Optimization on Antenna Selection Using Imperialist Competitive Algorithm

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ABSTRACT:
Nowadays, the multiple antenna transmission technique, which may be modeled as Multiple Input Multiple Output (MIMO) systems, is used for increasing the capacity of the wireless communication systems. However, complexities and cost are associated with MIMO systems. Here, we propose a technique based on Imperialist Competitive Algorithm (ICA) to reduce the computational complexity and hardware cost. A new suboptimal configuration on antenna selection both in receiver and transmitter sides is the outcome of applying our method on MIMO systems. Our algorithm achieves almost the same outage capacity as the optimal selection technique while having lower computational complexity than the exiting nearly optimal antenna selection methods such as genetic algorithms. The antenna selection algorithm requires an exhaustive search of all possible combinations and permutations to find the optimum solution at the transmitter or receiver side, thus resulting in extremely high computational complexity. To reduce the computational load while still maximizing channel capacity, the ICA method is adopted to determine the suboptimum solution. The simulation results show that the ICA method has better performance from the point of view of both computational and time complexities, when compared with the Genetic Algorithm (GA) and Exhaustive search method (ES).

KEYWORDS: Antenna Selection; Genetic Algorithm; Imperialist Competitive Algorithm; MIMO System.

1. INTRODUCTION

MIMO systems can increase the capacity of the wireless communication systems, without any need to increase the bandwidth or transmission power [1-4]. It is demonstrated that capacity of MIMO system has linear relation with minimum number of antennas both in receiver and transmitter sides. The above value is called $\min(N_R, N_T)$, where N_R and N_T are the numbers of transmitter and receiver antennas respectively. Due to the cost of the Radio Frequency (RF) channels, the number of transmit and receive antennas is limited. So, recently special attempts are done to select a subset of the available antennas which is called optimum antenna selection schemes. Using this method, the RF chains can be optimally connected to the best subset of the transmitter or receiver antennas. The conventional mechanism for finding an optimum selection of antenna is exhaustive search of all possible combination for one that gives the best Signal-to-Noise Ratio (SNR) or capacity. The complexity order of this search is exponential. Hence, a computationally efficient antenna selection algorithm is required.

Here, we try to find an efficient evolutionary algorithm for the antenna selection problem in MIMO system to reduce the cost while keeping much of the benefits of the multiple antennas. We assume the above problem as a combinational optimization problem in order to maximize the capacity of MIMO system. The upper bound on the capacity of MIMO systems is studied by Molisch et al. in [5], which is considered here as a target for comparing our method with the others.

Their effectiveness of our algorithm is verified through simulation under different scenarios. Simulation results verify that evolutionary technique of ICA based antenna selection algorithm provide a lower complexity solution to the problem.

2. SYSTEM MODEL AND PROBLEM FORMULATION

In the first and the second part of this section, the MIMO signal model and antenna selection are formulated.

A. System Model

Figure 1 shows the block diagram of the considered system. From the antennas, the signal is sent through the mobile radio channel. The channel is assumed to be flat-fading, so it can be shown as a matrix H which is $N_R \times N_T$. So that the $N_R \times 1$ vector y of the received signal can be written as

$$\vec{y} = H\vec{s} + \vec{n} \quad (1)$$

In this equation, S is a $N_T \times 1$ transmit vector and n is the (complex) noise samples vector at the receiver antenna elements use.

B. Antenna Selection

In Figure 1, we show a typical MIMO system with antenna selection capabilities at both transmitter and the receiver sides. In MIMO systems, complexity, size and cost may increase if we use complete RF chains. These negative effects can reduce by using antenna selection. In addition, many of the benefits of MIMO systems can still be obtained [6, 7]. The system is containing N_T transmitter and N_R receiver antennas, although in antenna selection a lower number of RF chains has been considered $N_t < N_T$ and $N_r < N_R$ at the transmitter and receiver, respectively.

The capacity of a MIMO system using all antenna elements is given by [4].

$$C_{full} = \log_2\left[\det\left(I_{N_R} + \frac{\overline{\eta}}{N_T} HH^H\right)\right] \quad (2)$$

Or

$$C_{full} = \log_2\left[\det\left(I_{N_T} + \frac{\overline{\eta}}{N_T} H^H H\right)\right] \quad (3)$$

Where I_{N_T} is the $N_T \times N_T$ identity matrix, $\overline{\eta}$ is the mean SNR, and superscript $(.)^H$ denotes the Hermitian transpose. In the transmitter antenna selection we want to select those antennas which can maximize the capacity, so that

$$C_{select} = \arg\max_{S(\tilde{H})}\left(\log_2\left[\det\left(I_{N_r} + \frac{\overline{\eta}}{N_t}\tilde{H}\tilde{H}^H\right)\right]\right) \quad (4)$$

And $\tilde{H}$ is a matrix which can maximize the capacity of the MIMO system.

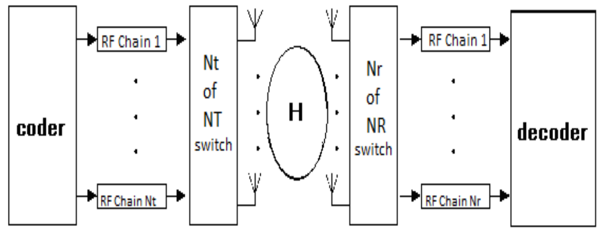

Fig. 1. Block diagram of antenna selection

We assume channel matrix H as a 5×10 matrix, it means we have 5 antennas at receiver and 10 at the transmitter. Antenna selection at the transmitter selects 5 antennas from 10 in order to have an optimum capacity with channel matrix $\tilde{H}$. So, we used evolutionary algorithm such as ICA and GA. At the end of this paper we compare these algorithms with ES method.

3. PROPOSED ALGORITHMS

In this Section, First a brief discussion on ICA is presented, and then our proposed algorithm, which is based on ICA, is explained.

A. Imperialist Competitive Algorithm

Imperialist Competitive Algorithm is a kind of heuristic global optimization technology that is used to solve optimization problems. Despite of the other methods in the area of evolutionary computations, the gradient of the function and its optimization process is not necessary in ICA. Figure 2 shows the flowchart of the Imperialist Competitive Algorithm. The algorithm begins to generate a set of candidate random solutions in the search space of the optimization problem. These generated random points are known as the initial countries. Here, countries are the same as the chromosomes in GA. Some of the initial countries which produce the least cost function value become imperialists based on their power and start taking control of other countries which are called colonies and form the initial empires [8].

Assimilation and revolution are the main operators of ICA. Assimilation is an operator that makes the colonies of each empire get closer to the imperialist state in the optimization search space. Revolution causes the sudden random changes in the position of some of the countries in the search space. A colony might reach a better position and has the chance to take the control of the entire empire and replace the current imperialist state of the empire during assimilation and revolution. Imperialistic competition is another part of this algorithm. All the empires try to take possession of colonies of other empires [9].

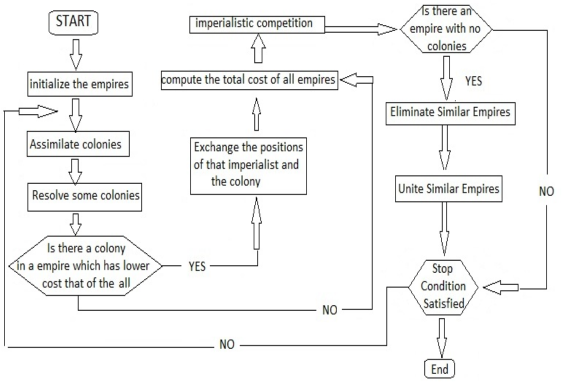

Fig. 2. Flowchart of Imperialist Competitive Algorithm (ICA)

Based on the empires power, in each step of the algorithm, all of the empires have a chance to take control of one or more of the colonies of the weakest one. Algorithm continues with the steps that containing Assimilation, Revolution, and Competition until a stop condition is occurred. The below pseudo code is for the above steps:

0) Define the cost function: $f(x), x = (x_1, x_2, ..., x_d)$.

1) Initialization of the algorithm. Generate some random solution in the search space and make initial empires.

2) Assimilation: Colonies move towards imperialist states in different in directions

3)Revolution: Random changes occur in the characteristics of some countries.

4) Position exchange between a colony and imperialist. A colony with a better position than the imperialist has the chance to take the control of empire by replacing the existing imperialist.

5) Imperialistic competition: All imperialists compete to take possession of colonies of each other.

6) Eliminate the powerless empires. Weak empires lose their power gradually and they will finally be eliminated.

7) If the stop condition is satisfied, stop, if not go to 2.

B. *An Overview on Genetic Algorithms*

Genetic algorithms were pioneered at the University of Michigan by J. Holland and his associates [11]-[14].

GA maintains a constant-sized population of candidate solutions, known as individuals. The initial seed population from which the genetic process begins can be chosen randomly or on the basis of heuristics, if available for a given application. Each individual is evaluated and recombined with others in each iteration which is known as a generation on the basis of its overall quality or fitness. The expected number of times an individual which is selected for recombination is commensurate to its fitness relative to the rest of the population. The high strength individuals selected for reproduction.

Two main genetic operators are used to create new individuals which are known as Crossover and Mutation. Crossover operates by selecting a random location in the genetic string of the parents (crossover point) and interconnecting the initial segment of one parent with the final segment of the second parent to create a new child. The remaining segments of the two parents are used when a second child is simultaneously generated. The string segments provided by each parent are the building blocks of the genetic algorithm. Mutation provides for occasional disturbances in the crossover operation by reversing one or more genetic elements during reproduction. This operation guarantees diversity in the convergence of the optimization technique. Other characteristics of the genetic operators remain implementation dependent, such as whether both of the new structures obtained from crossover are retained, whether the parents themselves survive, and which other knowledge structures are replaced if the population size is to remain constant. In addition, issues such as the size of the population, crossover rate, mutation rate, generation gap, and selection strategy have been shown to affect the efficiency with which a genetic algorithm operates [13].

4. SIMULATION RESULTS AND ANALYSIS

In order to compare the effectiveness and performance of proposed antenna selection algorithms with ES algorithm many simulations are done. First, the simulation results are presented in Table 1 and Figures 3 to 5. And then the analysis of the results is described.

A. *Simulation Results*

In Table 1, antenna selection algorithms are shown from the point of time complexity where $N_t = 5$ is the number of selected transmit antennas and $N_T = 10$ is the number of total antennas and $N_{GA} = N_{ICA} = 100$ are the iterations used in GA and ICA methods. τ_{GA} , τ_{ICA} and τ_{ES} are simulation times for each iteration of GA, ICA and ES methods, respectively.

In the first scenarios, the population size of the individuals for ICA and GA is 20 and the maximum number of generation is set to 100. In ICA the value of nImp is considered as 3, zeta is equal 0.02 and In GA the probabilities for crossover rate and mutation are assumed as 0.9 and 0.1 respectively. Also we generate the matrix of channel randomly without using any optimization algorithms for the graph of figure 3 which is named “Random”. Figures 3, shows the system capacity as a function of SNR. The effectiveness of the proposed antenna selection algorithms is verified over a wide range of SNR.

In the second scenarios, the population size of the individuals for ICA and GA is 20. ICA uses nImp=3, GA uses a crossover rate and mutation probability of 0.9 and 0.1 respectively. Figures 4, shows system capacity as a function of iteration. The effectiveness of the proposed antenna selection algorithms is verified over a wide range of iteration.

In the third scenario, the maximum number of generation/iteration is set to 100. ICA uses nImp=3, GA uses a crossover rate and mutation probability of 0.9 and 0.1 respectively. Figures 5, show system capacity as a function of population of size (Popsize). The effectiveness of the proposed antenna selection algorithms is verified over a wide range of Popsize.

A. Simulation Analysis

As shown in Table 1, ICA has better result in simulation time, it means that ICA is faster than GA and ES methods.

In the first scenario as shown in Figure 3, ICA method has better capacity for a specific SNR in comparison with the others. In the second scenario as shown in Figure 4, ICA method has better capacity for a specific iteration in comparison with the others. ICA need only 70 iterations to reach the optimum solution but the GA method after 100 iterations can not reach the optimum solution. In the third scenario as shown in Figure 5, one may realize that the ICA method is not dependent on the Popsize, whereas the GA method is sensitive to the Popsize. It means the ICA method can be considered as a faster algorithm.

Table 1. Algorithms and Their Complexities

Algorithms	***Complexity Order O***	***Simulation Time (Second)***
ES	$o\left(C_{N_t}^{N_T} \times \tau_{ES}\right)$	152.460 (s)
GA	$o\left(N_{GA} \times \tau_{GA}\right)$	4.4956 (s)
ICA	$o\left(N_{ICA} \times \tau_{ICA}\right)$	1.5481 (s)

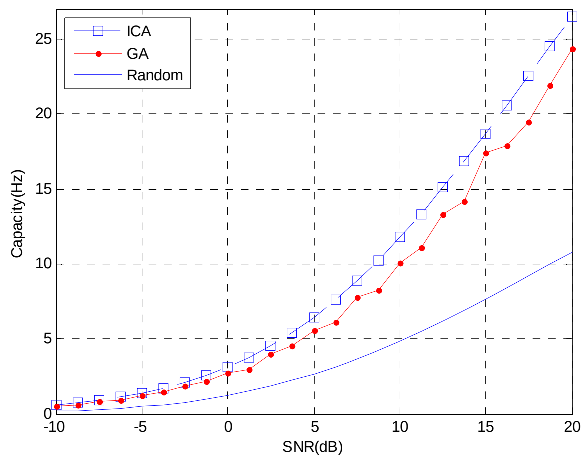

Fig. 3. Capacity versus SNR.

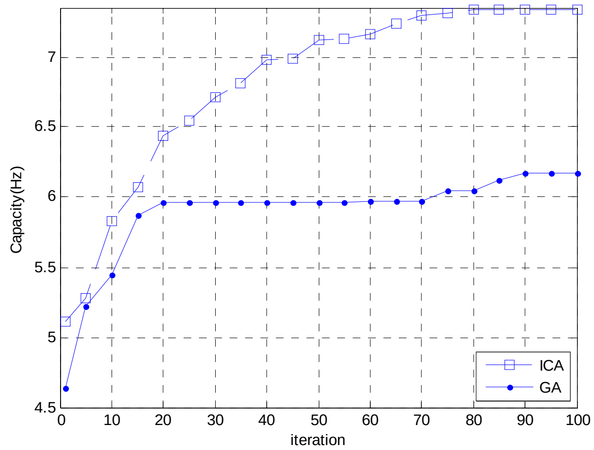

Fig. 4. Capacity versus the iteration at SNR = 6 dB

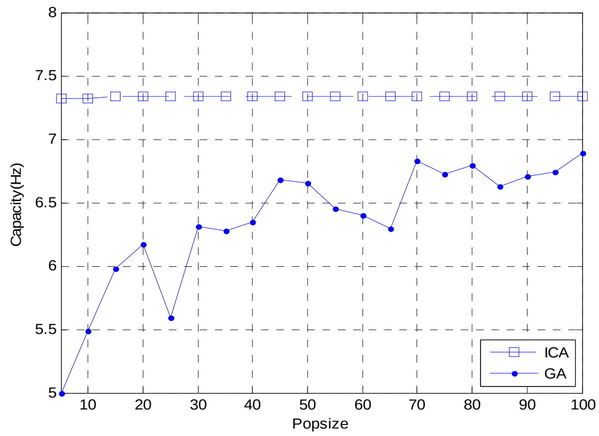

Fig. 5. Capacity versus the population size at SNR = 6 dB

5. CONCLUSION

In this paper, a new algorithm is proposed for antenna selection based on ICA. The algorithm achieves more capacity than the GA method and reduced computational and time complexities.

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