A OPTIMIZED GA-SVD BASED SIGNAL DETECTOR FOR COGNITIVE RADIO

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***Abstract*— Cognitive radio is an intelligent wireless communication technology in order to increase the spectrum efficiency. Increasing efficiency of the spectrum usage is an urgent need as an intrinsic result of the increasing demand for higher data rates, better quality of services and higher capacity. FCC decided to make a paradigm shift by allowing more and more number of unlicensed users to transmit their signals in licensed bands so as to efficiently utilize the available spectrum. Spectrum sensing is the most important task upon which the entire operation of the cognitive radio rests, there are the various sensing techniques available, But there are some practical challenges and limitations in these techniques. This paper examines the implementation of Genetic Algorithm (GA) based optimize Singular Value De-composition (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, Singular Value De-composition, Signal detector, 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: 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]. Maximum-maximum eigenvalue (MME) method is quite better as compared to rest of other sensing methods. The MME. method use random matrix theory (RMT) to detect the presence of signal. This method can only be applied to certain classes of square matrices. The SVD is quite similar to the eigenvalue decomposition method. However, the SVD is very general in the sense that it can be applied to any m × n 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 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-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

Being the focus of this paper, for detecting a signal two Hypothesis are involved, H_0 and H_1. H_0 is null hypothesis means signal is absent while H_1 means signal is present. The received signal under two Hypothesis is given as

$$H_0: \; y(n) = w(n) \qquad (1)$$

$$H_1: \; y(n) = s(n) + w(n) \qquad (2)$$

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, the probability of detection P_d, and probability of false alarm P_f are given by following formulas:

$$P_d = P(y > \lambda / H_1) \quad (3)$$

and $$P_f = P(y > \lambda / H_0) \quad (4)$$

III. SVD BASED DETECTOR

The SVD-based signal detection is most efficient way of sensing signal without knowing the properties of the transmitted signal. SVD plays a crucial role in the field of signal processing and statistics, specifically in the area of a linear system. For a time series y (n) with n = 1, 2. . . N, commonly, we can construct a Henkel matrix with M = N-L+1 rows and L columns as follows,

$$R = \begin{bmatrix} y(1) & y(2) & y(L) \\ y(2) & y(3) & y(L+1) \\ \vdots & \vdots & \dots \ \vdots \\ y(N-L+1) & y(N-L+2) & y(N) \end{bmatrix} \quad (5)$$

Then R is an M ×L matrix. Its elements can be found by substituting of y (n) , R_{ml} = y (m+l-1), m = 1, 2…M and l = 1, 2…L , Using SVD, R can be factorized as

$$R = U \Sigma V^H \quad (6)$$

Where U and V is an M×M and L×L unitary matrix respectively. And the columns of matrix U and V are called left and right singular vectors respectively.

The Σ = diag $(\lambda_1, \lambda_2 \dots \lambda_m)$ is a diagonal matrix whose nonnegative entries are the square roots of the positive eigenvalue of $R^H R$ or RR^H.

These nonnegative entries are called the singular values of R and they are arranged in a decreasing manner with the largest number in the upper left-hand corner of the matrix. The $[\,]^H$ denotes the Hermitian transpose of a matrix.

Whenever the primary signal or any other signal is not present, then the received signal y(n) comprises only AWGN contribution such that its singular values are similar and close to zero. When other signals are active and having power more than a threshold offset, then there will be several dominant singular values that represent these signals. As a result, the signal can be detected by examining the presence of dominant singular values [7].

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,

1. Select number of columns of a covariance matrix, L such that k < L < N-k, where N is the number of sampling points and k is the number of dominant singular values.
2. Factorized the covariance matrix.
3. Obtain the maximum and minimum eigenvalue i.e. $\lambda_{\max}$ and $\lambda_{\min}$, of the covariance matrix.
4. Computation of threshold value γ.
5. Compare the ratio with the threshold. If $\lambda_{max} / \lambda_{\min} > \gamma$, is to be found then the decision will be in favour that signal is present otherwise it is not present.

IV. GENETIC ALGORITHM

A genetic algorithm is basically a part of the evolutionary computing, one of the rapidly growing area of artificial intelligence. Genetic algorithm is inspired by Darwin's theory regarding evolution..

In a genetic algorithm, a population of strings known as the chromosomes which encode candidate solutions generally called individuals,. Basically, all the solutions are represented in binary sequences consisting of 0’s and 1’s, but other encodings techniques are also possible. The evolution generally starts with a population of randomly generated individuals and it happens in generations. The fitness of every individual in the population is evaluated in each generation, and multiple individuals are then stochastically chosen from the current population (based on their fitness), and modified (recombined and possibly randomly mutated) to generate a new population. This newly generated population is used in the next iteration of the algorithm. Usually, the algorithm is terminated whenever either there is a production of a maximum number of generations, or a adequate fitness level has been acquired for the population. If the termination of algorithm is because of a maximum number of generations, then a satisfactory optimal solution may or may not have been reached

A path through the different components of the GA is represented as a flowchart in Figure 1 and described below:

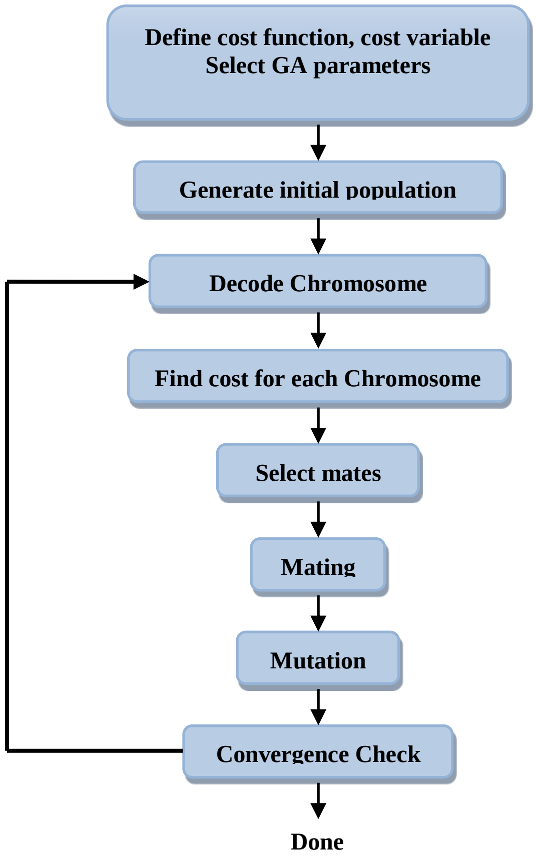

Fig. 1 A path through the components of the GA

1. **Define cost function and cost:**
   For each problem there is a cost function. For instance, maximum of a 3D surface with peaks and valleys when displayed in variable space, then a Cost (value) for fitness, is allotted to each solution.
2. **Chromosomes and genes:**
   A gene is a number lying from 0 to n-1. An array of these genes defines a chromosome.
3. **Create a Random Initial Population:**
   An initial population is generated from a random selection of chromosomes. It is the parameter upon which the number of generations needed for convergence depends.
4. **Decoding of chromosome and finding the cost:**
   A cost function is defined to find the assigned cost for each chromosome. The cost function has a result known as cost value. As a final point, averaging the cost values of each generation converges to the desired answer.
5. **Mating and next generation:**
   Those chromosomes with a higher fitness (lesser cost) value are used to produce the next generation. The offspring is a product of the father and the mother. The composition of offspring consists of a combination of genes derived from both (this process is termed as "crossing over").
   If a chromosome contained in the new generation, produces an output which is close enough or equal to the desired answer then the solution of problem has been obtained. If not so, then the newly generation will go through the same procedure as followed by their parents. This process will continue until a optimal solution is reached.

V. THRESHOLD DETERMINATION

The decision statistic for the maximum minimum eigenvalue (MME) detection is defined as the ratio of maximum to minimum eigenvalues of received signal covariance matrix as follows:

$$T_\lambda = \lambda_{max}/\lambda_{\min} \qquad (7)$$

An asymptotic formula of signal detection threshold in term of desired probability of false alarm for MME has been proposed in. The detection threshold in terms of desired probability of false alarm is calculated by using the results of the theorem.

VI. A GA-SVD BASED SIGNAL DETECTOR

The SVD-based signal detection is most efficient way of sensing signal without knowing the properties of the transmitted signal. Our approach in this work is to add absolute precision in the base method. Here comes the GA-SVD Based signal detector, marked as the more efficient method than previous methods, in terms of sensing of Signal without having knowledge of the basic properties of transmitted signal code

The Optimized SVD Algorithm is proposed by employing the Genetic Algorithm along with the existing SVD Based Signal detector. This Algorithm proceeds through the different stages which are here represented as the Flow Diagram, as shown in the figure 2.

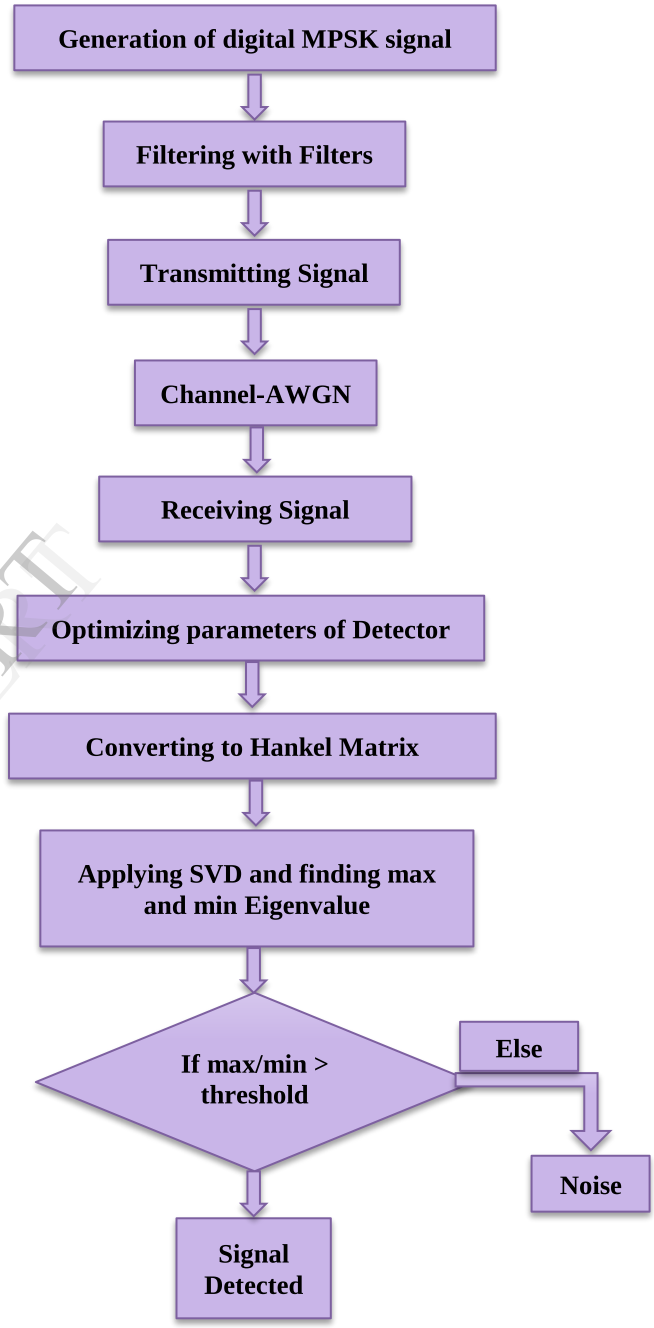

Figure 2 Flow diagram for GA-SVD Signal Detector

In this paper, k = 2, and the value of L is optimized by Genetic Algorithm.

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VII. SIMULATION PARAMETERS & RESULTS

A) SIMULATION PARAMETERS

The various Simulation result of SVD and GA for different inputs like Rectangular pulse, Raised Cosine pulse & Root Raised Cosine pulse for Probability of detection with respect to SNR, in aforementioned environment is shown here.

Design Specifications:

- **Modulation Scheme**:- MPSK, M=8
- **Signals**:- (1) Rectangular Pulse
  (2) Raised cosine
  (3) Root Raised cosine
- **SNR Range**:- -16 to -4 db
- $\boldsymbol{P_{fa}}$:- 0.01-0.1
- **Environment**:- AWGN.

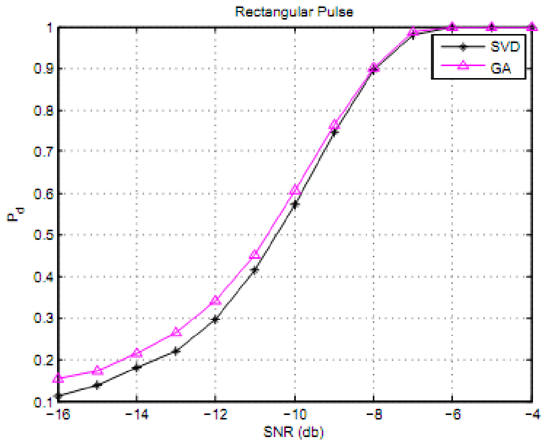
B) SIMULATION RESULTS

Figure 3 shows simulation results of the probability of detection (P_d) when the GA-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.

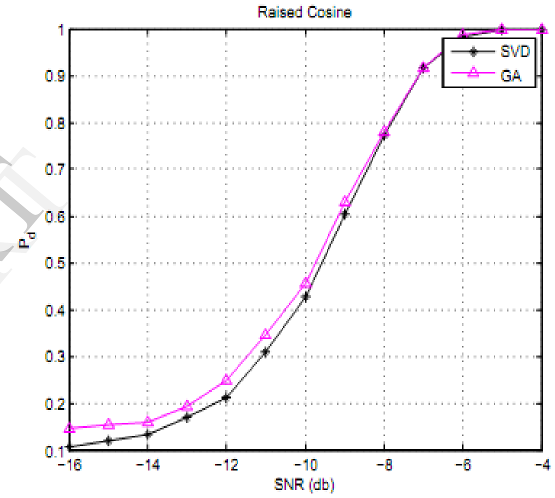
CONCLUSION

We implemented a GA-based approach to detect common signals in today's digital communication system. The rationale of detecting common signals is that, in order for a CR system to operate with an expectable quality of service, the CR need to avoid interference not only to/from primary users but any other signals, which could affect the delivery of information to the system. The brief simulation results show that SVD of the data matrix is very useful in finding the dominant singular values in which the presence of other signals can be detected.

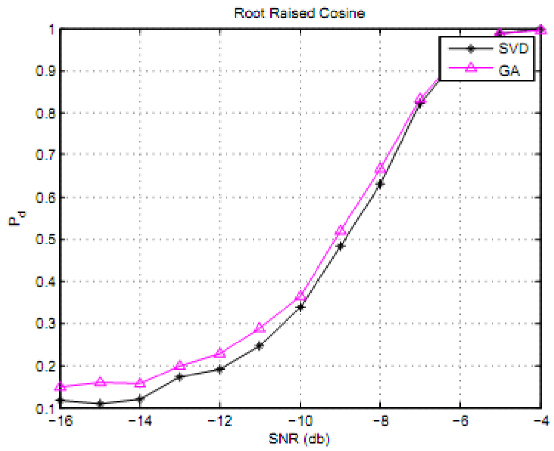
The method is more robust to numerical errors and very fast. These qualities are desirable in IEEE 802.22 standard since it is easily suited the need to shorten the period of sensing and hence making the system reliable



(a)



(b)



(c)

Fig. 3: Comparision of P_d between the GA-SVD and SVD detector for
(a) Rectangular pulse signal;
(b) Raised cosine signal
(c) Root-raised cosine signal

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