receive IOM services. This application explores the use of problems solving algorithms made globally available through the proposed application, and easily accessible through the Internet.

A prototype of this application was designed and implemented with the support of web technology and P2P networks and based on the use of XML and related technology.

An illustrative example of the use of the prototype of the web application, to solve a IOM problem using web service, was presented. Results were shown to be presented in several formats, namely Gantt charts, XML files and PDF files. The use of each format very much depends on what the results is used for., i.e. for simple decision making of for integration with other data for either further problem solving or reporting.

Further work needs to be carried out now to increase the IOM service providers and service users and create an effective network IOM web services.

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