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Paper:

Implementation of Fuzzy Legal Expert System FLES

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A fuzzy legal expert system FLES based on a fuzzy Housdorff similarity measure is implemented. The reasoning approach in this system includes the fuzzy case-based reasoning that is composed of knowledge representation, retrieval, and inference. The proposed approaches are illustrated by the experiments, where the target law is CISG (United Nation Convention on Contract for the International Sale of Goods).

1. Background

On the basis of the representation of vague legal concepts and the structural similarity measure, a fuzzy legal expert system (FLES) is implemented.

The study of legal vague concepts is a two-stage process including the understanding of query case and the related statutory rules, as well as the basic skill of legal argument. In order to satisfy these requirements, the FLES is composed of fuzzy legal case-based reasoning (FLCBR) and fuzzy legal argument (FLA) modules. The former provides a primary study of vague concepts. By means of the vague judgment, the user can determine which precedent is similar to the query case. The latter is the development of the former, it can make an argument by considering the two viewpoints of plaintiff and defendant. On the basis of this stage, users can judge the similarity and distinction between the cases from the viewpoints of plaintiff and defendant, respectively.

After the architecture of FLES is presented in 2, FLCBR is introduced in 3. The FLCBR is composed of four parts: knowledge representation, user interface, case retrieval and case inference. The precedent is represented by hierarchical fuzzy frame. The Hausdorff distance-based similarity measure between fuzzy sets is used in the retrieval and the inference.

2. Overview of FLES

2.1. Architecture of FLES

Statutory rules are different from the logical ones because statutory rules consist of vague legal concepts. Study of statutory rules is difficult for the beginner of law students. An intelligent fuzzy legal expert system (FLES) is constructed to support the law students in studying the vague
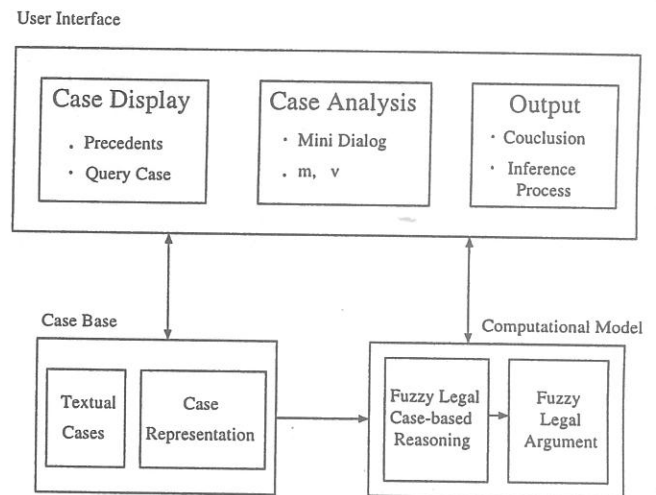

Fig. 1. Architecture of FLES

concepts in the CISG. It explains what the meaning of vague legal concept in a query case is.

Study of legal vague concept is considered to be a two-stage process including the understanding of query case and the related statutory rules, as well as the basic skill of legal argument with cases. Similar precedents are very useful for the understanding of the vague concept. That is why case-based reasoning is used in legal reasoning. Argument is an important characteristic of human intelligence. Especially in law, which is an adversarial domain, for the development of the conventional case-based reasoning, an argument made from the viewpoints of plaintiff and defendant is very useful for the study of vague legal concepts. In the first stage, the fuzzy legal case-based reasoning(FLCBR) is used. After this stage, users can know the vague concepts and the related case and statutory rules to some extent.

The architecture of FLES is shown in **Figure 1**.

- Case Base: contains the precedents selected from CLOUT. They are represented by the textual case and case representation including the hierarchical fuzzy frame and the fuzzy factor hierarchy.
- User Interface: consists of integrated tools for case display, case analysis and output of explanation.
- Computational Model: includes the computational models in the two modules.

In the case base of FLES, the case representation is a hybrid knowledge representation that can be appropriate for the two kinds of legal reasoning.

The user interface of FLES offers a set of menu-driven input and output windows, displaying the case representation of the precedent in a case base, the case analysis

Table 1. Characteristics of the Two Reasonings in FLCBR and FLA

	FLCBR	FLA
Knowledge Representation	Fuzzy Frame	Fuzzy Factor Hierarchy
Similarity	Distance-Based	Structure
Inference	Case Rules	Argument Moves
Function	Study of Rules, Cases	Skill of Argument
Viewpoints	Goal-Driven	Plaintiff, Defendant
Structure	Simple	Complex

Issue: I
Event of precedent : a
Event of query case : a'
Precedent : A(a) ---> Conclusion B(a)
a' is similar to a : $A (a') \fallingdotseq A (a)$

The conclusion on I : $B (a') \fallingdotseq B(a)$

Fig. 2. Schema of CBR in Law

for query case, as well as the inference process.

- Case Display consists of precedents in case bases and query cases. The case base is composed of a textual summary, hierarchical fuzzy frame and fuzzy factor hierarchy for each precedent. The textual cases of this system consist of eight precedents. All precedents selected here are relevant for the formation of a contract. All of these originate from CLOUT.
- Case Analysis is conducted by a Mini Dialog. A query case is given by making the judgment in terms of the membership and vagueness concepts that are represented by the linguistic expression introduced in the last section.
- Output consists of conclusion of the inference process and the final conclusion. It is of benefit to the students studying the legal reasoning by FLES.

The CISG is an international law, in order to apply our system to international exchange, the user interface of this system is developed in several languages.

The heart of the architecture of FLES is the legal reasoning approach in the computational model. FLES uses FLCBR in the model to retrieve similar precedents from the case base, and judge the adaptation of the retrieved case to the query case.

2.2. Characteristics of the Two Reasonings

Two kinds of the legal reasoning approaches in FLCBR are employed in the proposed system FLES. The characteristics of these two reasonings are summarized in **Table 1.**

FLCBR is a typical case-based reasoning, appropriate for retrieving a similar case form a large-scale case base, and knowing if the query case has a conclusion of the retrieved precedent. It is suitable for the case base from which the features and case rules can be obtained. It is useful for users to study the knowledge of the query case, the related precedents and the vague concepts.

Legal vague concepts have a clear kernel, and an uncertain border region, so there is room for argument. The fuzzy legal CBR is further extended by considering the legal argument. The training of law education involves learning to make arguments for and against the application of statutory rules, and for and against the previous case with respect to the query case. Argument has long been the main topic of AI and Law researches. Two types of arguments usually exist. One is rule-based, while the other is case-based. Our study is focused on the case-based argument.

FLA is a legal argument module based on the proposed

structural similarity measure that is combination of similarity measure theory and fuzzy theory. The viewpoints of plaintiff and defendant are both considered, thus the conclusion is a set of the similarity and dissimilarity measures. It is applicable to let students know the legal knowledge from the sides of the plaintiff and defendant, and learn the skill of legal argument.

Generally, the fuzzy legal argument needs a fuzzy factor hierarchy that describes the issues in a adversarial way. Accordingly, a structural similarity is measured in both symbolic and numeric ways. Knowledge representation and the similarity measure are more complex in FLA than those of the FLCBR, usually are time-consuming.

3. Fuzzy Legal Case-based Reasoning

In this section, the fuzzy legal case-based reasoning module is introduced in detail.

After the overview of the FLCBR, a precedent in the CISG is represented in detail by a hierarchical fuzzy frame that is structured by an issue, features and case rules. The case retrieval and inference are based on the case representation and corresponding similarity. The fuzziness in a judgment is represented by a fuzzy set that is constructed by the membership concept and vagueness concept. Based on the case representation and the similarity measure, a two-stage case retrieval method is presented in this section. A two-stage inference is used to judge whether the retrieved case is the most promising and the most appropriate one. Finally, this module is experimented with using the cases that are related with the CISG.

3.1. Overview

The schema of CBR in law is shown in **Fig. 2.**

On an issue I, the event on a precedent is described by $A (a)$, it leads to the conclusion $B (a)$. An event a' of a query case is described as $A (a')$. If $A (a')$ is similar to $A (a)$ on I, the conclusion $B (a')$ of the event a' in query case is also similar to the conclusion of event a in case A, namely, it is the $B (a)$.

In dealing with the vague legal concepts, CBR also involves the fuzziness, including the description of $A (a)$ and $A (a')$, as well as the similarity measure that $A (a')$ is similar to $A (a)$.

For capturing the fuzziness of the legal inference made by CBR, fuzzy sets are employed in the presented FLCBR module that is composed of four parts, i.e., case base, retrieval, inference and interface modules (**Fig. 3**). Fuzzy the-
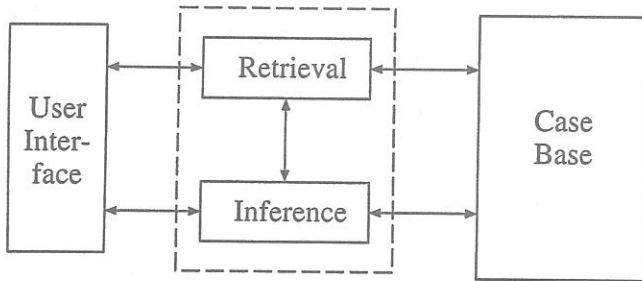
Fig. 3. The Structure of the Fuzzy Legal CBR Module

Fig. 4. The Case Rule for the Verification of Price of Entity

ory is applied for the case representation in the case base, retrieval and inference. In case representation, fuzziness is described by fuzzy sets. In retrieval and inference, similarity measures are made by considering fuzziness.

Each precedent is constructed by using the following three components: issues, features and case rules. For a query case, it is necessary to retrieve, from the case base, the precedents that are similar to it. The retrieval is made in terms of issues and features. Features are properties of a case that are not concerned with the details, but correspond to the abstract properties of a case. Usually features give a quick but coarse description of a case. The case rules of the retrieved precedents are used to infer the results that can be obtained from the retrieved cases, namely, whether the conclusion of a query case is the same as the retrieved precedent's or not.

The case base and user interface of FLCBR are parts of the case base and user interface of FLES, respectively.

3.2. Representation of Jet Engine Case

The *Jet Engine Case*, introduced in the last section, will be represented in detail in this section.

Issue

The *Jet Engine Case* is focused at the effectiveness of the offer. In order to judge it, a vague legal concept in the CISG 14, i.e. "A proposal is sufficiently definite" must be inferred. This vague legal concept is a point of argument and is consequently regarded as an issue of the case. According to the issue, the *Jet Engine Case* can be simplified as follows:

Event: proposal
Description of event:
  The goods are jet engine systems.
  The quantity of engine systems can be calculated by the
    quantity of planes that will be purchased.
Concerning the price:
  There is no description about the prices of Boeing jet
    engine systems.
  The price of Boeing jet engine is fixed.
  The jet engine system includes a support package, serv-
    ices and so on.

Features

On the basis of Article 14 of the CISG, the Hungarian Supreme Court declared that the proposal was not sufficiently definite, because the price of jet engine system was not fixed and jet engine system had no market prices[2].

According to the sentence, it is clear that the goods have been "indicated". It is also clear that the "quantity" has been "fixed". The price of entity, that consists of several parts, is not fixed and it needs expert's interpretation. We can extract the features from the *Jet Engine Case* as fol-
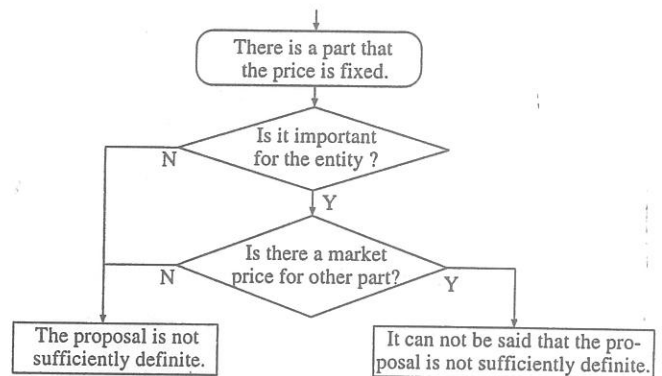
lows:
  Issue: The proposal is sufficiently definite
  Judgment: No
  Features: The goods are indicated
        The quantity is fixed
        The entity price is not fixed,
        The part price is fixed

The fuzziness in the judgment on the existence of the above features can be expressed through the m and v (cf. section 2.2).

Case Rules

The features are not sufficient to describe the case deeply. The verification of the entity price is further interpreted as follows: If the entity price does not exist, it is necessary to verify whether there is a part for which the price is fixed. If there is no part for which the price is fixed, we can know that "The proposal is not sufficiently definite." If there is a part for which the price is fixed, the importance of this part for the entity needs to be verified. If this part is not important, it is considered that "The proposal is not sufficiently definite." If this part is important for the entity then, for the other part, namely the part for which the price is not fixed, it needs to be determined whether there is a market price or not.

The process of the verification of the market price is as follows: If there is a market for this part, it is considered that there is a market price for this part. If there is no market for this part, it needs to be verified whether there is a market for a product that can substitute this part or not. If there is a market, it is considered that there is a market price for this part. If there is no market then, what needs to be verified is whether there is a price for a product that is similar to this one. If there is a price, it is considered that there is a market price for this part. If there is no price, it is considered that there isn't a market price for this part.

The process of interpretation of the price is shown in **Fig. 4** and **Fig. 5**. These are the case rules for the verification of the price of entity in Jet Engine Case.

The case rule, being a hierarchical structure, usually consists of more than one stage.

Fuzzy Frames of Jet Engine Case

The issue "The proposal is sufficiently definite", involved in the article 14 of the CISG, can be used to determine whether the proposal is sufficiently definite, which is relevant to goods, quantity and price. The issue, features and case rules of *Jet Engine Case* are described by fuzzy frames shown in **Fig. 6**.
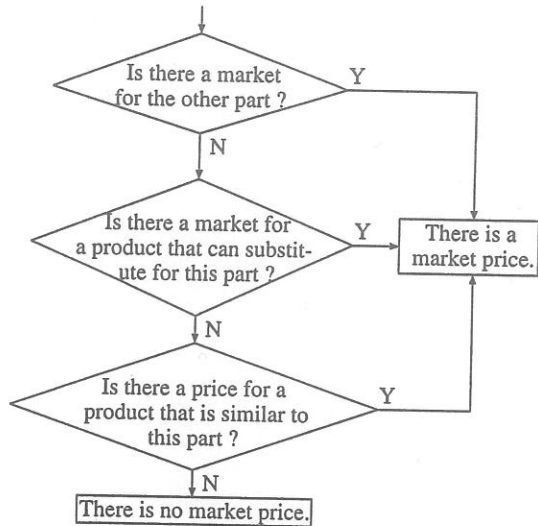
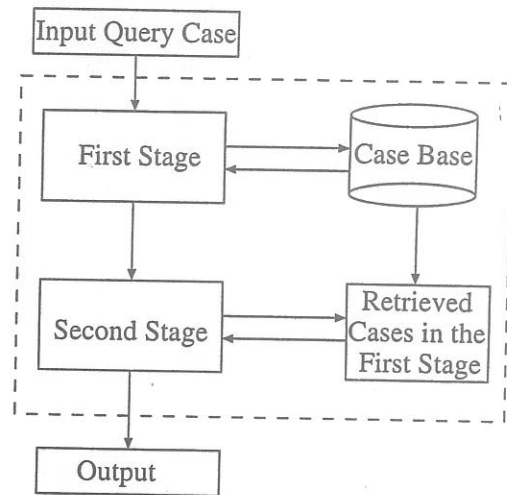Fig. 5. The Case Rule for the Verification of Market Price

Fig. 7. Two-stage Retrieval

Issue

The proposal is sufficiently definite	No

Features

	m	v
The goods are indicated	1.0	0.0
The quantity is fixed	1.0	0.0
The eneity price is fixed	0.0	0.0
A part price is fixed	1.0	0.0

Case Rules

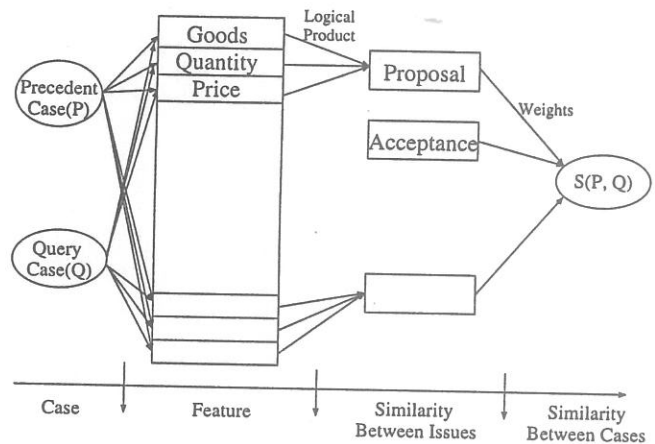|	m	v
It is an important part	1.0	0.0
The other part has the market price	0.25	0.0
It has the product that can be substitute	0.25	0.5
It has the product that is similar	0.25	1.0

Fig. 6. Fuzzy Frame Representation about Jet Engine Case

3.3. Retrieval

For retrieving the most similar precedent from a case base, a method of two-stage retrieval is proposed. In the first stage, called Issue Index, a set of precedents, in the case base, which seems to be relevant to the query case, is hunt. In the second stage, that is based on the similarity measure between features, the most promising case is further retrieved from the collection of the retrieved cases. The two stages are based on the hierarchical representation of the cases.

Issue Index

In FLBCR, a case is structured as concept-centered and each concept corresponds to an issue. An issue may include several other issues. Each issue is related to the corresponding features and case rules. So, the retrieval and inference are organized by issues. According to the issue, and the conclusion of the issue that the user is interested in, the related cases can be retrieved. The issues index can improve the utilization of the index in case retrieval, especially since it can smoothly narrow down cases to a single issue, to meet the users' needs from different viewpoints.

Fig. 8. Similarity Measure in the Retrieval

In the first stage, the cases can be indexed by the article number and the names of issues, as well as the conclusion of cases. This stage uses a simple crisp matching.

Similarity Measure between Features

In the second stage, the similarity between issues is measured by the similarity between the features of the cases, that are represented by fuzzy frames. The similarity is measured by means of similarity measure between fuzzy sets introduced in the last section.

Moreover, sometimes, not only a single issue is to be compared between two cases. The algorithm applied for more than one relevant issue should be considered. The result of comparison between two cases is different if users address different aims. So, the weight is introduced in the case retrieval, and the similarity between cases is considered to be the weighted summation of the similarity between issues (Fig. 8).

3.4. Inference Based on Case Rule

Inference based case rule can also be divided into two stages. In the first stage, according to the case rule, the inference is made by the correspondence of the facts of a query case and elements of the case rule, and is expressed by YES or NO. The judgment of YES or NO is based on the fuzzy membership function. In the second stage, the inference by means of the similarity between the query case
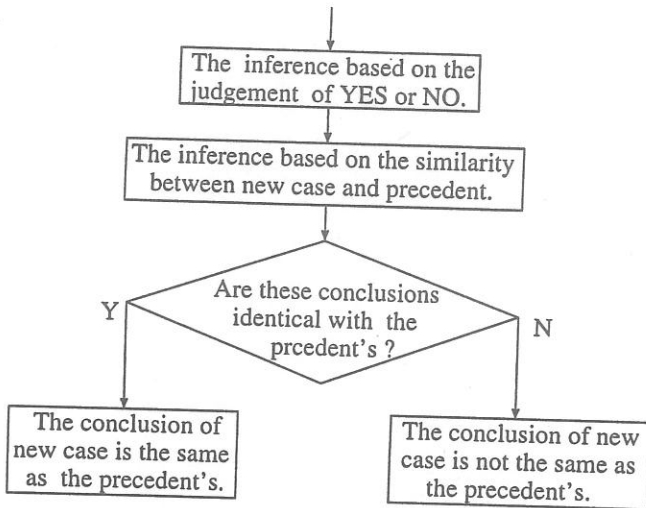
Fig. 9. The Process of Inference Based on Case Rule

Fig. 10. The Center of Gravity of Fuzzy Set

and the precedent is done.

Conclusions of these two stages are compared with the conclusion of the precedent. If they are identical with the conclusion of the precedent, the query case has the same conclusion as the precedent. If they are not identical, the query case can't arrive at the same conclusion as the precedent.

The process of inference is shown in **Figure 9**.

Inference Based on a Yes/No Judgment

The judgment on the correspondence of facts of the query case and elements of the rules is represented by fuzzy membership function. According to the case rules of **Figures 4** and **5**, a Yes/No judgment is necessary for the inference by case rules. Here, the judgment is determined by the center of gravity of a fuzzy membership function.

Let Q_i be a fuzzy set that describes the judgment of element of case rule for the query case shown in **Figure 10**.

Membership function of Q_i is μ_{Q_i}.

The center of gravity of Q_i can be calculated by

$$CG(Q_i) = \frac{\int_{c_1}^{c_2} x\,\mu_{Q_i}(x)\,dx}{\int_{c_1}^{c_2} \mu_{Q_i}(x)\,dx} \quad \ldots \ldots \ldots \ldots (1)$$

The center of gravity of Q_i belongs to [0, 1]. When the value of the center of gravity is near 1, it can be considered that the judgment is YES. When the value of the center of gravity is close to 0, it can be considered that the judgment is NO. The value 0.7 is selected as the threshold. When the value of the center of gravity is greater than 0.7, the judgment is YES. When the value of center of gravity is less than or equal to 0.7, the judgment is NO.

After all the correspondences of the elements of case rules and facts of query cases are judged, the conclusion whether the legal requirement occurs or not is inferred according to the case rule.

Inference Based on Similarity Measure

The case rule about an issue is represented by several frames. The similarity between the frames of the precedent and the query case can be measured by the method introduced in section 3.3.2.

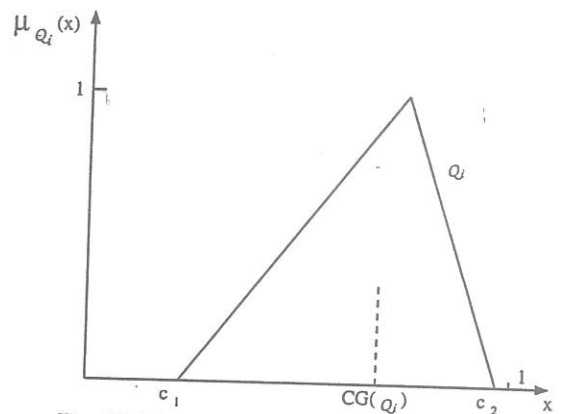If the degree of similarity is greater than the threshold

given in advance, the conclusion of frame FR_q of query case is the same as that of frame FR_p of the precedent. For example, in a precedent, if there is a conclusion that "The proposal is sufficiently definite", the conclusion of the query case is also "The proposal is sufficiently definite." If the degree of similarity is less than the given threshold, the conclusion of frame FR_q can't arrive at the same conclusion as that of FR_p. This does not mean that the query case has the conclusion opposite to the precedent's. It is necessary to infer the conclusion using the other precedents for this query case.

3.5. Experiment

The query case *Cultivator*[4], that is devised for the legal reasoning of the CISG, is cited for the experiment based on our fuzzy legal case-based reasoning.

The query case is as follows:

1) On April 1, company C in New York dispatched a letter containing an offer to the business branch of a Japanese company D in Hamburg, the content of which is that C sells a set of cultivator (the price of the tractor itself is $50,000 to D. The tractor should be equipped with a rake, which is product of company E. The farming machinery is delivered by a U.S. cargo ship).

2) The letter reached D on April 8.

3) On April 9, D telephoned C to tell "I accept your offer, but you should transport the machinery by a Japanese container"

There are several issues as to whether the contract is concluded. Whether the proposal from C is effective or not is one of them. On the condition that "The proposal is sufficiently definite," the proposal is effective.

According to the issue, this case can be simply described as follows:

Event: proposal

Description of event:

The goods are cultivator.

The quantity of cultivator is one.

Concerning the price:

The price of the tractor is fixed.

The price of a set of cultivator is not fixed.

The cultivator contains a rake.

There are eight precedents in the case base for the experiment:
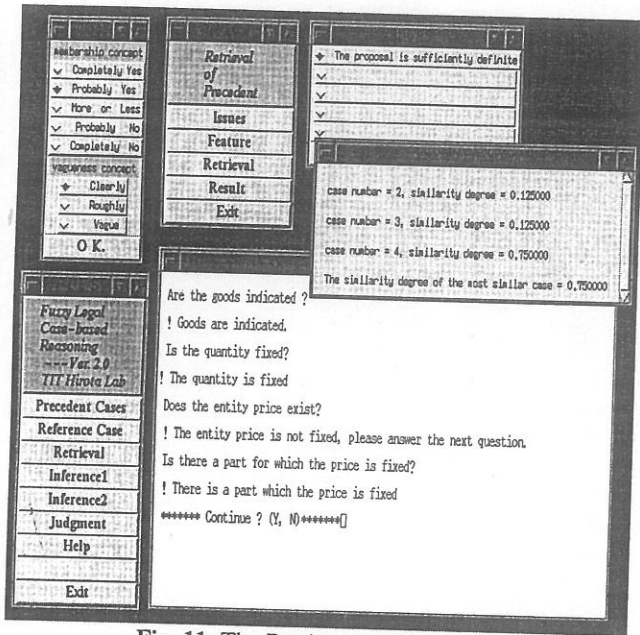
case1: Experiment tube affair
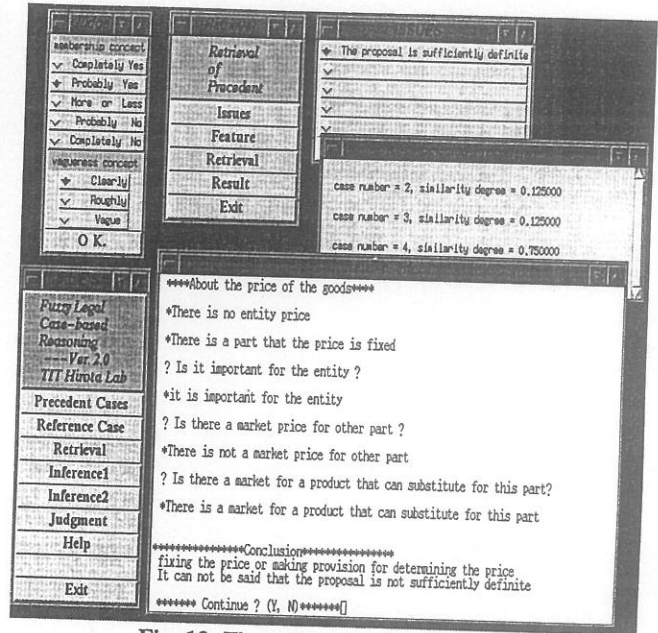
case2: Screw affair

Fig. 11. The Retrieval of Precedents

Fig. 12. The Inference by Case Rules

case3: Leather affair
case4: Jet engine affair
case5: Car affair
case6: Shoes affair
case7: Tyre affair
case8: Electronic parts affair

Articles of precedents can be read from precedents menu. All cases are also presented by a hierarchical frame structure that is composed of issues, features and case rules. The slot values of the frame are described with fuzzy membership value.

In the query case *Cultivator Case*, the controversy between the plaintiff and defendant i.e. whether a proposal is sufficiently definite, can be considered as an issue. The retrieval procedure is divided into two stages. In the first stage, pursuant to issue index, the cases dealing with CISG 14 are picked from the precedents. The precedents in the case base are narrowed down to a part of the precedents. As a result of this example, case2, case3 and case4 are searched for in the first stage. In the second stage, similarities between the query case and the retrieved precedents in the first stage are measured by the method introduced in section 3.3, are shown in the "Selected Precedent" windows. For example, the case 4 (*Jet Engine case*) is the most similar to the query case (**Figure 11**).

Then the case rules of Jet Engine Case is judged by users.

In terms of the fact of query case, users can select the fuzzy linguistic variables to answer the case rules (**Figure 12**). The conclusion on the basis of the judgment is derived and displayed in "inference window".

The result is different with the inputs selected by the user. A user can see how small changes in the problem could lead to different results. It is helpful for users to know that results are changed by the different inputs. It also helps users to understand the meaning of the statutory rules of the CISG and the meaning of precedents and query case.

FLCBR is constructed on the basis of the comments of the researchers on the legal domain and the law students[4].

The viewpoints of plaintiff and defendant are not emphasized in FLCBR. Legal argument made by plaintiff and defendant is also an important reasoning method in law. A fuzzy legal argument considering the viewpoints of both plaintiff and defendant will be proposed in a future study.

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