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Prediction of Population Aging in China Based on BP Neural Network

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Abstract

With the continuous development of China, the demographic structure of China has changed a lot, and the problem of population aging is getting more and more serious. This paper obtains the data of 1900-2021 based on the China Statistical Yearbook, and uses the Pearson correlation analysis to find out the main factors affecting the aging of the population, and then uses the data of the main factors of 1990-2021 as inputs to BP neural network to be trained. After that, the main factors from 1990 to 2021 are used as inputs for the BP neural network to be trained, and the trained model is used to predict the population aging situation in the next fifteen years, and the results show that China has entered into a deeply aging society, and the degree of population aging will be deepened gradually in the next period of time.

Keywords

Aging, Pearson correlation analysis, BP neural network, prediction.

1. Introduction

Population aging in China is becoming a serious social challenge. Population aging mainly refers to the increase in the proportion of elderly people over 65 years old, reaching 7% means entering an aging society, reaching 14% is a deep aging society, reaching 20% is a super aging society. Population aging is not only a simple demographic problem, but also a major constraint to China's sustainable economic and social development, as it will have a significant negative impact on the overall development of society. Therefore, it is of great significance to predict population aging in advance for the healthy and sustainable development of national economy.

Traditional population forecasting methods mainly include Logistic biological growth model, gray forecasting, regression analysis and other methods, which play a certain role in the field of population forecasting, but all of them have to make assumptions about the model when building the model. Since the real model is often nonlinear, if the data simulation is carried out under some simple models, the results often cannot achieve better results. [1]However, BP neural network, with a highly parallel information processing mechanism and high-speed self-learning and self-adaptive ability, can better reproduce the nonlinear dynamics of population growth, and overcome the human randomness factor in the population forecasting method. [2]Therefore, in this paper, BP neural network is used to predict the population aging in China.

2. Data Processing

There are many factors affecting population aging, and the article chooses the factors of total population, elderly population, birth rate, death rate, gross domestic product, and urban population.

Pearson correlation analysis is a statistical method used to measure the strength and direction of the linear relationship between two continuous variables. The Pearson correlation coefficient is denoted by r, and it is calculated as follows： $r = \sum_{i=1}^{n}(xi - \bar{x})(yi - \bar{y})/$

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$\sqrt{\sum_{i=1}^{n}(xi - \bar{x})^2 \sum_{i=1}^{n}(yi - \bar{y})^2}$,where n is the number of data points,xiand yi are the values of the two variables corresponding to the ith data point, $\bar{x}$ and $\bar{y}$ are the means of the two variables, respectively.

Pearson's correlation coefficient ranges from -1 to 1. When the correlation coefficient is +1, it means that the two variables are completely positively correlated, i.e., when one variable increases, the other also increases in a completely linear fashion, when the correlation coefficient is -1, it means that the two variables are completely negatively correlated, i.e., when one variable increases, the other also decreases in a completely linear fashion, and when the correlation coefficient is close to 0, it means that there is little or no linear correlation between the two variables.

Using the above formula, Pearson correlation coefficients were obtained for the six indicators, and the results are shown in Table 1.

Table 1 Pearson correlation coefficient table

	total population	older persons	Urban population
Pearson's correlation	0.911	0.999	0.961
Significance	0.000	0.000	0.000

	birth rate	mortality rate	GDP per capita
Pearson's correlation	-0.801	0.766	0.991
Significance	0.000	0.000	0.000

The original hypothesis is that the correlation coefficient between each independent variable and the dependent variable is 0. The above table can be found that the r-value of the t-test corresponding to the six indicators is less than 0.05, i.e., at the 95% confidence level, this paper can reject the original hypothesis, i.e., the six indicators selected in this paper are all significantly correlated with the nursing care beds, and therefore will be inputted into the BP neural network prediction model as variables.

3. Modeling

3.1. BP Network Model

BP Neural Network (Backpropagation Neural Network) is one of the most common types of artificial neural networks, also known as Backpropagation Neural Network. It is a supervised learning algorithm used to solve classification and regression problems. The design of BP neural network is inspired by the structure and function of the human nervous system. The BP neural network consists of several layers. In this paper, a three-layer structure is used, i.e., Input Layer, Hidden Layer, and Output Layer. The total population, old age population, birth rate, death rate, GDP and urban population are used as inputs to the network, so the input nodes are chosen as 6. The proportion of old age population in the population is used as the output layer, so the output layer adopts 1 node number. The following are the steps of model generation :

1: Data preparation：i*mporting data from files, generating training set and test machine data*

2: Normalization of data:

$$X\_std = (X - X.min(axis = 0)) / (X.max(axis = 0) - X.min(axis = 0))$$

$$X\_scaled = X\_std * (max - min) + min$$

3: Define the activation function and its derivatives:

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$$sigmoid = 1/(1 + e^{-x})$$
$$sigmoid_{delta} = 1/\ (1 + e^{-x})^2 * e^{-x})$$

4: Initialize neural network para*meters: Randomly initialize the weight matrices w1, w2 and the bias vectors b1, b2.*

5: Training of the neural network: set the *maximum number of iterations, the learning rate, and the final MSE error threshold. Iterative training is performed until the maximum number of iterations is reached or the MSE error is less than the threshold. In each iteration, forward propagation is performed to calculate the predicted output and the prediction error (MSE) is calculated. If the MSE error is less than the threshold, the iteration is stopped, otherwise back propagation is performed to update the network parameters.*

Forward propagation algorithm*:*

$$z^{(l)} = w^{(l)}a^{(l-1)} + b^{(l)}$$
$$a^{(l)} = sigmoid(z^{(l)})$$

Backpropagation *algorithm:*

$$\delta = (w^{(l+1)})^T\delta^{l+1} \odot sigmoid_{delta}(z^{(l)})$$

6: Prediction of Neural Networks: Pr*ediction using the trained network, forward propagation of the data to get the prediction results, reduction of the prediction results to the original data space.*

3.2. Model Training and Validation

After the population model was determined, the network was trained and tested. The maximum number of iterations was set to 60000 and the following training results are shown.

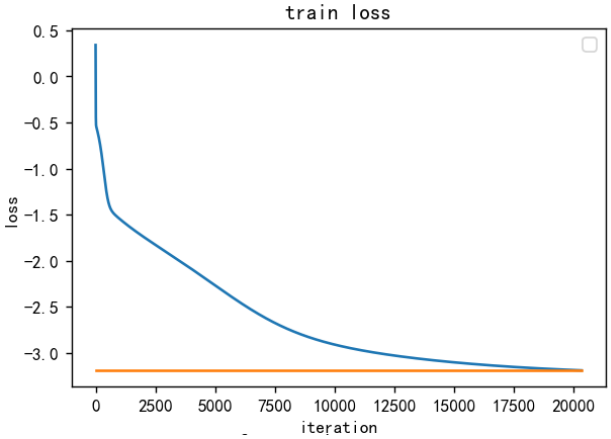

Figure 1 Loss curve

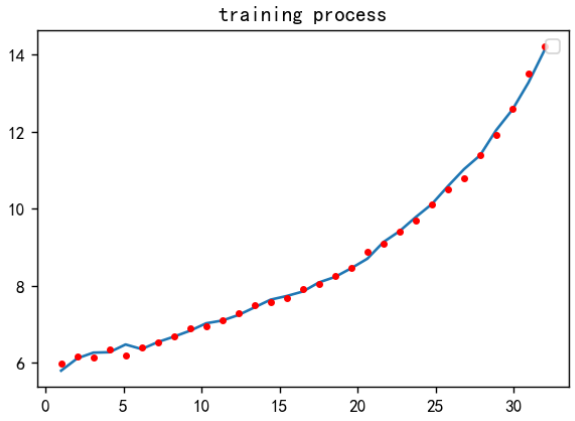

Figure 2 Training process

It can be seen that the network has converged at 17,500 iterations and the model has learned the main features of the data and achieved optimal predictions on the given training data.

3.3. Model Evaluation

In the regression prediction task, we can use MSE, MAE, and R^2 metrics to evaluate the model.

MSE is one of the most common metrics for evaluating regression models, which calculates the average of the squared errors between the predicted and true values, and the smaller the MSE, the better the model fits the data. The formula for calculating MSE is as follows:

$$\text{MSE} = \Sigma\,(\text{yi} - \hat{\text{y}}\text{i})^2 / \text{n}$$

where yi is the true value, ŷi is the predicted value, and n is the sample size.

The MAE is used to measure the average absolute error between the predicted and true values of the model. Compared to MSE, the calculation of MAE does not involve squaring the error, so its magnitude is the same as the original value, avoiding the problem of amplifying the error

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due to squaring, and at the same time it is more robust to outliers. The calculation formula is as follows:

$$MAE = \Sigma |yi - \hat{y}i| / n$$

where |x| denotes taking the absolute value of x.

R^2 is a measure of the goodness of fit of a regression simulation. It represents the proportion of variance between the predicted and true values, and takes values from 0 to 1. The closer R^2 is to 1, the better the model fits the data, and the closer R^2 is to 0, the worse the model fits the data. The formula for calculating R^2 is as follows:

$$R^2 = 1 - \Sigma (yi - \hat{y}i)^2 / \Sigma (yi - \bar{y})^2$$

where $\bar{y}$ denotes the average of the true values.

The results for the three indicators are shown in the table below:

Table 2 Evaluation results

	MSE	MAE	R^2
Result	0.079	0.246	0.985

It can be seen that the model MSE and MAE values are lower than 0.5, R^2 is close to 1, and the model fits well.

4. Conclusion

After several times of training and learning, and the predicted data are reduced to get the predicted value of BP network. The prediction results are shown in the following table

Table 3 Projected results

Time	aging rate
2022	14.29
2023	14.63
2024	14.90
2025	15.02
2026	15.10
2027	14.86
2028	15.25
2029	15.15
2030	15.66
2031	15.44
2032	15.68
2033	15.89
2034	16.01
2035	16.02
2036	16.23

It can be seen from the forecast that China has entered a deeply aging society, and the aging rate will continue to rise. The government should adjust its policies in a timely manner according to the structural characteristics of the continuous development of the aging

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population, and actively adjust the industrial structure in accordance with the trend of economic development, in order to continue to enhance the stable development of the economy.

References

[1]Yuan Shaoliang. China's population forecast based on BP neural network[J]. Science and Technology Square, 2014(10).

[2]Jia Nan, Hu Hongping, Bai Yanping. Population prediction based on BP neural network[J]. Journal of Shandong University of Technology (Natural Science Edition), 2011, 25(03).