Design and Realization of Mine Hydrological Alarm System Based on TTS and File Compression Technology

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***Abstract* — Underground coal mine is one of the main hazards of groundwater, the safety of coal mine production has a significant safety hazard. However, there are some deficiencies in the current automatic monitoring and warning system of Mine Hydrology. First, general automatic monitoring system can not be timely and effectively find the occurrence of sudden flood; second, testing cycle is long, there are amount of data, large occupied storage space.In this study, it was the foundation of hydrological alarm system research lied in prompt and effective returning of alarming information and less-space storage for such data. In order to meet its operating requirements, the design of its alarming unit adopted text-to-speech technology or TTS((text to speech), development package of Chinese language, TTS engine and Microsoft foundation classed to announce its alarming messages. Second, for less-occupied space of storage, the design employed file compression method based on LZMA algorithm, which compresses audio files containing alarm information into self-defined files and save them in its disks. In the process of application test, the result show that the design of alarming unit can timely service its abnormal sensors to make it functional, detect their abnormal parameters in advance, conduct inquiry into such data, read and record early alarming message and perfect the functions of hydro-alarm system.Hence, the study results demonstrate that it can play a positive role in ensuring coal mine safety and production.**

Keywords - Hydrological Monitoring;Voice Alarm; TTS; LZMA Algorithm;File Compression

I. INTRODUCTION

Mine hydrology alarm system is an automatic system to promptly return abnormal monitoring signals of water level, temperature, flow, etc.[1,2], which provide a convenient means of maintaining the mine's safety for related staff to timely detect hydrological dynamics, ensuring an early detection and treatment for flooding accidents. The application of TTS to voice alarm system greatly improves its automation level [3,4]. The status analysis of substations and sensors is able to filter fault messages and determine fault coverage[5,6]. Monitoring and correlation analysis can help operators accurately understand the anomalies, reduce the response time, and increase reliability. Nowadays, all the present literature concerning related problems have not achieved a complete realization method and design idea for the mine hydrology alarm system. Therefore, the purpose of this study is to establish a complete set of mine hydrological alarm system.

The remainder of this paper is organized as follows. Section 2 describes the general structure of the voice alarm system. Section 3 gave the realization of alarm system submodule. as well as, the analysis of the proposed algorithm implementation of audio file compression and decompression. Section 4 presented a test to evaluate the performance of the hydrological monitoring system for voice alarm in a coal mine.Conclusions are summarized in Section 5.

II. LITERATURE REVIEW

In order to make the mine hydrology alarm system more functional, a lot of researchers, such as Fu Ruifeng and others, have designed the multi-parameter hydrological dynamic monitoring system for its visualization[7] . Wang Kai, Jing Ning, Hao Ning etc. study on the underground intelligent voice broadcast, and realize the underground voice broadcast[8]. Zhao Bao Feng employs AHP fuzzy comprehensive evaluation method to research the threat level of mine water disaster, realizing voice broadcast in a degree in the system[9] . Li Hua, Li Cunrong, Wu Hao, etc. also develop a kind of voice broadcast to visualize information of the dynamic monitoring of the Mine Hydrology[10,11,12].

But this series of studies have failed to give a complete set of design ideas for the mine hydrological alarm system and implementation methods. Complying with the requirements of coal mine safety and stability, the paper puts forward a design of alarm system, with following features: (1) prompt and real-time alarm for operational status; (2)combination of audio and video allowing for a simple and accurate specified fault information ;(3)effective and efficient storage for early alarm information ;(4)intelligent inquiry about historical inf ormation. Combining the above function and its implementation process closely, the system applies speech synthesis technology to convert the text information into audible alarm voice to broadcast the messages anthropomorphically. After announcing the complete alarm message, the information will be extracted and compressed into files saved in a custom format in the system disk. In order to reduce reliance on storage space, this paper tries to compress alert audio files into self-defined files with compression algorithm, providing reliable and effective audio data files for monitoring staff's inquiry about historical alarm information.

III. THE OVERALL DESIGN FOR VOICE ALARM

Designing mentality for voice alarm unit-The mine hydrological alarm system utilizes TTS engine to convert its text message into voice and broadcast it. After that the data will be turned into an audio file in wav format. The lossless audio format and high capacity of such audio files ensure that compression technology based on LZMA algorithm will compress the wav audio files into self-defined files, namely kjtts files, which will be saved in the local disks, maximizing its existing capacity. In the case that monitoring personnel conduct inquiry about historical voice alarm information, what they need to do is to select and search kjtts compression files on the certain day, and then they use file decompression technology to restore kjtts files into audio files so as to obtain the historical voice alarm message.

The design flow of mine hydrological alarm system based on TTS and file compression technology is shown in Fig.1.The mine hydrological monitoring system alarm equipment is shown in Fig.2 and the core components of communication station is shown in fig. 3.

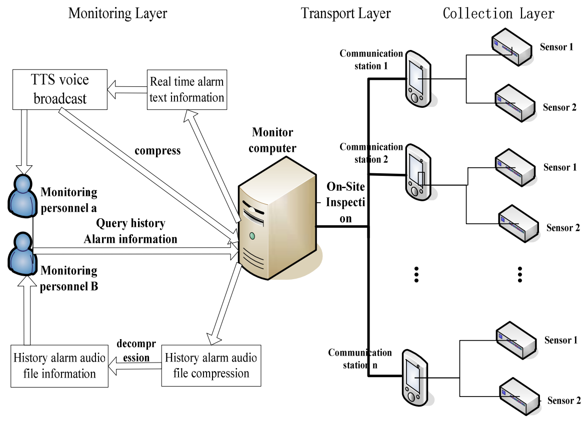

Figure 1. Design Flow of Alarm Module.

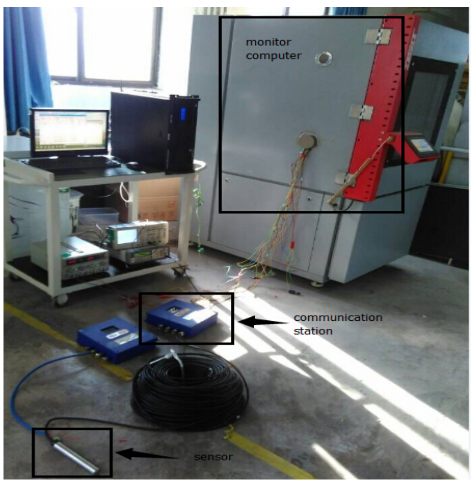

Figure 2. Mine hydrological monitoring system alarm equipment.

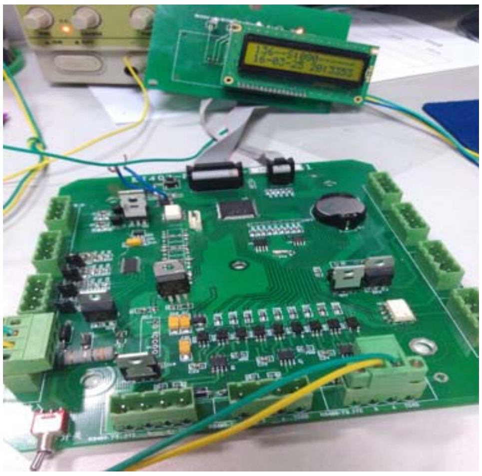

Figure 3. The core components of communication station.

Hardware configuration and development environment-The design flow of mine hydrology alarm module is shown in figure 1, whose hardware adopts computer-onboard audio card and multimedia voice box (or mine lot broadcasting system). Its software can be operated in Windows XP platform or above. As a voice engine of windows default installation, the Microsoft Simplified Chinese can only read Chinese poorly, so the paper will apply the database engine NeoSpeech, which can read English, Mandarin Chinese in simplified style, traditional Chinese and also support Chinese and English mixed reading. Its sound quality is excellent, close to sound effects of the standard announcer.

IV. DESIGN AND REALIZATION OF ALARM SYSTEM SUBMODULE

The goal of voice alarm unit is to collect alarm information, broadcast voice, convert and store audio messages, so it mainly consists of three parts: unit for the alarm information collection, unit for voice broadcast based on TTS, unit for compressing and decompressing audio files.

The alarm information collection unit aims at gathering information concerning connectivity state, work status and ultra-limited data information of all the substations and sensors. The connectivity state indicates whether the substations and sensors can communicate normally with the monitoring computer; work status represents whether the sensors can properly collect information under normal connections; ultra-limited data refers to abnormal water level, temperature and flow data acquired by sensors. Voice broadcast based on TTS is realized through the function of voice broadcasting of collected alarm information, which generates corresponding wav audio files. The large volume of WAV audio files leads to a waste of disk space, so the paper uses LZMA compression algorithm to compress audio files which reduces occupied disk space and raises its availability while guaranteeing the integration of saved information; Data extraction means restoring the compressed audio files through corresponding algorithm, which enables the monitoring personnel to examine and broadcast historical alarm messages.

Collecting submodule of alarm information-Alarm information collection unit consists of data check units, whose realization is shown in Fig.4.

Figure 4. Flow diagram of collecting alarm information

After the operation of mine hydrological monitoring system, the underground data collecting thread will be launched. The opening of system timer leads the monitoring computer to regularly send routing inspection commands to all the substations and sensors respectively through its serial ports. If the number of times of returning information without sensors'data is greater than maximum inspection times, it means that no data return from the sensors, then the sensors'information will be recorded. The purpose here of setting maximum inspection times is to avoid the appearance of disconnecting illusion due to postponed returning data for deferred transmission. If its communication is normal, the sensors send back state information and real-time data collected. The threshold value of monitoring data acquired by sensors can be used to determine whether the real-time data is within normal range. Supposed it is not within the normal range, it is necessary to save the sensors' data and abnormal real-time data in the files for alarming messages; Supposed they are within normal range, it needs to determine whether the returning status information is normal. Supposed the status information is abnormal, it is necessary to save the sensors' data and status information in the files; The signal "true" on _Run Alarm means voice broadcast will begin.

Submodule for TTS voice broadcast-The main realization process for voice broadcast achieved by TTS voice broadcast thread is shown in Fig.5.

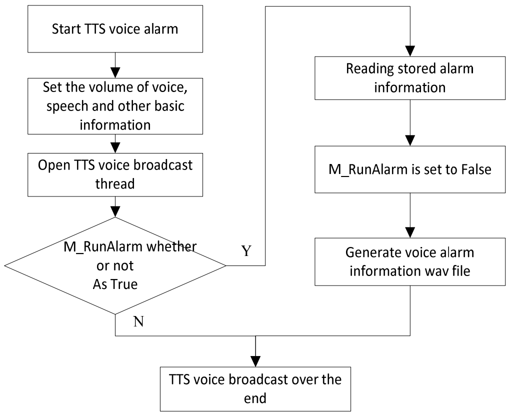

Figure 5. Flow diagram for TTS voice broadcast.

TTS voice broadcast thread will be started after the system starts. The basic parameters such as volume, speed and frequency can be entered manually. If such parameters aren't set beforehand, the volume will be at 50 by default, speed at 5 and frequency 2 times. M_Run Alarm is the symbol of reading alarm messages. Signal "True" on it indicates that the alarm messages will be broadcast in voice through audio card or multimedia loudspeaker box, which can be noticed by monitoring personal promptly. After that, it will be set to be "false" automatically and saved in files in the wav format.

The realization process of compressing and decompressing audio files- The fact that a large sum of wav audio files will be produced by the alarm system and they are usually saved in uncompressing format which leads to a much larger storage space to save[13]. So, the paper utilizes compressing mode based on LZMA algorithm to compress WAV audio files. LZMA, with the advantage of high compressibility, fast speed and small internal storage, is a lossless compression algorithm in open source code. LZMA compression algorithm can be effective to reduce storage space for wav files[14,15,16].

(1) The design of self-defined files

In order to maintain the high voice quality of original audio files, the paper adopts self-defined kjtts to replace defaulted .7z, and save compressed wav files. Kjtts files can both save the important attributes of the original files, and realize ideal compression ratio, shown in Fig. 6. The file header includes five kinds of property information using 4 bytes to save, such as sampling frequency, audio size, quantitative bit rate, channel number and file size of original WAV files. The data division of the files stores the main body of compressed wav files.

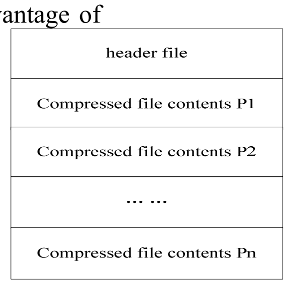

Figure 6. Self-defined kjtts diagram.

(2) Process for file compression

According to the structural features of WAV audio files, the paper uses the unit "frame" for compression sampling to avoid system paralysis due to too much data, and effectively reduce error rate in compression process. In this paper, 1152 sampling parameters make up a data frame. Multiple wav files can be generated in a certain period. Defining $w_i\left(i=1,2,3,\cdots,n\right)$ as all WAV files generated in a certain period, $hw_i\left(i=1,2,3,\cdots,n\right)$ corresponding file header's information, $Z_{ij}\left(i=1,2,3,\cdots,n;\ j=1,2,3,\cdots,m\right)$ audio content in a frame data in w_i :

A wav file consists of header information and data content, so its corresponding expression:

$$w_1 = hw_1 + \sum_{j=1}^{m} Z_{1j} \tag{1}$$

$w_i\left(i=1,2,3,\cdots,n\right)$ in a certain period can be shown as:

$$w_i = \sum_{i=1}^{n} hw_i + \sum_{i=1}^{n}\sum_{j=1}^{m} Z_{ij} \tag{2}$$

The aim of compression function, expressed as $\nabla(x)$, is to compress Z_{ij} and content of compressed audio will be shown as CZ_{ij} . Its expression is

$$CZ_{ij} = \nabla\left(Z_{ij}\right) \tag{3}$$

The compressing expression for a wav file is:

$$w_1 = hw_1 + \sum_{j=1}^{m}\nabla\left(Z_{1j}\right) \tag{4}$$

All wav files generated in a certain period will be compressed and make up a kjtts file. Defining K as the kjtts file, its expression:

$$K = \sum_{i=1}^{n}\left(hw_i + \sum_{j=1}^{m}\nabla\left(Z_{ij}\right)\right) \tag{5}$$

The detailed realization process to first compress and then save a wav file is shown in Fig. 7.

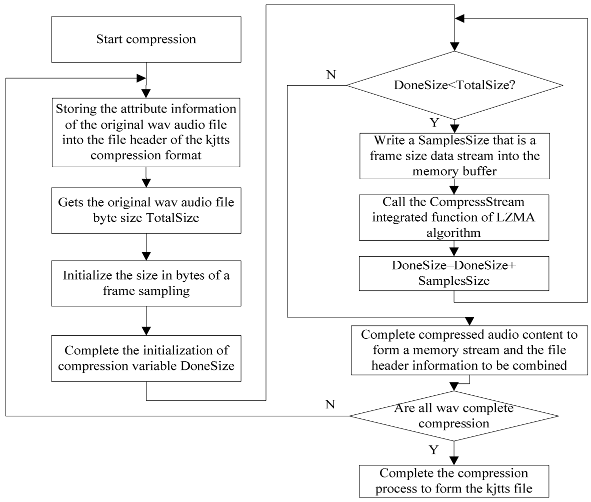

Figure 7. The flow diagram to compress an audio file.

Audio files directly generated after TTS voice broadcast will be wav audio files waiting to be compressed. Different audio files have different attribute values in a degree, so the audio property can be saved into the header part in self-defined format, occupying 20 bytes in total. Every Samplesize, also the amount of data contained in a frame, will be saved in the internal memory Readbuffer, which is a variable in the type of memory flow, a type of TMemoryStream. TMemoryStream provided by Delphi language is a storage medium, such as the operation class of abstract objects like magnetic disk file, dynamic stmemory, with data entered and outputted. Operation stream objects have strengthened the management of data objects, and can effectively reflect the size of the stream objects and determine starting position of Readbuffer for the smooth subsequent compression. CompressStream is a kind of function that integrates LZMA algorithm, whose interface is the original audio data of Readbuffer and Writebuffer after being compressed. Its function is to compress original data of Readbuffer via highly efficient LZMA algorithm. The compressed audio data will be saved into a memory stream Writebuffer, Finally, all compressed Writebuffer data and the file header information will be combined to save in the kjtss format. After that all cache space will be emptied.

(3) File decompression process

According to the users' needs, the saved kjtts files will be compressed into original audio files. However, the WAV files after being extracted still take up more storage space, resulting in reduced utilization. In order to resolve this problem, the file after being decompressed can be directly transformed into MP3 format. The realization of unziping the kjtts file is shown in Fig.8.

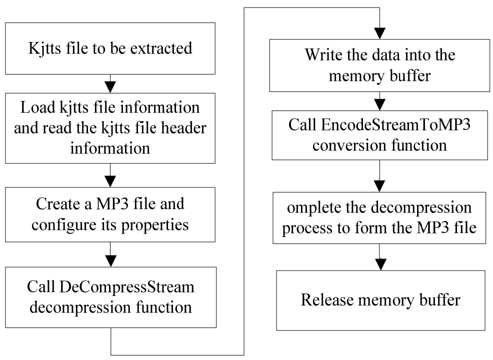

Figure 8. Flow diagram of decompressing audio files

Defining $mp_i\left(i=1,2,3,\cdots,n\right)$ as all extracted audio files in a certain period and the aim of DeCompressStream to decompress K, with $\Delta(x)$ decompression function, the expression after being extracted is:

$$\sum_{i=1}^{n}\left(hw_i+\sum_{j=1}^{m}\nabla\left(Z_{ij}\right)\right)=\Delta\left(K\right) \tag{6}$$

The decompressed expression of the audio file is:

$$mp_1=hw_1+\sum_{j=1}^{m}\nabla\left(Z_{1j}\right) \tag{7}$$

The kjtts files after being compressed are voice materials that customers need to inquire about. When they are loaded in the system, four parameters, such as the file header information, sampling frequency, sampling audio size, quantative bit ratio and port number, will be read first. The parameters will be assigned to corresponding attributes individually and respectively to create MP3 files. Then the compression function DeCompressStream will be launched, whose interface is Readbuffer's data volume of the compressed saved files and the outputted compression data volume Writebuffer whose role is to save the decompressed files. The Writebuffer is designed to restore the audio data in Readbuffer through the LZNA's corresponding algorithm, and then input the decompressed data in Writebuffer. The EncodeStreamToMP3 function is to convert the contents of the memory stream to MP3 audio files, whose interface was the memory stream before being converted and the full path of the MP3 files. The memory stream before being converted is Writebuffer in the extraction process, while the entire path of the output MP3 files represents the location of MP3 files needed to be output.

(4) Access process for compression and decompression

In the actual application, the real-time voice data are produced after TTS voice alarm broadcast system generates wav audio files, then they will be compressed into very small kjtts files with less storage space to save in the computer disks. When some audio files at a certain time are needed to be searched, users need to decompress the corresponding kjtts files to generate related MP3 files. The voice alarm messages can be obtained through playing corresponding MP3 files. The access process for compression and decompression is shown in Fig.9.

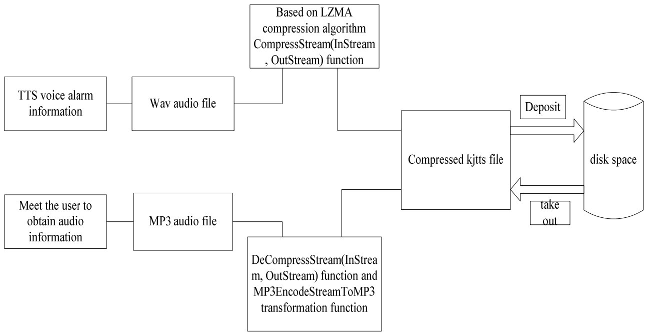

Figure 9. Compression and decompression access disk full procedure.

V. CALCULATION AND DISCUSSION

The hydrological monitoring system has been applied in a coal mine for voice alarm test, with data collected in first half of 2013. In the operation stage of the monitoring system, it can accurately capture sensors featuring disconnection, abnormal operation and ultralimited real-time data. All the information will be formed into alarm data files, broadcasted through TTS voice. After being tested, the monitoring staff of the mine can promptly notice and hear the alarm messages and repair the corresponding sensors. So, the system has distinct advantage compared with the monitoring system without voice alarm messages. The present system can adjust its volume, speed, frequency in line with requirements. Such test indicates voice alarm system with TTS is more prompt than traditional system with only voiceless text, and also reduce the amount of time for servicing the sensors.

The author tests and analyzes the compression of audio papers in line with different data sources from the mine's voice alarm messages. The audio files, lasting for 1 minute, 15 minutes, 30 minutes, 60 minutes and 120 minutes respectively, have been compressed for the purpose of test in the process:

The formula of compression ratio y

$$y = \left(1 - \frac{m}{n}\right) \times 100\% \tag{8}$$

where m represents the file size before and after being compressed.

The test statistics show the size of audio files after being compressed by LZMA algorithm has been effectively decreased with storage space distinctively reduced. The compression ratio is shown in table 1.

TABLE I COMPRESSION RATIO FOR AUDIO FILES

The data source	file size /M		compression ratio /%
	Data source	LZMA compression	LZMA compression
1min	2.79	0.35	87.3%
15min	42.75	4.90	88.5%
30min	85.50	10.5	87.7%
60min	175.39	20.45	88.3%
120min	366.57	41.20	88.7%

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In compression test, comparison between the audio files compressed with LZMA algorithm and files with MP3 compression technique shows the former's compression rate is larger than latter. Their effects in comparison are shown in table 2.

TABLE II THE EFFECT OF COMPRESSION RATE COMPARISON

Data source	compression ratio /%	
	LZMA compression	MP3 compression
1min	87.3%	83.6%
10min	88.5%	82.9%
30min	87.7%	83.9%
60min	88.3%	83.4%
120min	88.7%	84.0%

Test results show that in the process of compression tests of audio data larger than 10M, the compression mode based on LZMA algorithm is better than traditional audio compression technology. The average compression rate is about 88%. The larger audio data sources are, the more obvious the compression effect is. It is more applicable to the alarm system with larger amount of data.

VI. CONCLUSION

This article first analyzes the design idea of mine hydrological voice alarm system based on TTS and file compression technology, then complete the system of physical design, and analyze the actual measurement data. Due to the mining safety and stability requirements, real-time operation state of rapid alarm, precise broadcast fault information, and the alarm history information for effective storage is modern mine hydrology monitoring alarm system construction of the direction of the, is also monitored, ensuring mine hydrological safety tools.Due to the mining safety and stability requirements, real-time operation state of rapid alarm, precise broadcast fault information, and the alarm history information for effective storage is modern mine hydrology monitoring alarm system construction of the direction of the, is also monitored, ensuring mine hydrological safety tools.The main conclusions are drawn as follows.

(1) Use TTS technology, timely organization of alarm information voice broadcast, realize the real-time operating state of rapid alarm, and reduces maintenance time of the substation, the sensor.

(2) The LZMA compression algorithm based on the alarm information audio file compression processing, and through the custom audio compression format to the alarm information security and effective storage, increase the utilization of storage space.

(3) Through the LZMA decompression algorithm to compress the custom file for the reduction of the audio file, to meet the monitoring personnel to see and listen to the history of the information.

In this study, the technology of TTS voice and audio file compression technology to complete the mine hydrological alarm system can real-time, fast and accurate fault information broadcast based on effective storage and alarm information for subsequent queries for water disaster early detection and prevention to provide a favorable tool.

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