AN EXPERT SYSTEM BASED ON FUZZY DEFAULT INFERENCE IN IDENTIFICATION OF CHINESE MEDICINAL HERBS

Zhou Faqiang Sun Jizheng Yuan Pu

Teaching Group of Information & Knowledge Engineering
Dept. of Automation, China Institute of Mining & Technology, Xuzhou, Jiangsu, P.R.China

ABSTRACT The present paper, divided into three parts, introduces an expert system (Mehes) used in the identification of medicinal herbs, particularly the new theory we put forward to realize Mehes -- Fuzzy Default Inference (FDI), i.e. the combination of fuzzy inference and default inference. Part I, the introduction, introduces the necessity of realizing the expert system. Part II states eight distinctive features of Mehes. Our focus is on part III. In this part, the principle and algorithm of FDI are described in detail. This theory can be used not only in Mehes, but also in other expert systems. It can effectively process experience knowledge, uncertainty and fuzzy knowledge. Thus laying the foundation of the study and the realization of new generation expert system.

Introduction

The position and influence of traditional Chinese medicine and Chinese medical science are well-known. Especially in recent years, more and more people in the world are becoming interested in them and pay more attention to them. More and more medicinal herbs and its end products are imported from China. In Japan, for instance, the sale volume of the end products of medicinal herbs raises 23 to 33 % every year in recent years, the total sales had reached 33.7 billion yen by 1981.

Over a long period of time, the identification or inspection of medical herbs remains a main problem in medicine. This is the basic work that must be done. The ansmer to this problem will directly affects the clinical curative effect and human being's healthy. But as we know, the kinds of medicinal herbs are great in number (About 4000 kinds, in which the often used is near a thousand), they have a long history and wide-range producing areas. So there are herbs in which either different herbs have the same name or the same herb has defferent names. Moreover, in recent years similar and substitute articles continously emerge and in addition many herbs are similar in appearance. Because of the above reasons, there are many difficulties in the work of identification of medicinal herbs. The work often needs the help of many experts besides its large working amount and long working period. Seeing that case, we cooperate with Inspection Institute of Medicine in Baoying, Yangzhou, Jiangsu P.R.C. applying artificial intelligence techniques to identification of medicinal herbs so as to realize an expert system in prolog -- Mehes.

Distinctive Features of Our System

This expert system based on fuzzy default inference has many distinguishing characteristics in functions, structure and applied technology It can be discribed as follows in brief:

1. Since new artificial intelligence technology -- fuzzy default inference, is developed and adopted, the period of identification is greatly cut down and the accuracy is greatly raised.

2. Also for raising its accuracy, we comprehensively use three kinds of indentification, i.e. experience identification, micrological identification and physical-chemical identification.

3. In knowledge representation. one of the techniques we used is classified tree. This make it possible to quickly search and match.

4. In inference, we adopt two kinds of inference, forward and backward, besides developing the technique of fuzzy default inference. This greatly strenthens the system function.

5. In programming, we adopt modelizing programming. This makes the structure of the program crystal-clear, the program easy to be read, modified and transplanted.

6. In interface, any expert system must set up friendly interface with its user. This is also a distinguishing characteristic of our system. In our system we adopt menu displaying to collect user's primitive data. This makes it convenient for user to use.

7. In interpret, our system has better interpret function and this make its answer easy to be understood and accepted.

8. In machine learning, our system has better learning function.

The Principle of Our System

Here, we'd like to introduce you some of the techniques we have developed and adopted. Our focus will be on the techniques we have especially developed for our system by ourselves. (Certainly, this technique can be transplanted). others will only be briefly related.

1. Knowlegde Representation

Just as we know, the amount of medical herbs is very large. Knowledge representation will directly influence the effeciency of inference engine, searching and matching. Further more, it will influence the success and failure of our system. In our system, experts' experience is expressed as rules, and this is convenient to infer. Large number of facts is composed in data base. The database take the structure of classified tree since all herbs can be classified in ten groups depending on its using part in medicine.

See Fig. 1 below:

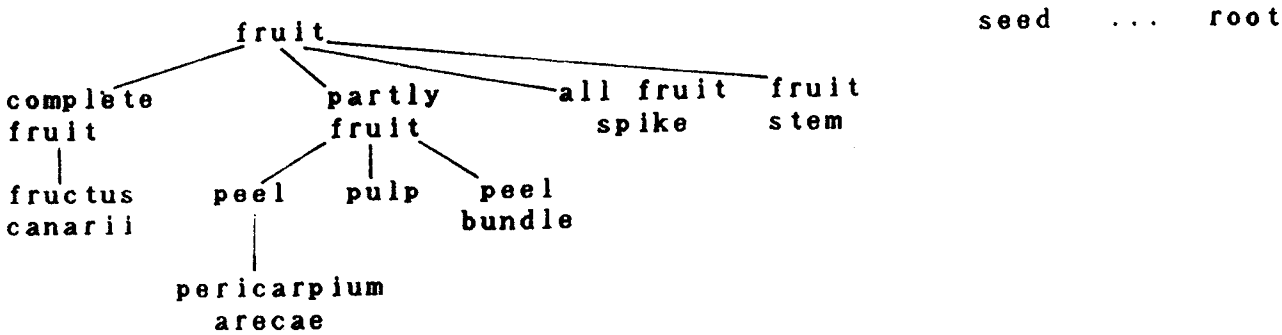


Fig. 1 the structure of database

2. Inferenc

(1) Way of Inference
In our system, we adopt forward and backward inference. To backward inference we will give a brief description below.

Firstly, the user or system put forward some hypotheses, then system verifys their truthfulness one by one. The inference process is related as follows:

a) Verify wether the goal is in data base. If it is , then the goal succeed, inference ends or goes to the next goal; if not, goes to next step.

b) Judge wether goals are leave nodes. If they are, system would ask user for the needed facts; otherwise goes to next step.

c) Find out those rules in which the goal is partly included in conclusions, take all the antecedents of the rules as new goals.

d) Repeat above three steps.

(2). Inference Model -- FDI
The intelligence identification of our system mainly embody in two aspects from the way of realization of system: (i) adpot the techniques of artificial intelligence (ii) adopt experts' identification experience from the domain. Both of them greatly raise the effeciency and result of identification.

Experts'experience,however, is not always effective (it is uncertainty) and is often fuzzy. But as we know, experts' work is quite exerllent. For effectively imitating this thinking characteristics of experts in our system, we put forward a new inference model ---- Fuzzy Default Inference(FDI), which can process uncertain knowledge and experience knowledge.

The basic thought of FDI is to introduce default inference onto fuzzy inference, whose inference form is:

$$\frac{\widetilde{P(x)} \ : \ M \ \widetilde{Q(y)}}{\widetilde{Q(y)}}$$

or: $\widetilde{P(x)}$: M $\widetilde{Q(y)}/\widetilde{Q(y)}$

or: $\widetilde{P(x)}$: M $\widetilde{Q(y)} \supset \widetilde{Q(y)}$

or: $\widetilde{P(x)}$ M $\widetilde{Q(y)}$ --> $\widetilde{Q(y)}$

Note: $\widetilde{P(x)}$ & $\widetilde{Q(Y)}$: fuzzy proposition.
M: If we tacitly approve that (x) is true and do not lead to controdictory, the meaning of this form is: under premise $\widetilde{P(x)}$ if we suppose that $\widetilde{Q(y)}$ is true and do not lead to controdictory then we default $\widetilde{Q(y)}$ is true.

The reckon of $\widetilde{Q(y)}$ can use goal-driven (or data -driven) default theorem prover depending on the thought of forward inference, backward inference and linear resolution principle.

The fuzzy true value of $\widetilde{Q(y)}$ can be got by using FTS algorithm (The solving of fuzzy true value). Relevant principle and algorithm can be related separately as follows:

a) Linear Resolution Principle
Suppose that subclause set S is known, the linear resolution proving of solving B has the form of Fig.2 described.

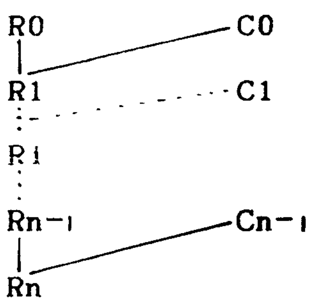


Fig.2 Known subclause set S linear resolution proving of β

Interpretation of Fig.2
(a). The first subclause R_0 is $\sim\beta$ subclause
(b). To $1 \le i \le n$, Ri is a resolution subclause of R_{i-1} and C_{i-1}.
(c). To $0 \le i \le n-1$, $Ci \in S$ or Ci is sub-clause $\sim\beta$ or Ci is Rj (here j<i)
(d). $Ru=\square$, $\square$ stands for empty subclause

b) Goal-driven Default Theorem Proving
Linear resolution is a theorem proving of goal-driven. If we realize the default theorem proving by linear resolution principle, then we must transform the default theory into the form of subclauses. So at first we need a way to represent default theory $\Delta=(D,W)$.

Definition 1.
Suppose that (a). the general form of default theory is: $\Delta=(D,W)$, D is a default set, W is a definite form;
(b). W is a subclause of Δ;
(c). $\delta=(\alpha : M\ W/W) \in D$;
(d). C_1 C_2 ... Cr is subclauses of W;
then sequencial pair (Ci (δ)) is called a conclusion subclause of default δ($1 \le i \le r$).

In fact, the conclusion subclause of will be a general subclause of W.

Definition 2.
Given and a closed normal default theory $\Delta=(D,W)$, then the goal-driven default proving of based on is a linear resolution proving sequence L ,L , ... ,Lk. This sequence set up the following conditions:

(a). L is the linear resolution proving of B based on CLAUSE(Δ);
(b). To $0 \leqslant i \leqslant k$, Li return back Di;
(c). To $1 \leqslant i \leqslant k$, Li is the linear resolution proving of PREQUISITES(D_{i-1}) based on CLAUSE(Δ);
(d). $Dk=\Phi$;
(e). $W \cup \bigcup_{i=0}^{k}$ CONSEQUENTS(Di) is able to be satisfied.

Theorem 1. (The perfection of goal-driven default proving)
Suppose that $\Delta=(D,W)$ is a consistent closed normal default theory, β is closed form and $\beta \in L$, then the sufficient and necessary condition of β's extension exist in Δ is that there is goal-driven default proving of Δ in β.

An example of goal-driven default theorem proving.

Have known that $\Delta=(D,W)$ has default:

$$\delta_1 = \frac{E \vee F : M\ (A \wedge F)}{A \wedge F} \qquad \delta_2 = \frac{A : M\ B}{B}$$

$$\delta_3 = \frac{A \wedge E : M\ C}{C} \qquad \delta_4 = \frac{: M\ E}{\sim E}$$

$W=\{ C \supset D,\ A \wedge B \supset E,\ E \vee D,\ D \supset F \}$

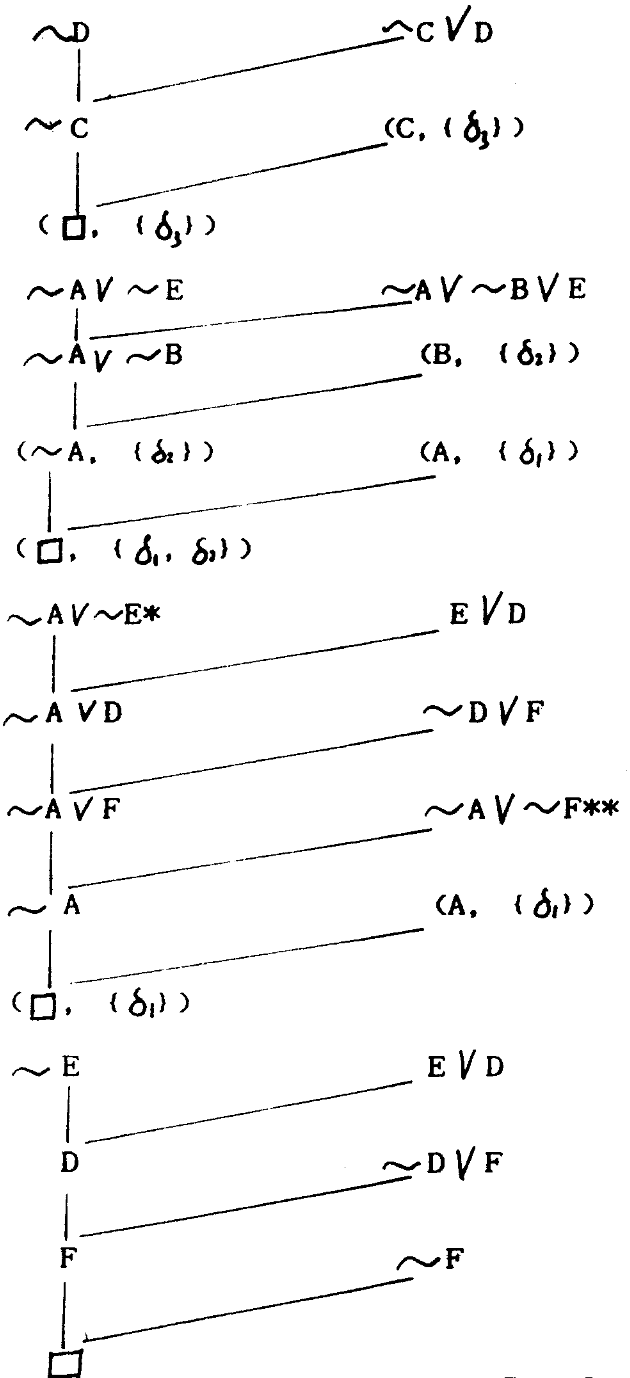
PROVE:
Δ has two extension $E1=Th(W \cup \{A \wedge F, B\})$, $E2=Th(W \cup \{A \wedge F, \sim E\})$. Both E1 and E2 include D. The default driven proving of element D of E1 and E2 on Δ is separately Fig.3(a) and Fig.3(b). See Fig.3.

c). Fuzzy Technique in FDI -- algorithm FTS
FTS is our preliminary work in combining fuzzy inference and default inference. Now we have put forward a newer and better method -- Twice Principle of Fuzzy Default Inference (TPFDI). Here we will briefly present you of FTS (it is a subprogram of FDI).

For introducing the thought of fuzzy inference into FDI, we express assertion as (A, U(A)) and has the following definitions:

Definition 1.
To any assertion (A,U(A)), U(A) is a subset of fuzzy set U=(0,1) and it is closed interval on the left. That is $(0, U_A)$ or $(0, U_A)$ in which $U_A \in U$. U(A) is called attached-degree of A.

Definition 2.
Suppose that P is set of premise of FTS (basic proposition or axiom). If x P, then Mx P. Mx represent default proposition.



* is a subclause of PREREQUISITES ({δ_1, δ_2})=A $\wedge$ (E $\vee$ F)

** is another subclause of PREREQUISITES ({δ_1, δ_2})=A $\wedge$ (E $\vee$ F)

Fig. 3 (a)

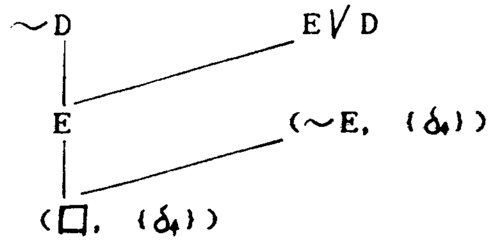


Fig. 3 (b)

Fig. 3

Definition 3.
Suppose that A is any proposition formula on FTS. U(A)=(0, u_A) or U(A)=(0, u_A), then:

xt(A)= u_A ; xf(A)=1− u_A ;

$$xT(A)=\begin{cases}1 & I(U(A))=(0,1) \quad \text{Definition of I is omitted}\\ 0 & \text{others.}\end{cases}$$

$$xF(A)=\begin{cases}1 & I(U(A))=(0);\\ 0 & \text{others.}\end{cases}$$

Definition 4.
Suppose that Ai & B is proposition formula and ui & u is separately right boundary of U(Ai) & U(B).

when B= not A1 then $U(B)=\begin{cases}(0,\ 1-u1), & \text{when } U(A1)=(0,u1);\\ (0,\ 1-u1), & \text{when } U(A1)=(0,u1).\end{cases}$

when B=A1 and A2 then $U(B)=U(A1)\wedge U(A2)$.

when B=A1 or A2 then $U(B)=U(A1)\vee U(A2)$.

when B=A1 --> A2 then $U(B)=\begin{cases}(0,\ 1), & \text{while } X_T(A2)+X_F(A1)\geqslant 1;\\ (0,\ \min(1-u1+u2,\ 1)), & \text{others.}\end{cases}$

when B=A1 <--> A2 then $U(B)= U(A1\text{-->}A2)\wedge U(A2 \text{-->} A1)$.

Relation definition is omitted.

The basic thought of algorithm FTS is described as follows:

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ALGORITHM FTS:
(Algorithm of Fuzzy True Solving)
PROCEDURE FTS(B); (B is the assertion to be deduced)
BEGIN
 FOR each rule R in the rule base that has B as its head DO
   BEGIN
    IF (A1,A2,...and An already exist) AND ((A1A2...An ->B) is a tautology)
     THEN (Ris a standard deductive rule)
     BEGIN
      U(B):=U(B) U U(A1) U U(A2) U ... U U(An);
       (The non-existing proposition has a fuzzy criterion of (0))
      CASE

       Xt(B)=Xt(NOT(B))=1: CONTRIDICTION PROCESSING;

       Xt(B)=1:              BEGIN
                                  IF Xt(B)=1 THEN U(B):=(0,1);
                                  U(NOT(B)):=(0);
                                  U(NOT(MB)):=(0);  (Delete NOT(B),NOT(MB))
                                  U(MB):=U(B);
                                  ADD(B,U(B));ADD(MB,U(LB));
                               END;
       ELSE BEGIN
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          ADD(B,U(B));
          U(NOT(B)):=(0,Xf(B));
          IF U(NOT(B)) > U(NOT(MB)) THEN U(NOT(B)):=U(NOT(MB));
          U(LB):=U(B);
         END;
   END;
   ADD(B,U(B));    {If B already exists then update the U value}
  END;
 END;
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MAIN REFERENCE

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