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Building a fuzzy knowledge management system for personalized e-learning

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Abstract

Personalization of learning is one of the most important ways of improving the effectiveness of education. At the same time, it is also a complex process that requires consideration of numerous factors such as learners' profiles, learning materials and learning strategies. The Fuzzy Knowledge Management System (FKMS) for personalized learning presented in this paper considers all the above-mentioned factors as a whole, but not separately, in contrast to many studies on the research problem. The main objective of the system is to offer the most appropriate learning materials to the learners by considering their knowledge level and other learning characteristics. The knowledge base of the system contains course and concepts ontologies, learners' profiles and learning objects knowledge. For expressing and processing of the knowledge, fuzzy logic methods are applied. Preliminary experimental results reveal the operability of the system.

Keywords: Personalized e-learning, learners profiles, course ontology, learning object;

1. Introduction

Personalization of learning (PL) is one of the most important ways of improving the effectiveness of education. However, it is also a complex process that requires consideration of numerous factors such as learners' profiles, learning materials and learning strategies. To improve personalization aspects of the learning systems, some researchers propose that intelligence properties can be integrated into these systems. For this purpose, ontology-based approaches are usually recommended. Such a system, described in Jovanovic et al. (2009), provides a dynamic assembly and personalization of learning content in which an ontology-based approach is used. The researchers rely on learner modelling and instructional design in order to handle personalization issues. Tu et al. (2002) suggest an ontological approach to design a student model for a tutorial agent system. This model emphasizes the classification and detection of error types. The system, presented in Pedrazzoli & Dall'acqua (2009), allows a personalized learning approach based on the learning curricula of the students. Shih & Tseng (2009) suggest that a personalized e-learning system using the Item Response Theory can be employed. To recommend appropriate course materials to learners based on their individual requirements, the researchers use the item characteristic function with difficult parameters. Chen & Duh (2008) present the fuzzy item response theory, which could be capable of recommending courseware with suitable difficulty levels for learners according to learners' fuzzy feedback responses. In the study of Vargas-Vera & Lytras (2008), the concept of personalization is considered in the context of semantic web and ontology research. The main emphasis is given to the management of personal

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profiles and identities. Aroyo et al. (2002) discuss the problems, which are related to the integration of learning standards, semantic web, and adaptive technologies in order to meet the requirements of learners. Dağ & Erkan (2010) aspire to form a personalized learning environment in their proposed framework. In this framework, the researchers operate three types of model. These models are the domain model, the user model, and the adaptation model. Components of the system are realized by an ontology based knowledge modelling approach. A web-based Intelligent Tutoring System, which allows students to generate suitable courseware and provides adaptive feedback, is presented in the study of Kosba et al. (2003). In their study, Muñoz & Oliveira (2004) describe the main steps taken in developing an Adaptive Web Training Environment including an application profile of the LOM standard, Domain and Student Knowledge Models and Web Ontology.

Analysis of studies devoted to problems of personalization presents the following preferences. Many personalized learning systems, tutoring systems have been developed based on ontology, and semantic web features. For processing and expressing ambiguous information, which is related to learners' profiles, and learning objects, the Fuzzy Logic Theory is widely employed. However, although the researchers pay attention to the aspects of personalization in a great majority of the studies, they do not consider this problem as a whole. In our opinion, this is the main cause of the inefficiency of learning systems.

In this paper, the Fuzzy Knowledge Management System (FKMS) for personalized learning is presented, in which the main factors affecting PL, are considered not separately, but in an integrated manner. We propound an approach, which reckons with the mutual influences of all factors affecting the efficiency of the personalization of the learning system. The main objective of the system is to offer the most appropriate learning materials to the learners considering their knowledge level and other learning characteristics. The knowledge base of the system contains course and concept ontologies, learners' profiles and learning objects knowledge. The learner feedback information is applied to promote learning effectiveness. Preliminary analyses of the system assert that the proposed approach is effective.

2. Architecture of the Fuzzy Knowledge Management System

3.1. The Objectives of the System

The objectives of the proposed Fuzzy Knowledge Management System are: to assist learners in choosing the appropriate course materials; to give recommendations for the instructors about the course content; to review and re-evaluate the learning object metadata values and learner's profile knowledge; to help instructors to create new learning materials and update existing ones based on feedback information about the effectiveness of learning materials.

The system consists of seven components: an ontology management module, user interface, recommendation module, information retrieval module, learners' profiles module, and learning object metadata (LOM) module, and the coordinator.
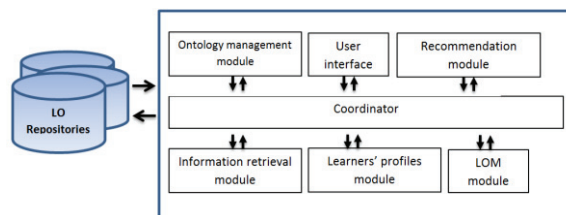

Figure 1. The architecture of the Fuzzy Knowledge Management System for Personalized e-Learning

3.1. Learners' Profile Module

The module includes two components: Learners' Profile Database and Computation Block. The Learners' Profile Database contains information about learners' identities (name, university), educational knowledge (course, learning style, and knowledge level), statistical and computational knowledge (numbers of login for each learner, level of understanding of learning materials, exams, and test results).

The degree of the learner's knowledge level (LKL) can be determined in the following ways: 1. Through the direct introduction of this information by the user; 2. By using the exam marks and other quantitative indicators of educational knowledge if the user is enrolled in the system; 3. Through the re-evaluation of the previous LKL by considering the issues of learners' understanding of the learning material.

The Computation Block determines the learners' knowledge level by using item response theory (Baker, 2011).

3.2. The LOM module

The main component of the module is a metadata database, which was designed according to the specifications of LOM (IEEE LTSC, 2002). In addition to the standard metadata descriptors, the database contains statistical data, which includes information particularly about the understanding of the learning objects used by learners. This data is utilised to determine the difficulty levels of the learning objects, to determine the learner's proficiency, and can be used by the recommendations module for the definition of suitable learning materials. Some aspects regarding the use of fuzzy metadata in Learning Management Systems are presented in the studies of Salahli & Özdemir (2011), and Salahli et al. (2010).

3.2. Information Retrieval Module

To retrieve necessary learning materials from a repository, the query expansion method is employed. The idea of query expansion is to insert new elements in the set of query terms that are semantically close to the initial elements of the set. The use of the method improves the precision and recall of the retrieval. New query terms are determined by using course and concept ontologies. The ontologies express generalization, specialization, and semantic association relations between the course topics for course ontology and between the concepts for concept ontology. The use of ontology knowledge also allows instructional and learning strategies to be considered and recommendations regarding the selection of the most appropriate learning objects to be made.

3.3. Ontology

In the FKMS, two types of ontology are applied. One of them is course ontology and the other one is concept ontology. Course ontology describes the semantic relationships among the course topics. The most appropriate reference books are used in the determination of the course topics. The following three types of relationships between the topics are used. The first one is *IsPrerequisiteFor* that describes the learning order of the topics; the second one is *IsSuperTopicOf* that states super or sub relations between the topics; and the last one is *IsSameOf* which expresses the similarity of the topics in terms of contents.

The list of the concepts is created for a particular course on the basis of the index terms from the reference textbook. The following types of relationship between the concepts are used. The first one is *IsSuperTopicOf* that presents super or sub relations between the concepts, the second is *IsSinonymousOf* that defines the relation between synonymous concepts and the final one is *IsSemanticallyRelatedTo* that defines the semantic relationships between the concepts.

3.4. Recommendation Module

The objective of the module is to assist the learner in order to answer questions such as "*what should I read to learn the topic*", "*what should I do if the proposed materials are difficult to understand*", or "*materials offered to me are very simple*". The Module includes various learning scenarios and recommendations for learners. For instance, the following scenario can be performed as the learner-system interaction if the learner does not understand the learning material on "second normal form"

Learner: "*I did not understand this material*".

System: *What is the reason for not understanding this material? Choose one of the following answers:*

    a)   *The material is very theoretical; it could have been more clear with practical examples;*

    b)   *I could not understand the following concepts (the concepts are entered by the learner);*

    c)   *I could not understand a particular part of the material (the appropriate part of the learning material is marked);*

    d)   *I do not understand anything.*

Imagine that the learner chooses the option *d*. In this case, the module determines that the node "*functional dependency*" is the sub node of the "*second normal form*" through reviewing the structure of the course ontology. Based on this illustration, the learning materials about the topic of "*functional dependency*" are offered to the learner. A screenshot of the page "Recommendation Module" is given in Figure 2. Data and control flow between the modules are realized by the coordinator.
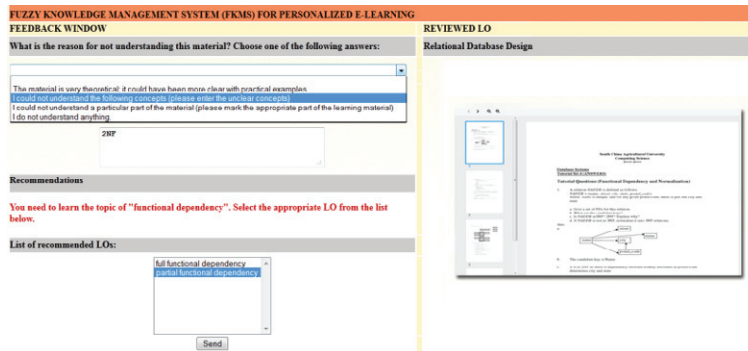
Figure 2. A screenshot of the page "Recommendation Module"

3. Fuzzy properties of the System

In the FKMS, fuzzy logic is used for three purposes:

a) For expressing some LOM descriptors, some metadata descriptors are expressed by linguistic values according to the LOM standards. In particular, five linguistic values are recommended to evaluate the difficulty level of learning the objects. These values are *very easy, easy, medium, difficult, and very difficult.* The value spaces of the category, the interactivity Level*,* and the Semantic Density are defined by means of linguistic values as well. Since these values principally reflect subjective evaluation of instructors (the creators of objects), it is advisable to consider them as fuzzy parameters. The use of fuzzy logic, in some degree, allows the avoidance of negative consequences associated with subjective interpretations. For this reason, fuzzy interpretation of the metadata is preferred in the FKMS. For instance, if a learner wants to have learning materials with "medium" difficulty, in addition to those requested, the system will also offer him/her materials with "easy" and "difficult" complexity.

b) For query expanding**,** searching for and retrieving the required materials from the repository is one of the main tasks of the metadata editor. In the most conventional searching tools, a Boolean Model is employed for this purpose. This model has some shortcomings. For instance, search words that are entered by the user sometimes do not match the keywords, which determine the learning object. There may be many materials that convey desirable semantic information without containing these keywords, and these materials are not retrieved. The query expanding method is one possible approach to removing this deficiency.

c) For specification of the degree of semantic closeness of concepts**,** in some cases, it is more appropriate to take into account the semantic closeness among the concepts rather than the hierarchical relations among them. Based on this consideration, the relationship type "*IsSemanticallyRelatedTo*" is included to express the semantic relationships among the concepts in the ontology. The degree of relationships among the concepts is evaluated with fuzzy values.

4. Development Issues and Experimental Results

Since the system consists of different functional blocks, a modular approach is applied to the development and the testing of the system. Preliminary performance evaluation of the information retrieval module, based on the comparative results obtained from the implementation of crisp (original) and fuzzy (extended) queries are given. For this purpose, a data set containing more than 200 learning materials concerned with six topics from the "database management system" is created. Fuzzy weighted keywords are defined for each material. Then, the concept ontology, expressing the relationships between these keywords, is formed. A single query is taken for each topic in order to evaluate the efficiency of the search process. The keywords for original (crisp) queries and for appropriate expanded queries are shown in Table 1. The effectiveness of the method used is evaluated by the recall, precision, and F-measure parameters. The values of these parameters obtained following the implementation of crisp and appropriate fuzzy queries are listed in Table 2.

Table 1. The original and expanded queries

Query	Original Query	Expanded Query
Q1	ER model	ER model, database design, ER diagram, conceptual model, EER
Q2	2NF	2NF, normal forms, normalization, logical design
Q3	Distributed Database	Distributed database, fragmentation, local database, resource allocation
Q4	Transaction	Transaction, concurrency protocol, deadlock, parallel query processing
Q5	Query Processing	Query processing, query analysis, query optimization, query execution
Q6	Relational Operations	Relational operations, relational algebra, query language

Table 2. Comparative values of the parameters recall, precision, and F-measures for the test queries

Query	Recall		Precision		F-measure	
	Crisp	Fuzzy	Crisp	Fuzzy	Crisp	Fuzzy
Q1	0,66	0,89	0,62	0,85	0,60	0,87
Q2	0,44	0,72	0,80	0,80	0,56	0,75
Q3	0,50	0,77	0,81	1	0,62	0,87
Q4	0,53	0,88	0,81	1	0,63	0,93
Q5	0,30	1	0,71	0,77	0,42	0,87
Q6	0,11	1	1	0,90	0,19	0,95
Average	0,42	0,89	0,79	0,88	0,47	0,85

5.   Conclusions

In this study, the Fuzzy Knowledge Management System for personalized e-learning is presented. In this system, all factors affecting the personalization process are considered as a whole. The knowledge base of the system contains course and concepts ontologies, learners' profiles, and learning objects' knowledge. Learner feedback information is utilised in order to promote learning effectiveness. Fuzzy logic methods are applied to express and process linguistic metadata values, to expand original search queries, and to specify the closeness of concepts. Preliminary experimental results demonstrate the operability of the system. However, a large number of further data, in particular, learners' feedback information, is required to assess the functionality of the system completely.

Acknowledgements

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