# Accuracy of Direction-of-Arrival Estimation with Immune Algorithm

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## 1. Introduction

The Genetic Algorithm is used in the direction-of-arrival estimation [1]. We have proposed the new direction-of-arrival estimation method using the Immune Algorithm (IA) which is the expansion of the Genetic Algorithm. We can also apply this direction-of-arrival estimation method for the case where the number of signals is unknown and signals are coherent. Furthermore, this method can be expanded to two-dimensional estimation. However, in the Immune Algorithm, the performance sometimes depends on parameters.

This paper presents computer simulation results of the performance of direction-of-arrival estimation using the Immune Algorithm for various parameters. The Genetic Algorithm can be applied to the direction-of-arrival estimation easier than the other methods. The Immune Algorithm has a large search area in comparison with the Genetic Algorithm, and adapts to any changes in a different environment.

## 2. Immune Algorithm

In this section, we describe the Immune Algorithm which is used to estimate the direction-of-arrival.

First, set a population which is an array of individuals. Each individual is a candidate of solution to the problem, consisting of a number of antibodies which represent the set of signal parameters as shown in Figure 1. Each antibody is an array of genes. Each gene represents a number of signals $d$, a correlation coefficient $\rho_{ij}$, noise power $\sigma^2$, a normalized amplitude of $i$-th signal $s_i$, a relative phase of $i$-th signal $\phi_i$ and direction-of-arrival of $i$-th signal $\theta_i$. Each value is expressed in the analog quantity.

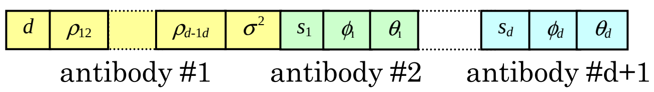



Figure 1: Individual

A simplified flow chart of the Immune Algorithm applied to the signal parameter estimation is shown in Figure 2. The data is obtained by measuring the complex response of the antenna array elements.

The first step of the Immune Algorithm is to generate an initial population of individuals. The second step is to evaluate the fitness of each individual, and to rank the individuals. Then, we evaluate the degree of similarity of the individuals, and store some individuals whose rank and degree of similarity are high. The stored individuals are called memory ones. The third step is to select the individuals whose rank is high, and to delete the individuals whose degree of similarity to the memory individuals is high. Therefore, the Immune Algorithm has a large search area in comparison with the Genetic Algorithm by introducing the memory individuals. Crossover is the method of exchanging genetic information between two individuals (parents) in order to form another pair of individuals (offsprings). The crossover method

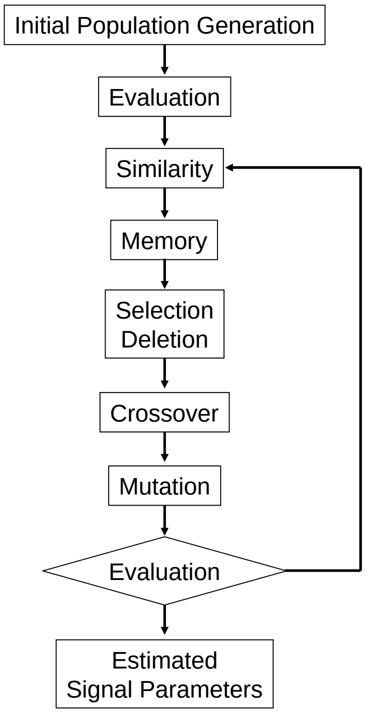



Figure 2: Immune Algorithm Flow Chart

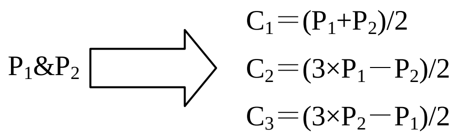



Figure 3: Crossover

is shown in Figure 3 [2]. Here, $P_1$ and $P_2$ represent the individuals of the parents, and $C_1$, $C_2$ and $C_3$ represent the ones of the offsprings. Mutation alters randomly a part of the individuals. The last step is to evaluate the fitness of each individuals again. The Immune Algorithm execution comes to the end when the number of generations exceeds a predefined maximum, or the evaluation function falls below the anticipated threshold.

The received signal of the $i$-th antenna array element and $ij$-element of the correlation matrix are given by

$$r_i(t) = \sum_m s_m(t) e^{j\phi_m(t)} e^{-j\frac{2\pi}{\lambda}(x_i \sin\theta_m - y_i \cos\theta_m)} + n_i(t), \tag{1}$$

$$R_{ij} = < r_i r_j^* > . \tag{2}$$

We express the IA signal of the $i$-th antenna array element and $ij$-element of the IA correlation matrix as

$$r'_i(t) = \sum_k s'_k(t) e^{j\phi'_k(t)} e^{-j\frac{2\pi}{\lambda}(x_i \sin\theta'_k - y_i \cos\theta'_k)} \tag{3}$$

$$R'_{ij} = \sum_k \sum_l s'_k(t) e^{j\phi'_k(t)} e^{-j\frac{2\pi}{\lambda}(x_i \sin\theta'_k - y_i \cos\theta'_k)} s'_l(t) e^{-j\phi'_l(t)} e^{j\frac{2\pi}{\lambda}(x_j \sin\theta'_l - y_j \cos\theta'_l)} \tag{4}$$

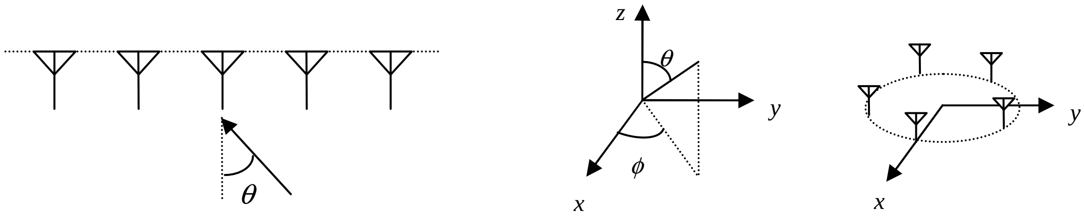
The degree of similarity and evaluation function (fitness) are as following,

$$similarity = \frac{1}{\sum_i \sum_j |R'_{ij} - R''_{ij}|} \tag{5}$$

$$fitness = \sum_i \sum_j |R_{ij} - (R'_{ij} + \sigma^2 \delta_{ij})| \tag{6}$$

## 3. Simulation results

In this section, we show the simulation results. We assume that some signals with an amplitude of 1 or 0.5 impinge on the 5 element linear array antenna as shown in Figure 4(a). Also, we assume that some signals with an amplitude of 1 impinge on the 5 element circular array antenna as shown in




(a) Linear Array Antenna (b) Circular Array Antenna

Figure 4: Array Antenna

Figure 4(b). We generated Gaussian random numbers for the noise whose power is $10^{-1}$(SNR=10dB). The parameters of the Immune Algorithm are shown in Table 1.

Table 1: IA parameters

| Population | Number of generation | Crossover probability | Mutation probability |
|---|---|---|---|
| 100 individuals | 50 | 100% | 20% |

First, Figure 5 shows the results of the Immune Algorithm in a case where one signal impinges on the 5 element linear array antenna. We examined 6 cases of the direction-of-arrival, namely 0°, 15°, 30°, 45°, 60° and 75°. From the figure, it is seen that we can estimate the direction-of-arrival and the normalized amplitude by the Immune Algorithm.

Next, Figures 6(a),(b) and (c) show the results of the Immune Algorithm in a case where two signals impinge on the 5 element linear array antenna. The direction-of-arrival of the first signal is fixed at 0°, and that of the second signal varies as follows: 15°, 30°, 45°, 60°, 75°. Figure 6(a) shows an incoherent signal case, and Figures 6(b) and (c) show coherent signal cases. In Figure 6(c), the amplitude of the second signal is 0.5. Figure 6(d) shows the results of the Immune Algorithm in a case where three signals impinge on the 5 element linear array antenna. The directions-of-arrival of the first, second, and third signals are 0°, 30° and 60°, respectively. From the figures, it can be said that we can estimate the directions-of-arrival and the normalized amplitudes by the Immune Algorithm.

Finally, we examine the two-dimensional estimation. Figures 7(a) and (b) show the results of the two-dimensional Immune Algorithm where two signals are incident on the 5 element circular array antenna. The directions-of-arrival of the first and second signals are $\phi = 0°, \theta = 60°$ and $\phi = 15°, \theta = 75°$, respectively. Figures 7(a) and (b) show the two-dimensional estimation results for incoherent and coherent signal cases, respectively. From the figures, it is seen that we can estimate the two-dimensional direction-of-arrival and the normalized amplitude by the Immune Algorithm.

## 4. Conclusion

We have shown the estimation of the signal parameters by the Immune Algorithm. In conclusion, we can say that the method is very effective according to the simulation results.

## Acknowledgments

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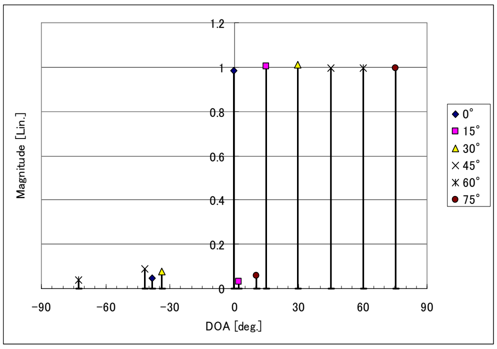
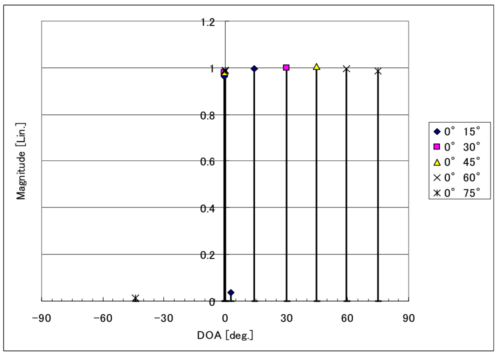
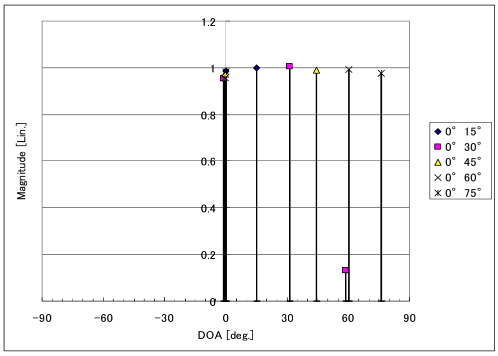


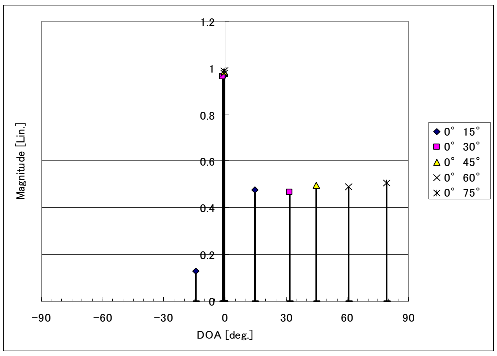

Figure 5: DOA and normalized amplitude estimation (First example).



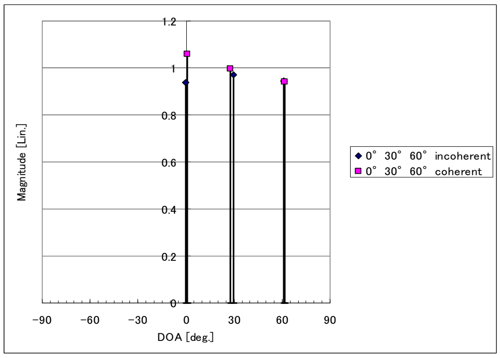
(a)



(b)

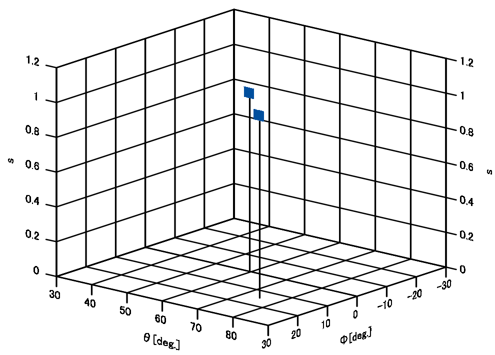


(c)

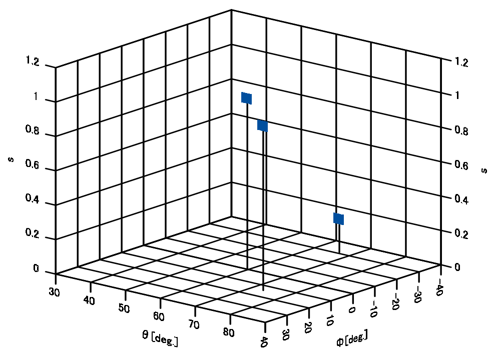


(d)

Figure 6: DOA and normalized amplitude estimation (Second example).



(a)



(b)

Figure 7: DOA and normalized amplitude estimation (Third example).