

# The Application of Fuzzy Ontology in Design Management

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**Abstract** - *Engineering design is a knowledge-intensive process, how to organize, store and retrieve such knowledge constitutes the foundation of engineering design management. In this paper, a fuzzy ontology and its application to design management are presented. The fuzzy ontology with fuzzy concepts is an extension of the domain ontology with crisp concepts. It is more suitable to describe the domain knowledge than domain ontology for solving the uncertainty reasoning and retrieval problems. Every fuzzy concept has a set of membership degrees associated with various events of the domain ontology. First, an ontology-based presentation and retrieval framework is put forward in the paper. Then, the fuzzy ontology-based presentation and retrieval mechanism are described.*

**Keywords:** Fuzzy Ontology, Engineering Design, Relevance Feedback

## 1 Introduction

Ontology has been applied in various domains[1-3], such as knowledge management [4,5,6], semantic integration[7]. Ontology is regarded as “a kind of conceptual description” by Gruber [8] in computer science. Embley et al. [9] present a method of extracting information from unstructured documents based on an application ontology. Alani et al. [10] propose a system that automatically extracts knowledge about artists from the web based on an ontology, which can generate biographies that tailor to a user’s interests and requirements. OntoSeek[11] is a system designed for content-based information retrieval, which combines understanding of a domain [12]. In recent years, many

presentation and retrieval methods has been also published in different application[13-16] , and fuzzy technique has been introduced into ontology presentation and processing[17,18,19]. Engineering design, a knowledge-intensive process, includes conceptual design, detailed design, engineering analysis, assembly design, process design and performance evaluation. Each step creates various areas of knowledge, experience and large amounts of engineering drawings. Effectively organizing, storing and retrieving such knowledge, experience and drawing is a major factor which can increase product development capability and quality, and reduce the development cycle time and cost, which is critical to that firm’s success and constitutes the foundation of engineering design management. Engineering knowledge, experience are often saved as text documentation and drawings are often saved in the way of binary (image) or vector figure. A typical way to retrieve engineering information online is to create a keyword-based query interface to a database. But the keyword-based approach would not perfectly solve the following problems: (1)How to guide user in focusing the interest within the database contents. Generally, designer often only has outline about the product information, and does not necessarily know what question to ask.(2)How to help user in expressing their queries. The user can not necessarily figure out what keywords to use in formulating the search corresponding to him/ her information need.(3)How to find relevant information.

In the paper, a framework of system based on ontology is described, then the presentation and retrieval methods based on fuzzy ontology are depicted. The

proposed framework can handle the usual similarity: graphical sketch-based queries and linguistic queries. We introduce fuzzy sets into model vagueness which is usually present in queries and allows us to retrieve information that might otherwise be missed.

## 2 Ontology-based presentation and retrieval Framework

As a representation of semantics, ontology provides a highly expressive ground for describing units of meaning and a rich variety of interrelations among them. Therefore, there are many literature in the recent years that studies the use of ontologies to improve the effectiveness of information retrieval and personalized search. In this paper, engineering knowledge and drawings are presented based on fuzzy ontology technique. Engineering knowledge ontologies are divided into many parts according to engineering design process, such as conceptual design ontology, detailed design ontology, engineering analysis ontology, etc. And engineering drawing is described as drawing region ontology. The paper shows a presentation and

comprehensive retrieval framework (see Figure 1).The given framework incorporates a module to control the degree of personalization that is applied in the search result ranking, automatically adjusting it depending on the uncertainty contained in the search before personalization.

As shown in Fig 1, user query includes two steps: 1) a formal ontology-based query, a global query, is issued by some form of query interface which formalizes a user information need. The query is processed against global ontology using any desired inferencing or query execution tools, outputting a set of ontology concept tuples that satisfy the query. 2) ontology mapping [20,21,22]:Because of local ontology is defined in local semantics, and the global ontology is defined by share semantics, there exists a ontology mapping between local ontology and global ontology. According to the mapping between global ontology and local ontology, user global query will be divided into many sub-queries which are performed in local domain. The results of every sub-query finally should be marshaled and converted to a uniform format and return to query interface.

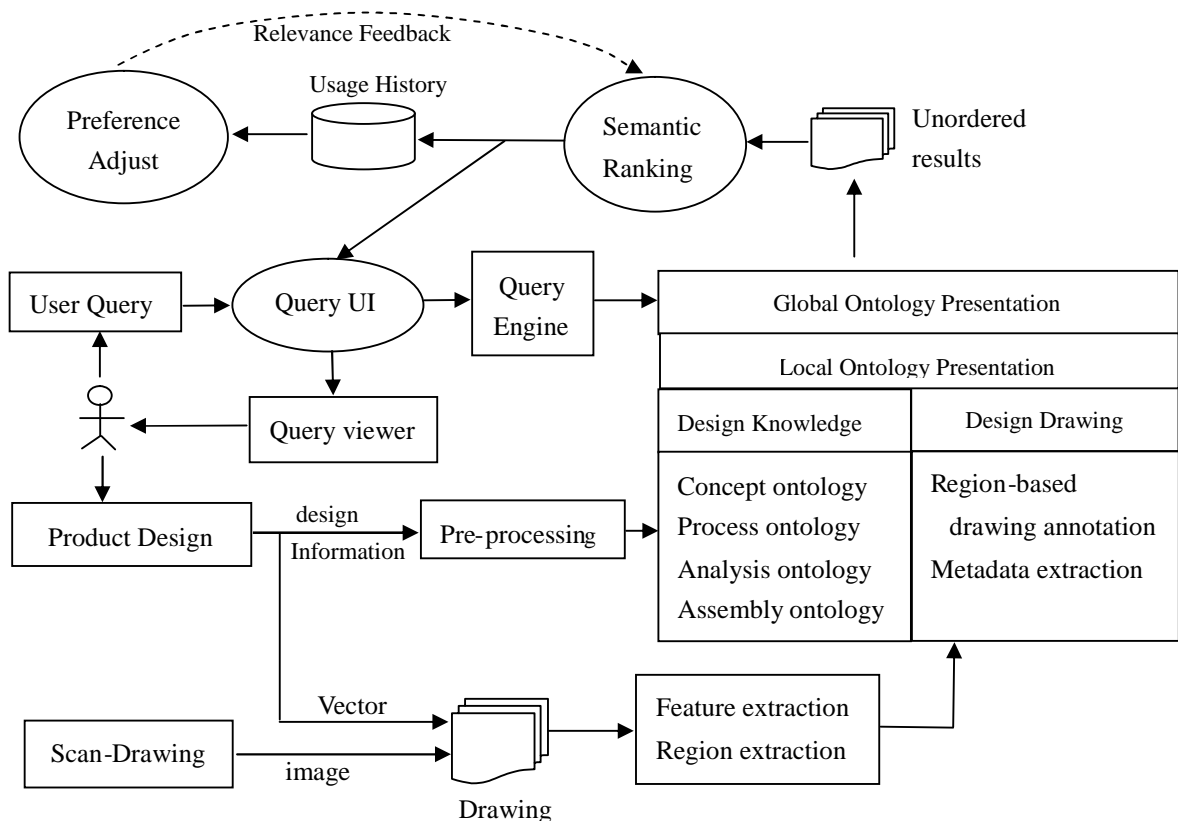


Fig. 1. Ontology-based presentation and retrieval Framework

### 3 Fuzzy ontology-based presentation

There are many different descriptions of the domain ontology for various applications. For example, a domain ontology defines a set of representational terms that we call concepts. Inter-relationships among these concepts describe a target world. Domain ontology can be defined as the following tuples:

$O = (C, A, H, R, E)$ , and

$C$ : concept set,  $C = \{C_1, C_2, \dots, C_i, \dots, C_n\}$ ,  $n$  is the number of concepts;

$A$ : attribute set of a concept, given a concept  $c \in C$ , then its attribute set is labeled as:

$A_c = \{a_c(i) | i=1, \dots, |A_c|\}$ ,  $|A_c|$  expresses the number of attributes;

$H$ : concept hierarchy set,  $H \subseteq C \times C$ ,

$(c_i, c_j) \in H$  expresses  $c_i$  is a sub-concept of  $c_j$ ;

$R$ : relation set which is not in concept hierarchy set,  $R = \{R_k, k = 1, 2, \dots, m\}$ ;  $R_k = r(c_i, c_j) \in R$  shows that there exists a relation  $r$  between concept  $c_i$  and  $c_j$ ;

$E$ : events set of a concept,  $E_k$  is an event of concept  $C_j$ ,  $E = \{E_{jk} | k=1, \dots, |E_{jk}|, j=1, 2, \dots, n\}$ .

In this paper, we extend the domain ontology to be the fuzzy ontology by embedding a set of membership degrees in each concept of the domain ontology and adding fuzzy relationships among the fuzzy concepts. The concept with the membership degrees is called fuzzy concept. Therefore, attribute values such as small and somewhat, as well as spatial relations such as left of and below, are handled much better by fuzzy techniques. Another advantage of using fuzzy sets is that the membership functions that represent concepts such as small and left of can be modified based on the user's (relevance) feedback for improved retrieval. Finally, the plethora of aggregation connectives in fuzzy set theory permit us to adjust weight and combine the different attributes in a way that is tailored to the application domain and the user's taste. Using ontology technology we use a fuzzy set to represent each drawing and engineering knowledge in the database, in which each object region in the drawing is represented by a node with attributes (e.g. blueness, size), and the relations between regions are represented by edges with attributes (e.g. spatial relation, adjacency). So the fuzzy ontology can be defined by extending set  $C$ ,  $R$  and  $E$ :

$\underline{O} = (\underline{C}, A, H, R, E)$

$\underline{C}_i = \{C_{i1}|P_{i1}, C_{i2}|P_{i2}, C_{i3}|P_{i3}, \dots, C_{ip}|P_{ip}\}$

where  $P_{ip}$  represents the membership degree of a

concept item  $\underline{C}_i$ ;  $p$  is the membership number of  $\underline{C}_i$ ;

$\underline{R}_k = \{R_{k1}|P_{k1}, C_{k2}|P_{k2}, C_{k3}|P_{k3}, \dots, C_{kq}|P_{kq}\}$

$\underline{E}_{jk} = \{E_{j1}|P_{j1}, E_{j2}|P_{j2}, \dots, E_{jn}|P_{jn}, n=1, \dots, |E_{jk}|\}$

### 4 Fuzzy retrieval mechanism

The way of keyword-based query has been used in many applications. Here the user may select filtering values or apply keywords to the different database fields, such as the "creator", "time", "material", or to the content descriptions including classifications and free text documentation. More complex queries can be formed by using Boolean logic. Keyword-based search methods exist several general limitations: a keyword in a document does not necessarily mean that the document is relevant, and relevant documents may not contain the explicit word, and semantic relations are not exploited. Keyword-based search is useful especially to a user who knows what keywords are used to index the drawings and document, and therefore can easily formulate queries.

In the given framework, we can adopt different way to retrieve information. The retrieval of engineering knowledge can be finished by linguistic queries and keywords, and retrieval of product drawing can be finished by sketch-based query. In the case of a sketch-based query, user can draw objects/ regions in the desired spatial positions, and ascribe attributes (such as size, color, and shape properties) to them. In the case of a linguistic query, user can describe the type of product information to be retrieved using words from a dictionary of object attributes and spatial relations.

As ontologies are presented in fuzzy method, user retrieval is finished using the membership degrees for each fuzzy concept of the fuzzy ontology. Every fuzzy concept has a set of membership degrees such as concept, attribute and relevant concept degrees, etc. The similarity degrees of a concept can be calculated:

$$\delta(C, \underline{C}_i) = \max\{\delta(C, C_{ik}), k = 1, 2, \dots, n\}$$

where  $C$  is a specific fuzzy concept formed from the user-interface, which is a user's query. The fuzzy similarity degree of fuzzy set  $\underline{A}$  and  $\underline{B}$  can be computed in many formulae, this paper uses the following equal:

$$\delta(\underline{A}, \underline{B}) = \frac{\sum_{i=1}^n (\underline{A}(x_i) \wedge \underline{B}(x_i))}{\sum_{i=1}^n (\underline{A}(x_i) \vee \underline{B}(x_i))}$$

To improve retrieval efficiency, the fuzzy similarity degree can be computed in different hierarchy:

1) For an ontology, such as concept design ontology, process ontology, we can obtain a clustering center of its concept:

$Q_m = \{ O_1|P_1, O_2|P_2, \dots, O_k|P_k \}$ ,  $m = 1, 2, \dots, kk$ , and  $kk$  is more less than the number of concept, a clustering center corresponding to a concept set;

2) For concept  $C$  formed from a user query, compute the fuzzy similarity degree of  $C$  and  $Q_i$ :

$$\delta(Q_i, C) = \max\{\delta(O_k, C), k = 1, 2, \dots, kk\}$$

3) when  $\delta(Q_i, C)$  is larger than a given threshold, we can think that  $C$  is belong to the concept class  $Q_i$ , then we compute the fuzzy similarity degree of  $C$  and all concept in this class to find similar concept set.

We can get a rough concept set according to a given threshold, then the user marks the results in three states: relevant, not relevant and non-processed. Finally each weight of concept will be adjusted in the following formula:

$$P_i = \begin{cases} P_i \times 1.05 & // C_{ij} \text{ is relevant with } C \\ P_i \times 0.95 & // C_{ij} \text{ is not relevant with } C \\ P_i & // \text{others} \end{cases}$$

For a user query, we can search other similar or relevant concepts from fuzzy set using  $R$  in the same way.

## 5 Conclusion

In this paper, a fuzzy ontology and its application to design process management are presented. The fuzzy ontology with fuzzy concepts is an extension of the domain ontology with crisp concepts that is more suitable to describe the domain knowledge for solving the uncertainty reasoning and retrieval problems. Based on the fuzzy ontology presentation of design knowledge and design drawing, the paper also describes a fuzzy retrieval mechanism which uses similarity degree to retrieve information according to user query. Design knowledge and product drawing can be effectively presented by fuzzy ontology. Otherwise, because of there are many different formats of design drawing(only for vector drawing), and the feature extraction of it is more complicated, a uniform presentation based on fuzzy ontology of it is very difficult. We plan to convert

design drawing into a medi-file such STEP, IGES, or XML file defined by us. Also, we are studying fuzzy clustering to improve retrieval efficiency and researching a finer method of adjusting weight automatic for more incarnating user's interests.

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