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Uncertainty Reasoning Research Based on the Expert System of Reasoning Network Model

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Abstract: Based on the rule chains, this study proposes a kind of reasoning network model. This model keeps track and correction to the uncertainty network caused by external evidence. On the basis of existing initial network built by rule base has been established, this model added corrective networks which include external evidence and made probability calculation again for the rule chains which influenced by external evidence. It makes sure the veracity in the uncertainty reasoning process. From the instance analysis we can see that the tracking result met the expectation, concluded the correct rule chains, accurately found the object assertion and gave out the correct reasoning result. It optimized the choosing decision-making function of expert system.

Key words: Expert system,uncertainty,reasoning network

INTRODUCTION

Expert system is a computer system like experts can resolve difficulty and complicated practical issue that is applied to a certain specialized field, the knowledge engineers through knowledge acquiring means, put the the knowledge of certain fields of experts solved, use some kind of knowledge to express method edit or automatically generate a certain expressive form, store in knowledge bases and then by inputting information, data or orders on man-machine interface, users can apply reasoning machine to control knowledge base and the whole system (Yang *et al*., 2007).

Uncertainty means could not know some issues or some decisions' outcome in advance, in another word, if only the possible outcomes of issues or decisions more than one, the outcome will generate uncertainty (Li, 2005; Bian, 2010) This study by taking the gear cutting error analysis for example detailedly described the uncertainty's solution in the error judgment process.

UNCERTAINTY REASONING

Establishment of uncertainty reasoning model: This study use the way of block associative network to express the whole model of reasoning network, as shown in Fig. 1. The model is the reasoning network formed by linked rules. The rules use the production rule to express, the assembly structure belong to the same set is represented by a set of production rules. At the mean time, these rules all have uncertainty coefficient attached.

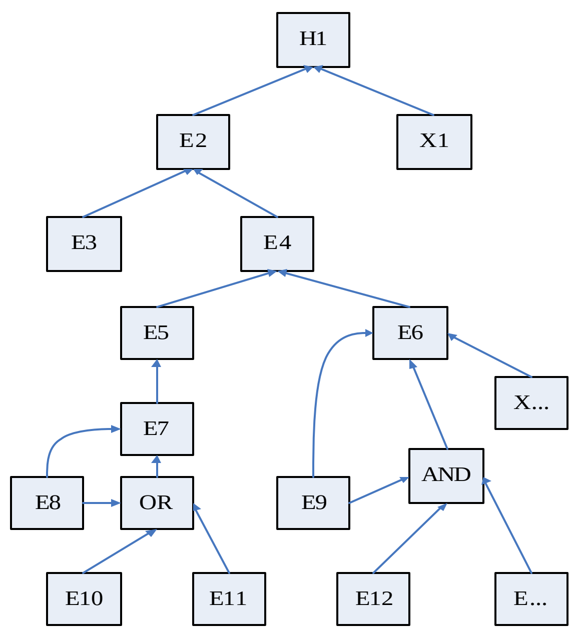

Fig. 1: Model of reasoning network

The specific facts in cases are represented by assertions in reasoning network and these facts are collected by asking users.

In the above figure, H_1 means object assertion, E_i means sub-object assertion, X_i means external evidence assertion, i = 1, 2, …, n.

Description of uncertainty reasoning process: First of all, the external assertions are provided by users, used for

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modifying the prior probability of the object assertion (Li, 1991). By the forward reasoning, system try to confirm the most probable object assertion. In this study, they are the set of the causes of gear cutting error.

After this, object assertion tracked by reverse chain, ascertain all the rules which regard this assertion as conclusion and pick the rule which most influential to current probability of the original assertion be tracked, the chosen rule's first component will become the next assumption be tracked. Follow this step, we can link up a rule chain access to a ending assertion. When the next tracking assumption corresponding an external evidence, users will be asked about this evidence. The effect produced by users response will immediately spread along the reasoning chain, until the probability of every object assertion that would be arrived that from the given ending assertion are all modified. when the spreading process finished, if the current object assertion still is the most probable assertion, then the backward reasoning will restart from this spot of the assertion be interrupted. Or, the backward reasoning will restart from the new most probable assertion (Johnson and Kelafunuo, 1989). The process of assertion reasoning transform as shown in Fig. 2.

Rule representation method: Production rule is an extremely natural knowledge representation and it has accuracy and flexibility (Zhang *et al*., 2002). This study uses production rule to represent knowledge. Its forms are as follows:

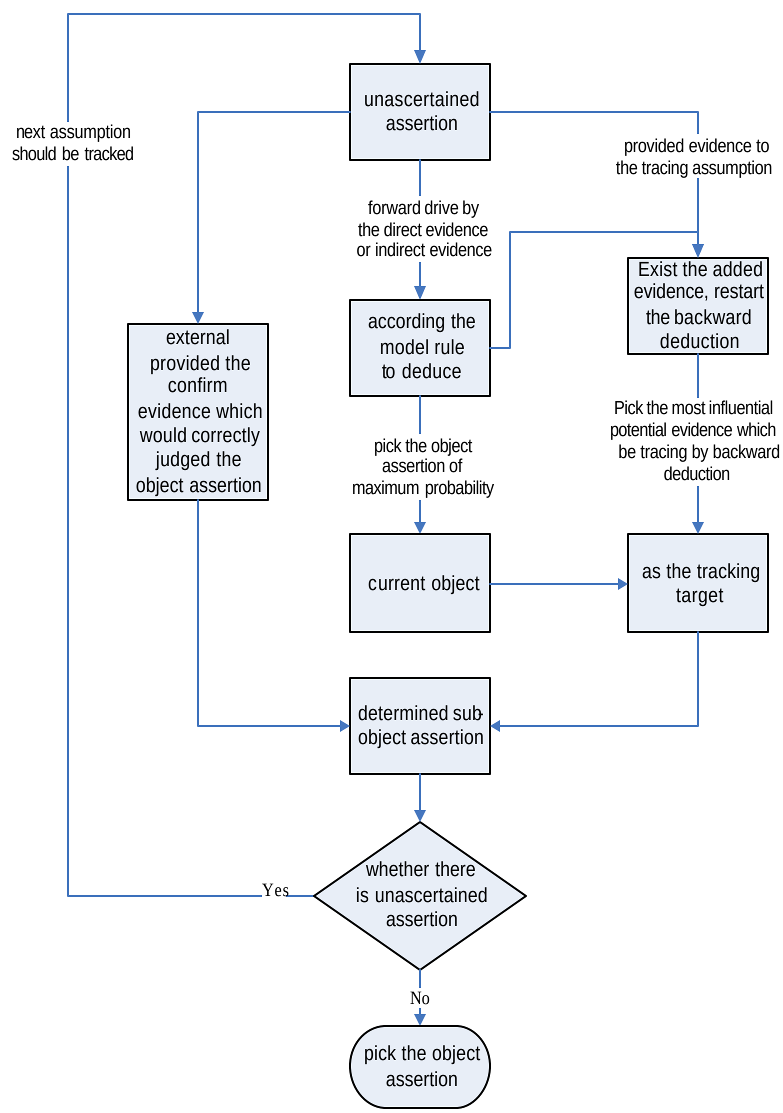

Fig. 2: Process of assertion reasoning transformation

- IF E THEN H (satisfied μ or ω established) among them:
  - μ means when H, the size of sufficiency of E:

$$\mu = \frac{P(E/H)}{P(E/\sim H)}$$

- ω means whenH, the size of necessity of E:

$$\omega = \frac{P(\sim E/H)}{P(\sim E/\sim H)}$$

All given by experts.

Uncertainty reasoning algorithm based on PROSPECTOR: According to Bayes' theorem:

$$P(H/E) = \frac{P(E/H)P(H)}{P(E)}$$

we can conclude:

$$P'(H/E) = \frac{P(H/E)}{P(\sim H/E)} = \frac{P(E/H)}{P(E/\sim H)} \cdot \frac{P(H)}{P(\sim H)} = \mu \cdot F(H) \quad (1)$$

$$P'(H/\sim E) = \frac{P(H/\sim E)}{P(\sim H/\sim E)} = \frac{P(\sim E/H)}{P(\sim E/\sim H)} \cdot \frac{P(H)}{P(\sim H)} = \omega \cdot F(H) \quad (2)$$

F(H) means the prior probability of H be true; P'(H/E) means when observed E, the posterior probability of H be true; P' (H/~E) means when observed E doesn't exist, the posterior probability of H be true.

According the above equation, we can bring out the relevant probability is:

$$P = \frac{P'}{P'+1}$$

The equation 1 is used for modifying the probability of H when observed E and it should use the sufficiency coefficient μ when modify it. The formula 2 is used for modifying the probability of H when observed E does not exist and it should use the necessity coefficient ω. When the current object assertion does not be confirmed, the multiple of probability which influenced by external evidence should be modified. So the modified multiple of probability is estimated to be:

$$\eta = \frac{F(H/E')}{F(H)}$$

Combination of the assume evidence: If an evidence represents another few evidences' logical combination, then its probability could got from its various components (Chen, 2011).

If exists:

$$P(E_1)\wedge P(E_2)\wedge \ldots \wedge P(E_i)$$

then:

$$CF(P) = \min(P(E_1), P(E_2), \ldots, i = 1, 2, \ldots, n$$

If exists $P(E_1) \vee P(E_2) \vee \cdots \vee P(E_i)$.

Then CF (P) = max $(P(E_1), P(E_2), \ldots, P(E_i), i = 1, 2, \ldots, n)$;

CF (P) is the final probability result of object assertion combined by evidences.

APPLICATION INSTANCE

Explanation of relevant parameters: Part of knowledge showed in Table 1.

Comparison table of part of knowledge parameters.

Uncertainty reasoning process of instance: This study introduces the uncertainty reasoning process of expert system by taking processing error of hobbing machining spur gear for example (Lu, 2005).

Table 1: Knowledge table

No.	Description of knowledge content
E_1	Hobbing
E_3	Spur gear
E_6	No. of modulus 30
E_8	Gear parameter
E_{10}	No. of modulus 6
E_{12}	Accuracy class 8
E_{15}	Radial jump 60<Fr<110 μm
H_6	Runout of radial jump of gear Fr over a little stroke
H_7	Runout of radial jump of gear Fr seriously over stroke
H_{10}	Installed location is inaccuracy when machining wheel blank, result in geometry eccentric
H_{11}	Center and center hole are ill manufacturing that makes locating surface contacted

Table 2 Knowledge parameters

	Prior probability P	μ
E_1	0.06	80
E_3	0.05	95
E_6	0.03	85
E_8	0.08	80
E_{10}	0.04	80
E_{12}	0.05	85
E_{15}	0.05	90
H_6	0.04	80
H_7	0.06	90

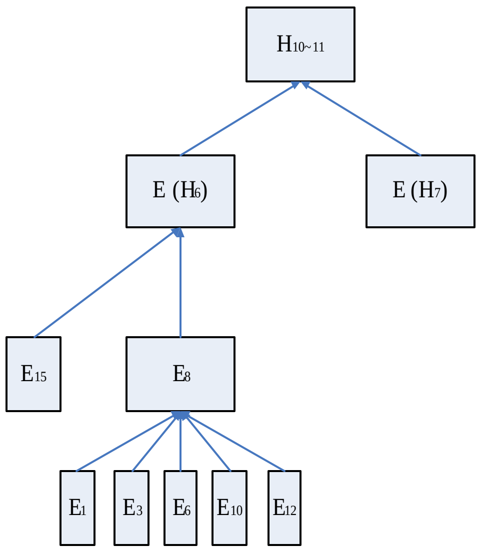

Fig. 3: Model of the early diagnosis

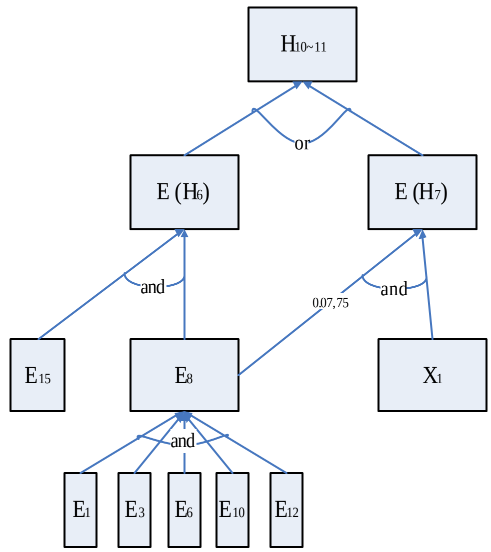

Fig. 4: Network model with external evidence

Table 3: Accurate external evidence

No.	Description of evidence	Prior robability P	μ
X_1	radial jump Fr>110 μm	0.04	70

Suppose during the early reasoning diagnosis process, according to the positive data drive reasoning, we got the following network reasoning result from the rule base (Fig. 3).

Users according to the network model provide accurate external evidences(this study regard the observed result as external evidence), suppose the accurate external evidence is

According to the assertion transform process, got the reasoning network structure which added external evidence, this structure described the process of according to the prior parameter, use the rule selection way of data drive, build a reasonable rule process and then got the best object assertion. The model of reasoning network structure which added external evidence, as shown in Fig. 4.

As can be seen from the figure,because X_1 actually exist, this external evidence will spread on this network and will modify the rule chain's assertion probability which related to the external evidence.

According to the Eq. 1, we got:

$$P'(E(H_7)/E_8) = 75\times\left(\frac{0.07}{1-0.07}\right) = 5.64525$$

$$P(E(H_7)/E_8) = \frac{5.64525}{1+5.64525} = 0.84952$$

$$P'(E(H_7)/X_1) = 70\times\left(\frac{0.04}{1-0.04}\right) = 2.9169$$

$$P(E(H_7)/X_1) = \frac{2.9169}{1+2.9169} = 0.7447$$

According to the rule of evidences combination, CF (P (E(H_7))) = min (0.84952, 0.7447 = 0.7447), Because influenced by the external evidence, E(H_7) didn't get a certain conclusion, it will be modified, the modified probability is:

$$\eta(E'(H_7)) = 90\times\frac{0.7447-0.04}{1-0.04} = 66.0654$$

Thus:

$$P'(H_{1011}/E'(H_7)) = 66.0654\times\left(\frac{0.06}{1-0.06}\right) = 4.21695$$

$$P(H_{1011}/E'(H_7)) = \frac{4.21695}{1+4.21695} = 0.80832$$

$$P'(H_{1011}/E(H_6)) = 80\times\left(\frac{0.04}{1-0.04}\right) = 3.3336$$

$$P(H_{1011}/E(H_6)) = \frac{3.3336}{1+3.3336} = 0.76924$$

According to the rule of evidences combination:

CF (P ($H_{10,11}$)) = max (0.76924, 0.80832) = 0.80832

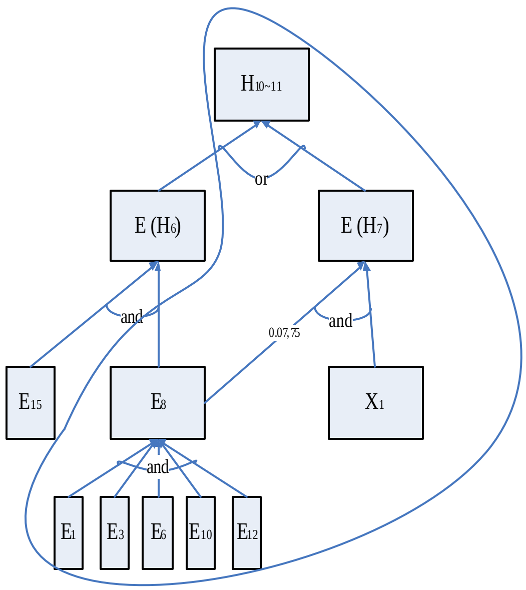

Fig. 5: Rule chain of the object assertion

According to the probability result we can see, through compared with the rule chain that tracked by the original model and then modified, the object assertion finally chose to conform the objective reality, picked the new rule chain with external evidence, determination of the rule chain provided the fundamental basis for accuracy of object assertion, the uncertainty evidence with external evidence could be determined by tracking and make the uncertainty problem become a certain rule chain, then finally got the accurate object assertion. The rule chain which reached object assertion, as shown in Fig. 5.

CONCLUSION

This study proposes one kind of reasoning network model. This model is formed by rule chains, through classification and identification and forward backward reasoning tracing and make the uncertainty problem become a certain rule chain. It reflects in that through tracing the rule base has already been established and build a initial network reasoning model. When meets a external evidence which actually exist, add the external evidence in a proper place of network model and modify the uncertainty network model caused by added external evidence. Then compare with the certainty model has already been established, by tracing the certainty rule chain with external evidence to find the object assertion which conformed the objective reality. From the instance analysis we can see that the tracking result met the expectation, concluded the correct rule chains, accurately found the object assertion and gave out the correct reasoning result. It optimized the choosing decision-making function of expert system.

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