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Optimization of Adaptive Beam forming using PSO Algorithm and Fuzzy Logic

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Abstract: *This present paper deals with a scheme to realize a smart and adaptive antenna for the mobile base station using PSO(Particle Swarm Optimization) algorithm and fuzzy logic. This "PSO and Fuzzy based Adaptive antenna array system" determines the optimal DOA (Direction of Arrival) estimation and Smart Antenna Technology which tracks the mobile user continuously by steering the main beam towards the user and at same time provides minimum power in the directions of the unwanted interfering signals. The uncertainty of the motion of the mobile user can be noticed very efficiently by Fuzzy Logic Control based scheme and this can also incorporate the effect of the random weight fluctuation. It can be observed that the effect of using PSO and Fuzzy Based system is provided far better results than only fuzzy logic based adaptive antenna system.*

Keywords: *Adaptive Antenna System, Fuzzy Logic Controller, Smart Antenna, Matrix pencil Method, PSO (Particle Swarm Optimization) algorithm.*

1. INTRODUCTION

In future wireless mobile systems will be more sophisticated and more widespread. This growth has triggered an enormous demand not only for capacity but also better coverage and higher quality of service. Smart antennas or adaptive arrays those are dynamically able to adapt to the changing traffic requirements. Smart antennas, usually employed at the base station, radiate narrow beams to serve different users. As long as the users are well separated spatially the same frequency can be reused, even if the users are in the same cell. Smart antenna is one of the most promising technologies that will enable a higher capacity in wireless networks by effectively reducing multipath and co-channel interference. This is achieved by focusing the radiation only in the desired direction and adjusting itself to changing traffic conditions. The process of combining the signals and then focusing the radiation in a particular direction is often referred to as digital beam forming. The advent of powerful, low-cost, digital processing components and the development of software based techniques have made smart antenna systems a practical reality for cellular communications systems.

2. FUZZY BASED ADAPTIVE ANTENNA SYSTEM

The Fuzzy logic based adaptive antenna array system has been implemented using MATLAB2012. In Mobile communication environment, tracking of a mobile telephone unit is an essential task due to the unpredictable motion of the mobile unit. This "Fuzzy Logic based Adaptive Antenna Array system" determines the required deviation of angle (DOA) to be brought in for controlling the orientation of the base station antenna beam towards the mobile unit. It can also take care of the varying and uncertain feature inherent to the mobile unit tracking' process besides incorporating the effect of the random weight fluctuation. Here, the actual performance of the system depend upon the implemented weights, the effect of random weight fluctuation leads to reduced array gain, the proposed fuzzy logic based system can also incorporate the effect of this random weight fluctuation. This fuzzy scheme can easily cope up with the varying and uncertain random features inherent to the mobile unit tracking process. In this section, Simulation results are given for the DOA estimation, here work is done using Matrix pencil method and fuzzy logic [10]. Estimation of Direction of Arrival (DOA) of different signals with different voltages in microvolt is carried out using only a single time snapshot. In Matlab editor, signals having different voltages and then the desired DOA angle is computed. After doing this, the outputs of estimated Direction of Arrival angle from the fuzzy based adaptive system.

Assumptions:

Consider a Uniform Linear Array containing 7 elements, which are radiating in free space i.e., n=0, 1, 2, ...6. Therefore, N=6. The assumptions considered are as follows:

1) Array elements are Omni-directional isotropic point radiators.
2) Total number of plane waves incident on the array are, p≤(n+1)/2 for odd elements.
3) Incident fields and antenna elements are co-planer.
4) Signal sources are located in the far-field of the array.

Parameters defining the elements:

There are some parameters as following that are-
1) No. of the elements of the array=n=N+1=7
2) Length of the elements, L=λ/2
3) Radius of the elements, a=λ/200
4) Loading at the centre, Za=50 λ
5) Operating frequency, f=1800 MHz

Where "λ" is the wavelength corresponding to the operating frequency

Matrix Pencil method For DOA estimation:

Matrix Pencil, the DOA estimation is very accurate. An advantage of MPM is that it does not require multiple snapshots. The performance of MPM using a single snapshot, while the accuracy is lower, it is still quite accurate. This is clearly due to the inaccurate estimate of the correlation matrix. Another significant advantage of MPM In comparing the computation loads Matrix Pencil is at least twice as fast at Root-MUSIC. This is because of the fact that MPM does not require the estimation of a correlation matrix. Basically, MPM has high accuracy and fast convergence. It may compute complex calculations very fast. After doing this, Using Matrix pencil method and formulas Desired DOA signal is calculated. This is Desired DOA means that in this particular direction user is present; radiation pattern given by adaptive antenna to mobile unit is fully concentrated on it, on other sides sends nulls. Then the estimated DOA angle is calculated. The system model of fuzzy logic controller for adaptive antenna system is shown in Fig.. The input of the simulator is estimated DOA angle, which is the parameter of desired angle, in that direction beam is to be shifted. But the actual performance of the system is dependent upon the implemented weights, which are erroneous due to many types of errors caused at the various points in system. This effect of random weight fluctuation leads to the reduced array gain. The fuzzy logic based scheme can also incorporate the effect of this random weight fluctuation. These schemes easily cope up with the varying and uncertain random features inherent to the mobile unit tracking process.

Fuzzy Logic Controller:

Antenna array is a set of several antenna elements. It is mainly used to generate radiation pattern with a high directivity. In case of practical use, it is desirable to have the radiation in a certain direction. Any practical use of an antenna array, it should ensure the minimum acceptable radiation pattern under certain constraints. The aim is to determine the physical layout of the antenna array that produces a radiation pattern which is nearest to the desired pattern. This process is, in general, called synthesis [10]. We can synthesize the antenna array by reducing its side lobe level or by decreasing its null point etc. The system model of Fuzzy logic controller for Adaptive antenna system is shown in Fig. 1. The input of the simulator is Estimated DOA angle, which is the desired angle parameter, to the direction the beam is to be shifted.

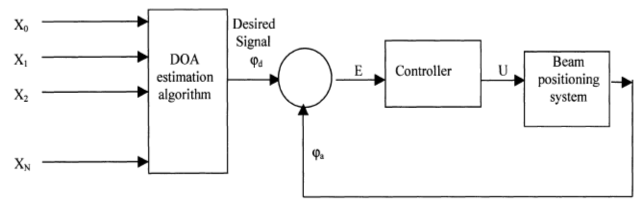

Fig. 1: System model of Fuzzy logic controller for Adaptive antenna system

The varying and uncertain random nature inherent to the mobile unit environment is simulated first by setting initial conditions based on the actual beam position for the Simulink system block and then the error signal is derived from the difference between the estimated DOA angle and actual (present) angle of the beam [22]. Again this error (E) is used to beat with the previous error, to derive the change in error (delE). Then mixing of E & del E in MUX (Multiplexer), will result in a signal that is input to the Fuzzy Logic Controller. Data are sampled at required interval of time, and are compared with the desired DOA angle $\varphi_d(t)$. If difference in error (E) and change in error (delE) are not equal to zero, then controller will issue an incremental control signal change, to the Beam positioning system. The required amount of signal necessary to counteract the differences is determined by the fuzzy inference system.

3. PSO ALGORITHM AND FUZZY LOGIC BASED ADAPTIVE SYSTEM

Particle Swarm Optimization (PSO) [7,8] is a technique used to explore the search space of a given problem to find the settings or parameters required to maximize a particular objective. This technique, first described by James Kennedy and Russell C. Eberhart in 1995, originates from two separate concepts: the idea of swarm intelligence based off the observation of swarming habits by certain kinds of animals (such as birds and fish); and the field of evolutionary computation. PSO is a meta-heuristic technique as it makes few or no assumptions about the problem being optimized and can search very large spaces of candidate solutions. Over the decade, PSO has been proved to be one of the most promising algorithms for many intricate problems in engineering and sciences. Its simplicity and faster convergence make it an attractive algorithm to employ. The population is called swarm and the individuals are termed as particles. The word 'swarm' is inspired from jagged movement of particles in the problem region. The particles are assumed to be mass-less and volume-less. In the context of PSO, a swarm refers to a number of potential solutions to the optimization problem, where each potential solution is referred to as a particle. The aim of the PSO is to find the particle position that results in the best evaluation of a given fitness function. In the initialization process of PSO, each particle is given initial parameters randomly and is "flown" through the multi-dimensional search space. Each particle maintains its position, composed of the candidate solution and its evaluated fitness, and its velocity. It remembers the best fitness value it has achieved thus far during the operation of the algorithm, referred to as the individual best fitness, [17] and the candidate solution that achieved this fitness, referred to as the individual best position or individual best candidate solution.

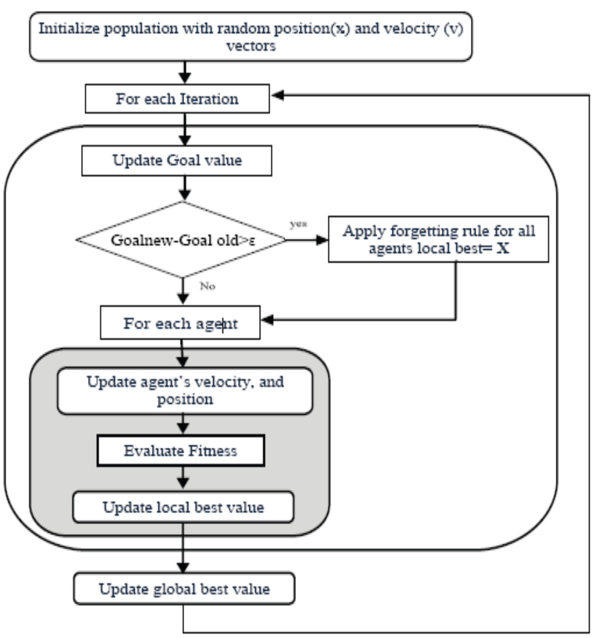

Fig. 2: Flowchart of the PSO algorithm

Finally, the PSO algorithm maintains the best fitness value achieved among all particles in the swarm, called the global best fitness, and the candidate solution that achieved this fitness, called the global best position or global best candidate solution. It consists of just three steps, which are repeated until some stopping condition is met, and steps are as following:

First evaluate the fitness of each particle, then Update individual and global best fitnesses and positions after doing this Update velocity and position of each particle. Now during each generation, each particle uses the information about its previous best individual position and global best position to maximize the probability of moving towards a better solution space that will result in a better fitness [18]. When a fitness better than the individual best fitness is found, it will be used to replace the individual best fitness and update its candidate solution according to the following equations:

$$v_{id}(t) = w \times v_{id}(t-1) + c_1 \theta_1 (p_{id} - x_{id}(t-1) + c_2 \theta_2 (p_{gd} - x_{gd}(t-1))$$

Here, v is the particle velocity and x is the particle position at time t. The parameters in above equation are called as w inertia weight, learning factors c_1, and c_2 ($0 \le w \le 1.2, 0 \le c_1 \le 2, and\ 0 \le c_2 \le 2$) are user-supplied coefficients. Then θ_1 and θ_2 are random numbers between 0 and 1. After this p_{id} is particle's best position and p_{gd} is global best position.

Advantages of the PSO algorithm:

PSO is based on the intelligence. It can be applied into both scientific research and engineering use. PSO have no overlapping and mutation calculation. The search can be carried out by the speed of the particle. During the development of several generations, only the most optimist particle can transmit information onto the other particles, and the speed of the researching is very fast. The calculation in PSO is very simple. Compared with the other developing calculations, it occupies the bigger optimization ability and it can be completed easily. PSO adopts the real number code, and it is decided directly by the solution. The number of the dimension is equal to the constant of the solution.

4. RESULTS AND DISCUSSIONS

In Mobile communication environment, tracking of a mobile telephone unit is an essential task due to the unpredictable motion of the mobile unit. This paper's result deals with a scheme to realize a smart/adaptive antenna for the Mobile base-station using Fuzzy Logic Control. The uncertainty of the motion of the mobile unit can be taken care very well by Fuzzy Logic Control based scheme. This "Fuzzy Logic based Adaptive Antenna Array system" determines the required deviation of angle (DOA) to be brought in for controlling the orientation of the base station antenna beam towards the mobile unit. It can also take care of the varying and uncertain feature inherent to the mobile unit tracking' process besides incorporating the effect of the random weight fluctuation. Results tables are as following:

Table 1: Results of Estimated DOA angle of only Fuzzy based Adaptive System.

X0 in µ volts	X1 in µ volts	X2 in µ volts	X3 in µ volts	X4 in µ volts	X5 in µ volts	X6 in µ volts	Desired DOA angle	Estimated DOA fuzzy based
1.0	0.8	0.6	0.4	0.2	0.1	0.2	15.463	14.477
0.1	0.2	0.7	1.0	1.3	1.6	1.3	29.463	28.477
0.05	0.1	0.2	0.7	1.0	1.3	1.1	90.152	89.167

0.9	0.15	0.4	0.15	0.9	0.4	0.9	20.552	19.566
0.5	0.01	0.4	0.01	0.5	0.4	0.5	-15.464	-16.449
0.0	0.1	0.2	0.3	0.4	0.5	0.6	25.675	24.689
0.5	0.4	0.3	0.2	0.1	0.2	0.3	11.250	10.271
0.4	0.3	0.2	0.1	0.0	0.1	0.2	-60.260	-61.242
1.0	0.33	0.75	0.75	0.75	0.33	1.0	-20.656	-21.644
2.0	0.005	0.7	0.08	1.8	0.7	0.33	37.557	36.572
0.7	1.5	0.1	1.2	0.2	0.5	0.7	77.777	76.792

But here Fuzzy logic based adaptive antenna system shows some error in the estimated DOA. In table 1, induced emfs are in micro volts of different signals at antenna elements. Desired DOA=15.4630 and estimated DOA=14.4776, so there is an error in this. Then the beam is shifted in direction not the desired one, it produces interference to other mobile units which are placed very near to this unit. To solve this problem, Estimated DOA is improved here by using combination of Fuzzy logic and Particle swarm optimization PSO algorithm. After this Simulation Results of PSO algorithm and fuzzy logic based adaptive system are as following:-PSO algorithm is very powerful technique to optimization and computed very easily and it is provide very efficient results. Then the combination of fuzzy logic controller & PSO gives far better results of DOA than the only Fuzzy based adaptive antenna system. So here in this thesis, there is been use of integration of PSO algorithm to optimize the results of DOA angle with Fuzzy based adaptive antenna system.

In Table2, in first row here desired DOA=15.4630 and estimated DOA=15.2923 as so listed. Then from these values it can be calculated that the combination of fuzzy logic controller and PSO gives far better results of DOA than the only Fuzzy based adaptive antenna system. So here in this, there is been use of integration of PSO algorithm with fuzzy logic to optimize the results of estimated DOA (Direction of arrival) angle with Fuzzy based adaptive antenna system.

Table 2: Results of Estimated DOA angle Using PSO algorithm and Fuzzy logic

X0 in µ volts	X1 in µ volts	X2 in µ volts	X3 in µ volts	X4 in µ volts	X5 in µ volts	X6 in µ volts	Desired DOA angle	Estimated DOA Using PSO
1.0	0.8	0.6	0.4	0.2	0.1	0.2	15.463	15.292
0.1	0.2	0.7	1.0	1.3	1.6	1.3	29.463	29.292
0.05	0.1	0.2	0.7	1.0	1.3	1.1	90.152	89.981
0.9	0.15	0.4	0.15	0.9	0.4	0.9	20.552	20.381
0.5	0.01	0.4	0.01	0.5	0.4	0.5	-15.464	-15.634
0.0	0.1	0.2	0.3	0.4	0.5	0.6	25.675	25.504
0.5	0.4	0.3	0.2	0.1	0.2	0.3	11.250	11.086
0.4	0.3	0.2	0.1	0.0	0.1	0.2	-60.260	-60.437
1.0	0.33	0.75	0.75	0.75	0.33	1.0	-20.656	-20.826
2.0	0.005	0.7	0.08	1.8	0.7	0.33	37.557	37.387
0.7	1.5	0.1	1.2	0.2	0.5	0.7	77.777	77.607

In Table3, It shows about the comparative analysis between the adaptive system that is based on combinational Fuzzy PSO algorithm, and only fuzzy Logic Based Adaptive antenna System. The combinational fuzzy PSO gives much better results of estimated DOA than the only Fuzzy based adaptive antenna system. After simulating in MATLAB Software, the obtained results that are shown in Fig. 3, now it is sure that the obtained results of Desired DOA using fuzzy PSO algorithm based adaptive antenna system are much better than the other scheme fuzzy based adaptive antenna system.

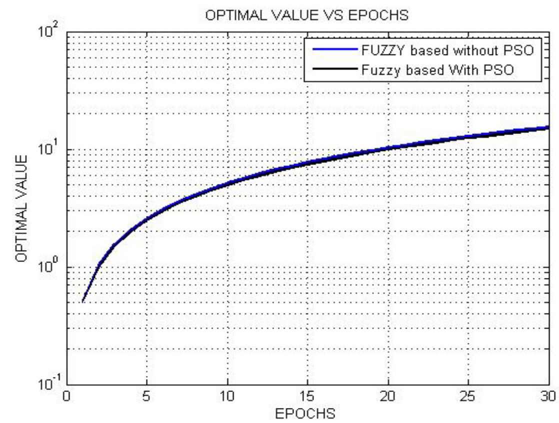

Fig. 3: Positive DOA Semilogy plots between Fuzzy based and Fuzzy PSO algorithm

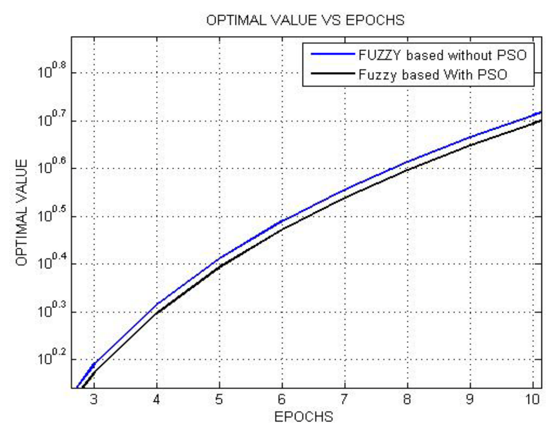

Fig. 4: Develop Clear results by Zooming the positive

DOA Semilogy Plot of Fig. 3

In Fig. 3 Estimated DOA values in positive angles shows by curves, Blue curve is of Fuzzy based system and black curve is of PSO algorithm based. Black curve PSO shows that results are better and efficient than fuzzy logic based adaptive system and Fig. 4 shows that clear results of curves by zooming it.

Table 3: Comparative Results between Fuzzy based Adaptive System and Fuzzy PSO algorithm System

Desired DOA angle	15.46	29.46	90.15	25.67	11.25	37.55	77.77
Estimated DOA only Fuzzy based	14.47	28.47	89.16	24.68	10.27	36.57	76.79
Estimated DOA using PSO Fuzzy	15.29	29.29	89.98	25.50	11.08	37.38	77.60

5. CONCLUSION

In this proposed work, Optimization of adaptive beam forming using PSO algorithm and fuzzy logic shows far better performance and results of estimated DOA, than the only Fuzzy logic based adaptive antenna array system. Simulation has been implemented using MATLAB2012. Here, simulated results has investigated that fuzzy PSO algorithm scheme based adaptive antenna system gives better performance and result as compared to without PSO algorithm Scheme.

In future, the optimization of adaptive beam forming of DOA angle can be much more improved by using Neural Networks and newly developed optimization algorithms like BFO, GSA etc. Interference can be much more reduced as well as capacity of the network can be increased in future by using another technique.

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