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GA optimized SVD based signal detector for Cognitive radio Networks

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***Abstract*— This paper examines the implementation of the Genetic Algorithm (GA) optimized Singular Value Decomposition (SVD) method to detect the presence of wireless signal. We simulated the algorithm using common digital signal in wireless communication namely rectangular pulse, raised cosine and root-raised cosine to test performance of the signal detector. The algorithm is suitable for blind spectrum sensing where the properties of the signal to be detected are unknown. The GA optimized SVD gives better result in the low signal to noise (SNR) environment.**

***Index Terms*— Cognitive radio, Genetic algorithm, signal detector, singular value decomposition (SVD), spectrum sensing.**

I. INTRODUCTION

Cognitive radio(CR) is emerging as key enabling technology for improving the utilization of electromagnetic spectrum. The term cognitive radio was coined by Joseph Mitola [1].Spectrum sensing is one of the most important function in cognitive radio for the efficient utilization of spectrum. Spectrum sensing is one of the major steps of spectrum management, spectrum management consist of four major steps [2]: 1) spectrum sensing,2)decision making,3)Spectrum sharing and 4) Spectrum mobility. Spectrum sensing aims to determine spectrum availability and the presence of licensed users or primary user. Spectrum decision is to predict how long the spectrum holes are likely to remain available for use to the unlicensed users or secondary users. Spectrum sharing is to distribute the spectrum holes fairly among the secondary users bearing in mind usage cost. Spectrum mobility is to maintain seamless communication requirements during the transition to better spectrum.

There are various spectrum sensing techniques such as energy detection (ED), the eigenvalue based detection, the covariance based detection, feature based detection, and singular value based detection. These methods are discussed in [3], [4], [5].

Eigenvalue based detection techniques achieve both high probability of detection and low probability of false alarm with minimal knowledge about the primary user signals [6].The SVD method is quite similar to the eigenvalue decomposition method, but it can be applied to $m \times n$ matrix while, eigenvalue decomposition is only applicable to $m \times m$ matrix.SVD has several advantage as compared to the other decomposition method as it is more robust to numerical error [7].Genetic algorithm is an iterative process defined by Holland [8] as a metaphor of the Darwinian theory of evolution applied to biology Genetic algorithm is an optimization technique here it is used to optimize the value of L(number of column) in covariance matrix.GA optimized SVD gives better result as compared to SVD based detection.

The rest of the paper is organized as follows. Common signal detection model for spectrum sensing is introduced in section II. SVD based signal detection given in section III. Genetic Algorithm is described in section IV. Algorithm for signal detection given in section V. In section VI threshold value is determined. In Section VII, simulation parameters and results of implementing GA optimized SVD based signal detector is described. Finally conclusion is given in section VIII.

II. SYSTEM MODEL

In spectrum sensing technique, for detecting a signal two hypothesis are involved.H_0 and H_1. H_0 is null hypothesis, meaning signal does not present; H_1, means signal is present. The received signal under two hypothesis is given as [9],[10].

$$H0: y(n) = w(n) \tag{1}$$

$$H1: y(n) = s(n) + w(n) \tag{2}$$

Where,

y(n): is a received signal

s(n): is a transmitted signal samples

w(n): is white noise which is independent and identically distributed. The decision statistics of the energy detector [4] can be defined as the average energy of N observed samples

$$T = \frac{1}{N}\sum_{t=1}^{N} |y(t)|^2 \tag{3}$$

There are two probabilities involved for signal detection: probability of detection Pd which defines the hypothesis H_1. Probability of false alarm; P_{fa} which defines at hypothesis H_0 [9].

$$P_{fa} = P_r(T > \lambda | H_0) \tag{4}$$

$$P_D = P_r(T > \lambda | H_1) \tag{5}$$

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III. SVD BASED SIGNAL DETECTOR

SVD plays an important role in statistics and signal processing and, particularly in the area of a linear system. For a time series y (n) with n=1, 2….N, a matrix with L column and M=N-L+1 rows is constructed,

$$A = \begin{bmatrix} y(1) & \cdots & y(L) \\ \vdots & \ddots & \vdots \\ y(N-L+1) & \cdots & y(N) \end{bmatrix} \quad (6)$$

Here, A is an M×L matrix. Its elements can be found by substituting of y (n), Using SVD [11], A can be factorized as

$$A = U \quad S \quad V^T \quad (7)$$

Where, U and V are an M×M and L×L unitary matrix respectively. The columns of U and V are called left and right singular vectors, for A. S is diagonal matrix whose non negative entries are arranged in diagonal in a decreasing manner. S is a rectangular matrix with the same dimension as A. When signals are received whose power is higher than the threshold, there exist several dominant singular values to represent these signals

In implementing SVD based signal detector, we adopt method by Zeng and Liang (2007) in [12].SVD based signal detector has following algorithm to detect the presence of signal

Step 1:Select the number of column of covariance matrix L.

Step 2: Factorized the matrix using SVD to form equation as in (7).

Step 3:Obtain maximum and minimum Eigenvalues of matrix which are λ_{max} and λ_{min}

Step 4: Compute threshold value, γ.

Step 5: Compare the ratio with the threshold. If $\frac{\lambda_{max}}{\lambda_{min}} > \gamma$ the signal is present, otherwise the signal is not present.

IV. GENETIC ALGORITHM

GA is an iterative process. Each iteration is called a generation. A typical number of generations for a simple GA can range from 50 to over 500. In a genetic algorithm, a population of strings, which encode candidate solutions to an optimization problem, evolves toward better solutions. Solutions are represented in binary as strings of 0s and 1s, but other encodings are also possible. Flow chart of genetic algorithm is shown in figure1.

V. ALGORITHM FOR GA OPTIMIZED SVD BASED SIGNAL DETECTOR

Step 1: Optimized the value of L,by Genetic algorithm.
Step 2: Factorized the matrix using SVD to form equation as in (7)
Step 3: Obtain maximum and minimum Eigenvalues of matrix which are λ_{max} and λ_{min}.
Step 4: Compute threshold value, γ. The threshold value determination will be highlighted in the next section.

Step 5: Compare the ratio with the threshold. If $\frac{\lambda_{max}}{\lambda_{min}} > \gamma$ the signal is present, otherwise the signal is not present.

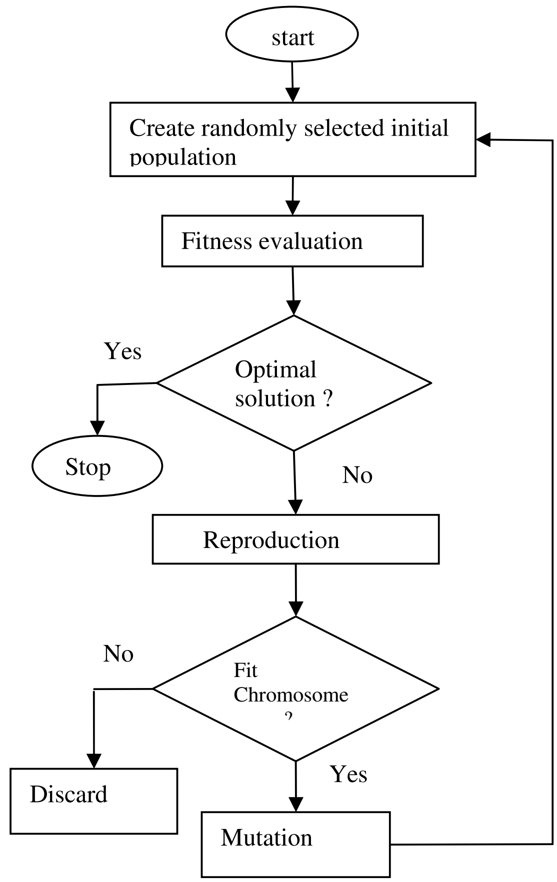

Figure1.Flow chart of the Genetic Algorithm [13]

VI. THRESHOLD DETERMINATION

In terms of desired probability of false alarm ,detection threshold can be calculated by using the results of the theorem in [14] and [12] and it is given as follows(here M=1)

$$\gamma_{mme} = \frac{(\sqrt{N_s}+\sqrt{L})^2}{(\sqrt{N_s}+\sqrt{L})^2} \times \left(\frac{(\sqrt{N_s}+\sqrt{L})^{\frac{2}{3}}}{(N_s L)^{\frac{1}{6}}} . F_1^{-1}(1-P_{fa}) \right) \quad (8)$$

Where, γ_{mme} denotes detection threshold. F_1^{-1} denotes the inverse of cumulative distribution function of the Tracy Widom distribution of order 1 [15]. N_s is the number of samples and L denotes the level of covariance matrix.

The density of test statistic, T_y is required to define threshold in terms of probability of false alarm or vice versa and is defined as, the ratio of maximum eigenvalues to minimum eigenvalues of received signal of covariance matrix as follows:

$$T_y = \frac{\lambda_{max}}{\lambda_{min}} \quad (9)$$

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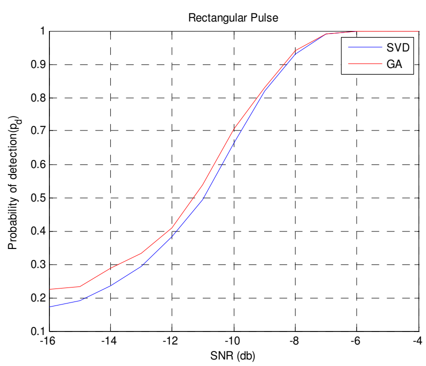
VII. Simulation Parameters and Results

A. Simulation parameters

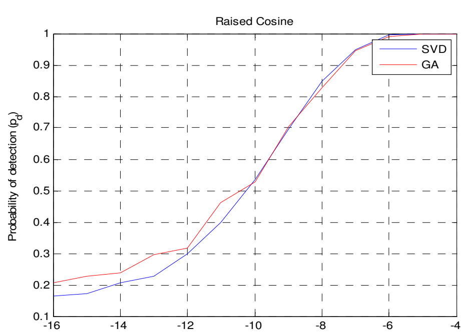
Additive white Gaussian noise channel is used. It is assumed that the channel is not changing during the period of samples. The results are averaged over 1000 tests using Monte Carlo simulations written in MATLAB. Simulation results are taken using MPSK modulated random primary signal and independent and identically distributed (iid) noise sample with Gaussian distribution are used. Three types of signal namely rectangular pulse, raised cosine and root-raised cosine were listed and compared. To find the threshold, we require the probability of false alarm is Pfa 0.1 and probability of detection is Pd 0.9 as required by IEEE 802.22 standard.

B. Simulation results

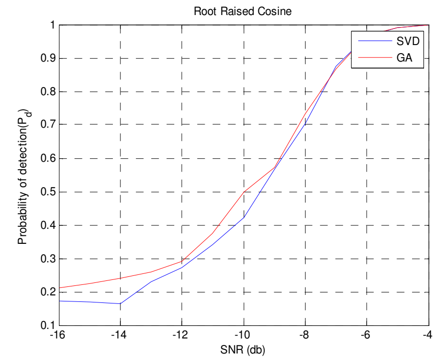
Figure 1 shows simulation results of the probability of detection (Pd) when the GA optimized SVD method and SVD method are used for comparison when SNR ranges from -16 dB to -4 dB. From these figures, it can be concluded that the GA optimized SVD based detection gives better results than SVD based detection in low SNR. It can be noticed from the graph that the performance of the SVD method and GA optimized SVD are nearly equal at -6 dB ,while GA optimized SVD shows better results at -16 dB for all the three signals ,rectangular pulse signal, raised cosine and root-raised cosine. Although SVD at certain points better than the GA optimized SVD method for root raised cosine signal, but the overall performance of the detector is better than the SVD method.



a) Rectangular pulse signal



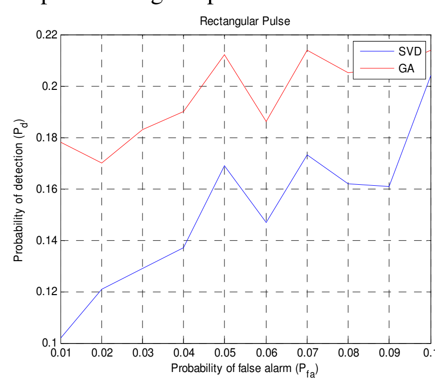
b) Raised cosine signal



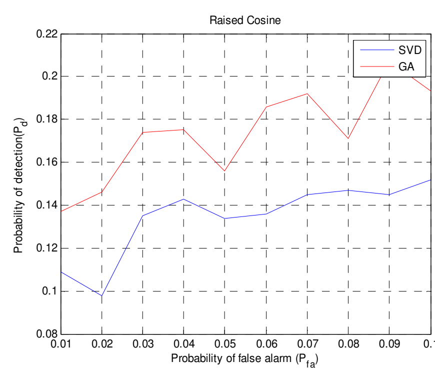
c) Root- raised cosine signal

Figure2: Comparision of Pd between the SVD method and energy detector for (a) Rectangular pulse signal; (b) Raised cosine signal(c) Root-raised cosine signal

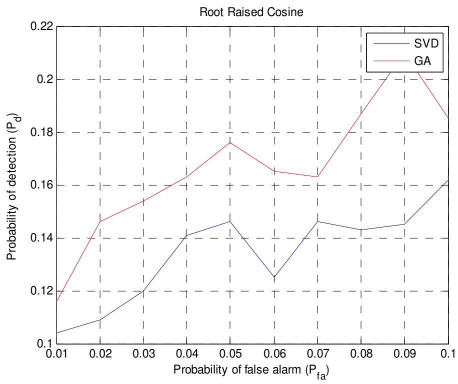
In terms of performance of the detector, the receiver operating characteristic (ROC) curves are shown in figure2. Both methods were simulated at -16 dB SNR and tested for three types of signal we plot the Pd under H1 against Pfa under Ho when Pfa changes from 0.01 to the desired value of 0.1.It is clearly shown that the ROC curves of the GA optimized based detection are higher than the SVD method which proves the good performance of the detector.



a) Rectangular pulse signal



b) Raised cosine signal



c) Root-raised cosine signal

Figure3: Comparision of ROC curves between SVD method and energy detector for a) Rectangular pulse signal)Raised cosine signal c) Root-raised cosine signal

VIII. CONCLUSION

In this paper, we implemented a GA optimized SVD-based approach to detect common signals in today's digital communication system. The rationale of detecting common signals is that, in order for a Cognitive Radio system to operate with an expectable quality of service. The brief simulation results show that GA optimized SVD of the data matrix finds the optimized value of L (no. of column).The method is more robust to numerical errors and very fast. These qualities are desirable in IEEE 802.22 standard since it is easily suited the need to shorten the period of sensing spectrum.

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REFERENCES

[1] J. Mitola and G. Q. Maguire, "Cognitive radio: making software radios more personal," Personal Communications, IEEE, vol. 6, no. 4, pp. 13–18, Aug. 1999.

[2] S. Haykin, "Cognitive radio: brain-empowered wireless communications," IEEE Journal on Selected Areas in Communications, vol. 23, no. 2, pp. 201–220, Feb. 2005.

[3] S. Xu, Y. Shang, and H. Wang, "Svd based sensing of a wireless microphone signal in cognitive radio networks," in 11th IEEE Singapore International Conference on Communication Systems, 2008 (ICCS 2008), 2008, pp. 222 –226.

[4] T. Yucek and H. Arslan, "A survey of spectrum sensing algorithms for cognitive radio applications," Communications Surveys Tutorials, IEEE, vol. 11, no. 1, pp. 116 –130, 2009.

[5] I. F. Akyildiz, W.-Y. Lee, M. C. Vuran, and S. Mohanty, "NeXt generation/dynamic spectrum access/cognitive radio wireless networks: a survey," Comput. Netw., vol. 50, no. 13, pp. 2127–2159, 2006

[6] A. Kortun, T. Ratnarajah, M. Sellathurai, and C. Zhong, "On the performance of eigenvalue-based spectrum sensing for cognitive radio," in New Frontiers in Dynamic Spectrum, 2010 IEEE Symposium on, 2010, pp. 1 –6.

[7] S. Leach, "Singular value decomposition – a primer," Solutions, p. 8, 2000. [Online]. Available:http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.2.6587

[8] Holland, J. 1975. Adaptation in Natural and Artificial Systems. University of Michigan Press

[9] Beibei Wang and K. J. Ray Liu, "Advances in Cognitive Radio Networks: A Survey," in IEEE journal of selected topics in signal processing,vol.5,no.1,February 2011,pp.5-23.

[10] A. Sahai and D. Cabric, "Spectrum sensing: Fundamental limits and practical challenges," in IEEE International Symposium on New Frontiers Dynamic Spectrum Access Networks (DySPAN), November 2005, Baltimore, MD.

[11] D. Tufts and R. Kumaresan, "Singular value decomposition and improved frequency estimation using linear prediction," Acoustics, Speech and Signal Processing, IEEE Transactions on, vol. 30, no. 4, pp. 671 – 675, Aug..

[12] 1982Y. Zeng and Y.-C. Liang, "Maximum-minimum eigenvalue detection for cognitive radio," in IEEE 18th International Symposium on Personal, Indoor and Mobile Radio Communications PIMRC 2007., 2007, pp. 1 –5

[13] Sapna Katiyar, A Comparative Study of Genetic Algorithm and the Particle Swarm Optimization," A.B.E.S. Institute of Technology, Ghaziabad

[14] I. M. Johnstone, "On the distribution of the largest eigenvalue in principal components analysis," Annals of Statistics, vol. 29, no. 2, pp. 295–327, 2001.

[15] C. A. Tracy and H. Widom, The distribution of the largest eigenvalue in the Gaussian ensembles, ser. CRM Series in Mathematical Physics 4. New York: Springer-Verlag, 2000, pp. 641–472.