Research on Health Management Platform Based on Data Analysis

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Abstract. In order to solve the problem of economic loss and human casualties caused by aging and damage of resistant material lining of torpedo tank during steelmaking, this paper proposes a health management platform of torpedo tank based on data analysis combining cloud platform and big data analysis. The platform has completed the acquisition, transmission, storage, analysis, mining and visualization of real-time temperature data of torpedo tank truck. The fault prediction of refractory lining of torpedo tank truck based on temperature data is realized, which provides data basis for torpedo tank overhaul. This platform can be used for reference for remote monitoring and health management of similar objects.

1. Introduction
In the steel industry, torpedo tank truck is mainly responsible for the transport and storage of molten iron, and has a pivotal position. However, the torpedo tanker fault prediction and maintenance is a rather difficult problem, which has long troubled the steel industry. In the high temperature environment, the damage and aging of the resistant liner of torpedo tank can bring great economic loss and casualties to the production.

To solve these problems, industry offers a prognostic and Health Management [1] (PHM). Through the analysis of monitoring data, this platform can obtain the health status of equipment in real time and predict whether there will be failures, so as to improve production efficiency and reduce maintenance costs. Common PHM techniques include linear/nonlinear regression, ARAM [2], neural networks and fuzzy logic systems [3]. With the development of artificial intelligence and the improvement of computing power and efficiency, the use of neural network for data mining is more and more widely used. For example, Zhang, Yang et al. [4] proposed a two-channel fusion model CNN-LSTM that fuses CNN and LSTM, and effectively predicted pitch parameters during flight. Wang, Guo, et al. [5] comprehensively used CNN and GRU to propose a new neural network structure, and effectively predicted the remaining life of aero-engine.

However, domestic data mining is not widely used in many fields, even less in the steel industry. It will be very convenient for industrial management if the torpedo tank truck real-time data can be deeply mined to obtain valuable information conducive to decision-making. Therefore, the health management platform of torpedo tank truck proposed in this paper uses convolutional neural network to mine the temperature data of torpedo tank truck, so as to predict the failure of refractory lining. It provides data basis for torpedo tank truck overhaul and reference for torpedo tank truck health management.
2. System Architecture

The overall architecture of the torpedo tank car health management platform is shown in figure 1. The platform takes cloud platform as the carrier, and its architecture is divided into three layers: data layer, support layer and Application Layer.

![Architectural Diagram](image)

**Figure 1.** Architecture diagram of torpedo tank car health management platform.

The data layer mainly includes data acquisition and data storage. The sensor equipment is installed in different positions of the torpedo tank, and the real-time data collected is passed into the database. The database is divided into a library and a slave library. The master library is mainly responsible for writing real-time data and synchronizing binary logs to the slave server. The slave library is mainly responsible for the user’s read operation, sharing the reading and writing pressure of the master server.

The data layer includes the following hardware modules:

- The DSP430 module collects temperature, time, date, latitude and longitude and other data, and sends the collected data to STM32 through serial communication.
- The STM32 module sends the data to the cloud server for local storage.
- BC28 module serves as the bridge between the underlying data acquisition system and the cloud server to realize NB-IOT communication.

The support layer is the core function layer of the system. The convolutional neural network is used to analyse the temperature data of torpedo tank truck, establish the temperature prediction model, and complete the temperature fault diagnosis and prediction. The analysis steps of temperature data in this paper are as follows:

- Data acquisition: obtain the original temperature data in the cloud database.
- Data pre-processing [6], missing value processing and related attribute merging for original data.
- After data pre-processing, neural network is used to identify and predict temperature fault points.

The application layer realizes the remote visualization of the platform. The application is used to monitor the equipment temperature, manage the platform users, register the equipment information, obtain the temperature data of different thermocouple sensors in different locations of torpedo tank truck, and view the previous equipment data recording status and operation status.

The application program mainly includes system management module, device management module, user management module and data management module.

The application is developed by using Web services back-end and front-end technologies and combining B/S architecture ideas. The back-end design adopts the SSM framework based on MVC pattern. SSM framework layered design structure is clear, can improve the development efficiency. The front-end uses HTML5, CSS and JavaScript language. Based on Bootstrap front-end framework, ECharts and other visual plug-ins are integrated to realize the visualization of platform functions. The visualization forms include table, graph, line graph, scatter graph and electronic map. Ajax technology is adopted to realize the data interaction at the front and back ends.
3. Platform Design

3.1. Cloud Platform Design

The system cloud platform adopts Tencent Student Cloud. The configuration and running process on the cloud server includes four main steps: renting the cloud server, registering the domain name, and running the Web server program on the cloud platform. Parameters are as follows:

- CPU cores: 1 core
- Memory: 2 GB
- Operating system: Ubuntu
- Bandwidth: 1 Mbps
- IPv4 public network IP: 129.211.5.236

The cloud server background socket communication module receives data from NB-IOT hardware module and stores it in the database. The domain name is mapped to flexible public network IP 129.211.5.236 to access the website of torpedo tank health management system, so as to realize data monitoring and equipment control. The specific deployment steps are follows:

1. Configure the Java runtime environment on the cloud host, including installing the JDK and configuring environment variables. Then install and start the Tomcat server.
2. Install MySQL server, release remote connection permissions, and start MySQL server.
3. Open access port on the cloud server configuration page, log in the server of the cloud platform service company selected, click the security group option to select New port and open all ports.
4. Configure the cloud server firewall, open the server manager, select the public configuration file in the advanced Security Windows firewall properties, and set the inbound link to be allowed. The server is configured to run the Web server program.

Remote access to the cloud host using Putty software. Figures 2 and 3 respectively show the start schematic diagram of MySQL service and Tomcat service on the cloud host. After the detection of the whole system, the cloud host can be accessed remotely through Putty software under different LAN environments.

![MySQL service start diagram](image2.png)

**Figure 2.** MySQL service start diagram.

![Tomcat service start diagram](image3.png)

**Figure 3.** Tomcat service start diagram.

3.2. Databases Design

The system collects real-time temperature data of torpedo tank vehicle through thermocouple, and sends the data to the cloud via NB-IOT.

The system data link is shown in figure 4. Thermocouple, GPS sensor and DSP430 are responsible for collecting molten iron temperature and GPS data and communicating the collected data to STM32 through serial port. After STM32 receives the data, it sends the data to the cloud server through BC28 module and makes a local SD card backup.
The system uses MySQL server to build torpedo tanker database. The real-time data produced by torpedo tank truck includes the location data of torpedo tank truck, temperature data and working status data. According to the different data functions, the torpedo tank database is divided into two modules: system management and data management. The user management module includes user information table, user log table, user permission table and system parameter table. The data management module includes torpedo tank truck table, sensor information table, temperature data table, GPS data table, voltage and current data table and alarm record table.

The table of DATA_ECORDE is one of the most important tables of system. The structure of DATA_RECORD is shown in figure 5. The DATA_RECORD table contains nine temperature data fields for the torpedo tank thermocouple, which are used to record temperature data.

4. Data Mining Algorithm
Convolutional neural network (CNN) is an efficient recognition method developed in recent years. It is a kind of feed-forward neural network with deep structure that includes convolution computation [7]. Its artificial neurons can respond to the surrounding units in a part of the coverage area, which has excellent performance in large-scale image processing and can also be applied in text classification. The convolutional neural network mainly consists of three layers: convolutional layer, pooling layer and full connection layer [8].

The platform deeply excavates the temperature data of torpedo tank truck to obtain valuable information which is beneficial to decision-making and provides great convenience for the health management of torpedo tank truck. After data processing and processing on the basis of the original temperature data, data mining algorithm is used to mine the data features, and finally the torpedo tank truck fault classification results and fault prediction results are output. In this paper, a convolutional neural network is used for data analysis.

The process of using CNN to diagnose and predict the torpedo tank data set is shown in figure 6. The torpedo tank data set is divided into training set and test set. The training set is used to train THE CNN network, find the optimal parameters and determine the CNN model. The test set is used to test the accuracy of CNN network.

Each convolution layer is composed of several convolution units, and the parameters of each convolution unit are optimized by the back-propagation algorithm. The purpose of convolution operation is to extract different features of input. The first convolutional layer may only be able to extract some low-level features such as edges, lines and angles, while more multi-level networks can iteratively extract more complex features from low-level features.
\[ h(i) = f \left( \sum_{x=1}^{m} \sum_{y=1}^{n} a_{x,y} \times w'_{x,y} + b' \right) \]  

(1)

Formula (1) for calculating the output matrix of the convolutional layer is shown. Where, \( h(i) \) is the value of point I in the output matrix. \( a_{x,y} \) represents the value of the input matrix at \( (x,y) \), \( w'_{x,y} \) represents the weight of the \( i \)th convolution kernel at \( (x,y) \), and \( b' \) represents the deviation of the \( i \)th convolution kernel.

Pooling layer is used for feature dimension reduction, compression of data and parameters, reduction of overfitting, and improvement of fault tolerance and training speed of the model. In this paper, Max Pooling is adopted.

Each neuron in the fully connected layer is connected to all neurons in the preceding layer for classification [9].

\[ a' = f(W'a^{-1} + b') \]  

(2)

The input of layer L is shown in equation (2). The output of the previous layer is \( a'^{-1} \), weight \( W' \), bias \( b' \), followed by an activation function.

The neural network training data is then combined with the cloud database of torpedo tank truck to derive the temperature value of the fire-resistant layer and cold end compensation measured by 9 thermocouples from March 28, 2019 to October 30, 2019 a total of 20041 data. The ratio of training connection to test set is 7:3. The convergence curve of CNN after training is shown in figure 7. The training stopped when the maximum cycle was reached, the final misclassification rate was about 1.896%.

Figure 6. Flow chart of CNN fault diagnosis and prediction of torpedo tank Truck.

Figure 7. CNN convergence curve.

5. Implementation

The platform realizes real-time monitoring of torpedo tank vehicle data, which can be divided into detailed monitoring of single vehicle and overall monitoring of main vehicle. It provides three different working modes for iron and steel enterprises to manage the torpedo tanker equipment in the transportation stage: light load mode, heavy load mode and overhaul mode. In light load mode, the torpedo tanker is in a state of waiting for molten iron to be loaded, when the refractory is in a state of cooling or temperature surge, etc. In heavy duty mode, the torpedo tank truck equipment is transporting molten steel running on the rails, and the temperature of the refractory material should be closely monitored. Repair mode, torpedo tank truck equipment for maintenance, no steel transport during the period.

Figure 8 is the torpedo tank health management function diagram.
6. Conclusion
This paper proposes a health management platform based on data mining. Tencent cloud server is adopted as the platform carrier to achieve remote access to the platform. In terms of data collection and storage, thermocouple and GPS sensor are adopted to collect molten iron temperature and GPS data, and NB-IoT module is used to package and send the data to the cloud MySQL for data storage. After that, CNN was used for data mining and fault basis, which reduced the maintenance cost of steel industry and promoted the integration of artificial intelligence and steel industry.

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