

## Intelligent Interface for a Knowledge-based System

Nyoman Karna<sup>\*1</sup>, Iping Supriana<sup>2</sup>, Ulfa Maulidevi<sup>3</sup>

Sekolah Teknik Elektro dan Informatika, Institut Teknologi Bandung, Indonesia  
Ganesha 10, Bandung, +62-22-2500935

\*Corresponding author, e-mail: bogi@students.itb.ac.id<sup>1</sup>, iping@stei.itb.ac.id<sup>2</sup>, ulfa@stei.itb.ac.id<sup>3</sup>

### Abstract

Every knowledge-based system has its own knowledge formalism depending on the problem that needs solving, goal to be achieved, and proposed solution. This means the knowledge contained in the system will differ from one system to another. This also means that this knowledge cannot be used by another system, which in turn means every system must start with a learning phase right at the beginning. One of the solutions to overcoming this problem is providing a unified model that can accept all types of knowledge, which guarantees automatic interaction between the knowledge-based systems. Interaction in this paper is defined as knowledge sharing, integration, and transfer from one system to another. This research provides a model and conducts a test on interaction capability. It will help to accelerate the establishment of a new knowledge-based system because it does not need knowledge initialization.

**Keywords:** unified knowledge representation, sharing knowledge, knowledge integration, transfer knowledge

### 1. Introduction

Knowledge is a proposition that contains facts and is definitive, while representation is a relation between two domains, the symbol and what the symbol represents. Knowledge representation is a field of study that explores symbol formalism, which is used to represent knowledge [1]-[2]. Knowledge itself has many interpretations and so far there have been no agreed definitions for knowledge. Although there are no definitive definitions for knowledge, we can look at several aspects, machine learning, expert systems, and knowledge management. In machine learning, information is acquired and retained (stored) for future recall to obtain knowledge from the existing information. In an expert system, information is acquired from an expert's knowledge and retained for future recall to obtain the expert's knowledge. In knowledge management, a large amount of knowledge is also basically stored in information fact types, which will be easily recalled to expand the user's knowledge.

Every knowledge representation needs a specific language to provide an optimal way to represent a symbol. The symbol itself is needed to represent the knowledge in such a way that it can be easily understood by a simple machine, that is, a program. Language will provide an effective way to represent knowledge using three aspects [1], which are as follows.

1. Syntax, to define how the formalism of knowledge representation forms a sentence with clear and standard structure by building it with logical symbols (punctuation, connectives, variables) and non-logical symbols (function and predicates)
2. Semantic, to define how the formalism of knowledge representation forms a sentence with a structure that can be understood through:
  - a. interpretation
  - b. denotation
  - c. satisfaction
3. Pragmatic, to define how the formalism of knowledge representation forms a meaningful sentence.

Language is used to represent knowledge that is declarative and has a specific and definitive meaning. A declarative sentence that fulfills all three aspects (syntax, semantic, and pragmatic) can be used to establish knowledge representation using logic-based formalism, such as first-order logic. Besides logic-based formalism, we can also choose to use other approaches, like frame-based and also rule-based approaches. Each of the previously mentioned types of formalism has its own benefits and disadvantages, depending on the content and what the knowledge will be used for [3].

Knowledge representation is a branch of artificial intelligence, which is a field of study that explores how to represent information that is acquired from anywhere in a format that can be understood by a program. A program here refers to a knowledge-based System, such as a machine learning system or an expert system. The knowledge representation itself can also be described as a knowledge model, because it can explain the model of the knowledge, the syntax and the semantics of the information. When we choose the model of knowledge it depends on three aspects.

1. Problem, what is the problem to be addressed?
2. Goal, what should the knowledge fulfill?
3. Proposed solution, how does the knowledge solve the problem?

From the problem aspect point of view, the model of knowledge can be separated into decision making, the recommender, and the human life enhancer. From the decision making perspective, the knowledge model is significantly related to data mining. From the recommender perspective, the knowledge model is significantly related to the expert system. In human life enhancement, the knowledge model is significantly related to knowledge management. From the proposed solution point of view, the model of knowledge can also be approached using machine learning and the expert system along with an appropriate method of reasoning. The method of reasoning itself is comprised of a decision tree, Bayesian, rule-based, back propagation, a support vector machine, and an association rule [4]-[5]. Each of these proposed methods have different benefits, depending on the proposed solution offered.

The contextual differences between these three aspects result in every machine learning or expert system using different knowledge representation, depending on the problem, goal, and proposed solution involved. For example, to solve a problem related to knowledge from an expert, the knowledge model will be established using a decision tree that provides attributes to determine which path to take until a solution or recommendation has been reached. On the other hand, to solve a problem related to question and answering, the knowledge model chosen is a rule-based table that provides attributes to determine the nearest answer that can be given. These two examples demonstrate that there is no generic or unified knowledge model to be used in multiple cases (a multi-proposed solution).

## 2. Related Works

A knowledge model or knowledge representation is how we can define a formula that has the ability to describe the knowledge within. The formula must consist of a tuple that contains at least three components.

1. Knowledge atom
2. Rule
3. Relation

A knowledge atom, as the first component of a knowledge model of formalism, explains the knowledge entity itself in the simplest form. This will ensure that a program will be able to understand the knowledge and run a computation on it. Every knowledge atom also has an optional additional attribute to explain a specific behavior of the knowledge to help the computation. Rules, as the second component, provide a list of instructions that can be used to conduct inferences from the information stored in the tuple. A rule itself can only be used as an inference exclusively within the tuple. The result of this inference is a link that connects one tuple with another. A relation, on the other hand, as the third component, describes an interconnection between tuples. It provides the list of all the connections from a particular tuple. The link itself only describes a line that draws an imaginary interconnection between two tuples. The result of all the interconnected tuples will be a mesh network called a semantic network.

Up till now, research on knowledge-based system has focused on the application level, which is how to establish a knowledge-based system and utilize it for a specific purpose. This knowledge-based system will answer a specific problem in a specific domain of knowledge.

1. Document classification, where a knowledge-based system is assigned a task to retrieve documents from a specific source, conduct information extraction from the document to obtain the meta data, and create a classification using the meta data [6]-[12]
2. Real time information, where a knowledge-based system acquires knowledge from a real time source with spatial information [13]-[20]

3. Knowledge management utilization, where a knowledge-based system is built and managed for special purpose [21]-[26]
4. Multilingual information, where a knowledge-based system acquires knowledge from multilingual source, including tacit knowledge [27]-[29].

The requirements and ideas for building a unified model to accommodate the ability for knowledge transfer, sharing, and integration between two systems have already provoked long discussions [30]. However, there are still a few recent studies that have conducted research on the core of a knowledge-based system, which is the knowledge representation itself. Most of the recent papers have involved research on the application level, as described above.

To accommodate knowledge transfer, sharing, and integration ability, this research focuses on semantic network formalism. There are two types of semantic network approaches [31]-[37].

1. Static knowledge representation, where the network is static (predefined) and built to solve a specific problem
2. Dynamic knowledge representation, where the network is dynamic and built to solve multi-problems.

Static knowledge representation provides ease of use and ease of building. Static knowledge representation is easy to build because it uses two-phase method, training and testing. In the training phase, a semantic network is built using all the available nodes (tuple). In the testing phase, the semantic network proposes a problem and it must provide a solution or recommendation accordingly. One example of static knowledge representation is knowledge ontology. Dynamic knowledge representation, on the other hand, provides flexibility in solution finding, because the semantic factor is built when a problem is proposed to the network. In dynamic knowledge representation, the network is rebuilt when a new node (tuple) is integrated into the network. One example of dynamic knowledge representation is COKB (Computational Object Knowledge Base).

Both approaches above, static and dynamic knowledge representation use the same tuple formulation, as described in formula 1.

$$KM = \{KA, R, Rule\} \quad (1)$$

Where:

- KM means the knowledge model or knowledge representation for a specific domain knowledge
- KA means the knowledge atom, which describes the simplest and smallest form of knowledge, such as axiom or a concept
- R means the relation between KMs (inter-KM) or between KAs (intra-KM)
- Rule means a rule that explicitly stores the formula for inference.

### 2.1 Static Knowledge Representation

Static knowledge representation describes a semantic network comprised of nodes (KM) and links that connect the nodes. One example of static knowledge representation is knowledge ontology. In the knowledge ontology approach, knowledge is represented according to the domain characteristics of the knowledge itself. A study on creating the relation between knowledge model and knowledge ontology [22] is described in Figure 1. Figure 1 explains that, from a knowledge model point of view, both the domain and task knowledge models are related to knowledge atom and its relation, while the reasoning knowledge model is related to rules from a knowledge ontology point of view.

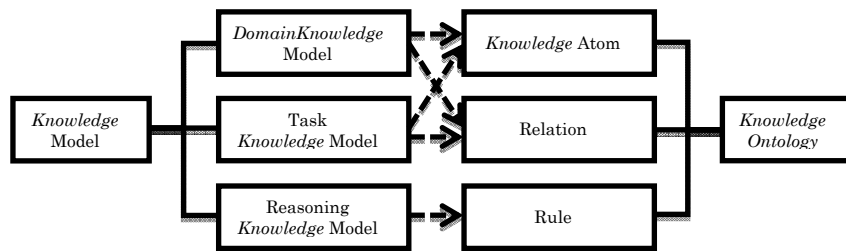


Figure 1. Relation between Knowledge Model and Knowledge Ontology

**2.1 Dynamic Knowledge Representation**

In dynamic knowledge representation, the composition in the knowledge model is slightly different from that with static knowledge representation. The knowledge atom is called a computational object (com-object) and is the simplest and smallest knowledge entity[31]. It comprises four components, attributes, functions, facts, and rules (Figure 2).

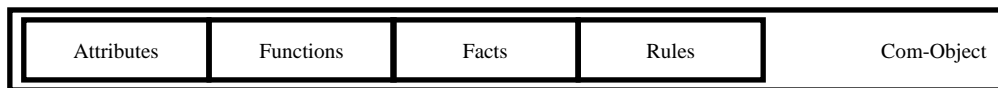


Figure 2. Computational Object as the Knowledge Atom

Where:

- Attributes mean a list of attributes corresponding to the object
- Functions mean computational interrelations between attributes
- Facts mean a group of properties or events relating to the object; this includes 11 types of facts, such as object type, object definition, object similarity, object dependency, etc.
- Rules mean rules for inference from facts

From the com-object (concept) entity, a knowledge representation is built using Figure 3.



Figure 3. Knowledge Representation for Computational Object

The concept contains a class of com-objects and its relation is drawn using hierarchy and relation, where this relation includes the operator and function. Rules contain instructions or guidelines that can be used for inferences from the concept. With the dynamic knowledge representation approach, using a computational object means that the network is built using an inference rule to create a hierarchical relation from the concept. The network can then be used to answer a problem like an expert would. The links that interconnect concepts in the computational object contain the direction; for example a "IS-A" explains that one concept is a member of another concept. This direction explains the relation between one concept and another. Figure 4 demonstrates four computational objects that build the network hierarchy and the link direction.

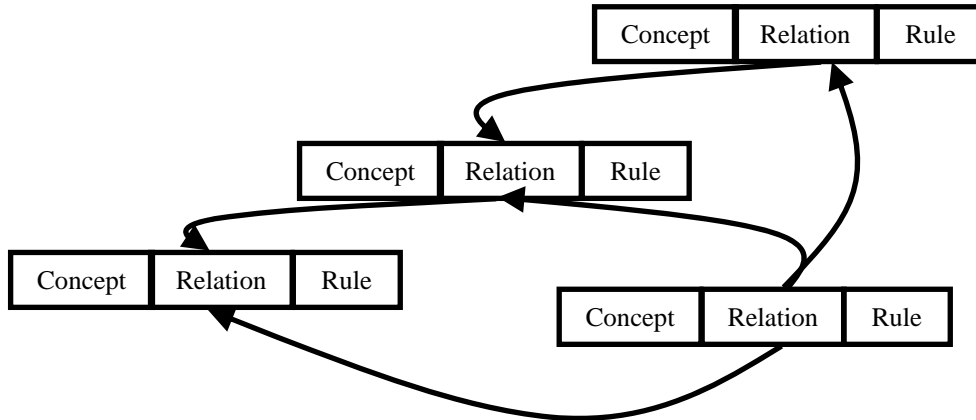


Figure 4. Knowledge Model Relation in Computational Object

Beside the computational object, there is also another example for dynamic knowledge representation, which is the relation model or Rela-Model [35]. The Rela-Model builds the semantic network by assimilating the human method of storing information and how humans retrieve the stored information. Several definitions for Rela-Model are given using formula 2 to formula 5. Formula 2 defines the relation between concepts using a list of rules.

$$(C, R, Rules) \tag{2}$$

Where:

- C is a group of concepts defined by

$$C = \{C1, C2, \dots\} \tag{3}$$

This has specific an attributes-values combination according to the usage of the concept.

- R is a binary relation between concepts, defined by

$$R = \{R1, R2, \dots\} \tag{4}$$

- Rules means a set of rules for inference purposes

$$\{f1, f2, \dots, fp\} \rightarrow \{fp+1, fp+2, \dots, fq\} \tag{5}$$

The establishment of the knowledge structure (defining every relation R between concepts) is achieved using iterated inference for every possible concept, starting from the concept that has a rule for the near-solution of the problem given. A comparative analysis of these three models (knowledge ontology, computational object, and Rela-Model) can be explained in Table 1.

Table 1. Comparative Analysis of the Three Models

Method/ Feature	Knowledge Ontology	Computational Object	Rela-Model
Knowledge Atom	Knowledge atom as a reference	Knowledge atom as a foundation to develop a hierarchical structure	Knowledge atom as a foundation to develop a hierarchical structure
Relation	There are fixed relations between knowledge atoms	Relation exists between knowledge atoms in a vector format	Relation exists between knowledge atoms in a binary format
Inference	Rule is predefined	Rule is adaptive, based on the problem	Rule is adaptive, based on the problem

### 3. Research Method

This research answers a common problem about knowledge sharing in a knowledge-based system, in terms of how two knowledge-based systems can share their knowledge so that one system can reuse another system's knowledge. This will ensure a new knowledge-based system does not need to perform knowledge initialization, and instead uses knowledge acquisition from another system. To find a solution for this problem, this research is conducted by carrying out a literature study of text books, papers, and the Internet. As a result of this study, the writer proposes a method that incorporates capability into a knowledge-based system, a capability to ensure knowledge integration, knowledge sharing, and knowledge transfer.

### 4. Results and Discussion

An idea about providing a unified knowledge representation to ensure knowledge transfer, sharing, and integration between two systems has already been proposed [30]. The research was conducted by building a framework, CreekL, which has the capability to provide a compatible knowledge representation for similar domain knowledge. There are two aspects from this research that can be further investigated.

1. CreekL can only accommodate a compatible representation for similar domain knowledge. This can be advanced by conducting research on different but related domain knowledge
2. CreekL can only accommodate compatibility for knowledge transfer from one system to another. This can be advanced by conducting research on how to accommodate knowledge integration and knowledge sharing.

By providing a unified knowledge representation, knowledge transfer, integration, and sharing can be possible. The knowledge transfer capability ensures all the knowledge within one system can be transferred to a new system. The knowledge sharing capability ensures the knowledge within one system can be shared to enhance the knowledge of another system. The knowledge integration capability ensures the knowledge within one system can be used by another system. This will ease the development of a new knowledge-based system because there will be no knowledge acquisition; instead, a new system can learn from already existing and learnt systems. The capabilities are shown in Figure 5.

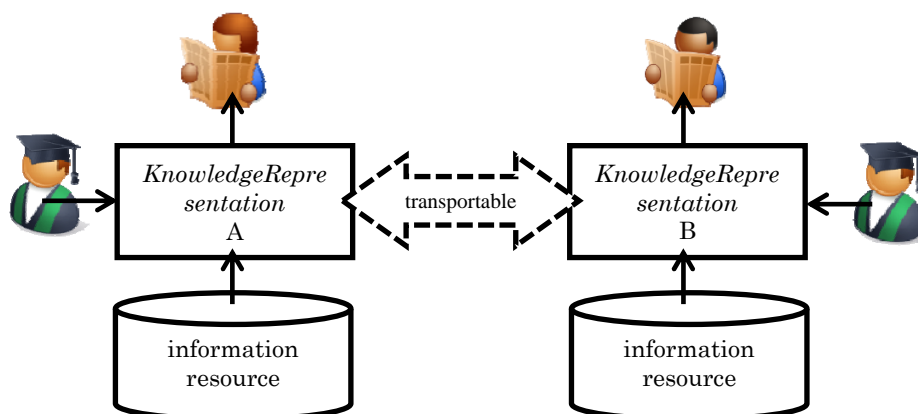


Figure 5. Knowledge Transfer, Sharing, and Integration between 2 systems

The main focus of this solution is demonstrating how to create a new knowledge-based system and initiate the knowledge from another system. There are two possible solutions to accommodate these capabilities and these are shown in Figure 6.

1. Distributed knowledge-based system, where an intelligent interface is provided to bridge knowledge inference from a correct knowledge base system. The interface provides a table where a piece of knowledge resides in a knowledge-based system; so when a problem is proposed to the interface, the interface can dispatch the inference to the correct knowledge.

2. Autonomous knowledge-based system with knowledge sharing, where every knowledge-based system provides an intelligent interface. This interface can ensure another knowledge-based system can infer knowledge from another system.

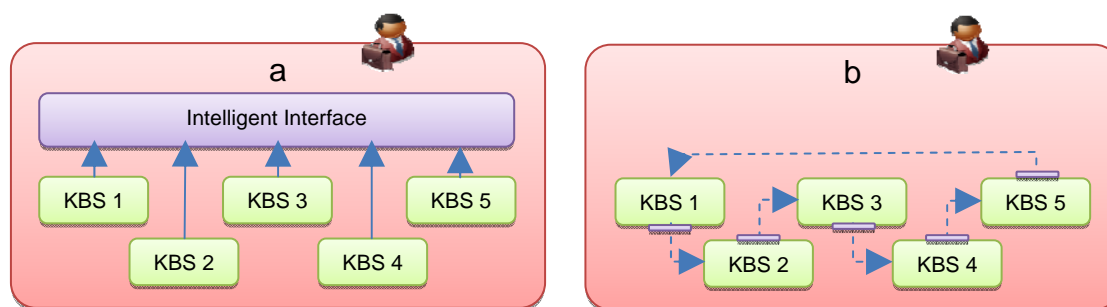


Figure 6. Knowledge-based System to Ensure Knowledge Integration, Sharing, and Transfer

## 5. Conclusion and Future Research

A knowledge-based system has a number of variances based on the knowledge representation used to store the information. This leads to difficulties in reusing knowledge that is already stored in a knowledge-based system. This research proposes a method for incorporating stored knowledge for reuse purposes by another system using knowledge integration, knowledge sharing, and knowledge transfer. The proposed method is an autonomous knowledge-based system, an additional method to an already existing distributed knowledge-based system. An autonomous knowledge-based system ensures that each knowledge-based system has the capability to draw inferences from another system to find an answer to a specific problem or even enhance its knowledge.

Future research will implement this proposed method using a unified platform that will accommodate multiple knowledge-based systems that are to be implemented on one platform. In using this platform, the method will be developed, tested, and measured to ensure knowledge integration, sharing, and transfer can be accommodated.

## References

- [1] Ronald J. Brachman, Hector J. Levesque. *Knowledge Representation and Reasoning*. San Francisco: Morgan Kaufmann. 2004: 2-11.
- [2] John F. Sowa. *Knowledge Representation: Logical, Philosophical, and Computational Foundations*. Boston: Course Technology, CENGAGE Learning. 2000: 11-29.
- [3] Emil Vassev, Mike Hinchey. Knowledge Representation and Reasoning for Intelligent Software Systems. *IEEE Computer*. 2011; 44(8), 96-99.
- [4] Jiawei Han, Micheline Kamber. *Data Mining: Concepts and Techniques*. San Francisco. Morgan Kaufmann. 2006: 291-337.
- [5] Qiu Yun, Fan Jingchao, Zhou Guomin. Research on the Knowledge ES Tool Based on Binary Tree. *TELKOMNIKA Indonesia Journal of Electrical Engineering*. 2014; 12(3): 2236-2244.
- [6] Shian-Hua Lin, Meng Chang Chen, Jan-Ming Ho. ACIRD: Intelligent Internet Document Organization and Retrieval. *IEEE Transactions on Knowledge and Data Engineering*. 2002; 14(3): 599-614.
- [7] Xiangfeng Luo, Jun Zhang, Feiyue Ye, Peng Wang, Chuanliang Cai. Power Series Representation Model of Text Knowledge Based on Human Concept Learning. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*. 2014; 44(1): 86-102.
- [8] Razvan Stefan Bot, Yi-fang Brook Wu, Xin Chen, Quanzhi Li. *A Hybrid Classifier Approach for Web Retrieved Documents Classification*. Proceedings of the International Conference on Information Technology: Coding and Computing. 2004; 1: 326-330.
- [9] Hao Chen, Shi Ying, Jin Liu, Wei Wang. *SE4SC: A Specific Search Engine for Software Components*. Proceedings of the Fourth International Conference on Computer and Information Technology. 2004; 4: 863-868.
- [10] Hsi-Cheng Chang, Chiun-Chieh Hsu. *Using Topic Keyword Clusters for Automatic Document Clustering*. Proceedings of the Third International Conference on Information Technology and Applications. 2005; 1: 419-424.

- [11] Li-Chun Sung, Chin-Hwa Kuo, Meng Chang Chen, Yeali Sun. *Progressive Analysis Scheme for Web Document Classification*. Proceedings of the 2005 IEEE/WIC/ACM International Conference on Web Intelligence. 2005: 606-609.
- [12] Shuchao Wan, Jun Wei, Jingyu Song, Heqing Guan. *Developing a Selection Model for Interactive Web Services*. IEEE International Conference on Web Services. Chicago. 2006: 231-238.
- [13] Chien Chin Chen, Yao-Tsung Chen, Meng Chang Chen. 2007. An Aging Theory for Event Life-Cycle Modeling. *IEEE Transactions on Systems, Man, and Cybernetics – Part A: Systems and Humans*. 2007; 37(2): 237-248.
- [14] Jun Wang, Li Zou, Hong Peng, Gexiang Zhang. An Extended Spiking Neural P System for Fuzzy Knowledge Representation. *International Journal of Innovative Computing, Information and Control, ICIC International*. 2011; 7(7(A)): 3709–3724.
- [15] Manish Joshi, Virendra Bhavsar, Harold Boley. *A Knowledge Representation Model for Matchmaking Systems in e-Marketplaces*. Proceedings of the 11th International Conference on Electronic Commerce. 2009: 362-365.
- [16] R. Mohamed, J. Watada. *Evidence Theory Based Knowledge Representation*. Proceedings of the 13th International Conference on Information Integration and Web-based Applications and Services. 2011: 74-81.
- [17] Jiangnan Qiu, Yunjie Du, Yanzhang Wang. *Extraction and Representation of Feature Events based on a Knowledge Model*. IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology. Sydney. 2008: 219-222.
- [18] Craig Schlenoff, Sebti Foufou, Stephen Balakirsky. *Performance Evaluation of Robotic Knowledge Representation (PERK)*. Proceedings of the Workshop on Performance Metrics for Intelligent Systems. Maryland. 2012: 1-8.
- [19] YAN Lei, WANG Xinying, DONG Junlei. *A Power Grid Knowledge Representation Using Agent-based Knowledge Representation in Pervasive Computing*. The 2nd IEEE International Conference on Information Management and Engineering (ICIME). Chengdu. 2010: 297-300.
- [20] Jun Xu, Yonghui Yao, Tao Pei, Changqing Yao. *Geographic Knowledge Map and Its Application in Seismic Knowledge Representation*. 17th International Conference on Geoinformatics. Fairfax. 2009: 1-5.
- [21] Zeti Darleena Eri, Rusli Abdullah, Marzanah A. Jabar, Masrah Azrifah, Azmi Murad. *Ontology-based Knowledge Model for Virtual Communities Profile*. Malaysian Conference in Software Engineering (MySEC). Johor Baru. 2011: 508-511.
- [22] Chenjian Hao. *Research on Knowledge Model for Ontology-Based Knowledge Base*. International Conference on Business Computing and Global Informatization. Shanghai. 2011: 397-399.
- [23] Li Zhiping and Sun Yu. *A Formal Model of Knowledge Base Systems in Intelligent Tutoring Systems*. International Conference on Computational Intelligence and Software Engineering. Wuhan. 2009: 1-4.
- [24] Jianhui Shi, Xiaoming Chi, Lihua Liu. *Design of a Dynamic Collaborative Learning Oriented Knowledge Model*. Information Technology and Artificial Intelligence Conference (ITAIC). Chongqing. 2011: 385-388.
- [25] Chuan Zhang, Xiangsheng Yang, Shimin Du. *A Distributed Knowledge Model for Knowledge Management System*. WiCOM 2008: International Conference on Wireless Communications, Networking and Mobile Computing. Dalian. 2008: 1-4.
- [26] Chin-Bin Wang, Yuh-Min Chen, Yuh-Zen Chen. *A Distributed Knowledge Model for Collaborative Engineering Knowledge Management in Allied Concurrent Engineering*. International Engineering Management Conference (IEMC). 2002: 701-702.
- [27] Chung-Yi Huang and Rung-Ching Chen. *Theses Cluster Based on Bilingual and Synonymous Keyword sets Using Mutual Information*. Proceedings of the Eight International Conference on Machine Learning and Cybernetics. Baoding. 2009: 2999-3004.
- [28] D.S. Kalana Mendis, Asoka S. Karunananda, U. Samararatunga, U. Ratnayake. *Tacit Knowledge Modeling in Intelligent Hybrid systems*. International Conference on Industrial and Information Systems, ICIIS. Penadeniya. 2007: 279-284.
- [29] Tony Veale and Yanfen Hao. *A Fluid Knowledge Representation for Understanding and Generating Creative Metaphors*. COLING '08: Proceedings of the 22nd International Conference on Computational Linguistics. 2008: 945-952.
- [30] Agnar Aamodt. *A Knowledge Representation System for Integration of General and Case-Specific Knowledge*. 6th International Conference on Tools with Artificial Intelligence. New Orleans. 1994: 836-839
- [31] Nhon V. Do. Model for Knowledge Bases of Computational Objects. *IJCSI International Journal of Computer Science Issues*. 2010; 7(3): 11-20.
- [32] Hu-Chen Liu, Qing-Lian Lin, Ling-Xiang Mao, Zhi-Ying Zhang. Dynamic Adaptive Fuzzy Petri Nets for Knowledge Representation and Reasoning. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*. 2013; 43(6): 1399-1410.



- 
- [33] Hu-Chen Liu, Long Liu, Qing-Lian Lin, Nan Liu. Knowledge Acquisition and Representation Using Fuzzy Evidential Reasoning and Dynamic Adaptive Fuzzy Petri Nets. *IEEE Transactions on Cybernetics*. 2013; 43(3): 1059-1072.
  - [34] Robert Harrison, Christine W. Chan. *A Tool for Dynamic Knowledge Modeling*. 6th IEEE International Conference on Cognitive Informatics (ICCI'07). Lake Tahoe. 2007: 513-521.
  - [35] Nhon V. Do, Hien D. Nguyen. *A Knowledge Model about Relations and Application*. ISSDM 2012 : 6th International Conference on New Trends in Information Science, Service Science and Data Mining. Taipei. 2012: 707-710.
  - [36] Guohai Zhang, Yusheng Li. Multiple Disciplines Product Design Knowledge Representation Strategy Based on Ontology and Semantic Network. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2013; 11(10): 6074-6079.
  - [37] Li Yue-xin, Hong Zong-xiang. Research of Semantic Network Knowledge Representation and Query Algorithm based on Relational Model. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2013; 11(11): 6591-6599.