

# Sensor Data Monitoring Software in Android

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**Abstract**— This paper introduces an Android App for use to monitoring sensor data. A sensor detects the gap of cylinder and the data will be sent to an Android embedded computer using Modbus protocol and displayed on a 2D graph. The proposed method will allow users to set the interval time to receive the gap sensor data. At any time, it can show the future gap trend in the 2D graph with Least Square Method algorithm. When the gap value reaches 0.6mm, it will generate an alert message and voice.

**Keywords**; Modbus protocol; Android platform; Cylinder gap data; Curve fitting; Least square process; 2D graph

## I. INTRODUCTION

TURBO COMPRESSOR is the main product of a company. The centrifugal compressor is a result of the company's advanced "turbo technologies", developed through years of experience in the manufacturing of rotary machinery (engines for planes, gas turbine engines, vehicular superchargers, liquid hydrogen for rockets, and turbo pumps for liquefied oxygen and hydrogen). In a turbo compressor, the cylinder will abrade and a gap will appear between the components. When gap exceeds 0.6 mm, it may cause damage to the machine. To avoid such danger, prediction and collection of gap data is necessary.

Android is a mobile operating system (OS) developed by Google, based on Linux kernel. With a user interface for direct manipulation, Android is designed primarily for touchscreen mobile devices such as smart phones and tablet computers, with specialized user interfaces for televisions (Android TV), cars (Android Auto), and wrist watches (Android Wear). Android is popular with technology companies that require a ready-made, low-cost and customizable operating system for high-tech devices [1].

To monitor the data of the compressor, Android application can allow convenient and flexibility. With an Android device, real-time data and future trend can be showed on 2D graph. It can also assist users to detect the alert data on time.

## II. MODBUS PROTOCOL

The Modbus protocol is an industry-standard protocol that allows controllers to associate with each other over a local link or network [2]. In this application, the Transmission Control Protocol (TCP) is used mainly because it can be applied at variation of physical network technology, including Local Area Network (LAN) and Wide Area Network (WAN).

The Modbus protocol describes a simple PDU which is independent of the underlying communication layers. The mapping on specific network or buses can draw some additional fields on the ADU. Generally, the data unit is created by the client that initiates a Modbus transaction and the Modbus application protocol will set up the format of a request. The function code field of data unit is defined in one byte. Actually valid codes range from 1 to 255 decimal, where the range 128-255 is used for exception responses and "0" is not valid. The function code field will inform the server to perform action determined by additional information contained in the data field of message when a Client has sent a message to a Server device.

TCP protocol file can be obtained from RFC793, which defines the transmission control protocol [3]. It can divide the message into several pieces and reform these pieces at the destination port. Furthermore, it supports the resending of messages that have not been received and provides full-duplex connection between two machines, allowing them to exchange large amount of data and effectively. As TCP rarely interrupt the work of underlying delivery system, it can adapt to many kinds of delivery system. It also supports flow control, enabling different systems of various speeds to communicate. The message segment is the base transmission unit used for data transmission and message control.

TCP transports message to upper layer by socket number, which tracks different session that go through the network at the same time. RFC1700 has defined the special socket number as Tabulated in Table I. Socket 502 is the only number owned by automation companies [4.]

Table I: Common Ports

Decimal	Keyword
20	FTP-Data
21	FTP
23	Telnet
25	SMTP
53	Domain
67	Pootps
80	Http
110	POP3
502	Modbus

The TCP has an extremely strong ability of data transmission. Under the Ethernet of 100M, it can transport 4000 message segments per second, with 125 words (16 bit) per segment, which amounts to  $4000 \times 125 = 500000$  analogue data.

However, it is tough to secure industrial Modbus TCP Protocol packets. Modbus TCP is fairly vulnerable though it is widely used in industrial communications as it has no built-in security systems. A packet may contain malicious communications if the system were able to filter packets by Modbus source device ID, function codes, or other Modbus command type. Actually industrial devices utilize cyber security devices, such as hardware firewalls, to provide critical missing protection. Unfortunately, conventional firewall solutions rarely include the technology to scan industrial protocols such as Modbus TCP.

Fig 1 shows the basic configuration of Modbus Slave software, used for data transfer to Android device via network. Function 04 reads the binary contents of input registers (3x) in the slave. Input registers start from number 30001 with its corresponding address being 0000. Every register value has 16 bits. The data of register 0030 represents the gap value of the cylinder.

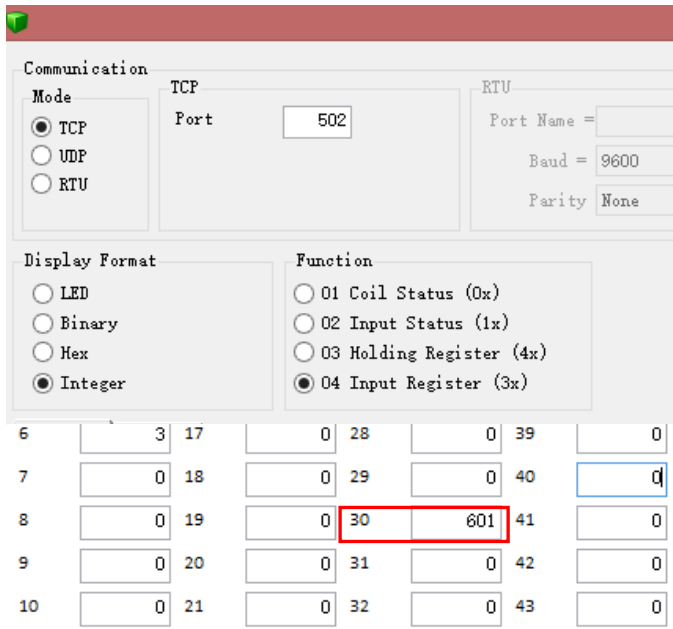


Figure. 1 Modbus configuration and Register 30 represents the gap data.

Fig. 2 shows the diagram of the data transported into the Android app. The whole picture is shaped as the compressor. Currently only the gap data is sent by Modbus Slave software. The number displayed in red box represents the data of gap.

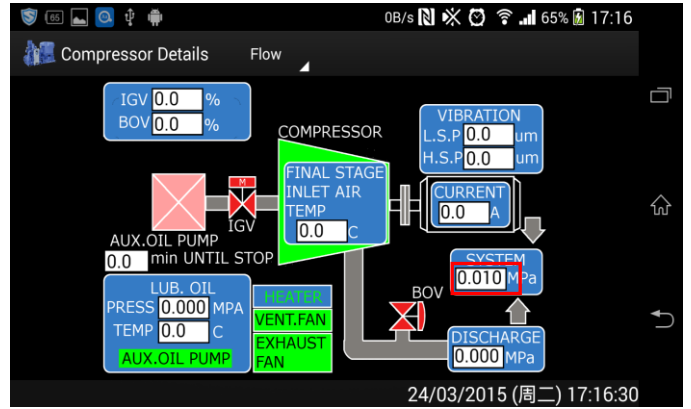


Figure. 2 Flow Chart of compressor; red signifies that the data of the gap value is 0.010 mm.

### III. LEAST SQUARE METHOD

In current science research, the relation between physical quantities can usually be described by function. Some functions are attained by analysis and derivation from classical theory, which provides the foundation for our further research. Curve fitting method is critical when the function relationship is difficult to derive from classic theory. Through combining experiment data and mathematical method, we can obtain the approximate function expression between the physical quantities.

#### A. Fundamental Principle of Least Square Method

Curve fitting, also known as function approximation, is to obtain a simple function  $p(x)$  for a complex function  $f(x)$ , making the mathematical error between  $f(x)$  and  $p(x)$  minimum in some measurement aspects. We consider the difference between the approximation  $s(x_i)$  and the measured value  $y_i$  as residual  $\delta_i$ , namely  $\delta_i = s(x_i) - y_i$ . Obviously, the value of residual is the critical symbol of evaluating the quality of curve fitting. The following are the three evaluating rules we have set:

- (1) The maximum absolute value of residual is the smallest:  $\max |\delta_i| = \min$ ;
- (2) The absolute value of residual is of the smallest:  $\sum |\delta_i| = \min$ ;
- (3) The sum of squares of residual is made minimum:  $\sum \delta_i^2 = \min$ ;

After analyzing the above methods, the calculation of the third is simpler. Thus we apply this method to predict the future tend.

Assuming that the given experiment value is  $\{(x_i, y_i), i = 1, 2, \dots, m\}$ , and the weights of each points are  $a_i$ , we next have to cope with the function relationship between the independent variable  $x$  and the dependent variable  $y$ , where  $y = s(x; a_0, a_1, \dots, a_n) (n < m)$ . The least square method does not require  $y = s(x)$  to go through all the measured points, but the residual must be of the least.

Making the approximation function as:

$$s(x) = a_0\varphi_0(x) + a_1\varphi_1(x) + \dots + a_n\varphi_n(x) \quad (1)$$

Assuming that the given group of points are  $\{(x_i, y_i), i=0,1,2,\dots,m\}$  and the corresponding weights are:  $\{\rho_i, i=0,1,2,\dots,m\}$ , the function  $y = s(x; a_0, a_1, \dots, a_n) (n < m)$  needs to be computed with the value of  $\|\delta\|^2 = p(a_0, a_1, \dots, a_n) = \sum_{i=0}^m \rho_i [s(x_i) - y_i]^2$  being the least. After which,  $(a_0^*, a_1^*, \dots, a_n^*)$  is the point that enable multiple function  $p(a_0, a_1, \dots, a_n)$  to attain a minimum value. This is the least square method of curve fitting.

To get the minimum value, we get the function:

$$\frac{\partial p}{\partial a_k} = 2 \sum_{i=0}^m \rho_i [a_0\varphi_0(x_i) + a_1\varphi_1(x_i) + \dots + a_n\varphi_n(x_i) - y_i] \varphi_k(x_i), \quad (2)$$

where  $k = 0, 1, \dots, n$ . When the function equals zero with the solution,  $(a_0, a_1, \dots, a_n)$ , the equation has acquired the minimum value.[5]

### B. Select Data and Analyze Algorithm

The Android application receives data messages from Modbus Slave Software at every time interval set in the Setting UI and stores it in the database. The time interval could be 5s, 10s, 15s or 20s. Assuming that it has stored 1302 (total amount showed as SIZE) points in the database and the latest group of 25 (N) points need to be used to predict algorithm, it would have 52 (quotient showed as A) groups of points and the remaining 2 (remainder showed as B) points is neglected. The 52<sup>nd</sup> group of points is considered as the experimental data, which is used for working out the predicting algorithm. Fig. 3 is the schematic diagram as well as the code of the method:

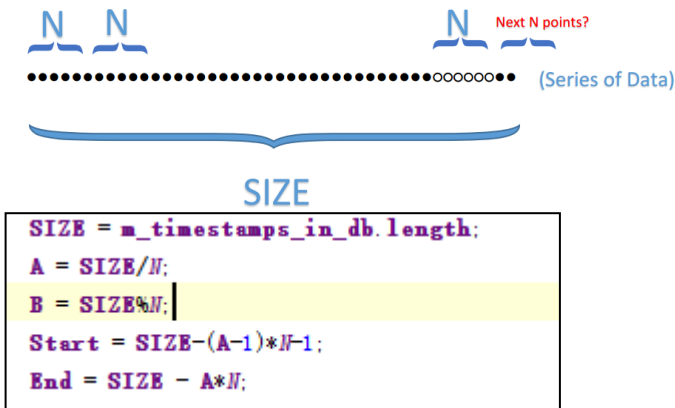


Fig. 3 Schematic diagram and code for selecting data.

## IV. RESULT AND ANALYSIS

When user first enter the application, a Flow chart will appear. The gap data will absolutely increase with time. At the initial period, the cylinder abrades slowly and the gap is small,

such as 0.01 mm. With times, the gap increases exponentially. We can assume the expected algorithm is  $y = A \exp(B * x)$ . If the gap exceeds the exact value, the cylinder has to be repaired. Therefore, it is important to predict the time when the gap data will exceed a critical value, such as 0.6 mm.

Fig. 4 shows that the input data, which is 0.601 mm. Hence, the alert voice and message pop up since it has exceeded 0.6 mm.



Figure. 4 The alert message

The screen then displays a Graph chart. At the start of chart display, the future trend is shown. After the addition of a series of data in Modbus Slave software, the trend move towards exponential function. Once we press the button “Set Timestamps” and select the timestamps and press the button “Update Graph”. It will show the real-time data in the 2D graph of Fig. 5. (PS: The label “SYSTEM PRESS” represents “GAP DATA”)

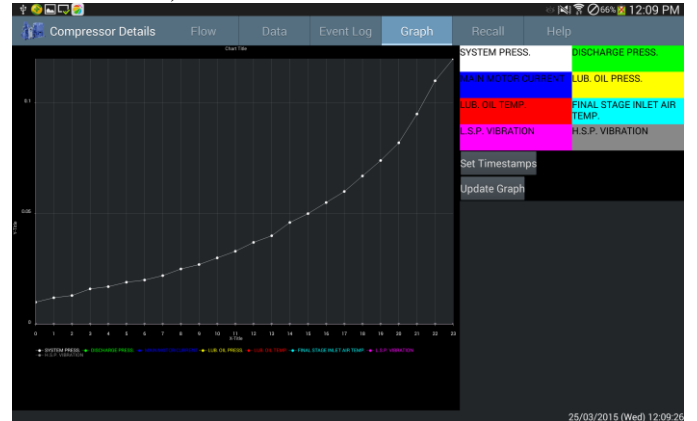


Figure. 5 The real-time data.

If we press the button “Update Graph” again, it will display the future trend curve on the 2D graph. The curve is the exponential function curve.

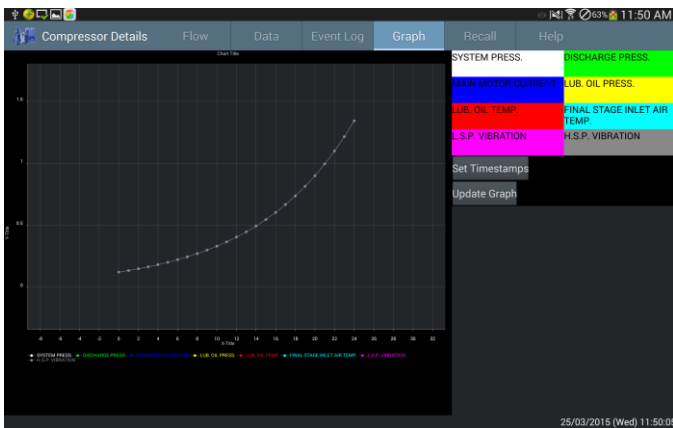


Figure. 6. The future trend  
V. CONCLUSION AND ANALYSIS

In this paper, different charts of various functions have been developed for Android device. To ensure the safety of the cylinder, the gap data is scrutinized at regular time interval. If the data exceed 0.6 mm, an alert message will be triggered. As the gap appears to increase exponentially, curve fitting is conducted on the data received and the function

$y = A \exp(B * x)$  is obtained;  $x$  is the time and  $y$  is the data value. In this application, the ability to estimate the future trend on 2D graph as and when the user required is also implemented. The user simply needs to press the button, "Update Graph" again.

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