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Combining Genetic Algorithm and Direction of Arrival for MIMO Wireless Communication System†

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Abstract—In the next generation of wireless communications, Multiple Input Multiple Output (MIMO) communication system will be a key technology to enhance the communication efficiency. The popular method for estimating the direction of arrival of sources impinging on an array of MIMO sensors is Multiple Signal Classification (MUSIC) method which is a problem of great interest in MIMO communication system. The iterative searching technique has been shown more likely to converge to a local maximum, causing errors in Direction of arrival (DOA) estimation. A new system is proposed to estimate direction of arrival of sources for Multiple Input Multiple Output (MIMO) communication system by combining Genetic Algorithm and (MUSIC) method. In the proposed model, by using Genetic algorithm the direction of arrival angles can be selected automatically good response by fast convergence, efficiency and yield more accuracy to estimate the direction of arrival of the sources over existing conventional spectral searching methods which is shown by the result of computer simulation for proposed system. The important feature of new system is that, it is observed that Genetic Algorithm (GA) combined with MUSIC method is a powerful alternative in online DOA estimation

Key Word: Multiple Input Multiple Output (MIMO) system, Genetic Algorithm (GA), multiple signal classification (MUSIC) method

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1. Introduction

The idea of Multiple Input Multiple Output (MIMO) system has been recently become a hot research for its potential advantages. MIMO system has been proposed as a new system with various applications [1], [2]. Direction of Arrival (DOA) estimation is a problem of considerable interest in MIMO array. Many methods like Capon, ESPRIT and MUSIC [3], [4] , have been developed, they use the data received at a sensor array to perform DOA estimation. Estimating the Direction of Arrival (DOA) of ultra wideband waveform, impinging on an array of sensors has long been of great research interest in a noisy environment using an array of L sensors [5]. The signals parameters are of interest and of spatial nature, require the cross-covariance information among the various sensors, which are the spatial covariance matrix. This covariance matrix R consists of a noisy covariance, and signal covariance matrixes. The covariance matrix is estimated from a finite number of samples of the data vector. In this paper, MUSIC method is used as it offers better performance than others. For conventional spectral searching estimators with local scattering, the searching complexity and estimating accuracy strictly depend on the number of search grids used during the search. In order to obtain high-resolution and accurate DOA estimation, a smaller grid size is needed. This is time consuming and it is unclear how to determine the required number of search grids. Therefore, the possibility of obtaining the global optimal solution is lower. Genetic Algorithm (GA) [6], [7] is a global probability search algorithm, which emulates the biological evolution process of Darwin's genetic selection and natural elimination. It possesses self-adaptability, global optimization, and implicit parallelism, manifesting the strong capability in solving problems [8]. In this paper, based on genetic algorithm and multiple signal classification (MUSIC), a new system is proposed to estimate direction of arrival of sources for Multiple Input Multiple Output (MIMO) communication system.

2. MIMO Signal Model

Consider a uniform linear array of M sensors with inter sensor spacing of d. If plane waves from different ultra wideband signals arrive at the array at angles θ_1, θ_2, ..., θ_n, with respect to the array normal, the MIMO received signals data model is given by

$$y(t) = \sum_{m=1}^{M} a(\theta_m) s_m(t) \quad (1)$$

Where $s_m(t)$, m=1,2,……..,M denotes the ultra wideband signal and $a(\theta_m)$ is the steering vector of single signal at DOA θ_m, the compact form of the output vector including an additive noise can be written as [9]:

$$y = As + n, \quad (2)$$

where $y = [y_1(t) \quad y_2(t) \quad .... \quad y_M(t)]^T$, $n = [n_1(t) \quad n_2(t) \quad .... \quad n_M(t)]^T$ is zero-mean additive white complex Gaussian noise of variance σ^2, and

$$s = [s_1(t) \quad s_2(t) \quad .... \quad s_n(t)]^T \quad (3)$$

is the vector of source signals at time t.

The *steering-vector* matrix A is given by [9]:

$$A = [a(\theta_1) \quad a(\theta_2) \quad ... \quad a(\theta_n)], \quad (4)$$

Where

$$a(\theta_l) = [1 \quad e^{jw_l} \quad e^{j2w_l} \quad ... \quad e^{j(M-1)w_l}]^T$$

and $w_l = kd\sin(\theta_l)$. It is assumed that the sources are mutually uncorrelated and that the auto-correlation of each source decayed exponentially. It is also assumed that the signal and noise are uncorrelated. The covariance matrix of the data vector would then be:

$$\begin{aligned} R &= E\left[yy^H\right] \\ &= AE\left[ss^H\right]A^H + E\left[nn^H\right] \\ &= APA^H + \sigma^2 I, \end{aligned} \quad (5)$$

where

$$P = E\left[yy^H\right] = diag\left[\sigma_1^2,\ \sigma_2^2,\ ...,\ \sigma_n^2\right],$$

and $E\left[nn^H\right] = \sigma^2 I$. Let R be eigen decomposed as [9]:

$$R = \left[UV\right]\begin{bmatrix} \Lambda & 0 \\ 0 & \sigma^2 I \end{bmatrix}\begin{bmatrix} U^H \\ V^H \end{bmatrix} \quad (6)$$

where U and V are the signal subspace and noise subspace eigen vector matrices, respectively. It can be shown that $A^H V = 0$ [5] or equivalently.

$$a^H(\theta)VV^H a(\theta) = 0 \quad (7)$$

at the true DOAs. An estimate of R is obtained from N samples of the data vectors as,

$$\hat{R} = \frac{1}{N}\sum_{t=1}^{N} y(t)y^H(t). \quad (8)$$

If R is eigen decomposed as in eqn (6), one would arrive at the estimate of the noise subspace eigen vector matrix as $\hat{V}$. Since $\hat{V}$ is only an estimate, the left-hand side of eqn (7) would be minimum, and not zero, at the true DOAs if it is replaced by $\hat{V}$. Spectral MUSIC utilizes this fact, so that the ambiguity function [10]

$$B(\theta) = \left(\frac{1}{a^H(\theta)\hat{V}V^H a(\theta)}\right) \quad (9)$$

peaks at the true DOA

3. Genetic Algorithm (GA)

The parameters which need to be searched by GA in the training are the range of initial weights (R) and initial values of learning rate. The initial weights are generated using a uniform random number generator in the range [-R,R]. The GA proposed as searching process based on the laws of the natural selection and genetics. This algorithm which is used firstly to obtain the optimal values of the initial weights and the initial value of learning rate top-level description of a simple GA is shown below [11]:

a. Randomly generate an initial population $P^0 = \left(a_1^0,\ a_2^0,\ ....,\ a_m^0\right)$

b. Compute the fitness $f\left(a_i^t\right)$ of each chromosome a_i^t in the current population p^t.

c. Create new chromosome p^{1t} of mating current chromosomes, applying mutation and recombination as the parent chromosomes mate.

d. Delete numbers of the population to make room for new chromosomes.

e. Compute the fitness of $f\left(a_i^{1t}\right)$, and insert these into population.

f. Increment number of generation, if not (end-test) go to step c, or else stop return the best chromosome.

4. The Proposed Model

Due to the fact that the performance of the abovementioned spectral searching MUSIC estimator is governed by the scanning grid size and the number of search grids while implementing the high resolution DOA estimation, it is time consuming and the search grid is not clear. Therefore we proposed model for estimating direction of arrival for sources based on genetic algorithm and MUSIC methods, in order to reduce the scanning accurate angle problems of high computation cost, the genetic algorithm is used to replace scan in the MUSIC method. The operating steps of the Genetic Algorithm combined with MUSIC method is as follows:

Step1. Initializations of the population and Initial population in DOA applications are formed by sets of possible angles. In most DOA problems, a pre-estimator is used to determine the range of the initial. a plain MUSIC algorithm is used for a rough estimate of region of interest. Each possible solution set in the initial population is defined by column vectors of containing the real valued representation of angles

Step2. The fitness (objective) function for genetic algorithm is defined as in (9). Our objective is to search θ to achieve the maximum of (9).

Step3. The individual who have a high fitness would be to the next generation by genetic.

Step4. Crossover and mutation operation can be used to deal with the current population to produce the next generation of the population.

Step5. Then decoding the new population and calculate the fitness function.

Step6. Repeat step2 to step5. Go to step 3 until obtaining determined fitness value, then the suitable θ is obtained.

5. Simulation and Result Evaluation

To examine the effectiveness of the proposed system, computer simulations have been carried out. A uniformly linear array with 10 sensors is employed. Each number detection result is carried out based on 128 snapshots. In section, we compare the performance of proposed system (estimating direction of arrival by using Genetic Algorithm and MUSIC Method (GA-MUSIC)) with classic system (estimation of sources by using MUSIC Method without using Genetic Algorithm). MATLAB 7 builds the proposed algorithm. In the proposed system, parameter settings for the genetic algorithm are mutation rate=0.05, crossover rate=0.65, population size=20 and real coding to the chromosomes. We consider four cases with different angles for sources. In first case, two sources are considered with SNR=4 dB, the first source is at 80^o and second source is at 83^o. In this case, The MUSIC searches for the peak is illustrated in Fig.(1), from the graph, it is easily shown that two emitter signal is available due to the two peaks in the spectrums, it gave the result for two emitter sources in direction 80^o and 82^o. When the MUSIC is implemented by using GA , it gave the result for two emitter sources in direction 80^o and 83^o, therefore the proposed system gives correct direction of arrival for source and the classic system gives incorrect direction of arrival for source as shown in Figure (1) and Table (1), also the proposed system achieves fast convergence with the selected parameters, which means that it needs less iterations to approach the desired global extreme . In second case, for two closely spaced emitter sources, two sources are considered with SNR=5 dB, the first source is at 80^o and second source is at 82^o. In this case, the MUSIC searches for the peak is illustrated in Fig.(2). Only one emitter signal is available due to the only peak in the spectrums as it's shown in the graph. The estimated DOA is 81^o degree has been shown By Search for the peak of emitter signal. When the MUSIC is implemented by using GA , it gave the result for two emitter sources in direction 80^o and 82^o, therefore the proposed system gives correct direction of arrival for sources but the classic system gives incorrect direction of arrival for sources as shown in Figure (2) and Table (2). In third case, two sources are considered with SNR=10 dB, the first source is at 80^o and second source is at 81^o. In this case, The MUSIC searches for the peak is illustrated in Fig.(3). From the graph, it is easily shown that only one emitter signal is available due to the only peak in the spectrums. Search for the peak of emitter signal has shown that the estimated DOA is 80^o. When the MUSIC is implemented by using GA , it gave the result for two emitter sources in direction 80^o and 81^o, therefore the proposed system gives correct direction of arrival for sources but the classic system gives incorrect direction of arrival for sources as shown in Figure (3) and Table (3). In fourth case, two sources are considered with SNR=10 dB, the first source is at 80^o and the second source is at 80^o. In this case, Fig.(4) illustrates the MUSIC searches for the peak. From the graph, it is easily shown that only one emitter signal is available due to the only peak in the spectrums. Search for the peak of emitter signal has shown that the estimated DOA is 80^o. When the MUSIC is implemented by using GA , it gave the result for two emitter sources in direction 80^o and 80^o, therefore the proposed system gives correct direction of arrival for sources but the classic system gives incorrect direction of arrival for sources as shown in Figure (4) and Table (4).

6. Conclusion

For estimating the direction of arrival for source for Multiple Input Multiple Output (MIMO) communication system, a new system has been introduced by combining genetic algorithm with MUSIC method in this paper. For conventional spectral searching estimators with local scattering, the searching complexity and estimating accuracy strictly depend on the number of search grids used during the search. The proposed method based on optimizing to selected angles for sources. Precise estimation for direction of arrival based on genetic algorithm and music method without need to grid size can be given by the proposed method. The genetic algorithm achieves success in giving reliable results of DOA-MUSIC without the need of any spectral search for DOA angles. The proposed method is suitable for hardware implementation. An efficient approach to achieve the advantages of iterative DOA estimation with fast convergence and more accuracy estimate over existing conventional spectral searching methods is shown by the result of computer simulation for proposed system.

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Table 1 Composition between MUSIC Method and GA-MUSIC Method for first case (Angles in Degrees)

Actual DOA	**80,83**
MUSIC	**80,82**
GA-MUSIC(proposed method)	**80,83**

Table 2 Composition between MUSIC Method and GA-MUSIC Method for second case (Angles in Degrees)

Actual DOA	**80,82**
MUSIC	**81**
GA-MUSIC(proposed method)	**80,82**

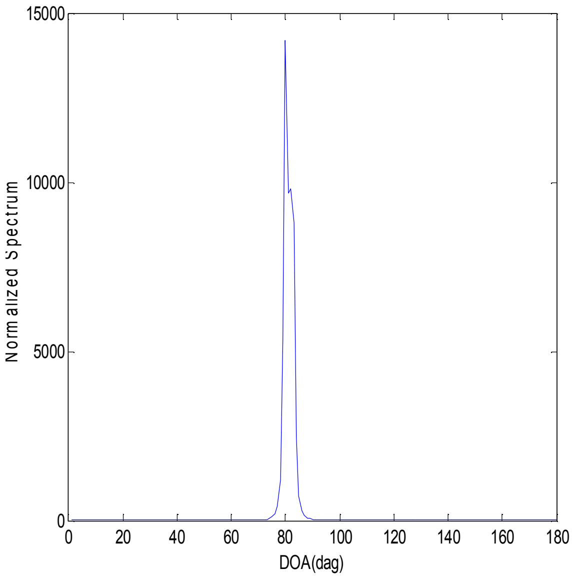

Figure 1 DOA for Two Sources at $\theta_1 = 80^\circ$ and $\theta_2 = 83^\circ$ by using classic system (MUSIC) for first case

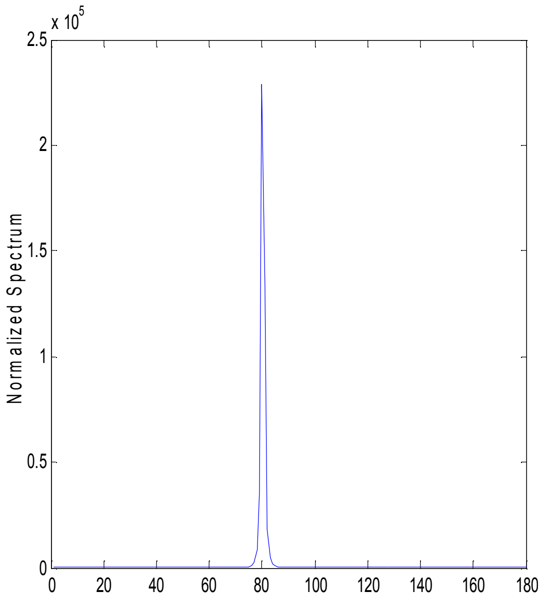

Figure 2 DOA for Two Sources at $\theta_1 = 80^\circ$ and $\theta_2 = 82^\circ$ by using classic system (MUSIC) for second case

Table 3 Composition between MUSIC Method and GA-MUSIC Method for third case (Angles in Degrees)

Actual DOA	**80,81**
MUSIC	**80**
GA-MUSIC(proposed method)	**80,81**

Table 4 Composition between MUSIC Method and GA-MUSIC Method for fourth case (Angles in Degrees)

Actual DOA	**80,80**
MUSIC	**80**
GA-MUSIC(proposed method)	**80,80**

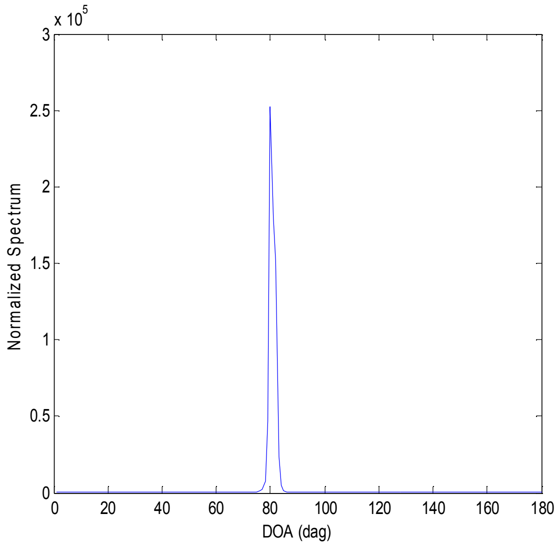

Figure 3 DOA for Two Sources at $\theta_1 = 80^\circ$ and $\theta_2 = 81^\circ$ by using classic system (MUSIC) for third case

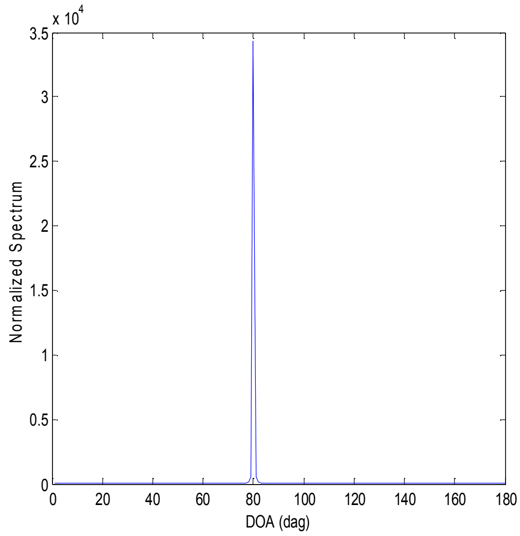

Figure 4 DOA for Two Sources at $\theta_1 = 80^\circ$ and $\theta_2 = 80^\circ$ by using classic system (MUSIC) for fourth case