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Radar emitter recognition method based on AdaBoost and decision tree

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Abstract: For the poor real-time, robustness and low recognition accuracy of traditional radar emitter recognition algorithm in the current high density signal environment, this paper studied a kind of radar source recognition algorithm based on decision tree and AdaBoost. Firstly, the information gain can be used to construct single decision tree. Then using AdaBoost algorithm to train the weak classifier, and get a strong classifier. Finally, get the recognition results through the strong classifier. Simulation results show that the recognition accuracy of proposed method can reach 93.78% with 10% parameter error, and the time consumption is lower than 1.5s, which has a good recognition effect.

1. Introduction

Emitter recognition can analyze the intercepted radar signals by the identification database, and provide reference for grasp enemy radar technical parameters, activity rule, threat level and development [1]. But in current high density complex signal environment, the traditional radar source recognition methods such as template matching[2], expert knowledge[3, 4] and neural network [5-7], have problem of poor recognition accuracy rate or poor timeliness, this will inevitably lead to the subsequent estimation of threat situation of incomplete, inaccurate, and lack of key information to guide interference [8]. To solve this problem, this paper studied a radar emitter recognition algorithm based on decision tree and AdaBoost [9]. Firstly, by changing the weights of training samples, AdaBoost method build a strong classifier from learning multiple weak classifiers to obtain better classification results. Then due to the decision tree method of simple in principle and strong robustness, it’s very suitable for the weak classifier. Therefore, considering to combine the advantage of two algorithms to construct the new radar source recognition method.

2. Basic principles of AdaBoost algorithm

The Boosting algorithm originated [10] from Probably Approximately Correct learning model proposed by Valiant. It’s a good method to improve the accuracy of any given learning algorithm. The basic principle of boosting is the classification problem, this method use training sample to learn weak classifiers, change the weight and get a strong classifier. Adaptive Boosting algorithm does not need to know the exact distribution of sample space, only through comparing the classification accuracy for each sample to determine the weight of samples. The superiority of AdaBoost are reflected in the following aspects: high-precision; improve the generalization ability by reducing the training error; strong flexibility.

3. The basic principle of decision tree algorithm based on information gain

Decision Tree [10, 11] is one of the important algorithms in machine learning and data mining. It’s easy to understand and implement, has good robustness and predictive performance, so it’s widely used in various fields. Decision Tree is a prediction model of classification tree structure, which represents the mapping attribute relationship between the each object. The decision Stump is a typical simple decision tree, it’s only based on a single feature to make decisions. Because the tree has only a split process, the data processing is very rapid, simple, and good in real time, but the recognition result is not good, so the Decision Stump is very suitable as a weak classifier.

4. The step of radar emitter recognition based on AdaBoost and decision tree

Comparing with support vector machine, artificial neural network and other complex learning algorithms, the performance of single decision tree algorithm is weakness. However, a large number of research results show that the performance of the decision tree integration algorithm is often superior to other algorithms and their integration in many practical fields. Considering the current condition faced by radar source recognition, large volume of data, accuracy, real-time, new unknown signal recognition and other practical requirements, combining with the AdaBoost decision tree method has the advantages of high accuracy, strong generalization ability and good real-time, this paper studied a radar emitter recognition method, which based on decision tree and AdaBoost algorithm. The brief procedure as follows:

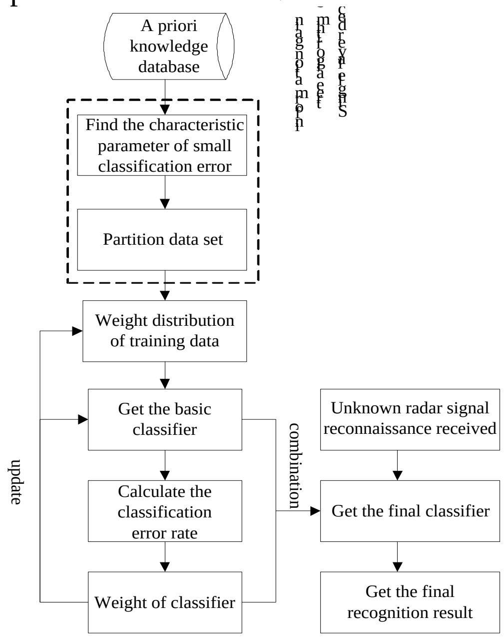

Fig. 1 Radar source identification process based on AdaBoost and decision tree

①The information gain of each feature is calculated based on the prior knowledge of database, and the feature of the maximum information gain is selected to partition data set. ②The initial weights of the training data are set, the classification error rate is calculated, and updated the weight distribution of training data according to the classification error, get the weight of weak classifier. ③With each iteration, until the training error is zero or weak classifier number reach the specified value, construct the strong classifier by calculating the weights of weak classifiers, at last using the strong classifier to classifier the received unknown radar signal.

5. Simulation experiment analysis

In order to verify the effectiveness of the radar source recognition algorithm based on decision tree and AdaBoost, 9 kinds of radar sources are simulated as known prior knowledge, DOA, PA, PW, RF, PRF, BW are selected as features, each radar source sample feature information as shown in table 1.

Table 1 Known radar emitter sample characteristic information

Radar	DOA/(°)	PA	PW/(μs)	RF/(MHz)		PRF/(Hz)		BW/(Hz)	Sample number
				Type	Range	Type	Range		
1	48～50	5～15	1.2～1.4	fixed	2104～2105	group variable	580/680/740	10.3	102
2	60～63	3～12	0.2～0.4	agile	2750～ 2850	shake	300～400	7.3	102
3	68～70	16～20	6.8～6.9	group variable	2282/ 2297	stagger	800/850/900/950/1000	18.6	114
4	56～58	6～13	13.3～13.5	agile	1550～1750	shake	700～900	39.3	109
5	30～32	33～38	6.6～6.8	fixed	1925～1926	group variable	810/830/880	50.1	110
6	49～51	23～31	3.3～3.4	group variable	1925/1926	fixed	3499～3500	11.6	112
7	31～33	50～56	60.1～60.3	group variable	2202/2217/2263	fixed	2998～3000	13.8	106
8	65～68	10～23	61～61.2	group variable	3278/3282/3297	fixed	3199～3201	16.6	104
9	36～38	40～50	61～61.1	fixed	2198～2199	fixed	1562～1564	10.2	112

(1)Robustness analysis

Set 9 kinds of radar sources listed in Table 1 as training data, a total of 971 samples. Generate test data by adding 10% and 20% parameter error with reference to the parameters in Table 1. The proposed radar source identification method is used to train the prior sample, generate the strong classifier, and then the test data is identified by the strong classifier. The recognition process as follows.

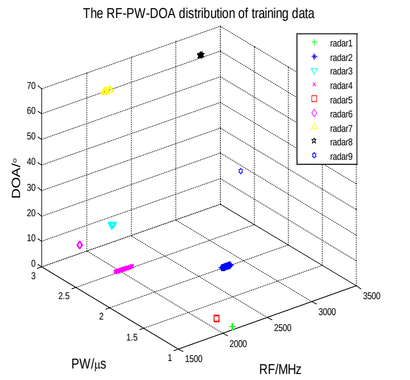

Fig.2 Training data distribution

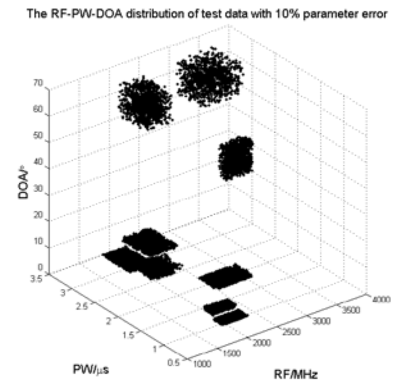

Fig.3 The test data distribution with 10% parameter error

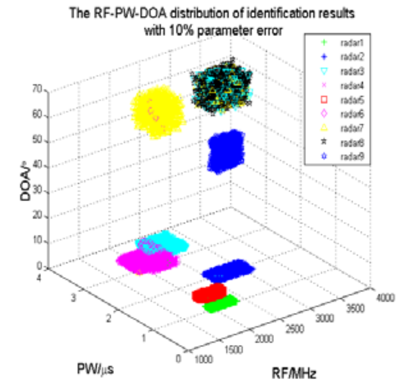

Fig.4 The identification results with 10% parameter error

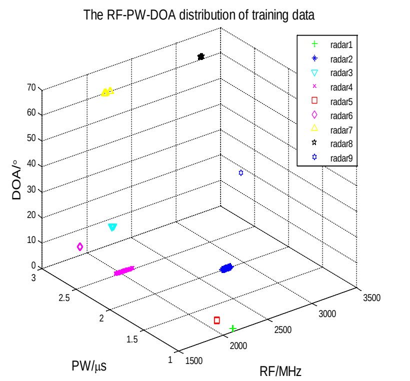

Fig.5 Training data distribution

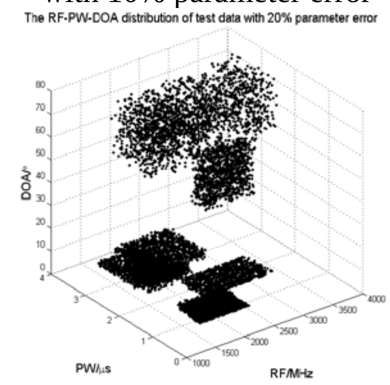

Fig.6 The test data distribution with 20% parameter error

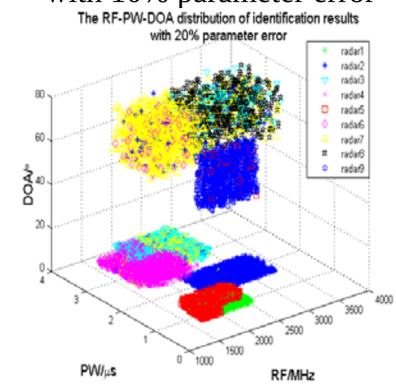

Fig.7 The Identification results with 20% parameter error

Total number of test data is 9753, the each number of 9 kinds sample is 1020, 1027, 1149, 1093, 1106, 1128, 1062, 1047, 1121. For the test data with 10% parameter error, when the number of weak classifiers is 46, the 93.78% recognition accuracy can be achieved, the recognition results are shown in Fig 4. Compare with Fig. 3, 6 and 4, 7, the parameter error increased from 10% to 20%, the test data distribution is more complicated, at the same time recognition accuracy is decreased. Even when the parameter error is 20% and the number of weak classifiers is set to 60, 80.08% recognition accuracy can be achieved. Indeed, the parameter error is generally less than 15%, so the proposed radar emitter recognition method can achieve a better recognition accuracy.

(2)Identification effect analysis

The recognition results are analyzed by identifying accuracy and time consumption. Training and testing sample data as shown in experiment (1), the parameter error is set to 10%, from the beginning of 1 to 100, increasing the number of weak classifiers, time consumption and recognition accuracy are shown as follows.

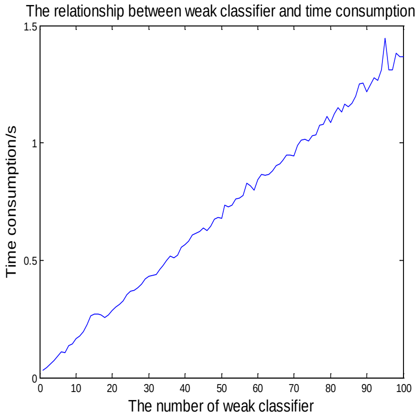

Fig. 8 The time consumption of the algorithm varies with the weak classifier

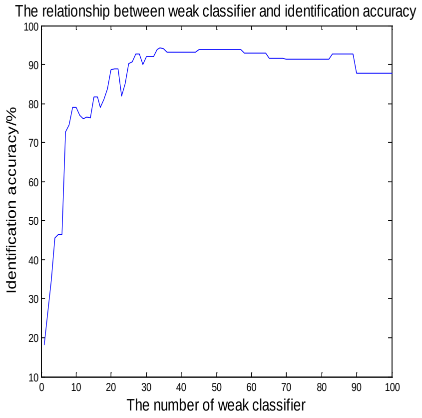

Fig. 9 The accuracy rate of the algorithm is changed with the weak classifier.

From Fig. 8, we can see that the time consumption of the proposed algorithm is approximately linear distribution with increasing the number of weak classifiers. But when the number of weak classifiers is 100, the time consumption is less than 1.5s. As shown in Fig. 9, when weak classifier numbers increased from 1 to 35, the algorithm of recognition accuracy increased rapidly, can get 93%. Continue to increase the number of weak classifiers, the increase of recognition accuracy is not obvious, even has not increased but decreased, thus selecting the appropriate number of weak classifiers has great influence with the recognition accuracy.

6. Conclusions

With the rapid development of information technology, promoted many new technologies of radar system, and created more complex signal pattern, so in the future battlefield, we will face the threat of unknown radar signal. In order to cope with the challenge, from the perspective of intelligence analysis, aim at the problem of the existing traditional radar source identification method with poor recognition accuracy and robustness, this paper studied a radar emitter identification method based on decision tree and AdaBoost. Firstly, construct the single decision tree based on information gain. Then use the AdaBoost algorithm to train the classifier, construct the strong classifier. Finally classification of test data by the strong classifier, and get the recognition results. Through the simulation analysis, it’s proved that the proposed radar source recognition algorithm not only has good recognition accuracy and robustness, but also has good timeliness. However, in the experimental process, it’s found that the selection of weak classifiers still can optimize, which will be the focus of next step.

7.References

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