"I hereby declare that I have read through this report entitle "Classify EMG data for upper limb muscle based on different movement of arm rehabilitation device" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)"

Signature : .....

Supervisor's Name : Mr. Mohd. Hafiz Bin Jali

Date : 16/6/2014

CLASSIFY EMG DATA FOR UPPER LIMB MUSCLE BASED ON DIFFERENT MOVEMENT OF ARM REHABILITATION DEVICE

'IFFAH MASTURAH BINTI IBRAHIM

A report submitted in partial fulfilment of the requirements for the Degree of Bachelor in Electrical Engineering (Control, Instrumentation & Automation)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

I declare that this report entitle "Classify EMG data for upper limb muscle based on different movement of arm rehabilitation device" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : 'Iffah Masturah Binti Ibrahim

Date : 16/6/2014

For my beloved Mama and Abah,

To my dearest Brothers and Sisters,

Hasanuddien, Mohd Hafiz, Muhammad NorHelmi,

NurulMuallimah, IffahAmirah.

Thanks for all the pray, supports and loves.

Your girl loves you.

Lots.

ACKNOWLEDGEMENT

Alhamdulillah, Thanks and Praise to Allah S.W.T;
I take this opportunity to express my profound gratitude and deep regards to my guide supervisor Mr. Mohd. Hafiz Bin Jali for his abundantly helpful and offered invaluable assistance, support and guidance. The blessing, help and guidance given by him time to time shall carry me a long way in the journey of life on which I am about to embark.

I realise that I would not have finished this thesis without the support and encouragement of so many people. Here goes my thanks and appreciation to members from FKP, UTeM for being my subjects on this research. Without your co-operation and patience I am not able to complete my experiment to prove in this thesis.

Finally, I would like to express my thanks to my beloved parents for blessed me in their prayer and being my good listener to all the complaints in the difficulties. I will not be able go through all the obstacles without the blessed. Special thanks to my beloved brother Muhammad Noor Helmifor his guidance in human anatomy, your medical field do help me a lot to understand this project. Last but not least, to my siblings, brothers and sisters your courage, support and pray brought me here to complete this thesis successfully.

ABSTRACT

Rehabilitation device is used as an exoskeleton for people who experiencelimb failure. Arm rehabilitation device may easethe rehabilitation programme for those who suffer arm dysfunctional. The device used to facilitate the tasks of the program should improve the electrical activity in the motor unit by minimising the mental effort of the user. Electromyography (EMG) is the techniques to analyse the presence of electrical activity in musculoskeletal systems. The electrical activity in muscles of disable person are failed to contract the muscle for movements. To prevent the muscles from paralysis becomes spasticity or flaccid the force of movements has to minimise the mental efforts. To minimise the used of cerebral strength, analysis on EMG signalsfrom normal people are conducted beforeit can be implement in the device. The signalsare collect according to procedure of surface electromyography for non-invasive assessment of muscles (SENIAM). The implementation of EMG signals is to set the movements' pattern of the arm rehabilitation device. The filtered signal further the process by extracting the features as follows;Standard Deviation(STD), Mean Absolute Value(MAV), Root Mean Square(RMS), Zero Crossing(ZCS) and Variance(VAR). The extraction of EMG data is to have the reduced vector in the signal features for minimising the signals error than can be implement in classifier.The classification of time-domain features only can be applied for three types of time-domain features are Mean Absolute Value(MAV), Root Mean Square(RMS) and Standard Deviation(STD).Thearm movements of 60˚, 90˚ and 120˚ are classified into their own class of degrees movements by using SOM-Toolbox for MATLAB are visualized in U- Matrix form.

ABSTRAK

Alat bantu pemulihan digunakan sebagai rangka luar bagi membantu individu yang mengalami kegagalan fungsi anggota tubuh badan. Alat bantu pemulihan tangan mampu memudahkan individu yang mengalami kegagalan anggota tangan menjalani program dipusat pemulihan. Alat bantu yang digunakan bagi memudahkan aktiviti di dalam program tersebut perlu meningkatkan aktiviti elektrik di dalam unit motor dengan mengurangkan penggunaan mental pengguna. Electromyography(EMG) merupakan kaedah untuk menganalisa kehadiran aktiviti elektrik di dalam sistem otot manusia.Aktiviti elektrik dalam tubuh pesakit tidak mampu untuk mengecutkan otot. Bagi mengatasi otot tersebut dari menjadi kaku atau lembik, daya tujahan untuk menggerakkan alat bantu tidak boleh melebihi kemampuan mental. Bagi mengurangkan penggunaan kekuatan mental, analisis isyarat EMGdari individu yang normal perlu dijalankan sebelum digunakan pada alat bantu pemulihan. Isyarat-isyarat tersebut dikumpulkan melalui kaedah penilaian otot menggunakan permukaan electromyography bukan invasif(SENIAM).Isyarat EMG ini digunakan bagi menetapkan jenis pergerakan terhadap alat bantu pemulihan.Isyarat signal yang ditapis seterusnya di proses bagi mengekstrak ciri-ciri seperti berikut; Sisihan Piawai(STD), Nilai Min Mutlak(MAV), Punca Min Kuasa Dua(RMS), Lintasan Zero(ZCS) and Varian(VAR). Ekstraksi dari data EMG ini bertujuan untuk mengurangkan vektor dalam ciri-ciri isyarat bagi mengurangkan ralat dalam isyarat untuk digunakan dalam pengelas. Pengelasan dalam domain masahanya boleh digunakan terhadap ciri-ciri Nilai Min Mutlak(MAV), Punca Min Kuasa Dua(RMS), dan Sisihan Piawai(STD). Pengelasan. Pergerakan lengan pada sudut 60˚, 90˚ dan 120˚ dikelaskan mengikut peringkat kelas pergerakan menggunakan SOM-Toolbox untuk MATLABdiperlihatkan dalam bentuk U-Matrix.

TABLEOF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Human support system is known as an endoskeleton. Endoskeleton plays a role as a framework of the body which is bone. Our daily movements are fully depends on the functionality of our complex systems in the body. The disability one or more of the systems in our body will reduce our physical movements. Exoskeleton device is known as rehabilitation device to facilitate disable person. The functionality of the rehabilitation device has to smooth as the physical movement of normal human.

People who have temporary physical disability have the chances to recover. The rehabilitation programs provide the suitable plan for conducting the nerve and stimulate the muscles. Nowadays, rehabilitation program are using rehabilitation devices in their tasks. The functionality of devices depends on muscle contraction. Electromyogram studies help to facilitate the effectiveness of the rehabilitation device.

The technique of measuring electrical activity that produced by muscles during rest or contractions known as electromyography (EMG). The electrical signal generates from the brain and sends to the muscles via motor neuron. The EMG could detect the dysfunctional of the muscles or failure in signals transmission from nerves to muscles. The failure of sending the electrical signal from the brain to the conducting nerves requires electrical stimulation from the external source to muscles. Electrodes are used for signal detection of electrical activity in muscles. The study of this electrical activity is important for combination of electromyogram into the rehabilitation device.

1.2 Motivation

Nowadays, increment number of accidents' victim who suffer the failure of the upper limb, demands for the affordable arm rehabilitation devices. Rehabilitation centre will cost the patients a lot amount of money to precede the training course. Besides that, the patients who can survive for unsupervised course are preferable to possess their own rehabilitation device. The unsupervised rehabilitation will facilitate the user to use with convenient. In order to help the needy, the studies on rehabilitation device are carried out.

Electromyography is a technique that has been commonly applied in the electromyogram studies into the rehabilitation device. Nowadays the development of exoskeleton for human performance is trending in this country. The government provides a lot of platform and provision of funds to share the findings and future development in the applied mathematics and engineering fields as well as to encourage collaborations between mathematical research and engineering applications. In attempt to welcoming of this move, the idea and research works of the rehabilitation device have to focus on these EMG signals processing for a smooth performance of the device. The study is carried out to understand the importance of the rehabilitation device and the development of the rehabilitation device to facilitate the user. Thus, the electromyogram studies including the extract features and the classification of the EMG signal is a goal of this study.

1.3 Problem Statement

The rehabilitation device is a tool that used to help movements in daily life activities of the patients who experienced the failure of muscle contractions. Due to failure of muscles contractions the movements is limited. The ability of the patients to do the tasks in the rehabilitation programs need to be measured. The rehabilitation programs have to ensure either the tasks is effective or harmful to the patients. Historically, the rehabilitation tasks have been avoided due to a belief that it would increase spasticity. [3] However, the spasticity is one type of failure in muscle contraction. In this study, the focus is on the patients who suffer the paralysis either flaccid or spasticity. In this study, the analysis of the data will be focusing on upper limb consisting of biceps brachii muscles only. The experiment is limited to several degrees of upper limb movements that use in the training.

EMG is divisions of bio signal analysis. The bio signal analysis is the most complex analysis. Thus, the signal analysis is a complicated process.The EMG signals must be reliable to include in the signal processing process.Therefore, the challenge of this study to ensure that signal processing is conducted properly towards reducing the environment noise during collecting data. The reliable signals is continued to extract the features that will use in movement classification. The study is succeeded when the EMG signals can be classify into the movements than soon will use in rehabilitation device and may not harm the user.

1.4 Objectives

The objectives of this research are to extract the time domain features of biceps brachii muscles based on different degree of arm movements using MATLAB and SIMULINK software. Subsequently, the extracted features are to cluster into several degrees of arm movements usingSelf-Organising Map technique.

1.5 Scope of Research

In achieving the objectives of this study, the experiment has to be conducted within the scope of study. The EMG signals are collected from the healthy subjects based on BMI standards without any medical history within 20 to 30 years old. The EMG signals is acquired from the muscles at the upper limb which is biceps brachii. The muscles biceps is taking into consideration for this experiment due to arm feed forward stretching movements that include the contraction of biceps muscles. The feed forward stretching movements' are set up with angle of 60˚, 90˚ and 120˚ by estimation. The studies of muscles contraction of normal and healthy subjects are important for better understanding before it can be applied to abnormal subject. The data is collected by using surface electrodes which is non-invasive method. The collected data are used for signal processing to carry out the extraction of signal features to be classified. The analysis of the EMG signals are conducted in powerful tool which are MATLAB 2013a, SIMULINK and SOM-Toolbox developed byEsaAlhoniemi*et al.* The features are classified by using Self-Organising Map technique.

1.6 Contribution of Research

After completing this research, the studies may contributes in rehabilitation field involves; extracted features in time-domain of the EMG signal of upper limb for several degrees of movement and the classified movements by using Self-Organising Map technique.

1.7 Outlines of the Report

This research comprises of five chapters. Chapter 1, the background and the idea of this research is proposed for better understanding. This chapter consists of the objectives and the scope of this research. Chapter 2, general reviews of the idea that related to this study. This chapter also include the flow of strategies that used in this research. Methodology has been briefly explained in Chapter 3; the study will begin with the experimental setup. Preparing the subject and collecting the data due to the angle degree of movements. The results of the raw EMG signals, features extraction and classifier are presented in Chapter 4. Finally, the conclusion of this study, experiment, recommendations towards the future works is covered in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews related to this research title. This review is referred from several research papers, books and journals that much related to engineering, muscle anatomy, signal processing and software.

2.1 Introduction

Hand consists of arm, forearm, wrist and fingers for physical movement. Arm is located at shoulder joint, while forearm is located at elbow joint. A physical arm movement is less complex compare to forearm, wrist and fingers motion. This is because when it refers to musculoskeletal, the largest muscles involved with the motion are biceps and triceps only. However, when the musculoskeletal system is failed on the arm it will disable the motion of the forearm and fingers. Nowadays, people who suffer from stroke(hemiplegic), flaccid and paralysis they have lost the limb function.[9] As the failure of upper limb, they still can feel the presence of the arm because it still there but cannot move it. Thus, their intention to move the arm is generated from their brain. The brain transmits the signal and this signal called electrical activity is send via neurons. This electrical activity is known as myoelectric signal. The signal that generates from the muscle contraction can be recorded by electromyography. This technique shows the muscles are active and able to do the physical movements.[4]

2.2 Arm Rehabilitation Device

Rehabilitation Engineering is a field for engineer and designer to share the idea and come out with the solution that may ease the disabled person to live their daily life such a normal people. The development of the rehabilitation device is improved gradually. The brilliant ideas and work pieces from these engineer and technologist helps to achieve the multifunctional rehabilitation device. The efforts by them bring a lot of enhancement in rehab's world. Nowadays, spill over rehab devices in marketplace helps the disable person to make a choice from the cheapest to the most expensive device that suits their finances. The devices rank always put the cheapest devices with the less function or motion while the expensive devices with multifunctional or more degree of motion. Therefore, the rehabilitation devices contribute into the entrepreneur technologies and establish the competency by implementing the devices.

Furthermore, to fulfil the demands from the user, engineer and designer should create the device to facilitate their movement and user-friendly. Currently, the superficial device is the best design to expand for the purpose of unsupervised modes. By referring to the United States Patent for Arm Rehabilitation and Testing Device documents by Reddy *et al.*, to invent the rehabilitation device, the design should provide:

i. a portable and extremely convenient device.
ii. a device that may use to measure the degree of recovery.
iii. an adjustable size or length of individual arms.
iv. a desired speed and force depending on patient's deficiencies.[23]

The mechanism of rehabilitation device is automatic without any force from the user and comfortable. This mechanism helps the disable person to train their muscle for rehabilitation in supervised or unsupervised modes.There are some beliefs that the rehabilitation device may harm the user.[3] Depending on the muscles either flaccid which is no muscle tone or spastic that has too much muscle tone. Flaccid patient needs the rehabilitation device to increase the muscle tone, while spastic patient may need the device to reduce the muscle tone. However, the spastic patient is the case where the technologist had to consider the force and speed in the device to preclude the spasm in the muscles.

Therefore, as an engineer the invention of a new thing have to follow the etiquette and the rule for the effectiveness and the user convenience.

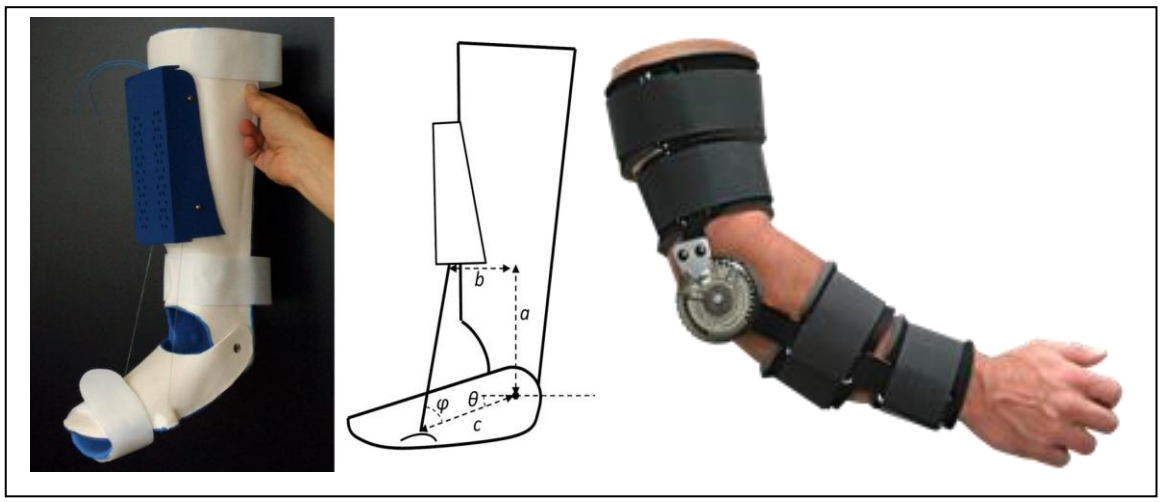

Figure 2.1 Example some of the arm rehabilitation device.

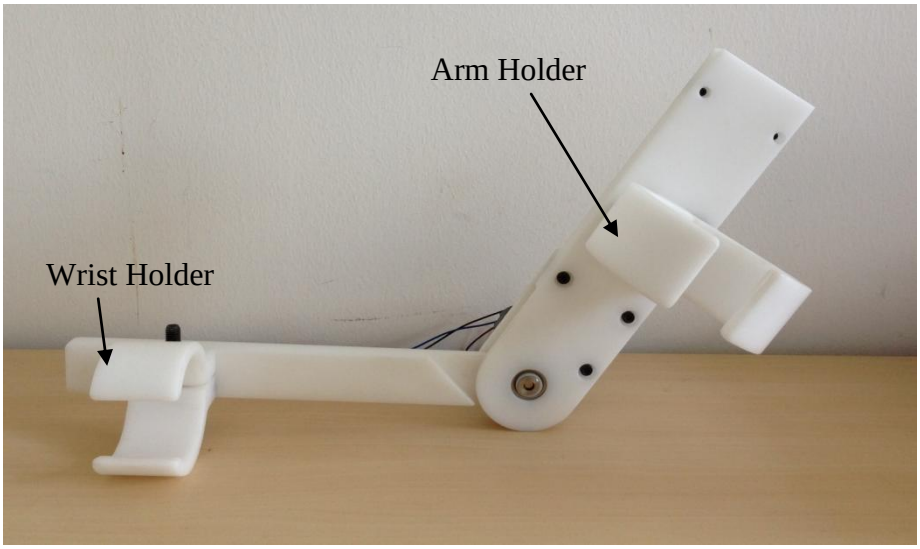

Figure 2.2 The arm rehabilitation device that used in this research.

2.3 Signal Processing

The output of the system commonly is defined by the input. The output is the main achievement of the system. However, the input is always raw signals that need to be process into several plants until it can produce the desired output. EMG signal is one type of bio signal that contains lot of noise from many factors. The noise may come from the skin at the electrode placement, type of electrode that may use for data collecting and also

the environment. There are various type of size and pattern of electrodes(Figure 2.3), depends on the muscle area would like to detect and the thickness of the skin layer. The EMG noise signal can be reduced by choosing the gelled electrode which were Silver – Silver Chloride(Ag-AgCl) as the substance. Ag-AgCl introduces less electrical noise into the measurements. However, these noise should be eliminate to have a better signal for analysing purpose, the noise can be eliminate by many factors such as control environment, electrode placements and signal acquisition circuitry and configuration.[7][13] As for the features extraction there were various types in terms of frequency domain, time frequency domain and time scale domain. These types are chose based on the purpose of the analysis of the signal. In signal conditioning for time domain analysis, there is some features that can be applied. These features are described briefly as follows:

i) Root-Mean-Square (RMS)

RMS is the square root of the mean over time of the square of the vertical distance of the graph from the rest state. It much related to the constant force and non-fatiguing contraction of the muscle. In most cases, it is similar to standard deviation method. [3]

$$RMS = \sqrt{\frac{1}{N}\int_{i=1}^{N} EMG(i)^2}$$

ii) Mean Absolute Value(MAV)

Mean absolute value is calculated by taking the average of the absolute value of EMG signal. Since it represents the simple way to detect muscle contraction levels, it becomes a popular feature for myoelectric controlled applications. [3]

$$MAV = \frac{1}{n}\sum_{i=1}^{n}|(x_i - \bar{x})|$$

iii) Standard Deviation(STD)

Standard deviation is a measure of the dispersion of a set of data sample from its mean. The more spread apart the data, the higher the deviation. Standard deviation is calculated as the square root of variance.

$$STD = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

2.4 Maximisation of EMG Signal

Signal is condition that always affected by the factors that make it unstable and non-linear. As EMG signal, the non-linear of the signal mostly came from the noise factor. There have a lot of noise factor that can be categorized as follows;

i) *Causative Factors:* This is the direct affect on signals.
   a. *Extrinsic* – The signal get affected by the electrode placement, structure, surface detection, distance between electrode(bipolar configuration), and location of the surface detection on the skin.
   b. *Intrinsic* – It may due to physiological, biochemical and anatomical factors.

ii) *Intermediate Factors:* This is the phenomena of influencing by one or more causative factors.

iii) *Deterministic Factors:* This is influenced by the intermediate factors.

Figure 2.3 The various type of wet electrodes that may used to detect the EMG signal.

By minimizing all these factor of noises, the quality of EMG signal will be much better and the analysis of the information will be less of error and easy to obtained. However, the precautions of handling the hardware and the electrode are needed. Figure 2.3 shows the several of electrodes that may use in collecting the EMG signals. This various type of electrodes depends on the size, radius and shape that might be use on skin surface. The shape and the size are depending on the area of muscles to detect and the thickness of the skin. If the skin is thick and the area of belly muscle is large, larger area of electrodes might be use for a better signals detection. Acquisition data play the important role to maximizing the quality of the EMG signal, such as minimizing the distortion in EMG signal, using any filtering tools are not recommended. In terms of signal-to-ratio(SNR) the information that carried in SNR should contain the maximum information of EMG signal [6][17]. Moreover, the quality of EMG signal is affected by the environment, also known as control environment. The environment has to set with minimizing the noise factor. The ambient noise sourced by electromagnetic devices such as radio transmission devices, fluorescent lights and power line interference from electrical wires.[17][10] These ambient noise and motion artifact can be reduced by the proper electrode placements, circuit configuration and control environment.

The flow of signal processing in this study based on the Figure 2.4. The placements and type of electrodes are important to ensure the electrical activity in muscles can be detected. The raw EMG signal from the electrodes goes into phase of signal and data acquisition for minimising the signal error. The raw EMG signal is need to reduce the vector to come out with extraction of signal features. Finally, the signal features can be classified into the classifier.

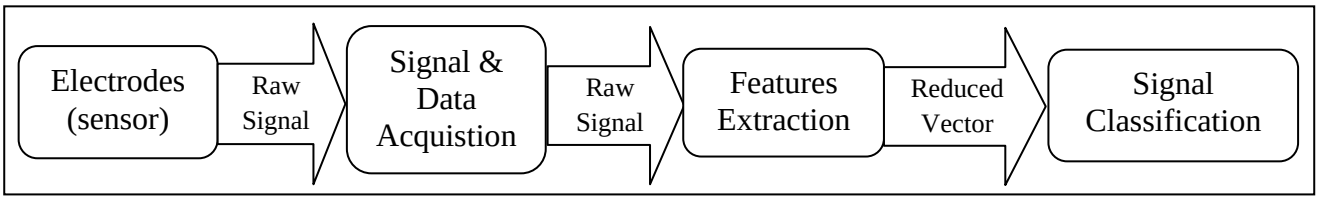

Figure 2.4 Flow of Signal Processing

2.5 Self-Organizing Map (SOM)

The Artificial Neural Network(ANN) analysis is one of the computer science's branch. The ANN's are significant in problem solving such as pattern recognition and classification. ANN analysis is a dominant tool to analyze data and tointerpret the results of the analysis, followed bysketchingthe conclusions on a structure of analyzed data. Self-organizing map(SOM) is well known as one type of neural network model that were commonly used for visualizing the data and to cluster the data. SOM was introduced by T. Kohonen in 1982, his exploration into this model to preserve the topology of multidimensional data. SOM is learns as unsupervised manner, which means no human intervention is needed throughout the learning. The SOM is a bundle ofnodes, attached to one another via a rectangular or hexagonal topology in Figure 2.5.

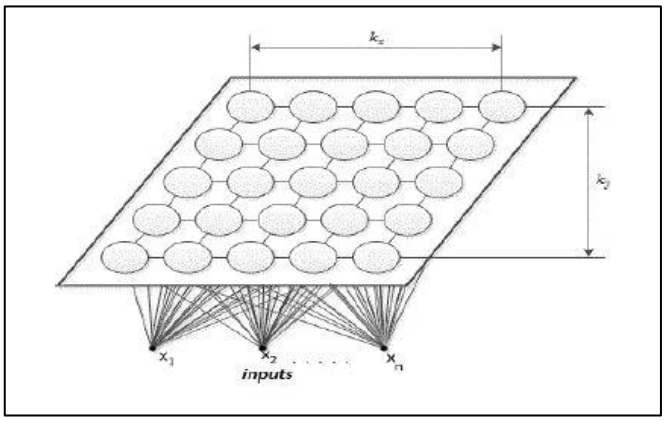

Figure 2.5 Rectangle Topology (Two-Dimensional SOM).[19]

The learningstarts from the components of the vectorsMij initialized at random. If *n*-dimensionalvectors X_1, X_2,...,X_m are needed to map, the components of these vectors x_1, x_2, ..., x_n are passed to the network as the inputs, where *m* is the number of the vectors, *n*is the number of components of the vectors. At each learning step, an input vector$X_p \epsilon$ {X_1, X_2, ...,X_m} is passed to the neural network. The vector X_p is comparedwith all the neurons M_{ij}. Regularly the Euclidean distance $|| X_p - M_{ij}||$ between the inputvector X_p and each neuron M_{ij}iscalculated. The vector (neuron) M_c with the leastEuclidean distance to X_p is electedas a winner. [19][22]