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The application of neural network system to the prediction of pollutant concentration in the road tunnel

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Abstract:. In this study, it was purposed to develop the new method for the prediction of pollutant concentration in road tunnels. The new method was the use of artificial neural network with the back-propagation algorithm which can model the non-linear system of tunnel environment. This network system was separated into two parts as the visibility and the CO concentration. For this study, data was collected from two highway road tunnels on Yeongdong Expressway. The tunnels have two lanes with one-way direction and adopt the longitudinal ventilation system. The actually measured data from the tunnels was used to develop the neural network system for the prediction of pollutant concentration. The output results from the newly developed neural network system were analysed and compared with the calculated values by PIARC method. Results showed that the prediction accuracy by the neural network system was approximately five times better than the one by PIARC method. In addition, the system predicted much more accurately at the situation where the drivers have to be stayed for a while in tunnels caused by the low velocity of vehicles.

1. Introduction

In Korea, a number of traffic road tunnels have been constructed through the many mountain areas and their lengths are also being extended significantly. For these reasons, tunnel ventilation system has been recently focused for the aspect of tunnel construction and its proper maintenance. And it has been considered that the longitudinal ventilation system with jet fans is a relatively practical and effective method for the road tunnel ventilation. For the design of tunnel ventilation system in Korea, the PIARC (Permanent International Association of Road Congresses) method has been widely used. However, it has to be emphasized that the many coefficients used in PIARC method are not adequate in some ranges for Korean tunnel situation. Previous studies said that data of the annual average daily traffic(AADT) is not applicable any more to tunnel ventilation design (Kim.N.Y, Kim.H.G, 2001, J.O.Yoo, C.H.Nam, H.J.Shin, 2000). In addition, there is another serious problem with the PIARC method. It is not recognized that the reduction of emission rate due to the incredible development of automobile technology has not been fully accounted yet.

In this study, a artificial neural network with back-propagation architecture was developed and executed for the prediction of pollutant concentration in road tunnels. Basically, neural network system is not affected by the problems in PIARC method because it is not the technique calculating with the many coefficients and factors like the emission rate. It is the technique in which actually measured data rather than calculated data is only used to train the neural network. And then new set of input data goes into the trained artificial brain (like a black box that people can't know what is going on inside) and the predicted results come out.

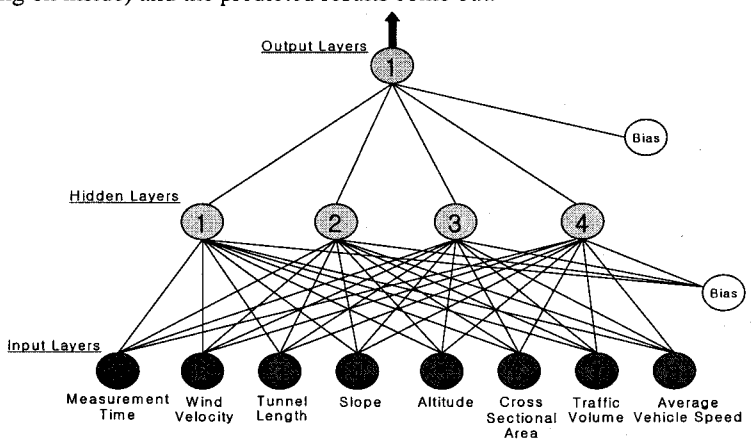
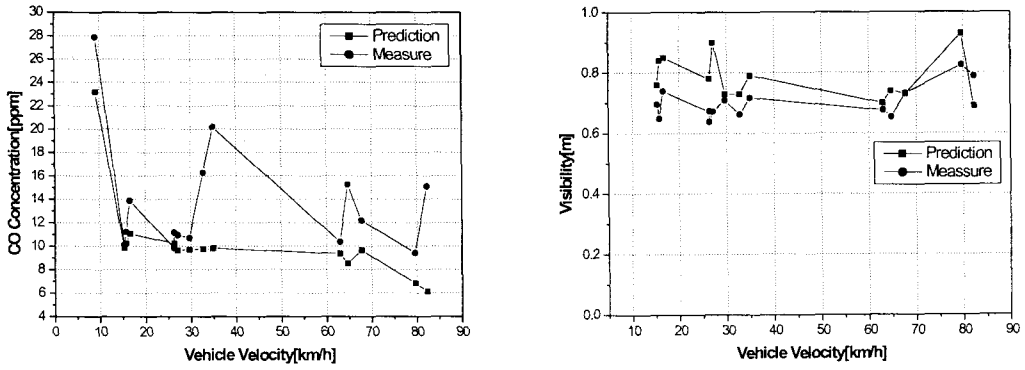


Fig. 1. Structure chart of the neural network.



a. Predicted CO Conc. by Neural Network **b. Predicted Visibility by NN**

Fig. 2. Prediction of CO Concentration and Visibility by Neural Network.

In this manner, the results are not influenced by the problems which can be possibly happened in PIARC method. Based on this study results, it is proposed that the prediction technique by artificial intelligence system is highly applicable to the design of ventilation system in road tunnels.

2. Artificial neural network for pollutant concentration

Neural network interpolates the previous data by repetitious training and it is a adequate method to control of the complex non-linear system (R.P. Lippman, 1988). The neural network used in this study is based upon the Back-Propagation algorithm and consisted of the input layers accepting eight physical and geological factors of tunnels and the hidden layers with four neurons. (Fig 1.)

Input factors

The selected input factors are independent each other for the design of ventilation system in road tunnels. They are classified into three categories - the natural factors, the tunnel geometry factors, and the traffics factors in tunnel.

① The natural factors : measurement time, wind velocity (include wind direction)

② The factors of tunnel geometry : tunnel length, slope, altitude, cross-sectional area

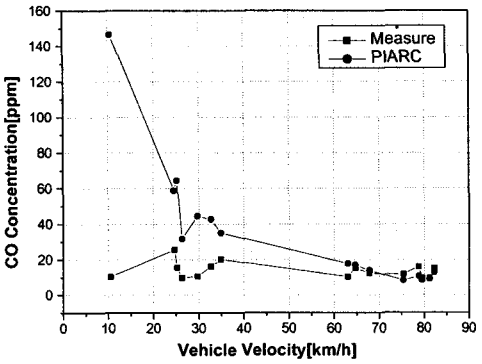
③ The factors of traffics in tunnel : traffic volume, average vehicle speed

Training of neural network

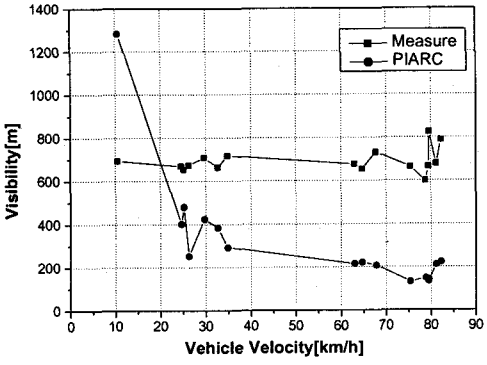
The artificial neural network was trained with more than 150 data sets of 8 factors and separated into two parts as the visibility and the CO concentration. After training procedure, it was found that the network with CO concentration and visibility was trained within 1×10^{-8} error which is almost negligible. Therefore, it was proved that the newly developed system was capable of predicting the pollutant concentration accurately in the road tunnels.

3. Results: compare neural network technique with PIARC method

The pollutant concentration for □□ tunnel was predicted by the successfully trained neural network system and also calculated again by the PIARC method to compare each other. The tunnel has two lanes with one-way direction and adopt the longitudinal ventilation system. Fig. 2 shows that all of the CO and visibility results predicted by the neural system have almost same pattern as the actual data. Particularly, it is interesting to note that the accuracy of prediction in the case of the low vehicle speed(below 30km/hr) is higher than the one for high vehicle speed. For the prediction of CO concentration, the error is in the range of 2 to 59 percent and for the visibility the error is in the range of 0.1 to 33 percent respectively.



a. Predicted CO Conc. by PIARC



b. Predicted Visibility by PIARC

Fig. 3. Prediction of CO Concentration and Visibility by PIARC.

With PIARC method, however, the errors for both of the CO concentration and visibility are much bigger than the errors produced by neural network system, especially at a low vehicle speed (Fig. 3-a). For the CO concentration calculated by PIARC method, the errors is in the range of 5 to 1,310 percent. Also, the visibility results pattern shows not very close with the measured data at most vehicle speed, and the error is in the range of 26 to 82 percent. It means that the required air quantity calculated by PIARC method has been overestimated as well. With all these regards, the ultimate reason of these wide-ranged errors with PIARC method might be carried with the incorrect emission rate, unsuitable coefficients, and the difficulty of estimation for the traffic volume.

4. Conclusions

In this study, we have developed the artificial neural network in order to predict the pollutant concentration in road tunnels which has two lanes with one-way direction and adopt the longitudinal ventilation system. The developed neural network was trained within 1×10^{-8} error and it was proved that the prediction system was capable of predicting the pollutant concentration accurately in the road tunnels. The pollutant concentration was predicted by the trained neural network and calculated by the PIARC method to compare with them. For the prediction of CO concentration, the error of neural network is in the range of 2.6 to 59 percent but the error of calculated PIARC method is in the range of 5 to 1,310 percent. The visibility error of neural network is 0.1 to 33 percent but the calculated PIARC method is 26 to 82 percent similarly. As the results, it showed that the prediction accuracy by the neural network system was approximately five times better than the one by PIARC method and especially, it was much more accurately at a low vehicle speed.

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