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Neural Networks in Predicting Communication Systems Performance Neuro Generalized Predictive Control

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Abstract: **With the ever-increasing demand of mobile communications, there has always been a requirement for effective coverage and increased capacity. The paper proposes the neural networks as the effective solution for the above problems. It investigates the role of neural networks in wireless communications, both in rural and urban scenario. The performance of mobile communication antennas can be enhanced by a special approach using neuro-based algorithm called "*Neuro Generalized Predictive system" (NGPS).* This paper deals with the unique performance of omni-directional and adaptive antennas. The paper concludes by saying that the conventional antennas can be converted into intelligent antennas by embedding the NGPS.**

Keywords: **Neural Networks, Neuro, GPC,NGPS.**

1. Introduction

Recent years have seen a dramatic increase in the demand for mobile communications services and with the introduction of 2.5G and 3G services, this demand is expected to increase further. With the introduction of these services the demand is going to be at an exponential rate. Such systems experience highly dynamic tele – traffic and the need for managing the system and its resources in a flexible manner arises. A plethora of concepts attempting to introduce adaptation into the systems to improve its performance exists. The paper explores one such pro-active approach for solving the problems of coverage and capacity by using "Neuro Generalized Predictive System" (NGPS).

Intelligence may be defined as the capacity for understanding or the ability to perceive and comprehend the meaning. A system is said to be intelligent if it is able to modify its actionsin the light of ongoing events. Such systems are being adaptive and give the appearance of being intelligent as they change their behavior without the intervention of the user. A neural network can be assumed as one such intelligent arrangement, which can be madestochastic to explore its environment more fully andpotentially to arrive at a better solution than linear methods might allow.

The conventional antenna system employed at the base stations of mobile communications employ not only omni directional antennas but even adaptive or switched beam antennas.

A. Intelligent Control:

Adaptive control using computers has progressed dramatically since the 1970's. Significant research in intelligent control continues and many applications have found their way in the techno world using fuzzy logic and neural networks. A 60% - 80% accurate prediction has been achieved compared with the other state of the art techniques

B. General Predictive Algorithm (GPC):

GPC is capable of stable control of processes with variable dead time and with a model order, which changes instantaneously provided that the input/output data are sufficiently rich to allow reasonable plant identification. All the communication systems are subjected to noise, which is due to various factors in a random fashion and is stochastic. To achieve offset-free closed loop behavior given these disturbances the controller must possess inherent integral action and GPC posses such an integral. But the only limitation in GPC is that it is suitable only for systems with long time horizons but to achieve high computational rates dynamically NGPC is proposed as a solution.

2. Neuro Generalized Predictive Antenna System

The block diagram of neuro generalized predictive antenna system consists of three components (as shown in fig 1). They are

1. Cost minimization function
2. The plant (Antenna)
3. The Model (neural network)

The NGPC algorithm operates in two modes, prediction and control. Prediction occurs between samples by setting a double pole/double throw switch, S, to the neural network model. The NGPC algorithm utilizes the model to predict over some finite range or capacity, the response of the antenna to the inputs calculated by the CMF algorithm. The CMF algorithm minimizes a user specified cost function to calculate the next control input. The NGPS system is set back to a mode of control before the next sample time when the switch is set back to the antenna. At this time the control input

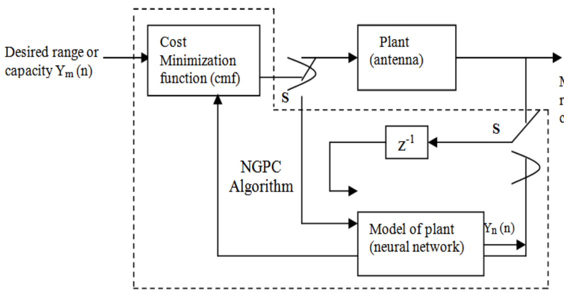

Fig.1. The Block Diagram

that minimizes the cost function over the entire range is passed to the antenna as the current command, (n). The algorithm used to accomplish this is outlined below.

The main steps of the NGPS algorithm are:

1. Starting with the previously calculated control input, u(n), predict the performance of the antenna for the specified range or the capacity using the model. The value of the range or the capacity is determined through a priori tuning.
2. Calculate a new control input that minimizes the cost function.
3. Repeat steps 1 and 2 until desired minimization is achieved.
4. Send the "best" control input to the antenna as the new u(n).
5. Repeat for each time step.

A. The cost function:

The cost function used for the range extension and capacity improvement of the base station antenna system has two terms. The first term represents the sum of the mean squares error between the desired output and the output of the neural network model. The second term is the weighted square of the control increments. The weighting factor λ_u, acts to smooth the control inputs. They are calculated for N_u future time steps. The only constraint on the values of the range or capacity is that N_u and N_1 be less than or equal to N_2

$$J = \sum_{j=N_1}^{N_u} [Y_m(n+j) - Y_n(n+j)]^2 + \sum_{j=1} \lambda_u(j)\,[\Delta u(n+j)]^2$$

Where,

- N_1 is the minimum range or capacity.
- Y_m is the desired tracking range orcapacity.
- Y_n is the predicted range or capacity.
- $\lambda_u$is the control input weighting factor.
- N_2 is the maximum range or capacity.
- N_u is the set range or capacity
- $\Delta u(n+j) = u(n+j) - u(n+j-1)$

3. Neural Network Model

The neural network architecture that is used for the base station antenna system is a multi – layer feed forward network (MLFN) with tapped – time delays. The network structure shown in the figure below (Fig 2) depicts the SISO structure with the linear model embedded into the weights. The required gain or phase is the input to the antenna system and range or capacity is the output. The inputs to the network are gain X(n), past values of the gain X(n-i), and the past range Y(n-i) or capacity measurements of the antenna. The network has a single input layer with multiple hidden layer nodes and a single output node.

Where,

X (n) – is the input gain parameter

Y (n) – is the expected range or capacity.

To embed the linear model into the network, the weights between the input layer and the linear hidden layer, node

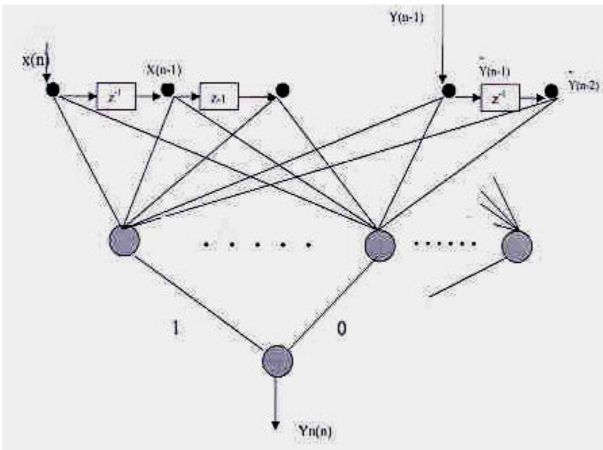

Fig.2. The Model Network

should correspond to the coefficients of the antenna system. The weight from this hidden node to the output node is set to one. Once stability is attained, the training algorithm is turned on until acceptable model accuracy is achieved. The weights associated with the linear model remain fixed through out training. The back propagation-training algorithm is usedwhere the weights were updated at each sample time.

4. The Plant (Antenna System)

A. Plant:

Let us now define the basic equation on which the plant i.e. the antenna isdependent. Whenconsidering regulation about a particular operating point, even a non-linear plant generally admits a locally linearized model,

$$A(q^{-1})y(k)=B(q^{-1})u(k-1)+x(k)$$

Where,

A and B are the polynomials in the backward shift

Y(k) is the power at the output of the antenna

X(k) is the gain which is supplied at the input.

But the neural plant incorporates integrated input that reduces excess noise. Hence the final equation for the plant is given as

$$A(q^{-1})y(k)=B(q^{-1})u(k-1)+\xi(k)/\Delta$$

Where,

$\xi(k)/\Delta$ indicates the integrated noise.

B. Rural scenario: Range extension:

The range extension is best suited to rural areas, where the user density is low and it is desirable to cover as much area with as few base stations as possible. If the user density is high simply expanding the coverage area will result in a cell containing more users than the base station can serve with its limited number of channels. In such areas, adaptive antennas (Fig 3) serve as the best alternative.

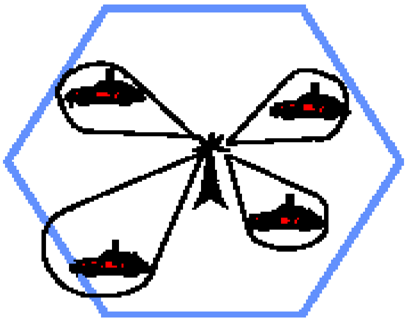

Fig.3 (a) Smart Antenna

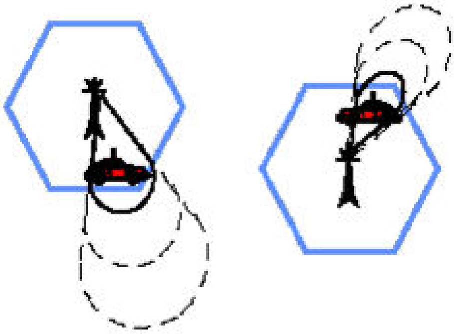

Fig.3 (b) Smart Antennas

Fig.3. Range Extension in Adaptive Antennas Using NGPS

The coverage area is the area of useful communications around a base station antenna

$A_c = \Pi R^2$

Where,

A_c – is the area of coverage of the cell,

R–is the maximum transmit-receive range

The relation between area of coverage and gain is given by $A_c \alpha G^{2/R}$

By incorporating the neuro generalized predictive antenna system at the base station the adaptive antenna placed at the station can be operated with more intelligence. In adapting to the user movement to increase the range and to provide an effective coverage, the antennafollows theNGPS system described above.

C. Urban scenario: capacity improvement:

The conditions in urban scenario are quite different to those of the rural areas. In urban areas the number of users is more per cell and the efficiency of any servicesystem lies in providing an excellent service to morenumber of users. Ifwe apply the same solution of adaptive antennas to this scenario it will be worsening the situation instead of easing the problem. The traffic conditions in urban areas are not constant and are varying continuously demanding more amount of complexity in maintaining them.

This paper proposes the use of conventional omni directional antennas (Fig. 4) with more intelligence incorporated in them using NGPS system. The procedure is described below:

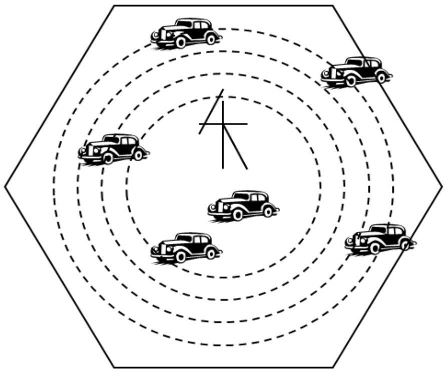

Fig.4. Increasing the Coverage in Urban Area Using Omni Directional Antennas

Whenever there is an increase in the traffic at a base station the power given by it should increase proportionately to maintain the quality of the service. Instead, if the same antenna is processed to increase the cell size dynamically depending on the traffic situation the problem can be solved. The method employs the NGPC antenna system, which has several set points of increasing the cell size and a maximum limit of cell extension. As the traffic under the base station increases the set points are changed for the neural plant and predictions are made at each level to adapt to the increase in traffic. As the capacity reaches the maximum limit, the connection of some of the users is transferred to the adjacent antenna system thereby maintaining the capacity in the cell as maximum.

5. Conclusion

The paper brought into light the major application of neural networks in mobile and wireless communications in solving its existing problems. It also discussed the problems of rural and urban mobile scenarios and proposed a pro-active method of solving these problems by employing neural networks, which can incorporate intelligence to the antennas. It has been made clear that the Neuro General Predictive Algorithm (NGPC) can be applied to a SISO where either range or capacity was considered as the input for the intelligent antenna.

6. Future Scope

This novel method of NGPC antenna system can also be adopted for MIMO systems where we can plan to improve both the range and capacity in both rural and urban areas with minimum power consumption.

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