International Journal of Control and Automation
Vol.7, No.2 (2014), pp.371-386
http://dx.doi.org/10.14257/ijca.2014.7.2.33

Design and Implementation of Paper Currency Sorting Process Management System

Bo Wang[1*], Liqun Liu[2] and Lin Qiu[3]

[1]*School of Applied Technology, University of Science and Technology Liaoning, Anshan, P. R. China*
[2]*Sinosteel Anshan Research Institute of Thermo-energy CO., LTD, Anshan, P. R. China*
[3]*Anshan Bozong Science and Technology CO., LTD, Anshan, P. R. China*

[*] *wangboustl@126.com*

Abstract

The lack of management on paper currency sorters and low work efficiency in paper currency sorting process make the low level of automation and information in current Chinese bank branch's currency counting and sorting system. To solve this problem, a new process management system was designed for paper currency sorters by the integrated use of sensor technology, serial communication technology, image recognition technology and information technology. The system consists of paper currency automatic sorting subsystem and management and control subsystem, and realizes functions such as sorter work data display, storage and analysis as well as management and control of paper currency sorters, through real-time data acquisition from multiple paper currency sorters. After systematic testing, this system has been successfully applied to practical work. The results show that this system is stable with good performance and high scalability.

Keywords: *management system, paper currency sorting process, real-time data acquisition, serial communication, financial information*

1. Introduction

China is a populous country; the liquidity of the cash is enormous. Larger proportion of damaged banknotes is in circulation, so it is hard for all the banks in counting, genuine and fake identification, banknotes picky and distinction different versions of banknotes. In order to improve the cleanliness of the RMB in circulation and maintain the reputation, the People's Bank of China has developed the national standards. Numerous commercial banks should turn over the banknotes in circulation and damaged banknotes into the treasury according to this standard. In order to improve the recognition rate of banknotes and speed up counting processing, banks are vigorously promoting the use of the sorter [1]. With sorter widely used, numerous problems have become increasingly apparent. For bank check center, on the one hand, manual operators should not only process sorting manipulations and data records for each sorter, but also manage and control, which is not only time-consuming, increased labor costs. On the other hand, most of the sorters only completed functions of counting machines or currency detectors. Most counting data information is not used and stored. Supervisors are unable to understand circulation information about banknotes timely and efficiently.

In response to this situation, the paper currency sorting process management system came into being. This paper presents the design and implementation of the paper currency sorting

ISSN: 2005-4297 IJCA

process management system. The subsystem of paper currency sorting obtains paper currency sorting process information through the serial communication to send information to epigenous machine. The subsystem of management and control receives and stores the data and then performs related manipulations [2]. In addition, this system designs and fulfills the management and control of multiple sorters, and meets the requirements of energy conservation and environmental protection. This system takes charge of real-time management of paper currency sorting process, and improves work efficiency of the bank check center, saves the cost, which owns a useful and practical value.

2. Relevant Theoretical Overview

Authors in this section describe some theoretical knowledge briefly [3-9].

2.1. Noise Elimination

The binarization is mainly used to separate the object from the background. The commonly-used method is to set a threshold T , the image data is divided into two parts: the greater than pixel group T and the less than pixel group T . Assuming that the threshold value is T , the transformation function of the binary image in equation (1).

$$f(x)=\begin{cases} 0 & x<T \\ 255 & x>T \end{cases} \tag{1}$$

In the process of image scanning, because of varies reasons the image must have noise. And noise in the image will seriously affect the feature extraction. There are a variety of methods to remove the noise in binarized image. Through a comprehensive comparison, the median filter $N \times N$ is chosen to remove interference noise in images. Assume that there is a point XY whose pixel is $f(i,j)$, with this point as the center selects $N \times N(N=3,5,7,¼)$ the shielding window, in which the median gray value is u , unconditionally set $f(i,j)=u$. In this way, the noise in the image can be removed effectively.

2.2. Edge Detection

Edge detection uses the method of linear least square fitting. Linear least square fitting uses a linear regression equation to deal with the relationship between the two variables and to estimate the parameters by using the least square method. Assuming a linear regression equation is shown in equation (2).

$$Y=\alpha+\beta X+\varepsilon \tag{2}$$

Where, α and β are the regression coefficients. X is the independent variable, Y is the dependent variable, ε represents the random error, assumes ε follow the normal distribution $N(0,\sigma^2)$, this means that the positive error and the negative error are the same opportunity, σ^2 is the size of the error.

α , β and σ^2 are usually unknown in the equation. They should be estimated by the data information. Assuming $\{(X_i,Y_i), i=1,2,¼,n\}$ is a set of data, if using the regression equation to fit, when $X=X_i$, the estimated value of Y_i in equation (3).

$$Y_i=\alpha+\beta X_i \qquad i=1,2,¼,n \tag{3}$$

The estimate value of α and β are obtained by the least square method, which makes the Y_i and Y_i closest. Q is the result of Y_i minus Y_i in equation (4).

$$Q=\sum_{i=1}^{n}\left(Y_i-Y_i\right)^2=\sum_{i=1}^{n}\left(Y_i-\alpha-\beta X_i\right)^2 \tag{4}$$

When Q reaches a minimum value, α and β are assigned to a and b respectively. Using partial differential solves extreme in equation (5) and equation (6).

$$\frac{\partial Q}{\partial \alpha}=-2\sum_{i=1}^{n}\left(Y_i-\alpha-\beta X_i\right)=0 \tag{5}$$

$$\frac{\partial Q}{\partial \beta}=-2X_i\sum_{i=1}^{n}\left(Y_i-\alpha-\beta X_i\right)=0 \tag{6}$$

A final least-squares equation seeks a and b for the straight-line fitting in equation (7).

$$Y=a+bX \tag{7}$$

There are a and b respectively in equation (8), equation (9).

$$a=\overline{Y}+b\overline{X} \tag{8}$$

$$b=\frac{L_{XY}}{L_{XX}} \tag{9}$$

In the equation,

$$\overline{X}=\frac{1}{n}\sum_{i=1}^{n}X_i\ ;\overline{Y}=\frac{1}{n}\sum_{i=1}^{n}Y_i\ ;L_{XX}=\sum_{i=1}^{n}\left(X_i-\overline{X}\right)^2\ ;L_{XY}=\sum_{i=1}^{n}\left(X_i-\overline{X}\right)\left(Y_i-\overline{Y}\right).$$

For banknote recognition system, four edges lines of the banknote image show four straight lines on the image. Therefore, we can use the least squares linear fit to edge lines of the banknotes.

The searching for the number of feature points on each edge line can be determined by the actual case. Each edge line makes the search for a finite collection as $\left\{(x_1,y_1),(x_2,y_2),¼\left(x_{n,}y_n\right)\right\}$. n is the number of finite point on one edge line.

According to the detection methods of fitting feature point, the value of n is determined as 9. For the first time, with nine finite points of the least squares linear regression equation fitting on the edge line is $Y=AX+B$.

There are A and B respectively in equation (10), equation (11).

$$A=\frac{\sum_{i=1}^{n}\left(x_i-\frac{1}{n}\sum_{j=1}^{n}x_j\right)\left(y_i-\frac{1}{n}\sum_{j=1}^{n}y_j\right)}{\sum_{i=1}^{n}\left(x_i-\frac{1}{n}\sum_{j=1}^{n}x_j\right)^2} \tag{10}$$

$$B=\frac{1}{n}\sum_{j=1}^{n}y_j-A\times\frac{1}{n}\sum_{j=1}^{n}x_j \tag{11}$$

We can see the idea of the least-squares linear regression fit line to meet all the sample points. However, the actual situation, the edges of the banknote may exist incomplete, if a finite number of points in the point of edge defects, i.e. outliers; it may result in a fitting line deviate from the edge line. Therefore, you need to use some method to find out outliers from the characteristic finite point, with the rest of the limited feature points does not contain outliers fit edge line again.

The detection method of fitting feature point in actual circumstances detects the limited point of individual point falls on the incomplete area and becomes outliers. That means the probability of the number of outliers is far less than 50%. According to the method of the least square's fitting line, ensuring the minimum value of Q in equation (4), the individual outlier's outside distance fitting line must be larger and most of the points inside distance fitting line must be smaller. Therefore, according to this point, we use equation (12) to find the edge points of finite points in the incomplete area.

$$outliers = \left\{ \left| y_i - \left(Ax_i + B \right) \right| \text{larger point} \right\} \quad i = 1, 2, ¼ , n \tag{12}$$

From the collection of a finite number of points, we will abandon the outliers and form a new set of feature points. A new finite set of points as least squares linear regression equation fits the upper edge line. The fitting line removing the destruction of outliers, edge line will be closer to the reality.

Additional three edge line equations using the same method to complete, the limited number of points is 7 in the left and right edges' lines. Ultimately, we determine the four edge line equation of banknote image.

Thereby determining out of RMB images in the image acquisition to the position, and thus can determine the banknote inclined angle.

2.3. Image Correction

Method of image rotation processing is the upper left corner pixels of the image as the coordinate origin transforms to the center pixels of the image as the coordinate origin. And then in the new coordinate system based on the rotational transform of the edge straight-line inclination angle, and finally shifted to the coordinate origin.

$\left(0,0\right)$ is the upper left pixel of the banknote image as the origin of coordinates in the coordinate system I, horizontally to the right as the positive direction of the x-axis, vertical downward as the positive direction of the y-axis.

Let width and height of the banknote image are w and h in respectively. $\left(0.5w, 0.5h\right)$ is the center of the banknote image as the origin of coordinates in the coordinate system II, horizontally to the right as the positive direction of the x-axis, vertical upward as the positive direction of the y-axis.

Equations of coordinate transformation from the coordinate system I convert to the coordinate system II in equation (13).

$$\begin{cases} xII = xI - 0.5w \\ yII = -yI + 0.5h \end{cases} \tag{13}$$

The coordinate transformation matrix of the coordinate system I convert to coordinate system II in equation (14).

$$\left[xII \quad yII \quad 1 \right] = \left[xI \quad yI \quad 1 \right] * \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ -0.5w & 0.5h & 1 \end{pmatrix} \tag{14}$$

Equations of coordinate transformation from the coordinate system II convert to the coordinate system I in equation (15).

$$\begin{cases} xI = xII + 0.5w \\ yI = -yII + 0.5h \end{cases} \tag{15}$$

The coordinate transformation matrix of the coordinate system II converts to coordinate system I in equation (16).

$$\begin{bmatrix} xI & yI & 1 \end{bmatrix} = \begin{bmatrix} xII & yII & 1 \end{bmatrix} * \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0.5w & 0.5h & 1 \end{pmatrix} \tag{16}$$

In the coordinate system II, (x_0, y_0) with the vector angle a, rotated θ angle to (x_1, y_1) with vector angle b, r is the radius of gyration. Counterclockwise rotation angle θ is positive. Clockwise rotation angle θ is negative.

Coordinate transformation equations of counterclockwise rotation of angle θ in equation (17).

$$\begin{cases} x_1 = r\cos(b) = r\cos(a+\theta) = r\cos(a)\cos(\theta) - r\sin(a)\sin(\theta) = x_0\cos(\theta) - y_0\sin(\theta) \\ y_1 = r\sin(b) = r\sin(a+\theta) = r\sin(a)\cos(\theta) + r\cos(a)\sin(\theta) = y_0\cos(\theta) + x_0\sin(\theta) \end{cases} \tag{17}$$

Coordinate transformation equations of clockwise rotation of angle θ in equation (18).

$$\begin{cases} x_1 = r\cos(b) = r\cos(a-(-\theta)) = r\cos(a)\cos(-\theta) + r\sin(a)\sin(-\theta) = x_0\cos(\theta) - y_0\sin(\theta) \\ y_1 = r\sin(b) = r\sin(a-(-\theta)) = r\sin(a)\cos(-\theta) - r\cos(a)\sin(-\theta) = y_0\cos(\theta) + x_0\sin(\theta) \end{cases} \tag{18}$$

Angle θ coordinates transformation matrix in equation (19).

$$\begin{bmatrix} x_1 & y_1 & 1 \end{bmatrix} = \begin{bmatrix} x_0 & y_0 & 1 \end{bmatrix} * \begin{pmatrix} \cos(\theta) & \sin(\theta) & 0 \\ -\sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 1 \end{pmatrix} \tag{19}$$

Image rotation correction algorithm for the new coordinate system II as the origin of coordinates to the effective center of the image $(0.5w, 0.5h)$ transform, and then to the origin of coordinates in the new coordinate system II, angle θ rotation transformation, and finally to the upper-left corner of the effective image pixel $(0,0)$ transform the old coordinate system I as the coordinate origin.

Image rotation correction algorithm for matrix transformation formula is shown in equation (20).

$$\begin{bmatrix} xI & yI & 1 \end{bmatrix} * \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ -0.5w & 0.5h & 1 \end{pmatrix} * \begin{pmatrix} \cos(\theta) & \sin(\theta) & 0 \\ -\sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 1 \end{pmatrix} * \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0.5w & 0.5h & 1 \end{pmatrix} \tag{20}$$

Let (x_1, y_1) be a point in the coordinate system I. After the rotation transformation, the coordinate point becomes (x_2, y_2).

Then the new transformation matrix is shown in equation (21).

$$\begin{cases} x_2 = x_1 \cos(\theta) - y_1 \sin(\theta) + 0.5h\sin(\theta) - 0.5w\cos(\theta) + 0.5w \\ y_2 = x_1 \sin(\theta) + y_1 \cos(\theta) - 0.5w\sin(\theta) - 0.5h\cos(\theta) + 0.5h \end{cases} \quad (21)$$

2.4. Damaged Banknotes Recognition

Banknote's defects in a variety of circumstances, including the lack of edge, chipping, drain holes, cracks, etc. The RMB image is divided into N characterized in blocks, and comprehensive consideration of the defect size standard and to identify the real-time. For each feature block, take the incremental average gradation characteristic value $F_i = \frac{1}{n}\sum_{j=1}^{n} f_j$ as this feature block, wherein f_i is characterized in gray pixels of the block. Taking into account the real-time requirements, s is the step length, which characteristic pixel block gray accumulates. Value s is selected by also taking into account the standard size of the defect.

Sample library of RMB template stores the characteristic value of N sample block. Using the same method, RMB image is divided into N characterized in blocks, according to the step length s is calculated each feature block gradation incremental average. Then N characteristic of this image block with the matching the sample library templates, both feature block characteristic value for the difference exceeds the closing value, that this feature block may contain defects. Defect with the same gray as the background area, then the block value with the matching characteristics as the sample containing the feature value of defect area varies greatly. So the matching threshold value of comparison selected is not difficult, but associated with the defect size standard.

3. System Architecture

The paper currency sorting process management system is divided into two major subsystems of paper currency sorting subsystem and management and control subsystem. The system is usually independent of the bank check center. Paper currency sorting subsystem is chiefly used for the acquisition and digitization of information. Management and control subsystem is chiefly responsible for the real-time data-acquisition management and control of the sorters [10]-[13]. The two parts can maintain real-time communication through data lines.

System architecture is shown in Figure 1.

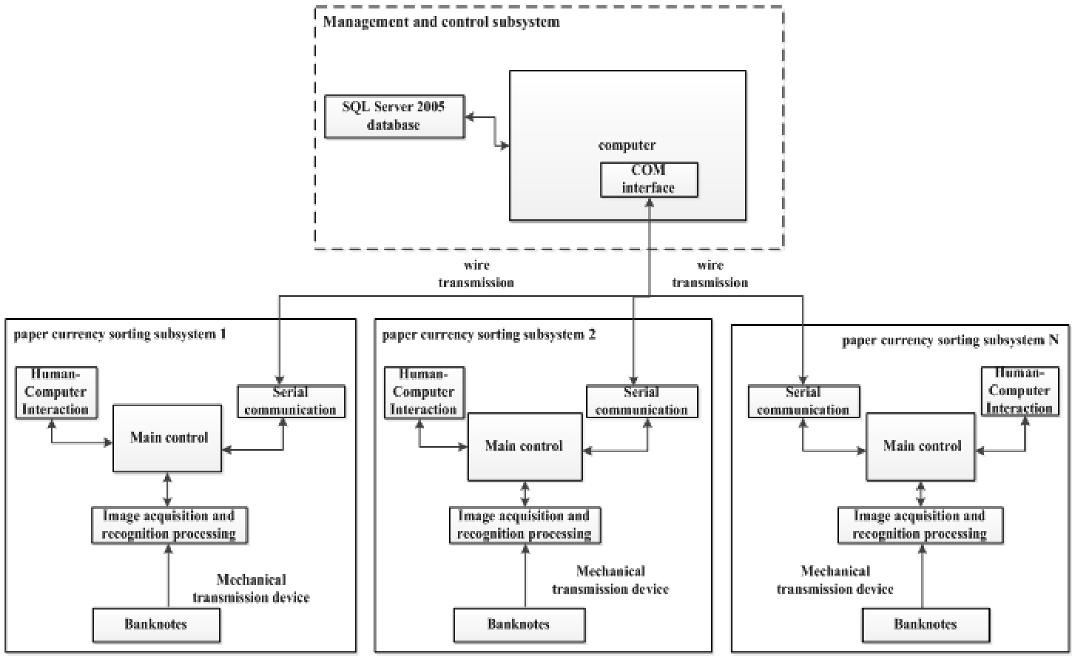

Figure 1. Paper currency sorting process management system structure

4. Hardware Implementation

The hardware part of paper currency sorting subsystem is mainly divided into five parts: the main control, image acquisition, image processing and recognition, human-computer interaction and serial communication.

The main control adopts C8051F020 produced by CYGNAL. The chip integrates ADC, DAC, programmable gain amplifier, voltage comparator, voltage reference, temperature sensor, SMBus/I2C, UART, SPI, timer, programmable counter/timer array, internal oscillator, watchdog timer and power monitor. The chip has higher computing speed, lower power consumption, instruction system compatible with MCS-51 instruction sets, single instruction execution time can be up to 1/25 μs [14]. As the core components within the system, the single-chip microcomputer completed intelligent manipulation such as the banknote's transmission and detection, sorting control, automatic start and stop, self-learning, self-detection and so on. The realization of image acquisition is using AMI company's PI625MC-A6 type CIS image sensors to scan banknotes and obtain the analog signal. Then through the ADI Company's AD9822 type A/D converter converts the analog signal into digital signal and stored in the RAM memory. Image processing and recognition adopts TMS320DM648 DSP produced by TI Company. TMS320DM648 belongs to the powerful DSP. Peak capacity up to 8800 MMACS (one million times by adding manipulation per second), and peripherals are rich, is the guarantee of system performance to satisfy the requirements of real-time and high-speed processing image data. The human-computer interaction selects the ATMEL Company's AT89C52 type single chip microcomputer to control keyboard and display. To meet the needs of real-time data acquisition, sorters lead to the serial port connected to an epigenous machine. This system utilizes C8051F020 MCU UART0 port connected with the epigenous machine. Due to the TTL level of MCU, the computer does not match the output level of the single-chip microcomputer such as the electrical specification of RS - 232 standards. So we choose the MAXIM company specially designed for computer serial port RS - 232 standard level conversion chip MAX232.

In addition, this system utilizes the EEPROM to storage system-related features such as banknote's magnetic security line signal, ultraviolet signal, infrared signal and thickness signal. This system utilizes the FLASH to storage system-related of driven code and algorithm code such as clutch drive, device driver and main motor drive. This system also realizes magnetic security line signal, ultraviolet signal, position sensor state, and the output of switch control signal by using CPLD [15]-[18].

Hardware component diagram of paper currency sorting is shown in Figure 2.

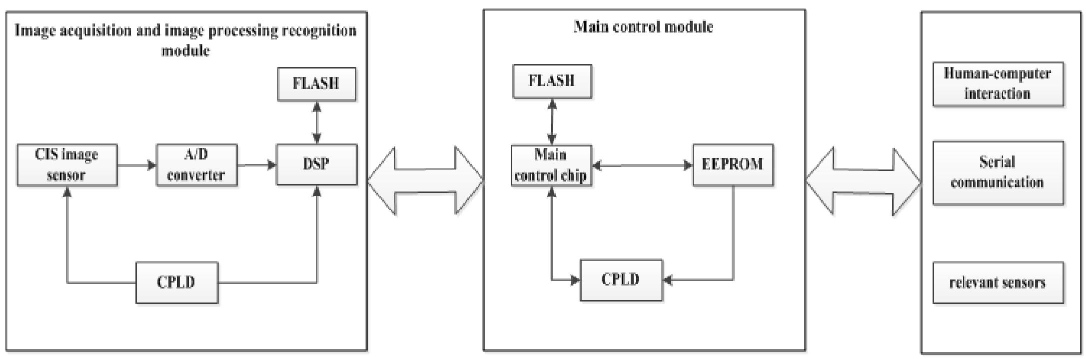

Figure 2. Hardware component diagram of paper currency sorting subsystem

5. Software Implementation

5.1. Software Control Implementation of Paper Currency Sorting Subsystem

The paper currency sorting subsystem consists of paper currency sorting, image acquisition and image recognition processing. The working principle of the subsystem is after power up, the program first enters the boot initialization state, and then into the status of self-checking. If self-checking passed, the program gets into the standby state of keyboard setting, otherwise enter the state of failure shutdown. In the standby state, if there are banknotes in sorter without failure, and there is no failure, it will enter running state. The tip of the human-computer interaction interface of the sorter will become a "beginning", sorter start automatically after 2 seconds. The main motor runs about 1 second after the driving motor starting, sorter begins to take the banknote counting. By detecting the switch signal of infrared counting sensor, the program determines whether the beginning or end of image data acquisition. At the same time, the program starts the CIS image sensor and the A/D converter to complete the banknote image acquisition. Then according to parameters, the program identifies the banknotes, and starts the DSP interrupt service to conduct the recognition of types of banknotes, denomination, oriented, watermark, dirty degree, defect area, adhesive tape and other abnormal banknotes and authenticity of banknotes. Eligible banknotes get into the top outlet, and unqualified banknotes enter the bottom outlet, and counterfeit banknotes or abnormal banknotes get into the middle outlet. When there are not banknotes in platform, sorter automatically stop running after 5 seconds. When outlet counting reaches the preset number, sorter automatically stops running and sends sound and light tips. When something is wrong, the sorter human-computer interface will be displayed "abnormal", all banknotes need recounting. When faced with the jam banknotes, the sorter will spontaneously stop running. After the shutdown command issued, the driving motor stops running, 3 seconds after the main motor stops running. When reaching the preset number of stops, if machines have paper currencies, sorter opportunity to start automatically. Whether qualified or not, unfinished banknotes enter the middle outlet. Sorters collected paper currency digital information which is sent to the management control subsystem after completing the work every time.

Paper currency sorting subsystem activity diagram is shown in Figure 3.

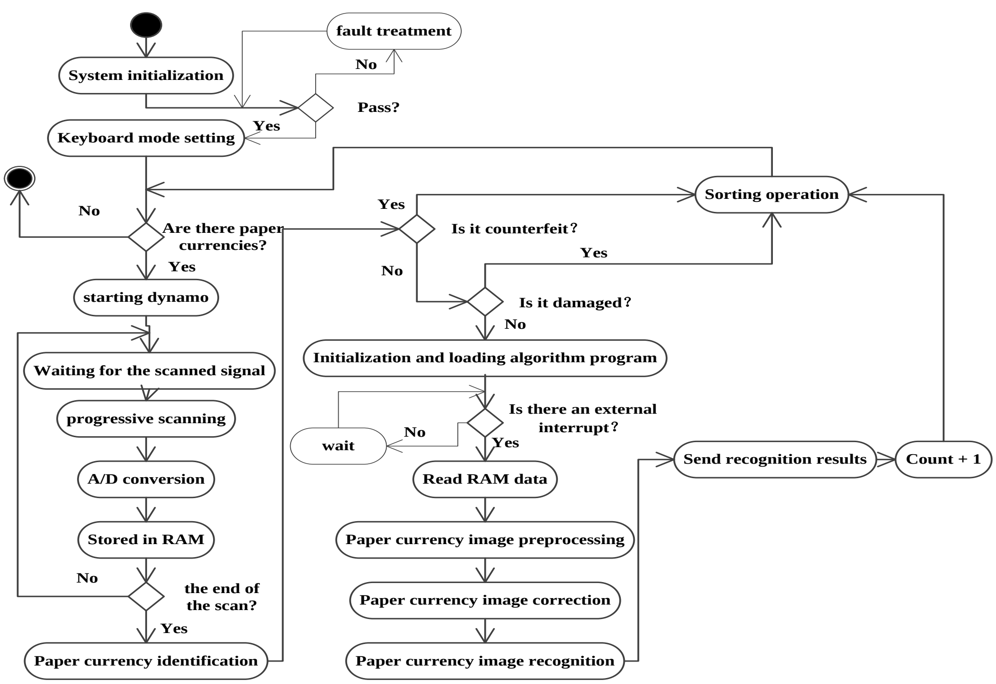

Figure 3. The activity diagram of paper currency sorting subsystem

5.2. Communication Mechanism

Communication mechanism in this study consists of two parts, one is the communication between image recognition and the main control, the other is the communication between epigenous machine and hypogenous machine. Implementation method of communication between the image recognition and the main control is shown in Figure 4.

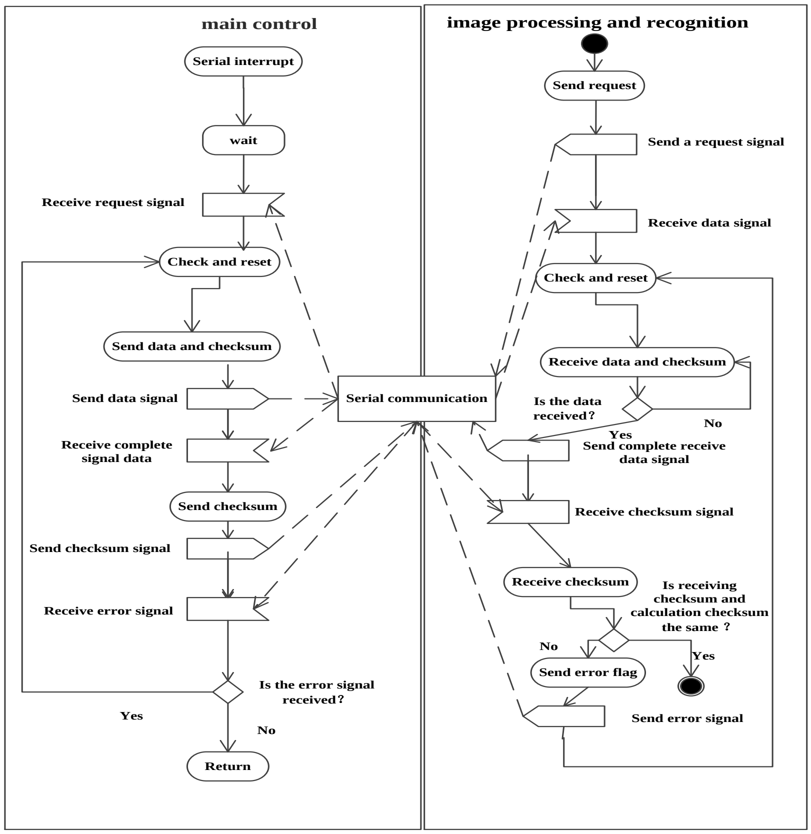

Figure 4. The activity diagram of the communication between image recognition and main control

Method of communication between epigenous machine and hypogenous machine is realized with the serial port of each sorter for real-time communication, epigenous machine through serial port real-time communication with all paper currency sorters. Therefore, when the management control subsystem working, MSComm serial communication control should be allocated to guarantee real-time communication.

In implementation of the serial communication between paper currency sorting subsystem and management control subsystem should be to develop a protocol for communication between the two sides. In addition, authors also define the communication data format as showed in Figure 5.

starting tag	machine number	year, month, day	week	hour, minute, second	preset number	total number of banknotes	cumulative number	number	bottom outlet counting	top outlet counting	common state	currency	status flag	ending tag

Figure 5. Data format

Follow defined communication protocols and data format, the two sides can be carried out in serial communication. Because of the amount of code to achieve and limited space, only part of the source code of the MSComm control initialization and data sent and received is given.

- **Initialize the MSComm control program is as follows:**

```
MSComm1.CommPort = 1
MSComm1.InputMode = comInputModeBinary
MSComm1.InBufferCount = 0
MSComm1.Settings = "57600, n, 8, 1"
MSComm1.InputLen = 0
MSComm1.InBufferSize = 3072
MSComm1.PortOpen = True
MSComm1.RThreshold = 1
MSComm1.SThreshold = 1
MSComm1.InBufferCount = 0
MSComm1.OutBufferCount = 0
```

- **Part of send data program is as follows:**

```
Dim comm（1 To 78）As Byte
Dim command As Variant
……
command =comm
MSComm1.OutBufferCount=0
MSComm1.Output= command
MSComm1.InBufferCount=0
……
```

- **Part of data receiving program is as follows:**

```
……
Select Case MSComm1.CommEvent
Case comEvReceive:
Dim receive() As Byte
Dim i As integer
Dim count As integer
Dim Receive As Variant
Receive= MSComm1.Input
count=UBound(Receive)
ReDim receive(count-1) As Byte
```

```
For i=0 to count-1
receive(i)=Receive(i)
Next i
……
```

5.3. Implementation of Management and Control Subsystem

Management and control subsystem includes sorter running state, sorter parameters display, sorter parameters settings, business statistics reports and print, currency in circulation queries, single business manipulation, sorter workload statistics and print, user management, and database backup and recovery.

Due to space limitations, authors only illustrate the implementation of single business manipulation as an example. Single business manipulation is achieved mainly by calling the single business manipulation module in VB programming language design and implementation.

The amounts of reconciliation are assigned to control srje. The numbers of scattered currency are assigned respectively to the control hb100, control hb50, control hb20, control hb10 and control hb5. The single business manipulation module obtains sorters counting value and assigns to control qfje, completes the relevant data type handling and then clicks on the button to call cmdks_Click () to judge whether the reconciliation successful.

- **Part of code is as follows:**

```
Private Sub cmdks_Click()
If Not RS1.EOF Then
RS1.MoveLast
 If RS1!bz = 99 Or RS1!bz = 96 Then
 If Val(RS1!k1) * 100 + Val(hb100.Text) * 100 + Val(hb50.Text) * 50 + Val(hb20.Text) * 20 + Val(hb10.Text) * 10 + Val(hb5.Text) * 5 = Val(srje.Text) Then
 MsgBox " success！！"
 Command1.Enabled = True
 Else
 Form4.Show
 End If
 End If
 ……
End Sub
Private Sub form_load()
Command1.Enabled = False
If CONN.State = 1 Then CONN.Close
CONN.CursorLocation = adUseClient
```



```
CONN.ConnectionString = "Provider=SQLOLEDB.1; Persist Security Info=False; User ID=sa; Initial Catalog=RS232; Data Source=R50E"
```

Table1. Test environment

Name	Quantity
Computer	1
Paper currency sorter	16
Data distribution box	1
Data line	30

Table 2. Epigenous machine configuration

Name	Configuration
Memory	2 GB
CPU	Pentium (R) Dual-Core E5700 (dual 3. 00GHz)
Operating System	Windows XP
Database	SQL Server 2005

```
CONN.Open
RS1.Open "select * from qfj", CONN, adOpenDynamic, adLockOptimistic
If Not RS1.EOF Then
 RS1.MoveLast
 If RS1!bz = 99 Or RS1!bz = 96 Then
qfje.Text = Val(RS1!k1) * 100 + Val(hb100.Text) * 100 + Val(hb50.Text) * 50 + Val(hb20.Text) * 20 + Val(hb10.Text) * 10 + Val(hb5.Text) * 5
 End If
……
End Sub
```

6. Experimental Results and Analysis

Paper currency sorting process management system involves paper currency sorting manipulation, real-time display of sorters information, sorter parameter display and setting, single business manipulation, business statistical reports and other functions. To detect real-time data-acquisition capacity, stability and performance status of the paper currency sorting process management system, authors use modern methods of software testing on paper currency sorting process management system with systematic testing and performance testing. Test environment and epigenous machine configuration are shown in Table 1 and Table 2 respectively.

6.1. Paper Currency Sorting Subsystem Test

In this test, we selected 500 banknotes (each denomination banknotes 100) each accounting for 50% of the old and the new banknote. And then the sorter inventories, distinguishes different denomination banknotes, identifies genuine and fake, distinguishes damaged banknotes (mixed methods) several times. The experimental results are shown in Table 3.

Table 3. Experimental data in paper currency sorting process

Type	Quantity	Identification number
Genuine and fake identification	100	99
Distinction denomination banknotes	100(￥100)	100
	100(￥50)	100
	100(￥20)	100
	100(￥10)	100
	100(￥50)	100
Distinction damaged banknotes (mixed methods)	100	99
Counting	100	100

From Table 3, we can see that testing correct rate and recognition rate are more than 99%, mostly at 100%. The test results show that the paper currency sorter conforms to China's industrial standards and performance indicators.

6.2. Management and Control Subsystem Test

The design functions of management and control subsystem were tested, with paper currency sorting subsystem test data as the principal test data. Each function test result is in accordance with the correct manipulation and error manipulation. Test results show the management control subsystem fully realizes the function of design, and the error manipulation has obvious hints.

7. Conclusions

This article focuses on the practical application of paper currency sorting process and researches on the design of the paper currency sorting process management system. The system realizes the design goals, improves work efficiency, and provides an effective solution to develop the financial information, and to build "digital finance". This paper describes the system used in paper currency sorting process management and control. According to the needs of the bank check center, this system can also be extended to develop different applications such as information analysis of the characteristics of faked money, information analysis of RMB circulation. Thus, this system in the financial sector has a broad market application prospect.

Acknowledgements

The authors would like to express their most sincere thanks to Anshan Bozong Science and Technology CO., LTD for the support to this research.

References

[1] H. F. Luo, "Research on the image processing system of currency sorter", M.S. thesis, Zhejiang University, Hangzhou, ZJ, P.R. China, **(2005)**.
[2] G. C. Walsh and Y. Hong, "Scheduling of networked control systems", IEEE Control systems magazine, vol. 21, issue 1, **(2001)**.
[3] J. X. Guo, J. Q. Yu, and F. F. Yan, "Image Preprocessing and Feature Extraction Based on Real Estate Archives Retrieval", Journal of Information & Computational Science, vol. 10, no. 1, **(2013)**.
[4] Y. F. Jiang, "Research on Image Characteristic Recognition of Paper Currency", M.S. thesis, Harbin University of Science and Technology, Harbin, HLJ, P.R. China, **(2008)**.

[5] Z. Y. Wei, "Research on Image Recognition Algorithm of Paper Currency", M.S. thesis, Harbin University of Science and Technology, Harbin, HLJ, P.R. China, **(2009)**.
[6] J. F. Liu, S. B. Liu, and X. L. Tang, "An Algorithm of Real-Time Paper Currency Recognition", Journal of Computer Research and Development, vol. 40, issue 7, **(2003)**.
[7] Y. H. Pan and R. Fan, "A Wavelet Neural Networks License Recognition Algorithm and Its Application", Journal of Computers, vol. 7, no. 7, **(2012)**.
[8] J. Zhi, J. Y. Liu, H. Yuan and G. H. Wu, "Design of Simulated Pattern Painting Based on Image Segmentation and Recognition Method", Journal of Software, vol. 6, no. 11, **(2011)**.
[9] H. Zhao, L. Hu, X. J. Peng, G. J. Wang, F. Yu and C. Xu, "An Improving MFCC Features Extraction Based on FastICA Algorithm plus RASTA Filtering", Journal of Computers, vol. 6, no. 7, **(2011)**.
[10] S. Li, J. R. Luo, Y. C. Wu, G. M. Li, F. Wang and Y. Wang, "Continuous and Real-Time Data Acquisition Embedded System for EAST", IEEE Transactions on Nuclear Science, vol. 57, issue 2, **(2010)**.
[11] D. Seto, J. P. Lehoczky, S. Lui and K. G. Shin, "On Task Schedulability in Real-Time Control Systems", Proceedings of the 17th IEEE Real-Time Systems Symposium, **(1996)** December 4-6; Washington D.C., USA.
[12] W. J. Sheng and A. H. Guo, "Design of New Structural Health Monitoring System Based on First in First out", Journal of Computer Applications, vol. 31, issue 12, **(2011)**.
[13] Y. H. Zheng, "Development of a Ubiquitous Industrial Data Acquisition System for Rotogravure Printing Press", Journal of Networks, vol. 6, no. 11, **(2011)**.
[14] Y. G. Zhang and J. Liu, Principle and Application of MCS-51 Single-Chip Microprocessor, Harbin Institute of Technology Press, Harbin, **(2008)**.
[15] Universal Technical Requirements of RMB-Banknote Discriminating Device, GB 16999-2010, **(2010)**.
[16] L. Qiu, S. J. Wang, J. H. Yin, and X. W. Xin, "Vertical Three Currency Sorter", P.R. China Patent ZL200720010793.0, **(2008)** February 6.
[17] L. Qiu and S. J. Wang, "Desktop Currency Sorter", P.R. China Patent ZL200820131665.6, May 27 **(2009)**.
[18] W. Chen, and Y.H. Zhao, "System for Discriminating Counterfeit", Techniques of Automation and Applications, vol. 22, issue 3, **(2003)**.

Authors

Bo Wang was awarded his Master’s degree from University of Science and Technology Liaoning. He is now a lecturer at the School of Applied Technology in University of Science and Technology Liaoning. His research interests include artificial intelligence and software engineering.

Liqun Liu is a Senior Engineer of Sino steel Anshan Research Institute of Thermo-energy CO., LTD; his research interests include systematic analysis and information management and information system.

Lin Qiu is a Senior Engineer of Anshan Bozong Science and Technology CO., LTD; his research interests include MCU application development.