Application of a Logical Reasoning Approach Based Petri Net in Agriculture Expert System

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Xia Geng[1,a], Yong Liang [1,b], Qiulan Wu[1,c]

[1]Institute of Information Science and Engineering, Shandong Agricultural University, Taian Shandong 271000,China;
[a]gx@sdau.edu.cn, [b]yongl@sdau.edu.cn, [c]zxylsg@sdau.edu.cn

Abstract. First of all, a goal-guiding graphic reasoning approach that based on the predicate/transition system has been proposed for the first-order predicate logic. In process of reasoning, the premise is separated from the conclusion, which has been taken as the beginning of the backward reasoning that is purposeful and effective as well. Next, this reasoning approach has been applied in the agriculture expert system to present a method of solving problem, providing a new way for studying the reasoning mechanism of the agriculture expert system.

Keywords: first-order predicate logic, Predicate/transition system, goal guiding, graphic reasoning, backward reasoning, agriculture expert system

1 Introduction

Agriculture expert system in agriculture is to widely apply the accumulated knowledge and experiences of agricultural experts by using computer techniques which can overcome the limit of time and space, so as to turn these knowledge and experiences into productivity[1].

To construct a good reasoning mechanism is the basis of agriculture expert system. Reasoning means the process of searching the answers from knowledge base for the given problems when domain-specific knowledge has been stored into the base in a certain form. A reasoning process is to determine whether the given proposition is contained in the selected sets of the first-level of facts and clause rules[2-3]. In the reasoning processes of agriculture expert system there already have applied many approaches. Recent years, the expert system based Petri net and its application have become one of the research hotspots in the field of intelligent control and intelligent system[2]. Yet, it is not common that the Petri net model has been employed by agriculture expert system, and, theoretical system has not been established.

The first-order predicate logic has already enjoyed a wide application in computer science. For its safety and reliability, the practical results of some other logic theories turn out that, the applications in which these logic theories had been employed can get essential conclusions no more than the application in which only the first-order predicate logic had been employed, and can not get a better intelligent system[7].

Petri net offers a new way to study the first-order predicate logic reasoning. Not only the Petri net itself can provide an intuitive semantic frame for traditional logic symbols, but also its properties can be used for the randomness of logic reasoning, which finds a way for realizing the machine reasoning, and which increases the chances for dealing with reasoning problems by using different and effective ways.

For the first-order predicate logic reasoning, predicate/transition system (Pr/T system) of the high-level Petri net can be utilized to build the model. Based on the model, researches of logic reasoning are divided into two types. ① For the set of Horn clauses, the algorithm of computing T-invariants had been proposed[9,15-16]; four reasoning algorithms that can support the conclusions obtained and can be popularized to the first-order predicate logic had been proposed, through the improved strategies of resolution refutation [17]. ② For the set of non-Horn clauses, an efficient algorithm and the backward and forward approaches of analyzing T-invariants had been put forward in accordance with the necessary and sufficient condition of contradiction which is contained in the set of non-Horn clauses[18-19]; for propositional logics, the reasoning process is turned to solve the non-negative integer solutions of linear equations of the incidence matrix, and this principle can be applied for predicate logic[8].

However, the existing reasoning methods of the first-order predicate logic that based on Pr/T system are equal to the traditional resolution refutation method, in which premise and conclusion are put together to make up the reasoning. In such a way, some heuristic information are not easily to be used for reasoning process, where a large number of useless steps may exist and the reasoning processes are inefficient. Therefore, this paper proposed, by borrowing ideas from the and/or resolution refutation reasoning and based on the Pr/T system, a goal guiding graphic reasoning approach of realizing the backward reasoning, which is applied in the agriculture expert system.

2 Basic Concepts

We assume that our readers know well the knowledge of agriculture expert system, Petri net, the first-order predicate logic and reasoning. For simplifying the description, we just list some related concepts and terms here.

Definition 1[8]: Given that D is the nonempty finite set, and V is the nonempty finite symbol set.

If all of the symbols of V set are representatives of the elements of D set, then V can be deemed as a variable set of D, and these symbols are the variables of D.

(1)Both the elements and variables of D are called the D-terms of D. If $f^{(n)}$ is an equation of D with n unknowns, and $v_1, v_2, ..., v_n$ are terms of D, then $f^{(n)}(v_1, v_2, ..., v_n)$ is also a term of D, and, no other terms exist.

(2)The n-ary vector $< v_1, v_2, \cdots, v_n >$ of which the components of terms of D is called the n-ary tuple of D, where n＞1.

(3)The sum that multiple n-ary tuples of D are connected by "+" is called as the n-ary symbolic sum of D, symbolic sum for short. When $n = 0$, it is called as the empty symbolic sum, which is represented with "$NULL$" or "< >".

(4)The symbol "+" is commutative.

Definition 2[8]: Given that $\Sigma=(S,T;F,D,V,A_S,A_T,A_F,M_0)$ is the Pr/T system, which meets the following:

(1) $(S,T;F)$ means the directed net, which is the basic net of $\sum$.

(2) D is the nonempty finite set which is called as the individual set of $\sum$, and there are operative symbols set Ω of D.

(3) V is a variable set of D.

(4) A_S : $S\to\pi$, where, π is the dynamic predicate set of D, for $s\in S$, if $A_S(s)$ is a n-ary predicate, then s is called as the n-ary predicate.

(5) A_T : $T\to f_D$, where, f_D is the formulary of D, for $t\in T$, $A_T(t)$ can contain only the static predicates and operative symbols of Ω.

(6) A_F : $F\to f_S$, where, f_S is the symbolic sum set of D. For a n-ary predicate $s\in S$, if $(s,t)\in F$ or $(t,s)\in F$, then $A_F(t,s)$ or $A_F(s,t)$ is the n-ary symbolic sum. For $t\in T$, free variables in formula $A_T(t)$ must be the free variables of the directed arc with the end of t.

(7) M_0 : $S\to f_S$, for a n-ary predicate $s\in S$, $M_0(s)$ is the n-ary symbolic sum.

When describing a logic problem, the first-order predicates can be divied into two types: describing the premise and describing the conclusion.

In general, this paper adopts the method proposed in literature [14] to build the Pr/T system model for the first-order predicate.

Definition 3: Assume that P and Q are predicates that describe the premise and conclusion respectively. Given that $\Sigma_1=(S,T;F,D,V,A_S,A_T,A_F,M_0)$ and $\Sigma_2=(S,T;F,D,V,A_S,A_T,A_F,M_0)$ are Pr/T net systems corresponding to P and Q respectively, then Σ_1 is called as the premise Pr/T net system, or called as the premise net for short, and Σ_2 is called as the conclusion Pr/T net system, or called as the conclusion net.

Definition 4: Assume that $\Sigma=(S,T;F,D,V,A_S,A_T,A_F,M_0)$ is the conclusion net, then $\forall t\in T$ means the target transition.

Definition 5: The two-ary tuple of $N=(S,F)$ which meets the following conditions is called as Predicate-and/or graph, or called as Pre-and/or graph for short.

(1) $|S|\geq \boldsymbol{2}$

(2) $F\subseteq(S\times S)$

(3) $dom(F)\cup cod(F)=S$

where,

$dom(F)=\{x\in S|\exists y\in S:(x,y)\in F\}$

$cod(F)=\{x\in S|\exists y\in S:(y,x)\in F\}$

(4) $\forall s\in S$ represents an atomic predicate formula.

(5) $s_1,s_2,...s_n(n\geq \boldsymbol{2})$ means that the relation between predicates is “or”, if and only if: $\exists s\in S$ and $(s,s_i)\in F(i=\boldsymbol{1},\boldsymbol{2},...,n)$

(6) $s_1,s_2,...s_n(n\geq \boldsymbol{2})$ means that the relation between predicates is “and”, if and only if: $\exists s\in S$ and $(s_i,s)\in F(i=\boldsymbol{1},\boldsymbol{2},...,n)$

$(s_i, s) \in F(i = \boldsymbol{1}, \boldsymbol{2}, ..., n)$ is connected with semicircle.

(7)If $\exists x \in S, {}^{\bullet}x = \varnothing$, then the node x is called as the end-node.

Definition 6: Assume that $\Sigma = (S, T; F, D, V, A_S, A_T, A_F, M_0)$ is a Pr/T net system, and $\Sigma' = (S_1 \cup S_2, T'; F', D, V, A_{S_1 \cup S_2}, A_{T'}, A_{F'}, M_0')$ is a two-level place Pr/T subnet of ∑, if and only if all of the following conditions are met:

(1) $S_2 = \{s_1, s_2, \cdots, s_m\} \subseteq S (m \geq 0)$;

(2) $T' = \{t | t \in T, t^{\bullet} = S_2\}$, and T' is not null set;

(3) $S_1 = \{s | s \in S, \exists t \in T', \textit{which makes } s^{\bullet} = \{t\}\}$;

(4) $F' = \{(x_1, x_2) | x_1, x_2 \in S_1 \cup S_2 \cup T', (x_1, x_2) \in F\}$, for $\forall (x_1, x_2) \in F'$, $A_{F'}(x_1, x_2) = A_F(x_1, x_2)$, $A_{S_1 \cup S_2} : S_1 \cup S_2 \to \pi,$ where π is a dynamic predicate set of D; $A_{T'} : T' \to \textit{true}$, for $t \in T'$, $A_{T'}(t)$ is a static predicate, $M_0' : S' \to <>$. S_2 is the output place set of Σ', and S_1 is the input place set of Σ'.

If ∑ itself is a two-level place Pr/T subnet, then this ∑ is called as a two-level place Pr/T net.

For example, fig.1 shows the basic net of a two-level place Pr/T net. In particular, both S_2 and S_1 in definition 7 can be null set, but because that no independent node shall exist in the net, they can not be null set at the same time. Besides, provisions (2) and (3) of definition 7 do not require T' and S_1 to be the maximal set. Therefore, even S_2 has been determined, the obtained two-level place Pr/T subnet may not be the only one.

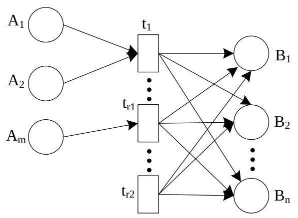


Fig. 1. The basic net of a two-level place Pr/T net

Definition 7: Assume that $\Sigma = (S, T; F, D, V, A_S, A_T, A_F, M_0)$ is a Pr/T net system, for $\forall t \in T$, if $t^{\bullet} \neq \varnothing$, then make $t^{\bullet} = \{s_1, s_2, \cdots, s_m\} (m \geq 1)$; define $\{s_1(X_1), s_2(X_2), \cdots, s_m(X_m)\}$ as the output predicate set of the transition t (where, $X_i (i = 1, 2, \cdots, m)$ is a term of $A_F(t, s_i)$). Similarly, if ${}^{\bullet}t \neq \varnothing$, then make ${}^{\bullet}t = \{s_1', s_2', \cdots, s_n'\} (n \geq 1)$; define $\{s_1'(Y_1), s_2'(Y_2), \cdots, s_n'(Y_n)\}$ as the input predicate set of the transition t (where, $Y_i (i = 1, 2, \cdots, n)$ is a term of $A_F(s_i', t)$). Elements of input/output predicate set are called the input/output predicate of transition t.

Definition 8: Assume that $\Sigma = (S_1 \cup S_2, T; F, D, V, A_S, A_T, A_F, M_0)$ is a two-level place Pr/T subnet, where, S_1 is the input predicate set of ∑ and S_2 is the output predicate set. For any atomic predicate formula set, $P = \{P_1(X_1), P_2(X_2), \cdots, P_n(X_n)\}$, the formula

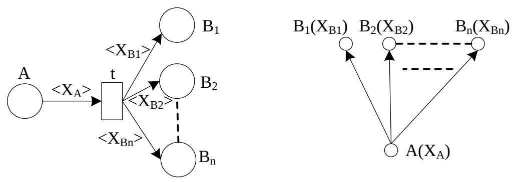
set is successfully matched with the two-level place Pr/T subnet ∑, if and only if both of the following conditions are met:
(1) The place set corresponding to the set P meets $\{P_1, P_2, \cdots, P_n\} = S_2$;
(2) Exist a replacement θ , which makes
$\forall t \in T$, $X_i\theta = A_F(t, P_i)\theta (i = 1, 2, \cdots, n)$.
For the purposes of simplifying discussion, we assume that:
(1) In definition 8, predicate symbols of the predicate formula set P are different;
(2) Each directed edge of the Pr/T net system has a $n(n \geq 1)$ -try tuple, and no symbolic sum forms that consist of $m(m \geq 2)$ n-try tuples.

3 Pre-and/or Graph Description of the Pr/T Net System

Assume that ∑ is a two-level place Pr/T net which contains $r(r \geq 1)$ transitions. According to the definition of the two-level place Pr/T net, ∑ can be shared composition of r two-level place Pr/T nets, each of which contains only one transition[22].

3.1 Pre-and/or Graph of the Two-level Place Pr/T Net System Which Contains Only One Transition

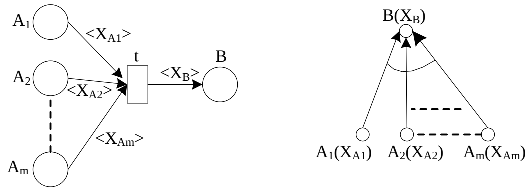
The ratio of the numbers of transition's input place and output place is represented by $m:n(m,n \geq 0)$. According to the different value of $m:n$, the discussion can be divided into the following:
(1) $1:n(n \geq 1)$, as shown in fig.2(a), and its Pre-and/or graph is shown in fig.2(b).



(a) $1:n(n \geq 1)$ (b) Pre-and/or graph corresponding to fig.(a)

Fig. 2. $1:n(n \geq 1)$ and its Pre-and/or graph

(2) For $0:n(n \geq 1)$, its Pre-and/or graph is similar to the fig.2(b), only that the atomic predicate formula $A(X_A)$ is replaced by " $NULL$ ".
(3) $m:1(m \geq 2)$, as shown in fig.3(a), and its Pre-and/or graph is shown in fig.3(b).

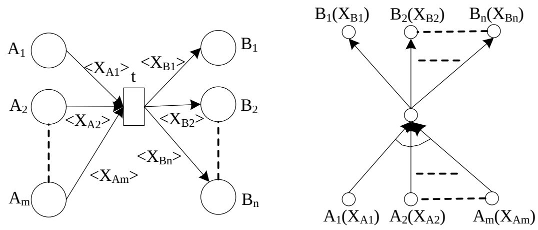


(a) $m:1(m \geq 2)$ (b) Pre-and/or graph corresponding to fig. (a)

Fig. 3. $m:1(m \geq 2)$ and its Pre-and/or graph

(4) For $m:0(m \geq 1)$, its Pre-and/or graph is similar to the fig.3(b), only that the atomic predicate formula $B(X_B)$ is replaced by "*NULL*".

(5) $m:n(m,n \geq 2)$, as shown in fig.4(a), and its Pre-and/or graph is shown in fig.4(b).



(a) $m:n(m,n \geq 2)$ (b) Pre-and/or graph corresponding to fig.(a)

Fig. 4. $m:n(m,n \geq 2)$ and its Pre-and/or graph

3.2 Pre-and/or Graph of the Two-level Place Pr/T Net

Theorem 1: Given that $\sum$ is a two-level place Pr/T net which contains $r(r \geq 1)$ transitions, and its Pre-and/or graph can be shared composition of the five Pre-and/or graphs described in section 3.1.

Proof of theorem 1: (1) when $r=1$, then the conclusion is always true.

(2) when $r>1$, we need to prove the following three situations according to the total number (n) of the output places of $\sum$ and definition 7.

1) When $n=1$, as shown in fig.5, where, $P_i(i=1,2,\cdots,r)$ is the output place set for t_i, and $|P_i| \geq 0$ (explanation for P_i is the same hereinafter). The graph of fig.5 can be made up with r subgraphs that shown in fig.6.

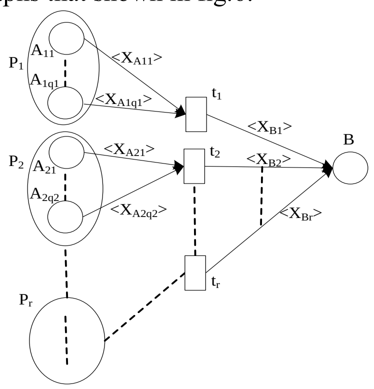


Fig. 5. $n=1$

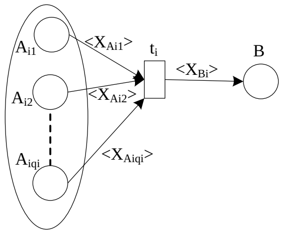


Fig. 6. A subgraph of fig.5

According to different $|P_i|$, the Pre-and/or graph of fig.5 can be composed by Pre-and/or graphs described in conditions (1), (2) or (3) of section 3.1.

2) When $n > 1$ as shown in fig.7, which can be composed by r subgraphs that shown in fig.8.

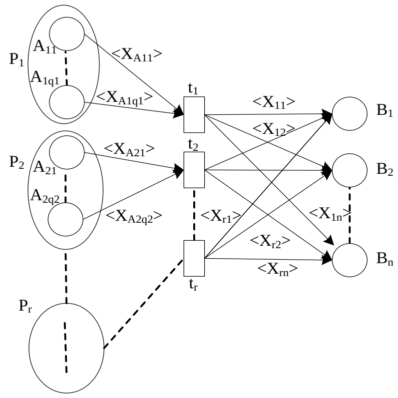


Fig. 7. $n > 1$

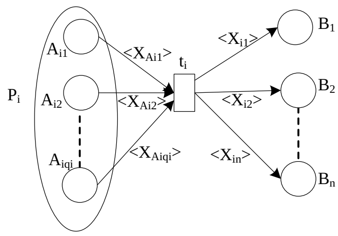


Fig. 8. A subgraph of fig.7

According to different $|P_i|$, the Pre-and/or graph of fig.7 can be composed by Pre-and/or graphs described in conditions (1), (2) or (5) of section 3.1.

3) When $n = 0$, as shown in fig.7 (where $|P_i| > 0$), which can be composed by r subgraphs that shown in fig.10.

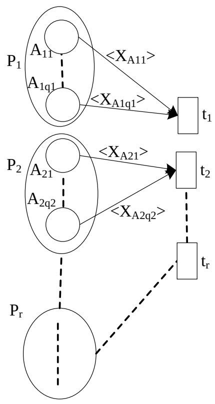


Fig. 9. $n=0$

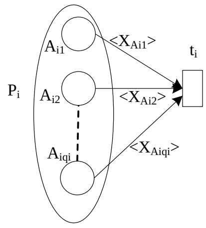


Fig. 10. A subgraph of fig.9

The Pre-and/or graph of fig. 9 can be composed by r Pre-and/or graphs described in conditions (4) of section 3.1.
From the above ,we know that theorem 1 is true. (over)
When $r>1$, the output place B of transition or $\{B_1, B_2, \cdots, B_n\}$ will appear r times in the Pre-and/or graph in conditions 1) and 2). In this paper, we regulate that in the reasoning process by referring to the Pre-and/or graph, only one (set) output place inherits the "and" or "or" relations of the original Pre-and/or graph, and these relations should be drawn up in the graph. For the rest $r-1$ (set) output places, although they also inherit the original "and" or "or" relations, they do not need to be drawn up for conciseness of the graph.

4 Graphic Reasoning of the First-order Predicate Logic

4.1 The Goal Guiding Graphic Reasoning Approach of the First-order Predicate Logic

We assume that the general form of the first-order predicate logic that needed to be proved is: $P: A_1, A_2, \cdots, A_m \to B$, in which, both the premise $A_i (i=1,2,\cdots,m)$ and conclusion B are the first-order predicate formulas, and B should be represented by prenex normal form without universal quantifiers. Specific steps of the goal guiding graphic reasoning approach of the first-order predicate logic are shown as follows:
Step1 Build the Pr/T net systems for $A_1, A_2, \cdots, A_m$, respectively, and merge the same places to obtain the premise net, which is assumed to be $\Sigma_1 = (S_1, T_1; F_1, D, V, A_{S1}, A_{T1}, A_{F1}, M_{01})$. Build the Pr/T net systems for predicate formulas which are after the quantifiers of B to obtain the conclusion net, which is assumed to be $\Sigma_2 = (S_2, T_2; F_2, D, V, A_{S2}, A_{T2}, A_{F2}, M_{02})$ [14]. Rename some variables to so that the same variables will not appear on the input/output arcs of different transitions;

Step2 For each target transition t_i ($i=1$ to $|T_2|$), initialize the corresponding Pre-and/or graph $G_i(i=1,2,\cdots,|T_2|)$ to be null;

Step3 for ($i=1$ to $|T_2|$){

Step3.1

(1) If the output predicates of t_i belong to a non-null set, then we assume the predicate set to be $Q_i=\{P_1(X_1),P_2(X_2),\cdots,P_n(X_n)\}(n\geq 1)$, and these n atomic predicate formulas, which are taken as the beginning of the reasoning, are represented by n end-nodes of G_i . If $t\in T_1$ and $t^{\bullet}=\varnothing$, then another end-node marked with " $NULL$ " should be added to G_i , which is also the beginning of reasoning;

(2) If the output predicates of the target transition t_i belong to a null set, then only one end-node that marked with " $NULL$ " should be established as the beginning of reasoning;

Step3.2

If (any subset of Q_i can not successfully match with any two-level place Pr/T subne in the premise net Σ_1), we consider that B is not an effective conclusion of $A_1,A_2,\cdots,A_m$, then goes to Step 5.

else{

While (a subset of Q_i is successfully matched with a certain two-level place Pr/T subnet Σ_1' in the premise net Σ_1), do{

Step3.2.1 Add the Pre-and/or graph of Σ_1' into G_i (if a node is involved in $n(n\geq 2)$ times of successful matching processes, then copy it for n times in G_i to make the Pre-and/or graphs adding into G_i independent with each other);

Step3.2.2 Obtain a new set of end-nodes;

Step3.2.3 If the atomic predicate formula of an end-node is the input predicate of the target transition t_i after replacement, then this end-node is marked as "terminational node";

Step3.2.4 Given that Q_i is the atomic predicate formula set of non- terminational end-nodes.

}

};

Step3.3

If there is in G_i a subgragh G_i' , which meets:

(1)the atomic predicate formula set of the output predicate set of the target transition t_i is equal to that of the reasoning beginnings of G_i' ;

(2)the atomic predicate formula set of all the "terminational nodes" in subgraghs is equal to the input predicate set of the target transition t_i after a certain replacement.

then, it proves that the reasoning of the target transition t_i is successful. Otherwise, the reasoning is unsuccessful, which proves that B is not an effective conclusion of $A_1,A_2,\cdots,A_m$, then goes to step 5.

};

Step4 If the reasoning of each target transition $t_i(i=1,2,\cdots,|T_2|)$ is successful, and replacements in reasoning process are coincident, then it proves that B is an effective conclusion of $A_1,A_2,\cdots,A_m$, else, it is not an effective conclusion.

Step5 End the reasoning.

In the above-mentioned approach, if the atomic predicate formula which is added to the Pre-and/or graph $G_i(i=1,2,\cdots,|T_2|)$ is equal to an existing atomic predicate formula of G_i after replacement, then the merging should be made under the condition that no new end-node is added to G_i. When making merging, the following should be met:

(1) If both nodes are marked as the "terminational nodes", then these two nodes needed to be merged, otherwise not;

(2) In order to keep the original reasoning relations, the two nodes are not really merged into one node, but connected through a dotted line.

Step 1 regulates that the same variable shall not appear on the input/output arc of different transitions in Σ_1 and Σ_2. Therefore, if a replacement exists in Step 3.3, then it must be consistent with the replacement in Step 3.2.3. It can be known from section 3.1 that, when Pre-and/or graph $G_i(i=1,2,\cdots,|T_2|)$ has $n(n\geq 2)$ "terminational nodes", then there are n terminational nodes that represent the "and" relation between predicates,and there are directed path from these "terminational nodes" to the beginning of reasoning. Thus, for the target transition t_i, we assume its input predicate set to be $I_i=\{P_1(X_1),P_2(X_2),\cdots,P_n(X_n)\}(n\geq 0)$, and output predicate set to be $O_i=\{Q_1(X_1),Q_2(X_2),\cdots,Q_m(X_m)\}(m\geq 1)$. When the two conditions in Step 3.3 are met, then the following proposition is true:

$P_1(X_1)\wedge P_2(X_2)\wedge\cdots\wedge P_n(X_n)\rightarrow Q_1(X_1)\vee Q_2(X_2)\vee\cdots\vee Q_m(X_m)$,i.e. the reasoning of the target transition t_i is successful, and Step 3.3 is correct. For other steps, it is obvious that they are effective and reasonable. Hence, for the first-order predicate logic, the proposed goal-guiding graphic reasoning approach is also effective and reasonable.

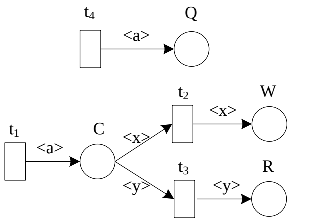
4.2 Application Example

Example:

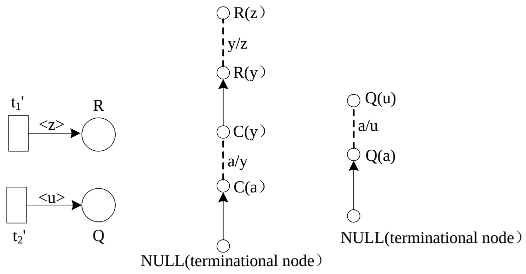
if $\forall x(C(x)\rightarrow W(x)\wedge R(x))\wedge\exists x(C(x)\wedge Q(x))$,

prove that $\exists x(Q(x)\wedge R(x))$.

Proof of the example: According to literature [14] and Step1 of the goal-guiding graphic reasoning approach, we get the premise and conclusion nets, as shown in fig.11(a) and 11(b), respectively. The reasoning process of the target transitions t_1' and t_2' is shown in fig.11(c) from the top to bottom. Because the two conditions in Step3.3 of the goal-guiding graphic reasoning approach are satisfied, the reasoning of t_1' and t_2' can be considered to be successful, and replacements in the reasoning process are consistent, thus the conclusion is true.



(a) Premise net



(b) Conclusion net (c) Reasoning process of the target transitions t_1' and t_2'

Fig. 11. Premise and conclusion nets and the reasoning processes

In fig.11(c), a dotted line represents a predicate formula of the premise net which is obtained by replacing the predicate formula of the corresponding node. In essence, the two nodes connected by the dotted line represent one node.

5 Application of the Goal-guiding Graphic Reasoning Approach in Agriculture Expert System

At present, production rule has become a knowledge representation mode which enjoys the most artificial intelligent application, and which has been employed in many successful expert systems to represent knowledge[2]. In this paper, we assume that the agriculture expert system use the production rule representation. for instance:
IF wz= suburbs, and nyhxptr=large
THEN it means a large quantity of carbon emission per unit area
The goal-guiding graphic reasoning approach can not only prove the already known results, but also solve questions in agriculture expert system. Specific steps as follows:
Step1 Build proper predicate formulas for production rules of the knowledge base and conclusions to be solved;
Step2 According to literature [14] and Step1 of the goal-guiding graphic reasoning approach, build the Pr/T net model for production rules of the knowledge base and conclusions to be solved, to get the premise net Σ_1 and the conclusion net Σ_2 ;
Step3 Do Step2-Step4 of the goal-guiding graphic reasoning approach;
Step4 If the question that need to be solved is an effective conclusion, then the value of the variable in Σ_1 that obtained by replacement in the reasoning process is just

the answer of the question; if the question is not an effective conclusion, then there is no answer for the question.

Example Take the judgment of several common pest and disease damages during the cotton seedling period. In such an agriculture expert system knowledge base, the production rule representation of syndromes and diseases is described as follows[20]:

Diseases during the cotton seedling period:

IF systemic and cotyledon foliage and appear one of syndromes of yellow net, purple plague, ralstonia solanacearum and yellows.

THEN the cotton would be withered.

IF local and cotyledon foliage and appear water-soaked dots or small spots and turbid juice when wiped on the glass.

THEN it shows the angular.

IF local and cotyledon foliage and appear pyorrhea or incrustation on the extended scab.

THEN it shows the angular.

IF local and rhizome and appear tawny and annular constriction.

THEN it shows the seedling blight.

IF local and root and appear arachnoid tomentum with soil particles but not the cotton fiber.

THEN it shows the seedling blight.

IF local and rhizome and burst of long-thin spindle-shaped fibers.

THEN it shows the anthracnose.

IF local and cotyledon foliage and appear small dots with ashen in the center and dull-red in outer area.

THEN it shows the anthracnose.

IF local and rhizome and appear dark brown long round spot and constriction.

THEN it shows the redroot.

Here we do not list the diseases during cotton budding, blossing and boll opening periods.

Table 1 lists the relations between the predicates and syndromes, in which x represents a disease.

Table 1. Relations between the predicates and syndromes

Predicate	Syndrome	Predicate	Syndrome
Q1(x)	Systemic	P4(x)	pyorrhea or incrustation on the extended scab
Q2(x)	Local		
Q3(x)	Rhizome	P5(x)	tawny
Q4(x)	cotyledon foliage	P6(x)	annular constriction
Q5(x)	root	P7(x)	arachnoid tomentum with soil particles
Q6(x)	seeding period		
Q7(x)	budding period	P8(x)	cotton fiber
Q8(x)	blossing period	P9(x)	burst of long-thin spindle-shaped fibers
Q9(x)	Boll-opening period		
P1(x)	yellow net, purple plague, ralstonia solanacearum and yellows	P10(x)	small dots with ashen in the center and dull-red in outer area
P2(x)	water-soaked dots or small spots	P11(x)	dark brown long round spot
		P12(x)	constriction

Predicate	Syndrome	Predicate	Syndrome
P3(x)	turbid juice when wiped on the glass	R(x,A1) R(x,A2) R(x,A3)	x is blight x is anthracnose x is red rot

Given: during the seeding period, some rhizomes appear burst of long-thin spindle-shaped fibers, and the disease is not systemic but local, question: what is the conclusion?

Step1: Build corresponding predicate formulas for production rule representation of the knowledge base, here lists parts of them:

$$Q_6(x) \wedge Q_2(x) \wedge Q_3(x) \wedge P_9(x) \rightarrow R(x, A2)$$

$$Q_6(x) \wedge Q_2(x) \wedge Q_4(x) \wedge P_{10}(x) \rightarrow R(x, A2)$$

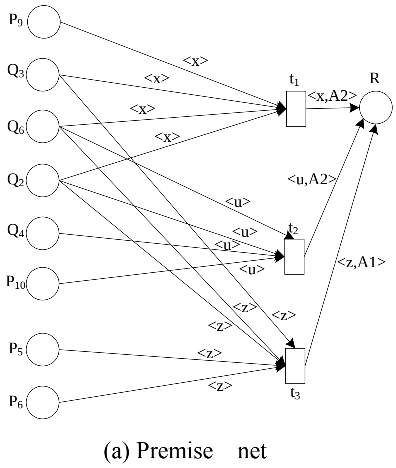
$$Q_6(x) \wedge Q_2(x) \wedge Q_3(x) \wedge P_5(x) \wedge P_6(x) \rightarrow R(x, A1)$$

Build predicate formulas for the conclusion that needs to be solved:

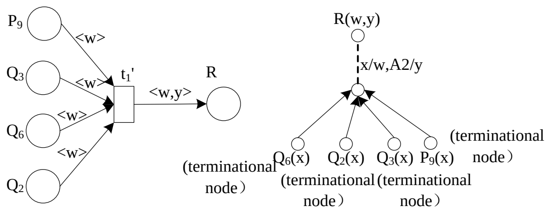
$Q_6(x) \wedge Q_2(x) \wedge Q_3(x) \wedge P_9(x) \rightarrow R(x, y)$, where, $R(x, y)$ represents that the disease x is y.

Step2: Part of the Pr/T net Σ_1 of corresponding production rules is shown in fig.12(a), and Pr/T net Σ_2 of the conclusion is shown in fig.12(b).

Step3: The reasoning process is shown in fig.12(c), from which we know that the question that needs to be solved is an effective conclusion.



(a) Premise net



(b) Conclusion net (c) Reasoning of the target transition t_1'

Fig. 12. Premise and conclusion nets and the reasoning processes

Step4: In the reasoning process, replacement A2/y had been used, which indicates that A2 is the answer of this question, namely, anthracnose is the conclusion.

6 Conclusions

In this paper, for the first-order predicate logic, a goal guiding graphic reasoning approach that based on the predicate/transition system has been proposed，and the approach has been applied in the reasoning process of agriculture expert system. Compared to other previous work,the paper has the following significance and innovation:

(1)The reasoning process of the approach proposed in this paper is started with the conclusion, so the approach is purposeful and effective with reducing many useless steps.

(2)For the approach in this paper,in process of reasoning, the premise is separated from the conclusion, avoiding the disadvantage that the causal relationship will be covered by traditional reasoning methods, therefore in this approach, the knowledge is highly readable and some heuristic information can be used in the reasoning process.

(3) When agriculture knowledge has been stored into the base in the form of the production rule, the proposed approach can be used to answer questions of the agriculture expert system, which provides a new way for studying the reasoning mechanism of the agriculture expert system.

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