Design of Aircraft Safety Monitoring System

Zhijie Zhao*, Xi Long & Weikai Xu
School of Aerospace Engineering, Shenyang Aerospace University, Shenyang, Liaoning, China

ABSTRACT: With the improvement of the level of the technology, the safety of aircraft has received more and more attention. In order to better monitor the aircraft safety, a Beidou-based aircraft safety monitoring system was designed. The main factors affecting the safety of the aircraft were obtained through cluster analysis. The system used BMP180, MPU9250 HS-FS01 and DHT11 to monitor the air pressure, altitude, attitude angle, acceleration, wind speed, temperature and humidity of the aircraft's position. It used the GPS/BDS dual-mode positioning module to accurately and timely synchronize the space and time of the aircraft, using the fuzzy analysis to comprehensively assess the safety status of the aircraft, using WIFI/GSM/GPRS switchable wireless network to send the acquired information to the PC monitoring software. The hardware and software design of the system are studied, and the test results are given. The results show that the system can accurately monitor the status information of the aircraft and comprehensively evaluate the safe working coefficient of the aircraft.

Keywords: aircraft safety monitoring; Beidou satellite navigation system; cluster analysis; fuzzy analysis; WIFI/GPRS/GSM wireless communication; PC monitoring

1 INTRODUCTION

In recent years, Chinese general aviation has developed rapidly. The total number of flight operations and the growth rate were over two-digit. The “Opinions on Deepening China’s Low-altitude Airspace Management Reform” was jointly issued by the State Council and the Central Military Commission. It expressed the willingness of promoting low-altitude airspace reform and prospering China’s low-altitude industries, and pointed out that the promotion of low-level industries is an important measure for the prosperity of China’s economic development [1]. The monitor of state parameters of the air traffic controls the system. It is a key measure to ensure flight safety and efficiency. It is imperative to strengthen the means of surveillance of the aircraft. The aircraft surveillance system is known as the “telescope in the sky”. Aircraft surveillance uses various information methods to implement a comprehensive and effective surveillance of the aircraft situation in the airspace. As for ADS-B systems commonly used abroad, it is necessary to increase the number of ground service stations in practical applications to improve the surveillance of related areas, because that its signal is easily affected. In addition, our country has a vast territory and a varied topography. If we adopt the same design as abroad, it will not only bring huge financial cost, but also have a long construction period [2]. The wireless GSM network has basically covered the whole country. Utilizing the resources of the mobile public networks needs less investment. Besides, it is more suitable for long-distance information transmission.

At the same time, the improvement of the Beidou satellite positioning system and wireless sensor net-work provides a more efficient solution for aircraft safety monitoring. Aiming at the shortcoming of China’s aircraft safety monitoring system, establishing an efficient aircraft monitoring system becomes the key to achieving high-speed development of the aviation industry. Therefore, we have developed an aircraft safety monitoring system based on Beidou positioning and timing functions.

2 OVERALL SYSTEM DESIGN

The researched system focused on the acquisition and display of various state parameters with time and space information of an aircraft at a particular time, then the safety factor of the aircraft at this time is ob-
tained through fuzzy analysis, so that the information is transmitted to the remote PC monitoring center to realize the real-time monitoring of the time and space location, altitude, pressure value, attitude angle, triaxial acceleration, humidity, surface wind speed and safety factor. The system consists of two parts, the aircraft safety monitoring terminal and the PC monitoring center. The safety monitoring terminal of aircraft consists of Arduino microprocessor, BMP180 atmospheric pressure sensor, MPU9250 nine-axis acceleration sensor, DHT11 temperature and humidity sensor, HS-FS01 wind speed sensor, Beidou module UM220, display module LCD1602, GPRS wireless communication module and WIFI module. The monitoring center consists of Arduino microprocessors, GSM wireless transmission modules, WI-FI modules, and PC monitoring software. System hardware schematic diagram is shown in Figure 1.

Figure 1. The structure of system hardware.

Operating principle is as following: through excellent positioning and timing capabilities of the UM220 module, the aircraft safety monitoring terminal gets access to the Beidou signal reception and the time and space information of the monitored aircraft, the use of BMP180 atmospheric pressure sensor, DHT11, temperature and humidity sensor, HS-FS01 wind speed sensor and MPU9250 acceleration sensor. All of these aimed to obtain the air pressure value, altitude, attitude angle, triaxial acceleration of the monitored aircraft, and the temperature, humidity and wind speed values of the aircraft surface. We use the Single-chip computer Arduino to display various aircraft states parameters on the LCD1602 screen.

We also use the fuzzy analysis to obtain the safety factor of the aircraft, controlling the GPRS module SIM900A or the WI-FI Module ESP8266 to transmit the information of the aircraft to the remote PC monitoring center. The GSM module/WI-FI module of the PC monitoring center is a signal receiving terminal. It is mainly used to receiving the signal from the GSM module/WI-FI module in the aircraft safety monitoring terminal, analyzing the signal through the single-chip computer Arduino UNO and displaying it on the PC side monitoring software. In terms of it, remote monitoring of aircraft status parameters can be achieved.

3 DETAILED DESIGN OF THE SYSTEM

3.1 Aircraft safety monitoring terminal design

The aircraft safety monitoring terminal is composed of an Arduino microprocessor, a sensor group, a UM220 module, a LCD1602 liquid crystal display module, and a GSM wireless communication module. It mainly achieves the acquisition, display and transmission of the time and position information, attitude angle, triaxial acceleration value, pressure value of the monitored aircraft, altitude values, temperature and humidity values on the surface of the aircraft, and wind speed values. Figure 2 below shows the circuit connection diagram of the aircraft safety monitoring terminal.

3.1.1 Design of UM220 module

The UM220 module communicates with the processing module through the UART serial port. Firstly, the RF signal received by the antenna is input to the RF input pin of the UM220. After processing, the UM220 serial port sends the date to the processing module for further processing [3].

In order to obtain the required time and space information, GNRMC, GNGGA, and GNZDA message using Beidou or GPS dual mode output, the GNRMC message format is SGNRMC,hhmmss.ss, A, dddmm.mmmmmm, a, dddmm.mmmmmm, a,x,x,x,x, ddm-yy,.x,.a*hh<CR><LF>. It is the useful information that needs to be extracted in the design includes latitude and longitude. The 3rd, 4th, 5th, and 6th fields in the information are the fields that need to be extracted. These fields represent the latitude format, south (north) latitude, longitude format, and east (west) [4].

Similarly, the information of the 11th and 12th fields in the $GNGGA information is extracted. The information contained in these fields including the height of the geoid fluctuation and the unit (m) of the
geoid fluctuation. The height of the module from the horizontal plane can be obtained from this information. And then we know the height of the aircraft. The 1, 2, 3 and 4 fields extracted in $GNZDA$ representation. And then we know the height of the aircraft. The following describes the data using GNRM information as an example $GNRMC$, 025615.000,A,4155.271667,N,12324.141653,E,0.000, 353.670,201215,,E,A*3F. The specific description is shown in Table 1.

Table 1. The description of message format.

| Name           | Format                  | Meaning                                      |
|----------------|-------------------------|----------------------------------------------|
| UTC time       | 025615.000              | h. min. sec. msec                            |
| Positioning    | A/V                     | $A=$Yes, $V=$No                              |
| Latitude       | 4155.271667             | degree. min. min                            |
| Direction      | N/S                     | N-north, S-south                            |
| Longitude      | 12324.141653            | degree. min. min                            |
| Direction      | E/W                     | E-east, W-west                              |

### 3.1.2 9-axis acceleration module design

The MPU-9250 is a powerful 9-axis motion tracking device consisting of a triaxial accelerometer, a triaxial gyroscope, and an AK8963 triaxial magnetic needle. It has three 16-bit acceleration AD outputs and three 16-position gyroscopes, three 6-bit magnetometer AD output[6], with integrated circuit bus (IIC) and serial peripheral interface (SPI) interface modes, transmission rates up to 400 kHz/s (IIC) and 20 MHz, respectively/f(SPI). Its gyroscope's angular velocity measurement is up to 2000 degrees per second and it has good dynamic response characteristics. The maximum measurement range of gravitational acceleration is 16g, and the magnetometer can reach 4800uT, which can be used for auxiliary measurement of yaw angle. One-chip computer can read 9-axis data through I2C protocol.

When reading signals, the data collected by each sensor has a corresponding weight, and the final value is calculated through Kalman filter. The MPU-9250 is installed at the bottom of the terminal to measure the aircraft's three-axis attitude angle and acceleration. The “SCL” pin and “SDA” pin of the MPU-9250 module are connected to the Arduino I2C pins A5 and A4 respectively. The microprocessor reads the corresponding acceleration and attitude angles through the IIC protocol.

### 3.1.3 Pressure altitude measurement module design

In the design, the pressure temperature sensor BMP180 produced by BOSCH is used. Compared with other pressure sensors, this module has the advantages of high precision, small volume and low power consumption. The measurement range of pressure is 3000-11000Pa[6], which is particularly suitable for installation on an aircraft to measure aircraft status parameters. The module consists of a control unit, A/D conversion module, data storage unit, 8-pin ceramic leadless chip carrier (LCC) ultra-thin package. The sensor converts the analog value of the air pressure to a digital signal at a rate of up to 128 times per second through the A/D converter module. At the same time, the control unit reads the 11 16-byte temperature compensation correction parameters in the memory EEPROM for temperature and pressure. The compensation calculation reduces the error caused by environmental changes.

After the sampling is completed, the data is transmitted to the microcontroller through the IIC bus, and the temperature, pressure value, and altitude of the current aircraft are obtained through the microprocessor processing.

#### 3.1.4 Temperature and humidity measurement module

The temperature and humidity sensor is the DHT11 module, which is a temperature and humidity composite sensor with calibrated digital signal output. The sensor includes the resistive moisture sensing element and an NTC temperature measuring element. It is connected with a high-performance 8-bit microcontroller, providing fast response and strong anti-interference ability[7]. Each DHT11 temperature and humidity sensor is calibrated in an extremely accurate humidity calibration chamber. The calibration coefficients are stored in the OTP memory in the form of a program. The sensor can use these calibration parameters when detecting signals to obtain accurate temperature and humidity values.

The DATA pin of the DHT11 module is connected to pin 7 of the digital port of the Arduino microprocessor. The single bus data format is used for data transmission. The digital signal transmitted by the sensor is obtained, and the temperature and humidity of the current surface of the aircraft are obtained through processing. A complete data transfer is 40bit, high-first-out. The specific data format is as follows: 8bit humidity integer data + 8bit humidity decimal data + 8bit temperature integer data + 8bit humidity decimal data + 8bit check. By analyzing the data, accurate temperature and humidity values can be obtained.

### 3.1.5 Wind speed measurement module

The wind speed sensor used in the design is the HS-FS01 module, which is a three-cup wind speed measurement sensor. The wind speed sensor utilizes the principle of differential pressure change. By setting three fixed baffles in the flow direction, a pressure difference will be generated according to different flow speeds. By measuring the pressure difference,
the flow rate can be measured. The wind speed sensor obtains the final wind speed value by measuring the number of pulses per unit time and multiplying the coefficient by 0.3 \[8\].

The HS-FS01 module is connected to the analog port A2 of the Arduino microprocessor to acquire the analog signal transmitted by the sensor and obtains the current wind speed value of the aircraft surface through processing. Using HS-FS01 wind speed measurement module helps to get the wind speed value. According to the wind level classification table, we can get the specific wind level.

### 3.1.6 Wireless communication module

The GSM/GPRS module used in the design is the SIM900A GSM/GPRS module. Among them, the baseband signal processor is the core part of the G600 communication module, and its role is equivalent to a protocol processor, which is used to process the AT commands sent by the external system through the serial port.

The RF part mainly realizes the modulation and demodulation of the signal, and realizes the signal conversion between the external RF signal and the internal baseband processor.

The GSM module is connected to the Arduino's virtual serial port 2 (TXD) and 3 (RXD). Through the AT command between the serial ports, information is transmitted.

The WI-FI communication module ESP8266 realizes the interaction with the processor through the serial AT command. The module includes three modes: STA mode, AP mode and STA+AP mode. AP mode is used as the control mode of the design. We can use the AT command to configure the WI-FI module and send "AT+RST" to reset; sending "AT+CWMODE=2" to set AP mode; sending “AT+CWSAP=“monitoring”, “12345678”, 1, 3”; setting the WI-FI name to monitoring with the password as 12345678.The WI-FI module is connected to the Arduino’s virtual serial port 2 (RXD), 3 (TXD), and sends the AT command “AT+CIPMUX=1” via the serial port to set the module to multiple connection mode; sending “AT+CIPSERVER=1, 8080” to open. SERVER mode, the port number is 8080. By entering the corresponding IP address and port number in the WI-FI module of the PC monitoring center, it is possible to connect with the WIFI to realize information communication.

### 4 SYSTEM SOFTWARE DESIGN

The system software design mainly includes the following tasks: GPS or Beidou module output data reception processing, aircraft safety factor evaluation model establishment, aircraft state information acquisition, GPRS module sending and receiving information, and PC monitoring software design. The overall work flow of the system is shown in Figure 3.

#### 4.1 Establishment of Aircraft Safety Factor Evaluation Model

There are many factors that affect the safety of aircraft. The main influencing factors of 10 influences have been obtained by investigating the corresponding literature: air pressure (X1), rainfall (X2), time (X3), light intensity (X4), wind direction (X5), altitude (X6), attitude angle (X7), acceleration (X8), wind speed (X9), temperature and humidity (X10), from these 10 factors we can see, there may be strong correlation between certain factors. We used R-type cluster analysis method to screen the main factors. We defined the value as the variable \(x_r\), then using the sample correlation coefficient of the two variables \(x_i\) and \(x_k\) as their similarity measure \[9\]. Using the following formula to calculate the correlation coefficient:

\[
r_{jk} = \frac{\sum_{i=1}^{n}(x_{ij} - \bar{x}_j)(x_{ik} - \bar{x}_k)}{\sqrt{\sum_{i=1}^{n}(x_{ij} - \bar{x}_j)^2 \sum_{i=1}^{n}(x_{ik} - \bar{x}_k)^2}^{1/2}}
\]

Through reading the literature, we found the sample data corresponding to the above 10 factors. Then we used Matlab to calculate the correlation coefficient and used the quantitative method to classify things and established the correlation coefficient matrix. The correlation coefficient matrix is shown in Table 2.

It can be seen that there are indeed strong correlations between certain evaluation factors. Therefore, several representative factors are selected from these indicators for cluster analysis. First of all, each factor is normalized. In terms of this premise, the similarity measure between variables adopts the correlation co-efficient.
The similarity measure between the classes adopts the sum of deviations. The clustering tree is shown in Figure 4. It can be seen from the clustering chart that the five factors including barometric pressure (X1), rainfall (X2), time (X3), light intensity (X4), and wind direction (X5) have a large correlation. They are brought together in priority. Therefore, X1 uses air pressure to replace these five factors, so that six analysis factors are selected from 10 factors: X1- air pressure, X6- altitude, X7- attitude angle, X8- acceleration, X9- wind speed, and X10- temperature and humidity.

Based on the six influencing factors of air pressure, altitude, attitude angle, acceleration, wind speed value and temperature and humidity, a comprehensive evaluation model of aircraft safety factor is established using fuzzy analysis. The correlation coefficients between various evaluation factors are obtained by consulting relevant data analysis and conclusion, and the judgment matrix is established in the order of air pressure, altitude, attitude angle, acceleration, wind speed value and temperature and humidity as follows:

\[
\begin{bmatrix}
1 & 1 & 1 & 1 & 1 \\
1 & 3 & 5 & 5 & 1 \\
1 & 2 & 1 & 5 & 3 \\
1 & 1 & 7 & 1 & 1 \\
1 & 1 & 2 & 1 & 5 \\
1 & 2 & 1 & 1 & 1 \\
1 & 5 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 \\
1 & 3 & 5 & 5 & 1 \\
\end{bmatrix}
\]

It may be considered that the comprehensive score of the safety factor of the aircraft is \( Y \), the evaluation scores of the six factors are \( Y_1, Y_2, Y_3, Y_4, Y_5, Y_6 \), respectively, and the final score of the suitability of the trip is:

\[ Y = Y_1 + Y_2 + Y_3 + Y_4 + Y_5 + Y_6 \]

The scoring criteria for each factor are as follows: The rated safety factor is rated at 100 points. The higher the score, the safer it is. When the air pressure is 0 atm-1.2 atm or more than 3 atm, the score is 0 points, 1.2 atm-1.5 atm is 5 points, and 1.5 atm-3.0 atm is 7 points.

When the flight altitude is 0-500m, it is 0 points, 500-3100m is 10 points, 3100-7800m is 24 points, and 7800m is 14 points. When the attitude angle is 0-10 degrees, it is 19 points, 10-35 degrees is 7 points, and when it is greater than 35 degrees, it is 0 points. When the acceleration was 20-40, it was 27 points, when it was 40-68 it was 15 points, 68-108 degrees was 4 points, and when it was greater than 108 it was 0 point. When the wind speed is 5-50.7m/s, it is 13 points, 50.7-100m/s is 8 points, and more than 100m/s is 0 points.

When the temperature is 0-5 degrees or greater than 50 degrees, it is 0 points, 5-35 degrees is 7 points, and 35-50 degrees is 3 points. According to the above scoring criteria, the scores obtained from each index are added to obtain the final safety factor score. When the safety factor is between 0-45, the status is unsafe, between 46 and 72, the status is safety; when it is greater than 72 the status is very safe.

4.2 Program of GPRS/GSM

The system uses GPRS, GSM, WI-FI as wireless in-formation transmission methods, through the three kinds of transmission modes. We can achieve the lowest cost of communication. Firstly, we detect whether there is a hotspots signal connected to the WiFi module. If there is equipment access, we use WI-FI communication. If not, we send the command "AT+CSQ" to the GPRS module to check the GPRS signal strength. If the signal strength is greater than 16, the GPRS communication mode is used; if the signal strength is less than 16, the GSM communication mode is used.

GPRS mode: Send AT+CGCLASS="B", set the mobile station class to B, send AT+CGDCONT=1, "IP", "CMNET", set the PDP context flag to 1, and adopt the network IP protocol, the access point is "CMNET"; Send AT+CGALL = 1, set up attached GPRS service; Send AT+CIPCSGP = 1, "CMNET", set to GPRS connection, access point to "CMN ET"; Send AT+CLPORT = "TCP", "2000", set the TCP connection local port number to 2000; Send AT+CIPSTA RT = "TCP", "103.44.145.243", "16919", the module will establish a TCP connection, the target
The address is 103.44.145.243, and the connection port number is 16919. Successful connection will return: CONNECT OK. After the connection is successful, send the AT+CIPSEND command to send the message, and then send "0x1A" to end the transmission.

GSM mode: When sending information in this mode, we send AT+CSCS="GPRS" first, and set the TE character set as the default character set, and then send the command AT+CMGF=1[11], setting the text message mode as text Format. After sending AT+CMGS = "photo", this command is used to send text messages, under the "GPRS" character set. It can send up to 180 bytes of English characters, of which photo is required to be sent to the phone's mobile phone number; Latter, the message of the short message can be input. Finally, the end command "1A" is sent, and the message is sent to the PC.

4.3 Network training and data simulation

PC monitoring center software design process: Firstly, setting the serial port logical name to be opened lpfilename, serial access type (dwDesiredAccess), specifying the shared attribute dwsharemode to 0, attributing reference security structure (lpsecurityat-tributes), setting the creation of the identification for the OPEN_EXISTING, setting the file attribute for the FILE_FLAG_OVERLAPPED, and allowing the file Overlap operation. The configuration of the serial port needs to use the DCB structure. This structure contains information such as baud rate, data bits parity and stop bits. When querying and configuring the serial port properties, we use the DCB structure as a buffer. Using CreateFile to open the serial port, calling GetCommState function to get the initial configuration of the serial port, modifying the serial port configuration, before these above, you should firstly modify the DCB structure, and then call the SetCommState function to set the serial port. The SetupComm function is called to set the input and output buffer size of the serial port so that it can hold a measurement data. When reading and writing serial ports with ReadFile and WriteFile, you need to consider overtime issues.

The role of the timeout is to not read or send the specified number of characters within the specified time, the ReadFile and WriteFile operations will still finish. Using GetCommTimeout function to query the timeout setting, this function will fill a COMMTIMEOUTS structure, and calling SetCommTimeout to use a COMMTIMEOUTS structure to set the timeout. The read and write of the serial port uses ReadFile and WriteFile functions. Synchronous or asynchronous is determined by the CreateFile function. If the FILE_FLAG_OVERLAPPED flag is set when the CreateFile creates the handle, the ReadFile and WriteFile functions are overlapped. If the overlap flag is not specified, the read and write the operation should be synchronized. If the operation is successful, both of these functions return TRUE. When they both return FALSE, they are not necessarily failed. The GetLastError function should be called to analyze the returned result. If the return value is ER-ROR_IO_PENDING, the overlap operation is not completed.

5 TEST RESULT AND ANALYSIS

The device is mounted on the aircraft for testing. Figure 6 below shows the aircraft. Opening the PC monitoring center to initialize the module, then opening the PC monitoring software, setting the serial port and baud rate, making the software enter the waiting state, opening the aircraft security monitoring terminal, then initializing the hardware. After waiting about 10s, relevant PC status parameters will be obtained on the PC monitoring software. The monitoring result on the PC side is shown in Figure 7, and the result will also be displayed on the LCD1602 of the aircraft security monitoring terminal.

![Figure 6. Test device diagram.](image)

![Figure 7. The test result of PC monitoring system.](image)

From the monitoring software on the PC side, the latitude and longitude of the aircraft to be monitored was 116.41667E 39.91667N, which was at 16:49:32 on December 9, 2016. The pressure value was 1003 hPa, the temperature was 23.5 degrees Celsius, the humidity was 23.5%, and the wind speed was at 3.5m/s; the altitude was 1052m, the triaxial accelerations were -247.60(x), 355.35(y), -714.90(z), and the triaxial attitudes were -110.35 degrees (Yaw), -19.10 degrees (Pitch), -153.51 degrees (Roll), the safety factor was 76, relatively safe.
6 CONCLUSION

In this paper, these were designed in detail: the status parameters of the aircraft monitoring, the acquisition of Beidou module location time information, the status assessment of aircraft safety, wireless data transmission, PC monitoring software design and other aspects of the content. The system's hardware and software, and the system Experimental tests were conducted. The result shows that this system realizes the acquisition and display of aircraft status parameters, time and space information, and remote transmission and reception. The system is fully functional. Through the combination of hardware and software, it shows that all-round remote monitoring of the state parameters of the aircraft during the flight. The establishment of the system can reduce the workload of aircraft safety supervisors and greatly improve the efficiency, control and science of aircraft safety supervision.

ACKNOWLEDGEMENT

This paper is sponsored by National College Students' innovation and Entrepreneurship Project (S1701025).

REFERENCES

[1] Lei, W.L., Ren, X.C., Cao, X.L. 2015. Design and implementation of automatic weather monitoring system based on single chip microcomputer. Modern Electronics Technique, 38(19): 121-124.

[2] Ren, X.L., Chen, J.X., Wang, J. 2015. Study on online environment monitoring system based on GPRS technology. Modern Electronics Technique, 38(4): 60-62.

[3] Zhang, X.H., Zuo, X., Li, P. 2015, Convergence Time and Positioning Accuracy Comparison between BDS and GPS Precise Point Positioning. Acta Geodaetica et Cartographica Sinica, 44(3): 250-255.

[4] Li, W., Zheng, X.Q. 2015, A Haze Monitoring Method Combined VIIRS Images with Real-time Observation Data Interpolation in Beijing. Acta Geodaetica et Cartographica Sinica, (44): 123-128.

[5] Qin, X.X., Gao, Y., Yu, H.Y. The Design of the Interface Circuit for a WideRange Barometric Pressure Sensor. Chinese Journal of Sensors and Actuators, 201, 28(3): 320-324.

[6] Wang, H., Huang, C. 2013. Design and study of temperature and humidity measurement system in high accuracy wireless environment. Journal of Electronic Measurement and Instrumentation, 27 (3): 211-216.

[7] Chen, T., Zhang, H., Zheng, L. 2016. Field Calibration Traceability and a Delivery Method of Wind Speed Indications of Automatic Weather Stations. Meteorological Science and Technology, 44(6): 923-926.

[8] Wang, X.L., Ma, M.Z. 2017. Design and implementation of GPRS based real time monitoring system for cold chain logistics. Modern Electronics Technique, 40(17): 109-112.

[9] Lu, Z.M., Shao, Q.L., Song, F. 2014. Application development of BD2 receiver based on embedded Linux. Modern Electronics Technique, 37(23): 155-158.

[10] Fang, J.J., Fan, J. 2017. Development and design of training room security protection system based on GSM Technology. Modern Electronics Technique, 40(18): 55-57.

[11] Qing, S.H. 2016. Research Progress on Android Security. Journal of Software, 27(1): 45-71.