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Intelligent Target Fusion Recognition Based on Fuzzy Petri Nets

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Abstract: For target recognition under complex environment, a target fusion recognition method based fuzzy sets and Petri net was brought out. The method first process the target data using fuzzy sets theory, including divide the characters into different status respectively and calculate the degree of membership function. Then the results of fuzzy classify and fuzzy recognition rules are modeled with fuzzy Petri nets. The target type estimation was gained through fuzzy Petri net inference. A simulation example demonstrates the validity of the model and the reliability of the inference results.

Key words: Target recognition, fuzzy petri nets, fuzzy reasoning, data fusion

INTRODUCTION

In recent years, the main study direction in the target identification domain's is how to withdraw the characteristics of the target and then differentiated the different goal using the characteristic. In order to obtain a more complete description, enhances the recognition precision, usually uses the multi-sensors to carry on the fusion recognition. The commonly recognition methods including DS evidence theory law (Weirong *et al*., 2002), Bayes algorithm (Guoyou and Yulan, 2003), artificial intelligence, expert system (Haspert *et al*., 2005) and so on. But these methods usually request to have the unification recognition frame, the complete prior probability and so on. And as a result of bad battlefield environment and sensor's multiplicity, the information usually is fuzzy and indefinite; therefore the target identification is an uncertainty inference process. In order to process the uncertainty for the target identification, this paper proposed one fusion recognition model based on the fuzzy Petri net's. This method integration the uncertainty information's fuzzy handling ability of fuzzy set theory and the rule reasoning faculty of the Petri net, which can be used in the multi-sensor data fusion recognition domain.

FUZZY PETRI NETS

Definition of fuzzy petri nets: The Petri net is one kind of oriented graph which is composed with place, transition and the directed arc which connect the place and the transition. It was first establishes by German scientist Professor C.A. Petri in 1962 in its doctoral dissertation. Now the Petri net theory has already become the research focus in the computer and the automation domain (Gao *et al*., 2004; Shi *et al*., 2007).

FPN is the expansion of basic PN, the token in place of FPN is a real value between 0 and 1. The transition is connection with Certainty Factor (CF) which between 0 and 1. The firing rules and the transition rules also has the corresponding change. FPN can be described with eight-tuples as follows:

$$FPN = (P, T, I, O, H, \theta, \varphi, C) \quad (1)$$

where, $P = \{P_1, P_2, ..., P_n\}$ is the finite set of palaces; $T = \{t_1, t_2, ..., t_n]$ is the finite set of transitions; $I: P\times T\rightarrow\{0,1\}$ is an $n\times m$ input matrix defining the directed noncomplementary arcs from places to transitions, $a_{ij} = 1$ if P_i is the input of T_j, Otherwise $a_{ij} = 0$. $O: T\times P\rightarrow\{0,1\}$ is an output matrix defining the directed arcs from transitions to places, $\beta = 1$ if P_i is the output of T_j, Otherwise = 0. $H: P\times R\rightarrow\{0,1\}$ is an $n\times m$ matrix defining the complementary arcs from places to transitions and I^T; HP; $P\rightarrow[0, 1]$ is a truth degree vectors, where $\theta_i\in[0, 1]$ means the truth degree of P_i. The initial truth degree vector is denoted by θ^0; φ: $P\rightarrow \{0, 1\}$ is the marking vector of tokens, the initial marking is φ^0; $C = diag\ \{c_1, c_2, c_m\}$ is the confidence of T.

Let A be a set of directed arcs. If $P_j \in I\ (t)$, then there exists a directed arc $a_{ji}\in A$, from the place P_j to the transition t_i. If $P_k\in O\ (t_i)$, then there exists a directed arc a_{ji} $\in A$, from the transition t_i to the place P_k.

The reasoning algorithm of FPN: FPN may used to describe the fuzzy generative rule. Making $R = \{R_1, R_2, ...R_3\}$ as a fuzzy rules. The ith fuzzy reasoning rule is expressed as follows:

$$R_i\text{: IF } d_j \text{ Then } d_k\ (CF = \mu_i) \quad (2)$$

Under the marking m_1, for the transition t_i, if $\forall P_j\in I\ (t_i)$: $m_1\ (P_j = 1)\ \wedge\alpha\ (P_j) = y_i \geq \lambda$, where $\lambda\in [0, 1]$ is the threshold value of transition t_i, m_1 (P_j) is the number of token of under the marking condition .Then the transition can firing, the new marking as follows:

$$\forall p_j \in I(t_i): m_2(p_j) = m_1(p_j) - 1 \quad (3)$$

The formal reasoning algorithm based on FPN can be described as follows:

Step 1: Read the initial inputs: I, O, H, C, θ^0, φ^0
Step 2: Let reasoning step k = 0

Following the reasoning step:

Step 3: Compute the k^{th} prior truth degree of the transition according to:

$$\rho^k = \overline{(I^T \otimes (\overline{\phi^k} \oplus \overline{\theta^k})) \oplus (H^T \otimes (\overline{\phi^k} \oplus \theta^k))}$$

- Compute from according to:

$$\theta^{k+1} = \theta^k \oplus [(O \cdot C) \otimes \rho^k]$$

- Compute from according to:

$$\phi^{k+1} = \phi^k \oplus [O \otimes \overline{(I+H)^T \otimes \overline{\phi^k}}]$$

Step 4: If $\theta^{k+1} \neq \theta^k$ or $\phi^{k+1} \neq \phi^k$, Let k = k+1, return to 3); otherwise the reasoning is over.
In the above algorithm:

- The horizontal lines above vector represent complementary operation£»
- $\oplus$: $A \oplus B = C$, where A, B, C are all m×n matrix, such that $c_{ij} = \max(a_{ij}, b_{ij})$
- $\otimes$: $A \otimes B = C$, where A, B, C are m×p, p×n, m×n matrix, respectively, such that $c_{ij} = \max_{1 \le k \le p}(a_{ik}, b_{ik})$

TARGET FUSION RECOGNITION BASED FUZZY PETRI NETS

Character extraction and fuzzy processing: Character extraction's duty is after the primary data are pretreated, extracts one or many characteristics which are direct correlation with target attribute, then use it as the information sources for target recognition. In the actual system, the characteristic number is not more better. In this paper, the distance characteristic (D), the speed characteristic (V), the altitude characteristic (H), the acceleration characteristic (AC) as well as RCS characteristic was used.

According to the target data's feature analysis we can take D, V, H, AC and RCS as the decision variable for target recognition. Here D can be divided into the long range, medium-range, the short-range three kinds. Vcan be divided into Supersonic speed and subsonic speed two kinds. H can be divided into Upper air, midheaven, low altitude three kinds. RCS and can be divided into big, medium and small three kinds. The degree of status of each character can be description using membership function method of fuzzy set theory. The membership function is the triangle function.

Therefore, the fuzzy language variable values of D, H RCS and AC can be P, Z, N. The fuzzy language variable values of V can beL, S . The results of fuzzy inference is the target type (T), the possible value is T_1, T_2, T_3, T_4, T_5 which express large aircraft class (early-warning aircraft, transport aircraft and so on), the medium airplane class (bomber aircraft and so on), the conventional fighter aircraft, the missile class as well as the helicopter class, respectively.

Fuzzy inference rules of target recognition: Because the target data often has randomness and the fuzziness in flight, so the inference rules and the inference process also has the fuzziness. We may establish the following target recognition inference rules based on the technical data and the expert experience.

R_1: If H is P and D is P and V is S and RCS is P then T is T_1 (CF = μ_1)
R_2: If H is Z and D is P and V is S and AC is Z then T is T_2 (CF = μ_2)
R_3: If H is Z and V is L and AC is P then T is T_4 (CF = μ_3)
R_4: If H is not P and D is N and V is L then T is T_4 (CF = μ_4)
R_5: If H is not P and V is S and AC is not P then T is T_5 (CF = μ_5)。

The petri net model of target recognition: According to the fuzzy reasoning rules of target recognition, we can take each variable's value in the inference rules as a place, each inference rules is expressed as a transition. The according Petri net model is shown in Fig. 1.

SIMULATION AND ANALYSIS

Suppose some air defense system carries on the search, the survey, the recognition and the track to the target with radars. In one time, the target information are: The altitude is 5283.3 m, the speed is 0.7173 Ma, the distance is 20.5 km, the RCS is 3.7917 m^2 and the acceleration is 7.3333 m/s^2. The degree of membership of various characteristic parameter variables are showed in Table 1.

Table 1: The degree of membership of control variables

Variables	Fuzzy value	Membership
H	P	0.2861
	Z	0.7139
	N	0.0000
V	L	0.7173
	S	0.2827
D	P	0.7000
	Z	0.3000
	N	0.0000
RCS	P	0.3102
	Z	0.6898
	N	0.0000
AC	P	0.7667
	Z	0.2333
	N	0.0000

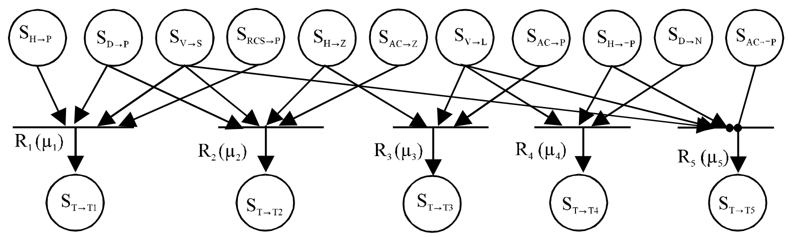

Fig. 1: FPN model of target recognition

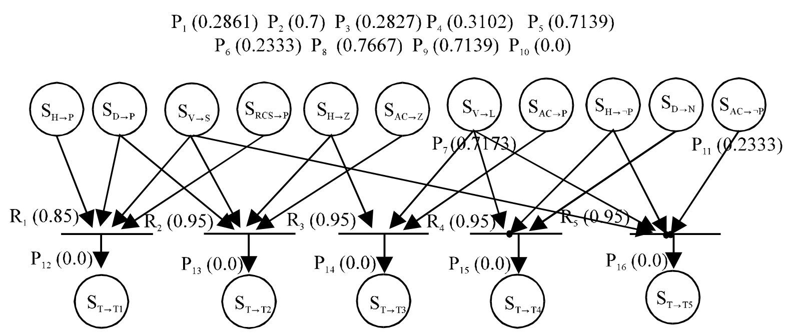

Fig. 2: Initial FPN for

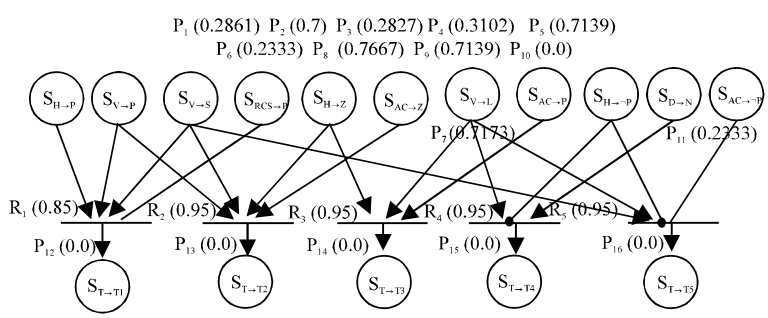

Fig. 3: The finial FPN for target recognition

Suppose the truth degree of the reasoning rules is [0.85 0.95 0.95 0.90 0.95]. After the degrees of membership are regularized, the initial FPN diagram can be expressed as Fig. 2.

From the FPN net which shown in Fig. 1, we can obtain its original states according to the FPN definition, then reasoning according to the FPN reason algorithm. The final FPN of target recognition is shown as Fig. 3.

And from the Fig. 3, we can judge that the target belong to the third class target, namely conventional fighter aircraft class.

CONCLUSION

This study proposed one target fusion recognition algorithm based on the fuzzy Petri net. This algorithm can processes the uncertainty and the fuzziness using the fuzzy set; carry on the modeling and the inference using the FPN decision-making inference rule. The method integrates the merits of fuzzy set theory and Petri network theory. The simulation results also indicated that the inference not only has the direct-viewing image merit, moreover the inference efficiency is high. The simulation results consistent with the supposition information.

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