Design and Development of Test-tube Label Automatic Printing and Pasting System Based on Database

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Abstract. Through analysis of the use requirements of tube labels in the hospital and the existing conditions of the hospital, the overall design of the system was determined. The technical issues, such as the integration of label printing and test-tube labeling, the selection of different types of test-tubes, the handling of the test-tubes with different size, and the acquisition of the information in the database by tag pattern generating software were determined. The purpose of the study is to develop the first full-automatic portable test-tube label printing and pasting system, integrated with printing and pasting, which can be linked with the database platform software. The actual operation of the system indicates that the printing and pasting system is in good condition and could be counted on.

1. Introduction

Test-tubes are common tools for collecting liquid samples from patients in the hospital. Most medical staffs manually paste the label printed by the label printer on the test-tube when collecting the specimen. In some private hospitals or clinics, labels are made by hand-written blank labels. If both the label making and the tube labeling are performed manually, the increasing labels will make the process, more time-consuming and laborious, and the label will be wrinkled and unaesthetic, affecting the reading of the information [1]. Nowadays, the existing test-tube printing and pasting devices in the domestic market are relatively bulky and heavy, and are difficult to transport. Most of these devices are expensive, and it is impossible to select the test-tube model or change the label content in time, and it cannot provide services for different needs in the hospital at the same time. Another type of tube label maker in the market does not have the integrated label printing function, which must be used with a specific type of label printer, and most of the labeling was carried out by manual operation.

In view of the above problems, we have developed an automatic portable test-tube label printing and pasting system. This system consists of a label pattern editing software, automatic test-tube label printing and pasting device which is also divided into a labeling device and a label printing unit. The software can obtain the patients information to generate the label pattern through the database interface on the hospital database platform; the printing and pasting device can print the label pattern on the label and automatically select different types of test-tubes for labeling. After receiving the
control signal of the software, the printing and pasting device can accurately complete the entire work within 3s. The development of the system will reduce the large amount of mechanical labor of the relevant medical staff and improve the work efficiency in the hospital.

In order to complete the six steps shown in figure 1 in full automation, we designed the printing and pasting device shown in figure 2. The device supports the operation of up to three tubes models. The test-tubes of three models are horizontally placed in the three sub-chambers of test-tube selection blank cabin 1. The single working process of the printing and pasting system is like the following. The medical staff scans the barcode of the patient so that the label pattern editing software acquires the patient ID, and the software accesses the patient information and generates a label pattern for confirmation. The print preview interface of the label pattern is shown in figure 3. Then the system determines the type of the test-tube based on the patient's specimens test information, and controls the test-tube blanking in the corresponding sub-chamber of blanking chamber 1, and the test-tube enters into the U-shaped groove of selection cabin baseplate 5. The blanking process is shown in figure 4. In figure 5, the push rod 3 pushes the test-tube in the U-shaped groove into the test-tube clamping and rotating gear 2; Next, as shown in figure 6, the label printing unit 8 prints and sends the label; When the position of the label 11 on the tray paper 9 passes through the limit axis 10, the label 11 is separated from the supporting paper 9 under the action of the tension force and contacts the test-tube in the gap formed between the pressure plate 12 and the test-tube; after that, the test-tube clamping and rotating gear 2 drives the clamped test-tube to rotate, and the label is roll-labeled on the test-tube; the test-tube is finally labeled into the receiver 13. Then the general process of the test-tube label printing and pasting is completed.

![Diagram](image)

**Figure 1.** Route chart of the printing and pasting system.

1. Test-tube selection blanking cabin; 2. Test-tube clamping and rotating mechanism; 3. Push rod; 4. Stepping slide; 5. Test-tube selection cabin baseplate; 6. Drive motor of rotary disc; 7. Drive shaft teeth; 8. Label printing unit; 9. Tray paper; 10. Limit axis; 12. Pressure plate; 13. Receiver; 14. Rotary shaft; 15. Photoelectric switch; 19. Middle frame wall

**Figure 2.** Isometric side view of the test-tube label printing and pasting device.

2. **Functional analysis and whole scheme design of the printing and pasting system**

The working objective of the printing and pasting system in medical test-tubes. After the label is printed, the label is affixed on the surface of the medical test-tube. Requirements: the label pattern editing software can instantly integrate the corresponding patient information and generate the label; the software can send work instructions to the printing and pasting device; the printing and pasting
system can immediately provide different types of test-tubes required for corresponding patients; the entire printing and pasting process is fully automated and labels can be reliably attached to the surface of the test-tube. Based on these new ideas, the printing and pasting device is equipped with a multiple test-tube cabin, and labeling will be carried out by "rotation method", that is when labeling, the front edge portion of the label is adhered to the rotating body of the tube, the label is taken away by the rotation of the bottle to complete the pasting process. The label pattern editing software is developed using the GUI design module in Matlab. At the same moment, the built-in "database" toolbox and the serial interface operation function is used to realize the access of the software to the hospital database and the communication with the printing and pasting device. Based on the working conditions of the hospital, a single operation of the system can be divided into six steps, as shown in figure 1.

Figure 3. Label design preview interface. Figure 4. Blanking process diagram of the test-tube. Figure 5. Process diagram of test-tube pushing process.

2. Test-tube clamping and rotating mechanism; 3. Push rod; 5. Test-tube selection cabin baseplate; 6. Driving motor of rotary disc; 7. Drive shaft teeth; 16. Gear ring
3. Software design of printing and pasting system based on Matlab

3.1. Design of label pattern editing software

It is required that the software can access to the hospital database and acquires data, as well as has the ability to communicate with other devices. The ample toolbox in Matlab perfectly satisfies the software requirements, greatly simplifies the software development process, so we chose Matlab as the development platform for the label pattern editing software. Most hospitals use the SQL server database, which can be accessed via ODBC driver with "database" tools in Matlab. At the same time, the "fetch" function in Matlab can be used to read the data in the database. In addition, series of functions are provided to open and close the serial port as well as serial port parameter settings in Matlab, which can meet the software communication requirements. The "Runtime GUI" application of the Matlab Runtime Server can be used to develop softwares divorced from Matlab environment.

We use the idea of modular design and multi-task management to design the software to improve program execution concurrency. The design process of the label pattern editing software starts with the input of the patient ID, and after the verification of the patient ID, the reading of the patient information, the integration of the patient data to form the label pattern, and finally the final hardware control.

The software completes the input of the patient ID by reading the ID number in the editable text box of the front panel or receiving the signal from the barcode scanner, that is, performing "Front panel input of managing task 1". This process is achieved by calling the "get" function in the driver. After the patient ID is entered, the "fetch" function is called in the driver to complete the patient ID proofing task and the patient data reading task. After the task is completed, call the "set" function to display the patient information in the list box for confirmation, or call the "msgbox" function to pop up the ID input error dialog box. If the patient ID is entered correctly, the bar code generation program is simply run, and the patient information is integrated to form the label pattern. After forming the label pattern, click on the different front panel buttons to execute the front panel management task 2 or 3, convert the pattern information into commands, and the software executes command processing tasks. The command processing task implements the interpretation and execution of legal commands. In this software, the command is sent to complete the control task of the pasting device, or to enter the label pattern editing task. The entire software system is composed as shown in figure 7.

3.2. Interface and use of label pattern editing software

The software login interface is shown in figure 8. After entering the account number and password of the database, the software can be opened and the database can be accessed. The retrieval interface is shown in figure 9. In response to many unexpected situations, two ID input mechanisms are set in the
software, namely barcode scanning input and keyboard input; after scanning the barcode, the patient ID input box will immediately input the patient's ID number, and the medical staff can also choose to use the keyboard to enter the ID number of the patient; after the patient ID number is correctly entered, the patient information is displayed in the lower list box for confirmation by the medical staff. When the patient's ID number is entered incorrectly, the three types of prompt boxes shown in figure 10 will appear. The print preview interface is shown in figure 3. This interface can display a preview of the label pattern to the operator. The operator can also adjust the position, font, and text size of the text and barcode on the label pattern in the window. Figure 11 illustrates the flowchart of the software.

Figure 7. The software system based on multi-task management.
Figure 8. Login interface.
Figure 9. Retrieval interface.
Figure 10. Prompt window.
Figure 11. Procedure of label pattern editing software.

4. Hardware design of the printing and pasting device

4.1. Test-tube clamping rotating mechanism
As shown in figure 12, the test-tube clamping rotating mechanism consists of gear rings 16, elastic media 17, centering ring 22, bearing block 20, rotary disc 21, bearing end cover 18 and three clamps. The rotary disc 21 is fixed on the middle frame wall 19 through the bearing and the bearing block 20; 3 holes in radial direction for mounting clamps is evenly distributed on the outer diameter of the rotary
disc 21. The outer circumference including shaft section of the mounting clamps of the rotary disc 21, together with the three clamps is covered with a layer of elastic medium 17, and at the same time there is a centering ring 22 is put between the middle of the three clamps of the shaft section, the elastic medium 17 and the bearing end cover 18. On the centering ring 22, there are three clamping rails with the same arc. When the clamps move radially along the rotary disc 21, the centering ring 22 rotates. The three clamps are simultaneously at the same speed under the limitation of the sliding wall, so that the test-tube is clamped in the middle. As shown in figure 5, the gear ring 16 is mounted on one of the shaft ends of the rotary disc 21 and is easily connected with the drive shaft teeth 7 on the same side. The drive motor of rotary disc 6 drives the teeth 7 to rotate so that the rotary disc 21 is rotated by the gear pair. When the test-tube is pushed into the centre hole of the rotary table 21 by the push rod 3, the three clamps are squeezed to different positions by the test-tube with different diameters by elasticity, so that the test-tubes of different diameters can be clamped; The test-tube is pushed by the push rod 3 from the U-shaped groove at the end of the baseboard of the test-tube selection blanking cabin 5 to the clamping rotating mechanism through the centre hole of the rotary disc 21.

4.2. Pressure plate mechanism and label supply mechanism

In the device, the labeling is accomplished by the combined action of the pulling of the test-tube on the label and the pressure provided by the pressure plate. To match the clamping rotating mechanism, we designed the pressure plate and label supply whose mechanism is shown in figure 6. The pressure plate consists of a shaft 23 and plate 12, with torsion springs to provide the required pressure for labeling. The label supply consists of limit axis 10, movable guide roller 24, No.1 fixed guide roller 25, No.2 fixed guide roller 26, rotary shaft 14, feed shaft 27, photoelectric switch 15, drive motor of rotary, two guide rails, two pair of spring holders and two reset springs; During the operation, the label printing unit 8 sends the label out. The tray paper 9 spit out a length of label through the export of unit 8, then the tray paper 9 tightly wound on the movable guide roller is automatically relaxed. The movable guide roller 24 fixed on the sliding block moves along the guide rail, toward the proximity sensor of the photoelectric switch 15 under the force of the reset spring. The switch 15 is turned on, which makes rotary shaft drive motor rotates the rotary shaft 14 to re-strain the tray paper 9; Under the tension of the tray paper 9, when the label 11 is brought to the limit shaft 10 by the tray paper discharged from the label printing unit, the label 11 is separated from the tray paper 9 and enters the gap between the pressure plate 12 and the test-tube, for the labelling.

5. Control system design of the printing and pasting system

The control system consists of host computer label design editing software, labeling device control system and label printing unit control system. The STM32F103ZET6 chip is the control core of the device control, which is used to control the motion logic and mechanical actions. The control of motion logic includes: monitoring the position of the test-tube, monitoring the position of the push rod 3 (figure 5) and the tray paper (figure 6). Based on the monitoring signal received by the motion logic
control section, the motor is controlled for the corresponding rotation to complete the mechanical motion control. The coordination between the motion logic control and the mechanical action control is completed by the external interruption of the GPIO in STM32. The main process is that the trigger of the sensor causes the change of the input level of the corresponding IO port, thus triggering the starting or stopping program of the motor in the interrupt service function. After receiving the level signal transmitted by the printing unit control system at IO port corresponding to the STM32, the motor of corresponding test-tube cabin is rotated to complete the blanking of the tube with relevant type, as shown in figure 5. As shown in figure 5, the piezoelectric switch on the U-shaped slot detects the arrival of the tube, the slide motor drives the push rod 3 to push the tube to the clamping rotating mechanism; the push rod 3 is installed with a Holzer switch, and 3 magnetic patches are installed on the reciprocating path of the push rod 3. The starting and reset position of the stepping slide 4 (see Fig. 2) is determined by the induction of the Holzer switch to the patch. For the label supply mechanism, as shown in figure 6, it is also through external interruption that the tray paper 9 is always outside the induction range of the photoelectric switch to ensure the tension of the paper. The label printing unit control system is an fixed control system, in which the independent CPU handles the picture information transmitted by the host computer. When the control system receives the picture information, it communicates through the serial port and the STM32, and the labeling device starts to blank. When the test-tube enters the test-tube clamping rotating mechanism, the STM32 sends the signal to the label printing unit control system, and begins printing labels. The entire block diagram of the control system is shown in figure 13.

6. Experiment and conclusion
In order to verify the physical accuracy and the function of the printing and pasting system, a test prototype was produced based on the software and the control system, and test-tube label printing and pasting experiment was carried out. The prototype is shown in figure 13. Its size and weight make it easy to carry. The medical test-tube with the diameter of 10-20 mm was chosen, and the labelled test-tube is shown in figure 14. The test results suggest that the design of the printing and pasting system is correct in theory. The device can immediately complete the whole process from the blanking to the labeling in 3S, and can accurately print and paste the test-tube label. The test result is shown in table 1.

| Test No. | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  |
|---------|----|----|----|----|----|----|----|----|----|
| Time (s)| 2.91|2.83|2.87|2.76|2.77|2.90|2.93|2.94|2.97|

Given that the test-tube labeling operation in the hospital is still done manually, a portable printing and pasting integration automation system is developed based on the hospital database, and the test prototype is made to achieve the printing and pasting test. The experimental results indicated that the printing and pasting system can efficiently and accurately complete the label printing and pasting. The system is easy to operate, and matches with the hospital workflow. It can effectively liberate medical staff from heavy repeatedly work.
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