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Research on the Remote Monitoring System for Chemical Raw Materials in Storage Tank Based on ARM Embedded System

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To effectively use the raw materials in tank in workshops of chemical engineering, embedded remote monitoring system is designed in this paper aiming at liquid ammonia. With the core ARM-Linux, the design uses modern sensor technology to monitor the pressure, liquid level, concentration of ammonia gas and temperature in tank. In traditional monitoring, non-linear structure can be damaged and monitoring efficiency is low in the process of processing data and modelling. A process monitoring method based on negative selection algorithm is put forward. The method firstly uses maximum variance unfolding method to get low dimensional manifold from original data. LTAS is then used to model low dimensional manifold and get “super global group” model. Process can be monitored in this way. Simulation result indicates the method is better than other method for monitoring process. In conclusion, the monitoring method based on ARM is effective for chemical raw materials in tank.

1. Introduction

Tank field is an important part and most dangerous place of enterprise. Most chemical raw materials are flammable, explosive and toxic under high pressure (Song and Si, 2017). It is necessary to monitor the liquid level, pressure and temperature in tanks of chemical raw materials and the environment of tank field. Some enterprises constantly expand production scale and adjust industrial structure but original tank filed cannot meet current production demand (Bergmann and Hou, 2014). Therefore, the scale of tank field must be expanded. Comparing with traditional wired monitoring (Maqbool and Chandra, 2013), wireless monitoring is flexible and cheap. It can be maintained and constructed simply (Mathurkar et al., 2014, Prathibha et al., 2017). Currently, the technology of embedded system is developing and has been widely used in many fields (Sankaranarayanan and Wan, 2013): industrial control, instruments and apparatus, equipment of communication, consumer electronics, electrical household appliances manufacturing etc (Naruephiphat et al., 2015). Embedded microprocessor, embedded development tools and embedded operating system are becoming more and more mature (Jia and Meiling, 2013).
The monitoring system for chemical materials tank field is an important part of chemical enterprise. With the development and expansion of enterprise, more requirements are raised on monitoring and managing scattered chemical materials tank fields (Nisha and Megala, 2014). It is significant to develop a set of real-time and reliable tank field monitoring system which can be easily expanded for highly-effective management and security guarantee to chemical materials tank fields (Allegretti, 2014). Based on ARM-Linux embedded operating system, this paper uses GPRS technology to achieve high-efficiency, accurate and real-time embedded remote monitoring system with the functions of remote monitoring, voice and message alarm and safe interlocking

2. Embedded Technology and Overall Structure Design

2.1 Introduction of ARM processor

ARM (Advanced RISC Machines) is 32-bit microprocessor system developed by Acorn Computer in

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Cambridge of Britain. ARM processor uses 32-bit Reduced Instruction Set Computer (RISC) with the advantages of low cost, high performance and strong stability. It has been widely used in embedded system with high market occupation rate.
ARM processor uses Reduced Instruction Set Computer (RISC), using three-address format and fixed-length instructions. At the same time, ARM microprocessor supports two instruction sets: ARM and Thumb. This is convenient for users to develop programs. Users can switch the two modes to meet their need. In status Thumb, processor executes 16-bit Thumb instructions with half-byte aligning; in status ARM, processor executes 32-bit word-aligned ARM instructions. ARM processor supports 7 operation modes shown in table 1. The system switches the operation modes according to peripherals and environment of system.

Table 1: Working mode of ARM processor

Processor operating mode	Instruction
User mode	The processor is in normal working order
Fast interrupt	It is used for high-speed data transmission and channel processing
Interrupt request	It is used for general interrupt handling
Supervisor mode	A protection mode used by a super system
Data access termination	It is used for virtual storage and storage protection

2.2 Introduction of embedded Linux operating system

Linux is an operating system like Unix. Its source code is free and open. All researchers around the world can improve it. The development and growth of Linux is closely related to the generation of Unix operating system, the popularity of GNU plan, the development of internet and the establishment of Posix standards. These software and standards offer good environment for developing Linux operating system. They are important bases of generating Linux. Embedded Linux system configures and clips itself to meet the demand of performance. The main characteristics of Linux operating system: completely open source code; following GPL (users can change source code in the rules without paying extra expense); low cost (development of the source code is supported by people around the world); abundant support of open source software and open projects.
Generally, Linux system can be divided to be three layers: hardware layer, core layer and application layer. Users can directly use application layer. Core layer calls application program. The structure of Linux system and the relation among different parts are shown in figure 1.

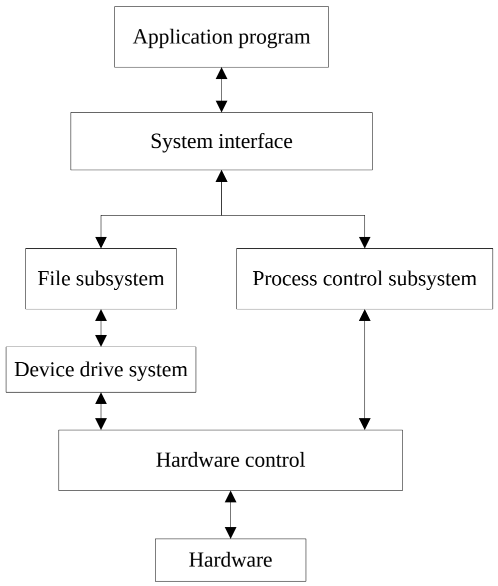

Figure 1: Structure of embedded Linux system

2.3 Design of functions

The design of monitoring and alarm system for chemical material tank field is mainly researched in this paper. A wireless remote monitoring platform is established for scattered chemical material tank fields with hostile environment. This paper mainly designs the monitoring system for the field of liquid ammonia tanks and offers solution for remote monitoring and alarm for chemical material tank field. To expand production scale, a chemical enterprise establishes a new field of liquid ammonia tanks on a small hill beside solvent preparation workshop. 8 30m3 liquid ammonia tanks are stored in the field. After the liquid ammonia purchased is transported by tank truck to field of liquid ammonia tanks, workers will use soft pipes to transfer liquid ammonia into tanks. Liquid ammonia is very dangerous chemical. The transport, loading, unloading and storage of liquid ammonia shall be strictly managed without any leakage. Therefore, we shall strengthen the monitoring and management of the field of liquid ammonia tanks and guarantee its safety. The field of liquid ammonia tanks is a major source of danger. We must design an effective monitoring system to collect the liquid level and pressure in liquid ammonia tanks, the concentration of ammonia gas and the temperature in the field of liquid ammonia tanks. Main functions of the system: Sensor is used in the field of liquid ammonia tanks to collect the liquid level and pressure in liquid ammonia tanks, the concentration of ammonia gas and the temperature in the field of liquid ammonia tanks; USB camera is used to take photos in the field of liquid ammonia tanks; GPRS network is used to transmit data and photos to remote data monitoring center; remote data monitoring center is responsible for receiving and storing data and displaying it on the interface based on Qt; when the liquid level and pressure in liquid ammonia tanks, the concentration of ammonia gas or the temperature in the field of liquid ammonia tanks exceeds upper limit, a voice alarm will be given to monitor and a message will be sent to safety manager. When danger happens, automatic safe interlocking mechanism will be started to decrease risks.

2.4 Configuration of the field of chemical material tanks

There are the following I/Q points in accordance with current status of tank fields. Table 2 is calculation of I/O points of 2#/9# tank field.

Table 2: 2#/9# tank I/O points calculator

Name	Input type			Output type		
Type	DI	AI(4-20mA)	Counting	DO	DO	Counting
Actual points	48	65	113	1	0	1
20% allowance	57.6	78	135.6	1.2	0	1.2
Card count	16	8	-	16	8	-
Card number	3.6	9.75	-	1	0	1

3 sets of 414 redundant-type CPU and corresponding memory cards are configured.
Redundancy processor is the combined AS414-4-2H with CP443-1; embedded RAM is 4M. Processing function: the time of CPU processing each binary instruction is 0.06 microsecond. Load memory is for users' program and parameters of 57-400H PLC; High speed memory is for users' program. Memory card is for expanding embedded loading memory. The information stored in loading memory includes 57-400H parameters and program. Therefore, 2 times of memory space is needed. The embedded loading memory cannot store large quantity of programs. Therefore, memory card is needed, including RAM and FEPROM card. Flexible expansion: 128K digital and 8K analog input/output at most. Several-connector MPI: a simple network with 32 stations can be established with data transmission speed 12M bit/s. Switch is designed to be key. The right of accessing users' data can be limited by option switch in rotation mode. The computing power of AS414CPU is shown in the following table 3:

Table 3: AS414CPU computing power

Processing capacity	Processing time
Bit operation	0.06 µs
Word instruction	0.06 µs
Integer arithmetic instruction	0.06 µs
Floating-point arithmetic instruction	0.18 µs

3. Simulation Experiment

3.1 Simulation of monitoring on chemical raw material tanks

This chapter uses LTSA algorithm and Greedy-S VDD modeling to complete process monitoring. In basic thought, firstly operate modeling data pre-processing and use LTSA algorithm to operate non-linear dimensionality reduction; then use SVDD to model the feature samples extracted in Greedy method. After processing to-be-tested data in the same way, the running status of system is judged using corresponding statistics. In simulation, 33 variables which most influence raw materials in tanks are chosen to be monitored. 300 groups of normal samples are collected (sampling time: 5min) from historical database for building model. Besides, some fault data is collected from the site. Fault happens at the 151st sampling moment. The corresponding fault curve is shown in the following figure 2.

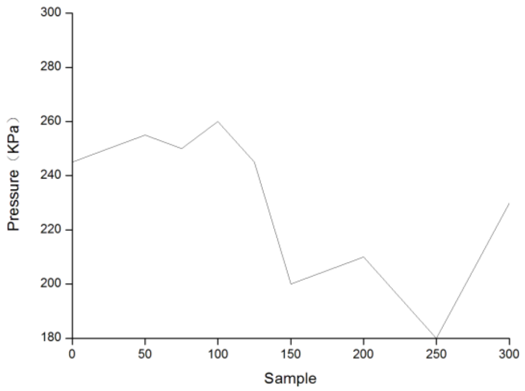

Figure 2: Fault curve

During safe and stable production, raw materials in workshop can be monitored in real time. Monitoring screen displays the transport and storage of chemical materials in different time. Based on fault analysis, the following figure can be got.

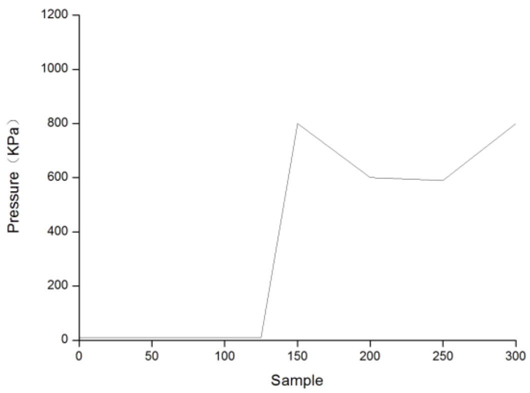

Figure 3: Fault curve

In simulation experiment, LTSA algorithm is used firstly to extract 12-dimension low dimensional manifold from 33-dimension data of normal operating ethylene cracking furnace; then useful information got from low dimensional manifold is used to build statistical magnitude; new combined indexes are calculated and statistical significance is estimated. From figure 3, the simulation indicates ideal monitoring effect got from the method. In comparison, the method based on weighting combined indexes has good monitoring effect. While monitoring normal operating condition, the method based on SVDD is sensitive to the noise in normal operating condition. Therefore, this method is superior in monitoring.

3.2 Analysis and detection on bottom of storage tanks

Excitation frequency is set to be 20Hz; driving power is miniwatt without liftoff. Detect the two defects with different depth in steel plate with thickness 10mm and extract the amplitude and phase of the defective signal output from the coil of corresponding magnetic sensor. The curve contrast of defective signal is shown in figure 4. The changing trend of initial phase of defective signal is shown in figure 5.

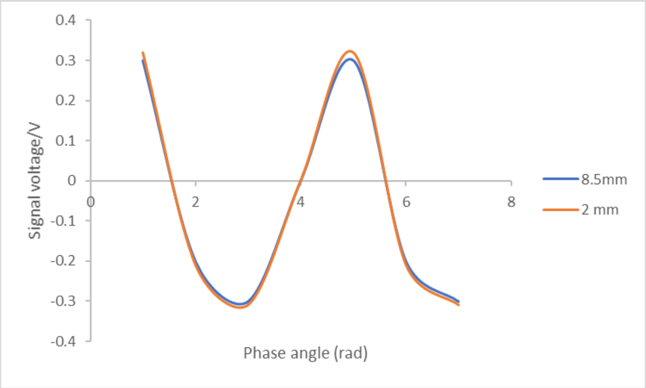

Figure 4: The curve contrasting diagram of defect signal

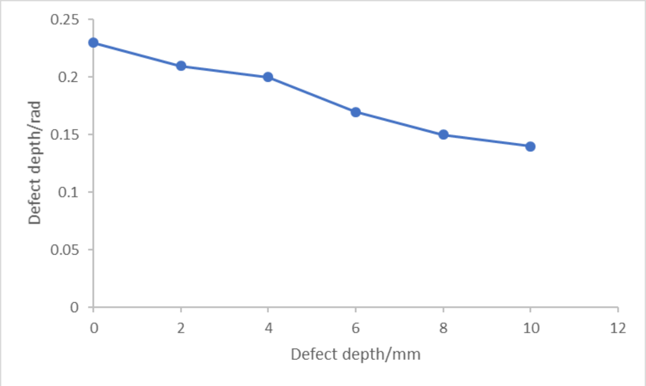

Figure 5: The changing trend diagram of initial phase of defect signal

As can be seen in figure 4 and figure 5, when excitation frequency, driving power and liftoff are constant, the signal output from the coil of inductive magnetic sensor becomes large at defective position or thin position. With the increase of depth of defect, the amplitude of signal detected increases and initial phase decreases. When driving power is miniwatt without liftoff and the frequency of drive signal is 15-30Hz, 8.5 mm defect of steel plate is detected. The relation between excitation frequency and peak-to-peak value of signal detected is shown in figure 6.

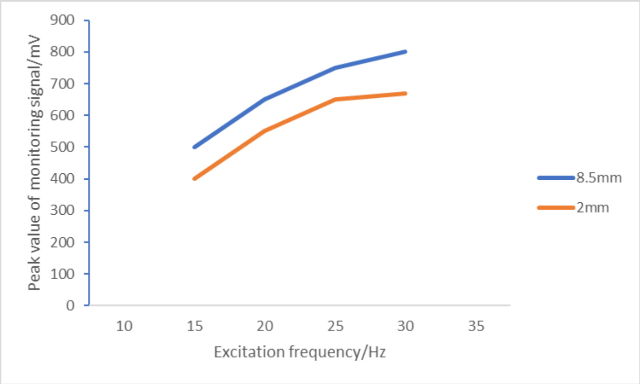

Figure 6: The comparison diagram of excitation frequency and detecting signal amplitude

4. Conclusions

The embedded remote monitoring system based on ARM and Linux is developing constantly. It has been gradually applied in the field of industrial control. As for the chemical enterprises which are developing and growing, higher requirements on automatic monitoring, warning and management to scattered fields of chemical material tanks have been raised. To monitor the new field of liquid ammonia tanks of a certain chemical enterprise, an embedded remote monitoring system based on ARM and Linux is used to achieve real-time monitoring on the field of liquid ammonia tanks, which is an effective method. In traditional method, original feature structure among data can be damaged while processing data and monitoring effect is not ideal. Aiming at this, a process monitoring method based on negative selection algorithm is put forward. This method firstly uses MVU method to reduce dimension of normal samples and then uses negative selection algorithm to directly build normal sample model and detector model for the non-linear data after dimension reduction. Process can be monitored in this way. In simulation experiment, LTSA method is proved to be able to effectively cope with the complex relation among data. It can better monitor the performance of chemical production field and raw material processing field.

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