

## Research on Extracting Workpiece Screw Hole Coordinates by Using CH376 in Screws Fastening Machine

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### Abstract

In order to solve the problem that the degree of automation is not high when the screw machine obtains the coordinates of the workpiece screw hole and the data accuracy is difficult to guarantee, a new method is proposed to obtain the coordinate of the workpiece screw hole by observing the form of the workpiece screw hole. The paper analyzes the drawing file of the workpiece in DXF format, studies the application example of the file management control chip CH376. In this method, CH376 is used to enumerate the DXF file in the user's U disk. according to the constitution rule of DXF files, an algorithm is given to check the additional string matching the whole sentence one by one byte. The method subdivides the read data as much as possible, and use it to find out the graphic element information in the specified file. After the graphic element information is transmitted to the STM32 controller, the controller selects the coordinate data that meets the requirements by using the judgment conditions of screw hole shape, graph element attachment relationship, screw national standard specification and so on. Finally, the result is stored in E2PROM chip 24C16 to prevent data loss after power failure. The experimental results show that the proposed method can successfully extract the screw hole coordinates of workpieces with high precision and speed. The process does not need human participation, thus improving the efficiency of screw fastening.

### Keywords

File management and control chip; Drawing documents; STM32; Memory chips.

## 1. INTRODUCTION

Many industrial products require screws for fastening, Therefore, the fastening of workpiece screw is an indispensable segment in industrial production. In order to improve the fastening efficiency of the workpiece screws, each enterprise has installed automatic screw- fastening machines on their own production lines. For the automatic screws fastening machine, the performance of obtaining coordinate data of workpiece screw holes determines the advantages and disadvantages of the machine. If the machine is slow to obtain the workpiece screw holes coordinates, it will slow down the overall production speed of the production line and reduce the output; Or The inaccurate location of the screw hole of the workpiece obtained by the machine will damage the processed products and increase the production cost of the enterprise. Therefore, it is very important to adopt a set of reasonable methods for obtaining workpiece screw holes to participate in the work of screw machine.

At present, many experts and scholars have studied and realized the method of obtaining workpiece screw holes coordinate data. For example, the automatic screw fastening designed by Lin Min et al, which enable the main controller to obtain relevant data by inputting screw holes coordinates into the HMI (Human Machine Interface) system Interface. Although the method is easy to come ture, it is necessary to measure the workpiece before inputting the screw holes coordinates, Which undoubtedly prolongs the acquisition time of workpiece screw holes data, and the accuracy of measuring holes varies from person to person. Huang et al [2-3] use the method of handle teaching to align the workpiece screw hole with the electric nozzle so as to obtain the coordinate data of the workpiece screw hole. The method combines the measurement and input steps together, which shortens the acquisition time of screw holes data, But the operation handle still needs manual participation, the degree of automation is low. Zhang et al[4]introduced machine vision technology, using industrial cameras to calibrate the location of workpiece screw holes. The method is more accurate to obtain screw holes coordinates data, and the working process can be automated. However, the operation of complex machine vision algorithm has higher requirements on the controller, which increases the input cost.

In conclusion, there are generally two methods of extracting the workpiece screw holes by screw machine in the market. One is to input the coordinate of the workpiece screw holes through manual teaching, and the other is to use machine vision technology to identify the screw hole. On the basis of summing up the experience of predecessors, this paper presents a method of automatically extracting the coordinates of workpiece screw holes based on reading DXF files by CH376. The new method abandons the tedious operation like manual teaching. At the same time, compared with the machine vision method, the new method can run on a relatively low-cost controller, which can effectively reduce the production costs. Moreover, since the coordinates data of the workpiece screw hole is directly extracted from the drawing file without any environmental intervention, the precision of extracted workpiece screw hole coordinates is very high, which further improves the fastening efficiency of the workpiece screw, and provides a reference for the upgrading and transformation of the screws fastening robot on the production line. In conclusion, this method has a broad application prospect.

As shown in figure.1, The screw hole coordinates extraction method based on CH376 is mainly composed of three parts: data communication, file management and data storage. In the data communication part, the CH376 file management and control chip uses the serial interface SPI to transmit data with the controller STM32. After extracting the screw hole coordinates, the main controller STM32 interacts with the E2PROM chip 24C16 by the I2C bus. In file management, CH376 needs to enumerate the file names of each DXF format in the user's U disk. After the user selects the required file, CH376 will extract the image elements from the selected file, and then feed the extracted meta-information back to the main controller, the controller analyzes the received image elements information. Finally, in order to ensure that the data will not be lost after power failure, and to facilitate the follow-up screw locking operation of the machine, The data storage part is established.

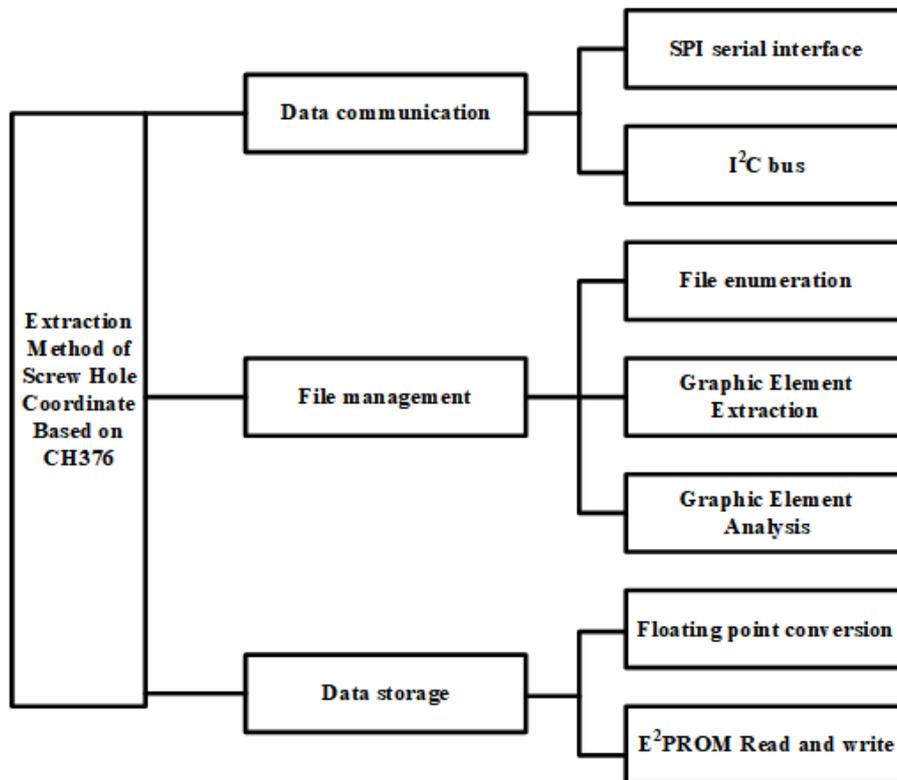


Figure 1. Method block diagram

## 2. THE SCREW HOLE COORDINATES EXTRACTION

### 2.1. Application of CH376 in Screw Hole Coordinate Extraction

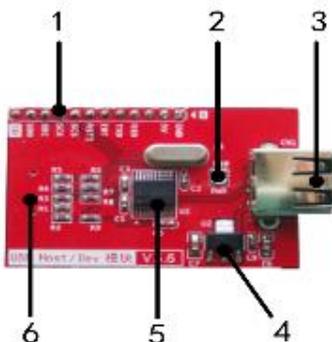


Figure 2. Physical diagram of CH376 module

The physical diagram of CH376 module used in this design is shown in Fig. 2, 1 control/data interface, 2 power instruction, 3 usb base, 4 3.3v regulate power supply, 5 CH376 chip, 6 cassette .CH376 is a low-power file management and control chip which can provide file creation, deletion, reading and writing functions, and can realize 1.5Mbps low-speed communication and 12Mbps full-speed communication. This CH376 chip is often used in In embedded systems such as single-chip microcomputer, It has built-in USB underlying transmission firmware program, FAT file system management firmware program and BulkOnly protocol transmission firmware program. The operation of CH376 includes four layers: file system layer, command layer, transport protocol layer and hardware interface layer. In this design, the hierarchical diagram of the internal structure of the master and slave devices is shown in Figure 3.

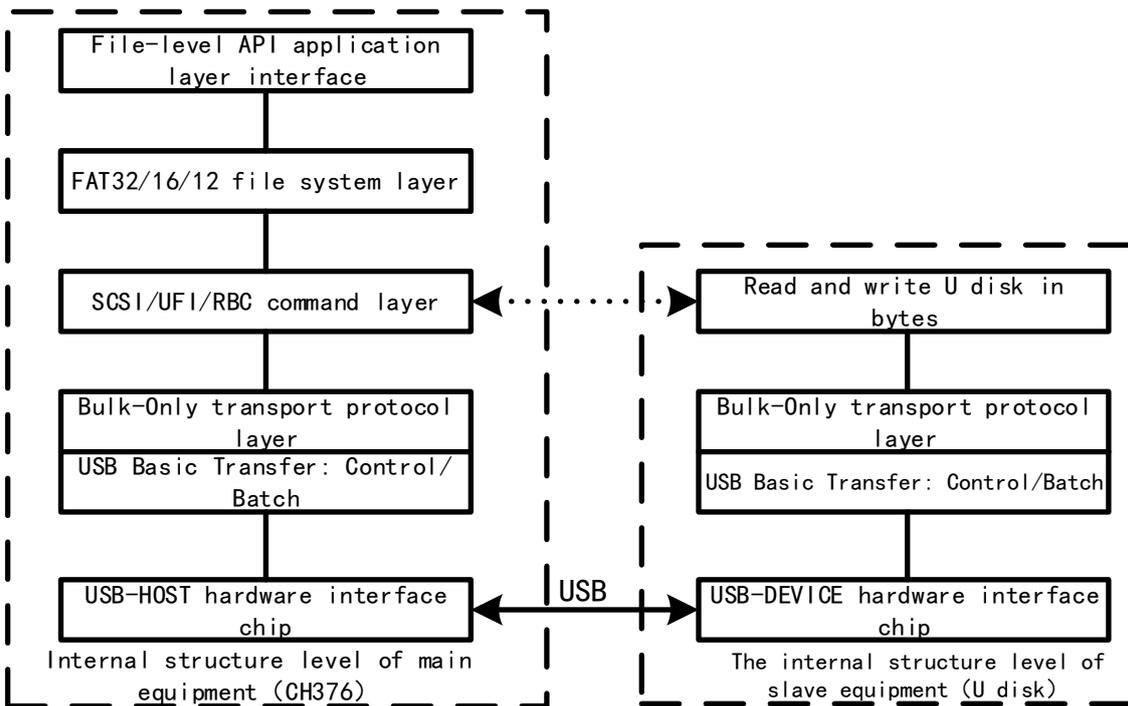


Figure 3. The hierarchical diagram of the internal structure of the master and slave devices

2.1.1 CH376 Communication and Initialization

The CH376 module provides three communication modes: 8-bit parallel port, SPI (synchronous serial port), and UART (asynchronous serial port). In this method, the 2MB/24MHz speed SPI interface is used to communicate with the controller. The SPI includes SDI (data input) and SDO (Data output), SCK (clock signal), SCS (chip select) 4 buses, and CH376 module also has INT# (interrupt request output port). Connect this port to the external interrupt of the controller to directly query the current status of the chip. The communication diagram between CH376 and the system is shown in Figure 4.

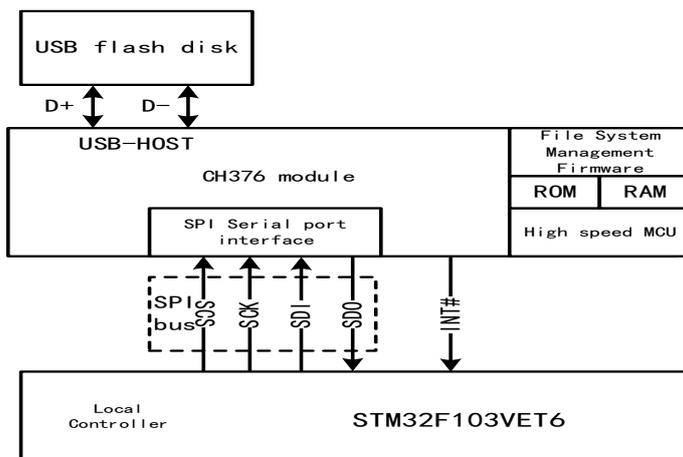


Figure 4. The communication diagram between CH376 and the system

CH376 initialization is a necessary step before any file operation. First of all, the CMD\_CHECK\_EXIST order is used to test the communication interface and working state of the module. The command requires the controller to input 1 data to CH376. If the data feedback by

the chip is Bit-by-bit inversion of input data, It shows that CH376 can work normally. Second, the controller calls the CMD\_SET\_USB\_MODE command and sends the mode code 06H to enable the USB host mode. At this time, CH376 will generate SOF packages automatically. Finally, In the USB host mode, using the CMD\_DISK\_CONNECT command to check whether the U disk is connected in real time. When the U disk is connected successfully, CH376 will request an interrupt from the controller. It is worth noting that after detecting the U disk connection, the disk must also be initialized using the CMD\_DISK\_MOUNT command and test whether the disk is ready. The initialization process of CH376 in this method is shown in Figure 5.

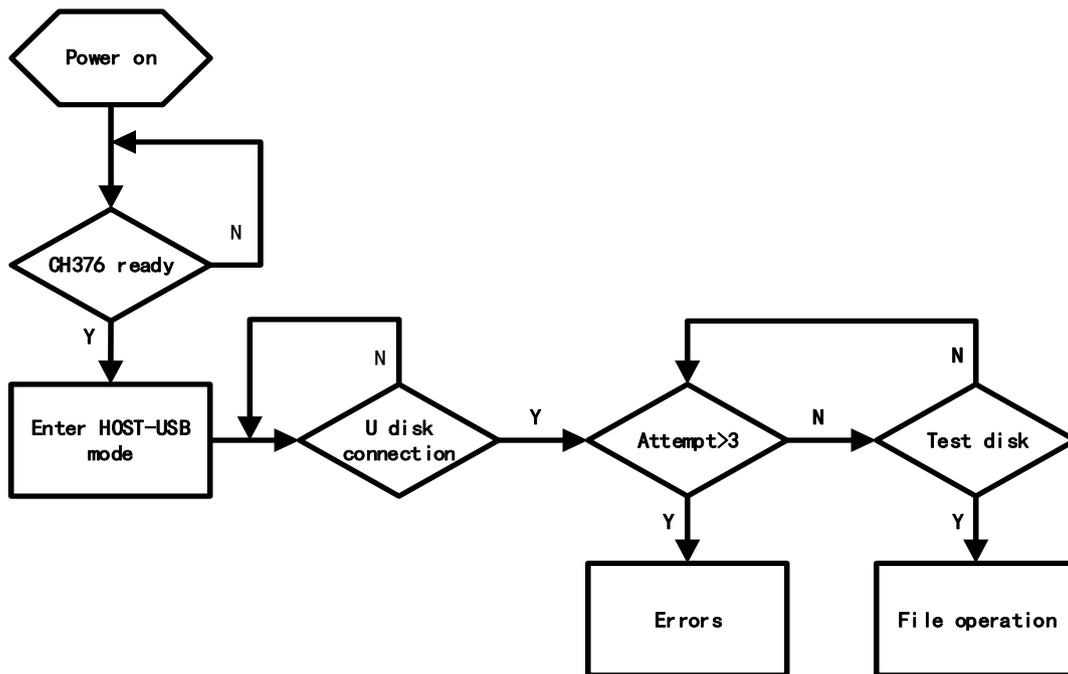


Figure 5. Initialization flow chart of CH376

2.1.2 Enumeration and Reading of Drawing Files

Before operating the workpiece drawing files, it is necessary to enumerate the related drawing files to provide users with view and selection. When enumerating the workpiece drawing files, calling the CMD\_SET\_FILE\_NAME command in conjunction with the use of wildcard character "\*" are used together. The "\*" can replace all or part of the characters in the file name that need to be queried. In this method, the string "/" is used to enumerate all the files in the root directory, and then use the CMD\_RD\_USB\_DATA0 command to read the FAT file directory, the feedback data is stored in the form of a structure, which contains information about file attributes, file names, file length and so on.

The specific FAT file information structure is as follows:

```

typedef struct _FAT_DIR_INFO
{
    UINT8 DIR_Name [11]; // 00H, File name,11 bytes in total, filling in blanks
    UINT8 DIR_Attr; // 0BH, File properties, refer to the following instructions
    UINT8 DIR_NTRes; // 0CH
    UINT8 DIR_CrtTimeTenth;// 0DH, File creation time, counted in 0.1 seconds
    UINT16 DIR_CrtTime; // 0EH, Time of File Creation
}
    
```

```

UINT16 DIR_CrtDate; // 10H, Date of file creation
UINT16 DIR_LstAccDate; // 12H, Date of the last access operation
UINT16 DIR_FstClusHI; // 14H
UINT16 DIR_WrtTime; // 16H, File modification time, refer to the previous
MAKE_FILE_TIME
UINT16 DIR_WrtDate; // 18H, File modification date, refer to the previous
MAKE_FILE_DATE
UINT16 DIR_FstClusLO; // 1AH
UINT32 DIR_FileSize; // 1CH, File length
}
FAT_DIR_INFO, *P_FAT_DIR_INFO; // 20H
    
```

Selecting the corresponding element in the file information structure for analysis and processing, enumerating the DXF format file, displayed it by the touch screen, and providing the user with further operations. When the user selects the appoint DXF file, First of all, using the CMD\_FILE\_OPEN command to open the corresponding file, Second, calling the CMD\_BYTE\_READ command to read the data blocks in the file in bytes, and Combining CMD\_BYTE\_LOCATE byte location command with CMD\_BYTE\_RD\_GO byte continue reading operation command. Finally, the primitive information used in reading the DXF file is traversed and transmitted to the controller for primitive analysis. The drawing file enumeration and reading program design. The design process is shown in Fig.6.

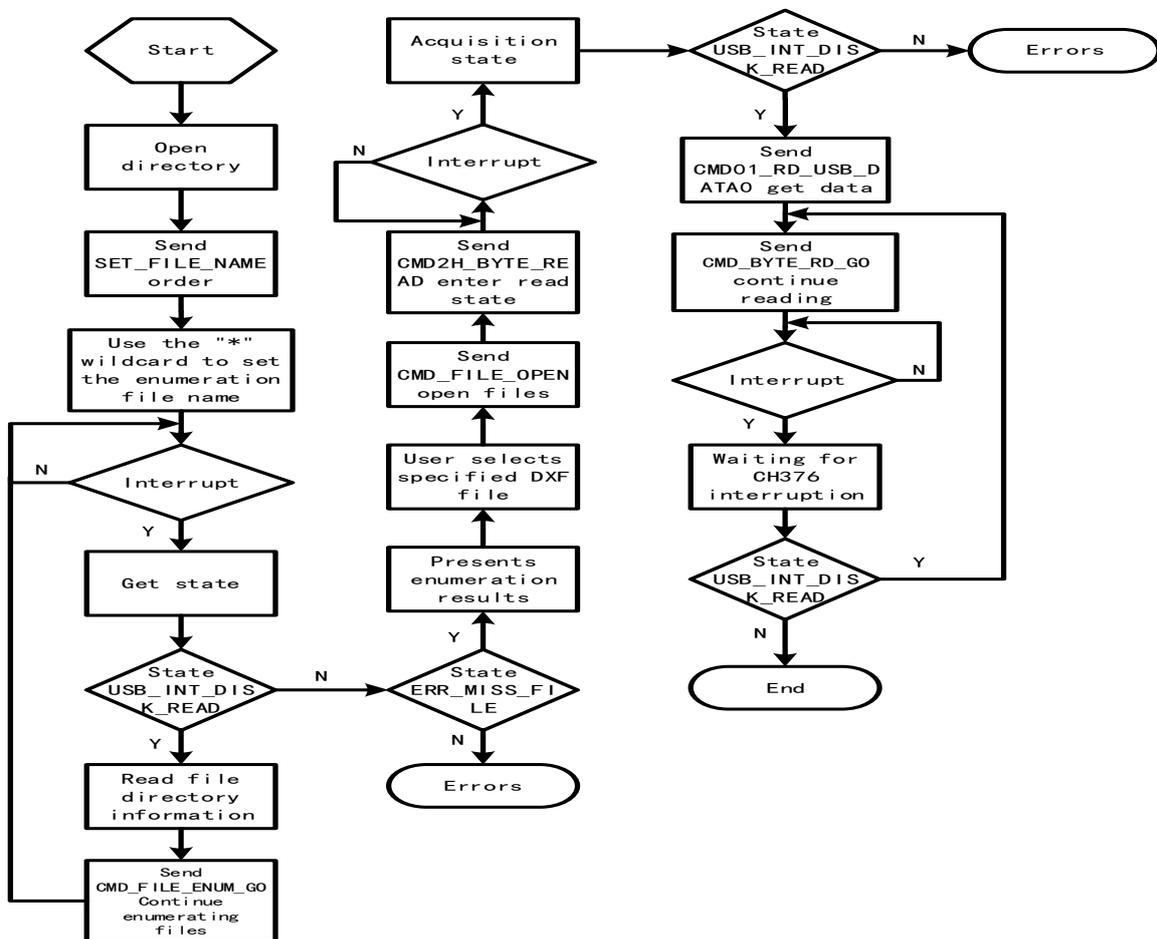


Figure 6. Drawing file Enumeration and reading programming flow chart

## 2.2. Analysis of Screw Hole Coordinate Information in DXF File

### 2.2.1 Introduction to DXF files and element search

The DXF file is a standard open vector data exchange file format developed by Autodesk Company. It can restore the workpiece graphics by extracting and analyzing its internal primitive information. [5] Since AutoCAD is widely used in the industry, DXF files are also called the standard of the CAD industry. The DXF file used in this method, which is an ASCII type with good readability. The whole DXF file is composed of 6 segments and 1 end-mark of the file, which are title segment HEADER, class segment CLASSES, table segment TABLES, block segment BLOCKS, Entity segment ENTITIES, and object segment OBJECTS. In this method, we mainly focus on the entity segment of DXF file, because it contains important graph element information such as arc, straight line, and circle, etc.. The meanings of each group code and group value in the entity segment are shown in Table 1.

**Table 1.** Entity Segment Code and Number Meaning

Keyword	Code	Meaning
LINE	10,20,30	X,Y,Z starting coordinates
	11,21,31	X,Y,Z end coordinates
	10,20,30	X,Y,Z center coordinates
ARC	40	radius
	50	starting angle
	41	end angle
LWPOLYLINEL	90	number of vertices
	10,20	X,Y vertex coordinate
CIRCLE	10,20,30	X,Y,Z center coordinates
	40	radius

In order to improve the accuracy of the primitive information search, it is necessary to subdivide the read DXF file data as much as possible. For this purpose, and the algorithm for checking the additional string matching the entire sentence is searched one by one for the primitive search. The algorithm is according to the rule that the DXF file's group code and value occupy a single line in the text format. When CH376 reads the DXF file data in bytes, every byte of data read out is immediately stored in the controller SRAM, If you read the byte "\n", that is, the carriage return sign, it proves that you have read a complete line of data, and then by comparing the strstr string matching function of C language with the key words of the required graphic elements, you can distinguish the required graphic element titles. The required primitive title is discriminated. Since the DXF file's group code and group value appear in pairs, the relevant parameters of the required graphic elements can be obtained successfully by this algorithm. Let the variables STR1 and STR2 be character arrays, which are used to store group values and group codes respectively. The flow chart of the search algorithm for graphic elements is shown in Fig. 7.

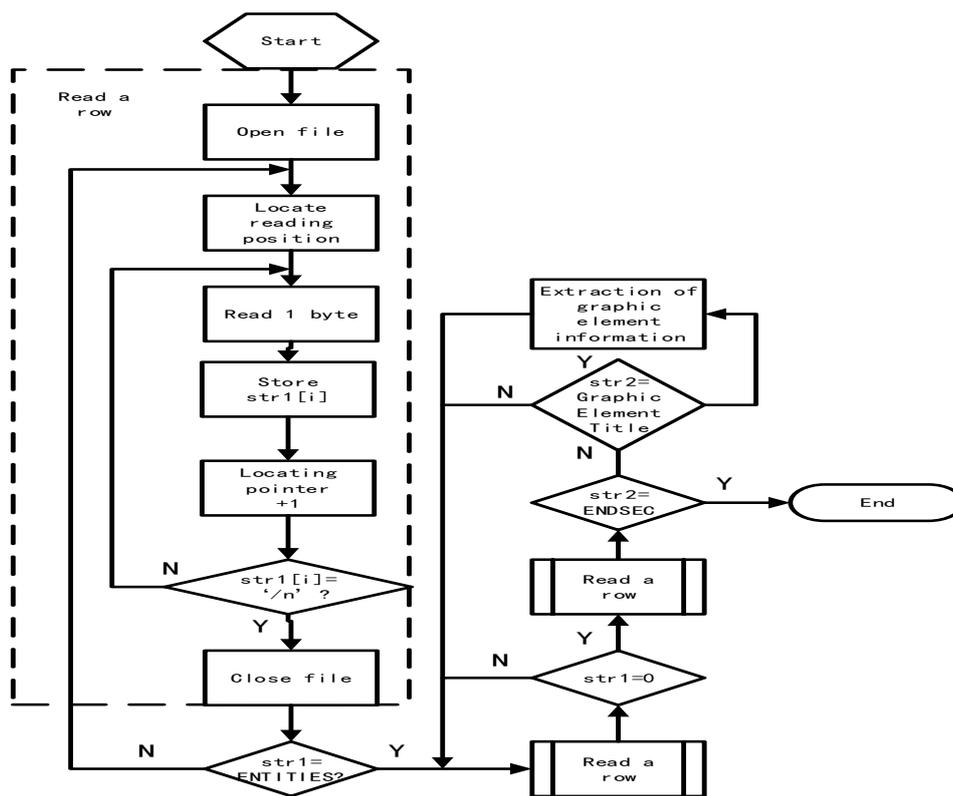


Figure 7. Flow chart of graphic element search algorithm

2.2.2 Analysis of Graphic Elements Related to Screw Holes

All graphic element information found from the DXF file may not be all usable data. Some of the results may be only interference line segment, decorative graphics, other functional modules and other non-relevant workpiece screw hole graphic element information. Therefore, in order to analyze the specific coordinate data of workpiece screw holes, it is necessary to observe the characteristics of workpiece screw holes, and find out the rules of identifying screw holes. In this paper, the process of analyzing screw holes related graphic elements in this method is explained to the reader by taking the mobile phone packaging back shell as an example. The CAD diagram of the mobile phone packaging back shell is shown in Fig.8.

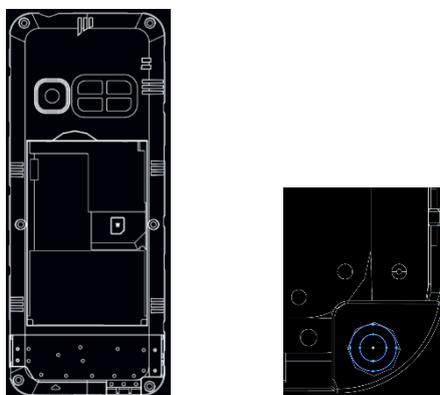


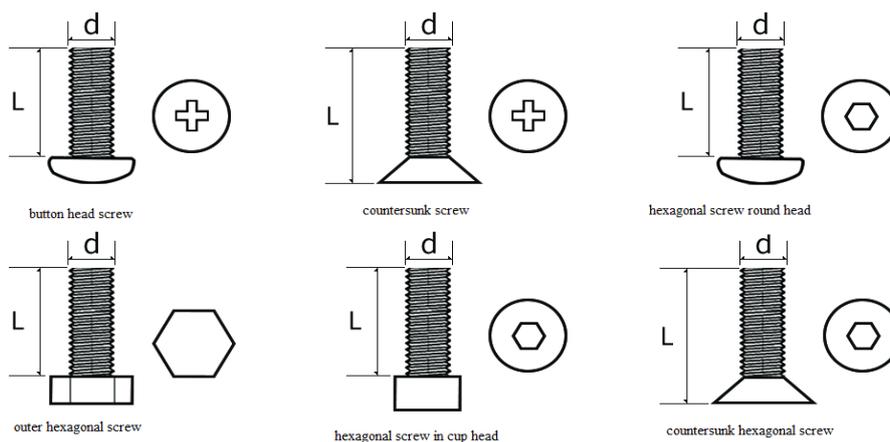
Figure 8. Mobile package back shell CAD diagram

It can be seen from Fig. 9 that the screw holes of the workpiece are all circular in image shape, but it is still impossible to accurately analyze the correct screw holes by relying on this feature.

As shown in the figure, there are other circular patterns on the back of mobile phone package, such as cell phone heat sink holes, which are not screw holes. Therefore, it is necessary not only to analyze the shape of graphics, but also to analyze the dependence relationship between graphics, the various commonly used screw diagrams shown in Figure 9, it can be seen that the screw is composed of nut and screw. The diameter of the nut is larger than the screw, So when qualified of workpiece CAD is drawn, engineers will draw the position of nut and screw according to meet the actual needs, Therefore, the screw hole is a concentric circle with a large or small circle nested in the figure. Figure 9(b) shows two concentric circles in a partially enlarged view of the CAD of the mobile phone package back shell, but the concentric circles at the top are only interference data, not real screw holes, Therefore, the way of adding concentric circle screening can not fully analyze the screw holes of workpiece. Finally, the national standard specifications of the screw should be added as the criteria to filter out the concentric circles that meet the standard, In this example, the screw of mobile phone packaging back shell mainly uses the national standard M1.4, M1.7 and M2 specifications. The specific parameters of the screw used are shown in Table 2. After investigation, in general, CAD engineers will not draw other functional patterns into the form of screw holes, which is not only easy to cause confusion, but also has no practical value. Therefore, the graphic element analysis algorithm proposed in this method can be used to analyze the screw holes of general workpieces.

**Table 2.** Spec of screw parameter (millimeters)

spec	M1	M1.2	M1.4	M1.7	M2
Screw diameter	1	1.2	1.4	1.7	2
Nut diameter	1.75	1.82	2.43	3.27	3.7
Nut thickness	0.65	0.7	0.98	1.13	1.21



**Figure 9.** Various commonly used screw diagrams

The steps of analysis of screw holes related graphic elements, firstly, the circular CIRCLE graphic elements are selected from all the extracted graphic elements. Secondly, the concentric circles are found by the way of circles center comparison. Finally, the minimum radius of the concentric circles is further selected by introducing the screw parameters as reference values, which are also selected. The circles center is store the screw hole coordinate, and graphic element analysis flow chart as shown in Fig 10.

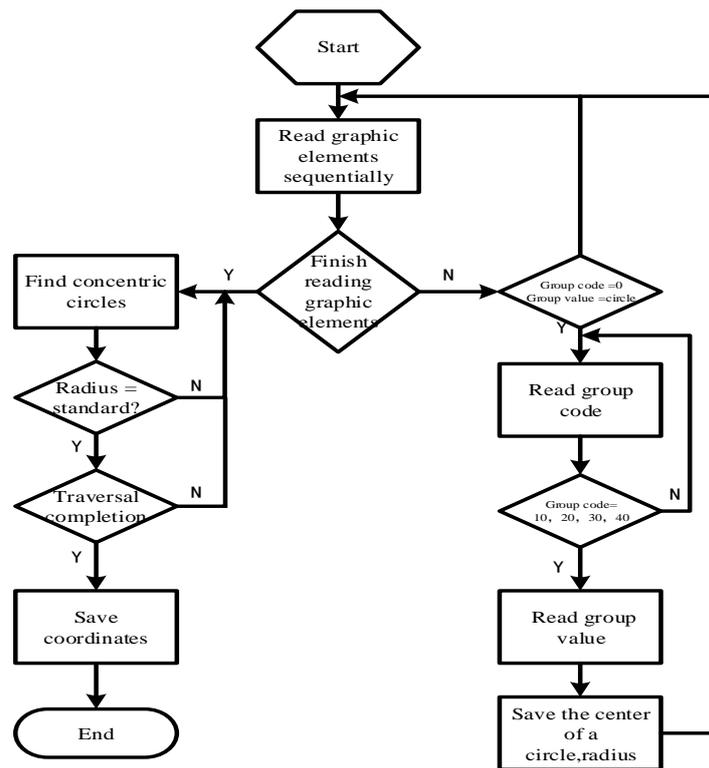


Figure 10. Graphic Element Analysis Flow Chart

### 3. SCREW HOLE COORDINATE DATA STORAGE

Under the cooperation of CH376 file management and control chip and controller STM32, For the first time, the coordinates of workpiece screw holes extracted from DXF files will be temporarily stored in SRAM of the controller. The data in the buffer can be conveniently provided to motor, batch, cylinder and other actuators for workpiece screw fastening. However, when the machine is powered off, all the data stored in the controller SRAM will be lost. If the screw hole coordinate data is needed after the machine is turned on, the relevant data must be analyzed and extracted from the DXF file by CH376 again. This meaningless repetitive operation not only extends the workpiece processing cycle, but also reduces production efficiency. For this reason, the E2PROM memory chip 24C16 connected with I2C data bus is introduced to build the data storage module. It has millions of programming/erasing cycles, preserving data for 100 years without power supply, it has 2048 Byte storage capacity, and store multiple types of workpiece screw coordinate data. The circuit connection of 24C16 is shown in Fig.11.

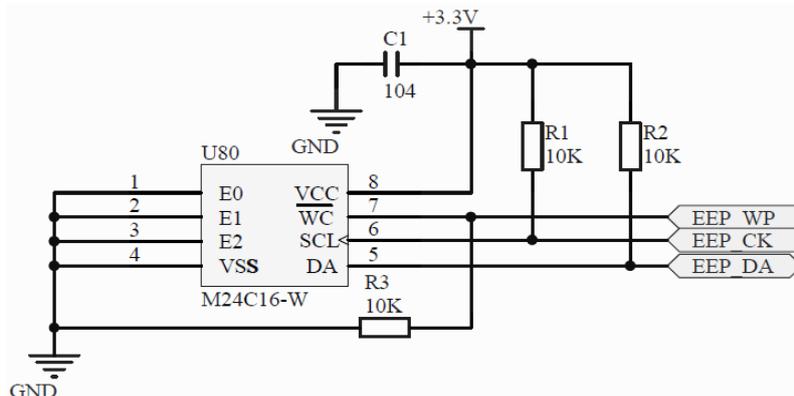


Figure 11. The circuit connection of 24C16

From Figure 12, it can be seen that 24C16 has eight pins, of which pin 7 is a write protection port. When the pin is grounded, it allows data to read and write normally; when connected to VCC, it starts the write protection function and can only read. Pin 6 is the clock input port, the rising edge is written, and the falling edge is read. Pin 5 is a bi-directional serial data transmission pin. Drain electrode open circuit, needing external pull-up resistance to VCC.

The screw holes coordinate data is temporarily stored in the controller RAM in the form of floating point type, while the minimum storage unit of 24C16 is in form of bytes, Therefore, when performing E2PROM write operation, the floating point type data needs to be split into four the bytes are sequentially stored; when the E2PROM read operation is performed, each of the 4 bytes is read and combined into a 32-bit data, which is converted into a floating-point type data, which is convenient for further use by the actuator. The programming flow of the screw hole coordinate data storage module is shown in Fig.12.

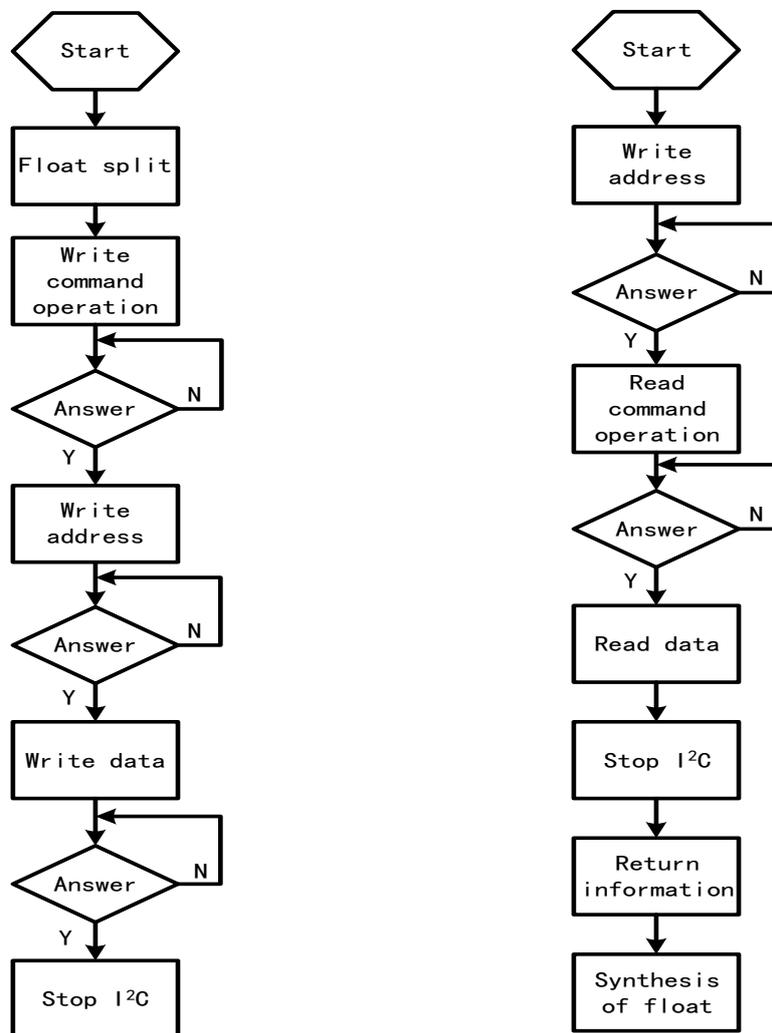
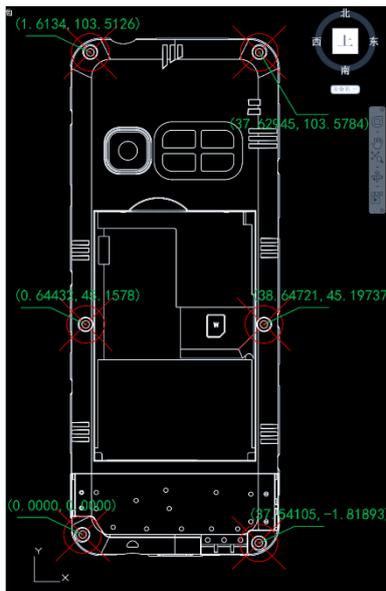


Figure 12. The programming flow of the screw hole coordinate data storage module

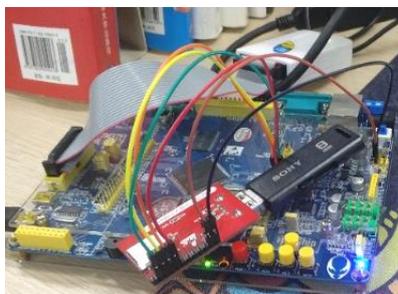
#### 4. SIMULATION AND RESULT ANALYSIS



**Figure 13.** Screw Hole CAD Survey Map

Fig.13 shows the workpiece DXF file opened in the CAD software. Using the mobile phone to encapsulate the back shell as the experimental object, we can see that the mobile phone back shell has six screw holes. The screw holes in the lower left corner are set as reference holes (0,0). At the same time, the coordinates of other screw holes are measured by the software tools. The measured data of these holes are actually the relative coordinates of the actual workpiece, which is used as the comparative data of the experimental results.

Before testing the method, the CH376 module is connected to the SPI serial port of the controller, and the experimental U disk is inserted into the CH376 module. The DXF file of the workpiece shown in Figure 14 is stored in the U disk. Then the control board is connected to the JLINK debugging, Opening the KEIL integrated development platform and download the program to the controller through JLINK. The field test diagram is shown in Fig. 14.



**Figure 14.** The field test diagram

In the process of method validation, firstly, all CIRCLE graphic elements in the entity segment of DXF file are found by CH376, and the data are transmitted to the controller for graphic element analysis. In graphic element analysis, the controller uses concentric circle characteristics and screw specification parameters to select CIRCLE graphic elements that meet the requirements, and the center of the circle is set as screw hole coordinates. Secondly, the extracted screw hole coordinate data are stored in E2PROM in turn clockwise. Finally, in order

to verify the effect of coordinate extraction and E2PROM storage at the same time, restarting the machine after power off, enabling JLINK to enter the hardware debugging state after power-on, setting a breakpoint at the corresponding program statement, and reading Data stored in E2PROM before reading is sent to controller buffer. The results shown in the debug window are shown in Fig.15.

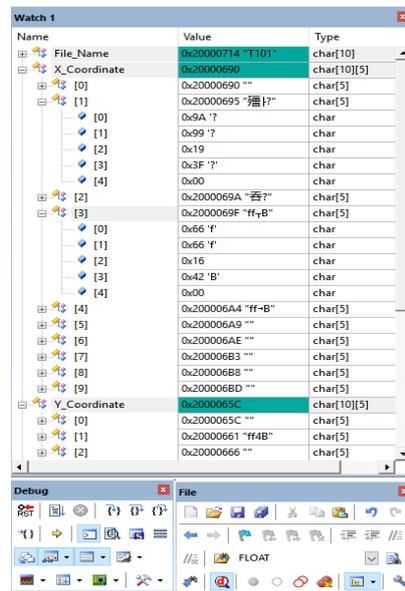


Figure 15. Debugging results

The data collected in Figure15, which is the coordinate data stored in the E2PROM. which is the four single bytes obtained by floating-point splitting. The data is converted to floating-point type and compared with other two commonly used screw hole acquisition methods. Taking the workpiece shown in Fig. 13 as an example, selecting the first hole at the lower left corner of the workpiece as the reference point, and arranging the screw holes clockwise. The statistical comparison data is shown in Table 3.

Table 3. Statistical table of screw hole data obtained by different methods

hole order	manual measuring	teaching	CH376 extraction
1	0.0,	0.05,	0.00,
	0.1	0.08	0.00
2	0.7,	0.68,	0.64,
	45.2	45.18	45.16
3	1.5,	1.58,	1.61,
	103.7	103.66	103.51
4	37.0,	37.56,	37.63,
	104.1	103.77	103.58
5	38.5,	38.60,	38.65,
	45.5	45.68	45.20
6	37.0,	37.37,	37.54,
	-1.5	-1.77	-1.82
Time-consuming	470s	300s	25s

It can be seen from table 3 that the accuracy of the extracted screw hole data is lower than that of the other two screw hole extraction methods due to the manual operation of the manual measuring hole. The data obtained can only retain one decimal place, and the working time is the longest. The teaching method takes about 10 times as long as the CH376 extraction method, and the result of CH376 extraction method is consistent with figure 13. However, the teaching method has the advantage of correcting the field error. When using the CH376 extraction method, the workpiece tray can be adjusted to make the data precision of CH376 extraction approach the teaching method data. In a word, the method proposed in this paper can accurately and quickly extract the screw hole of workpiece, which has higher practical value.

## 5. CONCLUSIONS

At present, some screw hole coordinate data acquisition methods adopted by the screw machine have overcome some practical problems, but they have also derived other shortcomings. On the basis of absorbing the experience of the predecessors, this paper proposes a new screw hole coordinate acquisition method. which uses file management and control chip CH376 to read workpiece DXF files, and analyzing graphic element information. Finally, the specific workpiece screw hole coordinate data are extracted. In order to avoid repeating the previous work after each boot, the data storage module is built by using E2PROM memory chip 24C16. The simulation results show that the method of extracting workpiece screw hole based on CH376 proposed in this paper can accurately extract workpiece screw hole coordinates and store them successfully. The method has high speed and accuracy in obtaining workpiece screw hole coordinates data, improving the fastening efficiency of workpiece screws, and has high social and economic value. It provides a new idea for screw machine to obtain workpiece screw hole coordinates.

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