Optimization of the parameters in SVM-based spectrum sensing model

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Abstract. The process of spectrum sensing plays a key part in Cognitive Radio (CR). In this paper, Support Vector Machine(SVM） is applied to spectrum sensing which can judge whether the Primary User (PU) exists or not for its good performance in many fields. Data set including training set and testing set with different characteristics is generated by laboratory instruments to verify the SVM-based spectrum sensing model of good performance in actual communication environment. To solve the problem of huge training set, the paper focuses on researching the optimal parameters of the number and dimension of training set. The simulation results show that the optimal parameter of Radial Basis Function (RBF) and the size of training set and testing set are different with different characteristics of training set and testing set.

1 Introduction

As is known, the spectrum resources are becoming more and more scare with the rapid development of wireless communication services. In the frequency range of 0-6GHz, the spectrum utilization rate is only 15%-85%, the licensed spectrum have not been fully utilized[1].

To improve the spectrum utilization, cognitive radio (CR) is firstly proposed by Dr. Joseph Mitola. By seeking the spectrum hole, cognitive user (CR) can use the free frequency band of primary user (PU) to communicate. There are many traditional spectrum sensing methods, such as, energy detection[2], matched filter and cyclostationary feature detection[3].

In recent years, more and more people focus on the support vector machine which has been widely used in face detection, web pages classification, medical treatment and so on. A spectrum sensing method based on support vector machine was studied in[4]. This paper discussed the three kinds of kernel functions and the performance of spectrum sensing with Radial Basis Function (RBF) is prefer. Spectrum sensing methods based on support vector machine were researched in[5,6]. It showed that this method outperformed energy detection. The spectrum sensing based on support vector machine has many aspects that need to be studied. For example, the selection of the parameters of training set and testing set. The performance of spectrum is low in low ratio of signal to noise (SNR). In this paper, training set and testing set with different characteristics are generated by the laboratory instruments to verify the SVM-based spectrum sensing model of good performance in actual communication environment. To solve the problem of huge training set, this paper focuses on analyzing the optimal parameters like the number and dimension of training set.

2 SVM-based spectrum sensing model

The earliest application of SVM is linearly separable classification. Suppose the training set was $D = \left\{ \left(\mathbf{x}_1, y_1 \right), ..., \left(\mathbf{x}_i, y_i \right) \right\}, \mathbf{x}_i \in R^n, y_i \in \{-1, 1\}$; $\mathbf{x}_i$ represents the training set vector and y_i denotes the class of $\mathbf{x}_i$. Linearly separable classification can't work when two groups of set mixed. Then the slack variables ξ_i is added which causes little change around training set[7]. C is the penalty parameter to restrict or reducing the damage degree. So the quadratic optimization record as

$$\min_{w} \quad \frac{1}{2}\|w\|^2 + C\sum_{i=1}^{l}\xi_i \tag{1}$$

$$\text{s.t.} \quad y_i\left(w\mathbf{x}_i + b\right) \geq 1 - \xi_i, \qquad \xi_i \geq 0, \quad i = 1,2,\ldots,l$$

The non-linear classifier for a sample x can be expressed as

$$y = \operatorname{sgn}\left[\sum_{i=1}^{l}\alpha_i y_i\left(\Phi\left(\mathbf{x}_i\right)\cdot\Phi(\mathbf{x})\right) + b\right]. \tag{2}$$

Where $K(\mathbf{x}_i,\mathbf{x}_j) = (\Phi(\mathbf{x}_i)\cdot\Phi(\mathbf{x}_j))$ is the kernel function. Φ is a mapping which is used to transform source set from low dimensional space to a higher dimensional space. In this paper, the kernel function is chosen as RBF for its good function in support vector machine and it is shown in Eq. 3

$$K(\mathbf{x}_i,\mathbf{x}) = \exp(-\|\mathbf{x}_i - \mathbf{x}\|^2 / 2\sigma^2) \tag{3}$$

Spectrum sensing model is actually a binary assumption model, which can classify spectrum based on the received signal. H_1 represents the presence of the primary user and cognitive user cannot access this band. On the contrary, H_0 represents its absence.

Defining $x(i)$ as the received signal samples at time i. $n(i)$ is a white gauss noise with mean zero, variance σ^2. $s(i)$ is the licensed signal to be detected. The detection model can be described as

$$x(i) = \begin{cases} n(i), & H_0 \\ s(i) + n(i), & H_1 \end{cases} \tag{4}$$

The receiver gets N_t signal samples in sensing period.

$$X = \begin{bmatrix} x(1) & x(2) & \cdots & x(N_t) \end{bmatrix} \tag{5}$$

Through vectorizing $X = \begin{bmatrix} x(1) & x(2) & \cdots & x(N_t) \end{bmatrix}$, matrices X_1 is get whose size is $M \times N$. $N_t = M \times N$.

3 Generating the training set and the testing set

In this paper, the data set including the training set and the testing set is generated by laboratory instruments produced by R&A including Base-band Signal Generator and Fading Simulator(AMU200A)、Vector Signal Generator(SMBV100A)、SMA、FSG·Spectrum Analyzer and RF Signal Generator(AV1442). In AMU200A the types of PU are FSK、ASK、QAM、BPSK and there are many fading scenarios like CDMA、WLAN、WIMAX and so on. The construction of the laboratory instruments is below in Fig.1.
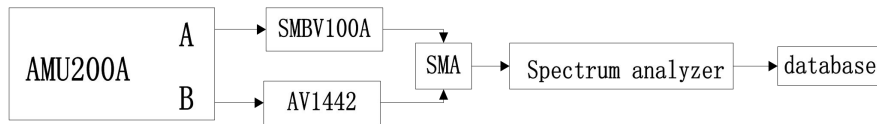

Figure 1. The construction of the laboratory instruments

AMU200A generates different amplitude base-band signal. Channel A generates Primary User, channel B generates noise. The type of PU is the signal of BPSK and the type of noise is AWGN. The bandwidth of signal is 1MHz. The center frequency is transmitted to 2GHZ respectively by SMBV100A and AV1442. The sampling rate is set 10MHz in Spectrum Analyzer.

4 Performance

To find the optimal parameters of SVM spectrum sensing, the data set with different size of data set in different ratio of signal to noise (SNR) is simulated. Matlab is chosen as the simulation platform. P_e represents the error detection probability including false detection and miss detection probability. P_d represents right detection probability. N represents the dimension of data set.

4.1 Optimization of the kernel function parameter

The kernel function Radial Basis Function (RBF) has only one parameter σ. The number of training set is 200 and test set is 200. N respectively equals 500 and 1000.

Table 1. The relationship of Pe and σ

σ \ P_e	N=500				N=1000			
	SNR=-20	SNR=-10	SNR= -5	SNR= 0	SNR=-20	SNR=-10	SNR= -5	SNR= 0
0.4	0.560	0.442	0.200	0	0.485	0.405	0.060	0
0.5	0.554	0.438	0.190	0	0.465	0.395	0.053	0
0.6	0.547	0.436	0.180	0	0.455	0.400	0.052	0
0.7	0.540	0.435	0.177	0	0.455	0.395	0.051	0
0.8	0.537	0.435	0.175	0	0.450	0.400	0.051	0
≥ 0.9	0.530	0.435	0.175	0	0.450	0.400	0.051	0

SNR is respectively -20db,-10db,-5db and 0db. As is shown in table 1, when $\sigma \geq 0.9$, Pe will be minimum value with N in 500 and when $\sigma \geq 0.8$, Pe will be minimum value with N in 1000. Simulation researches show that optimal σ is related to the characteristics of signal.

4.2 The optimal number of training set

To solve the huge training set problem, this paper is to find the optimal number of training set under good performance. The dimension of training set and testing set respectively equals 500 and 1000. SNR is from -20db to 10db and the number of testing set is 200.
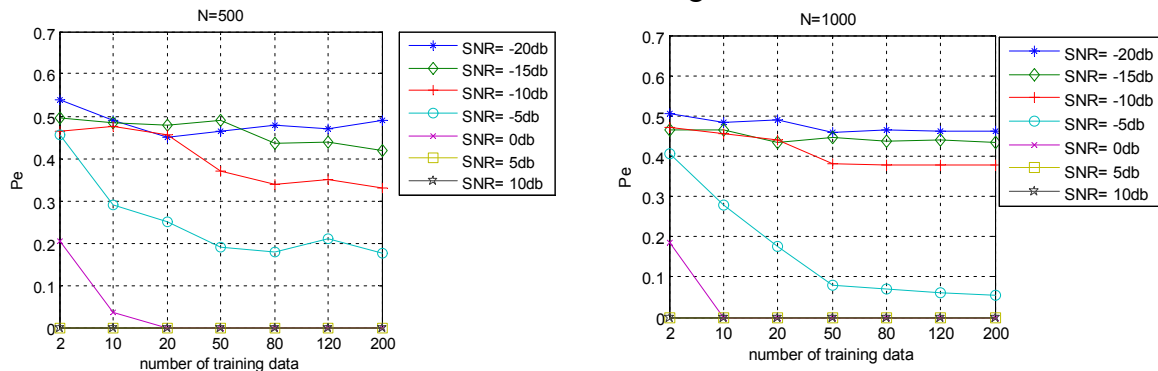

Figure 2. performance with different numbers of training set

As is shown in Fig 2, the horizontal axis representing the number of training set is from 2 to 200. From -5db to -20db, the performance of spectrum sensing will not become better with the number of training set larger than 80 in N=500 and larger than 50 in N=1000. So the number of training set can be set 80 in N=500 and the number of training set can be set 50 in N=1000.

4.3 The optimal dimension of training set

Here, the dimension of data set is from 200 to 2500. SNR is from -20db to 10db, the number of training set 80 and testing set 200.
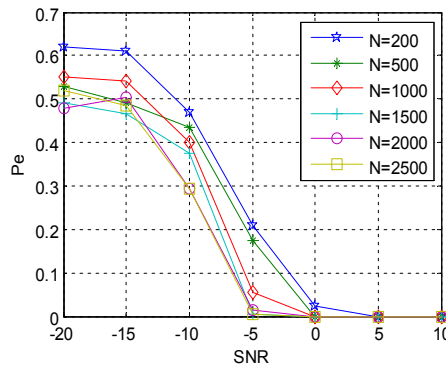

Figure 3. performance with different dimensions of data set

In Fig 3, P_e is the lowest with N in 200. The dimension of training set has no much effect on the performance of spectrum sensing when the SNR is lower than -15db or higher than 0db with N larger

than 500. From -15db to -5db, P_e gets lower with the dimension becoming larger and P_e is near to zero when the dimension is larger than 1500 in -5db. When the dimension is larger than 2000, the performance of spectrum sensing will not become better.

5 Conclusions

In this paper, SVM is applied to classification problem of spectrum sensing. Firstly, it starts from SVM theory. Then, the method of getting a data set including the training set and testing set generated by laboratory instruments is described to verify the SVM-based spectrum sensing model of good performance in actual communication environment. This paper focuses on researching the optimal parameter of RBF and the number and dimension of training set. By the simulation results, it concludes that the optimal parameter of RBF and the number, dimension of training set is different with different characteristics of signals. In this paper, the received signal is without any fading. So, in the future the performance of SVM-based spectrum sensing model with data set after fading will be researched.

Acknowledgments

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