An Anti-collision Early Warning System for Mine Trucks Based on RBF Network and WIFI

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Abstract. Heavy-duty trucks in open-pit mines are of huge size and blind areas, so it is difficult for drivers to see other vehicles around the blind areas. In addition, due to the dullness of transportation in mines, drivers are prone to distraction and other phenomena, so collisions between vehicles occur from time to time. In existing technologies, such as radar and infrared ranging, it is difficult to detect vehicles on the other side of the bend at the bend, and it is vulnerable to dust and weather, resulting in false alarm. Aiming at the above problems, a collision prevention and warning scheme for heavy truck in open pit mine based on RBF network and WIFI is proposed. That is to say, a WIFI ranging module is installed in the middle of each mining truck. When the distance between the two trucks is less than the defined range, an early warning signal will be sent, indicating that there are other vehicles near the driver and paying attention to driving safety. The measurement error of WIFI ranging is easy to fluctuate in a long distance, but WIFI ranging has the advantages of long measurement distance, not easily affected by weather and dust, low cost and so on. For the system modeling, the author went to Deerni Copper Mine to collect data, such as the main test parameters: ranging, signal intensity and so on. The model between WIFI signal intensity and distance is constructed. The results show that the system has better measurement accuracy, and thus realizes the early warning function. It realizes the automatic collection and identification of wireless information when vehicles approach, which is of great significance for reducing and eliminating the collision accidents of open-pit transport vehicles and improving the level of safety management.

Keywords. RBF network; ranging; wifi, mining truck; warning system.

1. Introduction

With the continuous progress of open-pit mining technology and the continuous increase of mining intensity, large-scale equipment is also developing. In the mining process, transportation is an important link. In the construction environment with complex transportation lines, more bends and ramps, and various types of vehicles, the existence of huge body of mining trucks and blind area of vision caused great obstacles to the driver's vision, especially in the night environment, because of insufficient light, the obstacle of vision became more serious. It is easy to cause fatigue driving in the process of driving, which is very prone to collision between vehicles. If the mine truck can give warning information to the driver in emergency during night driving, it can reduce the danger of the mine truck and reduce the incidence of traffic accidents effectively, which is an important issue to be solved urgently.
In the existing truck early warning technology, Ren and Guo [1] proposed a vehicle anti-collision early warning system based on ultrasonic and GPS technology. Master Zhang [2] uses Haar-like and AdaBoost algorithms to process images to solve the problem of vehicle distance detection at night. Guo used RF radio frequency communication technology, GPS positioning technology and three-dimensional electronic compass technology to study the anti-collision system of trucks [3]. Sun used three-dimensional positioning technology to build a three-dimensional driving assistance and approach warning system for open-pit mine vehicles [4]. Zhao uses TOF technology to locate trucks in open-pit mines [5]. Wei put forward a scheme of millimeter wave radar to solve the problem that dust has a great impact on the detection accuracy [6].

WIFI technology ranging is to use the strength of WIFI signal from another mining truck detected by a mining truck to approximately judge the distance of the workshop. If the strength is a certain value, it will prompt the driver to pay attention to the vehicles nearby. WIFI ranging has the following advantages as shown in table 1:

1. Compared with the ultrasonic distance, WIFI technology can effectively overcome the problem of dust covering on the ultrasonic sensor because of the large dust in the mine.
2. WIFI ranging technology has the ability to detect bends, especially in large blind bends. It is not restricted by the terrain to detect the other side of the bend.
3. WIFI ranging technology has large detection area and long distance.
4. WIFI is not affected by the light, and can achieve good results in the night environment.
5. WIFI ranging is inexpensive.

| Various technologies       | Measuring distance | Severe weather       | Dust         | Lobe area | Curve detection | Capability cost |
|---------------------------|--------------------|----------------------|--------------|-----------|-----------------|-----------------|
| Machine vision            | Short              | Great influence      | Great influence | Large     | No              | High            |
| Infrared ranging          | Short              | Great influence      | Great influence | Small    | No              | Medium          |
| Ultrasound radar          | Short              | Great influence      | Great influence | Small    | No              | Medium          |
| Laser radar               | Short              | Great influence      | Great influence | Small    | No              | Medium          |
| Millimeter wave radar     | Long               | No influence         | No influence | Large     | No              | High            |
| Gps technology            | Long               | No influence         | No influence | Large     | Yes             | High            |
| Wifi technology           | Long               | No influence         | No influence | Large     | Yes             | Low             |

2. Principle and Characteristic Analysis of 1 Algorithms

2.1. Principle of RBF Network
Radial Basis Function (RBF) [7, 8] neural network is a kind of neural network proposed by Moody and Darken in the late 1980s. RBF network as shown in figure 1 is a kind of forward network based on function approximation theory. The learning of this network is equivalent to finding the best quasi-plane of training data in multi-dimensional space. It has been proved that RBF neural network can be of arbitrary accuracy. Approximate any continuous function. The transfer function of each hidden layer neuron of RBF neural network constitutes a basis function of the fitting plane, which gives the network its name. The most commonly used transfer function, namely the radial basis function (also known as the kernel function), is the Gauss Kernel Function:
\[ u_j = \exp \left[ -\frac{(X - C_j)^T (X - C_j)}{2\sigma_j^2} \right] \quad (j=1, 2, \ldots N) \]  

In equation (1), \( u_j \) — Output of Unit J of implicit layer; \( X \) — Input sample, \( X = (x_1, x_2, \ldots x_n)^T \); \( C_j, \sigma_j \) — Center and width of unit J of implicit layer.

\[ y_i = \sum_{j=1}^{N} \omega_{ij} u_j - \theta_j \]  

Equation (2): \( u_j \) — output of unit J of the hidden layer; \( \omega_{ij} \) — The connection weights between the first recessive neuron and the jth output neuron; \( \theta_j \) — The output threshold of the unit I of the hidden layer.

Set up a group of P input and output samples \( x_p, y_p \), define the objective function (sum of squares error):

\[ E_{(t)} = \sum_p \|y_p - \hat{y}_p(t)\|^2 = \sum_p \sum_k (y_{pk} - \hat{y}_{pk}(t))^2 = \sum_p e^2_p(t) \]  

Equation (3): \( y_p(t) \) — Standard output for group P sample input; \( \hat{y}_p(t) \) — When the sample of group P is input, the actual output of the network is adjusted by t-th weight.

\( \varepsilon \) — Predetermined target error \( \varepsilon > 0 \).

The learning algorithm of RBF neural network consists of two parts: hidden layer unit learning and output layer unit learning. In the first stage of learning, the clustering algorithm of unsupervised learning is generally used. Its essence is to analyze the local area of input and determine the parameters of hidden layer neurons—the center and width of radial basis function, \( C_j, \sigma_j \) in equation (1-1). When the input information is close to the center of a hidden layer unit, the output of the hidden layer unit is the largest. With the information away from the center, the output of the hidden layer unit
will also decrease monotonously. The second stage of learning is tutorial learning. After determining the parameters of the hidden layer unit, according to the characteristics of the output neuron as a linear summer, the weights of the output layer $w_{ij}$ can be obtained by using the linear optimization algorithm. When the $E(t) \leq \varepsilon$, algorithm is finished.

2.2. Practical Analysis of the Algorithms

RBF neural network is a kind of local approximation network. The problem has a unique and definite solution, and can definitely get the global minimum. In addition, because the RBF neural network uses the Gauss kernel function, besides speeding up the training speed of the network, it can also better handle the test cases besides the learning data, so the generalization ability is further strengthened.

In a word, RBF neural network is usually large in scale, fast in learning, strong in function approximation, generalization, pattern recognition and classification because of their different construction nature.

3. Modelling

Although there is a method for calculating the distance of wireless communication when WIFI propagates in free space, this formula is based on free space propagation. The so-called free space propagation refers to the propagation of radio waves in an infinite vacuum around the antenna. It is an ideal propagation condition. When radio waves propagate in free space, their energy will neither be absorbed by obstacles nor be reflected or scattered. So we use RBF neural network to build the model.

3.1. Data Acquisition

The data between distance and dBm ($dBm = 10\log (P_{out}/1mW)$) were collected from Delni Copper Mine. As the monitoring of mining trucks only needs to be carried out at a short distance between vehicles, the data between 1-50m were collected. The collected data are divided into test set and training set as follows in figure 2.

3.2. Results and Analysis

The input is WIFI signal strength and the output is distance. A RBF neural network with 7 hidden nodes is established. The training model is as follows in figure 3.

The accuracy of calculating each distance is as follows in table 2.

![Figure 2. Training set and test set samples.](image1)

![Figure 3. Results of the training model.](image2)

| Distance (m) | 1-10  | 11-20 | 21-30 | 31-40 | 41-50 |
|-------------|-------|-------|-------|-------|-------|
| Deviations (m) | 2.8643 | 1.7998 | 2.9555 | 7.7926 | 2.5125 |

Table 2. Deviations of different distance classes.
Experiments show that the measurement error of WIFI ranging is prone to fluctuate when the distance is long. The average error of the training model is 1.7193m, and the average accuracy is 93.26%. The training model is feasible.

4. Conclusion and Prospect
When the distance is long, the measurement accuracy of WIFI ranging is easy to fluctuate, but WIFI ranging has the advantages of long measurement distance, not easily affected by weather and dust, low cost and so on. It is a feasible scheme for anti-collision early warning between mining trucks.

In the follow-up work, we can continue to study the appropriate combination of WIFI technology and other technologies to overcome the problem that WIFI can not detect the specific orientation of vehicles.

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