Design for classification and recognition system of teenager mental health based on LM-BP algorithm

Yongxiong Zhang[a], Liangming Wang*[b]
[a]School of Business, Guangzhou College of Technology and Business, Guangzhou, China; [b]School of Software Engineering, South China University of Technology, Guangzhou, China

ABSTRACT

In order to predict the psychological status of teenagers accurately and quickly and find their psychological problems in time, this paper proposes a BP neural network classification model based on LM algorithm. Compared with BP neural network of steepest descent algorithm, the LM algorithm has better convergence speed and accuracy in the inversion coefficient experiment. In the Chinese text sentiment analysis experiment, the Precision, Recall and F1 values of LM-BP were better than SD-BP. Based on LM-BP model, this paper presents a design scheme of teenagers mental health classification and recognition system. The scheme has good stability, availability and scalability, which lays a technical foundation for the implementation of the system.

Keywords: LM-BP, mental health, classification, recognition

1. INTRODUCTION

With the rapid development of science and technology and the continuous improvement of material productivity, people's living standards are getting higher and higher, but the psychological problems have not been significantly reduced. According to the statistics of WHO, more than 300 million people around the world suffer from mental health diseases of varying degrees, especially the immature adolescents, whose mental health problems are particularly prominent, such as self-harm tendency, suicide or depression and a series of mental health problems. Scholars all over the world have been doing research on adolescent mental health. The research of Carl et al.[1] shows that the content of mental health education in American universities focuses on students' all-round development, including psychological, physical and environmental training. The research of David et al.[2] shows that the scope of mental health education of American college students should include suicide, anxiety, depression and love. Shirley etc. al.[3] believe that college psychological chat room can effectively release students' pressure.

The research on teenager mental health abroad is earlier, but the Chinese government attaches great importance to it in recent years. In 2019, the National Health Commission issued the "Healthy China Action - children and youth mental health action plan (2019-2022)". Since the release of the plan, many schools and even social units have set up mental health education courses or counseling departments. However, due to the limitations of teacher team and education environment, many mental health guidance work is carried out by mechanically copying the existing mental health education mode, and problems cannot be found in time, which leads to the poor effect of mental health work. Aiming at these problems, this paper constructs a classification model of teenager mental health by using BP neural network. Levenberg-Marquardt (LM) algorithm was used to improve the efficiency of the model, and a classification and recognition system of adolescent mental health was designed based on the model, so that relevant departments and schools could accurately and quickly predict the psychological status of adolescents, so as to improve the effectiveness of the work.

The rest of this paper is organized as follows. BP neural network, steepest descent method, Levenberg Marquardt (LM) algorithm and LM-BP model are presented in Section 2. Inversion analysis of the optimization algorithm and model experiment analysis are presented in Section 3. Then, the design of the system platform is in Section 4. Finally, the conclusion is presented and future work is discussed.

*mustcsyxzhang@126.com

International Conference on Computer Application and Information Security (ICCAIS 2021), edited by Yingfa Lu, Changbo Cheng, Proc. of SPIE Vol. 12260, 122601V · © The Authors. Published under a Creative Commons Attribution CC-BY 3.0 License · doi: 10.1117/12.2637364

2. CONSTRUCTION OF LM-BP CLASSIFICATION MODEL

2.1 BP neural network

Artificial neural network is an algorithm that imitates biological neuron. It can be simply divided into input layer, hidden layer and output layer. And the hidden layer can be divided into multi-layer structure according to the complexity of the model[4,5]. BP neural network is an error back propagation neural network, which trains weights along the direction of reducing error. But it is not a feedback neural network.

The principle of BP neural network is to use the output error to calculate the error of the upper layer, and then use the calculated error of the upper layer to calculate the error of the previous layer, so as to calculate the error of each layer, and then modify the connection weight according to the error value, and repeat the process until the output error reaches the convergence condition, then, the model training is over.

The learning rules of BP neural network generally use the steepest descent method, through back propagation, that is, layer by layer forward propagation, constantly dynamically adjust the connection weight, so as to minimize the global error.

The step of BP neural network is simple. Firstly, the error of output layer is obtained by forward propagation, and then the convergence condition is judged. If it is reached, it will be over, otherwise, the error will be back propagated.

According to the above, the global error objective function of BP neural network is as following:

$$\mathrm{L} = \frac{1}{2}\sum_{i-1}^{n}\sum_{j-1}^{k}(y_{ij} - d_{ij})^2 \tag{1}$$

where, L represents the global error, n represents the number of samples, k represents the number of categories. y_{ij} represents the output value of the category j for the sample i. d_{ij} represents the expected value of the category j of the sample i. BP neural network model needs to minimize the global error value of L.

2.2 Steepest descent algorithm

In BP neural network, the steepest descent algorithm is usually used to minimize the error. The principle of the steepest descent algorithm is to use the opposite direction of the gradient to iterate until the convergence condition is reached. The steepest descent algorithm is to execute the current descent with the fastest speed, not the global descent with the fastest speed. Therefore, it is necessary to determine the length of descent while determining the direction of each iteration[6,7].

Assume that $f(x)$ is the objective function, d_k is the searched direction of x_k, i.e., $d_k = -\nabla f(x_k)$, λ_k is the search step size. Then,

$$x_{k+1} = x_k + \lambda_k d_k \tag{2}$$

$$\lambda_k = \arg\min_{\lambda}(f(x_k + \lambda d_k)) \tag{3}$$

Assume that H is the Hessian matrix of $f(x)$, and expand $f(x_k + \lambda_k d_k)$ at x_k with Taylor expansion of second order as following:

$$f(x_k + \lambda_k d_k) \approx f(x_k) + (\lambda_k d_k)^T \nabla f(x_k) + \frac{1}{2}(\lambda_k d_k)^T H(\lambda_k d_k) \tag{4}$$

The derivation of equation (4) is performed to λ_k, i.e.,

$$\frac{\partial f(x_k + \lambda_k d_k)}{\partial \lambda_k} = 0 \tag{5}$$

Optimal search step size can be found as following:

$$\lambda_k = \frac{d^T d_k}{d_k^T H d_k} \tag{6}$$

The implementation steps of steepest descent method are as follows:

Step 1: Calculate the value of function $f(x_0)$, gradient $\nabla f(x_0)$, search direction and H_0 of the initial point x_0, and set $k = 0$;

Step 2: Do the line search $x_{k+1} = x_k + \lambda_k d_k$. λ_k is attained by equation (6), then calculate $\nabla f(x_{k+1})$.

Step 3: Judge if it is on the convergence condition $\|x_{k+1} - x_k\|_\infty < \varepsilon$ or $\|\nabla f(x_{k+1})\|_\infty < \varepsilon$ or $k \geq k_{\max}$: If yes, the iteration is over and x_{k+1} is output; otherwise, calculate $f(x_{k+1})$, d_{k+1} and H_{k+1}, set $k = \underline{k}+1$. And turn to step 2.

If the Hessian matrix of the objective function is computationally complex or there is no second derivative, the search step size λ_k can be calculated by Armijo delimitation method or golden section method.

2.3 Levenberg-Marquardt algorithm

Levenberg Marquardt (LM) is a widely used optimization algorithm[8]. The convergence speed of LM algorithm is generally higher than the steepest descent method, which simplifies the difficulty of Newton method in calculating Hessian matrix and solves the problem that the approximate Hessian matrix of Gauss Newton method is not full of rank[9,10].

Assume that $\mathrm{M}(\mathrm{x},\theta)$ is a model function, and set

$$f(x) = M(x,\theta) - Y \tag{7}$$

Taylor expansion is performed at *x* and according to the least square method,

$$F(x) = \frac{1}{2} f^T(x) f(x) \tag{8}$$

where,

$$F(x+h) = F(x) + h^T g + \frac{1}{2} h^T H h + O(\|h\|^3) \tag{9}$$

$$g = F'(x) = \left[\frac{\partial F(x)}{\partial x_1} \cdots \frac{\partial F(x)}{\partial x_n} \right]^T \tag{10}$$

$$H = F''(x) = \left[\frac{\partial^2 F(x)}{\partial x_i \partial x_j} \right] \tag{11}$$

Assume that $J(x)$ is the Jacobian matrix, then,

$$g = F'(x) = J^T(x) f(x) \tag{12}$$

If $\mathrm{M}(x,t)$ fits well, i.e. $f_i(x) \approx 0$, then

$$H = F''(x) = J^T(x) J(x) \tag{13}$$

Therefore,

$$x_{new} = x - (H + \mu I)^{-1} g \tag{14}$$

Implementation steps of Levenberg -Marquardt algorithm are as following:

Step 1: Calculate $f(x_0), g_0$ and H_0 of the initial point x_0, and set $\mu = 0.001, k = 0$;

Step 2: Calculate $x_{k+1} = x_k - (H_k - \mu I)^{-1} g_k$, $f(x_{k+1})$, g_{k+1} and H_{k+1} by equation (14);

Step 3: Judge whether $\|x_{k+1} - x_k\|_\infty < \varepsilon$ or $k \geq k_{\max}$ is on the convergence condition. If yes, the iteration is over and x_{k+1} is output; otherwise, go to Step 4.

Step 4: Judge whether condition $\|f(x_{k+1})\| < \|f(x)\|$ is satisfied, if yes, $\mu = \mu / 10$, or, $\mu = \mu * 10$;

Step 5: set *k*=*k*+1, and go to Step 2.

2.4 LM-BP model

LM-BP model is based on BP neural network, using LM algorithm to calculate the minimum error. Firstly, the weights of the model need to be modified by a large number of sample data in the training stage, and then it can be applied to the real environment. The model is shown as Figure 1.

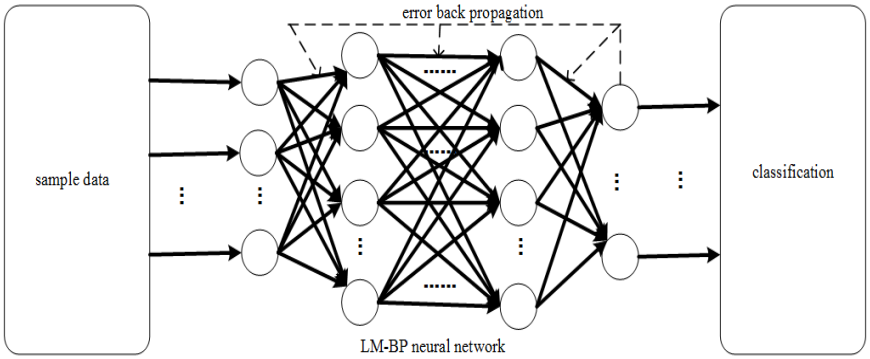

Figure 1. LM-BP model.

According to the mental health level identified by the model, it can accurately and quickly predict the mental status of teenagers, so as to improve the work effectiveness of relevant departments.

3. EXPERIMENTAL ANALYSIS

3.1 Inversion analysis of optimization algorithm

In this paper, two equations are constructed for inversion experiments to compare the convergence speed and accuracy of steepest descent method and LM algorithm. The equations are defined as follows:

$$f_1(x) = a_1 x^3 + a_2 x^2 + a_3 x + a_4 \tag{15}$$

$$f_2(x) = a_4 x^3 + a_5 x^2 + a_6 x - (a_1 x - a_2) \exp^{-x/a_3} \tag{16}$$

The variable x of $f_1(x)$ means to get 100 equidistant values between 0 and 10. The true coefficient is [3.4, 2.3, 5.3, 6.2], the initial coefficient is [3.9, 0.8, 41.3, 3.2]. The experimental results of inversion are shown in Table 1.

Table 1. Coefficient inversion comparison of $f_1(x)$.

Algorithm	Iterations	Inversion coefficient	Max. error (%)
SD	98883	[3.4000, 2.2999, 5.3003, 6.1996]	5.75e-3
LM	4	[3.4000, 2.3000, 5.3000, 6.2000]	4.77e-12

The variable x of $f_2(x)$ is equidistant between [0, 10] and takes 100 values of them. The true coefficient is [3.4, 2.3, 5.3, 6.2, 1.5, 8.4], the initial coefficient is [8.1, 1.3, 4.3, 3.2, 3.5, 4.4]. The experimental result is shown in Table 2.

Table 2. Coefficient inversion comparison of $f_2(x)$.

Algorithm	Iterations	Inversion coefficient	Max. error (%)
SD	9599400	[3.2683, 2.3049, 5.1402, 6.1998, 1.5103, 8.2704]	3.87
LM	4	[3.4000, 2.3000, 5.3000, 6.2000, 1.5000, 8.4000]	1.44e-8

From above, it can be proved that the convergence speed of steepest descent algorithm is much slower than LM algorithm. When the complexity of the equation increases, the accuracy of inversion coefficient of steepest descent method is not as good as LM algorithm.

3.2 Model analysis

Emotional data[11], the hotel reviews is used as experimental data. This data has 1172 negative emotion data and 5358 positive emotion data. Nlpir tool is used to process Chinese word segmentation. Precision, recall and F1 values were selected to evaluate the experimental results. In this paper, the steepest descent method and LM algorithm are used to compare and analyse the sample data. The result is shown in Table 3.

Table 3. Contrastive analysis.

Model algorithm	Precision	Recall	F1
SD-BP	0.802	0.738	0.769
LM-BP	0.853	0.784	0.817

According to the above contrastive analysis, Precision, Recall and F1 of model LM-BP is higher than model SD-BP.

4. DESIGN OF CLASSIFICATION AND RECOGNITION SYSTEM

As LM-BP model is better than SD-BP model in Chinese text emotion classification experiment, this paper uses LM-BP model as its classification model algorithm in the design of teenager mental health classification and recognition system. The system mainly consists of the terminal, load balancing module, application service module, classification module, LM-BP algorithm module and data management module, etc. The system architecture is shown in Figure 2.

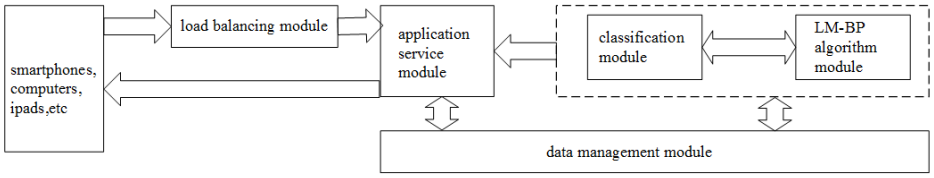

Figure 2. System architecture.

Considering the convenience and versatility of users, and their willing that not want to install too much software on smart phones, in the terminal development, browser, WeChat official account, or applet are firstly used as the interaction terminal. Based on the user's identity and input characterization information, the system uses specific interaction strategy to generate input data and submits it to the server for processing. After processing the data, the server returns the data to the terminal device.

The development of the server side of the system uses the micro-service architecture, which increases the stability and reliability of the system and facilitates the expansion of the function of the system in the future. Load balancing module, application service module, classification module, LM-BP algorithm module and data management module are all micro service modules. Each module has done the micro-service redundancy processing, which can ensure that the service will not cause the system crash due to the error of a module. Load balancing module is a function of load balancing, which avoids overload caused by a large number of users accessing the server in a short time.

The Data management module of server side is very import. It stores both structured and unstructured data. In order to improve the performance of the system, the trained data is stored in the Redis database to accelerate the retrieval speed of

the Classification Module. Meanwhile, the new analysis data will be stored persistently as the sample data of the re-training model to modify the weight of the model.

5. CONCLUSION

In this paper, the steepest descent algorithm and LM algorithm are used to invert the coefficients of the equation. From the experimental results, the convergence speed of LM algorithm is faster than the steepest descent algorithm, and the accuracy is better than the steepest descent algorithm when the inversion complexity is increased. At the same time, the emotional data of non-balanced hotel reviews are used to test the BP neural network model based on the steepest descent algorithm and LM algorithm, and the results show that the LM-BP model has better analysis effect than the SD-BP model. Therefore, in this paper, LM-BP model is used to design a classification and recognition system for adolescent mental health. The system has good stability and reliability. And it is easy to expand the function. It can effectively predict the psychological state of teenagers, and improve the work efficiency of the relevant departments.

In the next research stage, we will complete the test and lay out the application of the system, promote it to the surrounding schools for free, collect more sample data, and continue to improve the weight correction of the LM-BP model.

ACKNOWLEDGMENTS

This research was financially supported by the Project of Philosophy and Social Sciences Planning of Guangzhou in 2020 (Subject No.: 2020GZGJ295).

REFERENCES

[1] Carl, S., Seidman, L. J. and Keshavan, M. S., "The Massachusetts Mental Health Center: Going forward after 100 years," American Journal of Psychiatry, 169(10), 1037-1037 (2012).
[2] Fresco, D. M., Heimberg, R. G., Abramowitz, A., et al., "The effect of a negative mood priming challenge on dysfunctional attitudes, explanatory style, and explanatory flexibility," British Journal of Clinical Psychology, 45(2), 167-183 (2006).
[3] Ho, S. S. and Mcleod, D. M., "Social-psychological influences on opinion expression in face-to-face and computer-mediated communication," Communication Research, 35(2), 190-207 (2008).
[4] Cheng, C., Cheng, X. S., Dai, N., et al., "Prediction of facial deformation after complete denture prosthesis using BP neural network," Computers in Biology and Medicine, 66(11), 103-112 (2015).
[5] Cai, B., Pan, G. L., Fu, F., et al., "Prediction of the postfire flexural capacity of RC beam using GA-BPNN machine learning," Journal of Performance of Constructed Facilities, 34(6), 1-11 (2020).
[6] Deift, P. and Zhou, X., "A steepest descent method for oscillatory Riemann-Hilbert problems-Asymptotics for the MKDV equation," Annals of Mathematics, 137(2), 295-368 (1993).
[7] Geng, X. G. and Liu, H., "The nonlinear steepest descent method to long-time asymptotics of the coupled nonlinear Schrodinger equation," Journal of Nonlinear Science, 28(2), 739-763 (2018).
[8] Amini, K. and Rostami, F., "Three-steps modified Levenberg-Marquardt method with a new line search for systems of nonlinear equations," Journal of Computational and Applied Mathematics, 300(7), 30-42 (2016).
[9] Amini, K., Rostami, F. and Caristi, G., "An efficient Levenberg-Marquardt method with a new LM parameter for systems of nonlinear equations," Optimization, 67(5), 637-650 (2018).
[10] Lv, C. Q. and Ma, C. F., "A Levenberg-Marquardt method for solving semi-symmetric tensor equations," Journal of Computational and Applied Mathematics, 332(4), 13-25 (2018).
[11] Emotional Data, Available online: https://download.csdn.net/download/qq_42 208267/10904313