

Application of Expert System on the Analysis of Waveform Data in the Main Cab Signal Management Information System

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Abstract

The cab signal plays a very important position to guarantee the railway train operation safety and to improve the railway transport efficiency, so the accurate and stable cab signal is needed for the high speed railway. At present, among various factors impacting normal indication of cab signal, the exceptional indication of cab signal due to distortion of ground track circuit signal accounts for a large proportion[1][2], and this situation has a very great randomness, bringing about very great difficulty to failure location and equipment maintenance of the signal device of cab. According to the requirements of practical application of cab signal on railway site, this paper applies Artificial Intelligence techniques on the analysis of waveform data received by cab signal device. By making full use of the expert experience in data analyzing and the large quantity of waveform data collected in recent years, relying on the main cab signal management information, a network based expert system is established for analyzing waveform data received by cab signal device. The experiment results show that, this method can provide a unified, accurate and highly efficient analysis means for the users of cab signal device in the whole country.

Key words: EXPERT SYSTEM, MAIN CAB SIGNAL, WAVEFORM

1. Introduction

Following the increase of operation speed of railway train, the cab signal possesses a more and more important position to guarantee the railway train operation safety and to improve the railway transport efficiency, etc., furthermore, higher requirement is also proposed to accuracy and stability of indication of cab signal. The cab signal system is an important constituted part of the vehicle-borne train control system of the railway, its main function is to re-indicate the indication of ground in front of train operation via the signal, and provide to vehicle borne train control system various train operation information including speed limitation, etc. According to work theory of the system, the ground track circuit signal is to carry a large number of train operation control information

via certain signal modulation mode. The cab signal system adopts the ground track circuit signal as the receiving information of system, and the related cab signal receiving information parameter refers to information characteristic of track circuit signal, i.e., the various parameter indicators under the track circuit signal modulation mode. The cab signal acquires the related modulation information parameter after demodulation to the received information, and then translates the detailed value of the modulation information parameter to derive the related operation control information. At present, among various factors impacting normal indication of cab signal, the exceptional indication of cab signal due to distortion of ground track circuit signal accounts for a large proportion[1][2], and this situation has a very great randomness, bringing

about very great difficulty to failure location and equipment maintenance of the signal device of cab. Although the main cab signal device (with record function) can record the waveform data received, and provide it to the ground data processing system for analysis purpose, it is also required that the analysis personnel shall have fairly high theoretical level and rich practical experience. According to current utilization situation, it is very hard for railway site (especially the grass root application unit) to reach this requirement.

The expert system [3] is a program system with a large number of knowledge and experiences in the specific field, which applies a lot of technologies as artificial intelligence and computer, etc., to perform the reasoning and judgment according to the knowledge and experiences provided by one or several experts in the specific field, to simulate the thinking process of expert for problem resolution, and resolve the various problems in the related field. Generally speaking, the expert is a computer program system to simulate the human expert's problem resolution.

This paper integrates the detection experiences of multiple experts, such experiences are then stored in the computer via certain representation mode to form the knowledge base, and then the thinking process of experts for applying these knowledge to perform analysis and judgment are compiled into program to form the inference machine and constitute a cab signal waveform data analysis expert system, so that the computer can judge the waveform data signal, just like the human expert does, and then it is combined with main cab signal management information system to provide the unified, accurate and high efficient analysis means to the cab signal application unit of railway site of the whole country, to satisfy the actual demand of railway site.

2. Main cab information management information system

In the main cab signal system, it is embedded by cab signal recorder, and the ground waveform data and application status of cab signal can be recorded at the real time. According to requirement of informatization development of railway transport business of railway ministry, and the actual application demand of the railway site, the advanced computer network technology, database technology and signal processing technology

are used to build up the main cab signal management information system, to share the multiple information (including the cab signal practical application data) in the network, timely and accurately master the work status of equipment, and find and resolve the problem, and better guarantee the safety of train operation, and improve the office efficiency of each division. According to requirement of system composition mode, the application software system is built up, its foundation is work area and service depot, and its main part includes working area- service depot, railway bureau, and railway ministry, as shown in Figure 1.

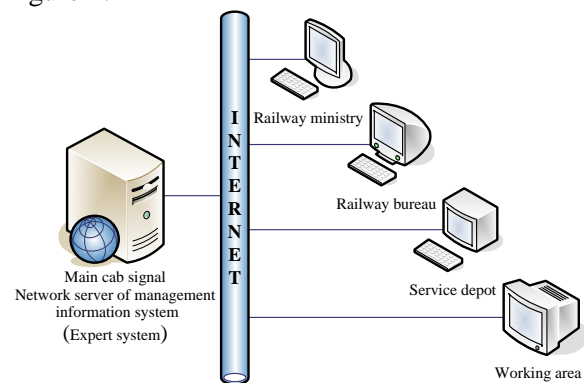


Figure 1. The network structure of main cab signal management information system

The structure of main cab signal management information system adopts the C/S mode, each level of user is respectively installed by related client software, and related server software is installed at server side. Each level of user can adopt the specific client software to realize the unload, indication and analysis to cab signal status data and waveform data. As to analysis to relatively difficult and complicated situation, the related waveform file can be uploaded to the server via the network, it is of direct interaction with the waveform analysis expert system on the server, to use the waveform analysis expert system to perform the analysis and processing to derive the analysis conclusion.

At present, China's railway automatic blocking system mainly includes the homemade frequency shift (i.e.: 4 information, 8 information and 18 information) automatic blocking system and UM71 signal based UT automatic blocking system (France made) etc. [4]. As to track circuit signal sent from ground of these two systems, their modulation modes both belong to frequency shift key signal

(FSK) of continual phase, as shown in Figure 2. Its information characteristic mainly includes: signal modulation low frequency, signal upper/lower side frequency and signal amplitude. Taking homemade 4 information frequency shift automatic blocking as an example, the related frequency shift signal information characteristic is shown in Table 1.

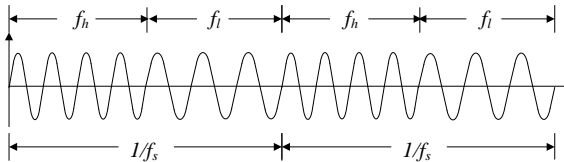


Figure 2. Sketch of frequency shift signal

Table 1. Information characteristic of homemade 4 information frequency shift signal

Operation direction	Carrier frequency	Low side frequency (f_l)	Upper side frequency (f_h)	Frequency offset
Up link	650 Hz	595 Hz	705 Hz	±55 Hz
	850 Hz	795 Hz	905 Hz	
Down link	550 Hz	495 Hz	605 Hz	
	750 Hz	695 Hz	805 Hz	
Modulation low frequency (f_s)	11 Hz	15 Hz	20 Hz	26 Hz

3. System structure of waveform data analysis expert system

The expert system based on main cab signal waveform analysis is composed of man machine interaction interface, knowledge base, reasoning module, interpretation module, integrated database, knowledge acquisition module, waveform data pre-processing module and database management module, etc., as shown in Figure 3.

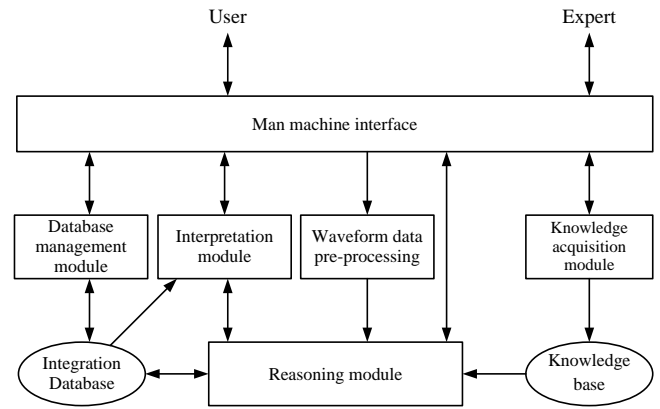


Figure 3. System structure of waveform data analysis expert system

3.1 Man machine interface

The man machine interface is used for communication among the expert system, user, expert or knowledge engineer, generally the interaction is usually performed via the menu, command, question/answer, etc.. The user is via this man machine interface to input the fundamental information and answer the related questions proposed by the expert system, furthermore the expert system outputs the reasoning result and related interpretation, etc.; while the expert system outputs the reasoning result and related interpretation, etc.; the expert is via the man machine interface to use the knowledge acquisition module to maintain the knowledge base.

3.2 Waveform data pre-processing module

The main role of the waveform data pre-processing module is to divide the waveform file (delivered to the server from the network) into some sections of data, each section of data is analyzed to acquire the information parameter which can be identified and utilized by the reasoning module.

The waveform data file format uploaded by the user includes information segment and data segment. The information segment records the cab signal application status information with relation to waveform data of data section, such as record time, lamp position, speed level, cab number, operation direction, principal work situation, signal system, cab operation location and speed, etc.. The data section is mainly to record the receiving waveform data of the cab signal. The pre-processing method to waveform data mainly includes: the waveform data is performed by STFT transformation to derive

the frequency spectrum change rule of the signal, the signal is performed by wavelet ridge line analysis, to derive the instantaneous frequency distribution and instantaneous amplitude distribution of the waveform data; the signal is performed by discrete dyadic wavelet transformation to perform the signal singularity detection and check the signal distortion situation; According to disturbance characteristics of railway signal, the waveform data is performed by specific disturbance analysis detection[4]. Furthermore, the processing function to waveform data pre-processing module can be expanded as per actual demand.

3.3 Reasoning module

The reasoning module is to repeatedly match the rule of the knowledge base subject to the conditions or known information of current problem, to derive the new conclusion and the resolution result of the question. The reasoning mode is composed of forward reasoning and backward reasoning. It can be seen that the knowledge base is to realize its value via the reasoning device, just like the thinking mode of problem resolution of the expert.

3.4 Interpretation module

The interpretation module can make description to the conclusion and resolving process subject to question of user, so that the reasoning process of the expert system is transparent to the user. In the whole analysis and consultation process, the questions as “why such parameter is inputted” and “how to derive this analysis conclusion, etc.” of the user are answered via the man machine interaction interface.

3.5 Integrated database

The integrated database is used to store the data of dynamic change such as original data, question description, each level of analysis result and the conclusion made by the expert system, etc.

3.6 Database management module

The database management module is via the man machine interactive mode to provide the query, statistics, sequencing, printing and privilege setup and password maintenance, etc., of the user to record information of the integrated database.

3.7 Knowledge base

The knowledge base is used to store the waveform data analysis knowledge provided by the expert. The rule in the

knowledge base is divided to two parts: the expert experience and book theory; a large number of original data from the processes of researching, manufacturing, utilizing and maintenance of cab signal device, these information have the original data, analysis process and final conclusion. Accordingly, the above information can be translated into waveform data analysis rule as per specific language and certain form.

Since the field knowledge of the waveform data analysis expert system has the cause and effect relation, the MYCIN expert system is based to adopt the production rule as the representation mode of knowledge base. The composition of the rule is shown in Figure 4, generally speaking, the rule form is:

RULE rule No. IF <precondition> THEN <action>

Wherein, the precondition may be the combination of logic relation of multiple conditions. The knowledge base shall be one-off loaded when the system is established, in the application process the knowledge acquisition module can be used for supplementation and correction, which has fairly high flexibility.

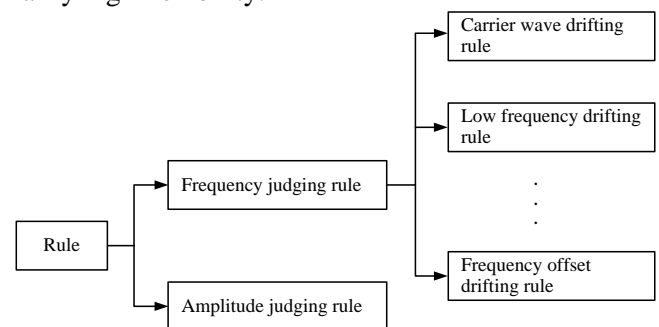


Figure 4. Composition of knowledge base rule

3.8 Knowledge acquisition module

The knowledge acquisition module is to derive the knowledge from the expert to supplement the content of the knowledge base. The knowledge engineer or expert can adopt the module to increase or modify the rule, to avoid the omission and imperfection, etc., of the rule.

4. Detection process of waveform data analysis expert system

According to above research and analysis, the diagnosis subsystem process designed in this thesis is shown in Figure 5. First, the uploaded waveform data is processed by waveform data pre-processing module

according to expert knowledge, to analyze the information derived, and find out the matched knowledge. Then the reasoning is performed subject to related knowledge, if it is the new result it shall be stored in the database, to

realize the dynamic update of the expert knowledge base. Finally the interpretation rule of the system is used to interpret the reasoning result. On the basis of interaction with the user, the final analysis result is derived.

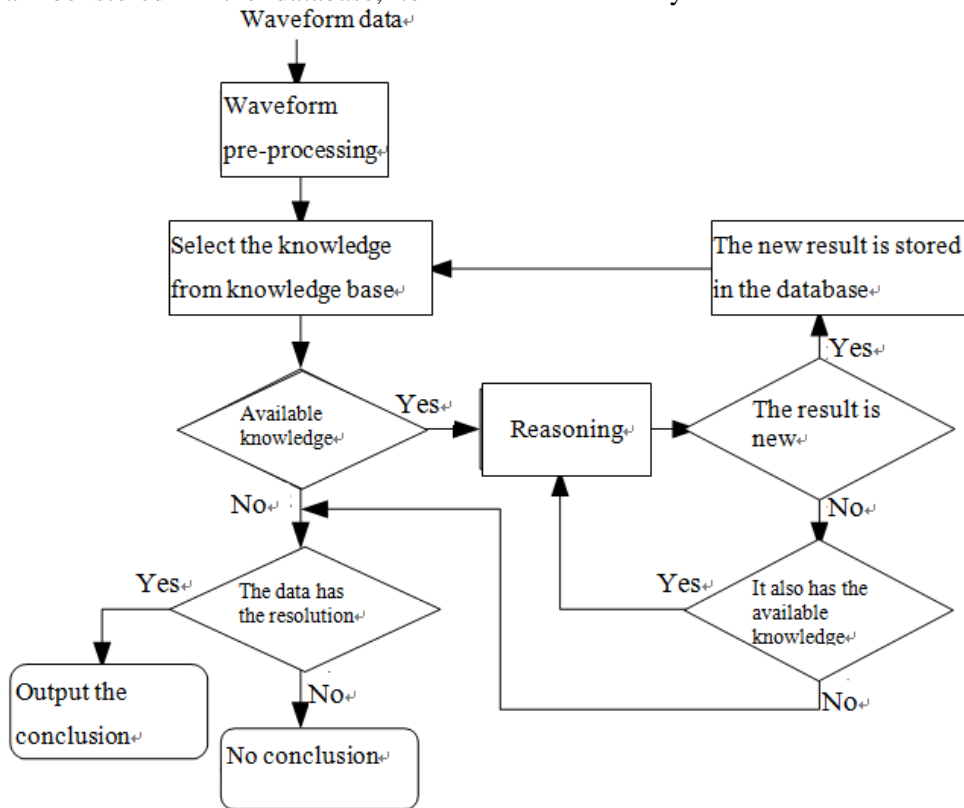


Figure 5. Detection process of waveform data analysis expert system

5. Actual detection

As shown in Figure 6, in the actual operation of cab signal device of service depot of certain railway has the signal waveform of exceptional phenomenon. After this signal is received by the cab signal device, the device does not normally decode it. When the signal waveform is observed at railway site, it may be caused by the interruption of signal at the relative time of 10.38seconds and 11.59 seconds, nevertheless, after it is uploaded to the main cab signal management information system via the network, and processed by waveform data analysis expert system, it is

found this waveform data meets the following rules:

IF (in the frequency shift signal spectrum, the frequency fluctuation of the carrier frequency is more than 1Hz) OR (in the UM71 signal spectrum, the frequency fluctuation of the carrier frequency is more than 2Hz)

THEN (signal carrier frequency is over-standard)

The rule shows that, the main cause why the cab signal cannot be normally decoded is that, the carrier frequency of the signal sent from the ground is not sTable (not the interruption of signal).

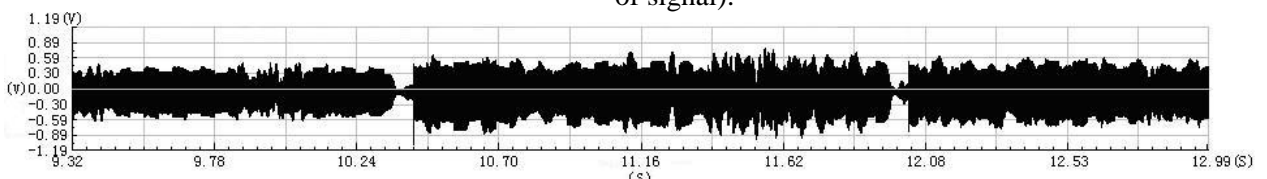


Figure 6. The instantaneous signal waveform for certain exception phenomenon in the actual application of cab signal

Figure 7 is the short time spectrum of actual waveform signal, Figure 8 is the short time

spectrum of normal signal. The waveform data uploaded by the user does not have the sTable

carrier frequency, incurring joggling phenomenon. This proves that the conclusion

provided by the waveform data analysis expert system is correct.

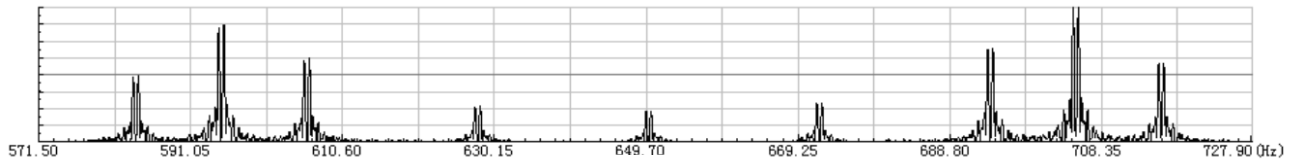


Figure 7. Short time spectrum for frequency shift signal waveform of the exception phenomenon

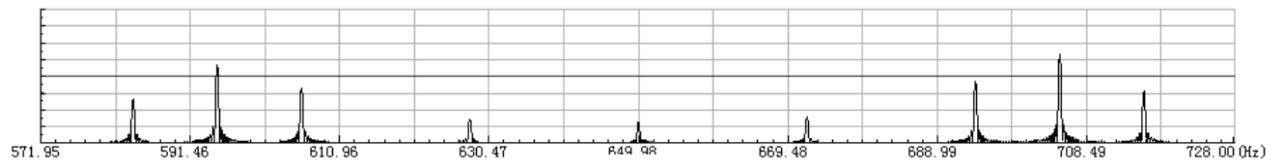


Figure 8. Short time spectrum of the frequency shift signal waveform in normal situation

6. Conclusions

In this thesis, man machine intelligent technology is used for waveform data analysis received by the cab signal according to actual application demand of the cab signal at railway site, the analysis experience of the expert and a large number of data information are comprehensively used to establish the network-based cab signal waveform data analysis expert system by relying on the main cab signal management information system platform. The test proves that, this method can provide the unified, accurate and high efficient analysis means to cab signal application unit of the railway site of the whole country.

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