Journal of Southeast University (English Edition) Vol. 23, No. 2, pp. 232 – 235 June 2007 ISSN 1003—7985

Design of fuzzy number recognition based on embedded system platform

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Abstract: A system of number recognition with a graphic user interface (GUI) is implemented on the embedded development platform by using the fuzzy pattern recognition method. An application interface (API) of uC/OS-Ⅱ is used to implement the features of multi-task concurrency and the communications among tasks. Handwriting function is implemented by the improvement of the interface provided by the platform. Fuzzy pattern recognition technology based on fuzzy theory is used to analyze the input of handwriting. A primary system for testing is implemented. It can receive and analyze user inputs from both keyboard and touch-screen. The experimental results show that the embedded fuzzy recognition system which uses the technology which integrates two ways of fuzzy recognition can retain a high recognition rate and reduce hardware requirements.

Key words: embedded system; multi-task concurrency; number recognition; fuzzy position transformation

Computer-aided character recognition has important and extensive usage in real life. At present, a few well-developed products have emerged in some regions. However, there are several problems which need to be researched.

Arabic numerals are the figures which are used all over the world. The research of handwritten Arabic numeral recognition is of a very important practical value involving character recognition. Now, the embedded systems are becoming an integral part of our daily lives. Implementing recognition of handwritten numbers on the embedded terminal will provide an easy way of input in many applications. In order to make a primary exploration into the more sophisticated embedded mobile interaction systems, we carry out development orienting these applications based on our experiment platform.

As a kind of advanced recognition technology, fuzzy pattern recognition is used more and more abroad in the field of modern computer technology. Especially, concerning handwriting palmtop computer products, this function must be supported.

1 Design of the System

The system development is based on the platform of the Hm701ESP experiment system, and its architecture is shown in Fig. 1[1].

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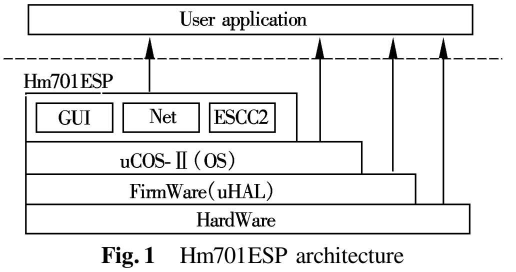

Fig. 1 Hm701ESP architecture

environment, which contains GUI API and uC/OS-Ⅱ API, and the micro hardware abstract layer (uHAL) and hardware API can be used directly. This design ensures the flexibility of the system (Failure from the upper layer does not affect the IRQ operating in the lower layer)[2].

In order to make the multi-task concurrency effective, we use uC/OS-Ⅱ API to create the tasks. The initialization is the same as that of conventional embedded systems. First, the system is started up by the initialization code (like the BIOS in a PC). Secondly, the system initializes the OS and the main task and then a suitable environment is built which means that all of the settings have been completed. Finally, the uCOS is started, and the main task creates the subtasks to launch the whole system[3].

Fig. 2 shows the relationship among the tasks. Link A shows that the system will be restarted by a system message which is sent by the key-scan task or the touch-operating task. Link B shows that the touch-operating task controls the LCD according to the touched area on the touch-screen. Link C shows that the key-scan task sends a key message to the key operating task. Link D shows that any user operation in the system resets a counter. Link E shows that when the

Received 2006-12-26.

Foundation item: Pre-Research Project of the National Natural Science Foundation of China supported by Southeast University (No. XJ0605227).

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counter increases to a fixed value, the counter operating task sends a system message to make the system run in the energy saving mode[4].

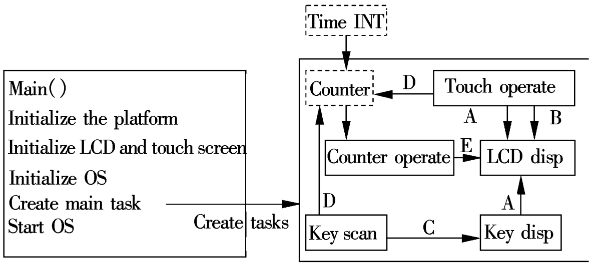


Fig. 2 The relationship among tasks

Since the method of handwriting has not been provided in the GUI API library, we implement it ourselves. The method is as follows: When there is no operation on the touch-screen in any other period of time, the system scans the IRQ of the touch-screen. When the touch IRQ is received, the touch-screen interface obtains the physical coordinates, and converts them to logic coordinates and then saves them in a data structure, or saves (− 1, − 1) when there is a no-touch-condition. This process will save coordinates continuously. As coordinates are derived, the system draws a line from the latest coordinate to the preceding coordinate[1,5]. All the processes above are executed 125 times per second; therefore, the thread can be drawn flowingly (see Fig. 3).

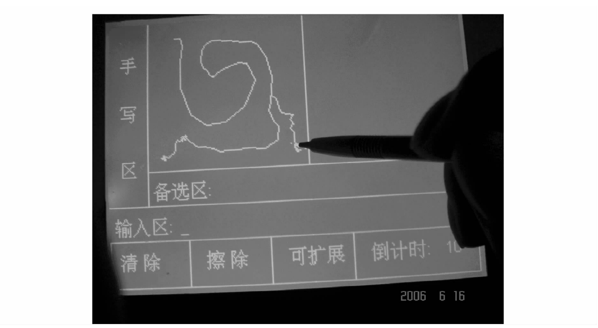


Fig. 3 Drawing thread

Drawing a flowing thread on the screen requires a fast and complex process, so we do not use a message queue. We combine these operations in one task.

All consumer inputs are saved in a char array. When a figure is inputted, the prompt is cleared and the figure is displayed at the same position. Then the prompt is displayed at $X\_$ coordinates +8. Making a blank, deleting input and using the enter key are realized by the same principle. Exception processes are also included.

The interrupt timer3 used by the system needs initialization before it runs. Some registers should be accessed first. We use uHAL_RegisterISR function in the firmware(uHAL) layer to link the IRQ to process function Timer3_Done(). This system uses the interrupt timer3 provided by the development platform. By accessing the related registers, the timer generates an interrupt every 0.05 s. The Interrupt function performs only two tasks: setting interrupt response byte and adding 1 to the counter[2].

2 Design and Implementation of Fuzzy Pattern Recognition Algorithm

There are only ten kinds of Arabic numerals and the strokes are also simple. However, experimental results show that the recognition rate of numbers is actually fairly low. One important reason is that there is little font information regarding these numbers. The writings and the fonts of different numbers are similar, and people in different areas write by hand in different ways. In practice, the accuracy demand of number recognition is stricter than that of word recognition. It is a fact that there is no simple scheme which can provide us with a high recognition rate and accuracy[6]. Therefore, we did some research in this field and in this paper we present a new method combining fuzzy recognition with structure analysis.

There are two basic ways in handwriting fuzzy recognition: the matrix method and the method of fuzzy position conversion.

The principle of the matrix method is as follows. First, we put one figure in a pane, then divide it into smaller panes, and then set appurtenant values u_{ij} to each small pane. If the part of the figure is in one small pane, we set it to 1. If the part of the figure is not in this small pane, we set it to 0. Subscript i and j show the numbers of the rows and the columns. Finally, we obtain a matrix which records the fuzzy relationship. While the recognition process is running, the matrix is converted to a vector based on the above principle, and the vector is compared with the standard vector by the fuzzy arithmetic to obtain the result. For example, in Fig. 4, the number 5 can be converted to the vector {111111, 110000, 111110, 110011, 000001, 110011, 011110}[7-8].

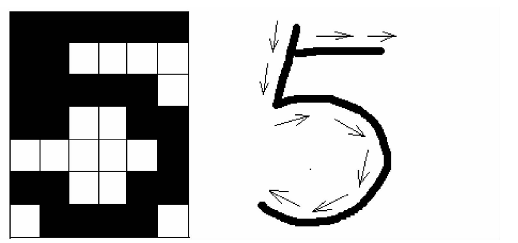


Fig. 4 Two different principles

The method of fuzzy position conversion is described as follows. We design the code for every standard direction first, and then we put the inputed figure in a pane (the pane's direction cannot be changed as shown in Fig. 5).

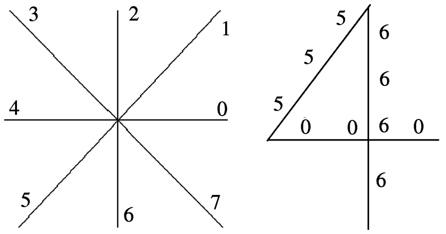


Fig. 5 Fuzzy position conversion

As shown in Fig. 5, there are eight directions which are represented by 0, 1, 2, …, 7. For instance, the number 4 can be converted into the vector set: {5, 5, 5, 0, 0, 0, 6, 6, 6, 6}. If the direction derived from that in the figure is different from that in the standard library, it will be mapped to the standard direction by the appurtenant function[7-8].

In order to recognize handwritten numbers, we need to design a standard fuzzy direction library of the numbers and store them in the memory. There are two principles of fuzzy arithmetic which we can choose from: the direct max appurtenant principle and the indirect approaching principle. We choose the direct max appurtenant principle because we recognize only one figure at a time here.

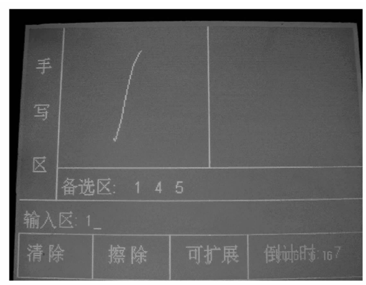
Since the embedded system's performance and memory capabilities are lower than those of a common PC, using only one algorithm in recognition can cause the following problems: ① There is a large library in the memory (especially in Chinese character recognition); ② It costs much time for the embedded CPU to compare input figures with every standard library. Considering these factors, we decide to utilize the combination of the two fuzzy arithmetics in our system: ① We use the fuzzy position conversion to classify the numbers; ② We use the matrix function to recognize the numbers.

The basic process of the fuzzy number recognition system is as follows. At the beginning of recognition, the system uses the fuzzy coordinates conversion to classify the number based on the first stroke at the first 0.3 s. According to general writing custom, we classify the 10 numbers into 3 parts: the part which contains 1, 4, 5 (direction 5 & 6 in Fig. 5), the part which contains 2, 3, 7 (direction 0 & 1 in Fig. 5), and the part which contains 6, 8, 9, 0 (direction 3 & 4 in Fig. 5). The system selects the standard library based on the classification (see Fig. 4, the black part corresponds to the standard "1", the white part corresponds to the standard "0"); then the system recognizes the figure by the position matrix function. We define a 7×6 matrix to describe the input reseau. When there is a point in the input reseau we set 1 to the corresponding element in the matrix and set 0 when there is not such a point. Then we convert the matrix to the fuzzy vector according to the following method: Treat line i of the matrix as the component i of the vector[9]. Then we use the following available fuzzy formula:

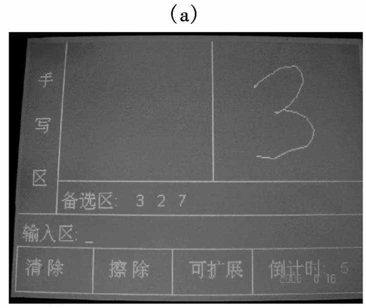
$$L(M_i, D) = \sum_{k=1}^{42} [(U_{M_i^k} \wedge U_{D^k}) \vee (\overline{U}_{M_i^k} \wedge \overline{U}_{D^k})]$$

where $L(M_i, D)$ is the approaching degree, M_i is the standard vector (i), and D is the fuzzy vector we obtain. $\wedge$ represents the operation obtaining the smaller value of the two operands, and $\vee$ represents the operation obtaining the greater value. Then we obtain the input approaching degree[10]. We choose three numbers whose approaching degrees are highest to be the available choices. The process is necessary for: 1) avoiding false recognition and 2) providing other choices to users. The relationship between successful recognition rates and personal writing habits is obvious. Size, width and font change also influence the recognition rate. Hence, the standard library should be improved regularly.

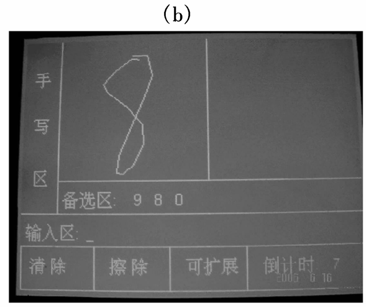
Fig. 6 shows the primary performance pictures. The inputted figure "8" is narrow at its lower half part. So the first choice which the system outputs is a 9. In



(a)



(b)



(c)

Fig. 6 The primary performance

order to avoid the input character being too large, too small or not at the center of the input area, we must explain here that, when a character is inputted, the system is designed to obtain the character's maximum and minimum coordinate values on the *X/Y* axis and convert the input area into a standard size, and in this way the recognition rate can be improved.

However, there remain some uncertainties. Otherwise, the standard we follow to confirm the end of the input of one character is that there has been no input for 2 s. Actually, it is a waste of time having to wait 2 s between every two inputs. In order to solve this problem, we provide two input areas. When one figure is waiting for recognition, we can write a figure in another area. In this way we can make input efficiency more effective.

3 Conclusion

The top level of domestic embedded handwriting recognition equipment can recognize figures at discretional bulk or position on the touch-screen, while the key technology is the enterprise's business secret. This paper uses fuzzy mathematics to analyze the technology. We find that the recognition rate is high. And the combination of two kinds of recognition functions can reduce the requirements of system configuration.

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基于嵌入式平台的数字模糊识别技术的实现

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摘要:在嵌入式开发平台上实现具有图形用户界面(GUI)的模糊模式数字识别系统.使用嵌入式操作系统 uCOSⅡ编程接口实现系统的多任务特性与任务间的通信;通过改进开发板附带的触摸屏接口函数实现手写输入;基于模糊数学的基本理论与方法,使用模糊模式识别技术分析手写输入的数据.在嵌入式开发平台上完成了一套实验性的支持手写输入的用户图形界面系统,该系统可以接受和处理用户通过键盘或者触摸屏输入的信息.实验结果表明,采用 2 种模糊识别技术相结合的嵌入式手写输入系统能在降低系统硬件配置的同时保持较高的识别率.

关键词:嵌入式系统;多任务并发;数字识别;模糊方位转换

中图分类号:TP311.52