Vision Based Gesture Recognition Using Neural Networks Approaches: A Review

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Abstract

The aim of gesture recognition researches is to create system that can easily identify gestures, and use them for device control, or convey some formations. In this paper we are discussing researches done in the area of hand gesture recognition based on Artificial Neural Networks approaches. Several hand gesture recognition researches that use Neural Networks are discussed in this paper, comparisons between these methods were presented, advantages and drawbacks of the discussed methods also included, and implementation tools for each method were presented as well.

Keywords: Neural Networks, Human Computer Interaction, Gesture Recognition System, Gesture Features, Static Gestures, Dynamic Gestures.

1. INTRODUCTION

The expectation of widely extensive range of computer systems with the rapid development of information technology in our life [1], would be inter in our environments [1]. These environments need simple, natural and easy to use interfaces for human computer-interaction (HCI) [1]. The user interface of any personal computer has evolved from primitive text user interfaces to a graphical user interfaces (GUIs) which still limited to keyboard and mouse input [2], however, they are inconvenient, unnatural, and not suitable for working in virtual environments [2]. By using the hand gestures an efficient alternative would be provided to these onerous interface devices for human-computer interaction [1].

Feelings and thoughts can be expressed by gestures, gestures can go beyond this point, hostility and enmity can be expressed as well during speech, approval and emotion are also expressed by gestures [3].

The development of user interface requires a good understanding of the structure of human hands to specify the kinds of postures and gestures [2]. To clarify the difference between hand postures and gestures [2], hand posture is considered to be a static form of hand poses [2]. an example of posture is the hand posture like ’stop’ hand sign [4], it’s called also static gesture [5], or Static Recognition [6]. On the other hand; a hand gesture is a comprised of a sequence static postures that form one single gesture and presented within a specific time period [2], example for such gesture the orchestra conductor that applies many gestures to coordinate the concert, also called dynamic recognition [6], or dynamic gesture [5]. Some gestures might have both static and dynamic characteristics as in sign languages [5].

Gesture can be defined as a meaningful physical movement of the fingers, hands, arms [5], or other parts of the body [3] [5], with the purpose to convey information or meaning for the environment interaction [5]. Gesture recognition, needs a good interpretation of the hand movement as effectively meaningful commands [1]. For human computer interaction (HCI) interpretation system there are two commonly approaches [1]:

a. *Data Gloves Approaches:* These methods employs mechanical or optical sensors Attached to a glove that transforms finger flexions into electrical signals to determine the hand posture [6]. Using this method the data is collected by one or more data- glove instruments which have different measures for the joint angles of the hand and degree of freedom (DOF) that contain data position and orientation of the hand used for tracking the hand [7]. However, this method requires the glove must be worn and a wearisome device with a load of cables connected to the computer, which will hampers the naturalness of user-computer interaction [5].

b. *Vision Based Approaches:* These techniques based on the how person realize information about the environment. These methods usually done by capturing the input image using camera(s) [8]. In order to create the database for gesture system, the gestures should be selected with their relevant meaning and each gesture may contain multi samples [9] for increasing the accuracy of the system. In this work we used vision based approaches and some researches that used glove based approaches are discussed as a comparative study.

(a) Data glove [10]. (b) Vision based.

FIGURE 1: Examples of data glove and vision based.

Vision Based hand gesture recognition approaches can be categories into: appearance based approaches, and 3D model based approaches [2]:

a) *Appearance Based Approaches*: these approaches use features extracted from visual appearance of the input image model the hand, comparing these modeled features with features extracted from input camera(s) or video input [2].

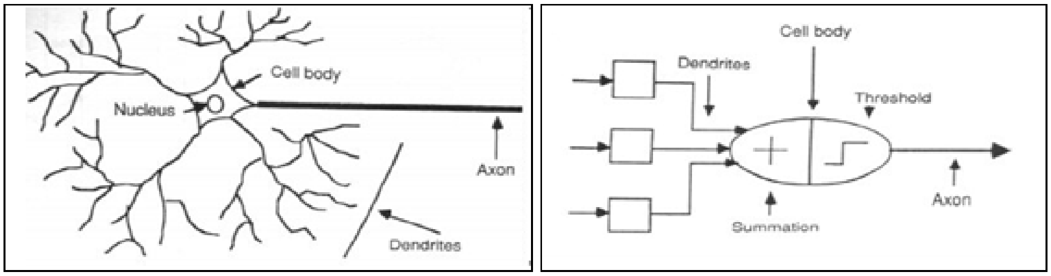
b) *3D Model Based Approaches*: Model based approaches depends on the kinematic hand DOF's of the hand. These methods try to infer some hand parameters like, pose of palm, joint angles from the input image, and make 2D projection from 3D hand model [2].

This paper is organized as follows. Section 2 briefly introduces an overview of Artificial Neural Networks (ANNs). Section 3 Gesture Recognition using Artificial Neural Networks. Section 4 Advantages and disadvantages. Section 5 Comparison Factors between these methods. Implementation Tools are presented in Section 6. Discussion and Conclusion are given in Section 7.

2. ARTIFICIAL NEURAL NETWORKS: OVERVIEW

During the development through the years the computational variation has growth to new technologies, Artificial Neural Networks are one of the technologies that solved a broad range of problems in an easy and convenient manner. The working concept of Artificial Neural Networks

(ANNs) is similar to human nervous system, hence it has synonym with the word neural networks, as in illustrated in Figure 2.



A Components of a neuron. B The neuron mathematical model.

FIGURE 2: Human Neurons versus Artificial Neurons [11].

According Haykin [12], and Marcus [4], an artificial neural network (ANN) can be defined as a hugely parallel distributed processor consists of simple processing units, which has a natural tendency for storing experimental knowledge and available it for use.

The artificial neuron (named perceptron) consists of numerical value multiplied by a weight plus bias [13], the perceptron fires the output only when the total signal of the input exceeds a specific threshold value. The activation function controls the magnitude of the output [13], and then the output is fed to other perceptron in the network. Mathematically, this process described in the Figure 3.

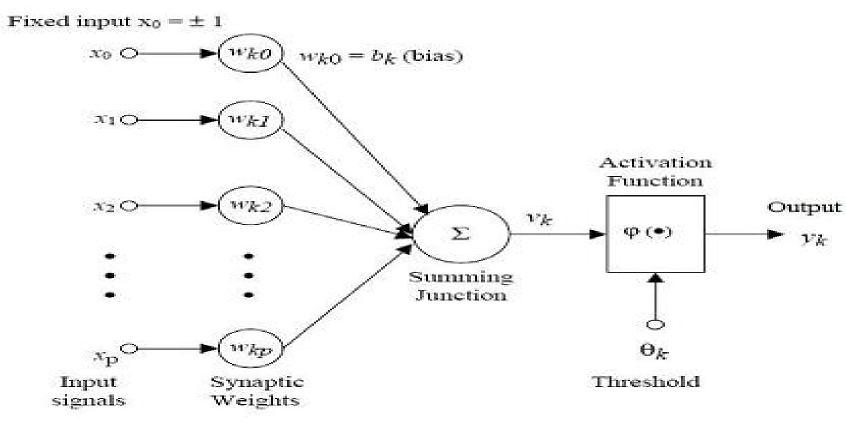


FIGURE 3: Representation of simple artificial neuron (From internet image gallery).

The system naturally is parallel which means; many units computations can carry out at the same time [14], the interval activity of the neuron can be shown in this equation:

$$v_k = \sum_{j=1}^{p} w_{kj} x_j \qquad (1)$$

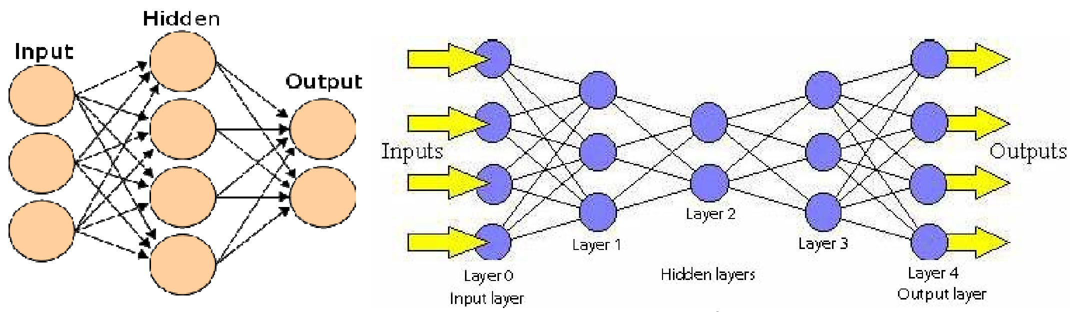
From Figure 3.The output of the neuron, yk, would be the outcome of some activation function of the value of vk [15].

2.1 Neural Network Classifications

The main important classifications of neural networks are briefly explained below:

2.1.1 Feed Forward Networks

Feed forward Networks are the simplest devised type of artificial neural network [16]. From its name 'forward' the information moves in one direction, starts from the input nodes to the output nodes goes through the hidden nodes (if any) with no cycles, It can be formed with different types of units [16].



a b

FIGURE 4: Feed forward Networks types. (a) Simple Feed forward Networks. (b) Multiplayer Feed forward Networks. (From internet image gallery)

2.1.2 Feed backward Networks or Recurrent Neural Network

Recurrent neural network can be models with bi-directional data flow [16], which allows connection loops between perceptron. Some of main recurrent neural network are demonstrated below.

i. Fully recurrent network:

In fully connected network there are no distinct input layers of nodes [17], and each node has input from all other nodes, feedback to the node itself is possible [17].

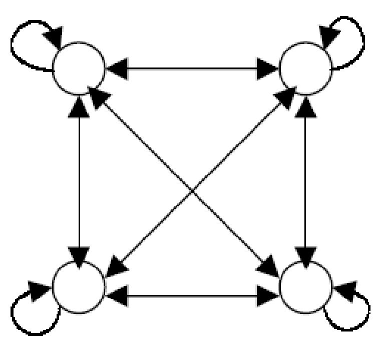


FIGURE 5 : An example of a fully connected recurrent neural network (from internet image gallery).

ii. Elman recurrent network

In this type of network architecture, three network layers are used with an extra units "context units" in the input layer, from the middle (hidden) layer to the context units, connections are available with a weight of one [16]. At each step, the input is proceeding in feed-forward manner, and applied a learning rule [16].

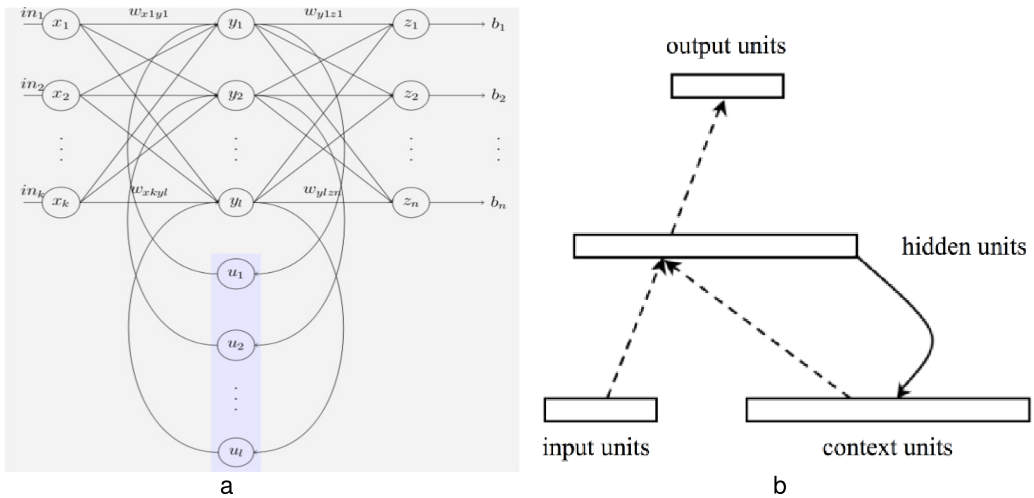


FIGURE 6: Elman recurrent network. (a) From [16] (b) from [18] .

iii. Continuous time recurrent network

When dynamic system used to design a biological neural network, continous time recurrent network were used for this purpose [16].

2.1.3 Kohonen Self-Organizing Maps (SOM)

Self-Organizing Map is a type of neural network, developed in 1982 by Tuevo Kohonen [14] [19]. ‘Self-Organizing’ called so since no supervision is required and learning by means of unsupervised competitive learning [20]. ‘Maps’ called so since they map the weights to be correspond to the given input, and the nodes in a SOM try to like the inputs presented to them [19]. This is how they learn, can also call as “Feature Maps”, Some of SOM applications are, Color Classification, Image Classification [20].

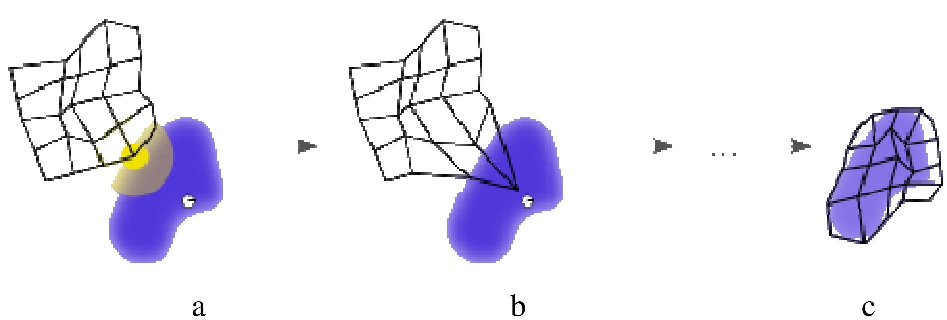


FIGURE 7: The training of a self-organizing map, the blue blob is the distribution of the training data, and the small white disc is the current training sample. (a) The node nearest to the training node (highlighted in yellow) is selected. (b) the grid become nearest the white disc and its neighbors. (c) After some iterations the grid tends to approximate the data distribution [19].

3. GESTURE RECOGNITION USING ARTIFICIAL NEURAL NETWORKS

Because of Artificial Neural Network ANNs nature that consist of many interconnected processing elements [21], it can be constructed for problems as mentioned in [16]; searching for identification and control, game-playing and decision making, pattern recognition medical diagnosis, financial applications, and data mining [22]. Also ANN has the ability to adaptive self-organizing [14] [21] [19].

Various approaches have been utilized to deal with gesture recognition problem ranging from soft computing approaches to statistical models [5] based on Hidden Markov Model HMM[21,22], and Finite state Machine FSM [24]. Soft computing tools generally include ANN [18][25] [26][27][28], fuzzy Logic sets [29] and Genetic Algorithms GAs [30]. In this paper we focus on the connectionist approach.

Manar [26] used two recurrent neural networks architectures for static hand gesture to recognize Arabic Sign Language (ArSL). Elman (partially) recurrent neural networks and fully recurrent neural networks have been used. Digital camera and a colored glove were used for input image data. For segmentation process, HIS color model was used. Segmentation divides the image into six color layers, five for fingertips, and one for the wrist. Thirty features are extracted and grouped to represent single image, expressed the fingertips and the wrist with angles and distances between them. This input features vector is the input to both neural networks systems. 900 colored images were used for training set, and 300 colored images for testing purposes. Results had shown that fully recurrent neural network system (with recognition rate 95.11%) better than the Elman neural network (89.67%).

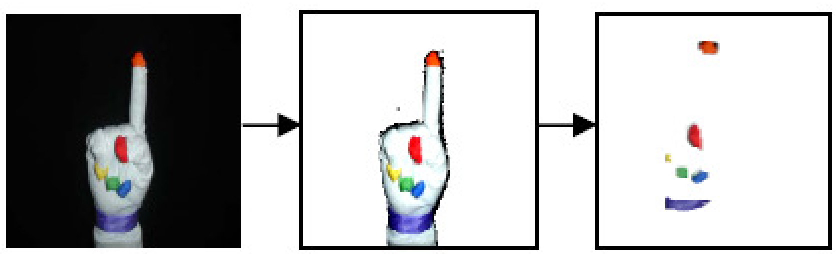


FIGURE 8: Color segmentation using colored glove [26].

Kouichi in [18] presented Japanese sign language recognition using two different neural network systems. Back Propagation algorithm was used for learning postures of Japanese alphabet. For input postures data glove was used, normalization was applied for images as preprocessing step. The features extracted from data gloves images was 13 data items, ten for bending, and three for angles in the coordinates. The output of the network was 42 characters. The network consists of three layers, input layer with 13 nodes, hidden layer with 100 nodes, and output layer with 42 nodes which corresponds 42 recognized characters. The recognition rate for learning 42 taught patterns was 71.4%, and for unregistered people 47.8%, while the rate improved when additional patterns added to the system, it became 98.0% for registered, and 77.0% for unregistered people.

The second system used Elman Recurrent Neural Network for gestures recognition that could recognize 10 words. the data item nave been taken from data glove and normalized. The features extracted were 16 data items, 10 for bending, 3 for angles in the coordinates, and 3 for angles in the coordinates. The network consists of three layers, input layer with 16 nodes, hidden layer with 150 nodes, and output layer with 10 nodes which corresponds 10 recognized words. Some improvements have been added to the system, first, the positional data that have been extracted from data glove was augmented using pre-wiring network and two kind of positional data have been used. And secondly, filtering data space, in which data in three different time points were given to the input layer, and these data will be shifted for next sample. With these two changes the input layer nodes would be 93 nodes instead of 16 nodes.

Integration of these two neural networks, in a way, that after receiving data from data glove, determine the start sampling time and if the data item considered a gesture it will be sent to the next network, for checking the sampling data the system hold a history, which decide the end of sign language, as shown in Figure 9.

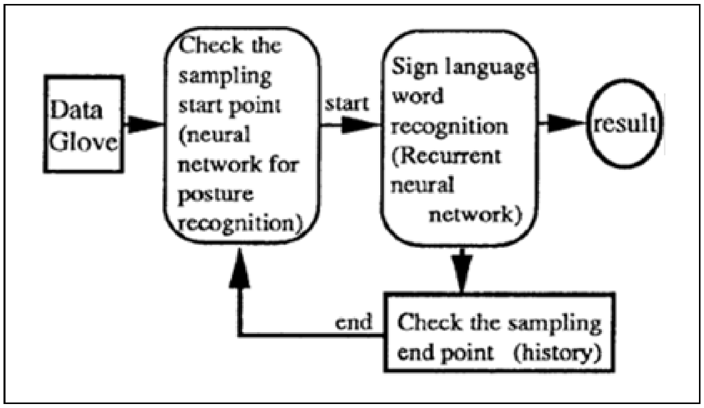


FIGURE 9: Sign language word recognition system [18].

Tin Hninn [15] used real time 2D hand tracking to recognize hand gestures for Myanmar Alphabet Language. Digitized photographs images were used as input images, and applied Adobe Photoshop filter for finding the edges of the image. By employing histograms of local orientation, this orientation histogram was used as a feature vector. The feature vector would be the input to the supervised neural networks system. MATLAB toolbox has been used for system implementation.

Gonzalo et al. [31] presented Continuous Time Recurrent Neural Networks (CTRNN) real time hand gesture recognition system. By using tri-axial accelerometer sensor and wireless mouse to captured the 8 gestures used. The work based on the idea of creating specialized signal predictors for each gesture class [31], standard Genetic algorithm (GA) was used to represent the neuron parameters, each genetic string represents the parameter of a CTRNN. The GA algorithm has following parameters: population size 100 individuals, one-point crossover rate of 70%, mutation rate of 1%, and elitism concept applied. With minimization of fitness function, this is computed according to measurement of Prediction Error of each sample

$$Fitness = \sum_{i=1}^{N} (Pred\_Gesture\_Error(T_i))/N \qquad (2)$$

Where $Pred\_Gesture\_Error$ is the prediction error for one gesture (which is the calculated mean value for the difference between real signal and the predicted one), T is the training set, and N is the total number of samples gesture i.The GA should be minimized for the better the predictor. For classification each gesture, an error measure was computed for all the predictors, the information of segmentation is used to extract the part of the signal that belongs to specific gesture, after computing all these errors, the lowest one indicates the class of the analyzed gesture. Two considered datasets have been applied one for isolated gestures, with recognition rate 98%for training set, and 94% for testing set. The second dataset for captured gestures in real environment, for the first set, with 80.5% for training, and 63.6% for testing. Figure 10 shows Acceleration signals was recording when the hand performing a circular motion. Figure 10 shows the shapes that performed by hand.

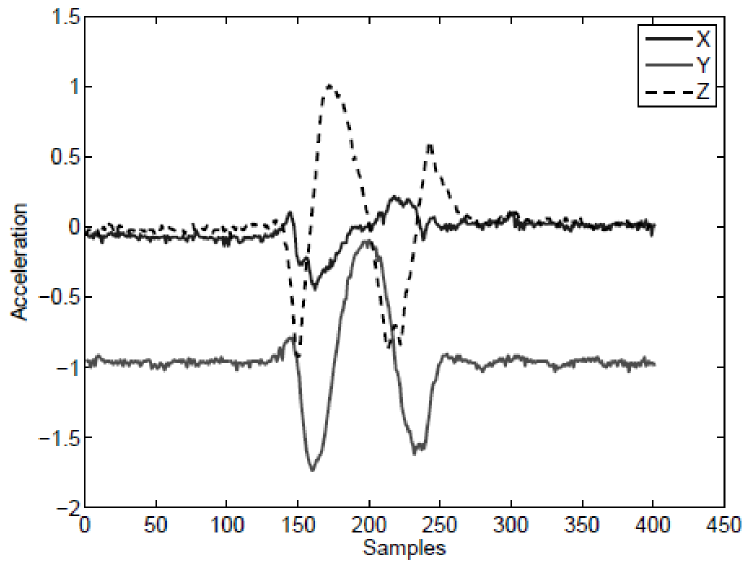


FIGURE 10: Acceleration signals was recording when the hand performing a circular motion [31].

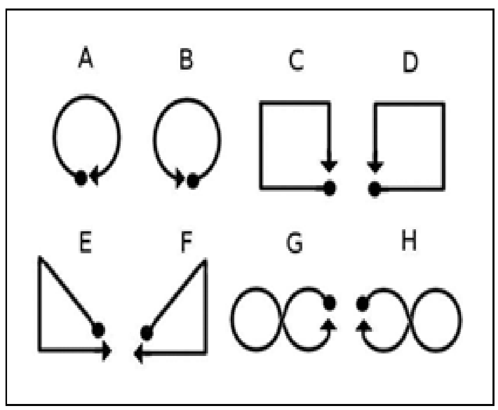


FIGURE 11: 8 Input sets used to analyze system performance in [31].

Stergiopoulou [28] presented static hand gesture recognition based Self-Growing and Self-Organized Neural Gas (SGONG) network. Digital camera was used for input image. For hand region detection YCbCr color space was applied, and then threshold technique used to detect skin color. SGONG network use competitive Hebbian learning algorithm, the learning start with two neurons, and grows in which a grid of neurons would detect the exact shape of the hand as shown in Figure 13. The number of the raised fingers was determined, but in some cases the algorithm might led to false classification as shown in Figure 14, the problem solved by applying comparison check for the mean finger length.

From this shape three geometric features was extracted, two angles based on hand slope was determined, and from the palm center. For recognition process Gaussian distribution model were used for recognizing fingertip by classifying the fingers into five classes and compute the features for each class. This method has the disadvantage that may be two fingers be classified to the same finger class, this problem has been overcome by choosing the most probable combination of the finger. The system could recognize 31 predefined gestures with recognition rate 90.45%, and 1.5 second.

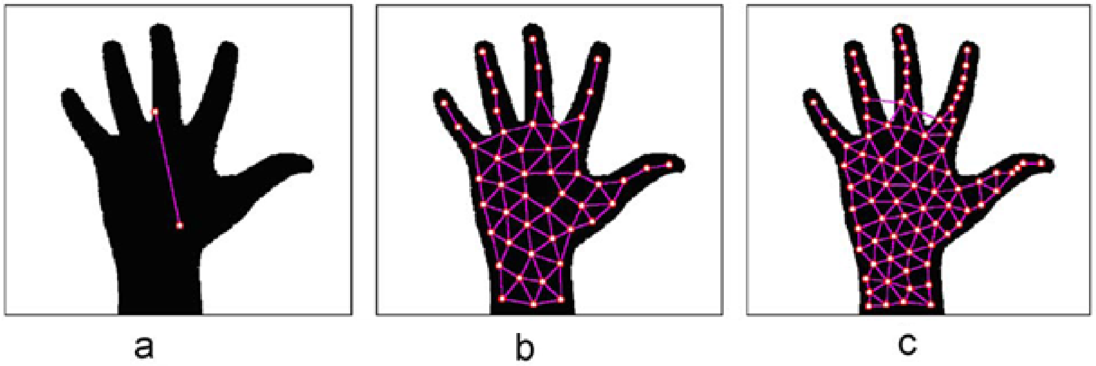


FIGURE 12: Growth of the SGONG network: (a) starting point 2 neurons, (b) growing stage 45 neurons and (c) final output grid of 83 neurons [28].

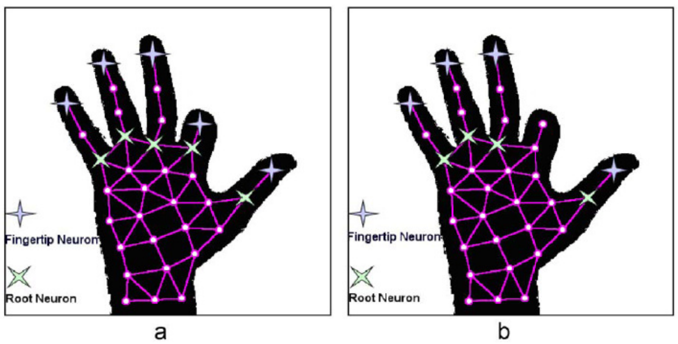


FIGURE 13: (a) False finger detection, (b) correct finger detection, by applying the mean finger length comparison check [28].

4. ADVANTAGES AND DISADVANTAGES

The Advantages and disadvantages of each hand gesture method using Neural Networks are listed in the following table:

Method	Advantages	disadvantages
Manar [26] for Arabic Sign Language	By using Recurrent Neural Networks which have feedback connections between the network layers and within the layer itself; helped the network to stabilize the network's behavior and, improved the ability to recognize hand gesture. Applying two networks system and testing many images on it give flexibility for the system for checking errors and decide what system more reliable for gesture recognition application.	In this system, two problems arisen, first: in feature extraction phase, the determination of best region of colored area was difficult, so clustering operation needed to implement on the image. And second the difficulty of determining the center of the hand for image noise or fingertip has been covered by a color, so default position in the middle of the image was used.
Kouichi [18] for Japanese Sign Language	The system is connected in simple and active way, and successfully can recognize a word. The automatic sampling proposed method, and augmented and filtering data helps for improving the system performance.	Learning time of both network systems take a long time, for learning 42 characters several hours needed, while it take four days to learn ten words. there was a noticeable difference between the recognition rate for both registered and unregistered people. Improvements made by making a

		dictionary consisted of six randomly selected people, and assuming that features dependent on each person by mixing the data. For 252 learning patterns, the recognition rate was 92.9% for unregistered people and 94.3% for registered people.
Hninn [25]: for Myanmar Sign Language	The developed system easy to use, and there is no need to use special hardware. Implementing the system in MATLAB tool box made the work easy because of the simplicity in design, and easy use of toolbox.	Many training images needed for testing the system performance. The whole system implemented in MATLAB which is slower than other languages that have complexity in design but speed in execution time.
Gonzalo [27] for signal gesture	the system is fast, simple, modular, and it's a novel approach in this field. High recognition rate was achieved 94% from testing the dataset, In spite of the second dataset achieved much less, but its high accuracy regarding to the number of gestures.	One of the system limitations was, person movements and activities caused a higher noise which has significant effect on the results. The device could not be held in same orientation for all gestures. The dependency of segmentation operation on the predictor to decide how the segmentation is done. Variety of data should consider to validate the approach and to prove system robustness, since all the experiments have been done by one person.
Stergiopoulou [28] Shape fittin	the exact shape of the hand was obtained which led to good feature extraction, fast algorithm proposed with powerful results, from experiments the recognition rate was effective and achieve very high results.	Some assumption was made for the system like; the input images include exactly one hand, gestures are made with the right hand only, the arm must be vertical, the palm is facing the camera, and the image background is plain and uniform, which restrict the applications of this system.

TABLE 1: Advantages and disadvantages of neural networks methodologies.

5. COMPARISON FACTORS

Comparisons between the selected methods have been concluded according some important factors, table 2 shows these factors. For simplicity the name of the method will be pointed as the name of work used in that paper. i.e. Kouichi [18] will be referred as Japanese language recognition. Manar [26] as Arabic language recognition. Hninn [25] as Myanmar language recognition. Gonzalo [27] as signal Gesture. And Stergiopoulou [28] as shape fitting gesture.

Method Name	# Neural network	Neural network type	Activation function	# gestures in input layer	# gestures in output layer	Learning time
Japanese language	two	back propagation network	sigmoid	13	42	Several hours

recognition		Elman recurrent network		93	10	4 days
Arabic language recognition	two	Elman recurrent network	sigmoid	30	30	N
		Fully recurrent netwrok		30	30	N
Myanmar language recognition	one	supervised neural network	Hard-limit	N	N	N
signal Gesture	one	Continuous Time Recurrent Neural Networks	Differential Equation	1	N	N
shape fitting gesture	one	Self-Growing and Self-Organized Neural Gas		2	≅ 80	N

TABLE 2: Comparison between recognition methods in neural network parameters.

Method Name	Type of input device	Segmentation operation	Feature vector representation	Neural network type	# sample gestures	Recognition rate	Recognition time
Japanese language recognition	Data glove	threshold	13 data item (10 for bending, 3 for coordinate angles)	back propagation network	42	71.4%	Several seconds
			16 data item (10 for bending, 3 for coordinate angles, 3 for positional data)	Elman recurrent network	10	96%	N
Arabic language recognition	Colored glove, Digital camera	HSI color model	Available Features from resource	Elman recurrent network	30	89.66%	N
				Fully recurrent network	30	95.11%	N
Myanmar language recognition	Digital camera	threshold	Orientation histogram	supervised neural network	33	90%	N
signal Gesture	accelerometer sensor, wireless mouse	Automatically (magnitude acceleration signal) / manually (wireless mouse button)	do not require in signal predictors	Continuous Time Recurrent Neural Networks	160	94%	N
shape fitting gesture	Digital camera	YCbCr color space	Two angles of the hand shape, compute palm distance	Self-Growing and Self-Organized Neural Gas	31	90.45%	1.5 seconds

TABLE 3: Comparison between recognition methods in hand gesture recognition approach used.

6. IMPLEMENTATION TOOLS

MATLAB programming language with image processing toolbox was used for implementing the recognition system and C, and C++ language were used less [21]. Hninn [25] use MATLAB for hand tracking and gesture recognition. Manar [26] use MATLAB6 and C language, MATLAB6 used for image segmentation while C language for HGR system. Kouichi [18] use SUN/4 workstation for Japanese Character and word recognition. Also Stergiopoulou [28] used Delphi language with 3GHs CPU to implement hand gesture recognition system using SGONG network.

7. DISCUSSION AND CONCLUSION

In this paper we have presented an idea of hand gesture recognition and Neural Networks approaches. One of the most effective of software computing techniques is Artificial Neural Networks that has many applications on hand gesture recognition problem. Some researches that handle hand gesture recognition problem using different neural networks systems are discussed with detailed showing their advantages and disadvantages. Comparison was made between each of these methods, as seen different Neural Networks systems are used in different stages of recognition systems according to the problem nature, its complexity, and the environment available. The input for all the selected methods was either digitized image camera or using data glove system. Then some preprocessing was made on the input image like normalization, edge detection filter, or thresholding which are necessary for segmenting the hand gesture from the background. Then feature extraction must be made, different methods presented in this paper, geometric features or non geometric features, geometric features that use angles and orientations, palm center, as in [18][28].non geometric such as color, silhouette and textures, but they are inadequate in recognition [31]. Neural Networks system can be applied for extracted features from the input image gestures after applying segmentation, as in [28] to extract the shape of the hand. Others systems used Neural Networks for recognitions process like [25][25][27]. Other systems might use two Neural Networks system [26][27]. In [26] two Recurrent Neural Networks system were used for recognizing Arabic sign language, concluding the best Neural Network system according to higher recognition rate. While in [27] two different Neural Networks system used for sign language word recognition system in final the two systems integrated, as a complete system that receive input posture from data glove and detect character form first network after determining the start sampling time, and second system detect a word after some checking for the history sample saved in the system.

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