



A fuzzy theoretical approach to case-based representation and inference in CISG

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Abstract. In a legal expert system based on CBR (Case-Based Reasoning), legal statute rules are interpreted on the basis of precedents. This interpretation, because of its vagueness and uncertainty of the interpretation cannot be handled with the means used for crisp cases. In our legal expert system, on the basis of the facts of precedents, the “statute rule” is interpreted as a form of “case rule”, the application of which involves the concepts of membership and vagueness. The case rule is stored in a data base by means of fuzzy frames. The inference based on a case rule is made by fuzzy YES and fuzzy NO, and the degree of similarity of cases. The system proposed here will be used for legal education; its main area of application is contract, especially in relation to the United Nations Convention on Contracts for the International Sale of Goods (CISG).

Key words: CISG, case-based reasoning, fuzzy logic, legal expert system

1. Introduction

Law is applied to represent and handle various ever-changing real events. But the amount of statute law is limited; complex situations cannot be clearly expressed and managed by law texts. Therefore, in order to deal with the various real situations, case-based reasoning (CBR) is used (Rissland and Ashley 1987). By applying precedents that are similar to a new case, conclusions for the new case can be reached.

In CBR, in order to apply law to cases, a statute rule is interpreted on the basis of the facts of precedents. Then judgements are made as to whether the facts of the case in question correspond to the elements of the interpreted statute rule. But there is fuzziness in such a judgement. The fuzziness is caused by the adaptation of a legal concept which is expressed in limited words applying to a given fact, and by the uncertainty of knowledge. Therefore, it is necessary that the representation of cases can cope with fuzziness.

Conventional case-based reasoning presupposes the crisp representation of cases (Kolodner 1993), and it cannot deal with the representation of cases involving fuzziness.

In order to represent a case with fuzziness, and give reasons for an appropriate conclusion, fuzzy theory is to be applied. A judgement with fuzziness is described by the concepts of membership and vagueness. Moreover, we suggest a method for judging the correspondence of fact and element of rule by YES and NO from the concept of membership function, and an assessment of the similarity of fuzzy cases.

Considering an actually decided case of CISG (United Nations Convention on Contracts for the International Sale of Goods) as precedent, we are going to show an experiment on legal fuzzy inference using CBR.

The CBR method for legal inference is introduced in Section 2. The representation of cases with fuzziness is described in Section 3. The method of inference is presented in Section 4. The result of the experiment is illustrated in Section 5.

2. CBR for Legal Inference

Legal inference consists of the recognition of facts and the interpretation of law. CISG is taken as an example to be discussed here. In CISG, when "the conclusion of contract" is to be judged, it is necessary at first to decide whether there is an offer or not. If this question has been answered in the affirmative, it is necessary to decide whether the offer is effective or not. This decision is to be followed by a check up as to whether the proposal is sufficiently definite, this being defined in statute 14(1) of CISG. The definition can be also expressed as follows:

The proposal is sufficiently definite =
{Indicating the goods} and
{Fixing the quantity or making provision for
determining the quantity} and
{Fixing the price or making provision for
determining the price}

The facts of a case fall seldom clearly under a statute rule. For example, the criterion of "Fixing the price" is not verbally written in the pertinent statute rule. So the statute rule cannot be used directly. But legal experts can, by way of analogy, apply the statute rule to similar cases. Thus, the rule of a new case can be inferred.

Such an inference goes as follows: A precedent is described in the light of the interpretation of a pertinent statute rule on the basis of the facts of a given case. The application of the statute rule consists in making connections between the facts of the precedent and the elements of the statute rule; the facts are spread out until they satisfy the legal requirements of the statute rule. These connections are called a case rule.

3. Representation of Case with Fuzziness

Legal knowledge consists of knowledge about statute rules and precedents. Especially precedents represent the legal knowledge in CBR.

The "Malev affair", a case of the Hungarian Supreme Court, is taken to be a precedent here. The main contents of the case are:

There was a sale of an aircraft engine by Pratt Whitey (PW), a subsidiary of United Technologies International, to Malev Airlines (Malev), the Hungarian National Airline.

The alleged contract had two parts:

(1) PW supplies replacement engines to Malev for its Soviet-built TU-154 jet airliners.

(2) PW supplies both original and replacement engines for Malev's soon-to-be-purchased wide body planes.

During the PW negotiations, Malev was negotiating with both the U.S.'s Boeing and Europe's Airbus for the purchase of aircraft. PW offered to supply the engines that would serve as original equipment on these jets and spare engines, and service, maintenance, warrant, financial support.

On November 9, 1990, PW's original offer provided for the sale of one of three types of engines to Malev:

If Malev chose the Boeing aircraft: PW 4056

If Malev chose the Airbus aircraft: PW 4152, PW 4156/A

On December 4, 1990, PW and Malev signed a letter of intent on (1), but (2) was still contingent on the aircraft purchase portion.

The price of the engine varied with the type: PW 4056 was quoted at \$5,847,675; PW 4152 was quoted at \$5,552,675; PW 4156/A was quoted at \$5,847,675. The offer's term further provided for a support package (involving service, maintenance, credit and so on) to be tailored to the type of aircraft ultimately chosen by Malev. The engines for the Airbus option were properly referred to as a "jet engine system". In contrast, the engine for the Boeing option only included the engine as such.

The requirement of "The proposal is sufficiently definite" can be interpreted here 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 statement about the prices of Boeing jet engine systems.

The price of a single Boeing jet engine is fixed.

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

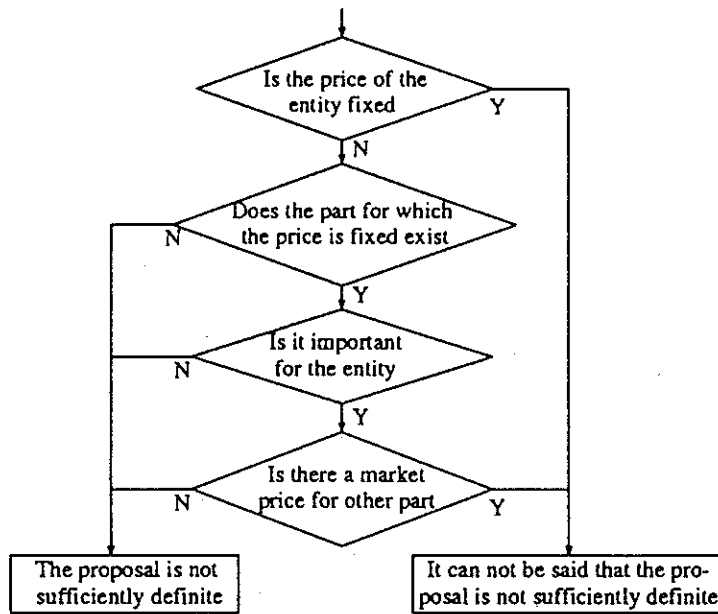


Figure 1. The case rule for the verification of price of entity.

In accordance with statute 14(1) of CISG, the Hungarian Supreme Court declared that the proposal was not sufficiently definite because the price of jet engine systems was not fixed, and jet engine systems had no market prices.

In this case, it is clear that the goods have been “indicated”. It is also clear the “quantity” has been “fixed”. It is the “fixing” of the price of an entity consisting of several parts that needs expert interpretation.

Initially, the entity price is judged. If there is no entity price, it is necessary to check whether there is at least a part for which the price is fixed. If there is no part for which the price is fixed, either, “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 checked. If this part is not important, it is considered that “The proposal is not sufficiently definite”. If this part is important for the entity, it needs to be determined for the other parts (the parts for which the prices are not fixed) whether there is at least a market price for them.

The process of checking whether there is a market price goes as follows:

If there is a market for another part, it is considered that there is a market price for this part. If there is no market for the part in question, it needs to be checked whether there is a market for a product that can substitute for it. If there is such a market, it is considered that there is a market price for this part. If there is no market, then it needs to be checked whether there is a price for a similar product. If there is a price, it is considered that there is a market price for this. If there is no price, it is considered that there isn’t a market price for this. This process of determining the price of an entity is shown in Figures 1 and 2. There are the case rules about the verification of the entity price in the Malev affair.

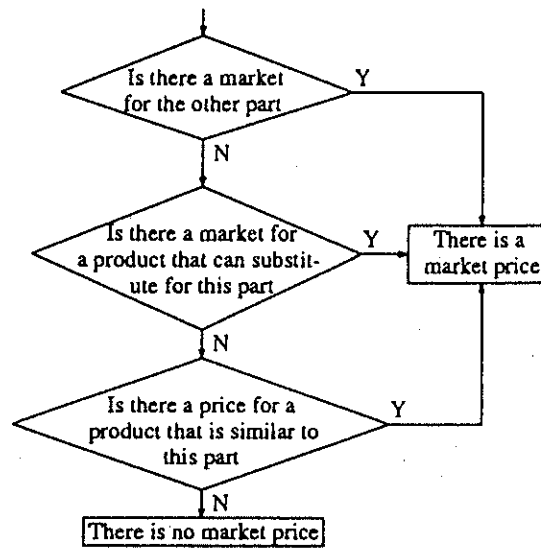


Figure 2. The case rule for the verification of market price.

Note that the hierarchy of case rules is not restricted to a single stage, but consists of several stages.

There is fuzziness in the application of a case rule. For example, it is sometimes difficult to clearly answer the question: "Is there a market for another part?" This kind of fuzziness is caused by the limits of the words chosen, and by the uncertainty of knowledge.

In order to deal with the fuzziness in the application of a case rule, fuzzy theory is to be introduced.

Fuzziness can be represented by several methods. We shall use the concepts of membership (a fuzzy theory concept), and of vagueness (expressed by probabilistic sets that represent fuzziness (Hirota et al. 1996; Hirota 1979)). The phenomenon that specific knowledge is described by unspecific words is represented by the concept of membership. The uncertainty of knowledge is represented by the concept of vagueness.

Table I. 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)	

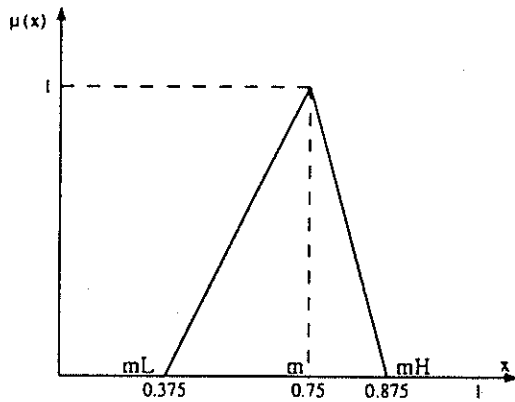


Figure 3. A triangular membership function.

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

To represent the membership function of fuzziness, a triangular membership function can be used. The vertices can be defined as:

$$mL = m - mv, \tag{1}$$

$$mH = m + (1 - m)v, \tag{2}$$

The proposal is sufficiently definite	N	
	m	v
Are the goods indicated	1.0	0.0
Is the quantity fixed or provisions are made for determining the quantity	1.0	0.0
Is the price fixed or provisions are made for determining the price		

The price is fixed or provisions are made for determining the price	N	
	m	v
Is the price of the entirety fixed	0.0	0.0
Does the part for which the price is fixed exist	1.0	0.0
Is it important for the entity	1.0	0.0
Is there a market price for other part		

There is a market price for other part	N	
	m	v
Is there a market for other part	0.25	0.0
Is there a market for the product that can substitute for this part	0.25	0.5
Is there a price for the product that is similar to this part	0.25	1.0

Figure 4. The frame on "the proposal is sufficiently definite" in the Malev case.

where mL and mH show the lower limit and upper limit of m , respectively. For example, imagine there is an element of a case rule with respect to whom the judgement would be: "probably yes, roughly". The membership function of the judgement of this element is shown in Figure 3.

When "clearly" is selected from the linguistic variables of vagueness, we get:

$$mL = mH = m. \quad (3)$$

This means that the membership function becomes a singleton.

The case rule can be represented by a frame, where the name of the frame is the name of a legal requirement, the slots are the elements of a case rule, the values of slots are the judgements of the elements. The frame is saved in a data base.

The frame that represents the interpretation and judgement of the Malev affair is shown in Figure 4.

4. Inference Based on Case Rule

Inference based on a case rule can be divided into two stages. In the first stage the inference is made by the correspondence of the facts of a new case and the elements of a case rule, which are judged according to YES or NO. The judgement of YES or NO is graduated according to the degree of fuzzy membership. In the second stage, the inference from the precedent to the new case is drawn, directed by the similarity between the cases.

The conclusions of both stages are to be compared to the conclusion of the precedent. If they are identical with the conclusion of the precedent, the new case has the same legal result as the precedent. If they are not identical with it, the decision on the new case cannot be backed by the precedent.

The process of inference is shown in Figure 5.

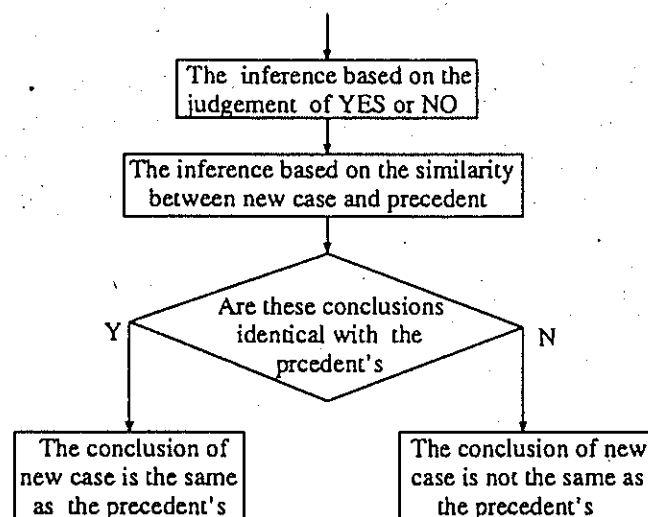


Figure 5. The process of inference based on case rule.

4.1. INFERENCE BASED ON A YES/NO JUDGEMENT

The judgement on the correspondence of the facts of the new case and the elements of a case rule is represented by the fuzzy membership function. According to the case rules of Figures 1 and 2, a Yes/No judgement is necessary for inference by case rule. The judgement YES or NO is determined by the centre of gravity of the fuzzy membership function.

Let C_i be the fuzzy set that describes the judgement on the correspondence between the elements of a case rule and the facts of a new case (Figure 6). The membership function of C_i is μ_{C_i} . The centre of gravity of C_i can be calculated by

$$CG(C_i) = \frac{\int_{c_1}^{c_2} x \mu_{C_i}(x) dx}{\int_{c_1}^{c_2} \mu_{C_i}(x) dx} \quad (4)$$

The centre of gravity of C_i belongs to $[0, 1]$. If the value of the centre of gravity is near 1, it can be considered that the judgement is YES. If the value of the centre of gravity is close to 0, it can be considered that the judgement is NO. The value 0.5 is selected as the threshold. If the value of the centre of gravity is greater than 0.5, the judgement is YES. If the value of centre of gravity is less than or equal to 0.5, the judgement is NO.

After the correspondences of all the elements of pertinent case rules and facts of new cases are judged established, the conclusion as to whether the legal consequence is valid or not is inferred according to the case rule.

4.2. INFERENCE BASED ON SIMILARITY ASSESSMENT

A precedent is described by case rules. The similarity between two cases is assessed by the similarity of judgements on the elements of the case rules.

Since there is fuzziness in the judgement of a rule, the judgement can be described as a fuzzy set; then the similarity assessment of cases becomes the similarity assessment of fuzzy sets.

There are several methods for similarity assessment of fuzzy sets available (Chen et al. 1995). Since the fuzzy set used here becomes a singleton if the judgement is crisp, and two fuzzy sets sometimes do not overlap, the methods proposed in (Chen et al. 1995) cannot deal with these problems (Lee et al. 1995). Therefore, a different method is introduced below:

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

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

New case: $C = \{C_i\}_{i=1}^n$,

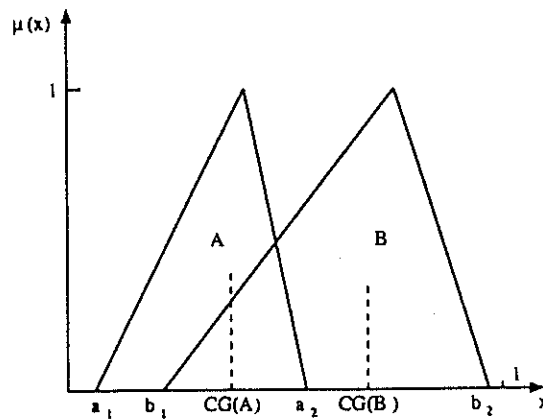


Figure 6. The similarity of fuzzy sets.

P is the the frame that represents the precedent, C is the the frame that represents the new case, P_i is the fuzzy set that describes the judgement of the elements of the case rule for the precedent (Figure 6), n is thethe quantity of slots in a frame.

The similarity assessment will be performed as follows:

The membership function of P_i is μ_{P_i} . The centre of gravity of P_i can be calculated by

$$CG(P_i) = \frac{\int_{P_1}^{P_2} x \mu_{P_i}(x) dx}{\int_{P_1}^{P_2} \mu_{P_i}(x) dx} \tag{5}$$

The degree of similarity is usually shown by a real number in $[0, 1]$, so the degree of similarity $S(P_i, C_i)$ is calculated by

$$S(P_i, C_i) = (1 - |CG(P_i) - CG(C_i)|) \tag{6}$$

$CG(C_i)$ is calculated by Equation (4).

Let $S(P, C)$ be the degree of similarity of P and C .

It can be calculated by

$$S(P, C) = \min(S(P_1, C_1), \dots, S(P_n, C_n)) \tag{7}$$

If the degree of similarity is greater than the threshold determined in advance, the conclusion of frame C is the same as that of frame P . For example, if there is a conclusion that "The proposal is sufficiently definite" in a precedent, the conclusion of new case is also "The proposal is sufficiently definite". If the degree of similarity is less than the given threshold, the conclusion of frame C cannot arrive at the same conclusion as that of P . This does not necessarily mean that the new case has the opposite conclusion as the precedent. Perhaps it is possible to reach the same conclusion by using another precedent.

The proposal is sufficiently definite						
	m	v	ml	vl	S	Yes/No
Are the goods indicated	1.0	0.0	1.0	0.0	1.000	Y
Is the quantity fixed or provisions are made for determining the quantity	1.0	0.0	1.0	0.0	1.000	Y
Is the price fixed or provisions are made for determining the price	N				0.750	N

The price is fixed or provisions are made for determining the price						
	m	v	ml	vl	S	Yes/No
Is the price of the entity fixed	0.0	0.0	0.25	0.0	0.750	N
Does the part for which the price is fixed exist	1.0	0.0	1.0	0.0	1.000	Y
Is it important for the entity	1.0	0.0	1.0	0.0	1.000	Y
Is there a market price for other part	N				0.833	N

There is a market price for other part						
	m	v	ml	vl	S	Yes/No
Is there a market for other part	0.25	0.0	0.25	0.0	1.000	N
Is there a market for a product that can substitute for this part	0.25	0.5	0.5	0.5	0.833	N
Is there a price for a product that is similar to this part	0.25	1.0	0.5	0.5	0.917	N

Figure 7. The frame of case(I) on "The proposal is sufficiently definite".

5. An Inference Experiment Based on a Case Rule

Let us construct two reference cases for an experiment based on a case rule.

The reference case (I) goes as follows:

(1) On April 1, *A* in New York dispatched a letter containing an offer to the business branch of a Japanese company *B* in Hamburg, the content of which was that *A* proposed to sell a set of farming machinery, including a tractor. (The price of the tractor itself was \$50,000 to *B*. The tractor should be equipped with a rake, which was a product of company *C*. The farming machinery should be delivered by an U.S. cargo ship).

(2) The letter reached *B* on April 8.

(3) On April 9, *B* telephoned *A* to tell "I accept your offer, but you should transport the machinery by 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. Under the condition that "The proposal is sufficiently definite", the proposal is effective.

The clarification of "The proposal is sufficiently definite" goes as follows:

Event: proposal

Description of event:

The proposal is sufficiently definite	m	v	m2	v2	S	Yes/No
Are the goods indicated	1.0	0.0	1.0	0.0	1.000	Y
Is the quantity fixed or provisions are made for determining the quantity	1.0	0.0	1.0	0.0	1.000	Y
Is the price fixed or provisions are made for determining the price	N				0.417	N

The price is fixed or provisions are made for determining the price	m	v	m2	v2	S	Yes/No
Is the price of the entity fixed	0.0	0.0	0.0	0.0	1.000	N
Does the part for which the price is fixed exist	1.0	0.0	1.0	0.0	1.000	Y
Is it important for the entity	1.0	0.0	0.75	0.0	0.750	Y
Is there a market price for other part	N				0.417	Y

There is a market price for other part	m	v	m2	v2	S	Yes/No
Is there a market for other part	0.25	0.0	1.0	0.5	0.417	Y
Is there a market for a product that can substitute for this part	0.25	0.5				
Is there a price for a product that is similar to this part	0.25	1.0				

Figure 8. The frame of case(II) on "The proposal is sufficiently definite".

The goods are farming machinery.
 The quantity of farming machinery is one.
 Concerning the price:

The price of the tractor is fixed.
 The price of the whole set of farming machinery is not fixed.
 The farming machinery contains a rake.
 The pertinent reference case (II) is as follows:

CompNet Inc. made a proposal to LexData Inc. to sell a computer system on May 4. The price of the computer hardware is 1,000,000 dollars. The computer system is installed with a new operating system of SysSoft Inc.. LexData Inc. accepted the proposal on May 8. But soon after, LexData Inc. claimed that the contract was not concluded because the proposal was not definite.

In this case the clarification of "The proposal is sufficiently definite" goes as follows:

Event: proposal
 Description of event:
 The goods are a computer system.
 The quantity of the computer system is one.
 Concerning the price:

Fixing the price or making
 provision for determining the price

Is the price of the entity fixed

PN

C

Does the part for which the price is fixed exist

CY

C

Is it important for the entity

CY

C

Is there a market for other part

PN

C

Is there a market for a product that can substitute for this part

ML

R

Is there a price for a product that is similar to this part

ML

R

Conclusion

There is not a market price

It does not satisfy the item of statute rule requiring that fixin
 the price or making provision for determining the price

The proposal is not sufficiently definite

Addition

Is this case added to the case base(Y/N)

N

Figure 9. The result of experiment on the reference case(I)

The price of the computer hardware is fixed.

The price of the computer system is not fixed.

The computer system contains the operating system.

In both cases the goods are indicated, and the quantity is fixed. But the price of the entity is not clearly definite. Therefore, the statute rule can not be directly applied.

In order to judge whether the proposal is sufficiently definite or not, the Malev affair is selected as the precedent which is similar to both cases. By quoting the case rule (Figures 1 and 2) that is applied to verify the price of an entity of goods, and by referring to the precedent, the conclusion for the reference cases can be derived.

By means of Table I, users can select the fuzzy linguistic variables to answer the elements of rule on term of the fact of the case.

In the proposed fuzzy legal expert system, the inputs are the user's answers. By using the Equations (4)–(7), a Yes/No judgement is made, and the degree of similarity is calculated.

In reference case(I) the rake of C is probably designed for the exclusive use for the tractor of A ; so it is not sold as an item on the market. The m_1 and v_1 in Figure 7 represent the value of fuzzy linguistic variables selected by the user. The degree of similarity is displayed in the column S as an output, the Yes/No judgement is displayed in the column *Yes/No* as another output.

In reference case (II) it is probably to be decided that SysSoft's operating system is sold on the market. The input m_2 , v_2 , and the Yes/No judgement, besides the degree of similarity, are shown in Figure 8.

The m , v in Figures 7 and 8 are the same as the m , v in Figure 4.

In Figure 7, the reference case (I) has the same conclusion as the precedent (namely that the proposal is not sufficiently definite) because the conclusions from the Yes/No judgement and the degree of similarity are the same as the precedent's.

In Figure 8, it has been decided from the Yes/No judgement that there is a market price of the operating system software. Therefore, the conclusion is reached that it cannot be said that the proposal is not sufficiently definite. Considering the degree of similarity, it is to be judged that the new case is not similar to the precedent. Therefore, the new case cannot arrive at the same conclusion as the precedent. In other words, the precedent does not apply to this reference case (II).

The result of the experiment on the inference is partly shown in Figure 9.

6. Conclusion

We analysed an actually decided CISG case, namely, the Malev case, so that we were able to formulate the case rule. The judgement of the elements of the case rule was represented by the concepts of membership and of vagueness in fuzzy theory. The inference based on the case rule was made by the Yes/No judgement and the degree of similarity. The Yes/No judgement was made according to the centre of gravity of the membership function. The degree of similarity was calculated by fuzzy matching. It was on the basis of these requirements that the inference experiment was carried out. This research enlarged the area of CBR implications. The same method can also be applied in other areas of law containing fuzziness.

Our case base is currently still small. Therefore, it should be extended. Further, the method for retrieving a precedent from the case base which is similar to a new case should be refined in terms of fuzzy theory.

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References

- Aamodt, A. 1995. Case-based reasoning: Foundational issues, methodological variations, and system approaches, *Artificial Intelligence Communications* 7(1), 10–15.
- Baldwin, J.F. 1994. Fuzzy reasoning by case for decision support systems, *Int. J. Uncertainty, Fuzziness and Knowledge-Based Systems* 2(1), 11–14.
- Chen, S.M., Yeh, M.S., and Hsiao, P.Y. 1995. A comparison of similarity measures of fuzzy values, *Fuzzy Sets and Systems* 72(1), 79–89.
- Hirota, K., Kurisu, H., and Yoshino, H. 1996. A precedent-based legal judgement system using fuzzy database, *Int. J. Uncertainty, Fuzziness and Knowledge-Based Systems* 4(6), 573–580.
- Hirota, K. 1979. Extended fuzzy expression of probabilistic sets, in M.M. Gupta et al. (eds.), *Advances in Fuzzy Set Theory and Applications*, North-Holland, pp. 201–214.
- Kolodner, J. 1993. *Case Based Reasoning*. Morgan Kaufmann Publisher, pp. 346–352.
- Lee, K.M. and Lee, K.H. 1995. Fuzzy information processing for expert systems, *Int. J. Uncertainty, Fuzziness and Knowledge-Based Systems* 4(6), 573–580.
- Nitta, K. et al. 1992. HELIC-II: A legal reasoning on the parallel inference machine, *Proceedings of the International Conference on the Fifth Generation Computer Systems*, pp. 1115–1124.
- Rissland, E.L. and Ashley, K.D. 1987. A case-based system for trade secrets law, *Proc. of ICAIL'87* 60–65.
- Watanabe, H. and Okuda, K. 1996. An integrated reasoning method using rules and cases, *Journal of Japanese Society for Information Processing* 31(2), 244–254 (in Japanese)
- Wang, Y., Inuzuka, N., and Ishii, N. 1995. Similarity metrics on frame knowledge expressions, *Journal of Japanese Society for Artificial Intelligence* 10(5), 118–125 (in Japanese)
- Yoshino, H. et al. 1993. Towards a legal analogical reasoning system knowledge representation and reasoning methods, *Proc. of ICAIL'93* 110–1165.