Paper:

An Application of Fuzzy Theory to the Case-Based Reasoning of the CISG

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In legal case-based reasoning (CBR), there exist problems concerning fuzziness, e.g., representation of precedents, their retrieval, and similarity measures. In our proposed fuzzy legal CBR system, the issues and features of precedent are characterized on the basis of the facts of precedent and statute rule. The case rule that is used for interpreting the court judgment, which cannot be obtained from the statute rule directly, is made by experts. Fuzziness is represented by membership functions. Features and case rules, written in terms of Compound Predicate Formula (CPF) and frame, are stored in a case base. Cases similar to a new case are retrieved by issues and features, and an inference is made by case rules. A user interface is devised for this system. The system proposed here will be used for law education, where the target law of the system is contract, especially as it relates to the United Nations Convention on Contracts for the International Sale of Goods (CISG).

Keywords: Fuzzy theory, Case-based reasoning, Legal expert system

1. Introduction

Law is applied to represent and handle various ever-changing real events, but the amount of law statutes is limited, and complex situations cannot be clearly expressed and managed by law text. Therefore, to deal with real situations, case-based reasoning (CBR) is used in law.[1] CBR is the process of using solutions to previously encountered problems as a basis for reasoning solutions to new problems (query case). By applying precedents that are similar to a new case, conclusions for the new case can be reached.

It is known that there is vagueness and uncertainty in CBR, e.g., in knowledge representation, retrieval, and inference of cases. Especially when dealing with the similarity assessment, it is difficult to find the cases from a case base that are completely the same as the new one. Fuzzy theory has already been employed in some legal expert systems.[3,6] In Ref.3), by using a fuzzy database, legal judgment is performed based on the resemblance of legal knowledge and facts. In Ref.6) vague legal concepts, i.e., the required period of waiting after traffic accidents is determined by fuzzy inference.

Fuzzy theory has been also employed in CBR.[2,7] In Ref.2), the fuzzy set-based model in CBR is discussed. A CBR system using fuzzy theory in the domain of Coronary Heart Disease Risk Assessment is detailed in Ref.7).

To capture the fuzziness of legal inferences made by CBR, fuzzy sets are employed in our legal CBR system. The target of our system is the CISG. Fuzzy theory is applied in all processes of legal CBR. In case representation, fuzziness is described by fuzzy sets. In retrieval and inference, similarity measures are made by fuzzy matching.

The system is introduced in section 2. Section 3 describes case representation. Similarity measures of fuzzy sets are made in section 4. The retrieval of similar cases is presented in section 5. The inference of cases is discussed in section 6. The user interface is illustrated in section 7. An experiment is described in section 8.

2. Fuzzy CBR System Overview

The system is composed of four parts, i.e., case base, retrieval, inference, and interface module.

A precedent of the case base is represented by issues, features, and case rules.

A precedent includes several issues. The issue describes the legal judgment, e.g., whether the proposal is sufficiently definite. Issue representation consists of an argument point and a court judgment. The argument point is represented by natural language and the judgment by "Yes" or "No." The issue can be further interpreted into features and case rules by experts.

In terms of statute rule and facts of precedent, issues are characterized by features. These are regarded as the surface features of a precedent. Because the statute rule is usually not enough for solving any case, on the basis of statute rule and court judgment, referring to the theory proposed by experts, case rules are made by experts. It is used to interpret connections between the precedent and court judgment.

The features and case rules are written by CPF and frame, stored in the case base.

For a query case, it is necessary to retrieve similar cases from the case base. The retrieval is made in terms of issues and features. What results can be gotten from retrieved cases, namely, whether the conclusion of a query case is the same as the precedent's or not, is inferred by case rules.

CISG is an international law, and has been used in many countries. To apply our system to international exchange, a user interface of this system is developed in several languages.

3. Knowledge Representation

3.1. Introduction

An important thing for building a legal expert system is to establish a method which cannot only represent the legal knowledge adequately and in detail, but also can be processed by computer. For this purpose, the Compound Predicate Formula (CPF) is proposed.[8]

The goal of our system is to implement fuzzy-case based inference. To realize the functions of fuzzy inference and retrieval, a case base of precedents must be established.

For building a precedent case base, there exists the problem of how to adequately express vagueness concepts implied in cases. To represent precedent cases with fuzziness, we introduce concepts of membership and vagueness[4] into CPF and frame representation form. At present, knowledge about precedent cases is represented in terms of a fuzzy frame.

3.2. CPF Contents and Features

The CPF takes the following form:

```
predicate (ID,
    [case symbol1: value1,
     case symbol2: value2,
          :
     case symboln: value n]).
```

CPF has two characteristics:

1. It has a device, which is an ID symbol, to express an individual concept.
2. It involves case symbols, which form a device for clarifying what role play in a predicate.

The theoretical basis of CPF is the standard first-order predicate. In other words, CPF can only be used to represent crisp knowledge in which a truth value is either true (1) or false (0). Because statute rules and cases are written in natural language, it is inevitable that vagueness and uncertainty exist in legal knowledge.

For example, in CISG rules, there exists vague everyday language such as "sufficiently definite," "reasonable time," and "materially alter."

To represent such statute rules and cases, a fuzzy frame is used to represent the fuzziness of legal knowledge by using concepts of membership and vagueness. Knowledge represented by the fuzzy frame is based on knowledge expressed by CPF.

3.3. Legal Precedent Case Base Representation

The precedent case base is a set of cases. Each case is constructed of three parts, i.e., issues, features, and case rules. On the basis of the representation of issues and features, fuzzy retrieval can be realized and, according to the case rules, fuzzy case inference becomes available.

Each case has the following structure:

```
case n: (N Case)
((Issue n1)
   :
 (Feature n1)
   :
 (Case rule n1)
   :
 (Issue n2)
   :
   :
 (Issue nm)
   :
   :      )
```

As an example, knowledge on the Malev case[9] can be represented as follows: The argument point is "The proposal is sufficiently definite" and the judgment is "No," which compposes the issue. Here, we assume that Malev's case number is No.1.

```
case 1:(Malev case)
((Issue 1)
  The proposal is sufficiently definite (No)
 (Feature 1)
  'fix'('fix-c-n1-1',[
   agt: 'Malev-proposal',
   imp: 'letter',
   obj: 'quantity'('q-c-n1',[
     obj: 'engine-system'
     ])
   ]).
  'fix'('fix-c-n1-2',[
   agt: 'Malev-proposal',
   imp: 'letter',
   obj: 'engine-system'
   ]).
  'fix'('fix-c-n1-3', [
   agt: 'Malev-proposal',
   imp: 'letter',
   obj: 'whole-price'('wp-c-n1', [
    obj: 'part-price'('pp-n1',[
     obj: 'engine',
     ])
    qua: '5,847,675'
    ])
   ]).  )
 (Case rule 1)
   :
   : )
```

Case rule on Malev[9] can also be written in CPF, but this is omitted here.

3.4. Knowledge Representation by Fuzzy Frame

Fuzziness can be represented by several methods. Here, we will introduce the concepts of membership and vagueness[4] into the frame, where the adaptation that specific knowledge described by limited words is represented by the concept of membership. The uncertainty of knowledge is represented by the concept of vagueness.

There are five values for input of the membership concept, and three values for input of the vagueness. The membership value is m, and the vagueness value is v. The correspondence between numerical representation and fuzzy

Table 1. Values of linguistic variables.

membership(m)	vagueness(v)
Completely No (CN) 0	Vague (V) 1
Probably No (PN) 0.25	Roughly (R) 0.5
More or Less (ML) 0.5	Clearly (C) 0
Probably Yes (PY) 0.75	
Completely Yes (CY) 1	

Table 2. Fuzzy frame representation of Malev case.

The proposal is sufficiently definite	No			
	m	v	y2	y3
It fixes the goods	1.0	1.0		
It fixes the quantity	1.0	1.0		
The entity price is not fixed, but the part price is fixed	0.0	0.0	0.0	1.0

linguistic representation is shown in **Table 1**.

The values of m, v can be assigned by experts and m, v about a new case can be adjusted by comparing them with the values of similar affairs previously saved in the case base. The values of m, v of previous affairs are determined by running the fuzzy legal expert system.

Precedent cases can be represented by a frame, where the name of the frame is the argument point about a case, the frame value is the judgment about a case, the slot name is the features about a case, and slot values are the values of m and v.

Here, we will use the fuzzy frame to represent the Malev case. The situation concerning an issue, "The proposal is sufficiently definite," is 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 a Boeing jet engine is fixed.

The jet engine system includes a support package, services, and so on.

The issue "The proposal is sufficiently definite" involved in Article 14 of the CISG can be used to determine whether the proposal is sufficiently definite which is relevant to goods, quantity, and price.

Article 14 of the CISG is:

A proposal for concluding a contract addressed one or more specific persons constitutes an offer if it is sufficiently definite and indicates the intention of the offerer to be bound in case of acceptance. A proposal is sufficiently definite if it indicates the goods and expressly or implicitly fixes or makes provision for determining the quantity and price.

About Article 14 of the CISG, we can extract knowledge from the Malev case as follows:

Argument point: The proposal is sufficiently definite

Judgment: No

Features: It fixes the goods

It fixes the quantity

The entity price is not fixed,

but the part price is fixed

The vagueness of features can be expressed through m and v.

The Malev case can be described by fuzzy frame as shown in **Table 2**. The explanation about y2 and y3 is given in section 5. Case rules on the Malev case can also be written by fuzzy frame.[9] (omitted here).

4. Similarity Measures for Fuzzy Sets

A triangular membership function can be used to represent the membership function of fuzziness. Vertices can be defined as:

$$mL = m - m\,v \quad (1)$$

$$mH = m + (1 - m)v \quad (2)$$

where m and v assume values shown in Table 1, and mL and mH show the lower limit and upper limit of m.

There are several methods for the determination of similarity measures of fuzzy sets.[5] Because the fuzzy set used here becomes a singleton when judgment is crisp, and two fuzzy sets sometimes do not overlap, the methods in Ref.5) cannot deal with these problems. Therefore, we propose a new approach discussed below.

Let the membership function of A be μ_A. The center of gravity of A can be calculated by

$$CG(A) = \frac{\int_{a_1}^{a_2} x\,\mu_A(x)\,dx}{\int_{a_1}^{a_2} \mu_A(x)\,dx}. \quad (3)$$

The distance between two centers of gravity, i.e., $|CG(A)-CG(B)|$, is used to describe the the similarity degree (**Fig.1.**). To satisfy the conditions of similarity relations, the degree of similarity $S(A, B)$ is calculated by

$$S(A, B) = (1 - |CG(A) - CG(B)|).. \quad (4)$$

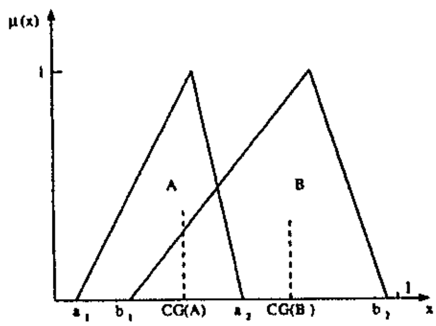

Fig. 1. Fuzzy Set Similarity.

5 Retrieval

All precedents are decomposed into a serial component in which the elemental item of provision can be indicated, and the work is done in the reference case. Based on the assumption that relevant elemental items are matched between two cases, similarity can be measured.

A method of two-stage retrieval is proposed to get the most similar precedent case step by step in a large-scale database of precedents. In the first stage, a part of a case which seems to be relevant to the reference case is searched for in the database of precedents. In the second stage, compared to the reference case by the method shown in section 5.2, the most similar precedent case is selected.

5.1. Issues Index

The issue that is suited to CISG articles and the judgment for this issue are indexed when precedents are described from the article form to CPF, then to the frame. So issues index can improve the utility of the index as a tool for case retrieval, especially since it can narrow cases smoothly down to one single issue. It meets users' needs from different points of view. For example, parts of cases are demanded that are dealt with in CISG article 14 (F_1), and are about a conclusion of contract (F_2) in precedents (X). This can be retrieved from the index (meaning that $F_1 \cap F_2 \subseteq X$. $F_1, F_2 \subseteq X$).

As a result, the case from a large-scale database of precedents X is narrowed down to relevant parts $F_1 \cap F_2$.

5.2. Elemental Similarity Measures

If elemental issue formulas are characterized by a single value, the distance between two cases is calculated directly. If elemental item formulas are characterized by more than one value, for instance, with a set of fuzzy memberships (m, v), the center of gravity is calculated by the triangular membership function of fuzziness and gravity composition by Eqs.(1) and (2). The center of gravity (CG) of the triangle can be obtained by Eq.(3). The distance(Δd) between relevant item between two cases(c_r and c_p) can be calculated as

$$\Delta d = | CG(c_r) - CG(c_p) |. \quad (5)$$

Conceptual similarity(Δs) of the elemental item within the law case is assessed as

$$\Delta s = e^{-\beta \Delta d^2}, \quad (6)$$

where β ($\beta > 0$) is amendment accuracy, the value of which should be fixed beforehand. The formulation of the provision acceptant depends on the elemental item that belongs to this issue (j).

The similarity of the issue (Δs_j) is assessed by the similarity of the elemental item as

$$\Delta s_j = min(\Delta s_1, \Delta s_2, \ldots, \Delta s_i, \ldots, \Delta s_n), \quad (7)$$

$$\Delta s_i \in [0, 1], n \in \mathrm{N},$$

where n is the number of elemental items that belong to the issue (j).

As a general rule, not only one relevant issue is to be compared between two cases. The algorithm applied in more than one relevant issue should be considered. The result of comparison between two cases is different if users are addressed on different factors and different aims, or where the controversy is between plaintiff and defendant. The weight (ω_i) is introduced in legal case-based retrieval. The average similarity with loads is calculated as

$$S = \frac{\sum (\omega_i \Delta s_i)}{\sum \omega_i} \quad (8)$$

where N is the number of addressed issues, and P is the significant multiple.

5.3. Inferential Similarity Measures

Case retrieval is not based on surface similarity (i.e., statistical properties of text or word occurrence), but in deeper, more inferential or conceptual similarities. A case and problem are more similar when they share similar legal issues and present similar conflicts among applicable legal issues. To solve a problem that cannot be processed directly by RBR, in CBR, we focus on functional features in describing a case, in addition to relevant legal issues. Because inferential case retrieval and conceptual resolution are desired, multidimensional fuzzy membership values are introduced here. This numerical description is based on CPF.

All cases are presented by CPF, and then further to be described into a frame structure with the aid of midterm language constructed by the hierarchical structure. In the frame structure, issues are picked up and slots of the frame are described with fuzzy membership values according to the relation of the hierarchical structure. CISG article 14, for example, is described as three elemental items, goods, quantity, and price. The distinction of predicates in CPF is assessed with the aid of midterm language where the relationship of relevant predicates is set up.For example, an agricultural machines affair is about a set of agricultural machines and the Malev affair is about the engine system contract. In CPF, predicate A SET and SYSTEM is assessed with the aid of a midterm language base. This part is being further studying now.

As a result of the frame structure, for example, CISG article 14 can be described as follows: goods[(m, v)], quantity[(m, v)], and price [(y_1, y_2, y_3)], y_1 = (m, v), y_2 = 0, or 1, y_3 = 0, 0.5, or 1, where the price of the entity is assessed by y_1 = (m, v); y_2 = 0 means that some parts exist for which the price is fixed and the price of the entity is not fixed; otherwise, y_2 = 1(including that y_2 is omitted); y_3 = 1 means making provision for determining the price to be reliable, y_3 = 0 means no reliable, y_3 = 0.5 means that it cannot be determined clearly.

In the Malev affair, for example, the entity price is not expressly fixed and there is a part for which the price exists. The elemental item on the price is described as

price [(0, 0), 0, 1].

In the same way, similarity can be calculated by Eqs.(1) - (3) and Eqs.(5) - (8).

6. Inference

Whether the retrieved precedent conclusion can be adapted for the query case should be decided after the retrieval phase has been completed. The precedent conclusion is made by the case rule judgment. The retrieved precedent case rules can be used for the query case.

It is known that, for rules, the more similar the antecedent, the more similar the conclusion.[4] Therefore, the inference can be made by the degree of similarity in case rule judgments between the precedent and query case.

Because there is fuzziness in the case rule judgment, the judgment is described as a fuzzy set here. Therefore, similarity measures of case rule judgment become similarity measures of fuzzy sets.

The case rule about a point of argument is represented by several frames. Each frame of the precedent and new case can be described as follows:

precedent: $P = \{P_i\}_{i=1}^{n}$,

new case: $Q = \{Q_i\}_{i=1}^{n}$,

P : frame that represents the precedent,

Q : frame that represents the new case,

P_i : fuzzy set that describes the judgment of case rule elements for the precedent,

Q_i : fuzzy set that describes the judgment of case rule elements for the query case,

n : quantity of slots in a frame.

Similarity measures will be performed as follows:

Let membership functions of P_i and Q_i be μ_{P_i}, μ_{Q_i}. The center of gravity of P_i and Q_i can be calculated by Eq.(3).

$S(P_i, Q_i)$ is the similarity degree of P_i and Q_i, and is defined by

$$S(P_i, Q_i) = (1 - |CG(P_i) - CG(Q_i)|) \quad (9)$$

Let $S(P, Q)$ be the degree of the similarity of P and Q. It is calculated by

$$S(P, Q) = min(S(P_1, Q_1), \ldots\ldots, S(P_n, Q_n)) \quad (10)$$

If the degree of similarity is greater than the threshold given in advance, the query case conclusion is the same as that of the precedent. If the degree of similarity is less than the given threshold, the conclusion of frame Q cannot arrive at the same conclusion as that of the precedent. This does not mean that the query case has the opposite conclusion of the precedent. It is necessary to infer it using other precedents or approach for this query case.

7. User Interface

This system is constructed for the purpose of CISG law education. It can deal with fuzziness that exists in legal case-based reasoning.

A user inference that is suitable to the process of legal inference is devised for this system to be operated easily.

The interface of this system consists of 3 modules: input, retrieval, and inference(cf., **Fig.2**).

Input module is comprised of the input of issues and facts of the reference case, and the judgment of the retrieved precedent case rule. Retrieval and inference are realized in section 5 and 6. The outputs of the conclusion and interpretation accompany the retrieval and inference process.

Even though the most important function of this system is retrieval and inference, the input and the output of this system are also crucial to assure high user friendliness. If there is no user-acceptable input and output function, the system cannot play the roles of retrieval and inference.

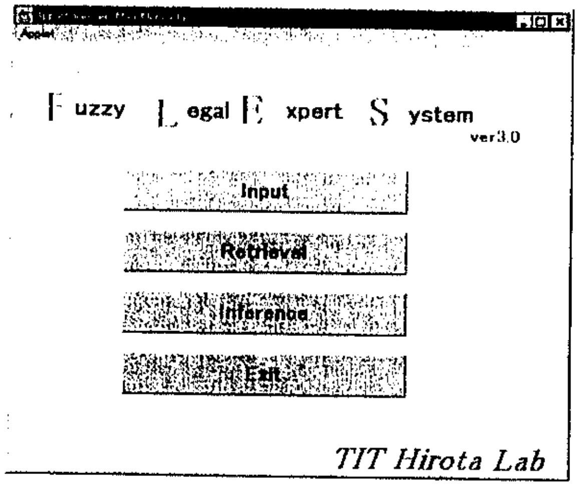

Fig. 2. Fuzzy Legal Expert System Main Menu.

The criteria of input are budget reduction, prevention of input operation error, and ease of operation.

According to these criteria, the answer for a question is selected by the candidate whenever possible. It can reduce input operation, avoid input operation error, and make operation simple. To give users the impression of a friendly atmosphere, the form and content of input is devised using image animation.

The interface of this system is also devised in several languages (English, Japanese, and Chinese) to be used in international law education.

8. Experiment

A reference case is made for an experiment based on fuzzy case-based reasoning.

The reference case is as follows:

1) On April 1, *A* in New York dispatched a letter containing an offer to the business branch of Japanese company *B* in Hamburg, the content of which is that *A* sells a set of farm machinery (the price of the tractor itself is $50,000) to *B*. The tractor should be equipped with a rake, which is the product of company *C*. The farm machinery is delivered by a U.S. cargo ship.
2) The letter reached *B* on April 8.
3) On April 9, *B* telephoned *A* to say, ''I accept your offer, but you should transport the machinery using a Japanese container.''

There are several points of argument as to whether the contract is concluded. Whether the proposal from *A* is effective or not is one of them. On the condition that ''The proposal is sufficiently definite,'' the proposal is effective.

The description of ''The proposal is sufficiently definite'' is as follows:

Event: proposal

Description of event:

The goods are farm machinery.

The quantity of farm machinery is one.

Concerning the price:

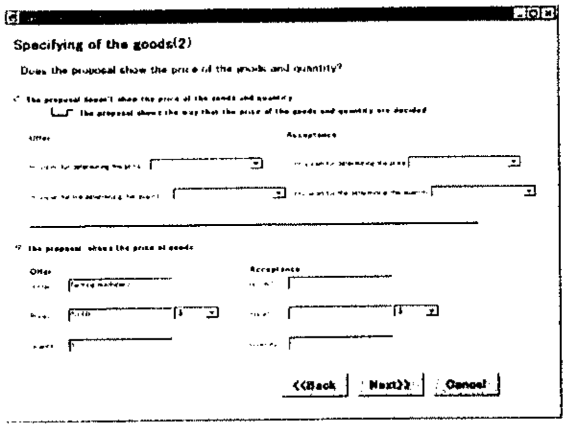

Fig. 3. Input of Reference Case.

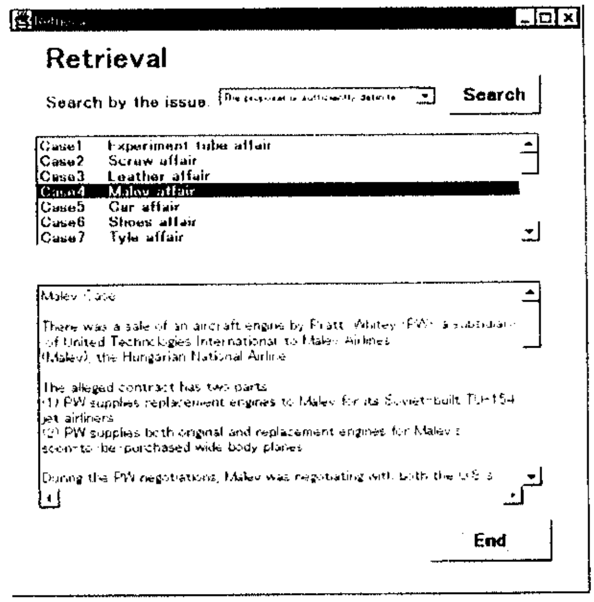

Fig. 4. Retrieval of Precedent.

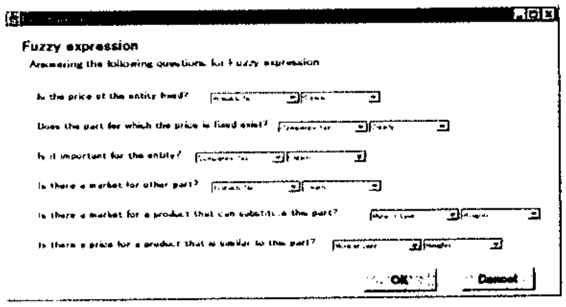

Fig. 5. Fuzzy Judgments on Case Rule.

The price of the tractor is fixed.
The price of a set of farm machinery is not fixed.
The farm machinery contains a rake.

This reference case is input by the Case Input of user inference (cf. **Fig.3**).

Cases similar to this reference case are retrieved from the case base.

There are eight precedents in the case base for the experiment. All precedents selected here are relevant to the formation of the contract. These are all from CLOUT(http://www.un.or.at/uncitral/clout/abstract/).

case1: Experiment tube affair
case2: Screw affair
case3: Leather affair
case4: Malev affair
case5: Car affair
case6: Shoes affair
case7: Tyle affair
case8: Electronic parts affair

Articles of precedents can be read from retrieval windows. All cases are presented by CPF, and then further described in a frame structure. The slot values of the frame are described with fuzzy membership values. The provisions that suit CISG articles and the judgment for issues are indexed.

The agricultural machine affair is a reference case. The details of the case are shown in a retrieval window. In this case, the controversy between plaintiff and defendant can be considered as a case of the format of a problem with the proposal. The retrieval procedure is divided into two stages. In the first stage, pursuant to index issue, cases dealing with CISG 14 are picked from precedents. The similarity measure is narrowed down to parts of precedents; As a result of this example, case 2, case 3 and case 4 are searched for in the first stage. As retrieval results, the name of precedents and articles can be shown in retrieval windows. In the second stage, similarity is measured in searched-for parts as mentioned in section 5. Similarities of case 2, case 3, and case 4 are assessed and retrieval results are shown in retrieval windows. Case 4 (Malev affair) is the most similar to the reference case (cf., **Fig.4**).

The Malev case rule is then judged by users.

In terms of the reference case, users can select fuzzy linguistic variables to answer the elements of case rules (cf., **Fig.5**). The conclusion on the basis of the judgment is derived and displayed. For example, if fuzzy linguistic variables are selected as Figure 5, the rake of C is probably considered as the exclusive use for the tractor of A; it is not sold on the market. The reference case has the same conclusion as the Malev case, namely, the proposal is not sufficiently definite.

The result is different from inputs selected by the user. It is helpful to users to know that results are changed by different inputs. It also helps users (students) to understand CISG and the meaning of precedents and reference cases.

9. Conclusion

Fuzzy theory is employed to deal with the fuzziness of the legal CBR system. CISG is selected as the target law.

The precedent of the case base is comprised of issues, features, and case rules. The issues and features of a precedent are characterized by facts of precedent and statute rules. The case rule used for interpreting the court judgment, is made by experts. The fuzziness of legal CBR is represented by fuzzy membership functions. The features and case rules, written by CPF, are stored in a case base. The cases similar to a query case are retrieved by issues and features, and inference is made by case rules. The system proposed here will be used for law education. A user interface that is suitable to such education is devised.

Our case base, which is yet still small, will be extended. A method for legal argument will also be phased into this system.

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