



**HAL**  
open science

## Knowledge discOvery And daTa minINg inteGrated (KOATING) Moderators For Collaborative Projects

Alok Choudhary, J A Harding, Hsiao-Kang Lin, M K Tiwari, Ravi Shankar

► **To cite this version:**

Alok Choudhary, J A Harding, Hsiao-Kang Lin, M K Tiwari, Ravi Shankar. Knowledge discOvery And daTa minINg inteGrated (KOATING) Moderators For Collaborative Projects. International Journal of Production Research, 2011, pp.1. 10.1080/00207543.2010.532166 . hal-00669189

**HAL Id: hal-00669189**

**<https://hal.science/hal-00669189>**

Submitted on 12 Feb 2012

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



**Knowledge discOvery And daTa minING inteGrated (KOATING) Moderators For Collaborative Projects**

|                               |  |
|-------------------------------|--|
| Journal:                      | <i>International Journal of Production Research</i>  |
| Manuscript ID:                | TPRS-2010-IJPR-0300.R1   |
| Manuscript Type:              | Original Manuscript  |
| Date Submitted by the Author: | 16-Jul-2010  |
| Complete List of Authors:     | Choudhary, Alok; , University of Loughborough, Wolfson School of Mechanical and Manufacturing Engineering<br>Harding, J A; Loughborough University, Wolfson School of Mech and Man Engineering<br>Lin, Hsiao-Kang; I-Shou University, Industrial Engineering and Management<br>Tiwari, M K; Indian Institute of Technology, Department of Industrial Engineering and Management<br>Shankar, Ravi; Indian Institute of Technology, Management Studies |
| Keywords:                     | ARTIFICIAL INTELLIGENCE, COLLABORATIVE ENGINEERING, COLLABORATIVE MANUFACTURING, VIRTUAL ENTERPRISE, DATA MINING   |
| Keywords (user):              | collaborative networks, Moderator  |
|                               |  |

SCHOLARONE™  
Manuscripts

## Knowledge discOvery And daTa minING inteGrated (KOATING) Moderators For Collaborative Projects

A.K.Choudhary<sup>5</sup>, J.A.Harding<sup>1\*</sup>, H. K. Lin<sup>2</sup>, M. K. Tiwari<sup>3</sup> and R. Shankar<sup>4</sup>

### ABSTRACT

A major issue in any multidiscipline collaborative project is how to best share and simultaneously exploit different types of expertise, without duplicating efforts or inadvertently causing conflicts or loss of efficiency through misunderstandings of individual or shared goals. Moderators are knowledge based systems designed to support collaborative teams by raising awareness of potential problems or conflicts. However, the functioning of a moderator is limited by the knowledge it has about the team members. Knowledge acquisition, learning and updating of knowledge are the major challenges for a Moderator's implementation. To address these challenges a Knowledge discOvery And daTa minING inteGrated (KOATING) framework is presented for Moderators to enable them to continuously learn from the operational databases of the company and semi-automatically update the their knowledge about team members. This enables the reuse of discovered knowledge from operational databases within collaborative projects. The integration of KDD techniques into the existing knowledge acquisition module of a moderator enable hidden data dependencies and relationships to be utilized to facilitate the moderation process. The architecture for the Universal Knowledge Moderator (UKM) shows how moderators can be extended to incorporate learning element which enables them to provide better support for virtual enterprises. Unified Modelling Language Diagrams were used to specify the ways to design and develop the proposed system. The functioning of a UKM is presented using an illustrative example.

Keywords: Collaborative projects, Learning, Moderators, Knowledge discovery, data mining, Universal knowledge Moderator, virtual enterprise

\*Communicating Author: [J.A.Harding@lboro.ac.uk](mailto:J.A.Harding@lboro.ac.uk)

<sup>1</sup>: Wolfson School of Mechanical and Manufacturing Engineering, Loughborough University, Loughborough, Leicestershire, United Kingdom

<sup>2</sup>: Department of Industrial Engineering and Management, I-Shou University, Kaohsiung, Taiwan ROC

<sup>3</sup>: Department of Industrial Engineering, Indian Institute of Technology, Kharagpur, India.

<sup>4</sup>: Department of Management Studies, Indian institute of Technology, Delhi, India

<sup>5</sup>: The Logistics and Supply Chain Management (LSCM) Research Centre, Management School, The University of Sheffield, UK

## 1. Introduction

Increasingly competitive market trends demand highly customized products with ever shorter production time and these market trends are expected to accelerate. Consequently, modern business entities are challenged to identify effective means of reducing production cost, improving product and service quality, reducing time to market delivery, accelerating responses to customer requirement and bettering flexibility and system's reusability. Industries are striving to meet these challenges by focussing on their core competencies, integrating and collaborating intensively and migrating towards knowledge based manufacturing (Hicks *et al.* 2002, Lastra & Delamer 2006). (Ikujiro & Takeuchi 1995) observed that, as the market shifts, technologies proliferate, competitors multiply, and products and services become rapidly obsolete, successful companies are characterized by their ability to consistently create new knowledge, quickly disseminate it, and embody it in new products and services.

A major issue in multidiscipline collaborative projects is how best to share and simultaneously exploit different types of knowledge, without duplicating efforts or inadvertently causing conflicts or loss of efficiency through misunderstandings of individual or shared goals. The concepts of Moderators to support collaboration and team working have been researched in major research projects (MOSES 1995, MISSION Consortium 2001, Lin 2004). The main function of a moderator is to support collaborative working teams by raising individual members' awareness of the needs and experiences of other team members and the concept has been successfully demonstrated in product design, manufacturing system design, extended enterprise and e-supply chain. Prototype Moderators have been demonstrated in the form of knowledge based software support 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.

This research enhances the functionality and capability of Moderators through the integration of a knowledge discovery based semi-automatic knowledge acquisition framework which enables Moderators to "learn" and "update" their relevant expert modules from knowledge discovered in the existing operational databases of companies. To accomplish the task, a knowledge discovery and data mining integrated (KOATING) framework has been developed. The proposed Moderator, equipped with knowledge discovery capability can increase awareness within the project teams by highlighting potential problem areas (from previous experience) and raise awareness of any issues affecting the team members.

## 2. Knowledge Management Systems to Support Collaborative Projects

Recent developments show that collaboration exists in many forms such as collaborative product design, collaborative product development (Li & Qiu 2006, Harding *et al.* 2007, Popplewell & Harding 1995), collaborative planning forecasting and replenishment (CPFR) (Skjoett-Larsen *et al.* 2003), virtual factory (VF) (Katzy & Dissel 2001, Katzy & Crowston, Katzy & Obozinski 1998), extended enterprises (EE) (Popplewell & Harding 2004), virtual enterprises (VE) (Browne & Zhang 1999), and virtual organizations (VO) (Camarinha-Matos & Afsarmanesh 2007b), virtual breeding environment (Camarinha-Matos & Afsarmanesh 2007b, ECOLEAD 2008, ECOLEAD 2005, Sánchez *et al.* 2005) etc. As discussed below, several types of knowledge management systems have been developed to support these collaborations.

When people from different disciplines, experiences and backgrounds try to work together in a collaborative project, there is potential for misunderstanding or lack of awareness of the needs and interdependencies of each of the individual contributors. The importance of awareness and understanding of other partners' requirements in collaborative projects was highlighted in the mid 1990s. In this context, Mediator was one of the earliest works proposed by (Gaines *et al.* 1995), it is an open architecture-based information and knowledge support system for geographically dispersed manufacturing processes ranging from requirements through design, engineering, production, maintenance and recycling. Also in the mid 1990s, the MOSES project in the UK funded by the Engineering Physical Science Research Council (EPSRC) introduced the concept of a specialist intelligent software system called a "Moderator", to increase understanding and awareness in concurrent engineering teams (Harding & Popplewell 1996).

Frécon & Nöu (1998) developed a distributed virtual environment to support collaborative work in teams that are geographically scattered. They supported synchronous as well as asynchronous group collaboration. Zhou & Nagi (2002) presented a distributed information system architecture using CORBA and STEP standards to overcome the heterogeneity of partners and promote standardization respectively for VE. In a research project partly funded by the European commission, Slade & Bokma (2002) discussed the application of an extensible ontology as a principle for integrated information, knowledge management and knowledge sharing among geographically distributed collaborators of an EE. However, they mainly focussed on sharing, organization, interrelation, and visualization of documents for team members. Shafiei & Sundaram (2004) proposed a multi-enterprise collaborative conceptual Enterprise Resource Planning (ERP)- Decision Support System (DSS) to

1  
2  
3 maximize the intelligence density, improve the quality and visibility of information and to  
4 achieve the foundation for multi-enterprise collaboration. Panteli & Sockalingam (2005)  
5 developed a framework for understanding the dynamics of trust and conflict within the  
6 context of virtual inter-organizational arrangements. Ahn *et al.* (2005) presented a knowledge  
7 context model to facilitate the use of contextual information in virtual collaborative work. A  
8 new software system called IntelliTeam was developed based on a web-based collaborative  
9 system framework using a multiple perspective approach (Cil *et al.* 2005). It consists of a  
10 group decision-making approach, many multiple criteria decision-making techniques, an  
11 intelligent system and advanced communication systems such as mobile e-services, wireless  
12 application protocol etc. Misono *et al.* (2005) proposed a distributed collaborative decision  
13 support system based on semantic web service technology to achieve collaborative goals.  
14  
15  
16  
17  
18  
19  
20  
21

22  
23 In the UK, the *Advanced Knowledge Technologies Interdisciplinary Research Collaboration*  
24 (AKTIRC) was a £7.6 Million project funded by EPSRC to develop knowledge management  
25 technologies as part of the e-science initiative on grid computing. Collaborative Advanced  
26 Technologies in the Grid (CoAKTinG) aims to support distributed scientific collaboration  
27 (Shum *et al.* 2002). Collaboration is the centrepiece of product development processes and  
28 involves multidisciplinary teams, functions and heterogeneous tools. Ramesh & Tiwana  
29 (1999) viewed new product development as a knowledge sensitive activity and identified  
30 problems associated with knowledge management issues of new product development by  
31 cross functional collaborative teams. Huang *et al.* (2000) proposed workflow management as  
32 a mechanism to facilitate team work in the collaborative product development environment  
33 where remote web-based decision support systems (TeleDSS) are extensively used by  
34 geographically distributed team members.  
35  
36  
37  
38  
39  
40  
41  
42

43  
44 Recently, the Decision Support Systems (DSS) journal published a special issue dealing with  
45 knowledge management and collaborative work related issues (Li & Lai 2005). However,  
46 none of the work discussed above dealt with the knowledge discovery issues to aid the  
47 decision making process in a collaborative projects. Scotney & McClean (2004) provided a  
48 flexible method of knowledge discovery from semantically heterogeneous data, based on the  
49 specification of ontology mapping. Wen *et al.* (2005) used web robots to discover the latest  
50 knowledge on the internet for better service of collaborative design. Numata *et al.* (1997)  
51 dealt with the knowledge conversion between and within tacit knowledge and explicit  
52 knowledge in new product development.  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 The European Collaborative networked Organizations LEADership initiative (ECOLEAD)  
4 was an “integrated project” funded by the European Commission within the 6<sup>th</sup> Framework  
5 Programme and involved 20 partners across 14 European countries. ECOLEAD results claim  
6 to provide a set of tools including a Dynamic VO creation assistance tool, a VO collaboration  
7 and performance measurement tool, a contract negotiation wizard tool, a VO management e-  
8 service tool, a collaborative problem solving support e-services tool, an advanced  
9 collaboration platform for professional virtual communities tools etc. (ECOLEAD 2008,  
10 ECOLEAD 2005, Ramesh & Tiwana 1999, Camarinha-Matos & Afsarmanesh 2007a,  
11 Pechoucek *et al.* 2005). However, so far, none of the published literature as an output of this  
12 project deals with the knowledge discovery issues to support collaboration in an industrial  
13 context (ECOLEAD 2005). Li & Qiu (2006) reviewed collaborative product development  
14 related works and based on the review of 130 papers, they concluded that one of the major  
15 issues for future collaborative system development is efficient learning and sharing of  
16 knowledge for multiple application domains.  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27

### 28 **2.1 Moderator Technology**

29 A moderator is a specialist software system that supports collaborative working by raising  
30 awareness of the priorities and requirements of other contributors. The moderator concept was  
31 first proposed in the MOSES research project (MOSES 1995) as a support tool for design  
32 project teams. It addressed the fundamental requirements for provision of support for design  
33 teams working in a concurrent engineering environment, by encouraging and facilitating  
34 communication between team members, by making them aware of when their activities and  
35 decisions may be of interest to, or affect the work of, other team members (Harding &  
36 Popplewell 1996, Harding 1996, Harding *et al.* 2003, Lin & Harding 2003, Lin *et al.* 2004).  
37  
38 Later the MISSION research project (MISSION Consortium 2001) saw the second phase of  
39 the development of the moderator concept where the Manufacturing System Engineering  
40 Moderator (MSEM) was designed as an intelligent support system to monitor design  
41 decisions, evaluate their significance to individual project members and when necessary  
42 communicate details of the identified problems to any affected team members (Harding *et al.*  
43 2003). The third phase of the research on Moderators was carried out to determine how  
44 Moderator technology can be extended or modified to benefit extended enterprise and e-  
45 supply chain environments (Lin & Harding 2003). An MSE ontology model was proposed to  
46 provide a common understanding of manufacturing related terms and thereby enhance the  
47 semantic interoperability and reuse of knowledge resources within globally extended  
48 manufacturing teams or e-supply chains (Lin & Harding 2003, Lin *et al.* 2004, Lin & Harding  
49 2007, Lin *et al.* 2005).  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 The quality of the support that any Moderator can provide is limited by its knowledge of team  
4 members as collected by its Knowledge Acquisition Module (KAM) and stored in its Expert  
5 Modules, where each Expert Module is the Moderator's high level model or representation of  
6 a team member which includes "item of interest" to that team member and Moderator's  
7 knowledge of what need to be done to support that team member and make him aware of  
8 potential problems or opportunities which are relevant to him. To date, all the knowledge  
9 acquired for the Moderators has been provided by human experts using traditional knowledge  
10 acquisition methods. However, huge amounts of experience and expertise lie within the  
11 databases' of manufacturing operations. Therefore, knowledge discovery for moderation has  
12 been identified as a research gap in the existing research (Choudhary *et al.* 2006, Choudhary  
13 2009).

### 22 23 **3 Knowledge Discovery and Data Mining**

#### 24 **3.1 Motivation for using KDD**

25  
26 In recent years, knowledge discovery in database (KDD) and data mining (DM) have  
27 attracted a great deal of attention in manufacturing enterprises due to wide availability of  
28 huge amounts of data and the challenges of converting it into useful and novel information  
29 and knowledge. The review section of this paper revealed that the Moderator system requires  
30 up to date knowledge and therefore Harding *et al.* (2007) recommended that the Moderators  
31 need the capability of ongoing learning. KDD techniques can help by (semi-) automating the  
32 time consuming process of knowledge acquisition and reducing the cost of development by  
33 decreasing the amount of time needed from experts and knowledge engineers.  
34 Implementation of KDD tools and techniques also has the potential to uncover knowledge  
35 that might otherwise be overlooked by those involved in the knowledge acquisition process.

#### 42 43 **3.2 KDD process**

44  
45 KDD refers to the overall process of discovering useful knowledge from data and data mining  
46 refers to a particular step in this multi step process. Data mining is the application of specific  
47 algorithms for extracting patterns from data (Piatetsky-Shapiro 1991, Fayyad *et al.* 1996). The  
48 KDD process includes several pre-processing methods aimed at facilitating the application of  
49 the chosen data mining algorithm and post processing methods aimed at refining and  
50 improving the discovered knowledge. KDD is interdisciplinary using methods from several  
51 research fields including machine learning, statistics, pattern recognition, databases  
52 technology, artificial intelligence, knowledge acquisition for expert systems, data  
53 visualization and high performance computing. The unifying goal is to extract high level  
54 knowledge from low level data within large data sets. The overall KDD process is interactive  
55 and iterative involving numerous steps and requiring several decisions to be made by the user  
56  
57  
58  
59  
60



(Fayyad *et al.* 1996, Mitra *et al.* 2002). Data mining uses automated tools and employs sophisticated algorithms to discover hidden patterns, associations, anomalies and/or structure from large amounts of data stored in data warehouses or other information repositories. The goals of data mining can be achieved using a variety of data mining functions such as classification, regression, clustering, summarization, discovering association rule, dependency modelling, sequence analysis. Fayyad *et al.* (1996), Mitra *et al.* (2002), Harding *et al.* (2006), and Choudhary *et al.* (2008) extensively reviewed the application of data mining and identified the several challenges and good practices of data mining.

#### **4 Knowledge discOvery And daTa minING inteGrated (KOATING) frame work for Moderators**

All previous Moderators have used a knowledge based approach to capture the relevant knowledge and information by interviewing experts and storing the knowledge in an object oriented database (OODB) based on a Knowledge Representation Model (KRM) (Harding 1996). This manual update has been done by a human operator which is a complex and time consuming task. In addition, every piece of knowledge has a lifespan for its validity and therefore it is necessary to continuously review and update the knowledge contained in any knowledge based system. Figure 1 show the existing structure of a typical Moderator, where the knowledge in any expert module can be manually updated by the KAM.

In the proposed framework, a knowledge discovery module (KDM) with combined functionality of knowledge miners, a knowledge manager and repository provides continuous learning, thus enabling semi-automatic update of its expert modules from time to time. Enterprises continuously generate large amounts of data during their normal operation and this data can be a valuable asset and potentially important source of knowledge. Identification and retrieval of these knowledge assets may be achieved by applying intelligent data analysis approaches to databases with the objectives of identifying patterns, discovering rules and predicting results. Therefore by providing a semi-automatic mean to discover and apply new knowledge, proposed framework will be able to reduce the time intensive activity of knowledge discovery and updating the expert module. In addition, it is also recommended that a check be made on the newly generated knowledge to avoid misunderstandings or contradictory knowledge within the knowledge assets.

<<Insert Figure 1 about here>>

##### **4.1 Proposed KOATING Framework**

The KOATING framework does not replace the existing KAM but supports it and enables knowledge update. The supporting module to perform this function has been termed as the

1  
2  
3 knowledge discovery module (KDM) which is proposed as an integral part of KAM. The  
4 main contribution of this framework is the elements within the knowledge discovery module  
5 which can be seen by comparing Figure 1 and Figure 2. Table 2 shows a comparative study of  
6 traditional and proposed Moderator system.  
7  
8  
9

10 <<Insert Table 1 about here>>

11 In the proposed framework, the project life cycle and operational data can be used to generate  
12 structured knowledge which should be at least as good as the knowledge provided by domain  
13 experts. Figure 2 shows the proposed KOATING framework which incorporates the features  
14 of a knowledge based system designed for individual as well as cooperative learning,  
15 knowledge reuse, and corresponding update of expert module knowledge within the  
16 Moderator system. The knowledge miners can use many different knowledge discovery and  
17 data mining tools to address the challenges of identifying and incorporating new knowledge  
18 within the existing expert modules.  
19

20 As in the original Moderators, each expert module manually stores knowledge about a  
21 participating project team member. In the KOATING framework, it also semi-automatically  
22 stores the discovered knowledge delivered by the KDM. The bottom part of the framework in  
23 figure 2 shows the database of individual project member.  
24  
25  
26  
27  
28  
29  
30

31 <<Insert Figure 2 about here>>

#### 32 33 34 35 **4.2 Knowledge Discovery Module of KOATING framework**

36 The KDM supports the KAM by providing a semi-automated knowledge acquisition  
37 mechanism to identify and retrieve appropriate knowledge from available data sources and  
38 store them in a format appropriate for further use by the Moderator. The proposed KDM  
39 requires its integration with the Moderator as well as the data source. This research assumes  
40 that the data source is accessible for analysis purposes by the KDM. The KDM supports  
41 knowledge discovery through all the period of learning and facilitates the update of the expert  
42 module(s) by the KAM. This is demonstrated using an illustrative example of virtual e-  
43 supply chain in section 7.  
44  
45  
46  
47  
48  
49  
50

##### 51 **4.2.1 Knowledge Discovery Approach Embedded in KDM**

52 The knowledge discovery process can be achieved through two different approaches namely  
53 Data Mining Software Tool Approach (DMSTA) and Data Mining Application System  
54 Approach (DMASA) (Holsheimer 1999). DMSTA approach involves the application of data  
55 mining software tools on ad hoc data mining projects and requires a significant expertise in  
56 data mining methods, databases and/or statistics. The disadvantages associated with this  
57 model include the need for several experts to collaborate in a project and poor transferability  
58  
59  
60

1  
2  
3 of results and models. This implies that the results and models derived can be used for  
4 reporting, but cannot be directly utilized to integrate with other systems (Holsheimer 1999).  
5  
6

7  
8 In contrast, the DMASA approach primarily focuses on the requirement of knowledge users  
9 and decision makers to enable them to view and exploit data mining models. Models can be  
10 presented in a user understandable manner through a user friendly and intuitive GUI using  
11 standard and graphical presentation techniques. Knowledge can be discovered by focussing  
12 on a specific problem domain covered by areas of analysis with the possibility of repeated  
13 analysis at periodic time intervals, or when required by the user, or at a particular milestone  
14 such as at the end of projects. Several authors and practitioners have recommended this  
15 approach for better integration in the business environment and in decision processes  
16 (Holsheimer 1999). Therefore, this research has adopted the DMASA approach.  
17  
18  
19  
20  
21

#### 22 23 **4.2.2 Process Model of KDM**

24 The process model represents how the knowledge generation and decision making process is  
25 supported by the knowledge based system. Determining the process model is one of the key  
26 issues for the design of the KDM for Moderators. The CRISP-DM (Cross-Industry Standard  
27 Process for Data Mining) process model is a data mining process model developed by the  
28 industry leaders in collaboration with data mining experts, users and data mining tool  
29 providers (Shearer 2005). The analysis of various other data mining models equivalent to  
30 CRISP-DM, identifies CRISP-DM as the most appropriate process model for knowledge  
31 based system implementation (Shearer 2005). In the present context, the CRISP-DM process  
32 model has been modified in order to make it applicable to the KDM. Unlike the CRISP-DM  
33 model, the process model for the KDM has been divided into seven phases and three stages.  
34 Each of these phases and stages includes a variety of tasks. The phases include: domain  
35 understanding, data understanding, data preparation, modelling, evaluation, deployment and  
36 conflict resolution. The sequence of the phases is not strict and moving back and forth  
37 between various phases is always required. Based on the outcome of each phase the next  
38 phase or a particular task of a phase that needs to be performed can be decided. The arrows  
39 indicate the most important and frequent dependencies between phases. The inner circle  
40 shows the cyclical nature of the knowledge discovery process itself. It means that a  
41 knowledge discovery process continues even after knowledge is discovered during the  
42 deployment phase. The lessons learned and experiences gained during this whole process can  
43 benefit the subsequent data mining processes. The elements of the KOATING framework  
44 have been shown as actors in Figure 3 with the modified structure of CRISP-DM that has  
45 been adapted to the needs of the KDM for three stages:  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

- the preparation stage

- the knowledge production stage and
- the implementation stage

The preparation stage of the process model prepares the area of analysis for production and implementation uses. This stage focuses on performing the first five phases, i.e. from domain understanding to evaluation in an iterative manner. The major reason why multiple iterations may need to be carried out is to achieve step by step improvement in all the phases. Datasets must be created automatically on a periodic basis, say every night based on the current state of the existing databases, data warehouse and the transactional data. The problems identified in the data preparation phase may demand changes in the data understanding phase. Models may be created and evaluated multiple times in order to fine tune the data mining algorithms. Depending on the results gained by evaluation through multiple iterations, the preparation stage can either reject the area of analysis due to insufficient quality of model or approve it with or without a slight modification to the objectives for domain understanding and this may consequently require changes in other part of the process.

<<Insert Figure 3 about here>>

The second stage is called the knowledge production stage, which mainly focuses on modelling, evaluation and deployment. At this stage the models are created and evaluated multiple times to fine-tune the algorithms and parameters used. These functions are performed by knowledge miners with support from knowledge managers and repositories. These are discussed in further detail in the next sections. The third stage, called the implementation stage, updates the fine-tuned knowledge into the expert module and consists of the modelling step through to the conflict resolution step. This stage provides inputs to all the previous stages based on the extracted knowledge, and stage requires interactions from users, knowledge miners, knowledge managers and repositories as shown in Figure 5. Conflict resolution between the existing knowledge and the discovered knowledge requires input from users based on their knowledge of the domain. The development of a process model for the KDM provides a basis for the development of knowledge integrated moderator services. As shown in the KOATING framework in Figure 2 and the process model Figure 3, KDM mainly consists of four components including (1) Knowledge miners (2) Knowledge Manager (3) Information Manager (4) Repository. The next sub-sections discuss the internal structure and the functionality of these components.

#### **4.2.3 Knowledge Miners**

The major functionality of a knowledge miner is to extract patterns, relationships and useful knowledge from the operational databases to populate and update the expert modules. In the

1  
2  
3 present context, the performance target of a knowledge miner is to generate knowledge which  
4 is as good as or even better than the knowledge associated with human experts in the same  
5 situation with the same input datasets. At present, a successful application of data mining  
6 generally relies on the experience and expertise of both the data mining expert and the domain  
7 expert.  
8  
9

10  
11  
12 Figure 4 schematically shows the architecture of a knowledge miner, which acts as an  
13 intelligent agent. A similar architecture was also developed in the context of shop floor  
14 control in manufacturing (Srinivas *et al.* 2008). The knowledge interface manages the  
15 communication between the knowledge manager and the knowledge miner. The  
16 communication is based on message passing based on a shared ontology; this means that  
17 when the knowledge miner receives messages that are represented in a common ontology, the  
18 knowledge miner interface converts these messages into local format based on the common  
19 ontology. In a similar way, when the knowledge miner sends messages to the knowledge  
20 manager, the knowledge interface translates them into a common format first and then sends  
21 them to the knowledge manager. A detailed study of ontology models and detailed structure  
22 are presented in (Huang & Diao 2008) but the complexity associated with this approach is  
23 beyond the scope of this research paper.  
24  
25  
26  
27  
28  
29  
30  
31  
32

33 The operational facility component is the central control and action part of the knowledge  
34 miner. It consists of sub components such as an inference engine, and KDD Facility. The  
35 KDD facility is one of the main components of the knowledge miner and it could be  
36 implemented in several different ways, e.g. as software code or an expert system. It performs  
37 the mining task of discovering causal and interesting relations from the dataset and presents  
38 them in a form compatible with the knowledge manager. This component must carry out  
39 several functions that are required to carry out the data mining functions discussed in section  
40 3.  
41  
42  
43  
44  
45

46  
47 <<Insert Figure 4 about here>>  
48

49 The knowledge required to perform the mining task, common vocabulary; knowledge about  
50 different users, past decisions, mining objectives and domain knowledge are stored in the  
51 agent knowledge base. The data interface component of the system provides a mechanism to  
52 extract data from the external data source such as data acquisition systems. In order to  
53 perform the mining task, KDD facility uses a variety of tools, techniques and functions. After  
54 the knowledge miners complete their tasks, they send the knowledge mining results to the  
55 knowledge manager using the knowledge interface and the knowledge miner then terminates.  
56  
57  
58  
59  
60

1  
2  
3 The functionality of the process model (Figure 3) accomplishes its main objectives of  
4 knowledge discovery through the implementation of 4 modules in the KDM. These are  
5 described as follows:  
6  
7

- 8 1. *Data Acquisition Module*: This module performs three major tasks; firstly it acquires  
9 data from the current data acquisition systems/data warehouses of the company.  
10 Secondly, it identifies data types such as structured numerical data or unstructured  
11 text based data. Thirdly, it selects a subset of the data or focuses on a subset of its  
12 attributes based on the objective.
- 13 2. *Data Preparation Module*: This module performs all the functions needed to  
14 transform the raw data into a form which can be fed into different algorithms. This  
15 involves (1) dealing with missing values (2) eliminating noisy data (3) normalizing  
16 the database to avoid duplication and eliminating various kinds of logical  
17 inconsistencies (4) transforming the data to different values and (5) creating derived  
18 attributes in order to reduce the computational burden.
- 19 3. *Modeling Module*: based on the goal of data mining, this module performs one or  
20 more combinations of the data mining functions such as classification or prediction,  
21 etc, using a set of data mining algorithms.
- 22 4. *Knowledge Evaluation Module*: this module evaluates the generated knowledge based  
23 on certain criteria to make sure that it is novel and useful. It applies statistical  
24 techniques to determine the validity of the identified knowledge over the universal  
25 set.

26  
27 The provision of these modules validates the process model discussed earlier as they provide  
28 all the functionality required to achieve all the stages mentioned in the process model.  
29  
30

31 Moderators require two types of update of expert modules (1) regular or periodic update and  
32 (2) user requested update. Considering these requirements of the Moderator system,  
33 knowledge miners function in two different ways, firstly as periodic knowledge miners and  
34 secondly as task oriented knowledge miners. A periodic knowledge miner starts at the  
35 beginning of the life cycle of project. Usually a periodic knowledge miner works periodically  
36 and generates knowledge based on changes in the database of the corresponding team  
37 member. A similar approach was used by (Wang 1997) for group decision making purposes.  
38 In contrast, task oriented knowledge miners are activated on a request from the knowledge  
39 manager when an expert's role or interest changes or whenever something unusual happens,  
40 or the knowledge about an expert is identified to be incorrect. After the knowledge miner has  
41 completed the task, the results are sent to the knowledge manager for further processing.  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

#### 4.2.4 Knowledge Managers

1  
2  
3 The knowledge manager acts as the heart of the proposed KOATING framework and plays a  
4 vital role of manager, mediator and communicator between the different knowledge miners,  
5 the information manager, the expert modules and the repository for knowledge sharing. The  
6 knowledge manager makes the decisions to create or delete expert modules based on the  
7 recommendations from the various constituent elements. The knowledge manager mainly  
8 consists of four components: miner interface, knowledge acquisition interface, functional  
9 facility and the knowledge manager agent knowledgebase that provides support for localized  
10 reasoning. The basic structure is represented in Figure 5.

11  
12  
13  
14  
15  
16  
17  
18 The knowledge manager checks what special types of knowledge are relevant to specific EMs  
19 and consequently which types of databases and files are appropriate to mine in order to update  
20 the knowledge content of any particular EM. It activates the responsible knowledge miner to  
21 perform the mining task. When mining and update tasks are completed, it stores the  
22 knowledge about these activities into the repository for possible future use and transfers the  
23 relevant new or updated knowledge into the EMs through the knowledge acquisition  
24 interface. The updated EMs can then be enabled, so that they can be used in the ongoing  
25 moderation processes. The operational facility provides the mechanisms for knowledge  
26 transactions.

27  
28  
29  
30  
31  
32  
33 The knowledge manager mediates requests from the user and analyzes these requests through  
34 its localized knowledge and inference engine and then initiates a knowledge miner to perform  
35 the desired task through the miner interface. It communicates the type of knowledge to be  
36 mined i.e. the function that needs to be performed on the data. The information manager, the  
37 repository and the knowledge miner are interfaced with the knowledge manager. It also  
38 communicates with the knowledge miner to start the task oriented mining process whenever  
39 the knowledge about a particular expert is not correct or appropriate.

40  
41  
42  
43  
44 <<Insert Figure 5 about here>>

#### 45 46 47 **4.2.5 Knowledge Repository**

48  
49 The repository temporarily stores the mining results and tuning parameters and helps the  
50 knowledge manager by providing a set of knowledge required by knowledge miners. When  
51 the knowledge manager receives the mining request for information, it first queries the  
52 repository to see if relevant knowledge pertaining to the request has already been discovered.  
53 If it has not been found, then the knowledge manager initiates the knowledge miner(s) to  
54 mine the appropriate knowledge/data bases. In addition, the repository provides the  
55 mechanisms for using a common vocabulary. As all the components within the KDM work on  
56 the same problem domain and communicate with a set of valid message objects, it is essential  
57 for all the components of the KAM to share a common vocabulary. Furthermore, meta-  
58  
59  
60

1  
2  
3 knowledge stored in the repository, such as system configuration, (e.g. various mining  
4 parameters of the knowledge miner like number of clusters, similarity criteria, interestingness  
5 measures, confidence etc.), can be shared and reused in the future.  
6  
7

#### 8 9 **4.2.6 Information Manager**

10 The main functionality of the information manager is to share and access the shared data and  
11 knowledge bases. It also notifies the knowledge manager about particular contributions or  
12 changes to the shared data desired by particular project team members. The information  
13 manager also signals the Moderator whenever a change in the project data is recorded in the  
14 project database. However this does not affect the knowledge acquisition process, so will not  
15 be considered further here. Further study of the information manager are presented in the  
16 earlier research by (Harding *et al.* 2003).  
17  
18  
19  
20  
21

#### 22 23 **4.2.7 Expert Module**

24 Moderators use expert modules to represent each team member and hence the collection of  
25 expert modules are populated with all the knowledge about the team members in the  
26 collaborative projects. Hence, the collection of EMs provides the moderator with the  
27 background knowledge that it requires to support the multidisciplinary team. Based on earlier  
28 Moderator concepts (Harding 1996), in the present context, knowledge about individual team  
29 members, knowledge of their area of interests, their competencies, and the knowledge about  
30 changes that are important to them and actions that need to be taken when such changes occur  
31 are stored in the EM. When the Moderator updates an EM, a notification is sent to the  
32 relevant team member indicating what knowledge has been updated and also of any  
33 conflicting rules found in the EM. In this manner, generated knowledge needs to be verified  
34 by the user before it is used in the moderation process. Section 7 provides an illustrative  
35 example of how the knowledge can be generated in the form of IF-THEN rules, which can be  
36 further updated based on changes in the dataset.  
37  
38  
39  
40  
41  
42  
43  
44

45 To integrate the proposed framework with the current state-of-art Moderator called Extended  
46 Enterprise Manufacturing System Engineering Moderator (EEMSEM) (Lin & Harding 2003,  
47 Lin *et al.* 2004, Lin & Harding 2007, Lin *et al.* 2005), the next section discusses the Universal  
48 Knowledge Moderator (UKM).  
49  
50  
51  
52

### 53 **5. Knowledge discovery for EEMSEM: Universal Knowledge Moderator (UKM)**

54 The complexity of moderator technology increases when manufacturing projects are large and  
55 members are globally distributed in the context of an extended enterprise (EE) or virtual  
56 enterprise (VE) (Popplewell & Harding 2004). Manufacturing projects operating within EE  
57 and VE environments face additional problems that different information models are likely to  
58 be used by different parts of the manufacturing project teams. Supply chain partners  
59  
60



1  
2  
3 inevitably use different vocabularies and terminologies in their work resulting in  
4 misunderstandings and confusions. Moreover, the escalating use of web technologies has  
5 also accelerated the growth and complexity of manufacturing digital information. The  
6 consequent enormous amounts of heterogeneous data (e.g. structural heterogeneity or  
7 semantic heterogeneity) make it increasingly difficult to communicate between different  
8 project teams and organizations. In response to this problem and to achieve true information  
9 interoperability, (Lin & Harding 2003, Lin *et al.* 2004, Lin & Harding 2007, Lin *et al.* 2005)  
10 adopted the ontology and semantic web technologies within a Manufacturing System  
11 Engineering Moderator (MSEM) to enable semantic interoperability across extended project  
12 teams (Popplewell & Harding 2004).  
13  
14  
15  
16  
17  
18  
19

20 This research builds on previous work on the MSEM and therefore, this section proposes how  
21 the MSEM may be extended to provide knowledge discovery for globally distributed and  
22 collaborative e-supply chains on the semantic web. The aim of this research is to develop and  
23 establish a flexible method for knowledge discovery from semantically heterogeneous data  
24 for the moderation of project teams in globally cooperative e-manufacturing chains by  
25 integrating the KOATING framework with a state-of-the art Moderator, which is called  
26 universal knowledge moderator. This should be able to:  
27  
28  
29  
30  
31

- 32 • Analyze and define the specification of a common manufacturing ontology for the  
33 manufacturing industry in an ontology server.
- 34 • Enable WWW information exchange between partners in cooperative manufacturing  
35 chains via common mediated meta-models across different disciplines within  
36 engineering project teams through semantic mapping.
- 37 • Enable the moderator's KAM to incorporate "learning", updating and reuse elements  
38 which exploit knowledge discovery techniques.  
39  
40  
41  
42

43 Previous research by (Lin & Harding 2003, Lin *et al.* 2004, Lin & Harding 2007, Lin *et al.*  
44 2005) has addressed the challenges of different partners within an e-supply chain using  
45 different vocabularies and terminologies and therefore the first two of the above objectives  
46 are beyond the scope of this paper. This section now sets the KOATING framework into the  
47 context of a Moderator to support collaborating working in extended supply chains or similar  
48 networks.  
49  
50  
51  
52  
53

### 54 **5.1 Universal Knowledge Moderator (UKM)**

55 This research integrates the KOATING framework with the functionalities of the MSEM. The  
56 previously listed research objectives are discussed in the context of an architecture model for  
57 UKM to enable semantic integration of geographically distributed knowledge discovery  
58 services. Three main modules have been identified as shown in Figure 6:  
59  
60

- Universal Manufacturing Enterprise Schema (UMES) Module (Lin & Harding 2003, Lin *et al.* 2004, Lin & Harding 2007, Lin *et al.* 2005)
- Knowledge Discovery Module
- Moderation Module

#### 5.1.1 Universal Manufacturing Enterprise Schema Module

This architecture of UKM uses a dynamic mediated and shared ontology model for manufacturing enterprises, in order to achieve information interoperation for a UKM within an internationally collaborative environment. The mediated ontology model may involve simple logical reasoning for semantic and syntax mapping. The methods of the UMES are listed and briefly described as follows (Lin & Harding 2003, Lin *et al.* 2004, Lin & Harding 2007, Lin *et al.* 2005):

- Analyze and identify the terminology, representation and classification of the manufacturing system for UKM activities in the context of a global high tech industry e.g. PC, IC manufacturing, operating in a globally co-operative e-manufacturing chain.
- Convert the UMES into a web-based ontology language, e.g. Resource Description Framework (RDF) and Web Ontology language (OWL).
- Define a set of semantic mapping rules for automatic reasoning of heterogeneous document structure and data for the UMES in the Metadata Integration Ontology server.

A detailed study of functionalities of UMES and further discussions are presented in (Lin & Harding 2003, Lin *et al.* 2004, Lin & Harding 2007, Lin *et al.* 2005) and therefore are not the focus of present research. Therefore only brief details have been included here for completeness.

**<<Insert Figure 6 about here>>**

#### 5.1.2 Knowledge Discovery Module of UKM

The basic structure and functionality of this module remains the same as discussed in section 4. It consists of knowledge miners, knowledge managers and miners interface. This module is interfaced with the UMES module to deal with the semantic heterogeneity of heterogeneous data sources and interoperability issues. Knowledge discovery is based upon the defined and common ontology, so that the KDM generates knowledge in an appropriate language or vocabulary to be used to update the expert module knowledge.

#### 5.1.3 Moderation Module

1  
2  
3 The major functions of the Moderation Module are to identify when one or more of the  
4 partners need to be made aware of a potential opportunities or problems that exist within the  
5 project or team. It does so by continuously reviewing the current state of the activities  
6 associated with the project and information about recent project decisions, and comparing this  
7 with the knowledge it has about team members' interests and requirements as stored within  
8 the EMs. The moderation process is activated whenever a project decision is made and this is  
9 identified by a change being made to the project information within the shared database. The  
10 information manager can notify the UKM of each change. The UKM checks the interests of  
11 the team member in its knowledge base by examining the expert modules. If the Moderator  
12 finds that one or more team members have an interest in the current type of change, the  
13 interested team members are contacted by the UKM and it may remain in dialogue with these  
14 team members until conflicts are resolved. Clearly when team members came from different  
15 cooperating companies, it is very important that information is understood by different parties  
16 and the use of ontologies has previously been covered in detail in (Lin & Harding 2003, Lin  
17 *et al.* 2004, Lin & Harding 2007, Lin *et al.* 2005).

## 28 **6. UML Modelling for Knowledge Acquisition Module**

30 This section details the modelling of the KAM using UML. Here the concept of UML grows  
31 from analysis to implementation mainly focussing on the knowledge acquisition aspect of the  
32 Moderator. In the following section, the use of "system" primarily refers to the KAM. It  
33 mainly consists of three stages: system requirement and analysis, system design and system  
34 implementation. However, for simplicity of description and considering length of the paper  
35 only use case analysis and class diagrams are presented.

### 40 **6.1. System Requirement and Analysis**

42 This phase of modelling focuses on the set of system requirements, the available resources  
43 and the user's desire along with the concept of the system. The behaviour of the KAM (that is  
44 what functionality must be provided by the KAM) is documented in this phase using a use  
45 case diagram and use case specification.

49 A use case diagram illustrates the interaction between the users and system's functions. Here  
50 the user is referred to as an actor, which is not part of the system, but represents anything or  
51 anyone that interacts or inputs information to or receives information from or both receives  
52 and inputs information to and from the system. Use cases represent the functionalities  
53 provided by the system. In the context of the Moderator, only the knowledge acquisition  
54 aspect has been considered. Therefore in the proposed modelling only those use cases and  
55 actors are considered which are essential for understanding the knowledge acquisition aspects  
56  
57  
58  
59  
60

1  
2  
3 of the proposed system. As shown in Figure 7, there are three actors which interact with the  
4 system:  
5

- 6  
7 • User: represents the person who uses the Moderator system and possesses the domain  
8 expertise and has a basic understanding of knowledge discovery.  
9
- 10  
11 • Database: represents the past project databases, project summary data and operational  
12 data of the enterprises etc., (changes to project information may necessitate changes to the  
13 expert module).  
14
- 15  
16 • Expert module: is a kind of knowledge base.  
17

18  
19 Generally, indicating the interactions between actors and the system can help to identify the  
20 use cases. The seven use cases that have been identified for the KAM are:  
21

- 22  
23 • Create expert module: This use case represents the creation of a new expert module when  
24 a new partner joins the collaborative project and agrees with the rules and regulation of  
25 the collaboration.  
26
- 27  
28 • Edit expert module: this includes the modification or deletion of an expert module.  
29
- 30  
31 • Addition of item of interest: Automatic and manual update of an item of interest. Here,  
32 the item of interest has been categorized into competencies and objects of interest related  
33 to changes.  
34
- 35  
36 • Edit item of interest: this can be either the modification or deletion of an item of interest.  
37
- 38  
39 • Regular automatic update of rules: this includes the regular update of knowledge in the  
40 form of rules in the expert module corresponding to the addition of data to the databases  
41 and verification of knowledge from the user.  
42
- 43  
44 • User requested update of rules: this identifies a special type of knowledge which is  
45 required by the user.  
46
- 47  
48 • Manual addition, deletion and modification of rules: this includes the manual addition,  
49 deletion or modification of rules in the expert module.  
50

51  
52 The details of each use case are documented with a flow of events to extract more information  
53 from the use case diagram. The flow of events for a use case is a description of events needed  
54 to accomplish the required behaviour of the use case. The flow of events for each use case is  
55 written in terms of *what* the system should do, not *how* the system does it. The use case  
56 specification for the *create expert module* is detailed in Table 2. The specification for the  
57 other 3 use cases relating to updating of rules is given in appendix A.  
58  
59  
60

<<Insert Figure 7 about here>>

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

<<Insert Table 2 about here>>

### 6.2 System Design: Class Diagram

The class diagram is a graphical view of the static structure of the model. A class diagram shows a set of classes, interfaces, collaborations and their relationships (such as dependency, generalization, and association). The UML representation of a class is a rectangle containing

<<Insert Figure 8 about here>>

three compartments stacked vertically, as shown in Figure 8. The top compartment shows the class's name. The middle compartment lists the class's attributes. The bottom compartment lists the class's operations. When drawing a class element on a class diagram, one must use the top compartment, but the bottom two compartments are optional. The class diagram shows that how the different entities of the system relate to each other, their internal structure and their relationships. Figure 8 shows the high level view of the class diagram. It mainly consists of Expert\_Module, RuleSet, Rule, Rule\_Condition, Resulting\_Action, Knowledge Miner, Knowledge Manager and Repository. Relationships between classes are represented by lines and labels, arrowheads and notation. The upper structure in the boundary line shows the KRM structure used in (Harding 1996, Harding *et al.* 2003, Lin & Harding 2003, Lin *et al.* 2004), therefore, the details are beyond the scope of this paper. The class name attributes and operations are represented in the diagram. The relationship between the Expert\_Module class and Knowledge Manager Class is uni-directional association. It shows that two classes are related but only one class knows that relationship exists. The second type of relationship is an association relationship and indicates the long term relationship between the classes. An association relationship exists between Knowledge Manager and Knowledge Miner. The knowledge miner is equipped with a variety of algorithms classes such as Apriori, C4.5, Neural\_Network, Rough\_Set and Stat\_App. These classes are connected with Knowledge\_Miner class with generalization relationship. Generalization provides the capability to create a superclass that encapsulates structure and behaviour common to several classes. These classes are examined for commonality of structure and behaviour. The repository class is also associated with the knowledge miner and Knowledge Manager with an association relationship and this is represented by a dotted line.

## 7. An Illustrative Example

The e-supply chain is the communication and operations backbone of a virtual network that links suppliers, business partners and customers together as one cohesive collaborative entity. A virtually enabled supply chain network is a series of value adding processes or stages owned by one or more enterprises, starting with a material or information supplier and ending with consumers. An open fast communication mechanism is essential for the companies

1  
2  
3 entering into supply chain network activities, allowing its members to jointly forecast,  
4 develop, produce, synchronize and deliver their product or services, and anticipate dynamic  
5 customer requirements. A typical example of an e-supply chain is schematically shown in  
6  
7 Figure 9.  
8  
9

10 <<Insert Figure 9 about here>>

11  
12 This example assumes that a VE has been created by a leading UK automobile manufacturer  
13 (X) which operates in UK and Europe. The automobile enterprise “X” wishes to contract a  
14 supplier to produce 2 parts ( $P_a$  and  $P_b$ ) in order to build a new prototype in the UK. However,  
15 no local manufacturer can be found with enough resource to meet the demand. The solution  
16 adopted was to form a collaborative virtual e-chain with 4 enterprises including suppliers and  
17 manufacturers. 4 EMs are created, each containing knowledge about one of the enterprises in  
18 the e-supply-chain.  
19  
20  
21  
22  
23

24  
25 Supply chain operations start when an order for the two products ( $P_a$  and  $P_b$ ) has been sent to  
26 the 3 suppliers ( $S_1$ ,  $S_2$ , and  $S_3$ ) through a web interface with requirements such as lead-time,  
27 quantity, and product type. Two different parts  $P_{a1}$  and  $P_{a2}$ , and  $P_{b1}$  and  $P_{b2}$  are assembled to  
28 produce the products  $P_a$  and  $P_b$  respectively. For product  $P_a$  supplier  $S_1$  can only provide  $P_{a1}$ ,  
29  $P_{a2}$  has to be ordered from  $S_3$ . Similarly, for product  $P_b$ ,  $S_2$  can only provide  $P_{b1}$ ,  $P_{b2}$  has to be  
30 ordered from  $S_3$ . On the other hand,  $S_3$  can supply all the parts  $P_{a1}$ ,  $P_{a2}$ ,  $P_{b1}$  and  $P_{b2}$  to produce  
31  $P_a$  and  $P_b$ . All the suppliers are able to produce different products with different lead times,  
32 quantities and prices. All the suppliers use different terminologies for the same context. For  
33 example  $S_1$  uses lead time,  $S_2$  uses due date, and  $S_3$  uses delivery time for the same context of  
34 delivering the product to the customer. Similarly,  $S_1$  uses quantity,  $S_2$  uses number of  
35 products, and  $S_3$  uses number of pieces for the same context. The product information for  
36 each supplier is given below in Table 2, which contains the data that the supplier wishes to  
37 share with the Coordinator X.  
38  
39  
40  
41  
42  
43  
44  
45

46  
47 Therefore, a semantic heterogeneity for the product information exists, where different  
48 suppliers use different terminologies for the same context. The UMES module of the UKM  
49 takes care of this semantic heterogeneity by developing a common and agreed ontology. For  
50 example in the present context an ontology can be developed for lead time, due date and  
51 delivery time. More details about the development of common/mediated ontology are  
52 discussed in (Lin & Harding 2003, Lin *et al.* 2004, Lin & Harding 2007, Lin *et al.* 2005).  
53  
54  
55

56 <<Insert Table 3 about here>>

57  
58 There are several combinations of price/quantity/time over several ranges of values which  
59 should be considered to ensure that the orders are placed with the most cost effective  
60 suppliers. All the EMs must contain the knowledge in the form of rules stating that which

combinations of supplier are cheapest. This expert module also contains the items of interest for each supplier such as orders detail, quantity, lead time, due date and price etc. The focus of this research is limited to the knowledge acquisition aspect therefore this example only shows that how knowledge can be generated for the EM associated with company X from shared database of suppliers. In the present context, the data presented in Table 3 is used as shared data. There is a need to transform these data into knowledge in order to obtain the effective combinations of quantity, price and due date. This knowledge can then be stored in the expert module for further Moderator activity.

In the traditional system, the knowledge in the form of IF-THEN rules is generated based on human experience and expertise by interviewing different suppliers and looking at their capabilities. In the proposed system, the UKM can help to semi-automatically discover the knowledge in the form of rules providing it has up to date information about current price/quantity/delivery combinations that are best for each supplier. In order to discover the knowledge, knowledge manager instructs the knowledge miner to find patterns, relationships and rules within the shared data associated with supply chain agents considering minimal price/product. The mining engine component of knowledge miner finds rules for minimum price. In the present context, IF-THEN rules were discovered using techniques such as decision tree. For example for the given data set the discovered rule may be as follows:

- 1 *IF (LeadTime>8) THEN Select Supplier  $S_1$  &  $S_3$ .*
- 2 *IF (Quantity  $\leq$  30) AND (LeadTime $\leq$ 3) THEN Select Supplier  $S_1$  &  $S_3$ .*
- 3 *IF (Quantity  $\leq$  100) AND ( $4 \leq$ LeadTime $\leq$ 8) THEN Select Supplier  $S_3$ .*
- 4 *IF ( $30 <$ Quantity  $\leq$  50) AND (LeadTime $\leq$ 8) THEN Select Supplier  $S_3$ .*
- 5 *IF (LeadTime>7) THEN Select Supplier  $S_2$  &  $S_3$ .*
- 6 *IF (Quantity  $\leq$  10) AND (LeadTime $\leq$ 3) THEN Select Supplier  $S_2$  &  $S_3$ .*
- 7 *IF (Quantity  $\leq$  100) AND ( $4 \leq$ LeadTime $\leq$ 8) THEN Select Supplier  $S_3$ .*
- 8 *IF ( $10 <$ Quantity  $\leq$  50) AND (LeadTime $\leq$ 8) THEN Select Supplier  $S_3$ .*

These rules are stored in the expert module of Company X and need to be checked whenever order is raised. Similarly, expert module of suppliers  $S_1$ ,  $S_2$  and  $S_3$  must be populated with knowledge about its area of interests. For example, for  $S_1$  the knowledge in the EM would be:

*IF (Lead time  $\leq$  3) AND (Quantity  $\leq$  30), THEN notify of order.*

*IF ( $9 \leq$  Lead time  $\leq$  12) AND (Quantity  $\leq$  150) THEN notify of order in competition with  $S_3$*

Similarly for  $S_2$ , The knowledge in the corresponding EM would be.

*IF (Lead time  $\leq$  3 ) AND (Quantity  $\leq$  10), THEN notify of order.*

*IF ( $8 \leq$  Lead time) AND (Quantity  $\leq$  150) THEN notify of order in competition with  $S_3$*

For  $S_3$ , Knowledge in EM would be

*IF (Lead time  $\geq$  4) AND (Quantity  $\leq$  100), THEN notify of order.*

*IF ( $8 \leq$  Lead time  $\leq$  12) AND (Quantity  $\leq$  150) THEN notify of order in competition with  $S_1$  &  $S_3$ .*

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

These are very simple rules and could be generated manually, but, consider a situation where several other qualitative and quantitative attributes such as supplier reputation, quality of product, physical location etc, are considered. In the present context scenario, a decision tree algorithm can be used by the data mining engine of a knowledge miner to generate these rules. These rules need to be updated whenever the data changes. It means that whenever the supplier changes their capability, the dataset will change. For example, after a few orders supplier  $S_1$  may have improved their way of production and be capable of producing more products at reduced cost. Based on this fact, they have changed the information related to the product and the combination of lead-time, quantity and price. Changes in the dataset will trigger the knowledge manager to prompt a message to the knowledge miner to initiate the mining task. The knowledge miner will therefore apply its data mining algorithm to extract new rules, patterns and relationships, and thereby generate and update new knowledge within the expert modules. At this stage, if it finds that there is a conflicting rule, it will trigger a message to the user to resolve this conflict based on its domain knowledge.

Now when the e-supply chain is operating and production is going on, the UKM discovers a delay in the delivery of part  $P_{a1}$  by supplier  $S_1$ . Details of each delivery and order are stored in the company's databases so regular updates of UKM knowledge could identify that there is an error in the usual rules as one of the suppliers has been delivering "later" than the quoted date. This delay is critical to the lead time requested by the customer. This delay can be a hindrance to the successful completion of the order by the suppliers involved. Therefore, UKM must notify this delay to relevant supply chain agent responsible for Supplier  $S_3$  and Company X. This alert can be sent in the form of an e-mail about the problem occurrence.

In this case, to overcome this problem UKM may recommend company X to:

- Send the order to an alternative supplier or;
- discuss the quality of deliveries with the existing supplier and negotiate new terms or;
- Increase the working hours of corresponding supplier.

There might be situation where the manufacturing enterprise "X" needs to collaborate with another supplier 4. In this case, chain will be increased based on an agreement of the entire supply chain. In this case, knowledge acquisition module will generate a new expert module corresponding to supplier 4. Above mentioned example is just an instance of several activities involved in the operation of virtual enterprise supply chain.

## 8. Conclusion and Discussions

In earlier research projects Moderator technology, in the form of knowledge based software support systems, has been successfully demonstrated in both the product and manufacturing system design domains. However, knowledge acquisition, learning and updating of



knowledge has not previously been studied fully. Therefore this paper presents a KOATING framework to provide semi- automated knowledge acquisition for moderator technology in collaborative projects to update the expert modules. This enables the reuse of discovered knowledge from operational databases within collaborative projects and facilitates the exploitation of the right knowledge at the right time in the right context.

In addition, a Universal Knowledge Moderator (UKM) system, consisting of a Universal Manufacturing Enterprise Schema Module, Knowledge Discovery Module and Moderation Module, has been proposed to improve the moderation activities. The Universal Manufacturing Enterprise Schema Module enhances the interoperability of the chain on the semantic web. This shows how the KOATING framework can be integrated with the state-of-art Moderator. The proposed KOATING framework will facilitate the decision making and moderation process by incorporating the “learning” and “knowledge reuse” element within moderators. This also facilitates semi-automated knowledge creation, updating and retrieving capability, and if necessary transforming the identified patterns and /or models to alternative representations and resolving conflict or contradictions with previously extracted knowledge. However, the application of Semantic Web technologies and tools require considerable technical expertise, and are thus not well suited for users outside the field of computer science. This makes it hard for domain experts and ontology engineers to work together on e-manufacturing tasks. One of the major challenges for the UKM research is to facilitate interaction and operation for mass collaboration and knowledge sharing.

Appendix A: Use case specification for use cases used in figure 8.

| 5. Flow of event for the use case automatic regular update of rules |  |
|---|--|
| Actors  | Database, user and expert module   |
| Pre-conditions  | System has access to relevant database and corresponding expert module exists  |
| Post-conditions   | User must be notified to edit, verify and resolve any conflict of rules. The edit of rules use case must execute after the execution of this use case  |
| Basic Flow  | This use case begins when new data is added to the data base. The data acquisition system passes this message to KAM. KAM has access to the database (E-5.1). It verifies the type of data and correspondingly activates the knowledge miner within the system to perform the knowledge discovery process (E-5.2). A set of rules are generated as a result of the knowledge discovery process (E-5.3). The rules are compared with the existing rules to check for a conflicting rule (E-5.4). If there is no conflicting rule update the expert module. This use case terminates when the rules have been updated. . |
| Alternative flows   | E-5.1: KAM is unable to access the database; user must be notified of this problem.<br>E-5.2: Unknown type of data identified, user needs to be informed.<br>E-5.3: KAM is unable to capture knowledge in the form of rules; in which case derived knowledge should be notified to user for manual entry of knowledge in the form of rules.<br>E-5.4: There exists a conflicting rule; user should be notified of this conflict and initiate the edit of rules use case.   |
| 6. Flow of event for the use case user requested update of rules    |  |

|  |  |
|--|--|
| Actors   | User, database and expert module   |
| Pre-conditions   | System has access to relevant database and corresponding expert module exists  |
| Post-conditions  | User must be notified of the discovered rules and edit rule use case executes after this use case.   |
| Basic Flow   | This use case is initiated by the user, when s/he needs any special type of knowledge. In this case, it prompts the system to the database and specifies the kind of knowledge to be mined (E-6.1). The system identifies the data type and applies the knowledge discovery process to discover the knowledge in the form of rules (E-6.2). A comparison is made with the existing rules for any conflict (E-6.3). Rules are added to the expert module (E-6.4) This use case terminates after notifying the user of discovered knowledge.   |
| Alternative flows  | E-6.1: User selected a wrong database, it can re-select the database or quit.<br>E-6.2: Unknown data type identified, user need to be informed.<br>E-6.3: There exists a conflicting rule; user should be notified of this conflict and initiate the edit of rules use case.<br>E-6.4: System is unable to capture knowledge in the form of rules; in which case derived knowledge should be notified to the user for manual entry of knowledge in the form of rules.  |
| <b>7. Flow of event for the use case manual addition, deletion and modification of rules</b> |  |
| Actors   | User and expert module   |
| Pre-conditions   | Create expert module and automatic regular update of rules must have executed before this use case executes.   |
| Post-conditions  | Expert module has updated list of rules  |
| Basic Flow   | This use case begins when the new rules are automatically discovered and need verification from the user for its authenticity. Identified conflict or rules are prompted to users to resolve them (E-7.1). The user resolves the conflict by performing activity such as ADD, DELETE, MODIFY and UPDATE of rules or QUIT the system.<br>If the activity selected is ADD RULE, system adds a new rule to expert module (E-7.2).<br>If the activity selected is DELETE RULE, system deletes the chosen rule from the expert module (E-7.3).<br>If the activity selected is MODIFY RULE, system facilitates the user to modify the rule based on domain knowledge (E-7.4).<br>If the activity selected is UPDATE RULE, system updates the expert module with updated rules.<br>If the activity selected is QUIT, the use case ends. |
| Alternative flows  | E-7.1: No conflicting rule found, system updates the expert module<br>E-7.2: An invalid rule is added, the user can delete or modify that rule and re-enter the desired rule or terminate the use case.<br>E-7.3: An invalid rule is selected, the user can re-select the desired rule to delete or terminate the use case.<br>E-7.4: The rule chosen for modification is invalid, the user can re-select the desired rule and modify.   |

## References

- Ahn, H.J., Lee, H.J., Cho, K. & Park, S.J. 2005, "Utilizing knowledge context in virtual collaborative work", *Decision Support Systems*, vol. 39, no. 4, pp. 563-582.
- Browne, J. & Zhang, J. 1999, "Extended and virtual enterprise-similarities and differences", *International journal of Agile Management Systems*, vol. 1, pp. 30-36.
- Camarinha-Matos, L. & Afsarmanesh, H. 2007a, "A comprehensive modeling framework for collaborative networked organizations", *Journal of Intelligent Manufacturing*, vol. 18, no. 5, pp. 529-542.
- Camarinha-Matos, L.M. & Afsarmanesh, H. 2007b, "A framework for virtual organization creation in a breeding environment", *Annual Reviews in Control*, vol. 31, no. 1, pp. 119-135.
- Choudhary, A.K. 2009, *Knowledge Discovery for Moderating Collaborative Projects. PhD Thesis, Loughborough University, UK.*
- Choudhary, A., Harding, J. & Tiwari, M. 2008, "Data mining in manufacturing: a review based on the kind of knowledge", *Journal of Intelligent Manufacturing*, vol. 20, no. 5, pp. 501-521.
- Choudhary, A.K., Harding, J.A. & Popplewell, K. 2006, "Knowledge Discovery For Moderating Collaborative Projects", *IEEE International Conference on Industrial Informatics*, pp. 519.
- Cil, I., Alpturk, O. & Yazgan, H.R. 2005, "A new collaborative system framework based on a multiple perspective approach: InteliTeam", *Decision Support Systems*, vol. 39, no. 4, pp. 619-641.
- ECOLEAD 2008, June 25, 2008-last update, *European Collaborative Networked Organisations Leadership Initiative*. Available: <http://ecolead.vtt.fi/> [2008, 7/14] .
- ECOLEAD 2005, *ECOLEAD Project Public Deliverable 21.1: Characterization of key components, features, and operating principles of the virtual breeding environment*, .
- Fayyad, U.M., Piatetsky-Shapiro, G. & Smyth, P. 1996, "From data mining to knowledge discovery: an overview" in *Advances in knowledge discovery and data mining* American Association for Artificial Intelligence, , pp. 1-34.
- Frécon, E. and Nöu, A. A. 1998, "Building distributed virtual environments to support collaborative work", *Proceedings of the ACM Symposium on Virtual Reality Software and Technology* ACM, Taipei, Taiwan, pp. 105-113.
- Gaines, B.R., Norrie, D.H. & Lapsley, A.Z. 1995, *Mediator: an intelligent information system supporting the virtual manufacturing enterprise*.
- Harding, J.A. 1996, *A knowledge representation model to support concurrent engineering teamwork.*, Loughborough University, UK.
- Harding, J.A. & Popplewell, K. 1996, "Driving concurrency in a distributed concurrent engineering project team: a specification for an Engineering Moderator", *International Journal of Production Research*, vol. 34, no. 3, pp. 841.
- Harding, J.A., Popplewell, K. & Cook, D. 2003, "Manufacturing systems engineering moderator: an aid for multidiscipline project teams.", *International Journal of Production Research*, vol. 41, no. 9, pp. 1973-1986.
- Harding, J.A., Popplewell, K. & Lin, H.K. 2007, "A Generation of Moderators from Single Product to Global E-Supply" in *Knowledge and Technology Management in Virtual Organizations: Issues, Trends, Opportunities and Solutions*, eds. G.D. Putnik & M.M. Cunha, IGI Publishing, Portugal, pp. Chapter 5.
- Harding, J.A., Shahbaz, M., Srinivas & Kusiak, A. 2006, "Data Mining in Manufacturing: A Review", *American Society of Mechanical Engineers (ASME): Journal of Manufacturing Science and Engineering*, vol. 128, no. 4, pp. 969.
- Hicks, B.J., Culley, S.J., Allen, R.D. & Mullineux, G. 2002, "A framework for the requirements of capturing, storing and reusing information and knowledge in engineering design", *International Journal of Information Management*, vol. 22, no. 4, pp. 263-280.

- 1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60
- Holsheimer, M. 1999, *Data mining by business users: integrating data mining in business processes*, ACM, San Diego, California, United States.
- Huang, G.Q., Huang, J. & Mak, K.L. 2000, "Agent-based workflow management in collaborative product development on the Internet", *Computer-Aided Design*, vol. 32, no. 2, pp. 133-144.
- Huang, N. & Diao, S. 2008, "Ontology-based enterprise knowledge integration", *Robotics and Computer-Integrated Manufacturing*, vol. 24, no. 4, pp. 562-571.
- Ikujiro, N. & Takeuchi, H. 1995, *The Knowledge-Creating Company*, Oxford University Press, New York.
- Katzy, B.R. & Obozinski, V. 1998, "Value System Redesign", *Database and Expert Systems Applications, International Workshop on*, vol. 0, pp. 650.
- Katzy, B.R. & Crowston, K. "Competency rallying for technical innovation—The case of the Virtuelle Fabrik", *Technovation*, Volume 28, Issue 10, October 2008, Pages 679-692.
- Katzy, B.R. & Dissel, M. 2001, "A toolset for building the virtual enterprise", *Journal of Intelligent Manufacturing*, vol. 12, no. 2, pp. 121-131.
- Lastra, J.L.M. & Delamer, M. 2006, "Semantic web services in factory automation: fundamental insights and research roadmap", *Industrial Informatics, IEEE Transactions on*, vol. 2, no. 1, pp. 1-11.
- Li, E.Y. & Lai, H. 2005, "Collaborative work and knowledge management in electronic business", *Decision Support Systems*, vol. 39, no. 4, pp. 545-547.
- Li, W.D. & Qiu, Z.M. 2006, "State-of-the-art technologies and methodologies for collaborative product development systems", *International Journal of Production Research*, vol. 44, no. 13, pp. 2525.
- Lin, H., Harding, J. & Teoh, P. 2005, "An inter-enterprise semantic web system to support information autonomy and conflict moderation", *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, vol. 219, no. 12, pp. 903-911.
- Lin, H.K. 2004, *Manufacturing System Engineering Ontology Model for Global Extended Project Team*, Loughborough University.
- Lin, H.K. & Harding, J.A. 2007, "A manufacturing system engineering ontology model on the semantic web for inter-enterprise collaboration", *Computers in Industry*, vol. 58, no. 5, pp. 428-437.
- Lin, H.K. & Harding, J.A. 2003, "An ontology driven manufacturing system engineering moderator for global virtual enterprise teams", *Advances in manufacturing technology XVI. Proceedings of the International Conference on Manufacturing Research*, eds. Y. Qin & N.P. Juster, Professional Engineering Publication, London, pp. 365.
- Lin, H., Harding, J.A. & Shahbaz, M. 2004, "Manufacturing system engineering ontology for semantic interoperability across extended project teams", *International Journal of Production Research*, vol. 42, no. 24, pp. 5099.
- Misono, S., Koide, S., Shimada, N., Kawamura, M. & Nagano, S. 2005, *Distributed collaborative decision support system for rocket launch operation*.
- MISSION Consortium 2001, "Final Report from MISSION Project—Deliverable D24.K" in *Modelling and Simulation Environments for Design, Planning and Operation of Globally Distributed Enterprises (IMS/ESPRIT29656)*, eds. K. Popplewell, J.A. Harding & M. Rabe,.
- Mitra, S., Pal, S.K. & Mitra, P. 2002, "Data mining in soft computing framework: a survey", *Neural Networks, IEEE Transactions on*, vol. 13, no. 1, pp. 3-14.
- MOSES 1995, *Model Oriented Simultaneous Engineering System (EPSRC Project Number GR/H24273)*. Available: <http://leva.leeds.ac.uk/www/amos/amos.html> [2008, 7/2] .
- Numata, J., Hane, K., Bangyu Lei & Iwashita, Y. 1997, *Knowledge discovery and sharing in an information system*.
- Panteli, N. & Sockalingam, S. 2005, "Trust and conflict within virtual inter-organizational alliances: a framework for facilitating knowledge sharing", *Decision Support Systems*, vol. 39, no. 4, pp. 599-617.

- 1  
2  
3 Pechoucek, M., Vokrinek, J. & Becvar, P. 2005, "ExPlanTech: multiagent support for  
4 manufacturing decision making", *Intelligent Systems, IEEE*, vol. 20, no. 1, pp. 67-74.  
5 Piatetsky-Shapiro, G. 1991, "Knowledge discovery in real databases: A report on the IJCAI-  
6 89 Workshop", *AI Mag.*, vol. 11, no. 5, pp. 68-70.  
7 Popplewell, K. & Harding, J. 1995, "Engineering Moderation - Supporting Concurrency in  
8 Engineering Using Hybrid Knowledge Representation", *Proceedings of IFIP Working  
9 Group 5 - 7 Working Conference on Managing Concurrent Manufacturing to Improve  
10 Industrial Performance, International Federation for Information Processing,  
11 Managing Concurrent Manufacturing to Improve Industrial Performance*, Seattle, USA,  
12 pp. 347-357.  
13 Popplewell, K. & Harding, J.A. 2004, "Impact of Simulation and Moderation through the  
14 Virtual Enterprise Life Cycle", *Proceedings of the 11th ASIM Dedicated Conference*,  
15 eds. K. Mertins & M. Rabe, IPK Berlin, Germany, pp. 299.  
16 Ramesh, B. & Tiwana, A. 1999, "Supporting Collaborative Process Knowledge Management  
17 in New Product Development Teams", *Decision Support Systems*, vol. 27, no. 1-2, pp.  
18 213-235.  
19 Sánchez, N.G., Apolinar, D., Zubiaga, G., Atahualpa, J., González, I. & Molina, A. 2005,  
20 "Virtual Breeding Environment: A First Approach to Understanding Working and  
21 Sharing Principles", *In Proceedings of InterOp-ESA'05* Springer, .  
22 Scotney, B. & McClean, S. 2004, *Knowledge discovery from databases on the semantic Web*,  
23 in the 16th International Conference on Scientific and Statistical Database Management  
24 (SSDBM'04), Santorini Island, Greece, June 21-June 23.  
25 Shafiei, F. & Sundaram, D. 2004, *Multi-enterprise collaborative enterprise resource planning  
26 and decision support systems*. HICS, in the Proceedings of the 37th Annual Hawaii  
27 International Conference on System Sciences (HICSS'04) - Track 8 - Volume 8 Page:  
28 80228.  
29 Shearer, C. 2005, "The CRISP-DM model: the new blueprint for data mining", *Journal of  
30 Data Warehousing*, vol. 5, pp. 13-22.  
31 Shum, S.B., Roure, D.D., Eisenstadt, M., Shadbolt, N. & Tate, A. 2002, "CoAKTinG:  
32 Collaborative Advanced Technologies in the Grid", *Proc. Second Workshop on  
33 Advanced Collaborative Environments*, Edinburgh, pp. 1-8.  
34 Slade, A.J. & Bokma, A.F. 2002, *Ontologies within extended enterprises*, in the Proceedings  
35 of the 35th Annual Hawaii International Conference on System Sciences (HICSS'02)-  
36 Volume 1 - page: 39.1  
37 Srinivas & Harding, J.A. 2008, "A data mining integrated architecture for shop floor control",  
38 *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering  
39 Manufacture*, vol. 222, no. 5, pp. 605-624.  
40 Skjoett-Larsen, Tage., Thernøe, Christian. and Andresen, Claus. 2003, "Supply chain  
41 collaboration: Theoretical perspectives and empirical evidence", *International Journal of  
42 Physical Distribution & Logistics Management*, vol. 33, pp. 531-549(19).  
43 Wang, H. 1997, "Intelligent Agent-Assisted Decision Support System: Integration of  
44 Knowledge of Discovery, Knowledge Analysis, and Group Decision Support", *Expert  
45 System with Application*, vol. 12, no. 3, pp. 323-335.  
46 Yue-jie Wen, Ling Tian & Bing-shu Tong 2005, *Knowledge discovery based on Web robots  
47 in collaborative design*, in the Proceedings of the The Fifth International Conference on  
48 Computer and Information Technology Pages: 1040 – 1044.  
49 Zhou, L. & Nagi, R. 2002, "Design of distributed information systems for agile  
50 manufacturing virtual enterprises using CORBA and STEP standards", *Journal of  
51 manufacturing systems*, vol. 21, no. 1, pp. 14-31.  
52  
53  
54  
55  
56  
57  
58  
59  
60

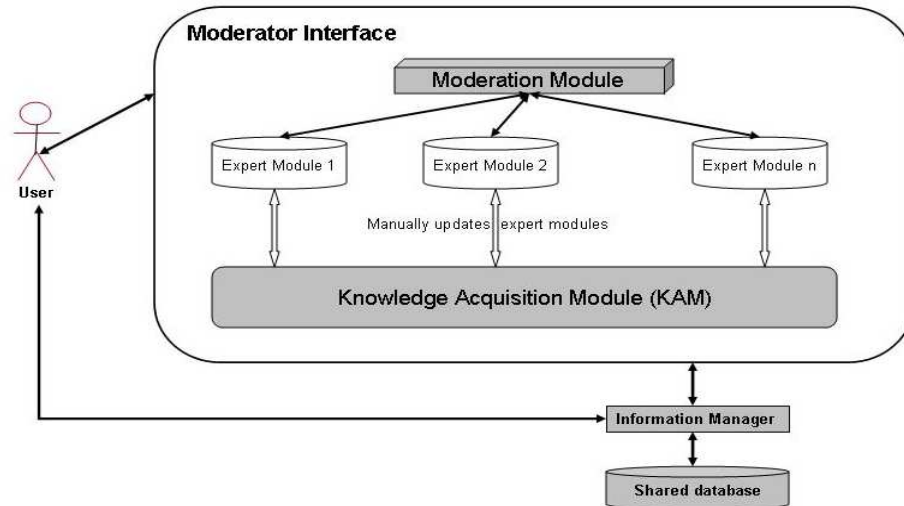


Figure 1: Existing structure of Moderator

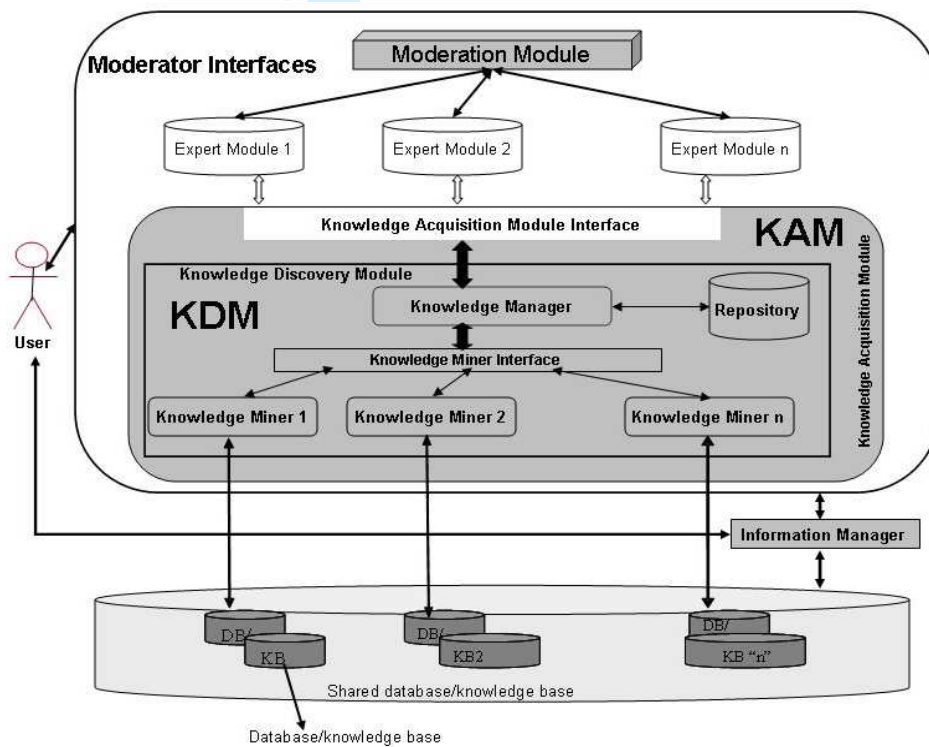


Figure 2: Proposed KOATING framework for Moderator ( Choudhary *et al.* 2006, Harding *et al.* 2007)

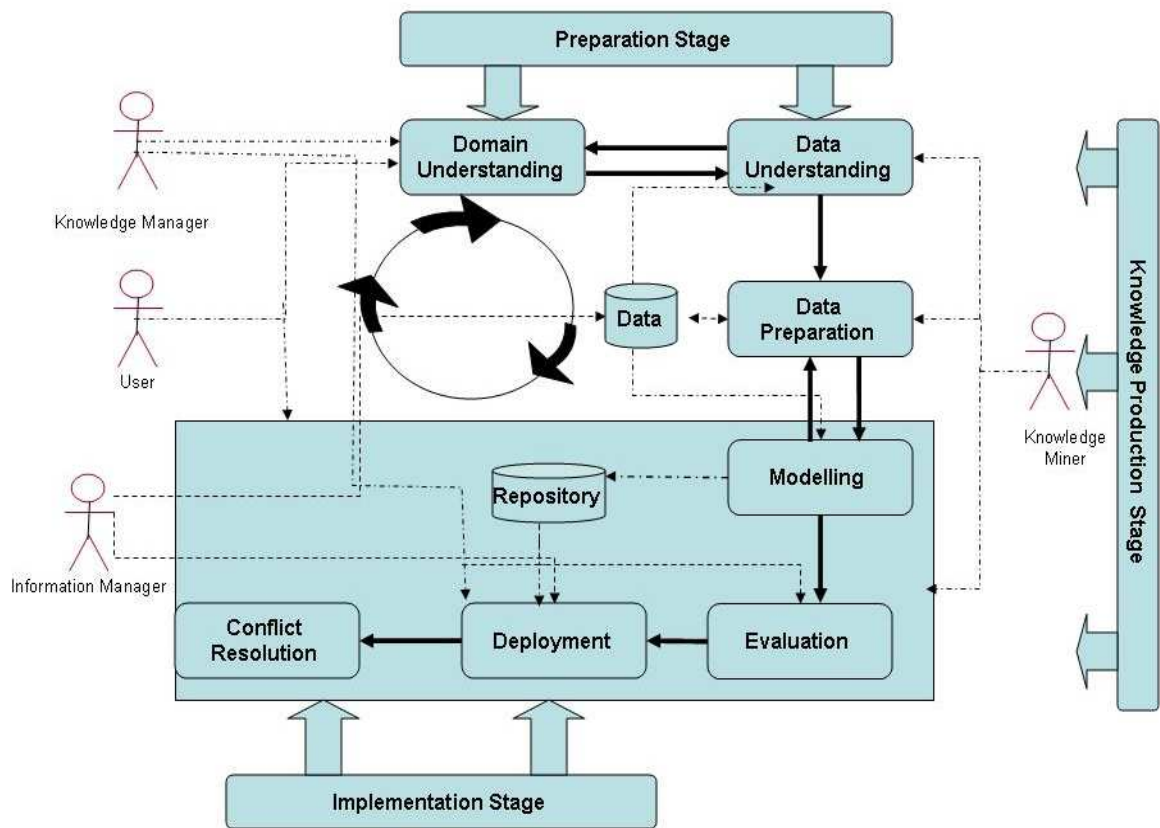


Figure 3: The Process Model of Knowledge Discovery Module

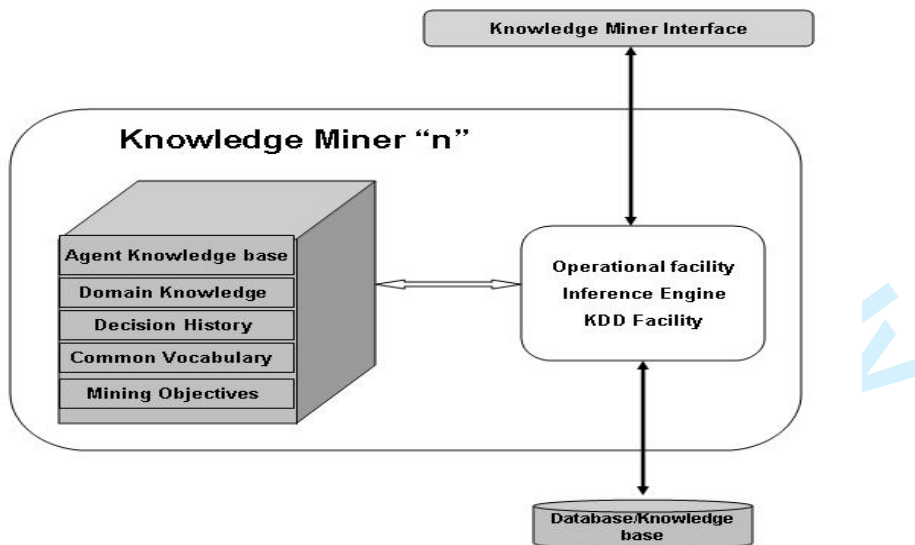


Figure 4: Architecture of the Knowledge Miner (Srinivas & Harding 2008, Wang 1997).

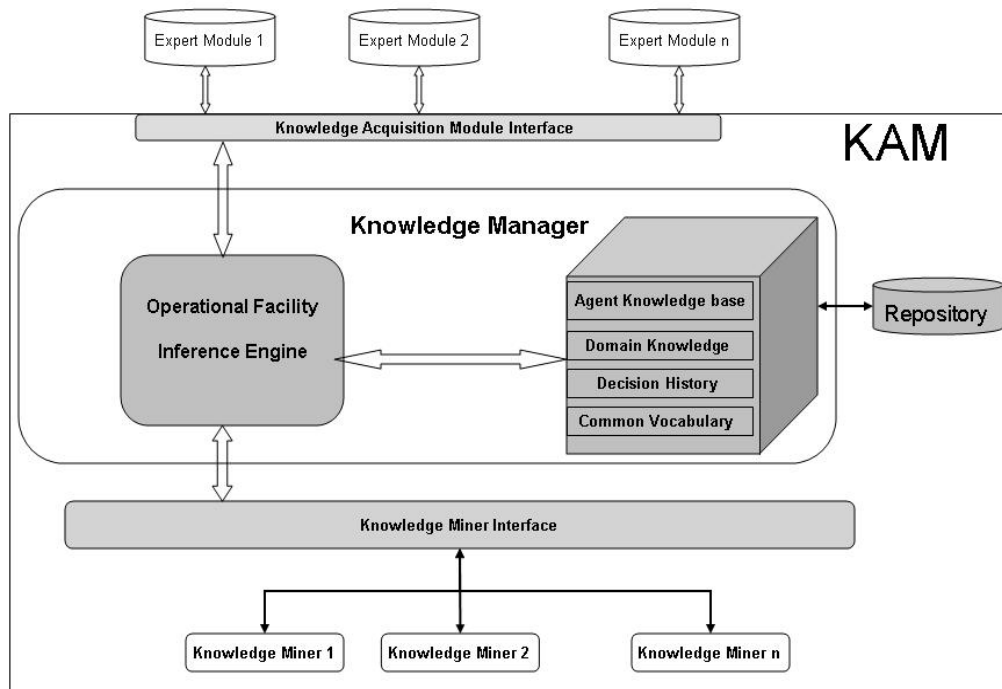


Figure 5: Structure of Knowledge Manager (Srinivas & Harding 2008, Wang 1997).

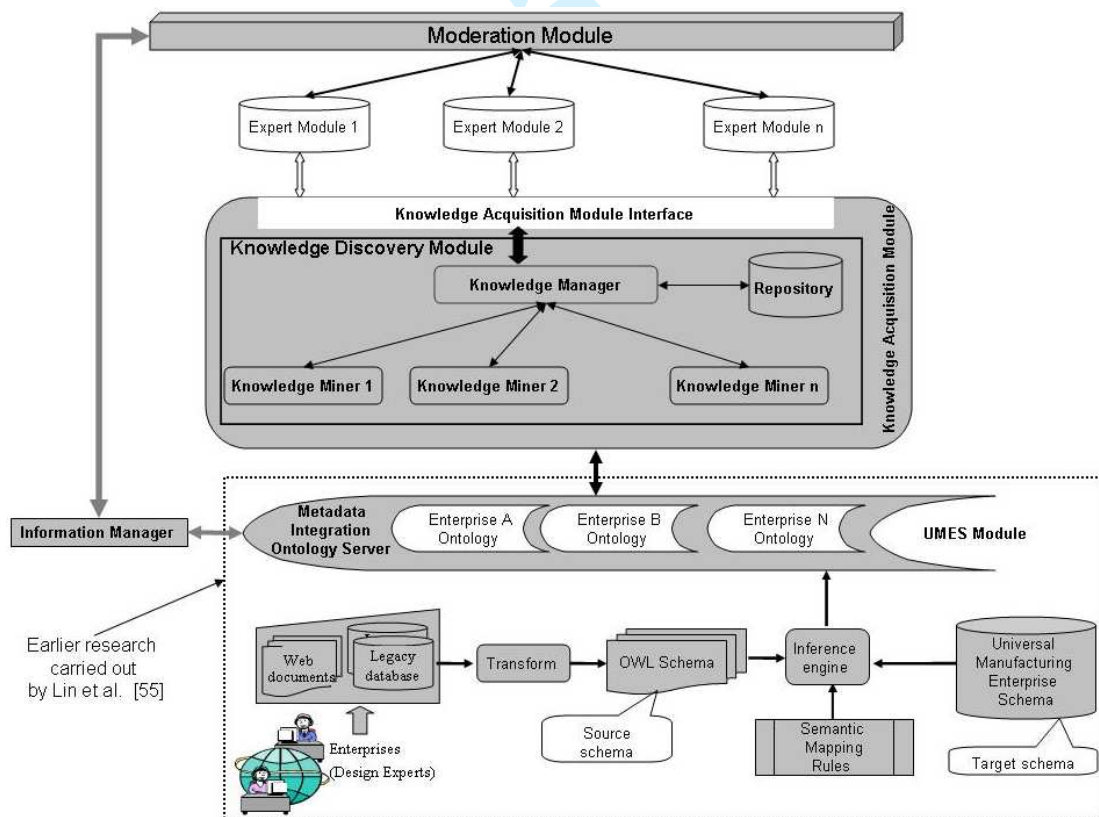


Figure 6: The Architecture of Universal Knowledge Moderator



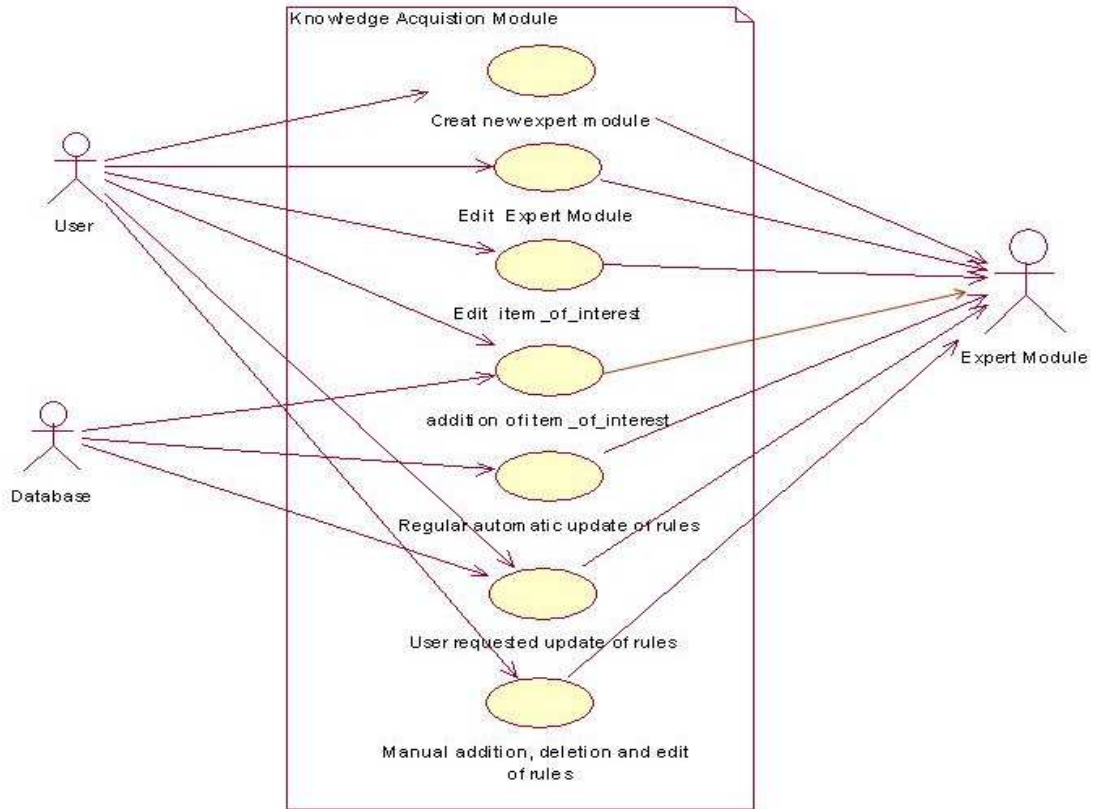


Figure 7: Use case diagram of Knowledge Acquisition Module

Review Only

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

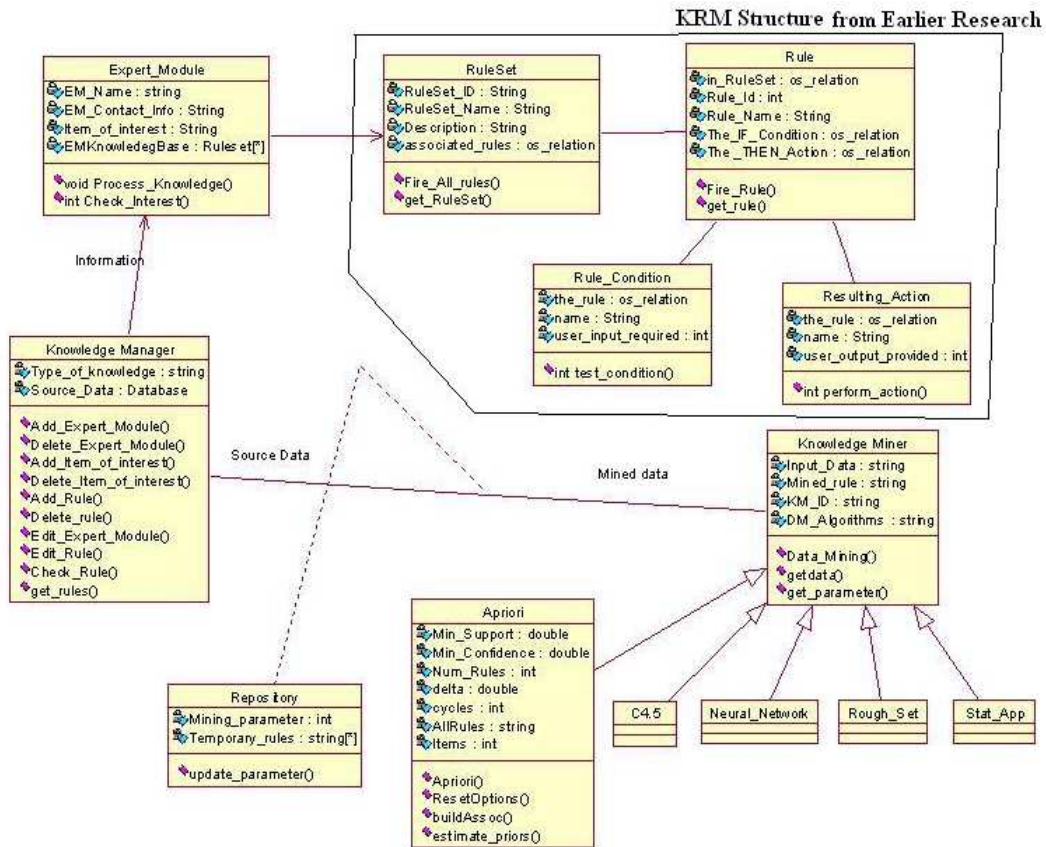


Figure 8: Class diagram of the proposed system.

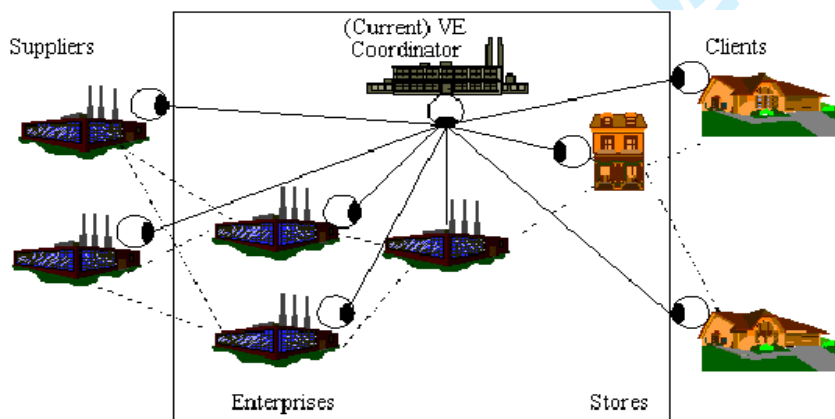


Figure 9: A generic view of Virtual e- Supply Chain

**Table 1: Comparison of traditional and proposed Moderator system**

| Traditional Moderator System (Fig 1)   | Proposed Moderator system (Fig 2)   |
|--|---|
| 1. Knowledge is acquired through Knowledge Acquisition module  | Knowledge Discovery Module is integrated with Knowledge Acquisition module for knowledge Acquisition.   |
| 2. Manual Update   | Semi-Automatic update of knowledge  |
| 3. Knowledge is gathered through interview, human experience and traditional knowledge acquisition approaches. | Knowledge is discovered from different kind of databases associated with operation or team of collaborative project.  |
| 4. Time consuming process  | Reduces the time of conducting interviews, however, knowledge discovered need to be verified by the expert.   |
| 5. Doesn't consider knowledge hidden in the operational or team related databases.                             | Discover hidden knowledge and patterns from databases using methods of knowledge discovery and data mining.   |
| 6. Unable to consider up to date knowledge   | As the time passes, the knowledge might change with the change in operational data, proposed system uses knowledge miner to discover up to date knowledge with change in operational databases. |

**Table 2: Use Case specifications of KAM**

| 1. Flow of Event for the Use case <i>Create Expert Module</i> . |  |
|---|--|
| Actors  | User and Expert module   |
| Pre-conditions  | The collaborative team must validate the creation of an expert module after a new partner joins the collaborative project.   |
| Post-conditions   | A partially populated expert module exists. This will require addition of item of interest and regular automatic updates of rules use cases.   |
| Basic Flow  | This use case executes when a new team member join the collaboration. User enters his/her password. The system verifies that the password is valid.(E-1.1) and prompts the user to create an expert module's profile(E-1.2). The system prompts the user to enter the information required in its profile such as name, contact details and communication method etc., or quit the system. |
| Alternative flows   | E-1.1: An invalid member and wrong password is entered. The user can re-enter its id and password or terminate the use case.<br>E-1.2: An invalid name of expert module is entered or an expert module with that name already exists. The user can re-enter the name or retrieve existing expert module or terminate the use case.   |

**Table 3: Supplier details and their capabilities for producing products**

| <b>Product information for supplier S<sub>1</sub></b> |                    |                         |
|---|--------------------|-------------------------|
| Lead Time   | Quantity           | Unit price (£)          |
| 1-4   | 1-30               | 48.5                    |
| 5-8   | 1-100              | 47.5                    |
| 9-12  | 1-150              | 45                      |
| <b>Product information for supplier S<sub>2</sub></b> |                    |                         |
| Due date  | Number of products | Cost per product        |
| 1-3   | 1-10               | 49                      |
| 4-7   | 1-70               | 48                      |
| 8-12  | 1-150              | 44.5                    |
| <b>Product information for supplier S<sub>3</sub></b> |                    |                         |
| Delivery Time   | Number of pieces   | Selling price per piece |
| 1-3   | 1-50               | 50                      |
| 4-8   | 1-100              | 46.5                    |
| 9-12  | 1-150              | 46                      |