International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869 (O) 2454-4698 (P), Volume-3, Issue-10, October 2015

Designing an Embedded System of Fingerprint Recognition Based on Artificial Neural Network on FPGA Device

Sunny Arief Sudiro, Bheta Agus Wardijono, Ire Puspa Wardhani, Hariyanto, Saepul Lukman

***Abstract*— This study shows about how to developt fingerprint pattern recognition in an embedded system. In this research has developed hardware prototype for fingerprint recognition component using neural network based on FPGA devices. Artificial neural networks are used for fingerprint recognition algorithms. These algorithms built within the scope of programming and FPGA architectures, especially on neural network processing device utilization, known as Cognimem.**

***Index Terms*— fingerprint pattern recognition, neural networks, FPGA.**

I. INTRODUCTION

Today the use of biometric recognition system has been used in many fields. Similarly to other studies that seek to offer a new method of biometric recognition systems. Biometric identification and verification system has been implemented in a number of application purposes, among others, as follows:

1. Commercial applications: access to buildings, computer systems, laptops, mobile devices, ATMs, and others.
2. Application in the government and institutions: Identity personal, driving license, passport
3. Forensic Applications: identification of death, birth identification

Each of these methods has its advantages and disadvantages of each implementation. Based biometric identification chosen with consideration that everyone has a biometric feature (universal), differ from one another (unique) even for a twin brother also has a different fingerprint patterns, permanent (not aging) and easily acquired. The choice of method also depends on the system to be built, on a real-time system based on embedded systems (embedded) has many limitations that must be met conditions. The system is based on embedded systems have adequate processing speed for a real-time operation, despite having limited memory resources, processors, interface and power components. Artificial neural network (ANN) works like the human nervous tissue. In the human brain contains about 1011 nerve cells (neurons), neurons's task are to process incoming information. Each nerve cell is connected with other nerve cells to about 104 synapses. Each cell works like a simple processor. Each one of these cells interacts to support the work ability of the human brain. The principle of neural networks will be used to process extraction and pattern matching fingerprints algorithm as part of the process of identification or verification. Classifiers category will determine suitability as an introduction, uncertainties introduction depends on the selection of clasifier (FBF or K-NN). [7]

This study describes the development of fingerprint pattern recognition in an embedded system. The first stage in this research is to make the extraction of the image of the fingerprint pattern as an example (template). This extraction method is based on local structures of matching minutiae points. Figure 1 will show an image of the structure of the fingerprint pattern with dots minutiae.

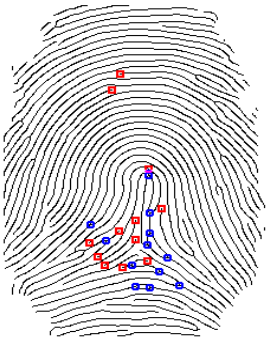

Figure 1: Structure of Fingerprint Patterns image with dots minutiae.

Artificial neural networks will be used for the extraction and pattern recognition algorithms fingerprints. These algorithms are built within the scope of programming and FPGA architectures, especially on the use of neural network processing device known as Cognimem. The second phase of this research is the implementation of algorithms into FPGA devices and final stage of this research is to obtain a prototype component extraction points minituae as a major part of the fingerprint pattern recognition system in real-time. Supporting equipment used in the main study is Cogniblox FPGA Board, this board is equipped with 4 cognimem devices [2] [3]

II. CONCEPT OF FINGERPRINT PATTERN RECOGNITION

The introduction of the fingerprint pattern itself is an old

Sunny Arief Sudiro, Chief of Academic Affair in STMIK Jakarta STI&K, Indonesia.
Bheta Agus Wardijono, Computer Science Department, STMIK Jakarta STI&K, Indonesia.
Ire Puspa Wardhani, Information System Department, STMIK Jakarta STI&K, Indonesia.
Hariyanto, Informatic Management Department, STMIK Jakarta STI&K, Indonesia.
Saepul Lukman, Information System Department, STMIK Jakarta STI&K, Indonesia.
The research was funded and sponsored by Dirjen Dikti on Competitive Research Grant scheme in 2014 with a Letter of Assignment No: 216 // K3 / KM / 2014.

method in biometric identification, at least since 2000 years before AD century. This method is used by the Assyrians, Babylonians, China and Japan since 1897, dactyloscopy or fingerprint identification pattern manually without computer assistance is used for identification and investigation of crimes.

Figure 2: Fingerprint Image

In the fingerprint pattern comprising grooves (lines on fingerprints) and valleys (space between grooves), see figure 2. The pattern of the fingerprint is unique, different from one another for every person. There are two main methods of pattern matching fingerprint is: [4]

1. Matching point minutiae (minutiae matching), or matching based on local structures. This method is used to analyze the flow and the end groove branching known as minutiae points. Fingerprint pattern consists of about 100 minutiae points and the measurement area contains 30-60 minutiae points, depending on the area of the sensor used. How many types of minutiae points can be seen in Figure 3.

2. The global pattern matching (global pattern matching), this approach focuses on the direction of the flow path can be: an arrowhead (arches), circle and whorl, and the detection of the presence of singular point, this point is the center point (core point), or points that form a triangle (delta point).

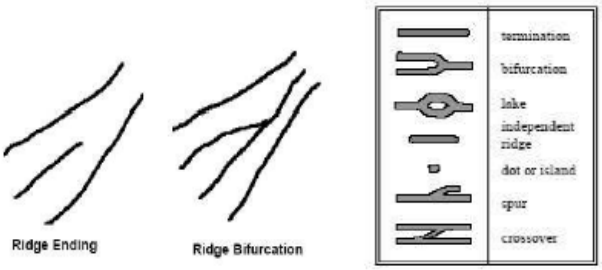

Figure.3. Various types of minutiae points. [4]

The main part of the introduction of fingerprint for identification / verification is how to get the fingerprint features as a template and store its data when registration. This template will be taken and compared with the new template to identify or verify. Some typical minutiae extraction algorithm can be seen in Figure 4. [8]

Fuzzy logic approach is used to try to detect the use of gray level minutiae point of the fingerprint image. The detection results can be promising but this is not enough to cover all situations such as error detection minutiae points. To overcome this problem, the neural network is added to the fuzzy logic system, so the performance increase. Unlike the classic approach, fuzzy method uses gray-level information to extract minutiae points. The bright pixels representing the valley or wrinkle, and other pixels are back structure. In human language it is known as the DARK and BRIGHT. With fuzzy logic, this level can be modeled and used together with the appropriate fuzzy rules to extract the minutiae points accurately. [10]

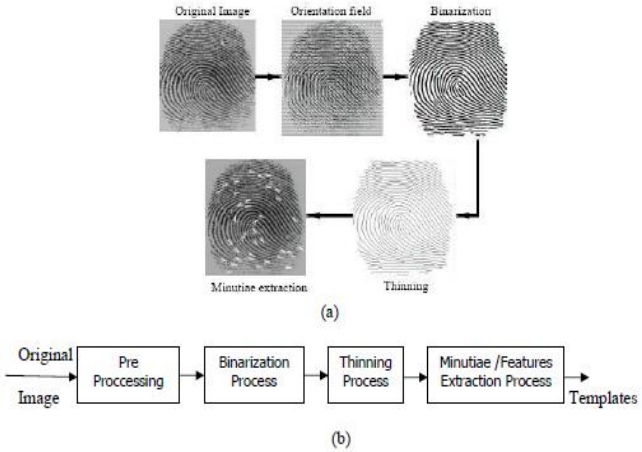

Figure 4. (a) Step minutiae extraction algorithms, (b) The classical approach for minutiae extraction process. [10]

III. Concept of Neural Network

In the human brain contains about 1011 nerve cells (neurons) are tasked to process incoming information. Each nerve cell is connected with other nerve cells to about 104sinapsis. Each cell works like a simple processor. Each of these cells can interact to support the ability of the human brain. [5]

The main component of neurons can be divided into 3 parts:

1. Dendrite = charge of receiving information for soma = input lines.
2. The cell body (soma) = where information processing
3. Axon = charge of sending impulses signals to other nerve cells = output path for soma.

Figure 5 presents an overview of the human neural network, comprising:

- A neuron receives impulses signals (information) from other neurons through the dendrites and transmit the signal generated (sum) by body cells through the axon.
- The axons of these nerve cells branch out and connect with the dendrites of other nerve cells by sending impulses through the synapses.
- Synapses are the functional unit between two pieces of nerve cells, for example A and B, of which one is a fiber axons of neurons A and the other is the dendrites of neurons B.
- strength of synapses can be decreased / increased depending on the extent of propagation (broadcasting) signals it receives.
- impulse signals (information) will be accepted by other neurons if they meet certain restrictions, which is often called the threshold value (threshold).

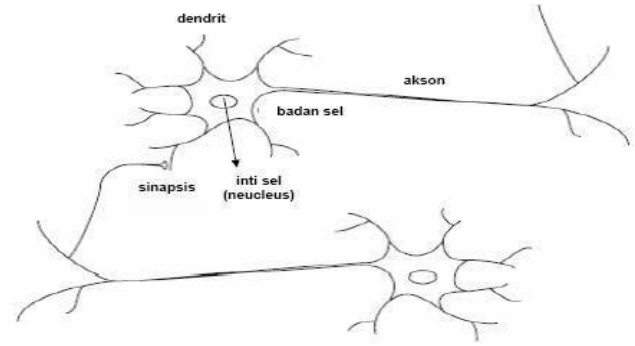

Figure 5. Human Neural Networks. [5]

Neural network is defined as an information processing system that has characteristics resembling human neural tissue, Figure 5 is a model neuron artificial neural networks are adopted from human nervous tissue (biological). Neural networks created as a generalization mathematical model of human understanding (human cognition) is based on the following assumptions:

1. Information processing occurs on simple elements called neurons
2. The signal flow between nerve cells neurons via a connection link
3. Each connection link has a corresponding weight. These weights will be used for doubling or multiplying the signal sent through it.
4. Each nerve cell will implement the activation function of the weighted sum of the signal coming to him to determine the output signal.

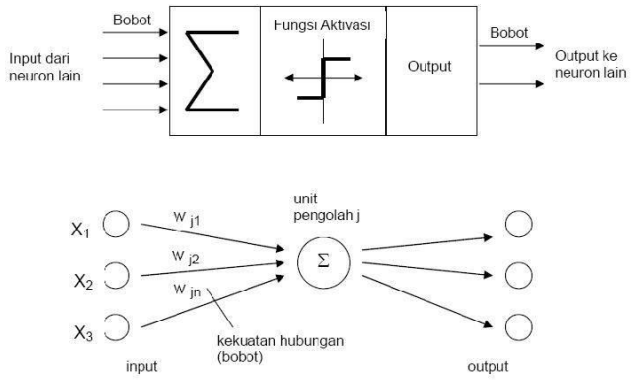

Figure 6. Neuron artificil neural network model.

IV. Concept of Hardware Implementation

In the course of implementing the hardware on fingerprint recognition system, a number of requirements must be met. These requirements are: (1) real-time, (2) is embedded, (3) small size, and (4) low power consumption. These algorithms must be optimized when implemented in FPGA devices, due to some limitations or constraints, such as memory capacity, components, power consumption, cost, and difficulty of building dependency modules.

Working in FPGA architecture should be careful with the amount of: data and data transfer mechanisms, the complexity of the algorithm, the interface I/O, speed, power consumption, and others. FPGA device itself is a programmable device that can be used to perform several tasks calculations at very high frequencies. It is divided into a number of logical blocks which contain logic and storage elements. [6] [9]

Many studies in the extraction process fingerprints is largely based on the value of the pixel representations of '1' and using trigonometric calculations involving floating point numbers when getting parameters minutiae. This method is very complex and difficult to implement in hardware environment. Other methods use global feature that also involve floating point calculations, as well as the size of the larger template. Using a neural network or fuzzy rules in detecting minutiae points are also possible, but very complex and difficult in the hardware environment. This difficulty has been reduced by CM-1K chip Neural.

This chip is a powerful neural network chip to display 1,024 neurons working in parallel and parallel buses, which enables an increase in the size of the network by cascading multiple chips. This chip is the ideal companion chip for smart sensors and cameras that can classify patterns at high speed while overcoming the data is not clear, unknown event detection, adaptive to changes in the context and working conditions, and others. In addition to the parallel neural networks, CM-1K integrates a recognition engine that can receive data directly from the vector sensor and transmitted to the neurons in real-time. After receiving the complete vector, the category of firing neurons with the closest matching transmitted to the output bus. In the case of a monochrome video sensor, Cognimem offer exclusive signature extraction from 2D video to 1D vector. Recognition engine can operate at speeds up to 27 MHz sensor. The use of high-speed recognition engine requires that the knowledge will be loaded prior to neurons [1]. Figure 7 shows the implementation of CM-1K chip pattern recognition system.

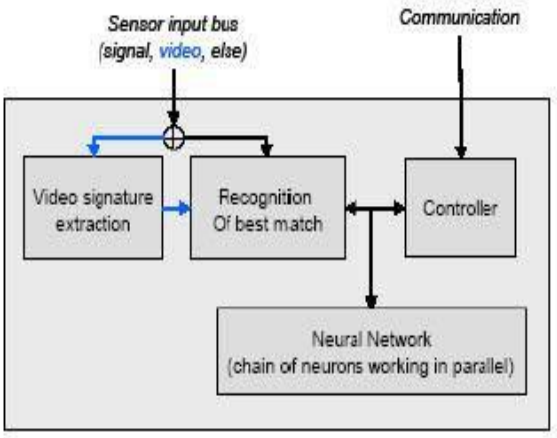

Figure 7: Cognimem chip diagram[1]

V. Prototype Design Based on FPGA Device

The design of the system prototype embedded fingerprint pattern recognition consists of two approaches. Figure 8 is the first approach that still uses a PC to feed the fingerprint image to be in the process. This approach is more emphasis on the purpose of the program evaluation component description given interface with a sensor has its own difficulty level.

In the development phase, image pre processing and minutiae points analysis are done by softare. Figure 9 until 12 are GUI interface for this application with feature : image feeding, extraction process and save the template, and recognition process based on artificial neural network hardware.

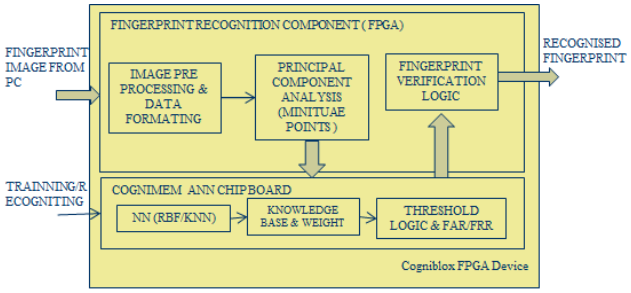

Figure 8: First approach of design hardware embedded systems

Figure 9. GUI for entering the image.

Fingerprint template consist of vectors whit format : x,y,angle, minutiate point type (1 for EP and 3 for BP). For example, minituae point on location 80,124, 145 degree and an end point minutia points will have vector : 80,124,145,1. For figure 1, there are 12 end point minutiae (red dots) and 13 bifuration point (blue dots), the vector template are :

108 81 0 1
101 96 195 1
132 170 315 1
132 174 225 3
132 176 60 3
143 207 270 1
133 211 60 3
121 218 255 1
83 222 60 3
107 228 315 1
133 230 285 3
121 236 255 1
96 237 225 3
82 239 315 1
131 241 135 3
89 252 135 1
148 253 150 3
131 256 165 1
95 260 30 1
118 260 75 3
110 262 135 1
141 266 135 3
158 279 150 3
121 280 0 3
133 281 120 3

Figure 10. GUI for saving the template when the data is already in the system.

Figure 11. GUI for recognizing the image.

Figure 12. GUI for recognizing result.

Figure 13 is a second approach, in the design of these components which is equipped with a fingerprint sensor interface. In this design, the fingerprint image is obtained from the sensor not from the PC, process it in the FPGA component and issue the results.

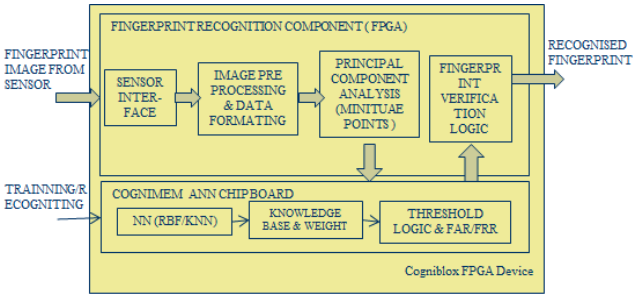

Figure 13: Second aprroach for hardware embeddd system.

The final stage of this research was the presentation of the results of the fabrication of electronic components based FPGA IP Core from previous studies. Figure 14 is the final prototype electronic components fingerprint pattern recognition coupled with neural network device Cognimem.

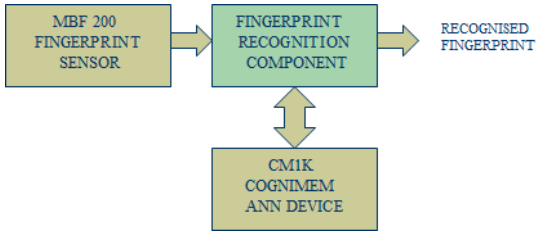

Figure 14: Electronic Components Fingerprint Identification Patterns and Artificial Neural Network Devices Cognimem

Figure 14 presents the final design of a prototype for those that can be implemented into a system based on fingerprint pattern recognition hardware FPGA.

VI. Conclusion

In this study has successfully designed a prototype, this prototype is used as the basis for the development of hardware fingerprint pattern recognition. This research will also produce electronic components for a fingerprint pattern recognition device using Neural Network component that can be used to build a embedded system to support real-time operations.

Acknowledgment

The authors thank Dirjen Dikti, Minister of Education Republik of Indonesia for funding this research based on Competitive Research Grant scheme in 2014 .

References

[1]. Anonim, " CogniMem 1K Neural Network Chip for High Performance Pattern Recognition (Datasheet)", 2008. http://www.recognetics.com. Version1.2.1
[2] Anonym, Cognimem Reference Guide, Version 2.2.1, Cognimem Technologies Inc., 2012.
[3] Anonym, Cogniblox User's Manual, Version 1.2.9, Cognimem Technologies Inc., 2013.
[4] Gerik Alexander von Graevenitz, " Intorduction to Fingerprint Technology", A&S International, Vol. 53. Taipei,2003, pp 84-86.
[5] Arief Hermawan, *"Jaringan Syaraf Tiruan (Teori dan Aplikasi)"*, Penerbit Andi Offset 2006
[6] Mark Zwolinski, "Digital System Design with VHDL" Pearson Education Ltd, Edinburgh Gate, Harlow, Essex CM20 2JE, England, 2000.
[7] Santu Sardar, Gaurav Tewari, K. A. Babu, "A Hardware/Software Co-design model for Face Recognition using Cognimem Neural Network Chip", 2011 International Conference on Image Information Processing (ICIIP 2011), 2011.
[8] S. Prabhakar, A. K. Jain, and S. Pankanti, 2003, "Learning Fingerprint Minutiae Location and Type", Pattern Recognition, Vol. 36, No. 8, 2003, pp. 1847-1857.
[9] Vaughn Betz, "The FPGA Place-and-Route Challenge", 2008, http://www.eecg.toronto.edu/_vaughn/challenge/challenge.html.
[10] Vijay Kumar Sagar, Koh Jit Beng, Alex, 1999, "Fingerprint Feature Extraction by Fuzzy Logic and Neural Networks", IEEE, 1999, pp. 1138-1142.

Sunny Arief Sudiro. lecturer at STMIK Jakarta STI&K., He finished his higher education S1 and S2 at the University Gunadarma. S3 graduated from the Université de Bourgogne in 2009. Currently serving as Chief of Academic Affair in STMIK Jakarta STI&K.

Bheta Agus Wardijono. lecturer at STMIK Jakarta STI&K. He finished his higher education at the University of Indonesia S1, and S2 at Trisakti University. Complete the doctoral program of the University of Information Technology Gunadarma. Currently serving as Chairman of the Program in Information Systems STMIK Jakarta STI&K.

Ire Puspa Wardhani. lecturer at STMIK Jakarta STI&K. S1 graduated from higher education in STMIK Jakarta STI&K and S2 at the University Gunadarma. This moment is as Chairman of Research in STMIK Jakarta STI & K.

Hariyanto, lecturer at STMIK Jakarta STI&K. This moment is as Chairman of Informatiq Management Department in STMIK Jakarta STI&K

Saeful Lukman, lecturer at STMIK Jakarta STI&K. This moment is as Staff of Information System Laboratory in STMIK Jakarta STI&K.