신경망을 이용한 지문인식 임베디드 시스템 설계에 관한 연구

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Study on Design of Fingerprint Recognition Embedded System using Neural Network

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요 약

지문인식 알고리즘에서 전처리 과정 중 방향성이 추출된 지문에서 블록을 형성하여 각 블록에서의 방향성 특징들을 신경회로망의 입력패턴으로 사용하여 학습을 시켜, 특이점을 추출하여 매칭에 이용했다. 이를 바탕으로 지문인식 임베디드 시스템을 설계하여 다양한 응용 시스템에 이용될 수 있도록 하기 위해 컨트롤 보드와 시리얼 통신을 통해 테스트한 결과 충분한 신뢰성을 입증할 수 있었다.

ABSTRACT

We generated blocks from the direction-extracted fingerprint during the pre-process of the fingerprint recognition algorithm and performed training by using the direction minutiae of each block as the input pattern of the neural network, so that we extracted the core points to use in the matching. Based on this, we designed the fingerprint recognition embedded system and tested it using the control board and the serial communication to utilize it for a variety of application systems. As a result, we can verify the reliance satisfactorily

키워드

Fingerprint Recognition, ARM, Neural Network, Minutiae, Singular Point

Ⅰ. INTRODUCTION

As the very high-speed communication network has been rapidly supplied and the e-commerce has been regularized via internet in the modern information society, the importance of security is significantly brought into relief. Unlike the previous era when computer was used only for the purpose of main information management of company, group or nation, every individual can use computer in these days to utilize various information thanks to the development of information technology and the expansion of information system. In these information utilization fields, even the information which should maintain the security is sent/received in the Internet environment. Accordingly, computer-related security accidents frequently occur, so the need for security is demanded to protect valuable information, and the importance has been also rapidly increased. To solve it, many information protection technologies have been developed. One of them is

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the bio-recognition, which is the advanced field using the minutiae of a living body and has been actively researched. Since 9/11 terrors, the bio-recognition has been applied to the immigration control such as airport or harbor in the world, in order to protect its nation from diverse types of terrors.

The bio-recognition is the front technology recognizing a person by using his/her body minutiae including face recognition, vein recognition, iris recognition, retina recognition, voice recognition, DNA recognition, fingerprint recognition etc.[1] The bio-recognition can be implemented on computer or on stand-alone. For the bio-recognition on computer, the bio-recognition system is built in the portions, where security is required, stand-alone bio-recognition means the bio-recognition embedded system where the technology implemented on the computer is made as an independent system by means of microprocessor.

The bio-recognition has been developed from the security system on computer to the embedded system using the bio-recognition technology. Currently, it is used in access control, home-purpose door lock or Immigration Office in airport and harbor, and it will be developed as a wireless recognition method using mobile communication in near future. Therefore, in this paper, we used the fingerprint recognition that is most actively among the bio-recognition fields and ensures the stability as well as the commerciality. In this research, we formed the fingerprint recognition algorithm for the individually-unique ridge flow and the feature out of minutiae by means of the neutral network, which is one of the artificial intelligent methods, and implemented the fingerprint recognition embedded system by using the ARM process, which is presently applied to PCS terminals or mobile phones.

This paper consists of Chapter 2 where the fingerprint recognition technology is introduced. Chapter 3 where the fingerprint recognition algorithm and the neutral network applied fingerprint recognition algorithm is introduced. Chapter 4 where the design and the test result of the fingerprint recognition embedded system is introduced. Chapter 5, as a conclusion, where the performance examination and the future research direction of the fingerprint recognition embedded system is suggested.

Ⅱ. FINGERPRINT RECOGNITION TECHNOLOGY

Even twins have different fingerprints. According to the research so far, the probability to have a same fingerprint is 1/4 billion, so it can be said that there is no persons who have same fingerprints on the earth. The fingerprints have two characteristics called minutia and singular point. Generally, the minutia has ending point, bifurcation, short ridge, isolated point and crossing point while the singular point has delta and core point. In addition, the sensor receiving the input of fingerprints uses the optical scanner method, which is most widely used. Recently, the sensor receiving the input of fingerprint using CMOS semiconductor method is highlighted due to technology development. Generally, when people check a person's fingerprints manually, most of the above-mentioned various features are used, but the automatic fingerprint recognition system uses the algorithm which extracts, saves and compares the features obtained from the singular point as well as the ending point and the bifurcation location among various minutiae.[2]

Ⅲ. FINGERPRINT RECOGNITION ALGORITHM

Fig. 1 shows the flowchart of the fingerprint recognition algorithm used in this research.

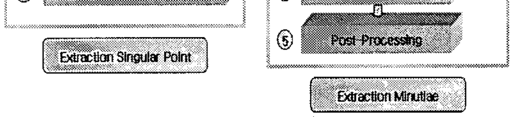

그림 1. 지문 인식 알고리즘 흐름도
Fig. 1. Fingerprint Algorithm Flowchart

Fig. 2 shows the environment and the procedure to test the fingerprint recognition algorithm on the computer.

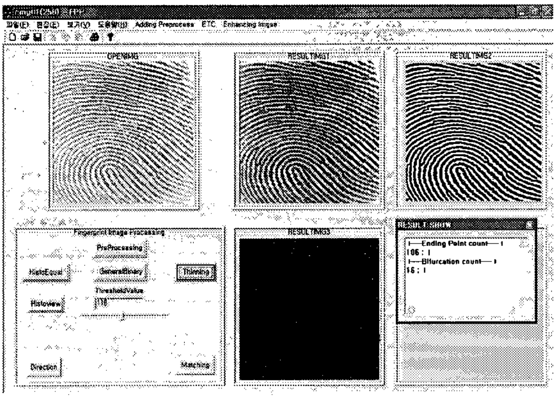

그림 2. 지문 인식 알고리즘 테스트 환경
Fig. 2. Fingerprint Algorithm Testing Environment

Fig. 3 shows how the direction-extracted fingerprint image forms blocks and the direction features of each block are used as the input pattern of the neutral network, which is one of the artificial intelligent techniques, in order to extract the singular point. Every block has 8*8 region, and every direction feature within the region is used as the input vector of the neutral network. Furthermore, it searches the singular point region, outputting 1 for singular point-existing region while 0 for no singular point-existing region.[2][3]

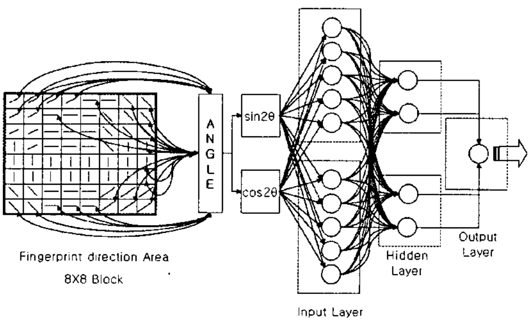

그림 3. 신경망 이용한 지문 방향성 계산
Fig. 3. Calculate fingerprint direction that use NN

Table 1 shows the minutiae in the fingerprint image. In Table 1, the isolated point and the crossing point are the pseudo minutiae which are to be corrected through post-process.

표 1. 특이점 구조
Table. 1 Minutiae structure

FE	Characteristic
0	Isolated Point
1	Ending Point
2	Ridge Point
3	Bifurcation Point
4	Crossing Point

As for the neutral network used in this paper, the input layer has 128 nodes (8*8*2); the hidden layer has 32 nodes; and the output layer has 1 node. We extracted 40 direction feature vectors of singular points out of various fingerprints randomly and used them as the training data for neutral network.

After obtaining the direction of ridge out of the fingerprint image, diverse techniques are currently used for extracting the direction. There are Mehtre method, Ratha method, window frame mask method, Sobel operator method etc., and in this research, we used Sobel operator method to obtain the direction. Once the direction of ridge is obtained out of the fingerprint image, we can have the direction, which almost agrees with the real ridge flow, in good fingerprint image regions; however, we have the direction irrelevant to the ridge flow in damaged regions. To correct this, we performed the direction smoothing of fingerprint.

The image improvement in gray-level should be transformed into the binary one. Here, the threshold is determined based on the histogram to transform it into the binary image. Here, the most important thing is the selection of threshold.

Here, we segmented the total image with the local threshold. Below is the range of local threshold:

$$2^8 - \text{Allowable range} \leq \text{Threshold value} \leq 2^8 + \text{Allowable range}$$

In this research, when we set the allowable range as 120, the transformation of fingerprint image into binary code was processed most properly.

It is difficult to extract minutiae only with the binary image. We created the image where the ridge width is 1-pixel, out of the image properly binary-coded for obtaining minutiae. After thinning, there remains only the ridge skeleton in the fingerprint image, showing the property of minutiae well.

We extracted the singular point and obtained the minutiae consisting of ending point and bifurcation, out of the thinned fingerprint image, and then corrected the pseudo minutiae through the post-process.

The minutiae extracted first by the minutiae extraction procedure contain pseudo minutiae resulting from damaged fingerprint image and image process error. This pseudo minutiae are removed through the post-process.[4]

The fingerprint passing through the post-process can perform the matching by means of singular point and minutiae point. When performing the matching by means of the singular point and minutiae point of fingerprint, the input fingerprint and the saved fingerprint image will have modifications such as rotation or parallel moving.

Here, we find the parameter that gives the maximum accumulator array value by rotating and parallel moving the data obtained from the minutiae of fingerprint image, by means of the concept of Hough Transform, suggested by Ratha et. al, used for the transformation of minutiae data. Using the parameter giving the maximum accumulator array by rotation and parallel moving, we computed the number of minutiae points of which position and direction agree with those saved in the database, to obtain the matching score. Here, it is determined whether the fingerprint of database giving the maximum matching score is identical to the inputted fingerprint. If the matching score is less than a certain level, it is considered that the fingerprints is not registered in the database. First, we should compute the general direction of minutiae point and ridge extracted from the inputted fingerprint image. Fig. 1 shows how the core point of fingerprint is computed from the singular point and how each minutia is saved as the data structure format, into the database.

In Fig. 1, 1 means the user ID; 2 is the user name; 3 is the core point coordinate; 4 is the number of minutiae; 5 and 6 are the coordinate and the direction of minutiae respectively, containing the information to show whether it is the ending point or bifurcation.

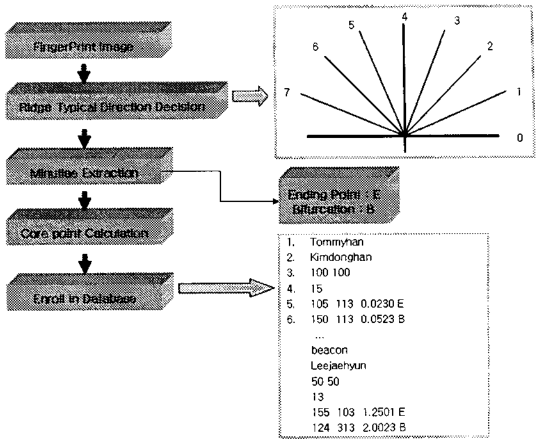

그림 4. 지문 데이터베이스 구조
Fig. 4. Fingerprint Database structure

The following is a matching procedure.

1) It counts the number of minutiae agreeing with the position and the direction of minutiae.

2) It inquires the saved fingerprint image with the highest matching score, by means of the matching score, and considers as being matched with the input fingerprint image.

The following is how to calculate the matching score:

$$MS(r, s) = \frac{100 N_{paired}}{MAX N_S, N_R}$$

Whereas, is the number of minutiae matched; is the number of minutiae of the inquired fingerprint images; is the number of minutiae for a certain fingerprint in the database. After calculating the matching scores of all fingerprints in the database, those with the highest matching score is recognized as the fingerprint registered for the inputted image.[5]

Ⅳ. DESIGN OF FINGERPRINT RECOGNITION EMBEDDED SYSTEM

The fingerprint recognition embedded system is composed in this research contains largely two parts: the sensor input part which receives 128 x 128 pixel images; and the main part which processes the input image data. Once capturing the fingerprint image as 128 x 128 pixel image, the fingerprint sensor has the built-in optimal engine, which operates within the sensor for the best fingerprint image. With one fingerprint input, more than 10 images are scanned per second.

4-1 Main CPU

The CPU of the fingerprint recognition embedded system designed in this research uses StrongARM containing a built-in ARM Core, which is used as a core element for PCS terminal mobile phones. The most remarkable characteristics of StrongARM are low-power and high-performance. It needs 400mW; in other words, it consumes very little power, which is especially acceptable for the embedded system. Moreover, the CPU is mBGA-type with 256-pin and very small, so it is good for small-size equipment like portable device. The disadvantage is that the cost for PCB is very expensive against the chip, because of mBGA-type.[6]

4-2 Main CPU and Memory Interface

1) Flash Memory

The total capacity of the flash memory used for the fingerprint recognition embedded system is 2Mbyte.[7] Table 2 shows the structure of the flash memory used in this research:

표 2. 플래시 메모리 구조
Table. 2 Flash memory structure

Block	Meaning
BLOCK10	Unused
BLOCK9	Fingerprint Data Part
BLOCK8	Fingerprint Data Part
BLOCK7	Fingerprint Data Part
BLOCK6	Fingerprint Data Part
BLOCK5	Fingerprint Data Part
BLOCK4	User Record Part
BLOCK3	Fingerprint Identification Program / Application Program Part
BLOCK2	Unused
BLOCK1	Unused
BLOCK0	BOOT Program

2) SDRAM

SDRAM has 4096 x 256 memory cells and is connected to the address pins (A0 to A24) of StrongARM. The total capacity of SDRAM is 16Mbyte.[8]

Fig. 5 shows the memory configuration of SDRAM:

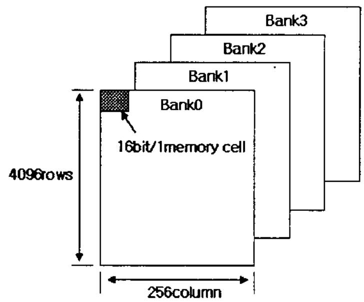

그림 5. SDRAM 메모리 구조
Fig. 5. SDRAM memory structure

4-3 Sensor

So far, the fingerprint input sensor mainly uses the optical method, but, recently, the semiconductor-type fingerprint input sensor has been increasingly used due to technology development. Especially, because the semiconductor-type can compact the size of the fingerprint module comparing with the optical method, and it can decrease the cost significantly, the system using this has been actively developed. The disadvantage is that it is somewhat weak against external impact or static electricity.

1) Characteristics and Driving Principle of Sensor

The sensor used in this research is a semiconductor-type, which is highlighted recently, and has JEDEC-standard PLCC with 68-pin. The sensor size is 13mm x 13mm with matrix type, and it has 128 x 128 pixels. The matrix consists of eight arrays from 0 to 7. There are 3mm-thick drive rings around the matrix, and when a fingerprint touches this, the sensor operates. Fig. 6 shows the overall operation mechanism of the sensor:

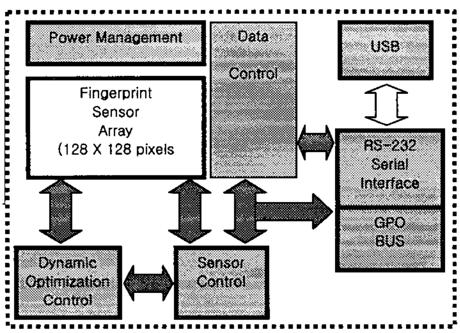

그림 6. 지문 센서 동작 흐름도
Fig. 6. Fingerprint sensor operator flowchart

Fig. 7 shows the real appearance of the fingerprint recognition embedded system made for the research:

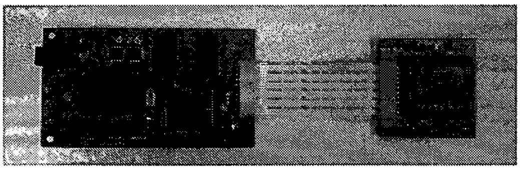

그림 7. 디자인된 지문 인식 임베디드 시스템
Fig. 7. Real designed Fingerprint Identification Embedded system

V. TEST RESULT

To test the reliance and the stability of the fingerprint recognition embedded system designed in this research, the experiments are performed in two ways. The first one is to implement the suggested fingerprint recognition algorithm through the computer program; and the second one is to test the reliance and the implementation through the control board and the serial communication so that the designed fingerprint recognition embedded system can be utilized in various application systems.

5-1 Algorithm Experiment on PC

The table shows the experimental environment:

표 3. 알고리즘 테스트 환경
Table. 3 Algorithm Testing Environment

contents	components
CPU	Intel Celeron 1.7MHz
OS	Window XP
Testing Program	Visual C++ 6.0
Fingerprint number that use in testing	Each other 50 fingerprint of man and women per 10 persons (50×10=500 fingerprint image)
Fingerprint sensor type	Optical type
Fingerprint image size	128×128 pixel
Fingerprint image resolution	500 DPI

As for the fingerprint images in this research, ten fingerprints per person are inputted for 50 persons by means of the optical-method fingerprint input device. Consequently, a total of 500 fingerprints are used for the experiment. The fingerprint images inputted by the sensor are made of 128 x 128 pixel.

5-2 Test of Fingerprint Recognition Embedded System

The fingerprint recognition embedded system designed in this research largely consist of two parts: the sensor part which receives 128 x 128 pixel images; and the main part which processes the inputted images.

In addition, the reliance and the implementation are tested through the control board and the serial communication so that it can be utilized in various applications.

Table 4 shows the experimental environment:

표 4. 테스트 환경
Table. 4 Testing Environment

contents	components
CPU	Atmel AT89C52
Testing method	Serial Communication
Complier Tool	Keil C(language)

1) Experiment Method

First, we inputted the fingerprints into the fingerprint recognition embedded system and checked the data transmit/receipt through the control board and the serial communication. The communication packet has a total of 7-byte. Table 5 shows the packet configuration:

표 5. 직렬 통신 패킷 구조
Table. 5 Serial Communication Pack Structure

Command	Para1	Para2	ErrorCode	CheckSum
1 Byte	2 Byte	2 Byte	1 Byte	1 Byte

① Command : It sends the commands to activate the fingerprint recognition embedded system.

② Para1 : It transmits data.

③ Para2 : In case that additional data of Para1 exists, it transmits data.

④ ErrorCode : It displays the execution result of the fingerprint recognition embedded system for the command.

⑤ CheckSum : It checks the communication error.

2) How to use Communication Packet

① All commands are transmitted from the control board to the fingerprint recognition embedded system.

② The fingerprint recognition embedded system receives the reply from each command authorized by using the same format in Command Packet.

Command Packet is sent from the control board to the fingerprint recognition embedded system.

Acknowledgement Packet is sent to the fingerprint recognition embedded system.

③ The fingerprint recognition embedded system sends the result of the command in the ACK error code field. If the activation of command is perfect without any error, the error code is "0".

Fig. 8 shows the block diagram of interface with the control board, for the test.

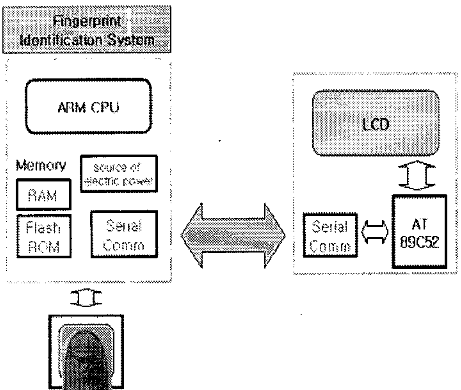

그림 8. 지문 인식 보드와 서브-제어기 인터페이스
Fig. 8. Fingerprint identification system and sub-controller interfacing diagram

Fig. 9 shows the interface and the serial communication between the fingerprint recognition embedded system and the control board.

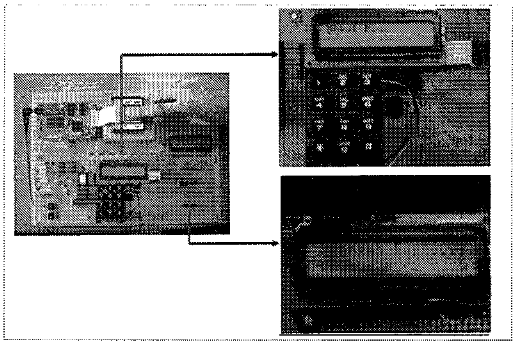

그림 9. 제작된 지문 인식 시스템과 서브-제어기 직렬 통신
Fig. 9 Real designed fingerprint identification system and sub-controller serial communication

Fig. 10 shows how the fingerprint is registered and recognized.

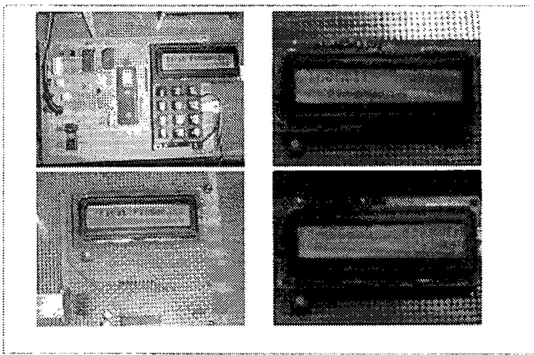

그림 10. 지문 등록과 인식
Fig. 10. Fingerprint enroll and identification

Ⅵ. CONCLUSION

In this research, we designed the fingerprint recognition embedded system by applying the neural network, which is the artificial intelligent technique, to the fingerprint recognition among the bio-recognition fields, and then evaluated the designed fingerprint recognition embedded system through two experiments. In future, we plan to study more about the system reliance and stability by applying the fingerprint recognition embedded system designed in this research to the practical access control systems.

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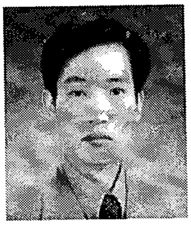
저자소개



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