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On a New Moving Method of Cloud Reasoning

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Abstract We proposed the principle of cloud reasoning based on the new idea of generating the consequent cloud, reflecting the expected value, variance, hyper-variance and movement to the consequent membership cloud in the view that clouded membership cloud can be considered as the movement of input membership cloud. The moving method of cloud reasoning by this principle satisfies the reductibility condition.

Key words cloud reasoning, moving method

Introduction

The great leader Comrade **Kim Jong Il** said as follows.

"Scientists and technicians should work to overcome by their own efforts the problems which require an urgent solution for the development of the national economy of our country, and to introduce the scientific and technical successes of developed countries in accordance with its specific reality."("**KIM JONG IL** SELECTED WORKS" Vol. 10 P. 195～196)

In the previous researches, they proposed cloud reasoning method inducting the conclusion using input information and feedforward cloud generator, and proceeded cloud reasoning without the cloudization of input information.

In the paper [2], there are some disadvantages that do not satisfy the reductibility because there is no cloudization of input information. The restoration is the property that consequent should be equal to the consequent of the cloud rule in the case that the fact information and the antecedent of the cloud rule when the cloud rule and the fact information are entered in the rulebase[1]. In the paper [3, 4], there is no process obtaining the variance and hyper-variance of the input cloud in generation of normal random number because of no cloudization of input. That is, it has some limitations in expressing the randomness of the antecedent of cloud rule and doesn't reflect the fuzziness and probabilistic characteristics which is one of the advantages of cloud theory simultaneously.

In this paper, we formulize the new idea of moving method of cloud reasoning based on moving method, and the basis of it we propose the cloud modus ponens from the new angle. Thus we overcome the disadvantage of the previous research[2－4].

1. Moving Method of Cloud Reasoning

We assume that there is some moving relation between the membership cloud of antecedent membership cloud and new input information when giving if~then~type cloud reasoning rule and the input information. Then moving method of cloud reasoning is defined as derivation of new consequent membership cloud by reflecting this relation in antecedent.

The simplest if~then reasoning modus ponens can be expressed as follows.

$$\begin{array}{ll} \text{antecedent 1} & \text{if } x \text{ is } A \text{ then } y \text{ is } B \\ \text{antecedent 2} & x \text{ is } A' \\ \text{consequent} & y \text{ is } B' \end{array} \tag{1}$$

where x is input variable, y output variable, A antecedent membership cloud, B consequent cloud, A' membership of input x' and B' consequent.

The concrete procedure realizing the moving method of cloud reasoning is as follows.

First the expected curved lines which the expected value of membership clouds A and B are x_0 and y_0, and width is b_A and b_B respectively are membership functions of A and B, represented as (2) and (3).

$$\mu_A(x) = e^{\frac{-(x-x_0)^2}{2b_A^2}} \tag{2}$$

$$\mu_B(y_k) = e^{\frac{-(y-y_0)^2}{2b_B^2}} \tag{3}$$

At that time the widths of the change of semi-normal rule b_{Alk}, b_{Ark} b_{Bl}, b_{Br} are as follows.

$$\begin{cases} b_{Al} = \dfrac{1}{3} \displaystyle\int_{x_0}^{x_0+\sqrt{\ln 8}b} \sqrt{1+[\mu_A'(x)]^2}\,dx \\ b_{Ar} = \dfrac{1}{3} \displaystyle\int_{x_0+\sqrt{\ln 8}b}^{x_0+3b} \sqrt{1+[\mu_A'(x)]^2}\,dx \end{cases} \tag{4}$$

$$\begin{cases} b_{Bl} = \dfrac{1}{3} \displaystyle\int_{y_0}^{y_0+\sqrt{\ln 8}b} \sqrt{1+[\mu_B'(y)]^2}\,dy \\ b_{Br} = \dfrac{1}{3} \displaystyle\int_{y_0+\sqrt{\ln 8}b}^{y_0+3b} \sqrt{1+[\mu_B'(y)]^2}\,dy \end{cases} \tag{5}$$

And deviation $E_n(x)$ and $E_n(y)$ are obtained as follows.

$$E_n(x) = \begin{cases} \sigma_{A\max} \exp\left(\dfrac{-(\Delta L_A)^2}{2b_{Al}^2} \right), & x \ge x_0 \\ \sigma_{A\max} \exp\left(\dfrac{-(\Delta L_A)^2}{2b_{Ar}^2} \right), & x \le x_0 \end{cases} \tag{6}$$

$$E_n(y) = \begin{cases} \sigma_{B\max} \exp\left(\dfrac{-(\Delta L_B)^2}{2b_{Bl}^2} \right), & y \ge y_0 \\ \sigma_{B\max} \exp\left(\dfrac{-(\Delta L_B)^2}{2b_{Br}^2} \right), & y \le y_0 \end{cases} \tag{7}$$

where

$$\Delta L_A = \int_{x_0+\sqrt{\ln 8}b}^{x} \sqrt{1+[\mu'(x)]^2}\,dx \tag{8}$$

$$\Delta L_B = \int_{y_0+\sqrt{\ln 8}b}^{y} \sqrt{1+[\mu_B'(y)]^2}\,dy \tag{9}$$

and $\sigma_{A\max}$ is the hyper deviation of antecedent membership cloud A, and $\sigma_{B\max}$ hyper deviation of consequent membership cloud B.

Fig. 1 shows the antecedent membership cloud A.

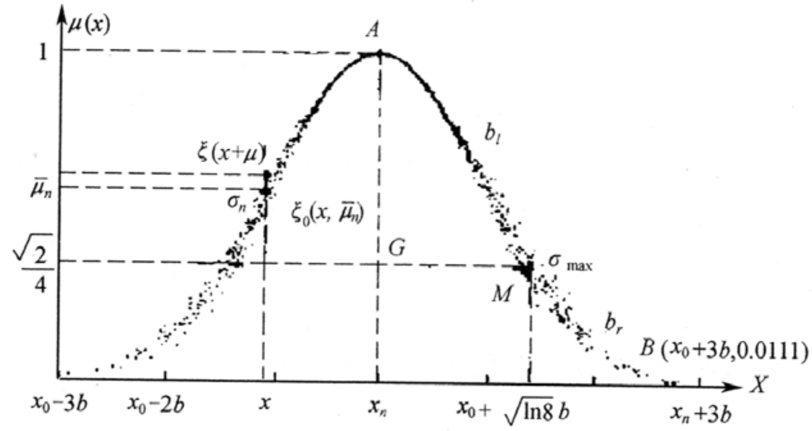

Fig. 1. Antecedent membership cloud A

Meanwhile the expected curved line which expected value is $x_{A'}$ and width is $b_{A'}$ is the membership of x expressed as (10), and the width of semi-normal rule change $b_{A'l}$, $b_{A'r}$ is expressed as (11).

$$\mu_{A'}(x) = e^{\frac{-(x-x_{x'})^2}{2b_{A'}^2}} \tag{10}$$

$$\begin{cases} b_{A'l} = \dfrac{1}{3}\displaystyle\int_{x_{x'}}^{x_{x'}+\sqrt{\ln 8}b} \sqrt{1+[\mu_{A'}'(x_{x'})]^2}\,dx \\ b_{A'r} = \dfrac{1}{3}\displaystyle\int_{x_{x'}+\sqrt{\ln 8}b}^{x_{x'}+3b} \sqrt{1+[\mu_{A'}'(x_{x'})]^2}\,dx \end{cases} \tag{11}$$

Then, deviation of membership cloud A' of input x' $E_n(x')$ is

$$E_n(x') = \begin{cases} \sigma_{A'\max} \exp\left(\dfrac{-(\Delta L_{A'})^2}{2b_{A'l}^2}\right), & x \ge x' \\ \sigma_{A'\max} \exp\left(\dfrac{-(\Delta L_{A'})^2}{2b_{A'r}^2}\right), & x \le x' \end{cases} \tag{12}$$

where

$$\Delta L_{A'} = \int_{x'+\sqrt{\ln 8}b}^{x} \sqrt{1+[\mu_{A'}(x)]^2}\,dx \tag{13}$$

and $\sigma_{A'\max}$ is the hyper deviation of membership cloud of input A'.

2. Moving Cloud Modus Ponens

Definition 1 The process obtaining membership cloud of reasoning result B' for membership cloud A' which is cloudized from input information for equation (1) is defined as (14).

$$(A \leftrightarrows A') \Rightarrow (B \leftrightarrows B') \tag{14}$$

where symbol $\leftrightarrows$ expresses the movement from antecedent membership cloud A to cloud A' of membership cloud of input information and the movement from consequent membership cloud B to output membership cloud B'.

Definition 2 To realize the cloud moving reasoning equation (14), we denote normal random number as NRN_k, denote cloud moving function as $CMF(x_k)$, and define them for k $(k=1, 2, \cdots, g)$, the number of cloud drop as follows.

$$CMF(x_k)=[(x'-E_x(x))+NRN_k] \tag{15}$$

where $E_x(x)$ is the expected value of the antecedent membership cloud A,

$$NRN_k = f(E_n(x),\ E_n(x'),\ H_e(x'),\ H_e(x)),$$

$E_n(x)$ is the deviation of the antecedent membership cloud A, $E_n(x')$ the deviation of membership cloud A' of input information, $H_e(x)$ the hyper deviation of antecedent membership cloud and $H_e(x')$ the hyper deviation of membership cloud A' of input information.

Definition 3 Consequent cloud moving action of cloud modus ponens for cloud drop number k $(k=1, 2, \cdots, g)$ is expressed as $CMA(y_k)$, and defined as follows.

$$CMA(y_k)=f(CMF(x_k)) \tag{16}$$

where f is the mathematical mapping and in case of one to one mapping, cloud moving action $CMA(y_k)$ of consequent is defined as (17).

$$CMA(y_k)=CMF(x_k) \tag{17}$$

According to how to select the mapping f in (16), the consequent membership cloud B' may be obtained variously. This is decided according to the detailed application object.

The process obtaining the consequent membership cloud as result is as follows.

The expected curved line which expected value is y' and width is $b_{B'}$ is the membership function of y and expressed as (18),

$$\mu_{B'}(y) = e^{\frac{-(y'-y)^2}{2b_{B'}^2}} \tag{18}$$

and the width of semi-normal rule change $b_{B'l}$, $b_{B'r}$ and its deviation $E_n(y')$ are expressed as follows.

$$\begin{cases} b_{B'l} = \dfrac{1}{3} \displaystyle\int_{y_0}^{y'+\sqrt{\ln 8}b} \sqrt{1+[\mu_{B'}(y')]^2}\,dy \\ b_{B'r} = \dfrac{1}{3} \displaystyle\int_{y'+\sqrt{\ln 8}b}^{y'+3b} \sqrt{1+[\mu_{B'}(y')]^2}\,dy \end{cases} \tag{19}$$

$$E_n(y') = \begin{cases} \sigma_{B'\max} \exp\left(\dfrac{-(\Delta L_{B'})^2}{2b_{B'l}^2} \right), & y \ge y' \\ \sigma_{B'\max} \exp\left(\dfrac{-(\Delta L_{B'})^2}{2b_{B'r}^2} \right), & y \le y' \end{cases} \tag{20}$$

where

$$\Delta L_{B'} = \int_{y'+\sqrt{\ln 8}b}^{y} \sqrt{1+[\mu'_{B'}(y')]^2}\,dy \tag{21}$$

and $\sigma_{B'\max}$ is the hyper deviation of consequent membership cloud B'.

Definition 4 The expected value of new consequent membership cloud B', y' is defined as follows.

$$y' = y + CMA(y) \tag{22}$$

where

$$CMA(y) = \frac{1}{g}\sum_{k=1}^{g} CMA(y_k)\,.$$

The membership cloud B' of the cloud reasoning result by moving method can be expressed as follows.

$$B' = \int \mu_{B'}(y')/y' = \int \mu_B\ (y + CMA(y_k))/(y + CMA(y_k)) \tag{23}$$

Equation (23) means that new reasoning result, membership cloud B' is obtained by moving the consequent membership cloud according to (22) corresponding to the moving of antecedent membership cloud A and input membership cloud A'. And the definite reasoning value can be simply obtained from (22).

Therefore the moving method of cloud modus ponens is formularized as the following 4 steps.

Step 1 For the cloud modus ponens expressed as (1), the expected curve of membership clouds A and B are obtained using (2)－(5).

Step 2 $E_n(x)$ and $E_n(y)$, the deviation of membership cloud A and B respectively are obtained using (6)－(9).

Step 3 Membership cloud A' which is cloudized from input information x' and its deviation $E_n(x')$ are obtained using (10)－(13).

Step 4 Obtain the normal random number and cloud moving function by using definition

2 to realize the cloud moving method by definition 1, obtain consequent cloud moving action by using definition 3 and calculate the membership cloud B' of reasoning result by using definition 4.

Conclusion

In this paper, we newly formularized the moving method of cloud reasoning based on the moving method of fuzzy reasoning, proposed the moving cloud modus ponens and showed that it not only satisfies the reductibility but also reflects the characteristics of the membership cloud.

References

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