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ENGINEERING MODERATOR TO UNIVERSAL KNOWLEDGE MODERATOR FOR MODERATING COLLABORATIVE PROJECTS

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ABSTRACT

One of the major issues in multi-discipline collaborative projects is how to best share and simultaneously exploit different types of expertise, without duplicating efforts or inadvertently causing conflicts or loss of efficiency through misunderstanding of individual or shared goals. This research discusses the development of Moderator from its first phase as engineering moderator to ongoing research on Universal knowledge moderator on semantic web. Moderators are knowledge based specialist intelligent software system which support each individual of a team to perform his particular role from a position of strength, using his preferred method of working whilst understanding the need of other team members and the whole team working on a collaborative project. Current research proposes an improved framework based on semantic web and knowledge discovery and data mining for engineering moderator to enhance the globally collaborative e-manufacturing work with better interoperability and efficiency. A universal knowledge moderator prototype system consisting of an enterprise data integration module, knowledge discovery module and moderation module is developed to significantly improve the moderation activities and performance of collaborative e-manufacturing.

Keywords: Collaborative project, Moderator, Semantic web, Knowledge discovery, E-manufacturing

Introduction

Current market trends indicate that demand is on the increase for highly customized products with ever shortening life cycle times and this trend is expected to accelerate. Manufacturing enterprise will achieve and sustain advantage competitive by improving productivity, responsiveness and flexibility. Manufacturers are striving to meet these demands by focussing on core competencies and migrating towards knowledge-based manufacturing [1].

A manufacturing enterprise can differentiate itself from its competitors and compete efficiently and effectively, through well targeted exploitation of its knowledge and expertise. Knowledge exists in all business functions, including purchasing, marketing and design, production, maintenance and distribution, but, knowledge can be notoriously difficult to identify, capture, manage and reuse [2].

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Mapping out where “knowledge” resides and identifying the conditions that fosters its generation and re-use has become a necessity. The knowledge assets of an enterprise reside in many different places, e.g., knowledge bases, filing cabinets, peoples mind and expertise, and are distributed across the enterprise. Therefore, enterprises need to know their knowledge assets and how to manage and make use of these assets to get maximum return [3]. Hence, manufacturing enterprises are faced with following twofold knowledge challenge;

- To thoroughly understand and efficiently capture their valuable knowledge and expertise, and
- To ensure that such knowledge is effectively reused and exploited to gain the best possible competitive advantage.

In this regard, knowledge discovery, knowledge management and knowledge engineering are currently topics of importance to manufacturing researchers and managers intent on exploiting current assets.

Need of Engineering Moderator for Collaborative Projects

A manufacturing system may be engineered and re-engineered for a variety of different reasons. Projects may range from partial or comprehensive overhaul of existing resources to a complete design of new manufacturing facilities and systems. Such projects are generally performed by multidisciplinary project teams. Project team members must be aware when decisions that they make may affect other team members. The strength and success of a team depends on how well each individual can contribute the maximum benefit of their skills to a consolidated and shared vision of the total group. The different backgrounds, experiences and environments of the individuals inevitably influence their views and interpretations of the overall objectives. Hence, as soon as people from different disciplines and backgrounds try to work together on a collaborative project, there is potential for misunderstanding or lack of awareness of the needs and interdependencies of each individual contributor. This is true even in small, co-located teams where individuals meet regularly to discuss overall project requirements and progress. It is clearly a far greater problem when teams are large and physically located in different companies or

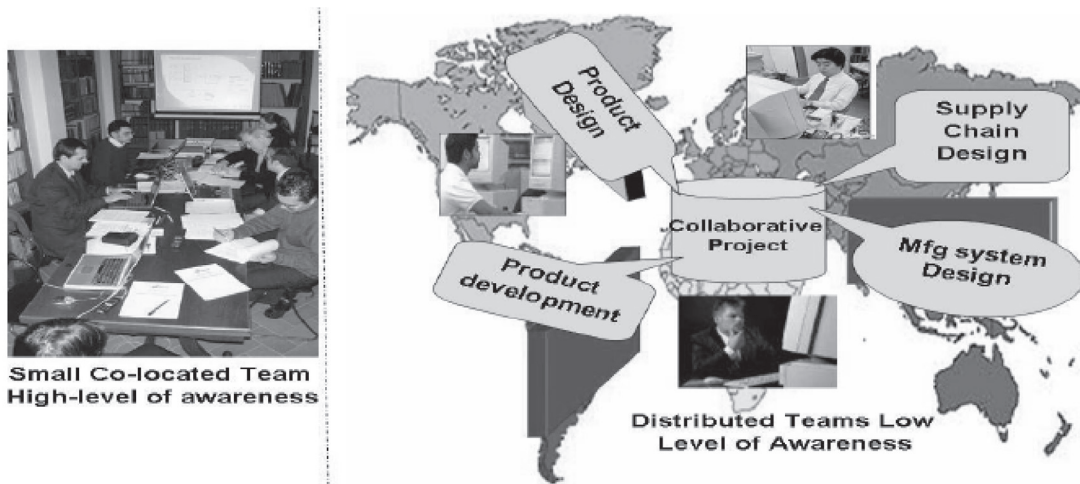


Figure 1: Awareness is critical to project success [4]

Engineering Moderator to Universal Knowledge Moderator for Moderating Collaborative Projects

even countries as shown in figure 1. The type size and context of collaborative projects varies considerably from scenario to scenario. It may represent the collaborative product development, collaborative process design, supply chain design, or even the manufacturing system design etc. Increasing competition in the global market pushed enterprises to strive for better product designs and more effective product development. As a result, more and more efforts are focussed on building a knowledge intensive design process that requires various globally situated domain experts to collaborate closely and share information and knowledge using information technology (IT). Therefore, it is necessary to raise the awareness among the project teams members working on a collaborative project to reduce or avoid the conflicts and misunderstandings that inevitably occurs in collaborative projects. Moderator technology which encompasses an intelligent support system provides possible approach to resolving these issues. Moderators support individuals to perform their individual roles from positions of strength and improve understanding through raised awareness of the needs of other contributors. Moderator also support individuals in their preferred methods of working whilst increasing understanding of the needs of both other individuals and the total team.

To date, all moderators have been designed and implemented as modular specialist software systems, consisting of a moderation module, multiple expert modules and a knowledge acquisition module. Until now, all knowledge acquisition for the prototype moderators has been done manually, based on human expertise and experience. There is however substantial potential for moderators to “learn” and update themselves from knowledge discovered in the existing operational databases of manufacturing companies. Data mining case studies have already shown that relevant knowledge for future designs and redesigns can be identified by exploring operational data collected during product manufacture [5, 6]. The objective of this research is to advance research in Moderator technology with particular emphasis on Knowledge acquisition. It explains the current research going on the development of Universal Knowledge Moderator

Moderator Technology

The moderator concept was first proposed in the MOSES (Model Oriented Simultaneous Engineering System, 1992-1995) research project as a support tool for design project teams. It was coordinating software for Concurrent Engineering (CE) design, to raise awareness among the inter-working cross disciplinary participants that exist and need to co-operate in modern day engineering teams. It addressed the fundamental requirements for provision of support for design team working in a concurrent engineering environment, by encouraging and facilitating communication between team members [7].

Evolution of Engineering Moderator

Generally, a concurrent engineering (CE) design project team contains specialist engineers from multiple disciplines with different types of experience and expertise. These may include, for example product development, process selection, equipment selection, project management, performance prediction (perhaps by simulation) and potentially many other. Hence the team brings together all the skills needed to design and develop products to meet defined project and /or enterprise objectives. In summary, the primary functions of moderators are to raise awareness, and to facilitate cooperation and coordination among engineers in design team activities. The role of a moderator is to identify the occurrence of each design conflict, and to orchestrate a dialogue between the interested design functions until the conflict is resolved. To identify and signal conflict in product design moderation within the MOSES system, the EM must be capable of performing following operations [7].

- To promote communication and negotiation between design experts.
- To identify that a significant problem may have occurred in the design.
- To determine the course of action to follow when a significant problem is identified.
- To maintain communication between interested design experts until the conflicts of interest has been resolved.

To facilitate the execution of these duties the EM must be able to use certain types of knowledge and to have access to particular types of information on which it can apply its knowledge. Therefore, the structure of EM in the MOSES system included three main elements, Design Expert Knowledge, Knowledge Acquisition Module, and Design Moderation Module.

Expert Module

The expertise within the CE project environment comes from many different disciplines and skills. Therefore, the EM needs a mental model of each design expert or source of knowledge or expertise within the CAE system. There are three main sections in each design expert module are : *Personal Profile Detail, Main Design Criteria, Communication methods.*

Knowledge Acquisition Module

This module contains the expertise to enable the engineering moderator to update its knowledge of available expertise. It must therefore retain and apply knowledge about the knowledge used by each of the design expert. The *Knowledge Acquisition Module (KAM)* provides the Moderator with all the knowledge that it requires to create, update and remove knowledge during the course of its operation. Part of the functionality of KAM is to add new design experts to the EM's design expert knowledge stores whenever a new team member joins the design team.

Design Moderation Module

This module contains the expertise to enable the EM to moderate the current design, and comprises of several elements. To all intents and purposes, this module embodies the EM's own expertise, as this module includes the EM's knowledge of how to carryout the tasks required during the design moderation process. For example the EM could detect the design change which has been made in the shared product model database, then carryout the moderation on the design, by applying the knowledge it has about existing design experts, from its Design Expert Knowledge.

Evolution of Manufacturing System Engineering Moderator

Designing a manufacturing system is a complex task and such projects often require expert contributions from many different disciplines to design or modify the system successfully. It requires the application of different area of expertise, including, for example functions such as process selection, equipment selection, facility layout, performance prediction (perhaps by simulation) and potentially many other. The primary function of the MSE Moderator was to support globally distributed MS design and enhance the degree of awareness, cooperation and coordination between members of the concurrent engineering team within the MISSION environment. The basic functionality of the MSEM is same as the EM

Additional necessary functionality for the MSE Moderator can be identified through examination of the activities in the moderation process. Figure 2 shows the content of MSE Moderator, which again includes three modules. These modules are Design Agent Module(DAM), Design Moderation Module (DMM) and Knowledge Acquisition Module (KAM).

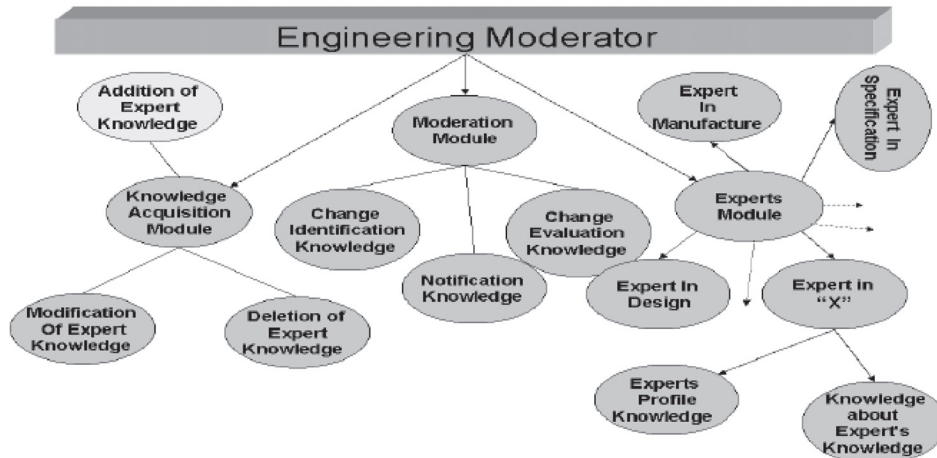


Figure 2: Structure of Manufacturing System Engineering Moderator

Third phase of the work was carried out to determine how the existing moderator concepts might be extended or modified to make them applicable to extended enterprise, virtual enterprise and E-supply chain (E-SCM) environments. An MSE Ontology model was proposed to enable the operation of an extended enterprise MSE Moderator (EEMSEM) to provide common understanding of manufacturing related terms, and therefore to enhance the semantic interoperability and reuse of knowledge resources within globally extended manufacturing teams or E- Supply Chain Management [8-10].

Extended Enterprise MSE Moderator/ E-Supply Chain Moderator on the Semantic Web (EEMSEM)

In the era of globalization, there is need for manufacturing systems to be designed, redesigned by extended project teams. Therefore, design is taking place in an Extended Enterprise (EE) / Virtual enterprise (VE) environment that can bring about both added value and various aspects of engineering product development. The growing complexity of VE knowledge has made it increasingly difficult to share and exchange knowledge and information between companies, where inevitably the individual partners will have their own terminology and information sources. Heterogeneity of data causes a major problem in sharing and exchanging the information within a VE. The three most general heterogeneity problems among the multi database community are as mentioned below:

- Syntax: Data format heterogeneity
- Structure: different data organizations, e.g. schema heterogeneity in RDBs and OODBs,
- Semantic heterogeneity: conceptual knowledge, where the intended interpretation or meaning of the data is specified in a special context. For example , semantic heterogeneity refers to differences or similarity in the meaning of data between the different component databases.

Therefore, it is an important requirement to make design knowledge effectively accessible and sharable across virtual enterprise team members, by using an explicit and well defined terminology (Lin and Harding 2003). The adoption of “semantic web” technologies, like ontologies, content metadata and reasoning about conceptual knowledge, have been

investigated by [9] to support a variety of the essential activities of evolving MSE Moderator knowledge management, including, knowledge retrieval, storage, sharing and moderation. Lin *et al.* [8] proposed an MSE Ontology to provide a common understanding of manufacturing related terms, and therefore to enhance the semantic interoperability and reuse of knowledge resources within the global extended manufacturing teams. They used protégé (<http://protege.stanford.edu/>) to automate the process of building domain specific knowledge acquisition and knowledge based systems.

The main function of the EEMSEM is to coordinate expertise and support the role of concurrency within the engineering activities of the inter-enterprise environment. Two major differences that exist between MSEM and EEMSEM are delineated as follows:

- Design Information changes (including addition or deletion) are expressed in different languages and terminologies and
- Information or knowledge of what team participants consider being important aspects of the design (e.g. key variables or values) is expressed in different languages and terminologies.

The first difference directly affects the EEMSEM's design moderation process and the second difference affects both the design moderation process and its knowledge acquisition process. The MSE Ontology model addressed both these differences. The major goals of EEMSEM is to:

- Provide an interoperability mechanism with well defined semantic definitions of an MSE ontology model among all the participating extended project team partners to support information autonomy.

To reduce the complexity of EEMSE systems by providing a set of knowledge of the profiles and characteristics of the participants within the extended enterprise group and communication mechanism to orchestrate dialogues between them.

Universal Knowledge Moderator

Ongoing research for Universal Knowledge Moderator is how the MSEM can be extended to Knowledge Discovery for Globally Distributed and Collaborative E-Manufacturing on the Semantic Web. The aim of this research is to develop and establish a flexible method for knowledge discovery from semantically heterogeneous data for the moderation of design knowledge among globally cooperative e-manufacturing chains. Therefore, Universal Knowledge Moderator mainly focuses on three main aspects:

- Analyze and define the specification of common manufacturing ontology for electronic industry in an ontology server.
- Develop a suitable framework enable WWW information exchange between partners of cooperative manufacturing chains via common mediated meta-models across all engineering design teams through semantic mapping.
- Development a knowledge discovery / data mining framework to enable the moderator's knowledge acquisition module should incorporate "learning", updating and reuse elements which exploit knowledge discovery techniques.

First two aspects are partially covered in the earlier version of Moderator. Therefore, developing a knowledge discovery and data mining based framework to support the knowledge discovery module of Universal Knowledge moderator is the focus of current research. This research proposes an architecture model in terms of the Universal Knowledge Moderator (UKM)

for enabling semantic integration of geographically distributed knowledge discovery services on the MSE moderator. It mainly consists of following three modules as discussed below:

1. **Enterprise Metadata Integration Module:** Main functionality of this module is to analyze and identify the terminology, representation and classification of manufacturing system for UKM activities. It defines the Universal Manufacturing Enterprise Schema (UMES) and Convert the UMES into webbased ontology language, e.g. Resource Description Framework (RDF) and Web Ontology language (OWL). A set of semantic mapping rules is defined for automatic reasoning of heterogeneous document structure and data to UMES in Metadata Integration Ontology server.
2. **Knowledge Discovery Module:** As shown in figure 3, this module incorporates features of knowledge based methodology designed for cooperative learning, knowledge reuse and corresponding update of expert modules knowledge within UKM. It makes use of knowledge discovery and data mining tools to resolve the challenges of identifying and incorporating new knowledge with the existing expert modules in the UKM. In the proposed framework, the KAM mainly consists of four components which act as intelligent agents:

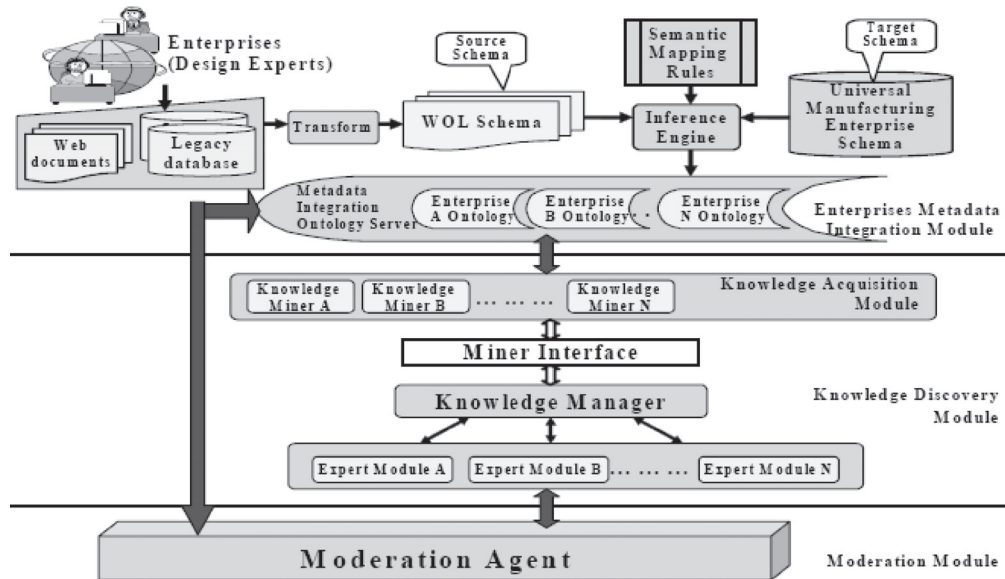


Figure 3: The Architecture of Universal Knowledge Moderator (UKM)

- **Knowledge Miners:** The main functionality of the knowledge miner is to find patterns, relationships and rules within data associated with the expertise of each team member. It mainly consists of three components; a knowledge interface, functional facilities and a knowledge base relating to current project team members (and including details of previous updates to knowledge that have been made using the KAM). The knowledge interface manages the communication between the knowledge manager and the knowledge miner. The mining tasks are carried out using the current project team member knowledge base. Knowledge about the project team members, domain knowledge, and the main data mining engine are part of this component. The mining engine is given a mining objective, and then it tries to discover special patterns of data by forming the data into clusters that share

some common properties, finding associations among the data, and discovering If Then Else rules. Overall, the knowledge miner plays a vital role in extracting the information, discovering hidden relationships, dependencies, patterns, etc., relating to particular team members specified within the knowledge base. After completing the mining task, the results are sent to knowledge manager for further processing and queries.

- **(2) Knowledge Manager:** The knowledge manager acts as mediator and communicator between different knowledge miners, the information manager, DEMs, and the repository for knowledge sharing. It also makes the decisions to create or delete DEMs based on the extracted information, recommendations from the various constituent elements, and information about changes being made to the design team. The knowledge manager mainly consists of four components; miner interface, manager interface, functional facility, and the manager knowledge base. The knowledge manager checks what special types of knowledge are relevant to specific DEMS and consequently which types of databases and files are appropriate to mine in order to update the knowledge content of the particular DEM. When mining and update tasks have been completed, it stores the knowledge of these activities into the repository for possible future use and transfers the relevant new or updated knowledge into the DEMs through the expert module assistant. The updated DEMS can then be enabled, so that they can be used again in the ongoing moderation processes.

Moderation Module

The major function of the Moderation Module is to identify the potential project conflicts and to perform moderation activities. The moderation process is activated whenever a project decision is made, and this is identified by a change being made to the project information within the shared database. Projects decision change is achieved by the Moderator polling and asking the information manager for details of any changes that have take place. When the Moderator had been notified of a change, it is connected to its object oriented knowledge database, which contain memory from knowledge miner and knowledge manager. The moderation of the current change stopped or moved to the next change, if no team members are interested in that change. However, if Moderator found that one or more team members did have interest in the current type of change, a conflict had been identified. To resolve the conflict, the interested team members are contacted by UKM and it remains in dialogue with these team members until conflicts are resolved.

Conclusion

This research discusses the development phases and ongoing research on Moderator technology. These includes: Engineering moderator for product design, Manufacturing system engineering moderator for manufacturing system design, extended enterprise manufacturing system engineering moderator to enhance the semantic interoperability and reuse of knowledge resources within globally extended manufacturing teams. Current research focuses on the development of universal knowledge moderator based on semantic web and, knowledge discovery and data mining technology to enhance the knowledge generation and reuse in globally collaborative e manufacturing work.

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