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A study on the comparative methods of a defuzzification in the fuzzy problem simulated car driving in the high way

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Abstract

Fuzzy theory may be constructed of Fuzzy sets theory, Fuzzy measurement and Appoximate reasoning, and nowadays the reseaches on it are done widely in both theoretical and practical aspects.

In this paper, the authors sought for the subject in Hirota's Fuzzy CAI: A decision making simulated fuzzy problem on the speed and accelerator control of a car driven in the high way. Interesting results on these fuzzy solutions of this problem, based on a defuzzification with 9 kinds of the methods, are reported. And the characters of these solutions, linear or nonlinear and their fuzzy control evaluations are stated.

1. Introduction

It may be thought that Fuzzy theory[1] is at the beginning of Fuzzy sets theory which was introduced by Prof. L.A.Zadeh, California University, U.S.A., in 1965 and it is constructed of Fuzzy sets theory, Fuzzy measurement and Appoximate reasoning.

On the other hand, there is a popular Expert system[2] on AI(artificial intelligence) that is stored the knowledge of an expert man in the computer's memory and a decision making is done with the same level of expert men by using these knowledges. Fuzzy CAI[3] edited by Dr. K.Hirota that is combined Fuzzy theory with Expert system with CAI's form was presented in Japan, in 1989.

In this paper, the authors investigated the solutions of Fuzzy Expert problem (the decision making problem on how to step on the accelerator of driving car in the high way) which is given in Hirota's Fuzzy CAI. And interesting results on Fuzzy solutions: an comparison on the character of solutions, as to interpolution of solutions, and the character, that is, linear or nonlinear, which the authors had investigated with our Personal computer, are reported with the figures.

2. A decision making simulated fuzzy problem

2.1 The model of a car driven in the high way

The model of a car driven in the high way which was given in the Hirota's CAI[3] will be introduced.

The situation that we will drive a car in the high way, that is, non-stop driving with keeping some constant speed (=80 km/h) is presupposed. So let an aim of the speed of this car be 80 km/h.

In data processing with a computer up to this time, as a causal relation was described with mathematical relations or digital logic equations, the judgement of 'slow' or 'fast' on the speed and the amount to step on the accelerator were assigned as the clear values (crisp values).

In this fuzzy model, the judgement of 'slow' on the speed will be the range of from 65 km/h to 75 km/h, for example, and if let the maximum of the amount to step on the accelerator be 100 %, in this case of judged 'slow' on the speed, let the amount to step on the accelerator be 60 %; such these correspondences are done in this model.

A corresponding relation between the judgement on the speed of a car and the amount to step on the accelerator is given in the following Diagram 1.

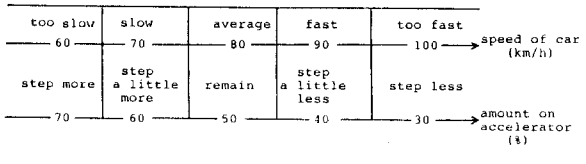


Diagram 1. A relation between speed and accelerator

We will give the knowledge for driving a car to this model: the rules on the knowledge are given in Diagram 2. Here, a representation of the rules on the knowledge is given: IF ～ THEN ～ form. That is, IF zenken-bu (the former conditions) THEN kōken-bu (the latter conditions).

Knowledge 1 IF 'too slow' THEN 'step more'
Knowledge 2 IF 'slow' THEN 'step a little more'
Knowledge 3 IF 'average' THEN 'remain'
Knowledge 4 IF 'fast' THEN 'step a little less'
Knowledge 5 IF 'too fast' THEN 'step less'

Diagram 2. The rules on the knowledge

The membership function of zenken-bu and kōken-bu are given in Fig. 1. and Fig. 2., respectively. Now, the shape of membership function is triangle-typed, linear function.

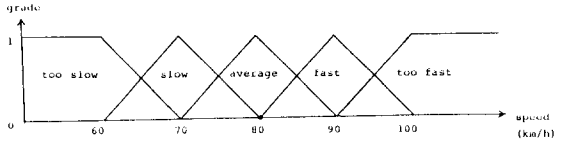


Fig. 1. Membership function of zenken-bu

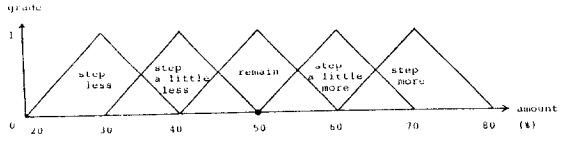


Fig. 2. Menbership function of kōken-bu

To get the solutions of this fuzzy problem, 9 kinds of methods on a defuzzification (the patterns of methods solving this simulated fuzzy decision making car-driving model's problem) will be given in the following: 5),6)

(A) algebraic - max - median method
(B) algebraic - addition - median method
(C) min - max - median method
(D) min - addition - median method
(E) ratio of grades method
(F) algebraic - max - center of gravity method
(G) algebraic - addition - center of gravity method
(H) min - max - center of gravity method
(I) min - addition - center of gravity method.

Here, min. denotes cutting by the grade ($0 \leqq \text{grade} \leqq 1$) gotten in zenken-bu of the top of triangle-typed membership function; max. denotes $h(v) = \max(f(v), g(v))$; algebraic denotes algebraic products, that is, the values of triangle-typed membership function multiplys the grade ($0 \leqq \text{grade} \leqq 1$) gotten in zenken-bu: that is, the reduction of triangle shape by the grade; median denotes the point (value) of which sum of the area on the right side and the left side is equal; and center of gravity denotes the point (value) of weighted mean, that is, bary center point (value) of corresponding values on kōken-bu membership function.

2.2 Solutions of this fuzzy problem and comments

We will explain the process of solving this fuzzy problem with a defuzzification (A): algebraic - max - median method.

For example, we will think the situation that a car is running at the speed of 88 km/h. Then, in the membership function of zenken-bu, it will be obtained that the grade of 'average' is 0.2 and of 'fast' is 0.8. See Fig. 3.

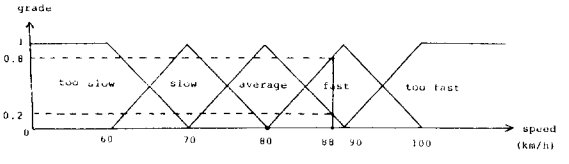


Fig. 3. Judgement of grade from the values of membership function of zenken-bu

And then, based on the rules of knowledges, we will multiply the grade (0.2, 0.8) by 2 triangle-typed parts ('remain', 'step a little less') of membership function in kōken-bu corresponding 2 triangle-typed parts ('average'(grade= 0.2), 'fast'(grade= 0.8), respectively) of membership function in zenken-bu. See Fig. 4.

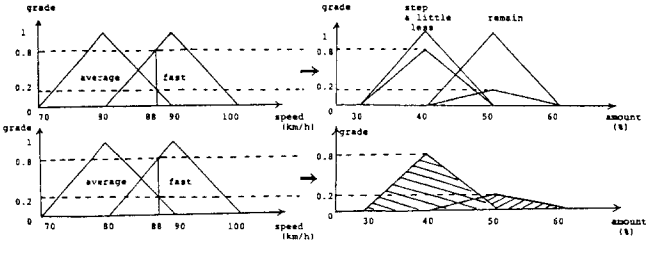


Fig. 4. Explanation of defuzzification (A) with figures

And, to 2 triangle-typed parts of membership function in kōken-bu of which the peak values are 0.8 and 0.2, we calculate the point (the amount to step on the accelerator) of which the

sum of the area on the right side and the left side is equal. This is the value of median, and the solution (defuzzification value) of the problem. The same of calculations are done for each 1 km/h of from 60 km/h to 100 km/h.

We will explain in the case of defuzzification (C):
When the speed of a car is 62 km/h, for example, it will be obtained that the grade of 'too slow' is 0.8 and of 'slow' is 0.2, in the membership function of zenken-bu.

And we will cut with the grade (0.8, 0.2) their tops of 2 triangle-typed parts ('step more', 'step a little more') of the membership function in kōken-bu corresponding 2 triangle-typed parts ('too slow',(grade = 0.8), 'slow'(grade= 0.2), respectively) of the membership function in zenken-bu. See Fig. 5.

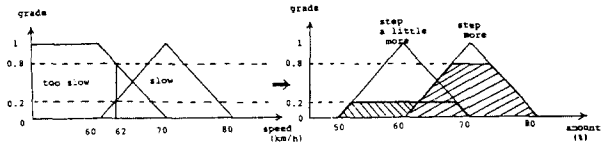


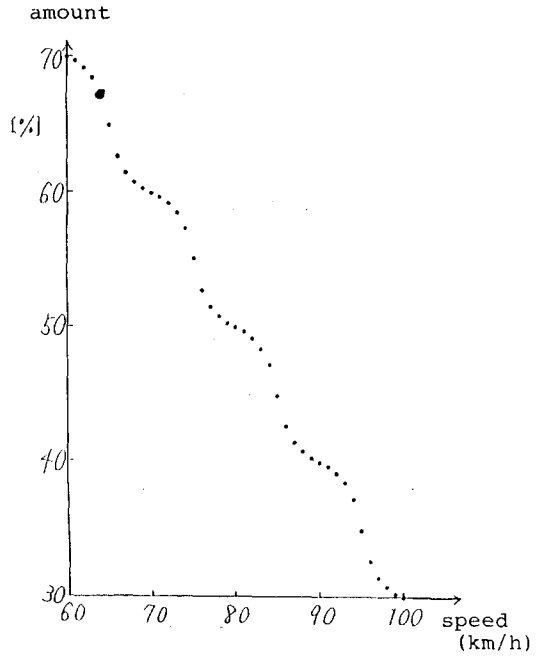
Fig. 5. Explanation of defuzzification (C) with figures

And then, we calculate the point (value) of median. The same of calculations are done for each 1 km/h of from 60 km/h to 100 km/h.

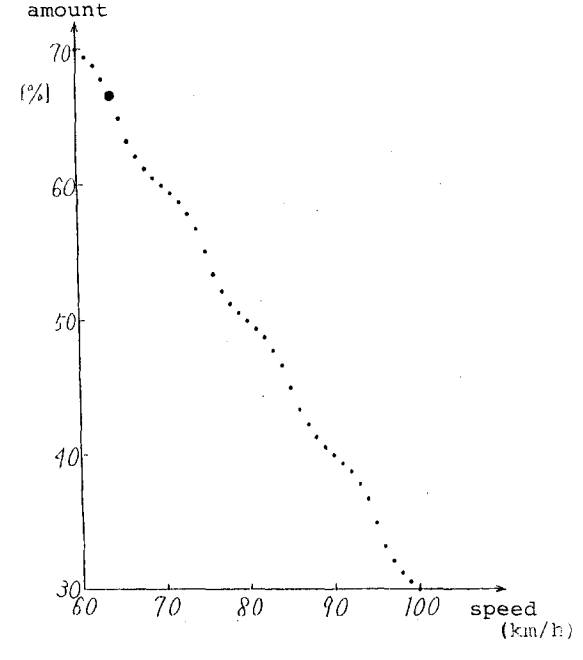
And a center of gravity method is used in weighted mean, a ratio of grades method is the ratio of two boundary grades, in a defuzzification.

The results (The graphs) of a defuzzification (A),(C),(G) and (I), as the typical types, are shown the following.

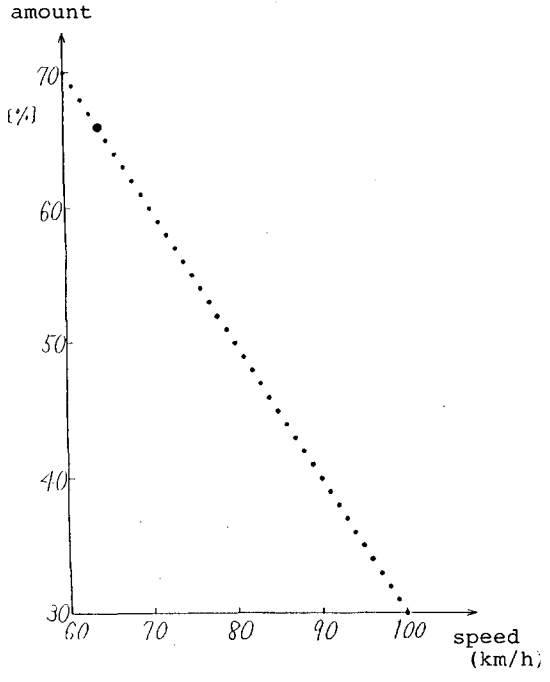
See Fig. 6.



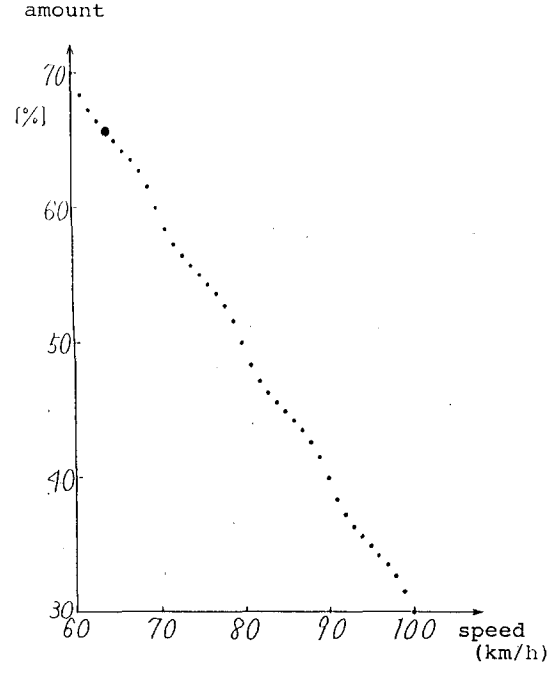
(A) algebraic - max - median method



(C) min - max - median method



(G) algebraic - addition - center of gravity method



(I) min - addition - center of gravity method

Fig. 6. The results of a defuzzification (A), (C), (G) and (I)

3. Conclusion

In this paper, to the decision making fuzzy problem (the problem decided on an amount to step on the accelerator corresponded to the speed) on a car driven in the high way, we introduced the decision making fuzzy model, and showed 9 kinds of the method on a defuzzification, and obtained the fuzzy solutions in this problem.

As we calculate the solutions for each 1 km/h (60 km/h ~ 100 km/h), such solutions are discrete and related the interpolution of ones, and as the result, to the evaluations on fuzzy solutions: for example, "Which is better, linear- or nonlinear-typed solutions?" "What is more fuzzy solutions?", it will be thought that fuzzy solutions (a defuzzification) should be chosen case by case, depending on their system's purposes.

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