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# Influence of adjacent shield tunneling construction on existing tunnel settlement: field monitoring and intelligent prediction

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# BP neural network

The BP neural network is a radial basis function neural network based mainly on the theory of error back-propagation. In addition, the number of input data n expresses the correlation between the subsequent prediction data and the first n data so that the correlation between the data can be reflected by the number of input data.

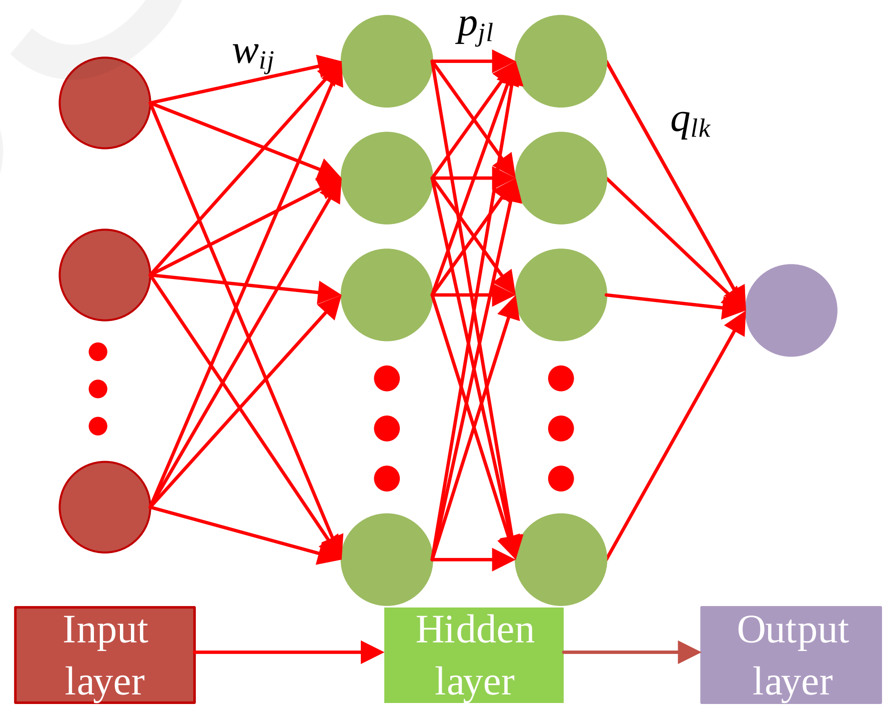
$$\frac{\partial e(k)}{\partial \omega_{hu}} = \frac{\partial e(k)}{\partial y_{ui}} \frac{\partial y_{ui}}{\partial \omega_{hu}}$$

$$= \frac{\partial\left[e(k) = \frac{1}{2}\sum_{u=1}^{q}\left(d_u(k) - y_{uo}(k)\right)^2\right]}{\partial y_{ui}} \frac{\partial\left[\sum_{h=1}^{p}\omega_{hu} z_{ho}(k) - b_u\right]}{\partial \omega_{hu}}$$

$$= \left(y_{uo}(k) - d_u(k)\right) g'\left(y_{ui}(k)\right) z_{ho}(k)$$

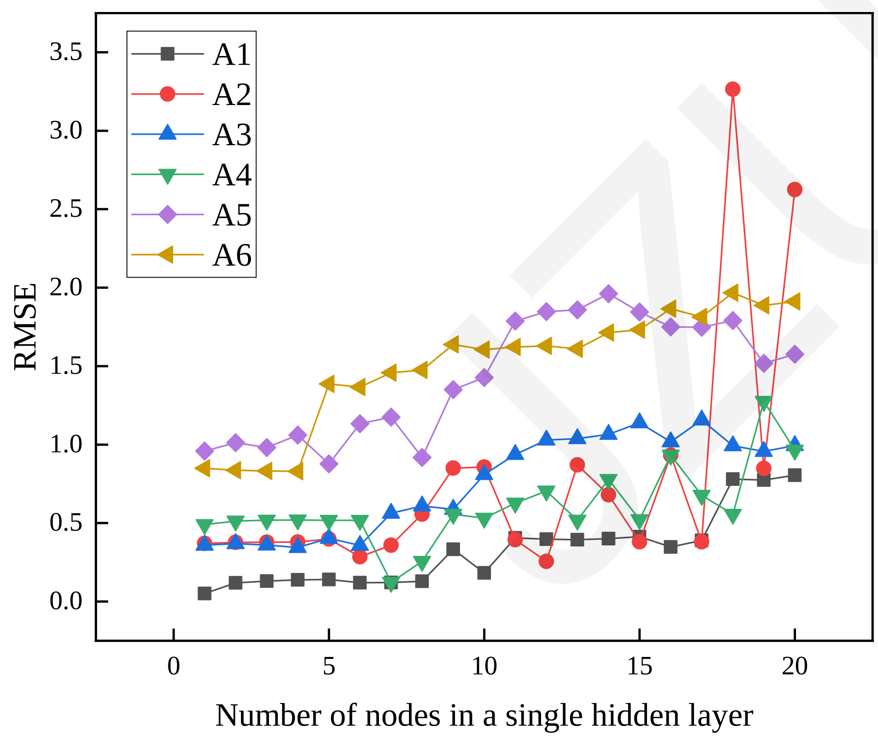
$$\frac{\partial e}{\partial \omega_{jh}} = \frac{\partial e}{\partial z_{hi}(k)} \frac{\partial z_{hi}(k)}{\partial \omega_{jh}}$$

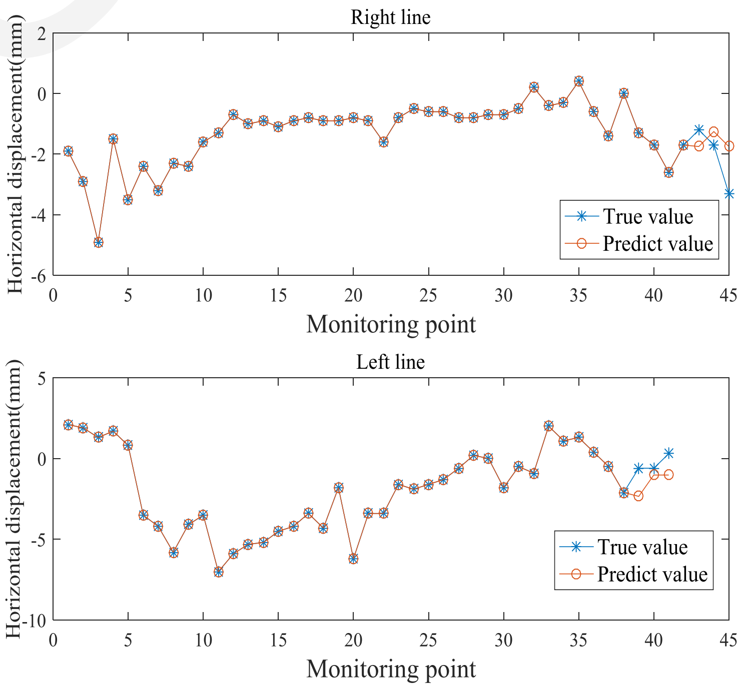
$$= \left(d_u(k) - y_{uo}(k)\right) \omega_{hu} g'\left(y_{ui}(k)\right) f'\left(z_{hi}(k)\right) x_i(k)$$



# Single input-single hidden layer-single output

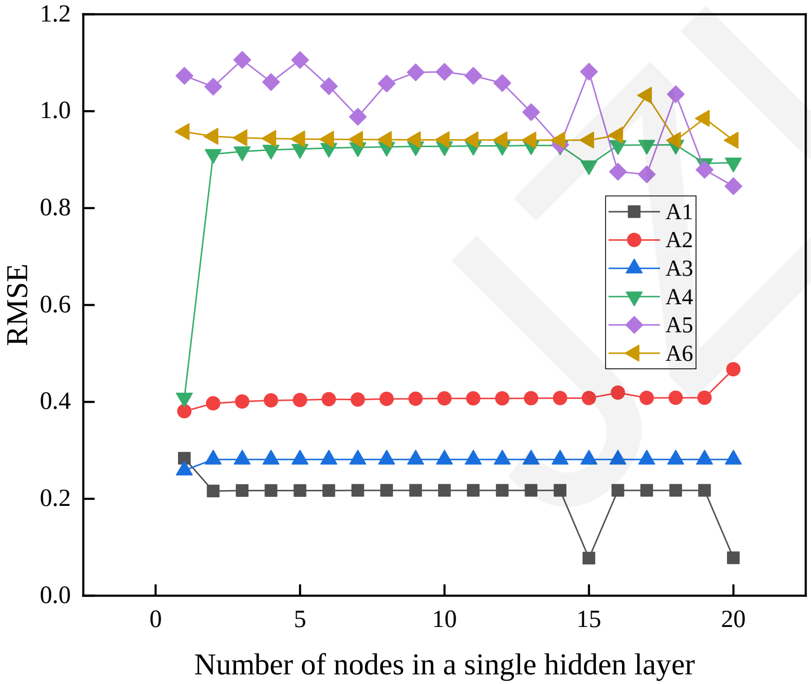
When the input number was 1, the influence of the number of nodes (1–20) in a single hidden layer on the prediction performance was analyzed. The Root Mean Square Error (RMSE) value increased gradually as the number of nodes in the hidden layer increased. This is mainly because the training effect will show an over-fitting phenomenon as the number of nodes is increased, which degrades the prediction performance.

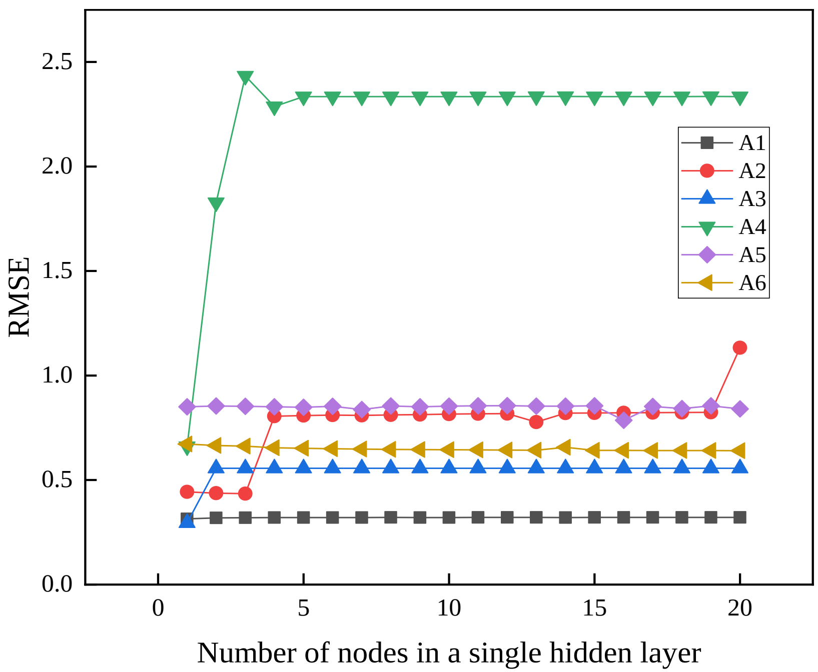


# Multiple inputs-single hidden layer-single output

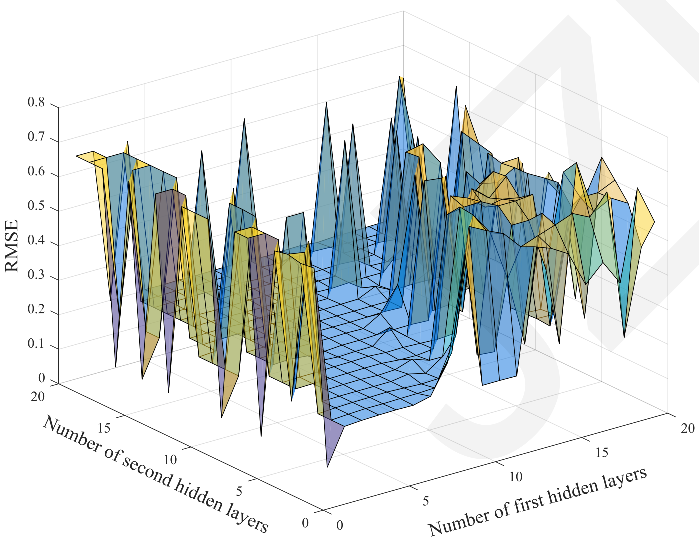
The influence of the number of nodes (1–20) in a single hidden layer on the prediction performance was analyzed when the input number was 2. For the A1 point, the RMSE value de-creased gradually as the number of nodes in the hidden layer increased. Considering computational efficiency and prediction performance, the optimal number of nodes is 2. In particular, when the input number was 2, and the number of nodes was 2, the RMSE value was 0.216. For A2, A3, and A6, the RMSE value changed slowly with increase in the number of nodes.

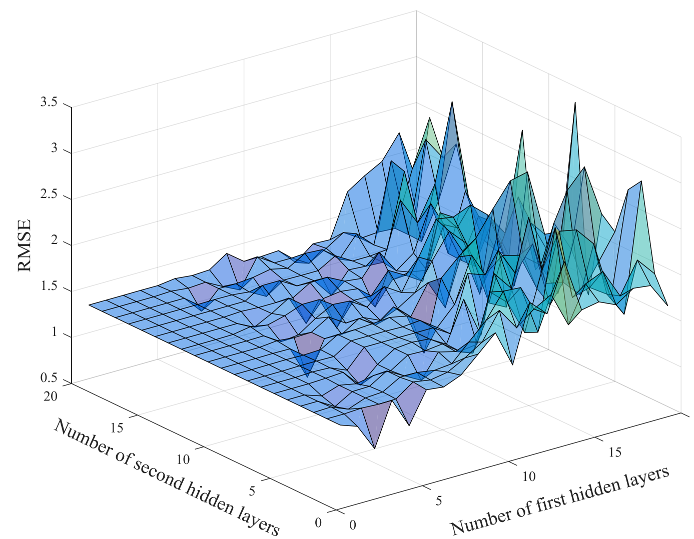


# Single input-double hidden layers-single output

- When the input number was 1, the number of hidden layers was 2. The influence of the number of nodes (1–20) in the double hidden layers on the prediction performance was examined. For the A1 point, the RMSE value increased gradually as the number of nodes increased. Specifically, the RMSE value is 0.091 when the input number and number of nodes in the double hidden layer were 1 and 1, respectively.
- The optimal number of nodes was 3 and 1, respectively. Specifically, the RMSE value was 0.939 when the input number was 1, and the number of nodes was 3 and 1 for the A6 point.



# Conclusions

- **For the single input–single hidden layer–single output BP neural network, the optimal number of hidden layers was 1. For the BP neural network with multiple inputs, a single hidden layer, and single output, the optimal number of inputs was 2, and the number of hidden layers was 1. For the single input–double hidden layers-single output BP neural network, the optimal number of hidden layers was 1 and 1. For the BP neural network with multiple inputs, double hidden layers, and single output, the optimal number of inputs was 5, and the number of hidden layers was 1 and 5, respectively.**
- **When determining the input number, the number of hidden layers should not exceed the input number to avoid over-fitting. In addition, when the input number is 1–3, the more hidden layers, the more the over-fitting phenomenon will appear in the training process. Therefore, the most hidden layers should be 1.**