Application of Artificial Neural Network in Course Design of Safety System-Taking a rail transit operation safety evaluation as an example

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Abstract. In the course design of safety engineering, artificial neural network was adopted to assess the operation safety of the urban rail transit system by using the generalized regression neural network. By comparing the evaluation values with the scores graded by the experts, the results indicated that predictions by using the generalized regression neural network had the better performance. Therefore, the GRNN was capable of evaluating and predicting the operation safety of the urban rail transit system.

1. Introduction

Safety system course design is an important part of the professional practice in safety engineering education. The purpose of this course is to integrate safety engineering theories with practice in addition to the theoretical study in the classroom.

The college of safety engineering at Ningbo University of Technology was built in 2015. And the resources for students’ practice are limited. For the previous students, they used the gas stations as an example to evaluate its safety. Moreover, the methods used in the assessment were the traditional methods that included the checklist method, pre-hazard analysis method, fault tree analysis and so on.

In order to include more research objects with the latest safety evaluation methods for students, the urban rail transit operation safety evaluation with artificial neural network was used in the course design.

2. Research object of curriculum design

Urban traffic is one of the main problems in modern cities. The effective way to improve the overall urban traffic is to develop urban rail transit. Urban rail transit has the characteristics of high speed and large passenger capacity. By the end of 2018, a total of 36 cities in China had had the urban rail transit with a mileage of 5494.9 kilometers [1].

Ningbo is the 21st city in China to operate urban rail transit lines. The first line of Ningbo Rail Transit opened on May 30, 2014. By the end of 2020, Ningbo urban rail transit had had 4 operating lines with a total mileage of 155 kilometers. Since the operation of Ningbo urban rail transit, there have been no major operational accidents. However, the safety plays an important role in the urban rail transit operation. Therefore, the safety evaluation of urban rail transit operation has a very important...
Thus, we selected Ningbo urban rail transit operations as the topic for the safety system course design.

3. Evaluation methods used in course design
In order to evaluate the safety of urban rail transit operation, some research works has been done with the traditional assessment methods [2-5]. Though those assessment consider lots of factors that affect the safety of urban rail transit operations. However, there are more factors that affect the safety of rail transit operations should be included. And there are complex non-linear relationships between factors, which makes it difficult to describe with a single model.

Because of the development of modern science and technology, artificial neural network (ANN) has been applied in the evaluation of rail transit safety operation. Artificial neural network has the characteristics of highly parallel processing, highly nonlinear mapping, and self-organizing structure. It does not need to know the exact relationship between input and output. It only needs to know the non-constant factors that cause output changes. Therefore, compared with traditional safety assessment methods, ANN has obvious advantages in processing random data and nonlinear data [6].

The most common artificial neural network for safety evaluation is back propagation neural network (BPNN). BPNN has been applied in the research of urban rail transit operation safety evaluation [7]. However, the utilization of BPNN to evaluate the safety of urban rail transit operations requires a large number of training samples. And because the training samples in BPNN are often limited and uneven, the parameters are not easy to determine, which affects the results of urban rail transit safety evaluation and reduces the prediction accuracy. The generalized regression neural network (GRNN) developed based on the radial basis function network has strong nonlinear mapping capabilities and learning speed, faster convergence speed, higher prediction accuracy. Thus, it is suitable for processing such as rail transit operation safety evaluation the nonlinear problem.

In this paper, safety system course design evaluates the safety of urban rail transit operations with BPNN and GRNN.

4. Curriculum design evaluation results

4.1. Selection of influencing factors
The urban rail transit operation’s safety is a complex non-linear prediction object, showing a high degree of complexity and non-linearity. These complexity and non-linearity cause great difficulties to select influencing factors. According to literatures, there are many factors that affect the safety of urban rail transit operations, ranging from a few to dozens. The course design focuses on the comparison and research of two artificial neural network prediction methods. Thus, several typical influencing factors are selected according to the literature. These factors include 22 influencing factors in four categories: human, machine, environment, and management [8]. The data was collected from Ningbo Rail Transit Group.

4.2. Course design evaluation results
In order to verify whether the selected artificial neural network can be used to evaluate the safety of rail transit operations, we adopt the following method: selecting all the data except one sample point to train the neural network. By crossing all the sample data, the prediction can be obtained. The safety evaluation value of rail transit operation predicted by this method can be seen in Table 1.

The errors between the prediction and measurement were showed in Table 2.

| Sample number | Expert rating | Backpropagation Neural Network | Generalized regression neural network |
|---------------|---------------|--------------------------------|---------------------------------------|
|               |               | The assessed value | Relative error | The assessed value | Relative error |

Table 1 Rail transit operation safety expert scores and BP and generalized regression neural network evaluation values

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|   | MAE  | MAPE | RMSE | RRMSE |
|---|------|------|------|-------|
| 1 | 28.32| 20.23| -28.56%| 25.34 | -10.49%|
| 2 | 23.77| -13.25| -155.78%| 27.52 | 15.78%|
| 3 | 20.49| 14.09| -31.22%| 26.75 | 30.59%|
| 4 | 41.86| 44.90| 7.28%| 48.92 | 16.87%|
| 5 | 76.38| 80.07| 4.84%| 82.13 | 7.53%|
| 6 | 90.02| 82.77| -8.05%| 89.91 | -0.12%|
| 7 | 85.98| 97.80| 13.75%| 87.26 | 1.49%|
| 8 | 35.15| 66.58| 89.44%| 44.02 | 25.25%|
| 9 | 73.09| 67.45| -7.71%| 77.41 | 5.92%|
| 10| 45.32| 46.73| 3.11%| 62.62 | 38.18%|
| 11| 79.57| 77.15| -3.04%| 86.42 | 8.62%|
| 12| 83.99| 79.00| -5.94%| 87.49 | 4.18%|
| 13| 85.55| 75.87| -11.31%| 88.12 | 3.01%|
| 14| 87.67| 82.93| -5.40%| 87.37 | -0.33%|
| 15| 36.41| 98.35| 170.12%| 41.30 | 13.44%|

Table 2 Evaluation of artificial neural network

| Evaluation index | MAE  | MAPE | RMSE | RRMSE |
|------------------|------|------|------|-------|
| BPNN             | 14.37| 0.32 | 18.69| 0.54  |
| GRNN             | 2.78 | 0.05 | 3.70 | 0.08  |

4.3. Result analysis

It can be seen from Table 1 and Table 2 that comparing the two artificial neural networks of BPNN and GRNN, the relative error between the evaluation value of rail transit operation safety of GRNN and the expert score is small, and the average relative error is 5.38%.

Table 2 shows the evaluation of the prediction effect of the two artificial neural networks. From the evaluation index results, it can be concluded that the MAE, MAPE, RMSE and RRMSE of GRNN reach 2.78, 0.05, 3.70 and 0.08, respectively. The evaluation index of GRNN is smaller than that of BPNN, which shows that the safety evaluation value of GRNN is closer to the expert score data.

5. Conclusion

In this safety engineering course design, the ANN was used to evaluate the safety of urban rail transit operation of Ningbo City. The methodology showed the ANNs have the capability for assessing safety of urban rail transit operation. Thus, the practice of safety system course design not only trained the students with the latest safety engineering theory, but also showed them the real utilization with the safety evaluation.

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