Design of digital recognition system based on FPGA

Yu Yuting, Qiao Ya*, Ren Gangqiang, Jiao Jiajun
Anhui Xinhua University, 555 Wangjiang West Road, Hefei, Anhui Province, China
email: qiaoya@axhu.edu.cn

Abstract. Digital recognition has become an important application of image recognition. We design a system, which takes FPGA as the core of hardware, Quartus II as the platform of software development, and uses hardware description language to complete the development. It completes the function of digital recognition. After the image is collected by the camera, the printed numbers in the image are recognized and displayed. Experiments demonstrate our design can achieve above functions on portable devices.

1. Introduction
With the acceleration of social modernization and the rapid development of information science and technology, more and more data need to be input into the computer system. At the same time, the continuous improvement of office efficiency also puts forward the requirements for the speed of information input. The traditional information input speed cannot meet the needs of computer processing speed and office efficiency. The original way of manually entering information has become the bottleneck of improving the efficiency of information processing system, and is gradually replaced by the high-speed automatic entry way. With the rapid development of computer hardware technology, image recognition technology has experienced a process from production to rapid development, and its application scope is more and more wide, covering artificial intelligence, system control, remote sensing data analysis, biomedical engineering, military target recognition and other fields[1-2]. The wide application of image recognition technology has a great impact on all aspects of social development.

Digital recognition is a branch of image recognition, which has developed into an independent research subject. Digital recognition technology involves pattern recognition, artificial intelligence, combinatorial mathematics, computer science and other disciplines, is a comprehensive discipline. According to the classification of recognition objects, digit recognition can be divided into printed digit recognition and handwritten digit recognition. As an important part of information, the recognition effect of numbers largely determines the speed of information input. As a universal symbol in the world, the number is composed of ten numbers from 0 to 9. There are few kinds to be recognized, so the recognition is less difficult. The research on number recognition is helpful to verify some new recognition algorithms and theories. With the rise of information technology, digital recognition technology has made rapid development and application. Now digital recognition theory has been relatively mature, and the recognition accuracy has reached a very high level[3]. Our work is mainly aimed at the specific implementation of these technologies on portable devices.

2. System design requirements
This design is mainly about the recognition of basic printed numbers. This system is based on FPGA hardware constraints to achieve the system design, that is, through FPGA to complete the whole process of digital character recognition system. The system is mainly divided into image acquisition module
(based on camera ov5640), image processing and recognition module, LCD display module and so on. In this system, the following work has been completed:

1. The image acquisition module (ov5640) is initialized by EEPROM.
2. Through the image acquisition module, the collected pixels are stored in SDRAM to complete the data storage.
3. Through the conversion of color space, rgb565 format is first converted to rgb888 and then to YCbCr. Only y (brightness) is extracted for threshold discrimination to realize binarization.
4. The brightness data of row and column are superimposed to realize projection segmentation.
5. Through feature recognition, the corresponding number is displayed on the nixie tube.

3. Hardware design

The hardware design of the system is divided into FPGA core board, memory system, camera and display module, as shown in Figure 1.

![Figure 1 System hardware block diagram](image)

The core board of FPGA is ep4ce10f17c8 of cyclone IV E series. It has 10320 logic units, 414kbits of embedded memory resources, 23 18 × 18 embedded multipliers, 2 general phase locked loops, 10 local clock networks, 8 user IO banks and 179 maximum user I/O.

The memory system of the system adopts the combination of EEPROM and SDRAM. The chip selected for EEPROM module is AT24C64 with a storage capacity of 64kbit (8K bytes); the chip selected for SDRAM is W9825g6KH-6 with a storage capacity of 256Mbit (32m bytes).

ATK-OV5640 camera is selected as the camera. OV5640 is a 1/4 inch CMOS QSXGA (2592 * 1944) image sensor produced by OV (OmniVision) company. It provides a complete 500W pixel camera solution and integrates the auto focus (AF) function. It has very high cost performance.

The display module is RGB TFT-LCD, and the ATK-4342 RGBLCD module is 4.3 inch LCD with a resolution of 480 * 272.

4. Software design

4.1. Block diagram of software design

The software is designed on quartusII15.0 platform by combining VHDL with Verilog HDL. The software system is divided into clock module, SDRAM read-write control module, camera initialization module, camera acquisition module, LCD screen driver module, color picture and binary picture switching module and digital recognition module, as shown in Figure 2.

![Figure 2 System software block diagram](image)
PLL clock is selected as the clock module to provide driving clock for I2C driver module, LCD module and SDRAM controller module; The SDRAM read-write control module is responsible for writing and reading user data into the off chip SDRAM memory; Camera initialization module is divided into I2C driver module and I2C configuration module, which is used to initialize OV5640 image sensor; The camera acquisition module is responsible for collecting the camera image data and writing the image data into the SDRAM read-write control module; LCD screen driver module is responsible for selecting LCD color display mode and driving RGB TFT-LCD display. The color picture and binary picture switching module selects whether the picture is binary or not by pressing the key. At first, the collected signals are color pictures, which can directly display the collected data on the LCD screen. If pressed the key, you can switch to the binary black-and-white image to recognize the printed numbers, and display the discriminated numbers on the nixie tube according to the digital characteristics. When you press the key again, you can return to the color image; the digital recognition module is used to complete the recognition of printed numbers and display the results on the display screen and nixie tube.

4.2. Realization method of digital recognition

In this design, the recognition algorithm of printed numbers is realized by binarization, projection segmentation and recognition of digital distribution according to digital features.

Binarization converts RGB to YCbCr by color conversion, extracts the luminance component as Y, and binarizes by threshold discrimination. The result of binarization is shown in Figure 3.

Figure 3 Result of picture binarization

Projection segmentation is to use an array to count the number of black pixels in each line of the binarized image, select an optimal threshold, and use an array to record the coordinates of the corresponding Y axis according to whether it is greater than the threshold. If it is horizontal cutting, we only need the cutting point of the vertical axis, the width is the width of the image by default, and the height can be obtained by subtracting the adjacent cutting points. Optimizing the cutting point can clear all the near cutting points. Finally, set the sensing area to cut the image. According to the digital features to identify the number is as shown in Figure 4, with y in the middle of the number, and X1 and X2 at 2/5 and 2/3 from the upper boundary. If there are focal features in the following table with the three lines, as shown in Table 1, the corresponding discrimination is carried out.

Figure 4 Digital feature recognition principle
Table 1  Digital feature recognition table

| Number | y | x1 | x2 |
|--------|---|----|----|
| 0      | 2 | 1  | 1  |
| 1      | 1 | 1  | 0  |
| 2      | 3 | 0  | 1  |
| 3      | 3 | 0  | 0  |
| 4      | 2 | 1  | 1  |
| 5      | 3 | 1  | 0  |
| 6      | 3 | 1  | 0  |
| 7      | 2 | 0  | 1  |
| 8      | 3 | 1  | 1  |
| 9      | 3 | 1  | 0  |

5. System test results
After debugging, the system can complete the real-time image acquisition and binary processing, and display on the LCD screen, as shown in Figure 5. It can also complete the recognition of printed numbers, and display the recognition results on the LCD screen and seven segment nixie tube, as shown in Figure 6.

Figure 5  Color pictures and binary pictures collected by camera

Figure 6  Digital image recognition results

6. Conclusion
We design a portable digital recognition system based on FPGA. Experiments show that the system has good recognition effect and is easy to reuse.

Acknowledgment:
This work was supported by the demonstration course EDA technology of Anhui Province in 2020, the key scientific research project of Anhui Education Department (KJ2019A0869) and the Anhui Provincial Quality Engineering Project (2018ylzy073).
References

[1] Wang H, Feng L, Sun Y.Z. (2007) Research and design of digital character-based CAPTCHA decoder. Computer Engineering and Applications, 43(32):86-87.

[2] Song W.J, Dong C.L. (2007) Handwritten digit recognition research of receipts. Central China Normal University.

[3] Wu J.L. (2006) Digital recognition and its application. Huazhong University of science and technology.

[4] Zhai Q.G, Liu Q, Li T.T, et al. (2020) Research and implementation of adaptive digital feature recognition system based on FPGA. In: 17th China Aviation TT & C Technology Annual Conference. Xi’an: Shaanxi.

[5] Jiang S.Y. (2018) Research and implementation of automatic recognition algorithm for printed number of machine printed invoice. Beijing University of technology,