ISSN 2616-5775 Vol. 5, Issue 6: 14-18, DOI: 10.25236/AJCIS.2022.050603

Research on Field Fire Prediction Based on Improved Grey Correlation Prediction Based on BP Neural Network

Wei Li, Yuchi Li, Xinshuo Du, Shumin Liu, Xin He

College of Engineering, Qufu Normal University, Rizhao, Shandong, 276827, China

Abstract: *In order to better prevent fire and adapt to the change of the probability of extreme fire events in the next ten years, we establish an improved grey neural network prediction model. According to the collected data of climate characteristics, precipitation, temperature, humidity, wind speed and air pressure in southeastern Australia, they are quantified and processed as learning samples, and the improved grey neural network is used to predict the scale of wildfires in southeastern Australia. Through sensitivity analysis, the robustness of the model is guaranteed.*

Keywords: *Wildfire monitoring, Gray neural network model, BP neural network*

1. Introduction

Australia is located between the South Pacific and the Indian Ocean, surrounded by the sea, with a land area of 7.692 million square kilometers, but about 70% of the land in the central part is in arid or semi-arid zones, extremely water-deficient and desolate. The vast majority of eucalyptus trees in the world are planted in Australia, Eucalyptus accounts for 70% of Australia’s forest area. Griffith explained that eucalyptus is a kind of "flammable", the leaves are rich in wax and oil, easy to cause forest fires.The famous Australian biologist and writer Jeremy Griffith said that the serious forest fires in Australia are caused by eucalyptus. The germs hidden under the bark of eucalyptus can also resist flames and can germinate quickly after a massive fire, so that the eucalyptus can survive the fire. But after a fire, eucalyptus lacks competition from other tree species, and it is easier to "encourage" fires [1].

Therefore, Australia pays particular attention to the issue of wildfire. During the annual fire season, all states are affected by wildfire, with New South Wales and eastern Victoria being the most affected. Figure 1 shows the fire hot spots in Southeast Australia from October 1, 2019 to January 7, 2020. As early as a few years ago, the Country Fire Authority (CFA) had used SSA drones to monitor wildfires and situational awareness [2], so that the Emergency Operations Center (EOC) could best command front-line personnel. However, deployed personnel carry handheld two-way radios operating in the VHF/UHF bands, and the range of the handheld radio is limited by low transmit power (typically 5 watts). Based on the above situation, the SSA drones cannot respond perfectly and quickly and monitor the situation of wildfire in the forest. The emergence of hovering drones carrying repeaters has solved this problem. Because the repeater is a transceiver that automatically rebroadcasts signals at higher power and can expand the range of radio signals, hovering drones with repeaters can be used to extend the range of front-line low-power radios.

2. Data processing

From November and December to January of the following year, summer in Australia is also a season for forest fires. During this period, due to the hot and dry weather, there will be plenty of dry thunderstorms (only thunder, no rain). When dry thunderstorms are strong, there will be 100 lightning strikes that touch the ground, making forests often large-scale forest fires. Due to the vast area of Australia’s forests, when the burning area expands, especially when the fire head meets where the downward tuyere is burning, it is easy to produce fire storms and spread the fire quickly.

ISSN 2616-5775 Vol. 5, Issue 6: 14-18, DOI: 10.25236/AJCIS.2022.050603

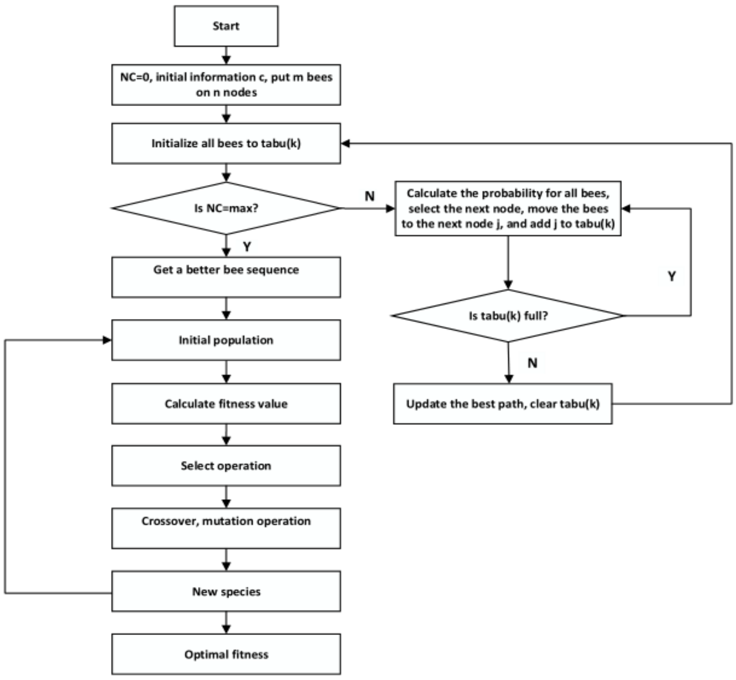

Figure 1: Flow chart of the working principle of artificial bee colony algorithm

Therefore, the main factors affecting the occurrence of fire incidents are temperature, precipitation and wind speed. Bring them into the model for consideration as parameters.

System main variable calculation:

Table 1: Variables required by the algorithm

Variables required by the algorithm	Algorithm core
Temperature, relative humidity, precipitation	$M_0 = 20.00 + \ln\left[\left(c_{DMC} - 244.73\right) / -43.43\right]$
Temperature, precipitation .	$Q_0 = 400 \times e - c_{DC} / 400$

In order to improve the possibility of the model adapting to fire changes in the next ten years, we need to predict the frequency of fires in Eastern Victoria in the next ten years, which is a typical prediction problem. Since the dimensions of each impact factor are different, the collected data must be processed through data standardization. The processed data can be used for scientific research and mathematical modeling, and it is suitable for more comprehensive comparative evaluation.

3. Establishment and analysis of grey neural network prediction model

3.1 The establishment of grey forecasting model [3]

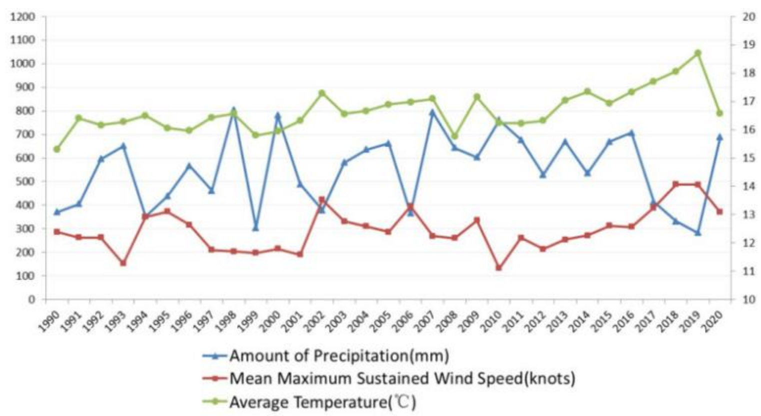

Figure 2: Line graph of average temperature, humidity and wind speed in Eastern Victoria from 1990 to 2020

Based on the previous data analysis and processing, we initially used the grey prediction model to simulate the number of fire incidents from 1990 to 2020. The steps are as following:

(a) Select sample data, normalize the data, and take the 2nd to nth data in the original sequence to obtain the data sequence

$$T = \left[X^{(0)}(2), X^{(0)}(3), \cdots, X^{(0)}(n) \right] \tag{1}$$

(b) Establish an improved GM.A sequence of numbersis generated from the data sequence T for 1 time accumulation (AGO)

$$T = \left[X^{(1)}(2), X^{(1)}(3), \cdots, X^{(1)}(n) \right] \tag{2}$$

Build differential equations:

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = u \tag{3}$$

The background value in B is

$$z^{(1)}(k+1) = \frac{1}{2}\left(x^{(1)}(k) + x^{(1)}(k+1) \right)(k = 1, 2, \cdots, n-1) \tag{4}$$

The actual area of the interval [k, k + 1] is infinitely approximated to the area between n cells, thereby improving the fitting accuracy. General Gray forecasting models are suitable for short-term and mid-term forecasts with high accuracy, but in the long-term forecasts, they may be affected by some disturbance factors [4-6], which will reduce the forecasting accuracy. In order to further improve the prediction accuracy, the BP neural network model is used to further improve the results obtained, and the gray prediction results are used as the input learning samples of the neural network.

3.2 The establishment of grey neural network model

The gray neural network algorithm is a predictive algorithm. The model is used to solve gray problems. The calculation is small, and high accuracy can be achieved even in the case of small samples. The error is controllable, which improves the efficiency of modeling and the accuracy of the model.

We then use the improved GM to process the sample data to get the data sequence

$$P = \left[Y^{(0)}(2), Y^{(0)}(3), \cdots, Y^{(0)}(n) \right] \tag{5}$$

(a) Take the data sequence P as the input vector of the BP neural network, and T as the output vector of the neural network.

Randomly assign an initial value W_{ij} to each θ_j weight and threshold, and for each sample in the sample (X_p, Y_p).

Output layer:

$$\zeta_{pk} = Q_{pk}\left(Y_{pk} - O_{pk} \right)\left(1 - O_{pk} \right) \tag{6}$$

Hidden layer:

$$O_{pj} = O_{pi}\left(1 - O_{pi} \right)\sum_{i} \zeta_{pi} W_{ij} \tag{7}$$

Adjust the weight matrix according to the minimal error method. Get the training function

$$O_{pj} = f\sum_{i}\left[W_{ij}(t) I_{pi} - \theta_j(t) \right] \tag{8}$$

(b) Use the established improved GM to predict

The GM simulation results are used as the input P of the neural network, and the raw data of the number of fire occurrences corresponding to the years are used as the output T, and the BP neural network with momentum and adaptive lr gradient descent method (traindx) is used for network learning and training. Get the corresponding output value.

4. Solving the grey neural network model

The independent variables of the gray neural network model are: maximum temperature, average temperature, humidity, maximum wind speed, precipitation; dependent variable: fire scale (fire level, affected area, number of fires/frequency). In the fire scale prediction of this model, it is assumed that the fire is only affected by the natural environment and climate, without considering human factors. Based on the collected climatic characteristics, precipitation , temperature, humidity, windspeed and pressure values of southeastern Australia, they are then used as learning samples to predict the scale of fire in southeastern Australia with a gray neural network. BP neural network can better predict the fire scale affected by multiple factors. In order to achieve better prediction results, the neural network model uses a feed-forward network whose structure is composed of three layers: input layer, hidden layer, and output layer. Each network unit can have multiple input, but only one output. The input layer in this model has 5 neurons, and each neuron corresponds to an influencing factor (the number of days with the maximum temperature ≥ 35℃, the maximum temperature extreme value, and precipitation The input of these influencing factors are all values after data standardization processing. The output layer has only 1 neuron, which is the scale of the Australian Fire [7].

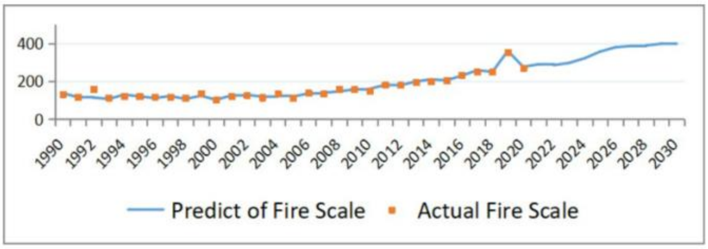

Figure 3: Results of grey neural network model predicting fires in the next ten years

It can be seen from the forecast map that the scale and frequency of fires in the next ten years will be slightly reduced but still maintain a high level, so more drones need to be deployed to monitor the fire situation, and then the planning model. It can be concluded that the number of SSA drones and radio repeater drones that need to be increased in the future, and thus the increased cost can be calculated.

5. Sensitivity analysis

We test the sensitivity of our model by changing the parameters and comparing the difference between the original result and the changed result. Change the value of the gray-scale neural network model input factors (days with maximum temperature ≥35℃, maximum temperature extreme value, precipitation, average maximum continuous wind speed, average temperature) values slightly. The predicted fire scale obtained by simulation is very different from the original predicted value Small, thus ensuring the robustness of our model. Australia’s terrain is dominated by plains, which have a small impact on the spread of fire. Our model ignores the impact of terrain factors.

6. Model advantages and disadvantages

Advantages: The gray neural network algorithm can reduce the deviation between the predicted value and the original data as much as possible, is convenient to use, has high prediction accuracy, and has high application value. The model uses an accurate and up-to-date database to ensure the accuracy of the results and make the calculation results more convincing. In addition, the model quantifies some index factors to make it more intuitive to display the results of the model.

Disadvantages: Some indicators are missing. In order to make the model simpler, we choose he main influencing factors to consider, while ignoring the secondary factors. As the sample data during the prediction is small, the predictive ability of the combined model needs to be confirmed by future research.

ISSN 2616-5775 Vol. 5, Issue 6: 14-18, DOI: 10.25236/AJCIS.2022.050603

7. Conclusion

The wildfires of 2019-2020 had a devastating impact on all Australian states, particularly New South Wales and eastern Victoria. In order to better prevent fire, an improved grey neural network prediction model is established in this paper. According to the collected data of climate characteristics, precipitation, temperature, humidity, wind speed and air pressure in southeastern Australia, they are quantified and processed as learning samples, and the improved grey neural network is used to predict the scale of wildfires in southeastern Australia. According to the prediction curve, it can be concluded that the scale of wildfires will increase in the next ten years.

References

[1] Sun Shouqin. Why did Australia's forest fires get out of control this time? [J]. Fire Fighting (Electronic Edition), 2020.
[2] Wang Miao, Wang Pengya, Chen Xin. U.S. carbon emission prediction based on gray neural network model J]. Science and Technology Information, 2019.
[3] Yang Lin, Kong Feng. Hybrid artificial bee colony algorithm embedded with particle swarm optimization algorithm [J]. Automatic Instrumentation, 2013.
[4] Yin Jianxia, Meng Hongyun. Artificial bee colony algorithm with chaotic differential evolution search [J].Computer Engineering and Applications, 2011.
[5] Zhang Dongnan, Shu Zhongjun, Chen Qingquan, Xu Yan. Application research of improved grey neural network in fire prediction J]. Chinese Safety Science Journal, 2012.
[6] Wang Wenye, Liu Jing, Jia Nan. Forest fire prediction analysis based on neural network[J]. Journal of Armed Police Academy, 2020.
[7] Li Chengxin, Zhao Liangchen, Li Dongyun, Ma Jiahui. Australian forest firespreadprediction model based on CA system and application of emergency supplies dispatching [J]. Forestry Inventory and Planning, 2020.