# A Distributed Knowledge Model for Collaborative Engineering Knowledge Management in Allied Concurrent Engineering

Chin - Bin Wang[1], Hui-Mei Yang[2] , Yuh-Min Chen[3], Yuh-Zen Chen[3]

[1]Department of Electronic Commerce Management, Nan Hua University ,Chiayi, 622, Taiwan

[2] Department of Business Administration, Tatung Institute of Commerce and Technology, Chiayi, 600,

[3] Institute of Manufacture Engineering, National Cheng Kung university , Tainan ,Taiwan R.O.C

## Abstract

**The objective of this research is to develop a distributed knowledge model for knowledge management, which is able to support collaborative knowledge management in the practice of allied concurrent engineering. The underlying approach to the development of this model includes: (1) modeling and characterization of allied concurrent engineering processes, (2) identification, analysis and modeling of knowledge involved in the allied concurrent engineering process, (3) development of a collaborative engineering knowledge management framework for allied concurrent engineering, (4) development of a distributed knowledge model for collaborative knowledge management in allied concurrent engineering.**

**The results of the research will enable the development of a collaborative engineering knowledge management system to support allied concurrent engineering, which, will consequently, increase the effectiveness of product and process development as well as enterprise competitiveness.**

**Key words: collaborative engineering knowledge management, concurrent engineering**

## Ⅰ. Introduction

With the advent of knowledge economy, knowledge has become the most important asset of enterprises in the 21st century. Whether the enterprise knowledge can be accumulated and effectively employed will be one of the key factors for the success of enterprises. Therefore, to formally manage knowledge resources in order to help knowledge workers facilitate creation, access, storage, and reuse of knowledge will be the most important enterprise activity in the age of knowledge economy.

In recent years, the concept of allied concurrent engineering [7,9] has been employed in product and process development across the boundaries of enterprises to increase product marketability. The essence of allied concurrent engineering is a distributed and collaborative process, where people in different disciplines from different enterprises cooperate to design products and develop related processes through remote coordination, communication, and control.

Many research efforts have been made on knowledge management strategy and methodology from organizational aspect. There is also a large number of useful works dealing with the development of information sharing systems and collaborative tools to support intra-organizational processes and teamwork. However, both the methodology and the software system functionality for knowledge management are highly dependent on the characteristics of the process itself and the involved knowledge. Hence, besides determining the strategy and methodology for knowledge management, the following two steps are required in establishing a full-fledged KM environment: (i) Identification of target business processes and their characteristics and (ii) Identification, analysis and modeling of involved.

## Ⅱ. Allied Concurrent Engineering Process Modeling

Allied concurrent engineering is a systematic approach to integrated product delivery that emphasizes quick response to customer expectations and embodies the values of trust, cooperation and sharing through enterprise alliance[16].

To further extend the concept, an allied concurrent engineering process can be formed by outsourcing or subcontracting some of these activities. This practice relies heavily on: (1) remote process formation, control, coordination and communication, (2) loose integration between engineering activities, application systems, and information, (3) management and sharing of various types of information from various heterogeneous resources, and (4) easy and quick changes in the process itself when there is a need for change.

Modeling an allied concurrent engineering process involves representing the characteristics and behaviors of the elements in the process and their relationships. An allied concurrent engineering process can be seen as a complex dynamic system consisting of concurrent and/or cooperative processes, where each process is a flow of activities which are triggered by real world events and performed from various organizational units using tools to process engineering items.

Following this concept, an allied concurrent engineering process model is constructed in terms of activity diagrams with inputs to the activity, interactions between activities; the controls on the activity; the outputs from the activity to a consumer; the resources from a repository used to perform the activity; and the server enterprise that performs the activity.

Inputs to an engineering activity can be models or information transformed by the activity. Outputs of an activity are the results transformed from the inputs by the activity. The output can be a model, an electronic file, or documents. Control to an activity indicates by whom the activity is controlled. The interactions between activities can be classified based on the actors and application systems (e.g. the interactions among development team members and the interactions between the application systems used when performing activities). An activity may interact with none or any number of other activities. Similarly, an activity may have no or any number of server enterprises. The resources to support an activity can be tools, actors or reference information.

The activities in allied concurrent engineering processes can be classified as real activities and virtual activities. An activity is real if it is performed by the leading enterprise. An activity is virtual if it is outsourced or subcontracted to, or supported by other enterprises. The virtual activities can be further classified as outsourced activities, collaborative activities, and cooperative activities. The first class of activities are outsourced to and completely performed by a server enterprise without interactions with real activities. The second class of activities are outsourced to and performed by a server enterprise with interactions with real activities. The third class of activities are performed cooperatively by both the client enterprise and one or more consulting enterprises. The inputs to activities can be from the customers, the leading enterprise, or the allied enterprises. Similarly, the outputs from activities can be sent to the customers, the leading enterprise, or the allied enterprises.

The higher-level activities in the allied concurrent engineering process can be further decomposed into lower-level activities. This forms the hierarchical structure of allied concurrent engineering processes, which also reflects the hierarchical, distributed, cooperative, and dynamic nature of virtual enterprising.

## Ⅲ. Knowledge Characterization and Modeling

In this section, the knowledge items involved in allied concurrent engineering are first identified. The characteristics, attributes, and semantics of the knowledge items, as well as the relationships among the knowledge items are then analyzed. A conceptual model is developed to represent the above findings, which is then transformed into an object-oriented model using object-oriented techniques.

### A. Knowledge identification and classification

From knowledge modeling aspect, the allied concurrent engineering process can be viewed as ‘the process that knowledge workers employ resources to perform activities that use, create and transmit knowledge to achieve activity goals under the specific constrains’. Therefore, knowledge items involved in allied concurrent engineering can be identified from the “Inputs”, “Outputs”, “Constraints”, “Resources”, and “Interactions”, as well as the “Activities” themselves of the IDEF0-based process model. The identified knowledge items are classified as shown in Figure-1.

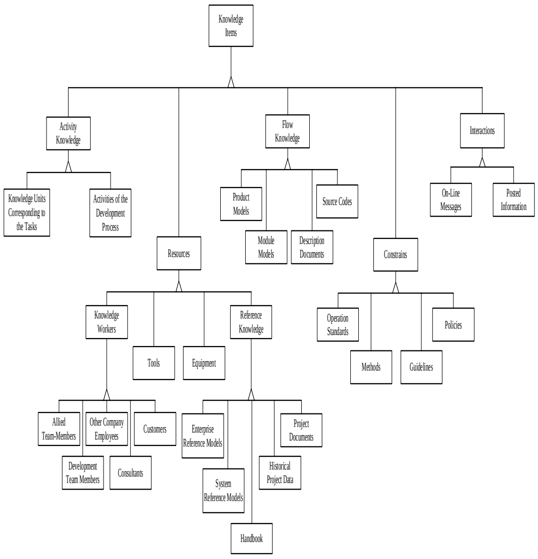


Figure 1. Knowledge classification

## B. Knowledge analysis

In this section, the main items of knowledge characterization analysis include the relationships among knowledge items(see Figure2,3) and the attributes and semantics of the knowledge items (see figure 4)

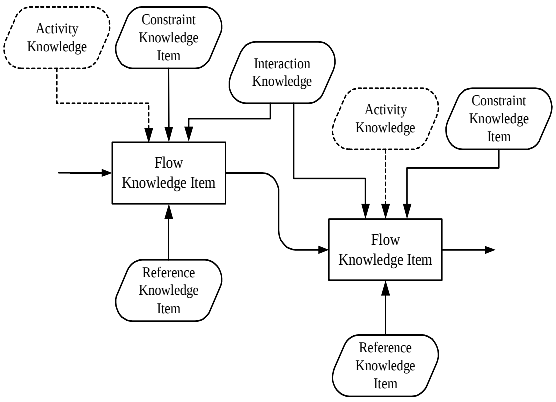


**Figure 2. Knowledge flow model**

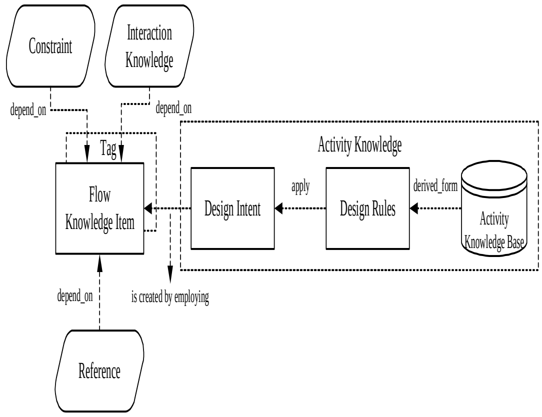


**Figure 3. The generate factors of a flow knowledge item with relationships**

According to the above analysis, the relationships between knowledge items can be classified as (1) the relationships between flow knowledge items, (2) the relationships between flow knowledge items and reference knowledge items/constraint knowledge items (3) the relationships between knowledge items and their duplications, (4) the relationships between flow knowledge item and activity knowledge, and (5) the relationships between flow knowledge item and interaction knowledge (See Figure 5). The first type relationships include depends_on/depended_by, associated_with, attach/attached_by, and contains/is_in, while the second type relationships include refer_to, and constrained_by. The examples of the third type relationships are copy_of, version_of, and check_out_of. Both of the fourth type relationships and the fifth type relationships include created_by employing and modified_by respectively.

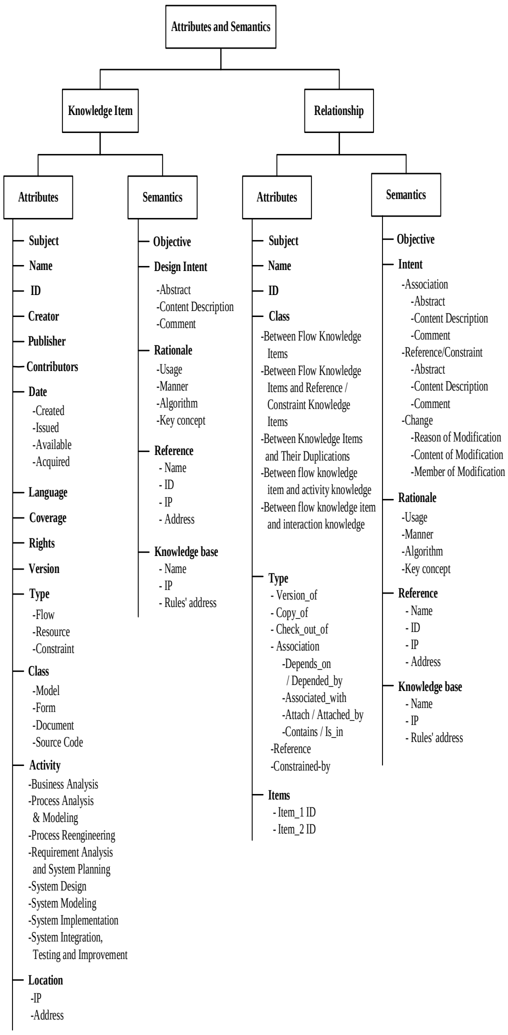


**Figure 4. Attributes and semantics**

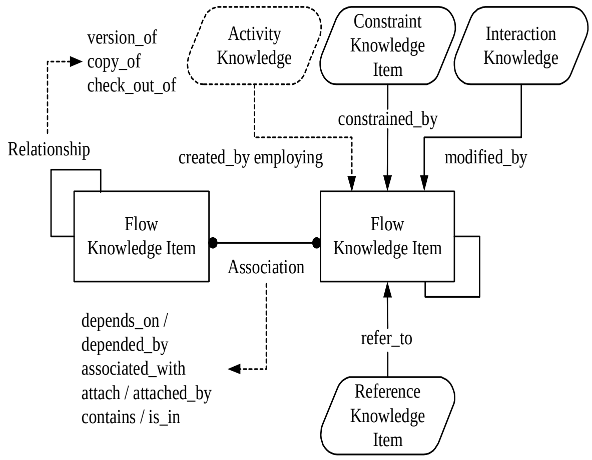


**Figure 5. Relationship types between knowledge items**

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The conceptual modeling is then conducted to pave the way for object modeling.

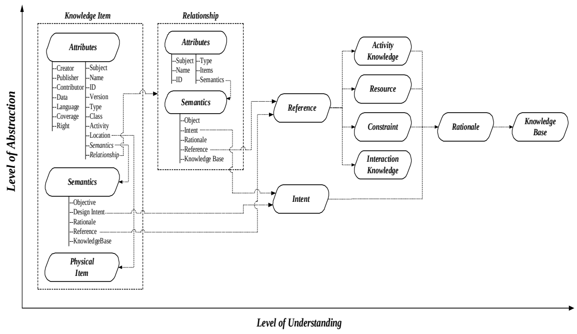


**Figure 6. Conceptual knowledge model**

## C. Knowledge Modeling

Knowledge modeling aims to define levels of knowledge details in terms of a set of models. In order to achieve above objective effectively, two techniques are applied to knowledge modeling. They are conceptual modeling(Figure 6) and object modeling (Figure 7) respectively.

## Ⅳ .Distributed Knowledge Model Development

In this section, the strategy and framework characterization of knowledge management are first developed and analyzed respectively in the context of allied concurrent engineering. A distributed knowledge management framework is

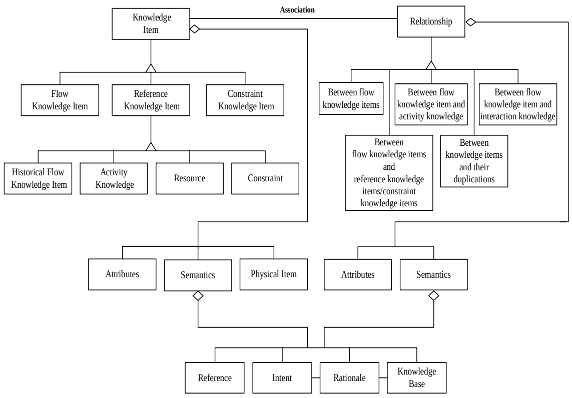


**Figure 7. Object knowledge model**

then developed based on the strategy and framework characterization. Ultimately, a conceptual model of distributed knowledge management framework is modeled and then the object-oriented modeling methodology is employed to transform the conceptual model into an object model so as to proceed system implementation.

## A. Knowledge management strategy and framework characterization

In general, the development of knowledge management strategy is usually dependent on the work mode or characterization of core process. According to the characterization of allied concurrent engineering discussed in Section II, the collaboration is one of the promising strategies for enterprise integration. Collaboration can be seen as a solution for enterprise integration. In practice, it is implemented by performing collaborative work process, where people in different disciplines from different departments or enterprises cooperate to do enterprise activities and develop related processes through coordination and communication by using information technologies. The success of collaboration depends on management and sharing of information and knowledge through process integration.

Collaboration is an approach to integrate resources from different enterprises to overcome the difficulties faced by traditional approaches, the tradition knowledge management approach does not completely fulfill the requirements of collaboration. Therefore, the knowledge management framework for allied concurrent engineering possesses the following properties: Dynamic-configurability, Project-based, Flexibility and heterogeneity, Hierarchical and recursive structure,Distributed and cooperativeness.

## B. Knowledge management framework in allied concurrent engineering process

### 1) Knowledge management life cycle

According to the concept of strategy as discussed in the previous section, the life cycle of knowledge management for allied concurrent engineering is tightly coupled with the allied concurrent engineering process, which includes phases of process integration, system integration, knowledge integration, knowledge management and sharing of process execution, and historical knowledge management and sharing as shown in Figure 8.

### 2) The development of distributive knowledge management framework

According to the characterizations of dynamic-configurability, project-based, flexibility and heterogeneity, hierarchical and recursive structure, and distributed and cooperativeness of allied concurrent engineering process framework as discussed in Section IV-A, a knowledge management framework is developed so as to reflect above characteristics. Therefore, this sub-section is mainly divided into two parts for discussion. They are Hierarchical allied concurrent engineering process structure and levels of knowledge management agents respectively.

Hierarchical allied concurrent engineering process structure: The structure of allied concurrent engineering process is identified to facilitate the design of knowledge management framework. Due to the allied concurrent engineering process is managed on a project-based, an allied concurrent engineering process project may consist of one or more processes, each process is composed of one or more activities.

An activity can be a real activity, collaborative activity or distributive activity. A real activity is conducted by a prime enterprise. A collaborative activity is conducted collaboratively by the process owner with one or more allied enterprises. A distributive activity is conducted totally by one or more allied enterprises. However, a real activity also can be a primitive activity if it is performed by

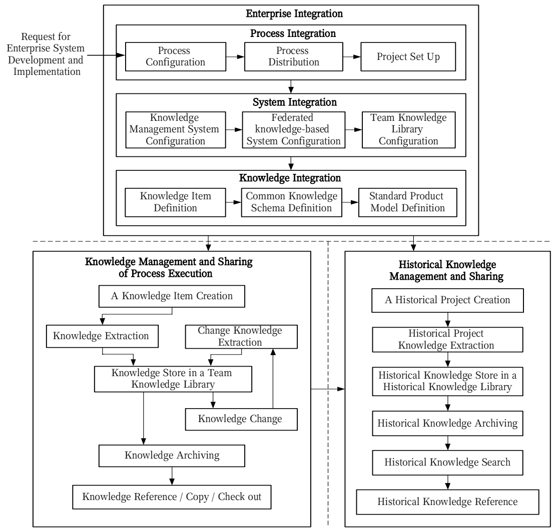


**Figure 8. Life cycle of knowledge management for allied concurrent engineering process**

an individual; or a team activity if it conducted by a team. Similarly, a distributive activity also can be a distributive primitive activity or distributive team activity.

On the other hand, a process also can be a real process, collaborative process or distributive process. A real process is composed of one or more real activities. A collaborative process is composed of at least one real activity and at least one collaborative activity or one distributive activity. A distributive process is composed of one or more distributive activities. Consequently, an allied concurrent engineering project can be in terms of a hierarchical structure based on the classification of process and activity.

Levels of knowledge management agents: In order to effectively support levels of knowledge management in an allied concurrent engineering project, four levels of knowledge management agents are proposed. They are project knowledge management, process knowledge management, activity knowledge management, and knowledge worker work area knowledge management respectively. A project knowledge management agent is responsible for knowledge management of a whole project. It can be linked with lower-order knowledge management agents for real processes, collaborative processes, and distributive processes. By connecting the lower-order knowledge management agents, a project knowledge management agent can monitor, control and support the knowledge management on its subordinate. In the level of process knowledge management agent, the different process agents are developed so as to support completely knowledge management of different types of processes. They are real process agent, collaborative process agent, distributive process agent, team activity knowledge agent, and knowledge worker area. A real process agent is able to monitor, control and support the knowledge management agents of other lower-level real processes, team activities and primitive activities. A collaborative process agent can monitor, control and support the knowledge management agents of team activities, distributive team activities and primitive activities, real processes, collaborative processes, and distributive processes. A distributive process agent also can monitor, control and support subordinate knowledge management agents for distributive team activities, distributive primitive activities, and other lower-level distributive processes. A team activity knowledge agent is able to monitor, control, and support subordinate knowledge management agents of knowledge worker areas. A knowledge worker work area is a private workspace for each team member when an activity of allied concurrent engineering process is performed. Knowledge items in any knowledge worker area cannot be shared until they are released to the common library of team.

### C Distributive knowledge management framework modeling

#### 1) Conceptual Modeling

Based on the development of knowledge management framework in the previous subsection ,the conceptual model aspect as briefly introduced framework in Section Ⅲ-C is employed to model the development of knowledge management framework as shown in Figure 9.

#### 2) Object modeling

Based on Rumbaugh's Object Modeling Technique (OMT) [4,14,17] the proposed conceptual model of distributive knowledge management framework is modeled in terms of objects and relationships.

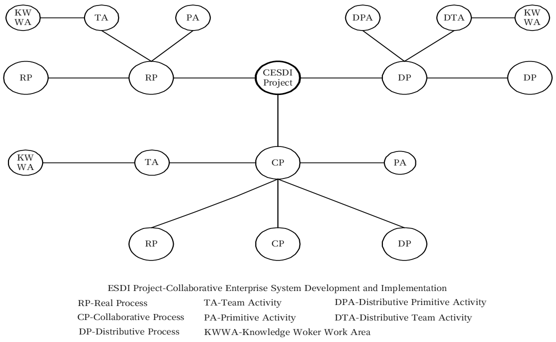


**Figure 9. Conceptual Model of distribute knowledge management framework**

Figure 10 illustrates the object model of distributive knowledge management framework. The CESDI project is the aggregation of process class. The process-class can be specialized as classes of real process, collaborative process, and distributive process. Each of the classes is composed of a set of activity class as shown in the below figure. However, the process class is again the aggregation of activity class. And, it also can be specialized as classes of primitive activity, and team activity.

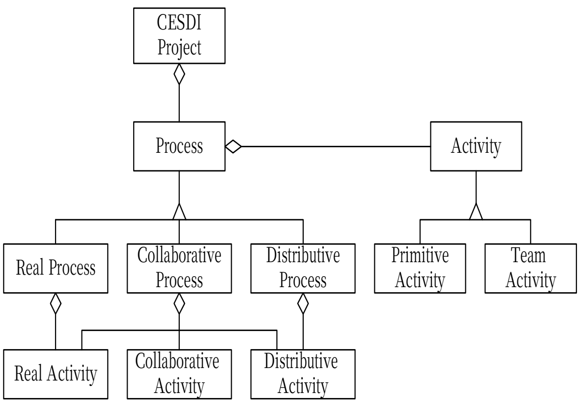


**Figure 10. Object model of distributive knowledge management framework**

## Ⅴ. Conclusions

In this paper, authors have presented a systematic approach to developing a distributed knowledge management model, The results of the research will enable the development of a collaborative engineering knowledge management system to support allied concurrent engineering, which, will consequently, increase the effectiveness of product and process development as well as enterprise competitiveness.

## References

1. Allen P, Forst S. Computer-based development for enterprise systems. Cambridge, UK: Cambridge University Press, 1998.
2. Barthelme F, Ermine J-L. Rosenthal-Sabroux C. An architecture for knowledge evolution in organizations. European Journal of Operational Research, vol. 109, Issue: 2, pp. 414-427, 1998.
3. Basu A. Perspectives on operations research in data and knowledge management. European Journal of Operational Research, vol. 111, Issue: 1, pp. 1-14, 1998.
4. Booch G, Rumbaugh J, Jacobson I. The unified modeling language user guide. Reading, MA: Addision-Wesley, 1999.
5. Carayannis E.G. Knowledge transfers through technological hyperlearning in five industries. Technovation, vol. 19, Issue: 3, pp. 141-161, 1999.
6. Carayannis E.G. The strategic management of technological learning in project / program management: the role of extranets, intranets and intelligent agents in knowledge generation, diffusion, and leveraging. Technovation, vol. 18, Issue: 11, pp. 697-703, 1998.

7. Chen Yuh-Min, Hsiao Yun-Tao. A Collaborative Data Management Framework for Concurrent product and process Development. Int. J. of Computer Integrated Manufacturing, vol. 10, No. 6, pp. 446-469, 1997.
8. Chen Yuh-Min, Lee Rong-Shean, Ho Cheng-Ter. A Framework for Integration of Design and Knowledge Based Environment. J. Of the Chinese Society of Mechanical Engineers, vol. 17, No. 6, pp. 587-599, 1996.
9. Chen Yuh-Min, Liang Ming-Wu. Design and implementation of a collaborative engineering information system for allied concurrent engineering. I J Comput. Integrated Manuf. 1999; 17, in press.
10. Chen Yuh-Min, Liao Chia-Ching, Biren Prasad. A Systematic Approach of Virtual Enterprising through Knowledge Management Techniques. J. of Concurrent Engineering: Research and Applications, vol.6, No. 3, pp. 225-244. 1998.
11. Davidow WH, Malone MS. The virtual corporation. USA: Harper Collins Publishers, 1992.
12. Demarest M. Understanding knowledge management. Long Renge Planning, vol. 30, pp. 317-472, 1997.
13. Drew S. Building knowledge management into strategy. Making Sense of a New Perspective, Long Renge Planning, vol. 32, pp. 130-136, 1999.
14. Jacobson I, Christerson M, Jonsson PM, Overgaard G. Object oriented software engineering: a use case driven approach. Reading, MA: Addision-Wesley, 1992.
15. Mayer RJ, Paintec MK, Dewitte PS. IDEF family of method for concurrent engineering and business reengineering applications, Technical Report. Knowledge Based Systems, Inc., Texas, 1994.
16. Prasad B. Concurrent engineering fundamentals, vol. I: integrated product and process organization. NJ: Prentice-Hall, 1996.
17. Prasad B. Concurrent engineering fundamentals, vol. II: integrated product and process organization. NJ: Prentice-Hall, 1997.
18. Purser R.E, Pasmore W.A. Organizing for learning. Research in Organization or Change and Development, London: JAI Press Inc, pp. 37-114, 1992.
19. Rumbaugh J, Blaha M, Premerlani W, Eddy F, Lorensen W. Object-Oriented Modeling and Design. New Jersey: Prentice Hall, 1992.
20. Studer R, Benjamins V.R, Fensel D. Knowledge Engineering: Principles and methods. Data & Knowledge Engineering, vol. 25, Issue: 1-2, pp. 161-197, 1998.