A prediction model of ground vibration considering the local amplification of vibration

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Abstract. The ground environmental vibration caused by traffic load will attenuate monotonously with the increase of the distance from the load source. However, considering the complexity of stratum factors, the attenuation of ground vibration will have local amplification of ground vibration instead of monotonous attenuation. This article is based on RBF neural network. The method can predict the ground environmental vibration of the local amplification phenomenon of the ground vibration. This paper selects the theoretical solution of the complex theoretical model to perform the fitting approximation and the numerical approximation with the measured discrete data. The results show that the numerical approximation is better. Since the RBF neural network does not require other neural network models to perform supervised learning training, the numerical convergence speed is also relatively fast.

1. Introduction

More and more cities have begun to build rail transit, which makes the operation of rail transit more convenient. However, the operation of rail transit will inevitably bring about increasingly severe environmental vibration problems.

Scholars such as Ma Meng[1], Zong Gang[2], Zheng Xin[3], Shan Tao Tao[4] have studied the attenuation relationship of the vertical displacement of environmental vibration caused by urban rail transit from different angles and methods. The mechanism of amplification phenomenon, but no prediction model of ground vibration caused by subway has been proposed. For the ground vibration attenuation model caused by subway, many domestic and foreign experts have proposed their own models[5-6], but none of the vibration models take into account the ground vibration of the local amplification phenomenon of ground vibration. The ground vibration attenuation model generated by rail transit is not attenuation in the strict sense, but there is a partial amplification. Therefore, it is difficult to predict the attenuation model of ground vibration caused by factors such as the discrete variation characteristics of formation parameters.

The research on the mechanism of ground vibration attenuation is mostly concentrated in two categories: one is to use analytical theoretical methods to establish a model to discuss the local amplification phenomenon of ground environmental vibration and the amplitude attenuation of ground vibration. In this case, the ground vibration attenuation curve Most of them are continuous functions, so the attenuation of ground vibration can be predicted, but in this case, the general theoretical situation is simplified, which is different from the actual situation; therefore, the establishment of the ground vibration attenuation model is better after numerical models and field measurements. However, for numerical simulation, it is impossible to establish the boundary of the model to be infinite, so it can only establish a finite boundary; and the measured data are discrete, so how to build a discrete data and
consider the local ground vibration amplification effect of the ground vibration attenuation model more important.

In this paper, the neural network prediction method based on RBF is used to predict the surface environmental vibration. It can not only learn and predict the discrete data of field monitoring, but also perform infinite function approximation to the ground vibration attenuation model with more complex theoretical solutions to simplify the prediction model.

2. Predictive model based on RBF neural network

2.1. Basic RBF neural network
Take the simplest 3-layer RBF network structure as an example, as shown in the figure:

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\begin{align*}
&\text{Figure 1. RBF neural network structure} \\
\text{In Figure 1, } x = [x_1]^T \text{ is the input layer of the neural network, } h = [h_j]^T \text{ is the hidden input layer of the network, and } h_j \text{ is the output of the } j\text{th neuron of the hidden layer:} \\
&h_j = \exp \left( \frac{\|x - c_j\|}{2b_j^2} \right) \\
&c = \begin{bmatrix} c_{i1} & \cdots & c_{in} \\ \vdots & \ddots & \vdots \\ c_{ni} & \cdots & c_{mn} \end{bmatrix} \\
&b = \begin{bmatrix} b_1 & \cdots & b_m \end{bmatrix} \\
&\text{Where } c \text{ is the coordinate of the center point of the Gaussian function of the } j\text{th neuron in the hidden layer, } b = [b_1, \cdots, b_m]^T, \text{ and } b_j \text{ is the width of the Gaussian function of the } j\text{th neuron in the hidden layer.} \\
&\text{RBF network weight is } w = [w_1, \cdots, w_m]^T, \text{ and RBF network output is } y(t) = w^T h = w_1 h_1 + w_2 h_2 + \cdots + w_m h_m \\
\end{align*}
\]

2.2. Predictive model establishment

2.2.1. RBF neural network simplified prediction of analytical model.
For the ground vibration model predicted by the established analytical model, due to the complexity and uncertainty of the formation parameters and the established analytical model needs to consider the coupling effects of train loads, tracks, foundations and many other models, the predicted ground vibration analytical model is derived. Usually the form of the solution is very complex, and for actual engineering, we need a simpler model, so we can approximate the analytical prediction model you get through the RBF neural network based on the radial basis of the complex model based on the analytical solution, so that you can simplify the prediction model. Figure 2 is the ground vibration solution based on Jones' theoretical model in literature [7]. From the figure, it can be seen that the RBF-based neural
network prediction model has a good fitting effect. Figure 3 is the neural network composition of the prediction model in Figure 2. Figure 4 is a ground vibration model based on the literature [3] considering the different damping ratios of the overlying soil layer on the foundation. It can be seen from the figure that the attenuation model of the ground vibration is not monotonous attenuation due to the difference in the nature of the ground structure, and even two ground vibration amplifications occur. In the rebound area, because of the large difference in stratum structure, the radial basis neural network has a good fitting effect.

![Figure 2](image1.png)
**Figure 2.** The local magnification prediction model of ground ground vibration based on RBF.

![Figure 3](image2.png)
**Figure 3.** Radial Basis Network.

![Figure 4](image3.png)
**Figure 4.** The local magnification prediction model of ground vibration based on RBF.
2.2.2. Predictive model based on discrete measured data.
Using on-site measurements to predict ground vibration attenuation is also a commonly used prediction method. However, due to the limited collection points of the actual model collection, especially the collection channels of the collection instrument, the establishment of a prediction ground vibration model based on the actual measurement is also of great significance. The attenuation model of ground vibration does not decrease monotonously with the increase of the distance from the vibration source, but there is a vibration amplification area. Therefore, the ground vibration model based on the measured data of the local ground amplification area needs to be established, and the RBF neural network can be used. The method of network establishment. RBF neural network can approximate any data model of discrete data, and does not need to train the collected data, so it is much simpler than other neural network methods, and the accuracy can also be well guaranteed.

![Figure 5](image1.png)  
(a) Sample1, down train, Ref [4]                  (b) Sample1, up train, Ref [4]

Figure 5. The local magnification prediction model of ground ground vibration based on RBF.

![Figure 6](image2.png)

Figure 6. Radial Basis Network.

Figure 5 is a ground vibration model based on the measured discrete data of literature [4]. It can be seen from the figure that the RBF neural network has a good fitting effect and high accuracy. Fig. 6 is the structure of the radial basis neural network of the model in Fig. 5.

3. Conclusion
1. Due to the difference of stratum structure, the area of ground vibration attenuation and vibration amplification is also quite different. Using the neural network prediction model based on RBF, it is possible to predict the ground environment vibration of the local ground vibration phenomenon.

2. The fitting approximation for the theoretical solution of the complex theoretical model and the numerical approximation of the measured discrete data are better, so this kind of applicability is wider.

3. The RBF neural network does not require supervised learning training for other neural network models, so the numerical convergence speed is relatively fast.
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