

# GSM Network Location Model Based on Self-Adaption and Error Correction Neural Network

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## Abstract

In view of the problems that the localization accuracy is not high and the convergence is slow of the basic BP neural network algorithm in the application of the GSM network positioning, this paper presents a GSM network location model based on self-adaption and error correction BP neural network. First, in order to speed up convergence and prevent oscillation, this paper introduces a momentum factor by adopting a new performance index function under the condition of the guarantee that the network training error is as small as possible to make the network with smaller weights. And then using the different learning rate to dynamically adjust the connection weights between different nodes and improve the adjustment efficiency of the weight, speed up the convergence rate of the error function. Simulation experiments show that the proposed GSM network location model based on self-adaption and error correction BP neural network has higher precision and faster convergence speed, it has good application effect.

Key words: GSM NETWORK LOCATION, SELF-ADAPTION ERROR CORRECTION, IMPROVED BP NEURAL NETWORK ALGORITHM, MOMENTUM FACTOR, DIFFERENTIATION

## Introduction

With the constant enlargement of the scope and scale of the network application, the management and optimization of the network become more and more important. Mobile communication network as a dynamic network, including network structure, wireless environment, users distribution and usage behavior are constantly changing, it needs operators to continuously adjust the network to adapt to the changes [1]. An important work is according to actual opera-

tion state of the wireless network system, having the parameter acquisition and data analysis for the operational wireless network, find out the cause of the network quality problems, through technical means or adjust the system parameters and other means to improve the performance of the system, ensure system running under state of providing optimal services, so that the network resources can obtain the best benefit [2].

GSM network localization way can divide into

two ways technically, they are time of arrival (TOA) [3], the increase of measurement time difference (E-OTD) [4]. He Yuanhua did the corresponding introduction to TOA location method, and had some improvement[5]. Wylie-Green present geometric measurement method, he made the receiving signal strength according to the propagation model formula mapped to the actual physical distance, merged with TOA method for improvement, it effectively against the interference of non-line-of-sight spread (NLOS), to a certain extent ensure the positioning precision in the complex communication environment [6]. TOA positioning method does not need to add additional software, it can be implement localization in any of the mobile terminal. But in the way to locate, it requires additional hardware facilities, namely the positioning measurement unit described earlier, it is used to calculate the arrival time of the signal under the condition of sudden [7]. S. Charitanetra proposed the protocol specification standard of GSM location, in the standards he proposed two localization ways of E – OTD. The positioning way mainly through the Position calculation function module of the mobile terminal or network, after a certain calculation, determine the position of the mobile terminal. When the parameters of the function provided by the network structure and the mobile terminal, measurement unit functions are same, location estimation method can be realized by the following two ways: hyperbola method and the way of arc [8]. Bai expounded the E - OTD actual application in GSM network positioning [9]. Among them, he mentioned E - OTD by processing arrival time (TDOA) between mobile station and at least three BTS get the estimated position of mobile station. However, when the multipath transmission exist in the process of signal transmission, the same signal from the base station is transmitted through multiple paths to the mobile station, it happened the same emission signals have different transmission delay. This kind of situation can bring

$$\phi_1 = \{(x(t), y(t)) | x \in R^m, y \in R^n, t = 1, 2, \dots, N_1, N_1 \leq N\} \quad (1)$$

$$\phi_2 = \{(x(t), y(t)) | x \in R^m, y \in R^n, t = N_1 + 1, N_2 + 2, \dots, N\} \quad (2)$$

Using  $\phi_1$  to establish a mapping relationship first, and then make sure if the network can give correct input – output to  $\phi_2$ , if it can, we say that the model can be used in practice to forecast. For such time series mapping building, we can use the three layers BP neural network whose input nodes is  $m$ , output node is  $n$ , hidden nodes is  $p$  to realize. The relationship between the network's input and output are as follows:

adverse effect to TDOA measurements. He put forward when the pending target in the network appeared the following two situations, E - OTD locating method was unable to complete positioning of the target: one is only a neighbor or the main service area in the overlay network, the second is the overlay network adopt repeaters [10]. A.K ushki described the method of field measurements for offline fingerprint database, from the description you can know that the field measurements need to prepare a lot of testing equipment (including laptops and mobile phones and other mobile handset), in the sampling points of populating area or broad test area, a large number of sampling points required, the required collection workload is also bigger [11]. Han Lyu's description is based on the received signal strength (RSS) fingerprint positioning technology, detailed introduces the selection of access point (AP) and the reference point (RP) of hoof process. The technical principle based on the received signal strength fingerprint positioning is that the received signal strength presents regular changes with distance of the base station, the change rule can be obtained according to the different propagation model calculation formula[12].

In view of the defects of basic BP neural network exist in the GSM network positioning in this paper, this paper proposes a GSM network location model based on self-adaption and error correction BP neural network.

### The defects of positioning based on neural network

The BP neural network is composed of input layer, hidden layer and output layer. The discrete time series of  $N$  sample set  $\{(x(t), y(t)) | x \in R^m, y \in R^n, t = 1, 2, \dots, N\}$ , BP network can complete the highly nonlinear mapping from input to output, we can find some kind of mapping:  $F : R^m \rightarrow R^n$ , all the samples are divided into training samples  $\phi_1$  and testing samples  $\phi_2$ :

$$\hat{y}_k(t) = \sum_{j=1}^p v_{jk} \cdot f \left[ \sum_{i=1}^m w_{ij} \cdot x_i(t) + \theta_j \right] + r_k \quad (3)$$

Among them,

$$f(x) = \frac{1}{1 + e^{-x}}, k = 1, 2, \dots, n, t = 1, 2, \dots, N_1, x_i$$

is the input of the network,  $\hat{y}_k$  is the output of the network,  $w_{ij}$  is the weights of input layer node  $j$  to the output layer node  $k$ ,  $\theta_j$  as the threshold of hidden layer node  $r_k$ ,  $r_k$  is the threshold value of output node

$k, f$  is the activation function. Set network total error is less than  $\varepsilon_1$ , then:

$$E_1 = \frac{1}{2} \sum_{t=1}^{N_1} \sum_{k=1}^n [y_k(t) - \hat{y}_k(t)]^2 \leq \varepsilon_1 \quad (4)$$

A test sample average error is less than  $\varepsilon_2$ , there are:

$$E_2 = \frac{1}{N - N_1} \sum_{t=N_1+1}^N \sum_{k=1}^n [y_k(t) - \hat{y}_k(t)]^2 \leq \varepsilon_2 \quad (5)$$

The learning process of BP algorithm is based on the gradient descent method to implement the correction of network connection right (weights and thresholds), make the network error sum of squares is minimal. First of all, give a set of networks initial connection randomly, and from the input layer to enter the training sample, step by step processing through hidden layer to output layer. If the actual output and desired output error of output layer is bigger than the setting standard error, then propagate the error signal along the original path back, and revised the original right of network connection, making the error smaller. After repeated adjustment of network connection rights until the network global error is less than the set value or training number reach to the preset values, the entire training process is over. To get a group of good connection right, further input test samples, if the error is less than the set error, then the network can be applied in practice.

By using the BP neural network algorithm to the GSM network positioning, the positioning result is shown in the following figure.



Figure 1. The results based on the GSM network positioning BP neural network

It can be seen from the diagram, when using the basic BP neural network algorithm for GSM network positioning, there is a big error, so this article carries

on the optimization.

**Neural network based on Self-adaption and error correction**

**The neural network error correction**

In order to accelerate the convergence and prevent oscillation, this paper introduced a momentum factor  $\alpha$ :

$$w(n_0 + 1) = w(n_0) + \eta(n_0)d(n_0) + \alpha\Delta w(n_0) \quad (6)$$

$\alpha$  is the momentum, it is usually a positive number.

Among them, the third is the change of a moment weight on memory, and the changing direction in the moment ( $n_0$ ) is the combination of the direction in the moment ( $n_0 - 1$ ) and ( $n_0$ ).

$$\begin{aligned} w(n_0 + 1) &= w(n_0) + \eta(n_0) \left[ d(n_0) + \frac{\alpha}{\eta(n_0)} \right] \Delta w(n_0) \\ &= w(n_0) + \eta(n_0) \left[ d(n_0) + \frac{\alpha\eta(n_0 - 1)}{\eta(n_0)} d(n_0 - 1) \right] \end{aligned} \quad (7)$$

The type is similar to the conjugate gradient method formula, but  $d(n_0 - 1)$  and  $d(n_0)$  are not conjugate, and  $0 < \alpha < 1$ , it is recommended that when  $\eta(n_0)$  makes adjustment, if  $\Delta E > 0$ ,  $\eta$  becomes smaller, make  $\alpha = 0$ , and then adjusting to the increase of  $\eta$ ,  $\alpha$  recover to 0.

Regularization method is the first step in changing the error function, the original error function is the sum of the squares of the network for training mode, namely:

$$F = mse = \frac{1}{N} \sum_{i=1}^N (e_i)^2 = \frac{1}{N} \sum_{i=1}^N (t_i - a_i)^2 \quad (8)$$

Here  $N$  is the training mode logarithmic,  $t_i$  is the network expected output,  $a_i$  is network actual output. Now the error function is revised as follows:

$$msereg = \gamma \cdot mse + (1 - \gamma)m_{sw} \quad (9)$$

Here  $\gamma$  is error coefficient,  $m_{sw}$  is the average of sum of squares of all network weight, then

$$m_{sw} = \frac{1}{N} \sum_{j=1}^N w_j^2 \quad (10)$$

As you see, through the adoption of a new performance index function, we can guarantee the network with smaller weights under the condition of network training error is as small as possible, even the network effective weight is as less as possible, this effectively automatically reduces the size of the network.

**Convergence speed optimization**

This paper also uses vector differentiated, dynamically adjust the connection weights between different nodes, and improve the adjustment efficiency of the weight, speed up the convergence rate of the error

function. Improved BP neural network, a new method of algorithm implementation process are described below, back propagation parameters is shown in figure 2.

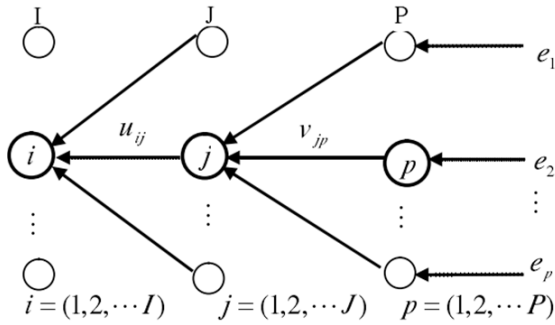


Figure 2. Improved algorithms propagation mechanism

The threshold of BP neural network can adjust together as weights, and include it in the weight matrix, set  $U$  as the weights matrix from input layer to hidden layer,  $V$  as the weights matrix from hidden layer to output layer.  $X$  is the input vector of the network,  $Y$  is the output vector of the network,  $M$  is the total number of samples,  $f(\cdot)$  is the activation function of BP neural network,  $d_y$  is the expected output of the network. Then:

$$X = \begin{bmatrix} 1 & x_{11} & x_{12} & \dots & x_{1I} \\ 1 & x_{21} & x_{22} & \dots & x_{2I} \\ 1 & x_{31} & x_{32} & \dots & x_{3I} \\ \dots & \dots & \dots & \dots & \dots \\ 1 & x_{M1} & x_{M2} & \dots & x_{MI} \end{bmatrix} = (X_{mi})_{M \times (I+1)} \quad (11)$$

$$U = \begin{bmatrix} u_{01} & u_{02} & \dots & u_{0J} \\ u_{11} & u_{12} & \dots & u_{1J} \\ u_{21} & u_{22} & \dots & u_{2J} \\ \dots & \dots & \dots & \dots \\ u_{J1} & u_{J2} & \dots & u_{JJ} \end{bmatrix} = (u_{ij})_{J \times (I+1)} \quad (12)$$

$$V = \begin{bmatrix} v_{01} & v_{02} & \dots & v_{0P} \\ v_{11} & v_{12} & \dots & v_{1P} \\ v_{21} & v_{22} & \dots & v_{2P} \\ \dots & \dots & \dots & \dots \\ v_{J1} & v_{J2} & \dots & v_{JP} \end{bmatrix} = (v_{jp})_{P \times (J+1)} \quad (13)$$

Using new adaptive algorithm to improve the BP neural network, there is no change in the propagation process of network:

$$f(x) = (1 + e^{-ax})^{-1} \quad (14)$$

$$Y_j = f\left(\sum_{i=1}^{I+1} x_{mi} u_{ij}\right) \quad (15)$$

$$Y_p = f\left(\sum_{j=1}^{J+1} Y_j v_{jp}\right) \quad (16)$$

$$E(n) = \frac{1}{2} \sum_{p=1}^P (d_y - Y_p)^2 \quad (17)$$

Set  $W(n)$  as the weight matrix of the  $n$  th research of BP neural network,  $W^*(n)$  is the reverse weight matrix of  $W(n)$ , The network's initial weights matrix and initial reverse weight matrix can be expressed as  $W(0)$  and  $W^*(0)$ . When adjust the weight  $W^*$ , set  $w_i(n)$  as the numerical value of the  $n$  th research of  $w_i$ ,  $\eta_i(n)$  as the learning rate of the  $n$  th research of  $w_i$ .

If  $W(n)$  is positive spread stage, it can meet the learning termination conditions

$$E(n) \leq e \quad (18)$$

In the equation,  $E(n)$  is the  $n$  th learning error of network,  $e$  is the preset value accuracy, then  $W(n)$  is the optimal weight matrices.

If it is not meeting the learning conditions, the BP neural network gets into the reverse adjustment phase of error. To clearly illustrate the back propagation process of new algorithm, now making any weight  $w_i$  in reverse order weights matrix  $W^*$  as an example, the adjustment method is as follows:

If the gradient of  $w_i$  is 0,  $\frac{\partial E}{\partial w_i} = 0$ . And adjust next weight  $w_{i+1}$ , the method of adjustment is as same as adjusting  $w_i$ .

If the gradient of  $w_i$  is not 0,  $\frac{\partial E}{\partial w_i} \neq 0$ . In the  $n$  th learning, according to equation (19) and (20) to calculate the new weight.

$$\Delta w_i(n) = - \eta_i(n) \frac{\partial E}{\partial w_i} \quad (19)$$

$$w_i(n+1) = w_i(n) + \Delta w_i(n) \quad (20)$$

If  $w_i(n+1)$  is according to the forward propagation calculation, better than  $w_i(n)$  (The error value get small), then:

$$\eta_i(n) \times 2 \Rightarrow \eta_i(n) \quad (21)$$

Then along  $w_i(n)$  the negative gradient direction, according to a new study recalculated rate  $\eta_i(n)$ . First, obtain a new weight  $w_i^{(1)}(n+1)$ , If  $w_i^{(1)}(n+1)$  calculated by the forward propagation error is less than  $w_i(n+1)$ , then press (21) continues to increase learning rate. Then, according to the new learning rate backpropagation obtained weights  $w_i^{(2)}(n+1)$ , If  $w_i^{(2)}(n+1)$  is still better than  $w_i^{(1)}(n+1)$ , continue to increase learning rate. If the weights  $w_i^{(m)}(n+1)$  calculated  $m+1$  times is not as good as  $w_i^{(m-1)}(n+1)$ , then let:

$$w_i(n+1) = w_i^{(m-1)}(n+1) \quad (22)$$

$$\eta_i(n) = \eta_i^{(m-1)}(n) \quad (23)$$

If  $w_i(n+1)$  is calculated by forward propagation,

not superior ( ie, error value increases ), then let:

$$\eta_i(n) / 2 = \eta_i(n) \quad (24)$$

Then along the negative gradient direction  $w_i(n)$ , according to the new learning rate  $\eta_i(n)$  recalculate  $w_i(n+1)$ . If new  $w_i(n+1)$  is not as good as  $w_i(n)$ , then press (24) continues to decrease learning rate  $\eta_i(n)$ . As long as the corresponding gradient of  $w_i(n)$  is not 0, according to this calculation method, will be able to find a different  $w_i(n)$  from  $w_i(n+1)$ , making  $w_i(n+1)$  is superior  $w_i(n)$ .

According to the  $w_i(n+1)$  calculation method, adjust the connection weights of all nodes again, that is called the completion of a learning. So we will get a new weight matrix  $W(n+1)$  and reverse weight ma-

trix  $W^*(n+1)$ , Analyzing whether the iteration termination condition (18) are satisfied. If so, then  $W(n+1)$  is the optimal weight BP neural network weights. If not, starting from  $W^*(n+1)$ , repeat the above calculation steps until the iteration termination condition is satisfied.

### Algorithm simulation

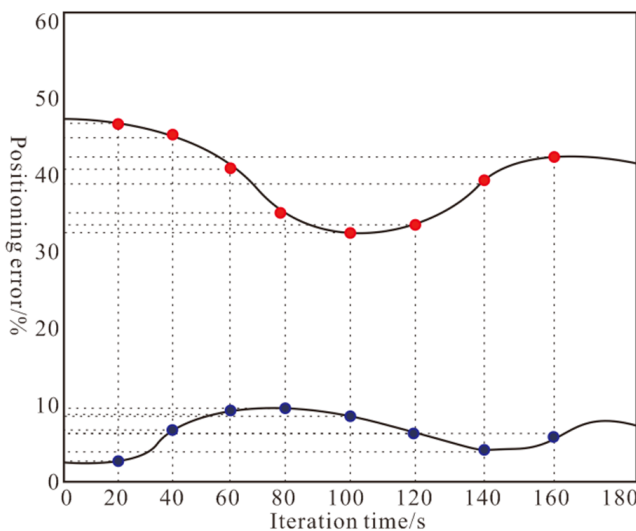
In order to verify the effectiveness of the improved algorithm proposed in this paper, we will do simulation experiments. Within a two experimental area, algorithm GSM network positioning test of standard BP neural network algorithm and improved BP neural network. The results are as follows:



**Figure 3.** Positioning the test results on the 1st test area



**Figure 4.** Positioning the test results on the 2nd experiment area



**Figure 5.** Two algorithms convergence speed comparison results

As can be seen from the simulation results, the improved BP neural network algorithm proposed in this paper has a good GSM network positioning accuracy and faster convergence.

### Conclusion

Now the positioning accuracy of GSM network positioning technology is still far cannot meet the needs of the user, the low accuracy of the positioning will greatly restrict the business development which is related with location services LBS. Therefore, the further research of the GSM network positioning technology is very necessary. In view of the defects of the basic BP neural network algorithm in the application of the GSM network positioning, this paper presents a GSM network location model based on self-adaptation and error correction BP neural network. Simulation experiments show that the improved model has higher precision and faster convergence speed, it has

good application effect.

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