A NEW METHOD BASED ON ARTIFICIAL NEURAL NETWORK FOR FINGERPRINT CLASSIFICATION AND RECOGNITION

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JANUARY 2015

A NEW METHOD BASED ON ARTIFICIAL NEURAL NETWORK FOR FINGERPRINT CLASSIFICATION AND RECOGNITION

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES OF
ÇANKAYA UNIVERSITY

BY
OMAR NAJEM

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE
IN
THE DEPARTMENT OF MATHEMATICS AND COMPUTER SCIENCE
INFORMATION TECHNOLOGY PROGRAM

JANUARY 2015

Title of the Thesis : **A New Method Based on Artificial Neural Fetwork for Fingerprint Classification and Recognition.**

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STATEMENT OF NON-PLAGIARISM PAGE

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ABSTRACT

A NEW METHOD BASED ON ARTIFICIAL NEURAL NETWORK FOR FINGERPRINT CLASSIFICATION AND RECOGNITION

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January 2015, 45 pages

In this work has been reached a method which is based on features of fingerprints patterns. In work method, fingerprint classification has been processed by using MATLAB software and then compared the result with previous methods. Results have proved the ability of the work method. Secondly it is morphological method so its accuracy is much better than other method. Feature extraction is performed using Co-occurrence matrix. Extracted features of the fingerprints are then classified by employing Artificial Neural Network. Many variants of neurons of these algorithms have been also implemented, wherever it is appropriate.

Keywords: Fingerprint, Human Identification, Classification.

ÖZ

PARMAK İZİ VE SINIFLANDIRMA TANIMA İÇİN YAPAY SİNİR AĞI DAYALI YENİ BİR YÖNTEM

NAJEM, Omar
Yüksek Lisans, Matematik - Bilgisayar Anabilim Dali
Bilgi Teknolojileri Bölümü
Tez Yöneticisi: Yrd. Doç. Dr. Yuriy ALYEKSYEYENKOV
Ocak 2015, 45 sayfa

Bu tez çalışmasında parmak izi desen özelliklerine dayalı bir yöntem önerilmiştir. Aynı tekniği parmak izi sınıflandırma için kullanılmıştır. Önerilen yöntem parmak izi sınıflandırma sonra MATLAB yazılımı kullanılarak önceden yöntemlerle karşılaştırıldı tarafından işlendikten. Sonuçlar önerilen yöntemin yeteneğini kanıtlamıştır. Doğruluğu başka bir yöntemle çok daha iyi yani İkincisi morfolojik yöntemdir. Özellik çıkarma Co-oluşum matrisi kullanılarak yapılır. Parmak izi Çıkarılan özellikleri sonra Yapay sinir ağı kullanılarak sınıflandırılır. Uygun olduğu yerde, bu algoritmaların nöronların bir çok çeşidi de uygulanmıştır.

Anahtar Kelimeler: Parmak izi, İnsan Kimliği, Sınıflandırma.

ACKNOWLEDGEMENTS

To my dear parents, from the depths of my soul, thank you for everything. To my dear family and my brothers, thanks for your support.

To my supervisor Dr. Yuriy ALYEKSYEYENKOV thank you for your valuable advices. To all of my teachers thank you for your guidance. To my friends and everybody help me thank you for your generosity.

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LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
FAR	False Acceptance Rate
ID	Identification
BPA	Back Propagation Algorithm
FVC	Fingerprint Verification Competition
CLAHE	Contrast-Limited Adaptive Histogram Equalization
GLCM	Gray-Level Co-occurrence Matrix
MLP	Multi-Layer Perceptron
PIN	Personal Identification Number
SAS	Statistical Analysis System
RGB	Red , Green and Blue
LMA	Levenberg-Marquardt Algorithm

CHAPTER 1

INTRODUCTION

1.1 Background

Biometrics is identifying humans by their physiological, behavioral and biological characteristics [1]. Biometrics can be divided into two categories: physiological biometrics and behavioral biometrics [1]. Physiological biometrics are those which recognize individuals from physiological or biological attributes like face, iris, fingerprint, finger vein, hand geometry, etc. Behavioral biometrics on the other hand, are those which recognize individuals from human attitudes such as hand writing, signature or voice recognition.

Tremendous amount of biometric identification systems are in use today. Many of such systems are based on fingerprint, face, iris, voice. Biometric technology has many advantages in comparison to the other techniques (e.g., password, PIN, keys and cards). Reasons for using biometric systems include:

- Ease of use: Biometric systems are mostly famous for their convenience to the end users. Individuals do not need to remember different passwords or carry any identity cards; in both cases they can forget the password or forget to carry the card.
- Enhanced security: Sharing passwords or losing cards can lead to trouble and insecurity; however, using unique biometric identifier reduces the stated risks. Moreover, duplicating biometric identifiers is too difficult or impossible.
- Low cost: Hardware and software improvements have led to decrease in the cost of biometric systems, making them a roadable to many organizations and

companies. For example, HP and Lenovo laptops are mostly equipped with fingerprint scanners nowadays [1].

1.2 Biometric Types

As mentioned before, there are different types of biometrics, and humans can be recognized by their fingers, hands, face, eyes, and voice, some of which are more widely used than others. In this section each technique will be discussed briefly and its advantages and disadvantages will be mentioned.

1.2.1 Facial scan

Facial scan technology is mostly used for identification of individuals instead of verification1. This technology uses some of the important features of the face, like, eyes, nose, lips, and so on [2]. One of the advantages of facial scan technology is identifying individuals from distance; therefore, it will not annoy people by touching any device. Moreover, images can be captured by different devices like video cameras. On the other hand, this technology has some disadvantages. For example, the quality of the captured image is dependent on lightening, background and angle of the camera. Moreover, users' appearance can change over time, and having glasses, beard, mustache, make-up or different hair styles, would have an impact on accuracy. Furthermore, having higher accuracy requires saving different images of users which in turn requires more memory space.

1.2.2 Iris scan

Iris scan technology is used for both identification and verification based on unique features of irises. This technology uses patterns that form the visual part of the iris to differentiate between humans [2].

Some advantages are that (i) this system has smallest False Acceptance Rate (FAR) among the other biometric systems, which is critical for high secure applications and (ii) iris does not change in time like some other biometric types (like voice that can

change). However, positioning of the head and eye are very important to get accurate results and people should not move their heads during data acquisition. Iris is a very small area; therefore, captured image should be very high resolution which makes the device expensive. Individuals feel discomfort able using this device even though they do not know infrared scan is used during the process [3].

1.2.3 Voice scan

Various vocal qualities such as frequency, short-time spectrum of dialogue and spectrograms (time frequency-energy patterns) are used for voice scan [2]. The devices e.g. microphones used for this technology are quite cheap. This system lets the users select an expression and repeat it during identification and verification which reduces the risk of impostors guessing the same phrase and entering into the system. However noise and echoes can reduce the system accuracy. Moreover voice can change during illness or in different moods, making authentication problematic. Enrollment to the voice-based system is longer than other biometric systems because users have to repeat the phrase for many times.

1.2.4 Fingerprint recognition

Fingerprint recognition is the most important part of biometric. Biometric is the most popular method of physical details belonging to a person with the aim of identification in a reliable way [4]. A biometric system includes many personal biological characteristics that are now used for personal recognition. For example, iris recognition, fingerprint recognition, voice recognition, signature recognition or face recognition. Since biological features are unique, and thus more reliable to identify people than traditional methods, such systems are more useful and suitable than traditional procedures.

Biometric systems are now commonly used in different parts of everyday life such as building access and computer login. Fingerprint recognition is the most widely used for personal identification within all biometric systems [5]. Throughout the world,

fingerprint recognition is accepted by a large part of the population because of its fast, secure, and easy way of personal identification.

Typically, fingerprints consist of ridge and valley patterns on the tips of human fingers. Thanks to their uniqueness and continuity, the use of fingerprints is considered to be one of the most reliable methods of personal verification. “Due to the continuing needs of law enforcement and interest from the developers of civilian applications, automated fingerprint verification system are becoming increasingly widespread and are being extensively researched by the pattern recognition and image processing communities” [6]. And also fingerprint recognition is today being increasingly used in a large number of various applications such as access control or online identification [7].

1.3 History of Fingerprint

Izmir Police Department Crime Scene Investigation Directorate (b.t) training documents, includes the following description in connection with the fingerprints: "Finger nail tip of the remaining papillary line between the first node, the surfaces as a result of the contact surface is called a fingerprint traces they create. “Constitute fingerprint thin line called papillae. Papillary, small holes are formed from the so-called cellular array as per a chain. When the body fluids passing through the pores of the papillary lines on the ruins they left fingerprints on a surface made contact with the transfer of these residues are formed. A criminal question the police since the start is an infallible way to distinguish the calls upon his people. In 1883, the first systematic interference in personal identifying a French police expert, by Alphonse Bertillon and are introduced. Bertillon system of a detailed description of the suspect exact body measurements, known as anthropometry with full size photos and profiles are based on integrated with the system. Use as an identification method of anthropometry, human bone system is based on measurement of the age of twenty until his death remains constant mainstay. Skeletal dimensions, it is considered that no two people have the variety of too have exactly the same dimensions. Bertillon to comply with the human anatomy is recommended to take on a measure of the routine

way. These Ones; height, arm length comprises the length of the width of the head and the left foot.

The system for twenty years is thought to be the most accurate method of identification. But police in the new century's first bass, a fingerprint identification system based evaluation is begun and to accept the classification of the line model, known as the H finger. Today fingerprints, modern criminal identity of the direct detection.

Evidence, fingerprints are put forward that the Chinese use to sign legal documents since three thousand years previously. However, this application of it as a way to determine the identity or a ceremonial tradition remains buried history is used as an assumption point. In any case, take fingerprints in ancient history examples are vague and very little is also available today Bulunmamıs contribute to the development of fingerprint technical as we know it today.

Bertillon, a few years before you start to work on your own system, William is a British civil servant who served in India Herschel printed on a stamp pad their contractual right hand has started the implementation of the native did not want to sign with a trail. Herschel is left outstanding at the reasons for the request; there is doubt as to take the Use of fingerprint identification as whether the vehicle according to Hindu tradition allowed contact with the body of the contract is binding even without a signature on the habit.

A study by the Scottish doctor at a hospital in Japan for the detection of personal identity Henry Faulds Up to publish views on the potential application of the fingerprint is not published nothing about Herschel activities.

Faulds, published in 1880, which established a special offenders may be important in determining the skin line model where communication is forward seconds. Whitewash been made on a wall in an event of a burglar leaving fingerprints and traces of suspicious traces in comparison with fingerprints that are completely different pitched. A few days later a suspicious else comparable to trace the fingerprints found on the wall and that you have to prove to plead met by this survey.

Faulds, fingerprints, is convinced that SAS does not give evidence of the determination. Even the costs to test the practicality of the method are to comply with the Scotland Yard offers a fingerprint bureau to establish a sole self. But the

proposal to be rejected in favor of the Bertillon system, but this decision was reversed after a period of less than twenty years.

Police agents' fingerprints of potential applications needed to ensure speed to realize, Francis Galton named president is able to make a comprehensive research on obtaining fingerprints made by an Englishman.

Police agents' fingerprints of potential applications needed to ensure speed to realize, Francis Galton named president is able to make a comprehensive research on obtaining fingerprints made by an Englishman. Fingerprint second stage in the development of technology, there has been the creation of thousands of trails and logical classification of claims that can be put into a searchable as well. Galton's work affected the Argentine police officer dr.ju the Vucetich is a concept applied in 1891 has discovered. Vucetich's classification system over the years, refined, and today most of the countries are still speaking Spanish been started to be used as a large scale.

Start to lose the taste of the twentieth century Bertillon measurement system has begun. Given the results of, especially when taken by people who are not given training on measurement, it has come against the error appears to be very sensitive.

System, in 1903 a prisoner named William West Fort Leavenworth has experienced the most severe and remarkable decay when he went to prison. A routine check of the prison file, the people that are already in prison of the body dimensions and even put forward the fact that prisoners could not be distinguished even with the new image. In fact, these two guys are similar to each other as twin brothers and dimensions are almost the same. Consequently both fingerprint prisoners is set aside from each of them.

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dimensions are almost the same. Consequently both fingerprint prisoners is set aside from each of them.

The first systematic and formal use of fingerprints to determine personal identity in the United States was accepted by the New York Public Service Commission in 1901. The method has been used to document all public services applications.

Some American police officers, 1904 in St. Fingerprint of representatives from Scotland Yard in the world fair in St. Louis is about determining IT TOOK lessons.

After the fair, and William West event taking fingerprints has begun to be used in a decisive way in all major cities of the United States. 1924 Research Bureau and Leavenworth Penitentiary fingerprint records new to form the core of the identification records of the Federal Bureau of Research for it is Birlestirmis. At the moment the FBI has the world's largest fingerprint collection. 1. World War criminals all over Europe, especially the UK with the start of Planning and diagnostic factors as the main method of fingerprint has adopted. Today, our well-Henri Galton based on our classification, mesh with Herschel's deputy assistant are Galton Darwin scholar Henri-founded.

Kriminalistlikl most California sun, some people will mesh as the inventor of fingerprint shows Alphonse Bertillon. Metric photography, the identity to photos, portreparle, symptoms, and finally put this great French police anthropometry is Bertillon Classification called a fingerprint classification method the build.

The aim of this work is to use easier and faster method for feature extraction of fingerprint images (Arch, Whorl, Left loop, Right loop). In addition use Artificial Neural Network for classification (Back Propagation Algorithm) select 70% of fingerprint images for training and 30% of images for testing and used Multi-Layer Perceptron for the classification stage precisely, where this method reaches best results to four classes of fingerprint images.

CHAPTER 2

NEURAL NETWORKS

2.1 Artificial Neural Network Definition and General Features

Computers have become an indispensable part of the modern world and computer systems today can decide on both events, to learn about the relationship between both events. Cannot be expressed mathematically and which cannot be solved problems can be solved by computers using methods based on experience. Computers equipped with this feature, and leading the development of these capabilities work "Artificial Intelligence" is known to be working. Outstanding features of the brain while working on artificial intelligence, scientists have been forced to work on the brain and inspired by the structure of the brain nörofiziksel tried to extraction the mathematical model. In order to model the brain with the idea that all behavior should be modeled accurately the physical components of a variety of artificial cell and network models have been developed. Thus, today's computer as a separate discipline of algorithmic calculation method “neural network” has emerged. In the most general sense of the ANN, mimic many nerve cells in the human brain that are the result of simple processors connected together in different levels of impact regarded as a complex system. Develop as a result of efforts to remove the mathematical model of nerve cells in the human brain ANN. In practice often very different structure and form of data which may be quickly identified and using for detection. Engineering ANN reason behind the widespread use in the field is the ability of the solutions put forward in the classic technique with an effective solution to difficult or even impossible problems. Computers are very successful in their mathematical and algorithmic calculation in the process requires a lot of learning and recognition systems under expectations accuracy can perform operations. Needed on this matter is best ANN resolves. Neural networks can be used

in non-linear equations and generalization capabilities due to a very complex and large-scale solutions to problems that are easily produced. Adaptable and be fast, easy, in order to analyze and design due to their ability to learn and have become one of the indispensable elements of our age.

Results can be obtained with very complex equation using other programs were made possible foresight of the neural network can be estimated easily. Machines that can be learned using neural networks due to in mind that because of the way people work areas or constraints of the human factor in the work to be done in the coming loss of precision has been achieved major improvements occur. ANN parallel can be defined as a distributed computing system, in other words, On the basis of the ANN are formed in the process room functions requiring intelligence. This system consists of a one-way beacon channel and interconnected operation elements. The output signal can be amplified by the fact that although the cases need one. Externally there is a simple though it seems extremely complicated internal structure of ANN. Because it is an imitation of biological neural networks, an understanding of the structure of biological neural networks will facilitate the understanding of the neural network. The building blocks required fiction artificial neural networks are neurons as well as in biological neural networks.

Own approximately 10 billion neurons in the human brain and the nerve cells which are estimated to makes up 60 trillion connections with each other. Nerve messages from the senses; they are transmitted to the next cell evaluated by nerve cells. Thus the message carried by the signal is transmitted to the central and nervous system. Generates response signals to evaluate the central nervous system signals. These signals are transmitted in response by the organ to the formation of the nervous system. Thus, the signals from the sensory organs response will be transmitted to the body through the nervous system. Despite a much slower process of the brain connected by parallel connections and experience gained in this enormous ability to renew connections between neurons is the ANN application directory.

At this point, the general structure of the ANN will be useful to sort out before entering into details about the features that make it important. The most basic capabilities of ANN in this context [8].

a. Non-linear function of the network:

The neuron itself is not linear the most essential component ANN. Accordingly, the neural network formed by the interconnection of neurons is not linear and also the non-linear characteristic is due to the nature of ANN is distributed across the network in parallel. In the absence of the desired linear mappings due to non-linear sub-units on the network structure in the fulfillment of the function is mathematically possible. So the function of structural flexibility allows taking place correctly.

b. Input-output association to:

ANN guided especially be mentioned later in the study has a structure that allows learning to take place. So that using the elements in the ANN training set to give the desired results for the specified entry revises free elements in its structure. Making fewer errors at each iterations resets weight and connections.

c. Becoming acceptable easy adapter:

When the threshold value is changed conditions in the ANN or by simple operations such as adjusting the weight applied to the input can be adapted to the new environment. ANN different structures used in different fields Thanks to this ability may be preferred.

d. The parallelism and function of structural disarray of the system:

Neurons within the network structures actually working simultaneously constitutes a complex function. Work simultaneously in multiple neurons does not directly affect the success of the network in the event of outages of any neurons. Depending on the application in order to get the proper output connections between neurons can be canceled automatically. This is indicative of the fact that in parallel and distributed structure of all the neurons in achieving the expected results of the ANN.

d. Generalization ability:

In other words, the network during training describing the mapping of numerical data used if the coarse features and thus able to produce meaningful answers for unused inputs during training (Figure1).

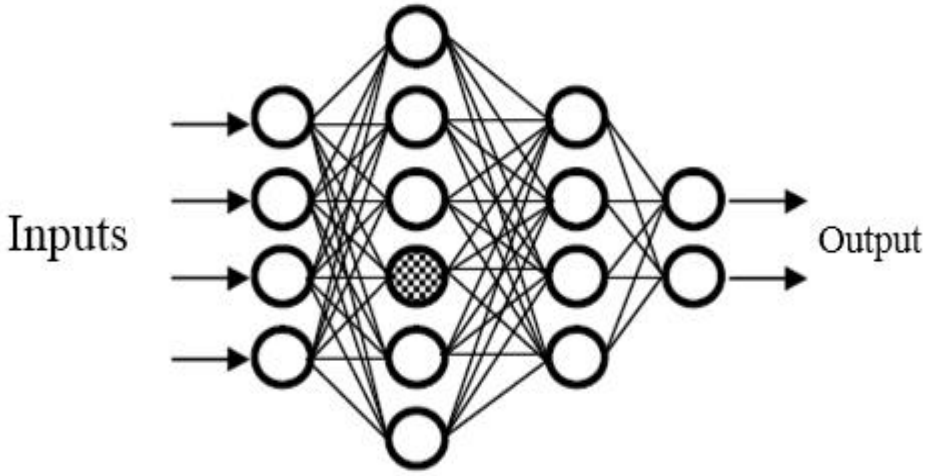


Figure 1: Neuron structure of the network in the event of breakdowns

e. Error tolerance:

ANN application of a possible error will occur in the system is also one of the most important advantage is that the quality will not allow a sudden collapse. ANN error will occur in the structure above Because of the mentioned features will result in gradual decline and the user will notice that something is wrong and will provide the time needed to measure.

f. Very large scale application compliance:

In particular, the number of neurons in the hidden layer of the multilayer structure used in increases, the ANN is very complex and very positive applications in nonlinear solution seems impossible results provide.

2.2 General Structure of Neural Network

Neurons, the building blocks of artificial neural networks, met in many layers can be used in solving highly complex problems. ANN four main parts forming dendrites, axons, the core and connections are shown in (Figure 2) [9].

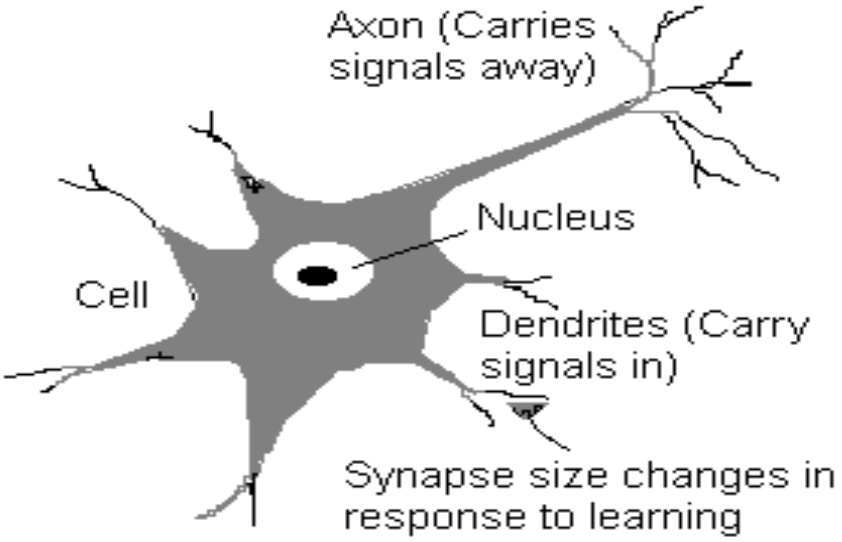


Figure 2: The sections making up the neural network

Dendrites: Dendrites that convey the core of the electrochemical excitation received from other neurons, tree root-like structures. Electrical stimulation of neurons and dendrites in consecutive sequence reaches through the synapses between them. Core: the central processing unit core of the nerve cell, which collects and transmits signals from the dendrites to the axon.

Axon: show and branching out from the body which is the cytoplasmic fraction. Each neuron there is one. Axon exiting the body, to move from the nerve cell signals in the environment is official, so other nerve cells, nerve cells, muscle cells, such as cells or operational ties with gland. Has an important role in message transmission. Connection: newly produced is responsible for transmission signals to other neurons. To receive notifications of a nerve cell is called the threshold stimulus intensity required intensity. The amplitude of the said notice must be at or above the threshold

in order to receive alerts. The warning threshold value below the response is not generated by neurons.

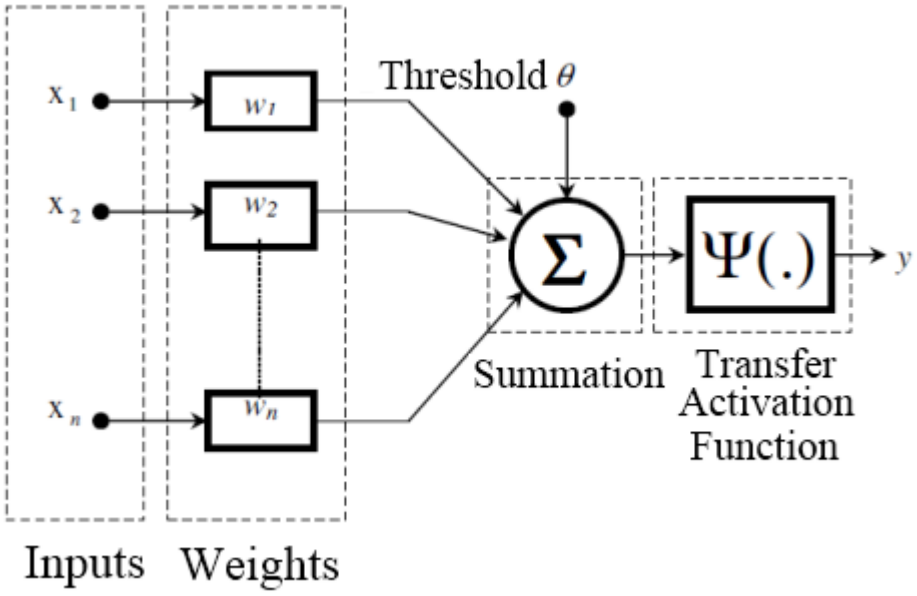


Figure 3: The structure of an artificial neuron

The neuron model shown in simplified form in (Figure 3) can also be considered as a threshold volume. Threshold (θ) unit, which collects the output and hazel Harmandir only produces an output, exceeds the sum of the internal threshold of the entrance. As a threshold neuron unit receives signals from the synapse and collects all the signals that are generated by multiplying the appropriate weight. You will now sign up to the power of the threshold gathered strong sign stimulus is transmitted along the axon and dendrites of other neurons. Intersecting compared with all the signs of internal threshold gated neurons with dendrites and synapses from the axons sign spreads threshold is exceeded. Output depending on whether the result of the sum function value is above or below the threshold activation functions are formed by the normalizing. ANN, connecting these simple nodes and the unit is obtained by conversion to a network. ANN block diagram shown in (Figure 4).

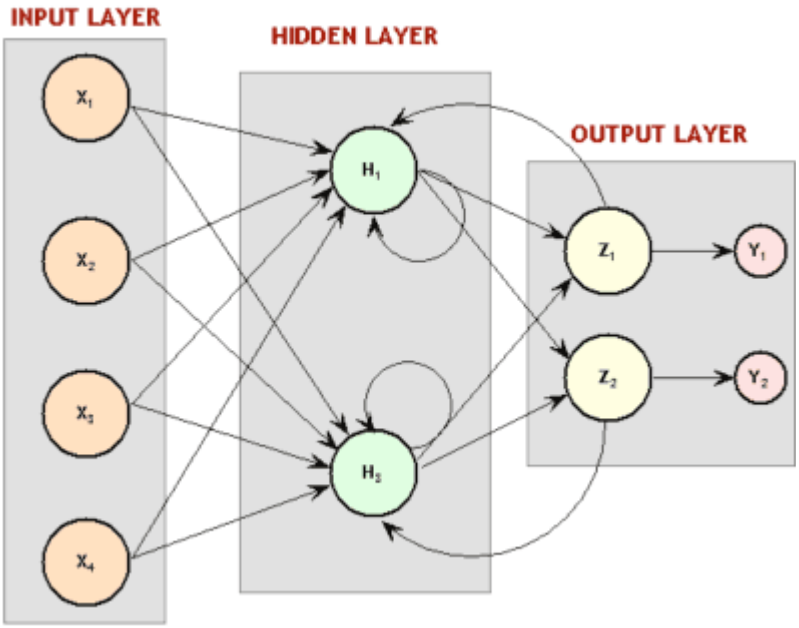


Figure 4: ANN general block diagram

To set the threshold value of the signal entering the activation function at this point bias (θ) is called a fixed input value applied to the input neurons, this allows the threshold to be changed in order to receive the expected outputs. ANN as a basic simple structure and versatile. Each node cells called the nth degree and a non-linear transfer. Processing elements called nodes and links there between, each connection is involved in the transmission of one-way mark delay. Unlimited numbers of processing element inputs and a single output connection. However, if this need to be copied and used in many cells of single output power supply. The output of the processing element may be any desired mathematical type. Indicate the function of the output of the processing element x input value, y output value, Ψ transfer function, f (x) collecting function, w, k, and j. k is the connection weights and θ k for sequential neurons, including neurons sequential threshold for k can be expressed as follows. [10]

$$f(x) = w_{k1}x_1 + w_{k2}x_2 + ... + w_{kn}x_{kn} + \theta = \sum_{j=0}^{n} w_{kj}x_j; \quad \theta = w_{k0}x_0 \tag{2.1}$$

$$y = \psi(f(x)) = \psi\left(\sum_{j=1}^{n} w_{kj}x_j\right) \tag{2.2}$$

Expressed in the form of a neuron matrix are as follows.

$$f_k(x) = \begin{bmatrix} w_{k0} & w_{k2} & w_{k3} \ldots w_{kn} \end{bmatrix} \begin{bmatrix} x_0 \\ x_1 \\ \cdot \\ x_n \end{bmatrix} = w_k^T x \qquad (2.3)$$

Inputs are information that enters the cell from other cells or from the external environment. The information enters the cell via links on weight and weights, will determine the effect on the corresponding input cell. The input values are weighted after entering the processing element, in other words, the impact on the system of each input signal can be replaced by the weight assigned to it. Weights the relative strength of the value to be used as inputs in a neuron (the mathematical coefficient) shows. Multiplication is used at this point. One neuron usually simultaneously many number is entered. There are different weight values of all connections to the transmission between neurons in the ANN input. Thus, the weights impact on all inputs of each processor element has a weight of its own each entry. These weights are the same function with varying biological effects synaptic neuron. In both cases, some entries will be more effective in producing a neural response of the coming process becomes more important element than others. Combining or commonly known as the aggregation function, is a function that calculates the input is coming from a cell and is usually entered is calculated as the sum of the product of the entries related to weight.

2.2.1 Transfer functions

2.2.1.1 Hard-limiter transfer function

The graph of hard limiter transfer function is given in (Figure 5) below. In this graph, n is the input of the function and a is the output of the function. The formula of this function is a=f(n). In this function; if the input value a is greater than zero, the output value is one; if the input value is smaller than zero, the output value is zero. Generally, this function is used in classification application

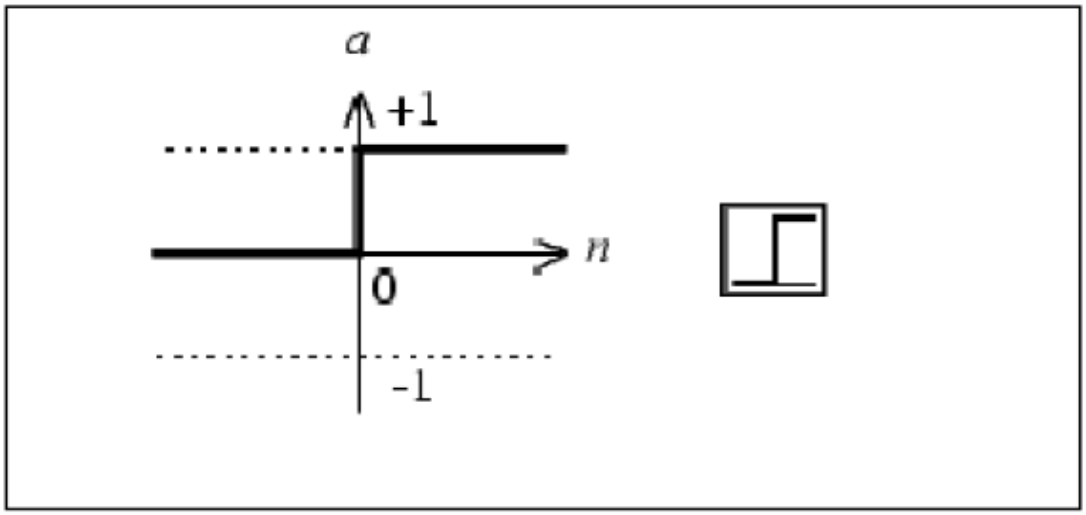


Figure 5: Hard limit transfer function

2.2.1.2 Linear transfer function

The graph of linear transfer function is given in the (Figure 6) as it can be seen from the figure; input is given to the output without any change. Here a is equal to n. This function is commonly used in linear filter problems.

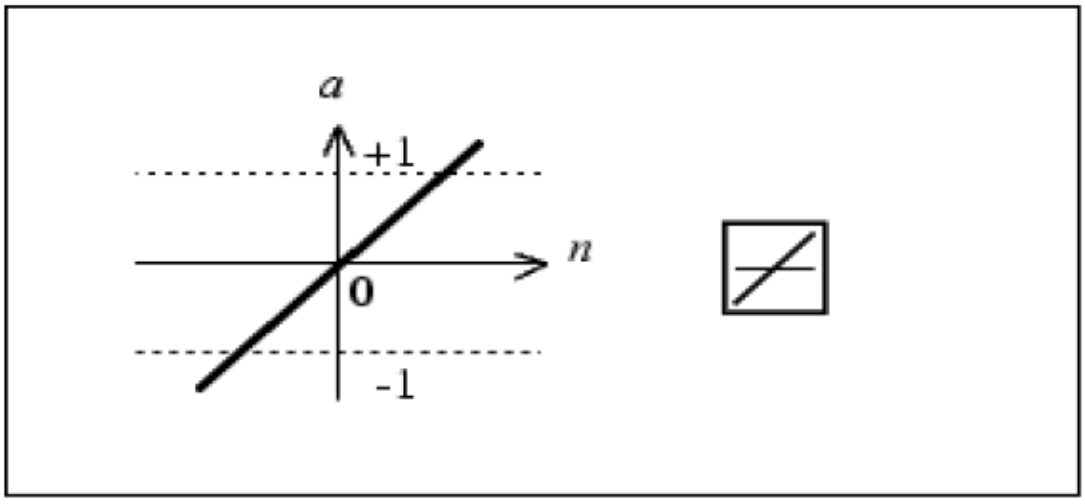


Figure 6: Linear transfer function

2.2.1.3 Log-sigmoid transfer function

The sigmoid is a nonlinear logarithmic function. The output values are between zero and one independent of in what interval the input values are. It is a differential function, so it can be used with back-propagation algorithms. It can be used in the solution of nonlinear problems. The graph of log-sigmoid transfer function is shown in (Figure 7).

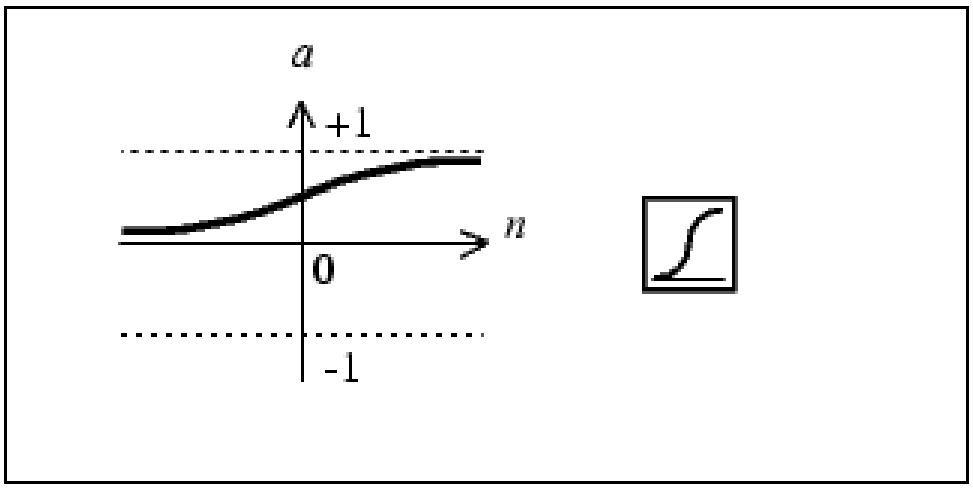


Figure 7: Log-sigmoid transfer function

The mathematical expression of the function is as equation (2.4) below:

$$a = \log sig(n) = \frac{1}{(1+10^{(-n)})} \tag{2.4}$$

2.2.1.4 Tan-sigmoid transfer function

The graph of tangent sigmoid transfer function is given in the (Figure 8). The mathematical expression of tan-sigmoid transfer function is as equation 2.5 below:

$$a = \tan sig(n) = \frac{2}{\left(1+10^{(-2\times n)}\right)} - 1 \tag{2.5}$$

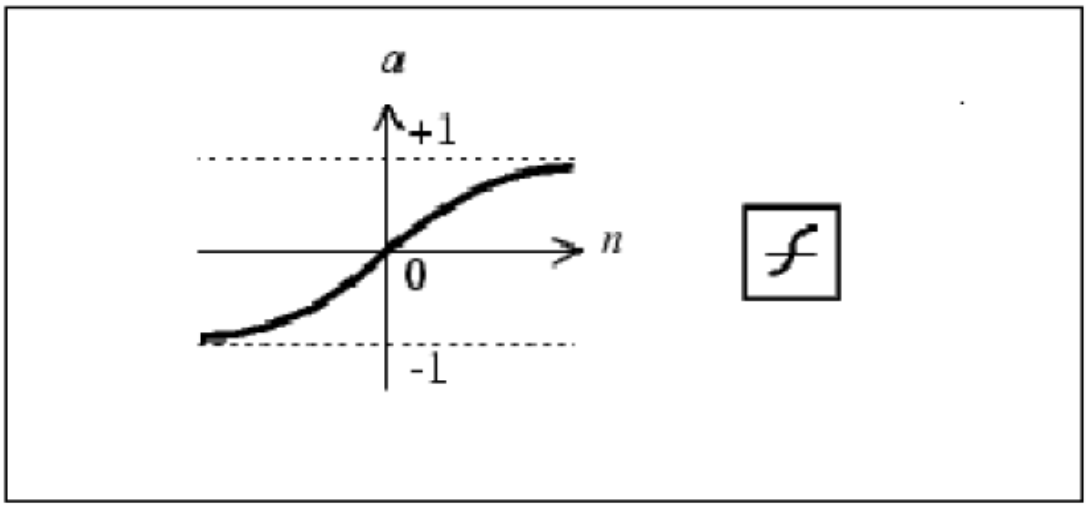


Figure 8: Tan-sigmoid transfer function

2.3. Learning in Neural Networks

Network should be adaptable to a good result from artificial neural networks. This is only possible by suitable weights and the right connections. The network connection must learn the proper weight and behavior of the system in order to obtain or should organize itself. Information in a neural network is kept in the weights of the neural connections in the network. Therefore, it is important how to determine the weight. Knowledge that the weight value is stored in the entire network with a node does not mean anything to a single press. Weight across the entire network should take appropriate value. However, there is a formula originally developed for determining the values of the optimum weights in a neural network. Network processor elements determine optimal weight values using a set of rules over time. This processing "train the network" is called. Accordingly, the weight value of a network to be trained must be dynamically varied within a certain rule [11].

Overall learning event in a neural network takes place in two stages. Weight values to be shown in the first stage random sample are taken and the network has to be generated by the output of the network. According to the accuracy of the output value of the second stage as different examples showing the weights of the network are changed. The objective here is to find a weight value which will be useful to get an accurate output for these samples. Finding weight values to produce the correct

output of the network, indicates that it has the ability to make generalizations about the events represented by the example of the network.
In the event of generalization of the network can "learning network" is called. Basically learning methods, supervised, unsupervised and reinforcement was collected in three groups [11].

2.3.1 Supervised learning

In this method, the intervention of an outside trainer said neural network. Trainers should produce results relevant for neural network input data to the neural network system. So the artificial neural network to input / output samples comprises two presentations.
These two represent the features you need to learn the network. Is part of the network input and generates an output current connection with the information represented by the weight. This output is compared with the output should be transferred over a network error and intermediate weights are modified to reduce this error.

2.3.2 Unsupervised learning

Is there any tutorial which helps the learning unsupervised learning network. Therefore, it is often not self-organizing (self-organized learning) also called. Networking gets his examples shown and classify according to certain criteria. These criteria can be known in advance. The network itself constitutes their learning criteria.

2.3.3 Reinforcement learning

This method is close to supervised learning rule learning. Reinforcement learning algorithm does not need to know the desired output. Does not provide an ANN output to the target output, the accuracy of a measure that is used to input the corresponding output obtained.

2.4 Back Propagation Algorithm (BPA)

The back-propagation algorithm is the most widely used learning algorithm for updating the parameters of the neural network. Today, problems with speech recognition solutions as artificial neural networks to the problem of non-linear systems are used with success in many fields generated [12]. Due to the attempt to reduce the error in the reverse direction network algorithm called back propagation algorithm. Today is derived from the developed many versions back propagation algorithm. But the back-propagation algorithm is usually expressed by the generalized delta learning algorithm.

Calculation of back-propagation algorithm consists of two parts.

- Advanced calculations
- Back calculation

Advanced methods of calculation start with the administration of the network from the input layer of each sample in the training data set. Input data is sent to the intermediate layer between the hidden layer and input without any change. Here, the collection function is applied to each of the neural cells in the hidden layer. What input gathered in the hidden layer of neural cells, with the result that the threshold value of the collection function is calculated. As in Biological neural cells, normalized to the net input of activation functions possessed by every neural cell to generate an electrical signal and produces an output value for the cell. This creates output value of the input value of the neural cells in the next layer. Continues until the output of the computation network. Exit output value is found in layers, advanced calculation of the network is completed.

CHAPTER 3

FINGERPRINT ANALYSIS

3.1 Fingerprint Recognition Systems

Fingerprint recognition is usually based on the comparison of the feature points in the fingerprint and of these parameters [13,14]. Therefore, clearing the fingerprint image and improvement, feature points to be used in fingerprint recognition systems and to determine the correct parameters and the comparison operation to be performed in the correct manner is important for fingerprint recognition systems [15].

3.2 The Principle of General Fingerprint Recognition System

Studies related to the determination of a person's fingerprint by first Dalton and Henry [13]. Galton (Figure9) called the characteristic features Endpoint translated point; the fork point is called the islets. Just use the end and fork spots to achieve successful results [13].

Figure 9: Galton's characteristic points

3.3 Terminology for Fingerprint

Terminology about fingerprint which used is described below.

3.3.1 Furrow lines, endpoint and fork point

Furrow line is a single circular line which fingerprints [16,17]. The sum of the furrow lines reveal the fingerprint pattern [15,17]. Fingerprint recognition systems are used in end and fork points of contour lines are formed by the sudden termination and bifurcation of [13,17].

3.3.2 Orientation maps

Orientation map shows the direction of the furrow lines [15,16] direction map is divided into small pieces composing images. Local routing process is performed on each piece. Determine the orientation of the slope on the other part of the unit vector. The average of all points in the track is calculated. The resulting vector determines the direction for the component. Orientation map of the low-resolution fingerprint is a general representation [13]. The classification of the permitted Orientation map with your fingers, the absence of a reference point, can be used for identification and fingerprint recognition systems and artificial neural network [15,16] (Figure 10). Orientation map are shown.

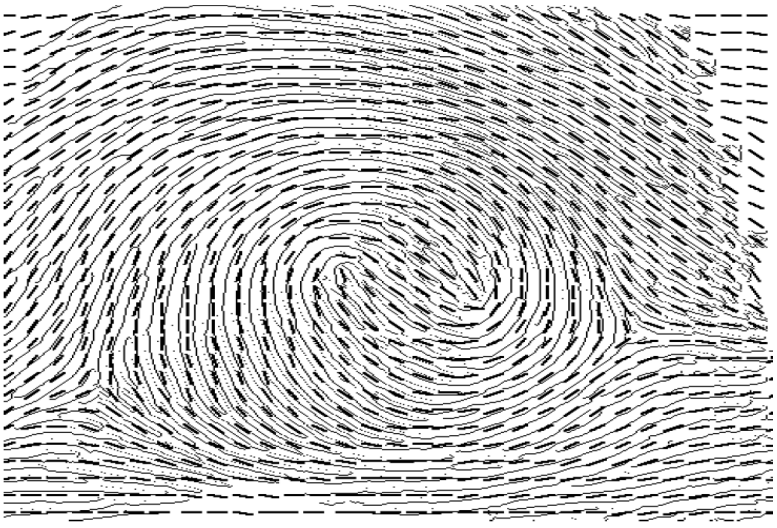


Figure 10: Representation of the orientation map on fingerprint

3.4 Classification of Fingerprints

Line in the center of fingerprints and valleys form a number of different custom shapes from each other. In this way, the different, is small enough to make a systematic classification of fingerprints. So it is possible to classify the shapes formed. Fingerprints classification to five types according to some studies [15.18] some of the six [15] while others are divided into eight classes [19]. Illustrates some fingerprint classes (Figure 11).

Arch Loop Whorl

Figure 11: Classified examples of fingerprints

3.5 Feature Point Extracting

Feature point extraction, representing a fingerprint, from the characteristics of the feature point is obtained from fingerprint images received as input. Automatic fingerprint alignments, striking the input fingerprint images, it is important to be represented in an appropriate manner. This representation generally has the following properties [20]:

- Crude fingerprint images not to lose the ability to the distinguish
- Few places covering
- Matching algorithms compliance
- Corruption and resistance to noise
- Simplify the calculation

Where in the first feature the feature of being the only protection of the fingerprint representation, so that means of identification can be made only on the basis of representation. The second feature of the distinguishing characteristics of fingerprint

representation is unnecessary to hold further information. The third feature is that it can be used to match the representation algorithm. Represented as said in the fourth article, no doubt, on fingerprint images must be resistant to noise and distortion. Finally, it must be difficult to calculate the representation. An automatic fingerprint matching, only two types of feature points detail the most conspicuous of detail, stability, and durability are used because:

- End of line
- Line of bifurcation

A good feature point extraction algorithm will be both safe and effective. Reliability, feature point extraction algorithm to extraction false feature points, do not miss the point of the existing property and calculating the position and orientation of the feature points are meant to be correct. Fingerprint is a reliable process to remove the property from the images. If good quality fingerprint images, fingerprints of flowing lines and valleys locally on the hard direction is well defined and can be easily separated from each other. In such cases, the lines are terminated with uneven lines and lines of branching places they can easily be identified, their position in binary (binary) images removed from the line. Depending on the quality, may be denied or can strengthen a weak fingerprint image before removing the feature. Very weak disrupted all of calligraphy fingerprint image should be rejected; the line structure can be seen that the level should be strengthened before removing a weak feature is the fingerprint image. A good feature extraction algorithm to a certain level is able to ignore the corrupted line structure. Fingerprint correction and pre-processing algorithms, occupies an important place in fingerprint recognition systems.

A fingerprint image part to be free from unnecessary information and carries some advantages in the presence of noise feature points provides [21]. Other processing steps through improving the quality of the picture, using this improved image as input.

3.5.1 Fingerprint improving the image (filtering)

There are several filters between the methods used in image enhancement [22]. Examples of these filters mean value filtering may be administered Laplacian filter

and median filter. One of the most commonly used filter is used in the field of computer vision in our study that the median filtering. Filters are taken together with neighboring pixels around each pixel applying. Center for a filter on the 3x3 pixel size and the surrounding pixels are sorted and discarded a number of series. Middle element of the sorted directory (5 elements) is assigned as the new value of the center pixel.

3.5.2 Fingerprint is transformed into binary image (thresholding)

Fingerprint images are usually gray level pictures. This consists of 8-bit gray level of inactivity on the image; the extraction of feature points is quite a difficult task. Image analysis must be converted to binary image consisting of black and white color values to be performed more easily. Fingerprint so black instead of values below this threshold identify a threshold value considering the average of the image color values to convert the image to black-white to 0, instead of the large amount of white that one subject [18].

3.5.3 The presence of feature points

Fingerprint recognition, although there are many features that are used most commonly used endpoint and fork spots are two features [13,14]. This feature points of a sudden interruption of the normal flow direction of a life line (end point) or a change divided into two (fork point) the form [13]. Endpoints used in identification and fork point shown in (Figure 12).

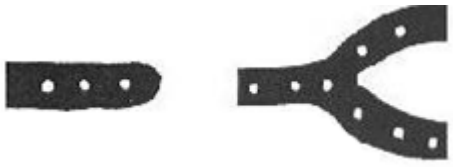


Figure 12: End and fork point

Identification of types of these feature points, according to a reference point coordinates, angles, distances and used the number of lines between the lines [18].

Fingerprint of corruption, scars and obtaining the correct some poor quality fingerprint images of the feature point is a difficult process because of the noise.
A fingerprint feature points are found primarily point to be decided is whether a pixel of a line. The previously mentioned noise reduction techniques are used. Then Thresholding and thinning these procedures. The presence of image feature points and improve the image of the thinning process is completed (fork and endpoint) for ready. Each feature point is identified by its coordinate data and angle [23]. Input used for finding the feature point is thinned fingerprint image that contains a picture frame. Approach will be used in our study presented by Xiao and Raafat. In the present approach end point and fork are made towards finding process.

3.6 Fingerprint Recognition Algorithm Types

Fingerprint recognition systems used in the three most basic algorithms "Correlation" Based," Minutiae" based and "Ridge" algorithms [24].

3.6.1 Correlation-based recognition

Line of hills and valleys in the fingerprint image properties worldwide level, and these characteristics are compared using parameters. Registration point correlation based techniques require knowing the precise position data.

3.6.2 Minutiae-based recognition

Fingerprint is determined by the location of the pustular point and point details consist of levels are compared. Recognition algorithms based on low-resolution fingerprint images are difficulties in extracting details. Therefore, before implementing algorithm tracks a pre-processing is subjected.

3.6.3 Ridge- based recognition

Fingerprint of the line direction and shape information is used. In this technique in the Minutiae based techniques as low resolution images to be able to correctly identify lines include preprocessing stage.

3.7 Fingerprint Varieties

Types of fingerprints, fingerprint lines created by the major delta shapes, Whorls and loops are based on. Basically, the kinds of fingerprint, fingerprints are determined depending on the number of the delta. However, the delta shape and the loop and coil as well as determining when provided also play a role in determining the kinds of fingerprints. Proposed by Galton and the first scientific study of fingerprints in the process, arc, loop and Whorl structure is divided into three groups. Later in the structure of Galton-Henry said five buildings are residential. This structures, arc, tents arc, left loop, right loop and Whorl has been named.

3.7.1 Whorl fingerprint

The Whorl formed by curved lines of the fingerprint in the remaining is a circular region. They are usually composed of two deltas and in the form of a helix [25].

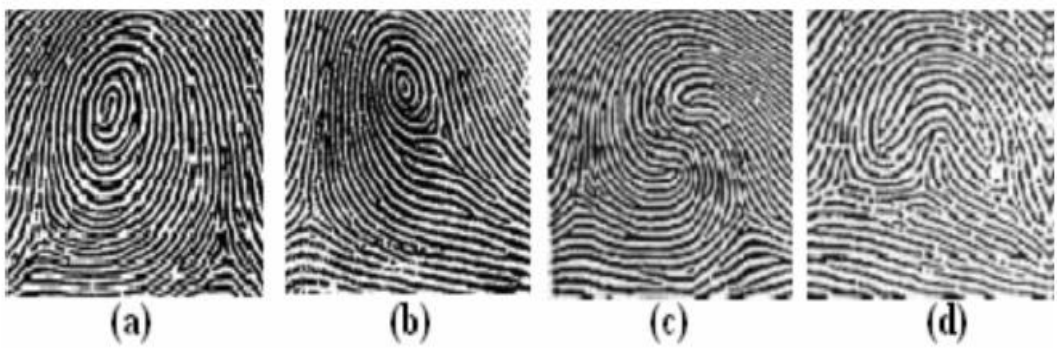


Figure 13: Whorl fingerprint

Simple Whorl type fingerprint, in the innermost area of the pattern, two deltas drawn between intersected by the imaginary line, the circle or ring form comprises attempting to create the line or lines (Figure 13).

3.7.2 Loop fingerprint

Fingerprints loop type the most common is a kind of fingerprint. These fingerprints in one or more lines, moving towards the delta core of the imaginary line, Log in by contacting or the cutting; leaning backwards Creates loops and ends in Login the region. Forming Loop to start and end lines determined by the nomenclature, fingerprints without knowing where it belongs, which handle can be determined which belongs to the type of loop. Left loop structure fingerprint pattern is in the structure form of loops to the left oblique. Right loop pattern of the fingerprint structure is in the structure form loops oblique to the Right side (Figure 14).

Right loop Left loop

Figure 14: Loop fingerprint

3.7.3 Arc fingerprint

Arc structure, starting from one end of fingerprints, creates and upgrade refers to the end of the other end. Arc structure that contains the fingerprints, the lines, on top of the belt creates a similar way, but the delta, loop, Whorl-like shape and has the core point. About 5% of people are in such a fingerprint. Some sources are also referred to as belt type fingerprint (Figure 15).

Figure 15: Arc fingerprint

3.7.4 Helical

A fingerprint by 360 degrees in the center of the fingerprint is defined as the structure formed by joining. Helical structure can be in the form of two loops or two deltas. Two loops named twin loop pattern (Figure 16 (a)), the loop is odd patterns is called lean loop (Figure 16 (b)).

(a) (b)

Figure 16: Lean loop and twin loop

3.7.5 Tents arc

The structure resembles the Arc in this class loop and delta constitutes fingerprints with a higher slope. Tent structure with arc fingerprints as in arc structure is to go from one end to the other end, creating a hill (Figure 17).

Figure 17: Tents arc

3.8 Fingerprint Anatomy

Contour lines fingerprint is a single circular line [13,17]. Some lines in fingerprints separated in half as fervid or termination point and the end point of a tool that reveals [26]. A fingerprint of the cycle or Whorl type design area includes two kinds of singular points (Figure 18). Delta and the mid-point (hub points). Internal stop the so-called mid-point (hub), the innermost specific points on the curved lines defined. External station the so-called delta point, the type of line closest to the separation point of the line, it can be defined as the point opposite the center. These characteristic points, in 1888, Francis Galton observed on the tracks and "nite" is defined as the rich details (Figure 19).

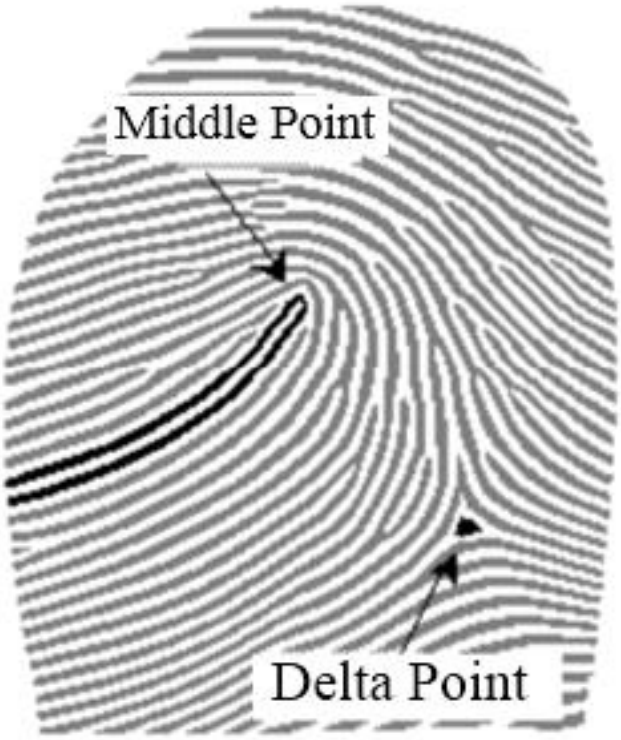


Figure 18: Delta and mid-point representation

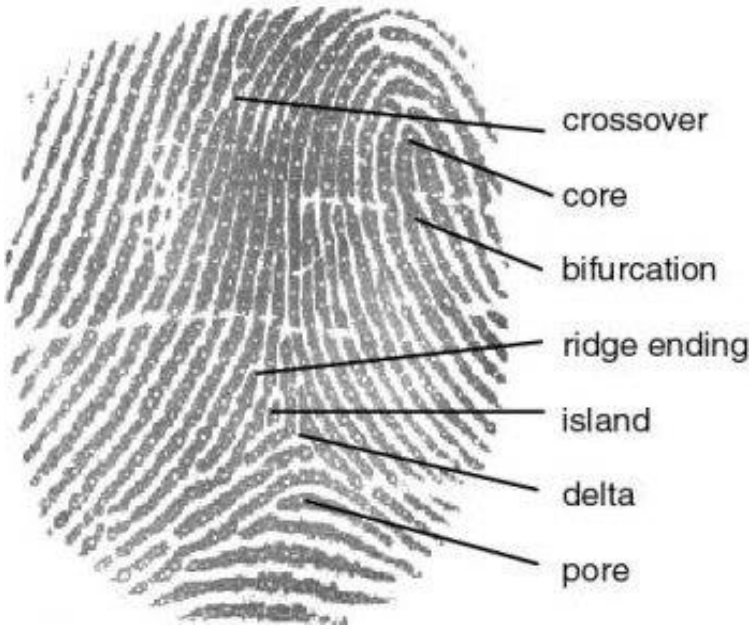


Figure 19: Nitem species

CHAPTER 4

IMPLEMENTATION

The Structure based on classification of fingerprint images grooves [27,29], local images are used to classify [27].the classification accuracy rate for five classes is 90% and to classify four classes is 91.5% [28]. A change in classification of syntactic grammar fingerprint and hence used their classification [30,31]. Grooves used to extract information about the structure of fingerprint and there are two main approaches about the grooves. The first method based on a mathematical model for the grooves. The second approach is defined by the unique characteristics (such as grooves endings and bifurcations known details). This second approach, would the record criteria of grooves and it is used to classify the characteristics of this information. Typically, fingerprint features are classified by these two approaches. In this work, the fingerprint image represented with a successful co-occurrence matrix and the normal tissue of fingerprint, classify according to a new approach. With some morphological operations in a number of fingerprint patterns were applied to highlight the groove structure. And then, training a classifier based on Artificial Neural Network, occurred in four main classes used to classify the fingerprint classes. In addition compare the result of this method with famous previous methods and algorithms.

Senior achieved 88.5% accuracy of correct classification [32]. Jain et al used fingerprints to Gabor filters to extract the four directional features [33]. Another attempt, Jain and minute their classification scheme of the fingerprint grooves structure stores information about the way and gained 94.8% of correct classification [33,34]. Chang and Fan have developed a fingerprint alternative representation that captures information. Which represents proposal mathematical model for each class of fingerprints and achieved 94.8% of correct classification [35,36].

Four famous fingerprints classes are used to evaluate the algorithm of this work, these classes are (Arch, Whorl, Left loop and Right loop) (Figure 20), where these fingerprints classes' images are taken from FVC 2000, FVC 2002 and FVC 2004 (Fingerprint Verification Competition) databases.

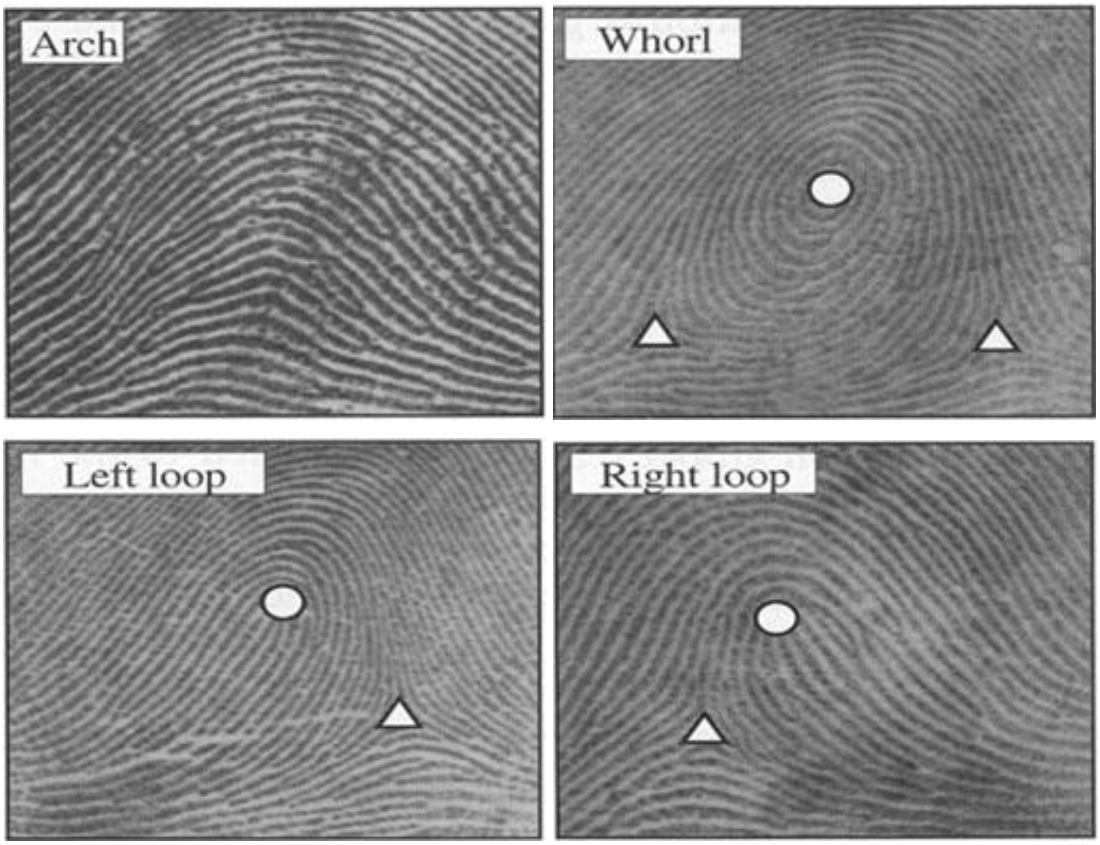
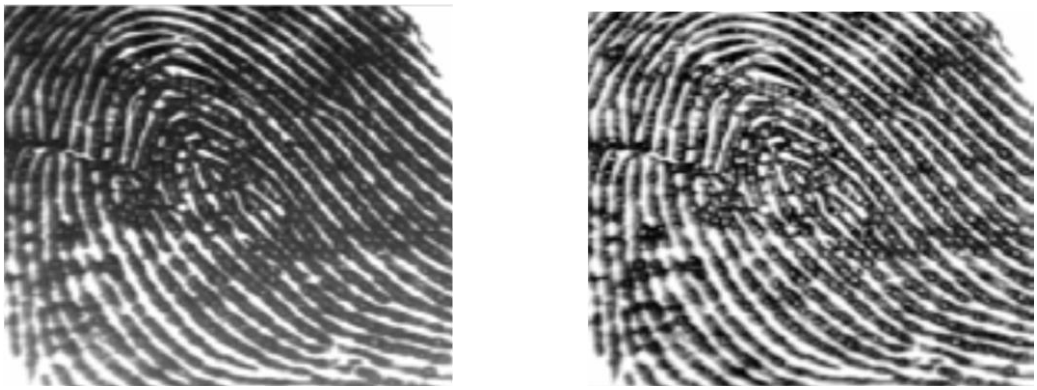


Figure 20: Fingerprints classes

The number of images which used in this work are 730 images, were classified into four classes of fingerprint images, the arch class contains 169 images, 140 images for the Whorl class and right loop class has 222 images and 199 images for the left loop. Where, about 70% of these fingerprints images used for training (learning) the artificial neural network and about 30% used to testing it.

The fingerprints images of the four classes are saved in a computer and recall (read) it by using four (for loops), where it is used MATLAB software for processing this work , (one loop) for each class, if these images are colored, (RGB) color model, it will converted to gray scaled image.

The moisture and scars of a finger as well as the pressure due to a fingerprint sensing could distort the quality of the acquired fingerprint image. So, after read the images and convert it to gray scaled, begin to increase the resolution of images (Image Enhancement), by using Contrast-Limited Adaptive Histogram Equalization (CLAHE) technique. This technique is just for increasing the resolution (Figure 21)



a) Before increasing the resolution b) After increasing the resolution

Figure 21: Increasing the resolution of images

4.1 Gray-Level Co-occurrence Matrix (GLCM)

Gray level co-occurrence matrix GLCM provides the information about the texture of images, so can extract the features. After image enhancement, use GCLM in four directions (Figure 22) as in the following equations, 0 °, 45 °, 90 ° and 135 °. In order to extraction the features of images.

```
g1 = graycomatrix(I,'Offset',[3 0],'N',64);
g2 = graycomatrix(I,'Offset',[3 3],'N',64);
g3 = graycomatrix(I,'Offset',[0 3],'N',64);
g4 = graycomatrix(I,'Offset',[-3 3],'N',64);
```

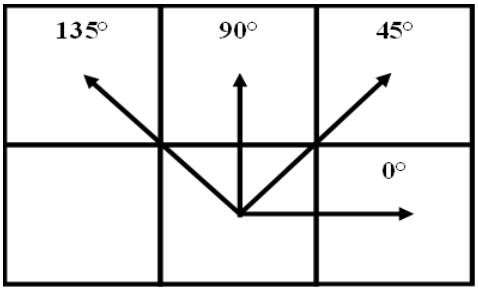


Figure 22: Gray level co-occurrence matrix (GLCM)

4.2 Feature Extraction

There are twelve feature extraction techniques used in this work such as: Maximum probability, Contrast, Entropy, Angular Second Moment, Homogeneity, Differences, Average, correlations. These feature extraction techniques used in four directions according to GLCM (0 °, 45 °, 90 ° and 135 °). So, get twelve features for each of the four directions and this means 48 features. In addition all of these feature extraction techniques applied for each finger images. Below some of feature extraction's equations which used in this work:

$$Energy = \sum_{i=1}^{n}\sum_{j=1}^{m} C_{ij}^2$$

$$Entropy = -\sum_{i=1}^{n}\sum_{j=1}^{m} C_{ij}\log C_{ij}$$

$$Contrast = \sum_{i=1}^{n}\sum_{j=1}^{m} |i-j|^2 C_{ij}$$

$$Correlation = \frac{\sum_{ij}(i-\mu)(j-\mu)C_{ij}}{\sqrt{\mathrm{var}(i)\,\mathrm{var}(j)}}$$

$$\max_{i,j} p(i,j)$$

The features of images are saved in matrix and then used this features matrixes in Neural Network for classification.

o1(1:4,i) = [1;-1;-1;-1]; % right_loop class
o1(1:4,i) = [-1;1;-1;-1]; % left_loop class
o1(1:4,i) = [-1;-1;1;-1]; % whorl class
o1(1:4,i) = [-1;-1;-1;1]; % Arch class

g1 : [**1** -1 -1 -1]
g2 : [-1 **1** -1 -1]
g3 : [-1 -1 **1** -1]
g4 : [-1 -1 -1 **1**]

4.3 Classification with Artificial Neural Network

In classification stage used Artificial Neural Network (Backpropagation Algorithm). The training algorithm which used is Levenberg-Marquardt algorithm (LMA). This algorithm (LMA) is the fastest method to teach the medium-sized feedforward neural networks (several hundred of weights). Also used Multi-Layer Perceptron MLP for the classification stage, where MLP is an advantage for real time classification cases by reducing the image processing time for the classifier. For training (Teaching) the Artificial Neural Network selected 70% of images and 30% of images for testing (figure 23).

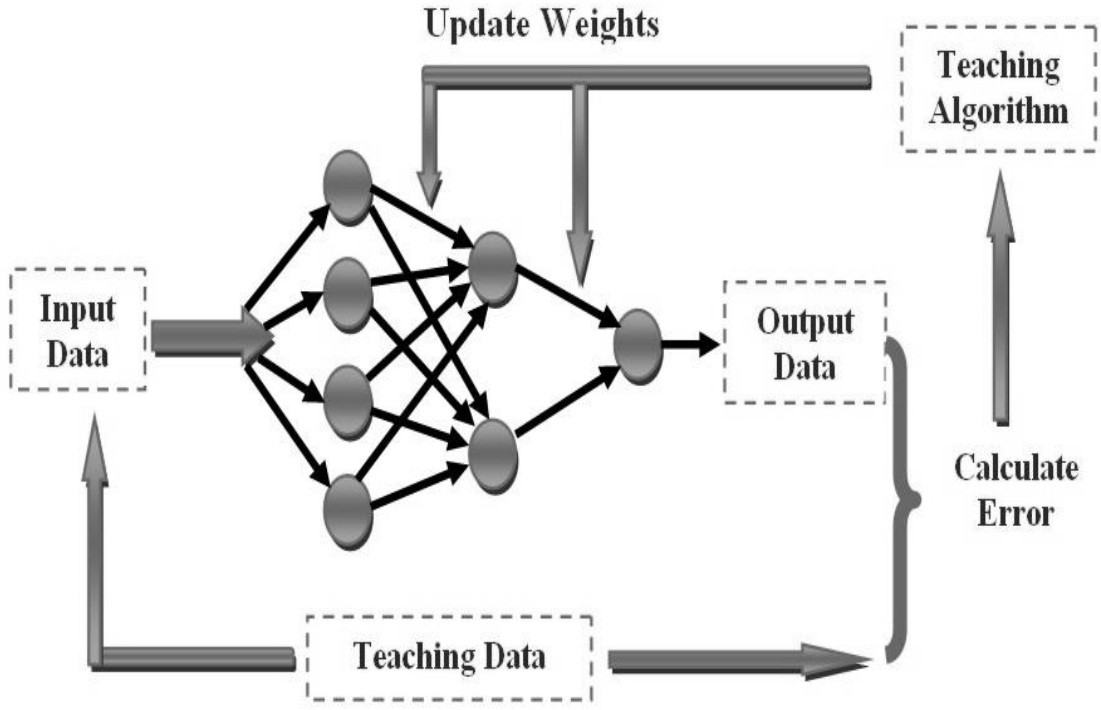


Figure 23: Classification with artifitial nural network

Increase the classification and recognition accuracy by select the best architecture where changed the number of neurons for each hidden layer until get best architecture which achieve the best accuracy. For this work, the best accuracy achieved by used 18 neurons in second hidden layer and 7 neurons in third hidden layer.

4.4 Results and Discussion

In this work method the gray level co-occurrence matrix used for feature extraction. In addition increased the classification and recognition accuracy by select the best architecture of neurons, layers and training algorithm (Table 1). Where used 48 features for input layer (12 features for 4 directions) for every fingerprint images.

In the second hidden layer used (18) neurons and in the third hidden layer used (7) neurons, since this architecture has achieved the highest percentage. In the output layer there are (4) neurons ([1;-1;-1;-1] ; [-1;1;-1;-1] ; [-1;-1;1;-1] and [-1;-1;-1;1]) (Figure 24).

Table 1: MLP Network Performance

Number of neurons in second hidden layer	Number of neurons In third hidden layers	Accuracy
7	9	95.25
8	9	96.15
16	5	95.06
18	**7**	**97.09**
24	7	96.45
19	9	96.55
17	11	94.51

After run MATLAB code, the (Training results) for each class are: 100 results for Arch class, 100 results for Whorl class, 150 results for Right loop class and 150 results for Left loop class (Table 2).

Table 2: Excerpts of Training Results

Right loop class:						
1	**2**	**……**	**100**	**101**	**……**	**150**
0.9906	0.9906		0.9906	0.9906		0.9904
-1.0000	-1.0000		-1.0000	-1.0000		-1.0000
-0.9999	-0.9999		-0.9999	-0.9999		-0.9999
-0.9987	-0.9987		-0.9987	-0.9987		-0.9985
Left loop class:						
1	**2**	**……**	**100**	**101**	**……**	**150**
-0.9997	-0.9993		-0.9986	-0.9995		-0.9991
0.9939	0.9984		0.9961	0.9950		0.9988
-0.9798	-0.9987		-0.9786	-0.9964		-0.9997
-0.9967	-0.9927		-1.0000	-0.9963		-0.9965
Whorl class:						
1	**2**	**……**	**50**	**51**	**……**	**100**
-0.9994	-0.9994		-0.9996	-0.9998		-0.9978
-0.9996	-0.9998		-1.0000	-0.9989		-0.9999
0.9884	0.8749		0.9997	0.9769		0.9999
-0.9970	-0.9919		-1.0000	-0.9934		-0.9987
Arch class:						
1	**2**	**……**	**50**	**51**	**……**	**100**
-0.9971	-0.9886		-0.9937	-0.9821		-0.9970
-0.9212	-1.0000		-1.0000	-0.9997		-1.0000
-1.0000	-0.9998		-0.9991	-1.0000		-0.9990
0.9627	0.9993		0.9937	0.9984		0.9892

The rest values for each class, it is for testing, where the (testing) images for Right loop are start from (151 to 222), because the images from (1 to 150) for training and the (testing) images for Left loop are start from (151 to 199), because from (1 to 150) for training and the (testing) images for Whorl are start from (100 to 140), because

from (1 to 100) for training and the (testing) images for Arch are start from (100 to 169), because from (1 to 100) for training (Table 3).

Table 3: Excerpts of Testing Results

Right loop class:						
151	**152**	**……**	**200**	**201**	**……**	**222**
0.9753	0.9856		0.9772	0.9711		0.9964
-0.9954	-0.9949		-0.9955	-0.9951		-0.9140
-0.9957	-0.9944		-0.9957	-0.9958		-0.9989
-1.0000	-1.0000		-1.0000	-1.0000		-1.0000
Left loop class:						
151	**152**	**……**	**170**	**171**	**……**	**199**
-0.9668	-0.9538		-0.9877	-0.9891		-0.9910
0.8383	0.7334		0.9520	0.9655		0.9667
-0.9127	-0.8724		-0.9396	-0.9418		-0.9621
-0.9999	-1.0000		-0.9952	-0.9921		-0.9972
Whorl class:						
101	**102**	**……**	**130**	**131**	**……**	**140**
-0.9786	-0.9763		-0.9927	-0.9657		-0.9796
-0.1215	-0.6972		-0.9862	-0.9167		-0.8618
0.5901	0.2437		0.7063	0.8503		0.6161
-0.9998	-0.9998		-0.9764	-0.9999		-0.9997
Arch class:						
101	**102**	**……**	**130**	**131**	**……**	**169**
-0.9997	-0.9996		-0.9996	-0.9994		-0.9995
-0.8159	-0.7408		-0.5550	-0.8242		-0.6490
-0.8884	-0.9128		-0.9312	-0.8942		-0.9405
0.9061	0.8843		0.7727	0.8543		0.7370

After that, simulate the results where, the targets result is (1 or -1) depending on the type of the class in order to (recognition) (Figure 25).
After get the results values of testing and training data, calculate the difference between all real values (testing) and all outcome values (training) and then calculate the mean of this data for all the classes.
Also after get the results for each class separately, calculate the mean values for all classes, in order to get the accuracy, where these results achieved accuracy equaled (**97.09)** percentage.

Finally, compare the accuracy of this work method with six famous methods accuracy. The accuracy of this work method equaled (**97.09)** by used four famous classes. In addition the accuracy of the other methods was less than (**97.09)** so this work mothed gets the highest performance percentage (Table 4).

Table 4: Performance of this Work Method with Famous Methods

Method	Class	Accuracy
Senoir	4	88.5
Chang and Fan	5	94.8
Zhang et al.	5	84.0
Karu and Jain	5	85.4
Yao et al.	5	89.3
Mohamed and Nyongesa	5	92.4
Work Method	**4**	**97.09**

The number of iteration (epoch) was 1000 and the stop error number was 0.00000001 where (error = desired - y output**)** (Figure 26). The Gradients, Mu, and Validation for work method (Figure 27).

Figure 24: Neural network training tool for work method (MATLAB)

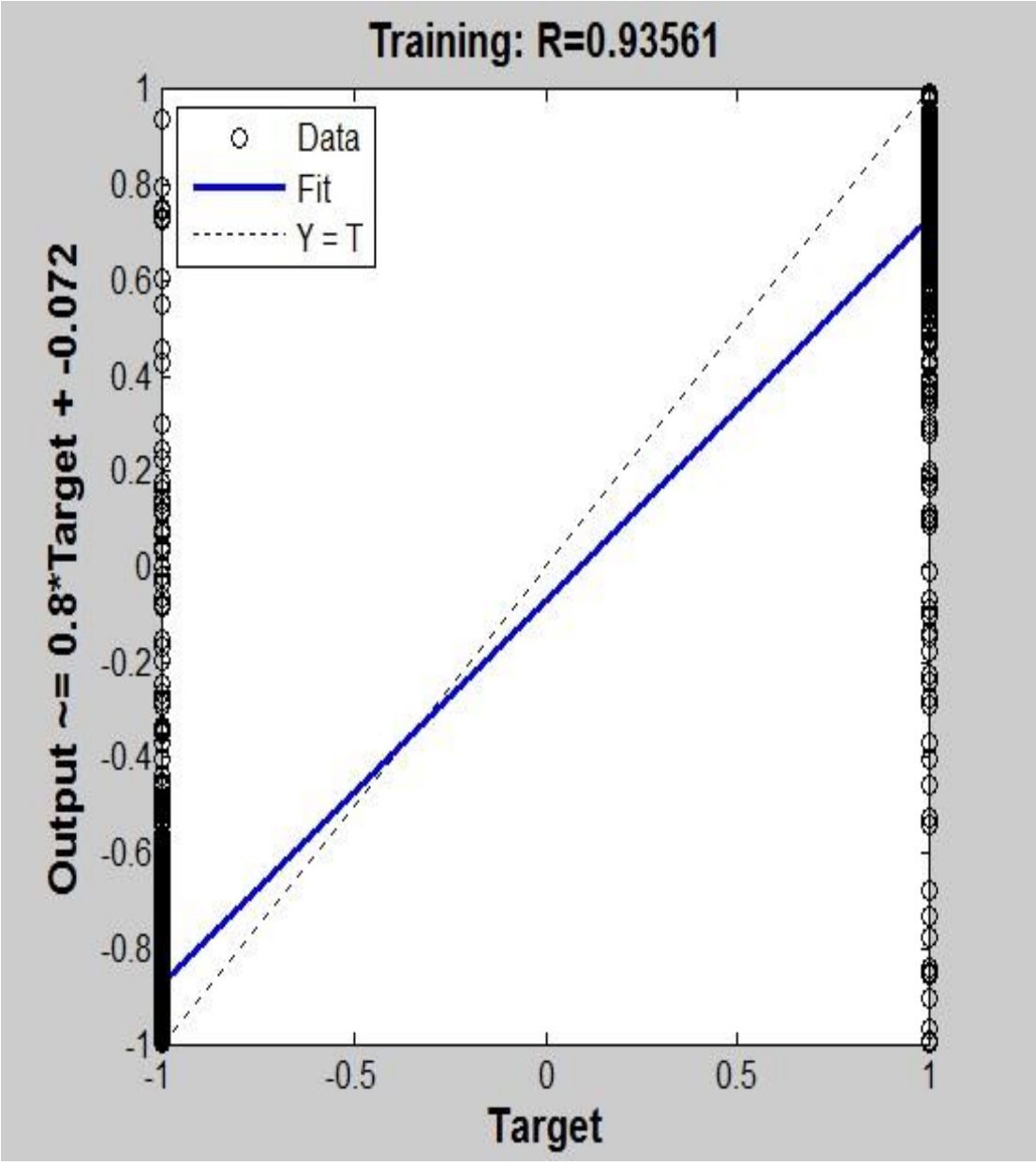


Figure 25: The regression of training after running for work method (MATLAB)

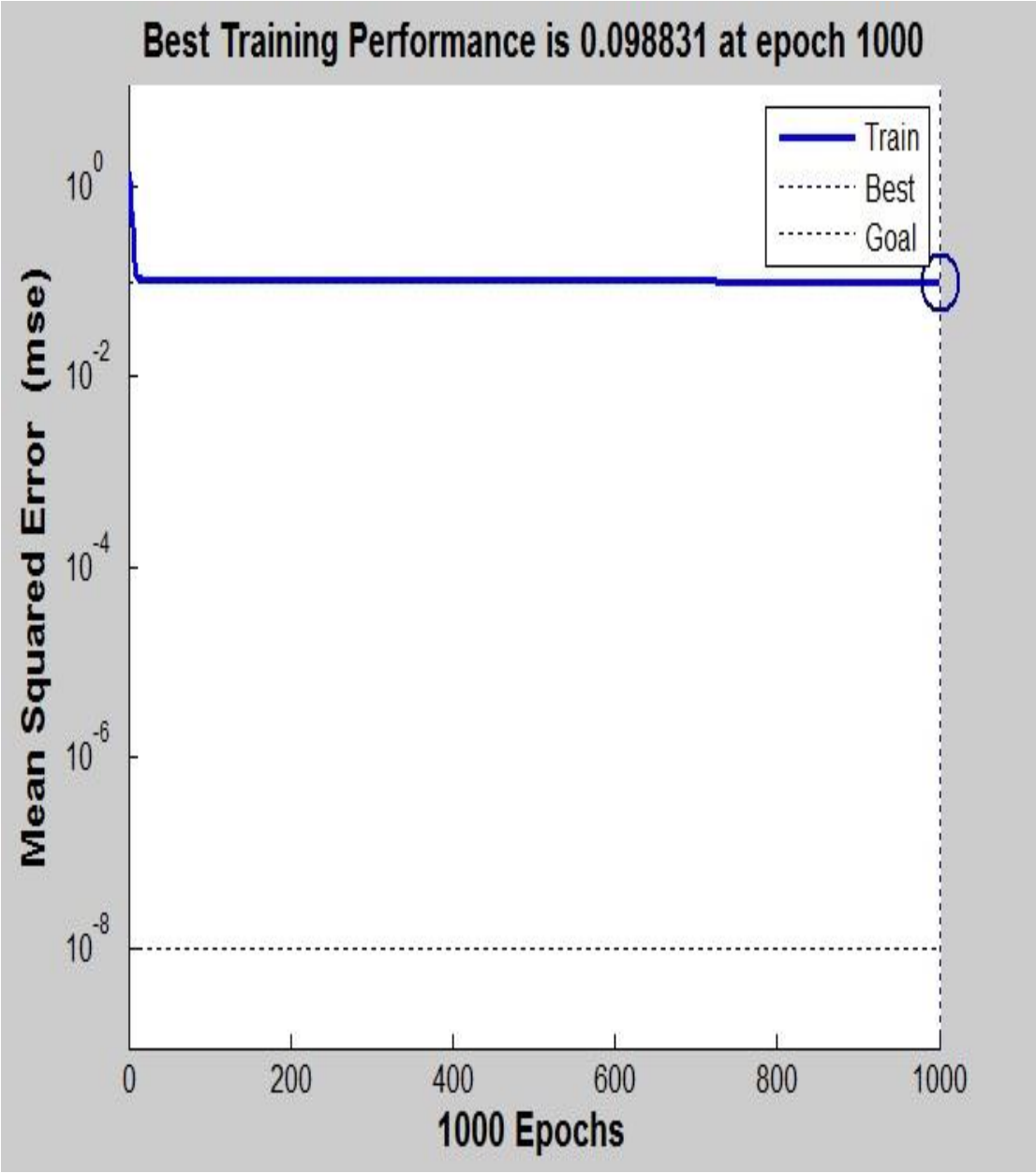


Figure 26: Mean squared error (average) and the best training performance for work method (MATLAB)

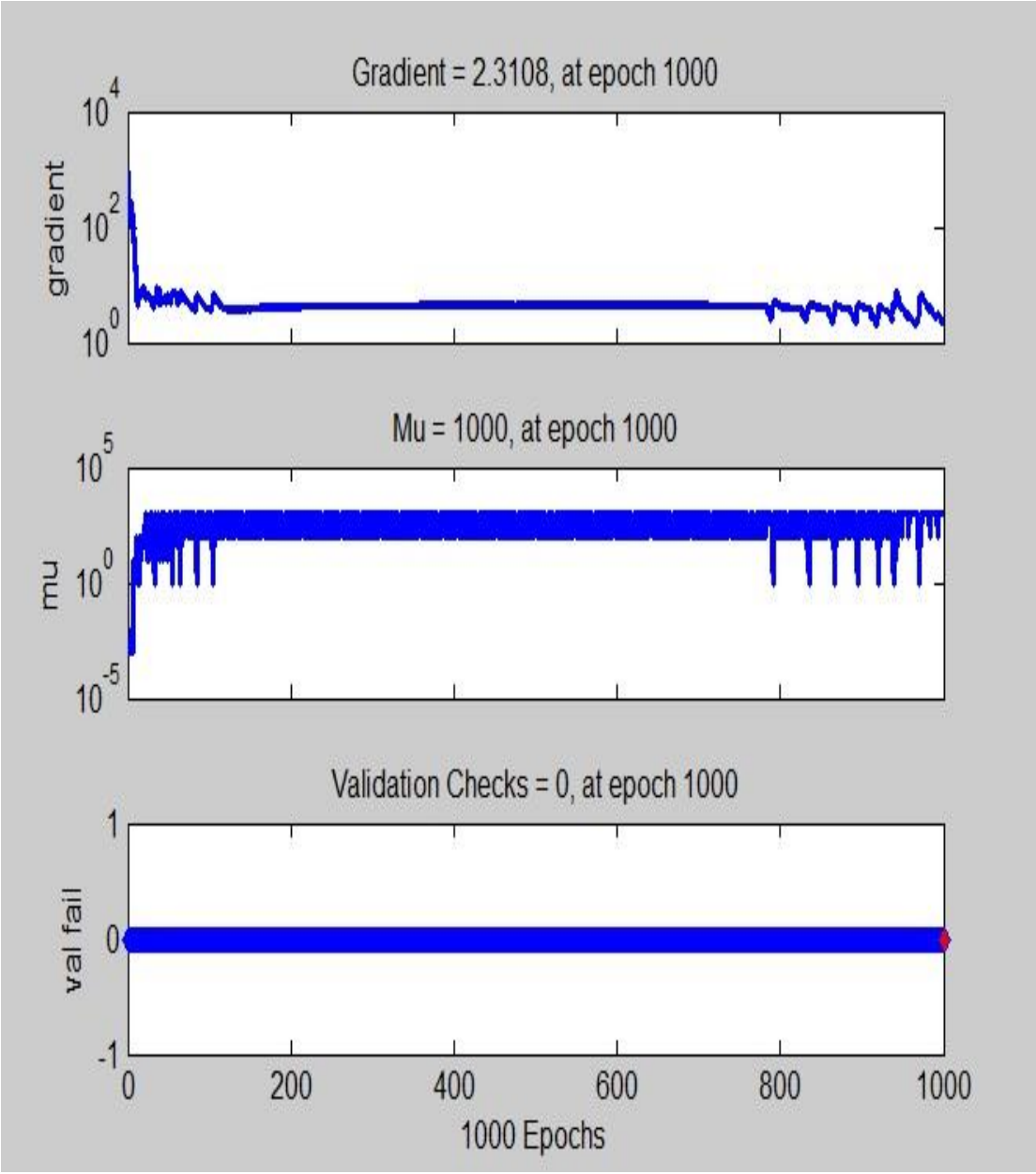


Figure 27: Gradients, mu, and validation for work method (MATLAB)

CHAPTER 5

CONCLUSION

In this work used successfully the gray level Co-occurrence matrix for feature extraction of fingerprint images. Also for classification with Artificial Neural Network used (Back Propagation Algorithm).

In addition the training algorithm which used is Levenberg-Marquardt algorithm. This algorithm (LMA) is the fastest method to teach the artificial neural networks Where, about 70% of fingerprints images used for training (learning) the artificial neural network and about 30% used to testing and Multi-Layer Perceptron used for the classification stage precisely.

Fingerprint classification has been processed by using MATLAB software. Increase the classification and recognition accuracy by selection the best architecture of neurons, layers and training algorithm, by used 18 neurons in second hidden layer and 7 neurons in third hidden layer. In this work achieved the best classification accuracy 97.09% by MLP network to four fingerprint classes (Arch, Whorl, Left loop and Right loop).

Compared the work method with other algorithms and test it for famous databases. The compared between the previous studies performance and work performance shows that this work method achieved accuracy more than the other famous method.

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APPENDICES A

CURRICULUM VITAE

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