

GUI Simulation for Movement of Human Arm Driven by EMG Signal

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Abstract

This work presents a simulation methodology applied to a human arm. It is aimed to allow the human-assisting manipulators to perform complex movement based on electromyography (EMG) signal for patient person in Virtual Reality (VR). This work achieves better classification with multiple parameters based K-Nearest Neighbor for different movements of a prosthetic arm. A K- Nearest Neighbor (K-NN) rule is one of the simplest and the most important methods in pattern recognition. The method implements in the 3D space and uses the MATLAB Ver.2009a approach. This methodology can be used with different robots to test the behavior of system and the different motion.

Keywords: Human Arm, EMG, Pattern Recognition, Virtual Reality.

واجهه تطبيق الرسوم لمحاكاة حركة ذراع الانسان بواسطة اشارة التخطيط العضلي

الخلاصة

هذا العمل يُقدّم محاكاة إلى ذراع إنساني. يهدف البحث للسّماح لمعالجي المُساعَدة الإنسانين لإداء حركة معقّدة مستندة على اشارة التخطيط العضلي (EMG) للشخص المعاق في الحقيقة المظهرية. في هذا العمل نحاول ايجاد طريقة جيدة لتصنيف مختلف الحركات بالاعتماد على اختيار العوامل المتعددة و استخدام طريقة اقرب جار (K-NN). طريقة اقرب جار (K-NN) هي إحدى الطرق الأسهل والأكثر أهمية في تمييز الانواع. تُطبّق الطريقة في فضاء 3D وتُستعمل MATLAB Ver.2009a. هذه الطريقة يمكن استعمالها مع مختلف الرجال الالبيين لاختبار سلوك النظام مع مختلف الحركات.

Introduction

Robot arms are versatile tools found in a wide range of applications. In recent years, applications where humans and robot arms interact, have received increased attention. The case where the interaction entails the human controlling a robot is called robot teleportation. The latter case requires a user interface to translate the operator commands to the robot. A large number of interfaces have been proposed on this issue in previous works, while the user moves his/her arm, electromyography (EMG)

activity is recorded from selected muscles, using surface EMG electrodes[1].

EMG classification is one of the most difficult pattern recognition problems because there exist large variations in EMG features. Especially, it is difficult to extract useful features from the residual muscle of an amputee. So far, many researches proposed many kinds of EMG feature to classify posture and they showed good performance. However, how to select a feature subset with the best discrimination ability from those feature is still an issue for classifying

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EMG signals [2]. Through a decoding procedure the muscular activity is transformed to kinematic variables that are used to control the robot arm. EMG signals have been used as control signals for robotics devices in the past. Motion is one of the most natural and important activities that a human being can practice, even before birth. Thus, one of the major difficulties by those who are fitted with prosthetic devices is the great mental effort needed during the first training stages. This makes it very difficult to precisely detect the spatial position as well as the forces done by the prosthesis in replacement of the muscle. This problem is still more complicated when working with upper limb prosthesis, whose function is to simulate its biological equivalents (shoulder, arm, forearm, elbow, and wrist). All these mechanisms present a very efficient system with a lot of information (degrees of freedom, speed, angles

etc) to be simulated and absorbed by brain commands to help professionals dedicated to special physical needs patient rehabilitation [3].

Some other works only make a 3D virtual that deal with the use of MATLAB for systems simulations, B. Lee et al [4] presents the simulation of humanoid walking pattern using 3D simulator with Virtual Reality Toolbox. By using the Virtual Reality Toolbox incorporated with MATLAB, The simulator was composed of three modules, namely, walking pattern code, kinematics code and display code. M.Z. Al-Faiz [5] presents architecture for posture learning of an anthropomorphic robotic arm using MATLAB/simulink with virtual reality. The approach was aimed to allow the robotic system to perform

complex movement operations of human arm; in this paper only forward kinematic is used in the simulation.

The main objective of the present work is to show a complete simulation of human arm, where, the combination of MATLAB and virtual reality is proposed. The method allows to manipulate the human arm system and to visualize the robot's behavior from different perspectives.

he unknown

Feature Parameters

The success of any pattern classification system depends almost entirely on the choice of features used to represent the raw signals. It is desirable to use multiple feature parameters for EMG pattern classification since it is very difficult to extract a feature parameter which reflects the unique feature of the measured signals to a motion command perfectly. But the inclusion of an additional feature parameter with a small separability may degrade overall pattern recognition performance

A. Wilson amplitude (WAMP)

This is the number of times that the difference between two consecutive amplitudes in a time segment becomes more than threshold.

$$WAMP = \sum_{i=1}^N f(|x_{n+1} - x_n|) \quad (1)$$

Where

$$f(x) = \begin{cases} 1 & \text{if } x > \text{threshold} \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

Where x_n represent the instantaneous EMG sample, x_{n+1} represent the next EMG sample of x_n , N is length of EMG signal. It can be formulated as this feature is an indicator of firing motor unit action potentials (MUAP)

and therefore an indicator of the muscle contraction level [6].

B. Integrated EMG

Integrated EMG (IEMG) is calculated as the summation of the absolute values of the EMG signal amplitude. Generally, IEMG is used as an onset index to detect the muscle activity that used to oncoming the control command of assistive control device. It is related to the EMG signal sequence firing point.

$$IEMG = \sum_{n=1}^N |x_n| \quad (3)$$

Which can be expressed as where N denotes the length of the signal and x_n represents the EMG signal in a segment.

C. Variance of EMG

Variance of EMG (VAR) uses the power of the EMG signal as a feature. Generally, the variance is the mean value of the square of the deviation of that variable. However, mean of EMG signal is close to zero. In consequence, variance of EMG can be calculated by

$$VAR = \frac{1}{N-1} \sum_{n=1}^N x_n^2 \quad (4)$$

D. Mean Absolute Value

Mean Absolute Value (MAV) is similar to average rectified value (ARV). It can be calculated using the moving average of full-wave rectified EMG. In other words, it is calculated by taking the average of the absolute value of EMG signal. It is an easy way for detection of muscle contraction levels and it is a popular feature used in myoelectric control application. It is defined as

$$MAV = \frac{1}{N} \sum_{n=1}^N |x_n| \quad (5)$$

E. Modified Mean Absolute Value

Modified Mean Absolute Value (MMAV) is an extension of MAV using weighting window function w_x . It is shown as

$$MMAV = \frac{1}{N} \sum_{n=1}^N w_x |x_n| \quad (6)$$

$$w_x = \begin{cases} 1 & \text{if } 0.25N \leq n \leq 0.75N \\ 0.5 & \text{otherwise} \end{cases}$$

(7)

F. Waveform Length

Waveform length (WL) is the cumulative length of the waveform over the time segment. WL is related to the waveform amplitude, frequency and time. It is given by [7].

$$WL = \sum_{n=1}^{N-1} |x_{n+1} - x_n| \quad (8)$$

K-Nearest Neighbor (KNN) Algorithm

The K-nearest neighbor (KNN) classification rule is one of the most well-known and widely used nonparametric pattern classification methods. When there is little or no prior knowledge about the distribution of the data, the KNN method should be one of the first choices for classification. It is a powerful non-parametric classification system which bypasses the problem of probability densities completely. NN is a “lazy” learning method because training data is not preprocessed in any way. The class assigned to a pattern is the class of the nearest pattern known to the system, measured in terms of a distance defined on the feature (attribute) space. On this space, each pattern defines a region (called its

Voronoi region). When distance is the classical Euclidean distance, Voronoi regions are delimited by linear borders. To improve over 1-NN classification, more than one neighbor may be used to determine the class of a pattern (K-NN) or distances other than the Euclidean may be used [8]. The KNN rule classifies x by assigning it the label most frequently represented among the K nearest samples; this means that, a decision is made by examining the labels on the K -nearest neighbors and taking a vote. KNN classification was developed from the need to perform discriminant analysis when reliable parametric estimates of probability densities are unknown or difficult to determine [9].

Nowadays, it is the most usable classification algorithm. It has less usability and is labor intensive when the training dataset is large. This algorithm operation is based on comparing a given new record with training records and finding training records that are similar to it. It searches the space for the k training records that are nearest to the new record as the new record neighbors. In this algorithm nearest is defined in terms of a distance metric such as Euclidean distance. Euclidean distance between two records (or two points in n -dimensional space) is defined by formula[10].

$$x_1 = (x_{11}, x_{12}, \dots, x_{1n}), x_2 = (x_{21}, x_{22}, \dots, x_{2n})$$

$$dist(x_1, x_2) = \sqrt{\sum_{i=1}^n (x_{1i} - x_{2i})^2} \quad (9)$$

Where x_1 and x_2 are two records with n attributes. This Formula measures the distance between x_1 and the point x_2 , in terms of take the difference between the corresponding values of that attribute in record x_1 and in

record x_2 . The K -nearest neighbor classifier is a supervised learning algorithm where the result of a new instance query is classified based on majority of the K -nearest neighbor category. The training samples are described by n -dimensional numeric attributes. Each sample represents a point in an n -dimensional pattern space. In this way, all of the training samples are stored in an n -dimensional pattern space. The following discussion introduces an example demonstrating the general concept of this algorithm in detail. The K nearest neighbor algorithm is very simple. It works based on minimum distance from the query instance to the training samples to determine the nearest neighbors. After K nearest neighbors is gathered, take simple majority of these K -nearest neighbors to be the prediction of the query instance. The data for KNN algorithm consists of several multivariate attributes names X_i that will be used to classify the object Y . Suppose that the K factor is set to be equal to 8 (there are 8 nearest neighbors) as a parameter of this algorithm. Then the distance between the query instance and all the training samples is computed. Because there are only quantitative X_i , the next step is to find the K -nearest neighbors. All training samples are included as nearest neighbors if the distance of this training sample to the query is less than or equal to the K^{th} smallest distance. In other words, the distances are sorted of all training samples to the query and determine the K^{th} minimum distance. The unknown sample is assigned the most common class among its k nearest neighbors. As illustrated above, it is necessary to find the distances between the query

and all training samples. These K training samples are the closest k nearest neighbors for the unknown sample. Closeness is defined in terms of Euclidean distance[11].

Here is step by step on how to compute K-nearest neighbors KNN algorithm

- 1-Determine parameter K = number of nearest neighbors.
- 2-Calculate the distance between the query-instance and all the training samples.
- 3-Sort the distance and determine nearest neighbors based on the K-th minimum distance.
- 4-Gather the category Y of the nearest neighbors.
- 5-Use simple majority of the category of nearest neighbors as the prediction value of the query instance.

Virtual Reality

With the advent of high-resolution graphics, high-speed computing, and user interaction devices, virtual reality (VR) has emerged as a major new technology in recent years. An important new concept introduced by many VR systems is immersion, which refers to the feeling of complete immersion in a three-dimensional computer-generated environment by means of user-centered perspective achieved through tracking the user. This is a huge step forward compared to classical modeling and CAD/CAM packages, VR technology is currently used in a broad range of applications, the best known being flight simulators, walkthroughs, video games, and medicine (virtual surgery). From a manufacturing standpoint, some of the attractive applications include training, collaborative product and process design, facility monitoring, and management. Moreover, recent

advances in broadband networks are also opening up new applications for virtual environments in these areas [12].

Simulation of Movement Based EMG Signal

The proposed method contain two parts, first EMG part, second the simulation of motion.

1- EMG Recognition Based K-NN Algorithm.

The overall method of recognition system is shown in fig.2 .Generally the methods of Recognition are divided into two states:

Training state: In this state data base is constrained with five muscles (biceps,triceps, deltoid, extensor carpi radialis and flexor carpi ulnaris). This state has following steps:

Step One: Take six frames from each muscle as shown in Fig.1 to produce thirty frames.

Step Two: Six features are extracted from each frame which introduced in section 2 .From this step thirty vectors are build, each vector has six elements.

$$X_i = [WAMP_i \ IEMG_i \ VAR_i \ MAV_i \ MMAV_i \ WL_i], \quad i = 1, \dots, 30 \quad (10)$$

Classification state: this state has following steps as shown in Fig.3 and Fig .4.

Step one: In this step take the feature extraction of input signal to produce vector of six elements Z.

Step Two: Taking Euclidean distance between input vector Z and the data base X.

$$D(x_i, z) = \{D(x_i, z) \quad i = 1, 2, \dots, 30\} \quad (11)$$

Step Three: Sort the distance and take first kth element.

Step Four: Calculate which class has more elements in this group which represents this class. Five kinds of arm

motion are recognized: Abduction of the arm, flexion the elbow, extension the elbow, extension and abduction of the wrist and flexes and adducts the wrist .These motions are produced by contraction of five muscles. Therefore, if the EMG signal of muscle is recognized then the specified motion of this muscle is recognized.

2-Proposed Model and VR Simulation for A Human Arm

The simulator was built using MATLAB with Virtual Reality Toolbox. MATLAB provides powerful engineering tool including frequently used mathematical functions. It is easy to implement control algorithm including visualization of data used in the algorithm. In addition, by using Virtual Reality Toolbox, it is convenient to treat 3D objects defined with Virtual Reality Modeling Language (VRML) . Thus, it is possible to build a simulator within a relatively short period. virtual reality is a system which allows one or more users to move and react in a computer generated environment. The basic VR systems allow the user to visual information using computer screens. The simulation contain two part ,first ,building model for human arm in VRML,second, call and run the model of human arm using virtual reality toolbox in the MATLAB.

To realize the VRML model for Human arm save the file as a All.wrl file, which is the file format for Virtual Reality software, the VRML model of the Human arm was designed in V-Realm Builder 2.0 .In Fig.5 is presented the VRML model of the Human arm.

EMG Simulator Based GUI

The method of recognition based K-NN algorithm and technique of

virtual reality are introduced, now the simulation which connect between the EMG recognition system and virtual reality is present.

From MATLAB, the user can set the positions and properties of VRML objects, create callbacks from Graphical User Interfaces (GUI), and map data to virtual objects. The user can also view the world with a VRML viewer, determine its structure, and assign new values to all available nodes and their fields. The Virtual Reality Toolbox includes functions for retrieving and changing the virtual world properties and for saving the VRML files corresponding to the actual structure of a virtual world. MATLAB provides communication for control and manipulation of virtual reality objects using MATLAB objects.

This part concerns with recognition of human arm movement using EMG Signal .it has following stage:

1-Build Data Base: this stage represents the training state which explained with more details in section (5.1).

2-Select Test EMG Signal: select the type of EMG signal to recognize with adding noise to test the quality of proposed method with different noise level .Five muscle are tested (biceps,triceps, deltoid, extensor carpi radialis and flexor carpi ulnaris) .Add noise for each tested signal to produce noisy signal and show to what level of noise can be recognized by the proposed method and show the powerful of proposed method with respect to artificial neural network. Add different level of noise to EMG signal and calculate the SNR of each noisy EMG signal .This produce four noised EMG signals for each muscle has SNR (25,9,5,2) dB .

3-Recognition Result: in this stat the K-NN algorithm is applied to recognize the EMG signal (see Fig.4) to produce the motion which provided by this EMG signal in virtual reality. Fig .6 shows this simulator. As example the test signal was biceps which perform the flexion of elbow as shown in this figure. The proposed method can be classified up to SNR=2 dB for this muscle (biceps).

Simulation Results

The implemented simulation of human arm which built in VR technique, the proposed algorithm based K-NN algorithm is achieved by MATLAB Ver.R2009a. To test the equality of this method K-NN compare with more popular method in the recognition of EMG signal (ANN method). The Back Propagation Neural Network (BP-NN) is used in this work the structure used for (BP-NN) is: six neuron in input layer, twenty neuron in hidden layer and seven neuron in output layer. Movement Recognition experiments were carried out in order to evaluate classification performance of the proposed method, to simulate real noise, different noises are considered which produce new EMG signal with lower SNR

The performance index for the recognition was given by

$$R = \frac{C}{T} \times 100\% \quad (12)$$

Where C the number of times EMG signals was correctly classified is, T is the total number of EMG signals which input to the system. Table.1, Table.2 show the result of recognition accuracy and the learning time for the training with noisy signal for the neural network and different value of k .

K-NN method has recognition accuracy 83 % with learning time = 0.0771 sec while ANN has recognition accuracy 50 % with learning time = 1.2824 sec .The results illustrate that the classification using K-NN present the best results(in term of recognition accuracy and learning time) than classification using neural network as shown Table.1 and 2, this table shows the result of Authentication with noisy signal has lower SNR for the neural network and different value of k . It can be found that , K-NN achieves best performance on the other method with $k = 15$. The possible reason for the poor results of ANN may be due to the simple decision function realized by this method. EMG signal has variation with the time therefore necessary to check the input signal with more frame for each muscle as shown in K-NN which provides more accuracy in the recognition

Conclusions

This paper presents the simulation of human arm motion in virtual reality to test the algorithm of EMG recognition. A proposed method uses the multiple feature parameters with KNN algorithm in order to increase the classification accuracy. From the results reported in the last section, it can conclude that, the proposed techniques achieved better accuracy in classification although when applied to lower SNR signal and the value of k can enormously affect the accuracy of classification. EMG signals recorded from muscles of the user's and activations from these muscles were used in order to control a human arm. Human arm movements recognition system based on EMG signals using K-NN is very good and easy to implement method from point of its simplicity , accuracy and it can be

implemented in many medical applications such as using of artificial limbs and high accuracy robot applications (interactive between human and robot). It can be concluded that, The Virtual Reality is useful to test the viability of designs before the implementation phase on a virtual reality prototype. It found that, MATLAB a convenient platform for development of computational algorithms, and with the visualization functions of MATLAB Ver.R2009a a reasonable amount of visualization techniques are available.

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**Table 1 Learning Time of Neural Network and
K-NN Methods**

Method	CPU Time(sec)
ANN	1.2824
K-NN,K=7	0.0741
K-NN,K=9	0.0749
K-NN,K=13	0.0752
K-NN,K=15	0.0771
K-NN,K=17	0.0771

**Table 2 Recognition Accuracy of Neural Network and K-NN
Methods with Noisy Signal**

SNR (dB)	ANN	K-NN K=7	K-NN K=9	K-NN K=13	K-NN K=15	K-NN K=17
25	83%	100%	100%	100%	100%	83%
11	66%	100%	100%	83%	100%	83%
9	66%	100%	100%	83%	100%	66%
7	66%	66%	83%	83%	83%	66%
5	50%	50%	66%	83 %	83%	66 %

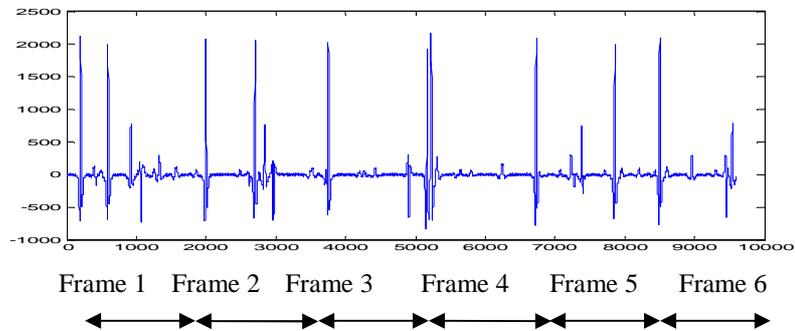
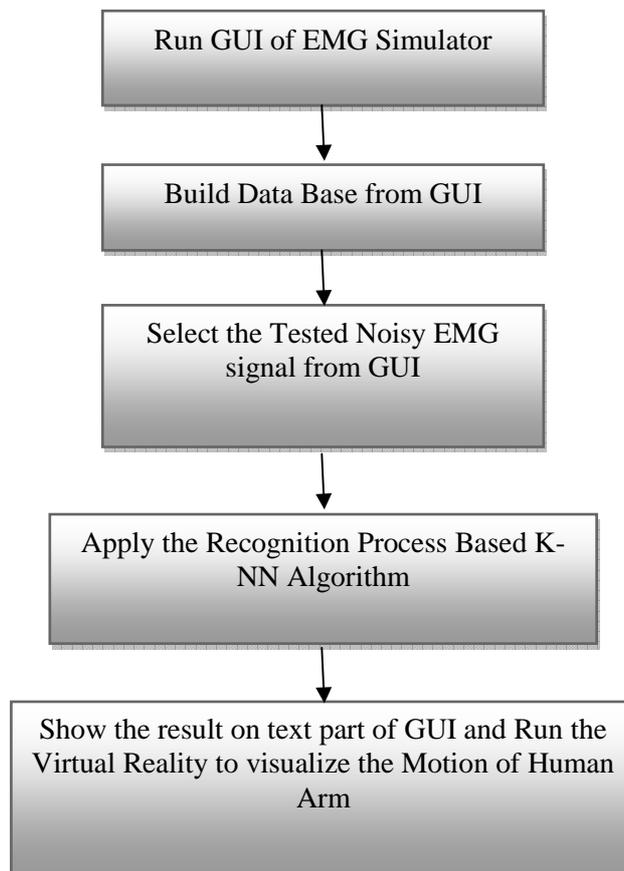


Figure1. EMG Signal



**Figure .2 Overall GUI simulation of Human Arm
Movement Recognition System**

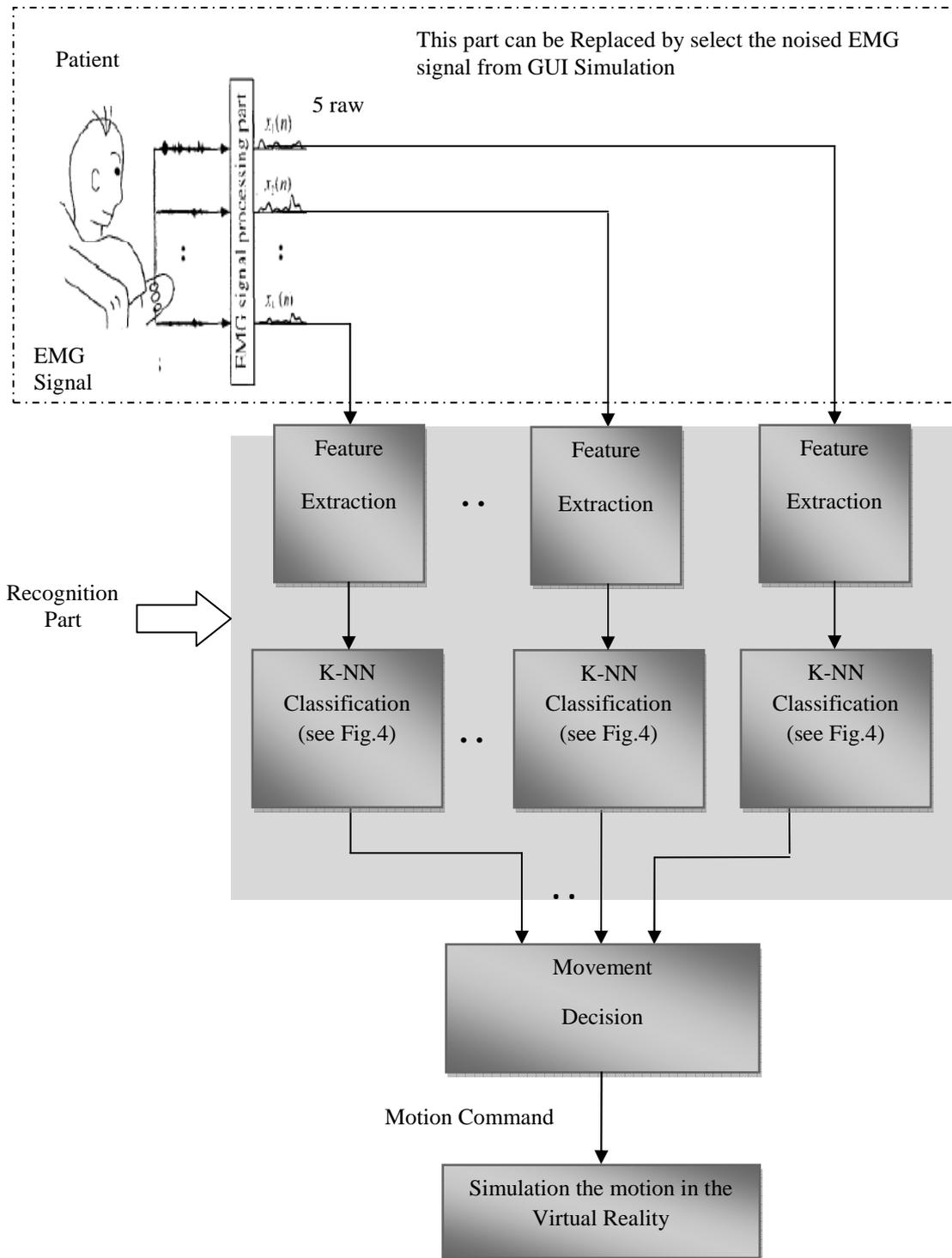


Figure 3 Structure of the Recognition system based on K-NN classifier

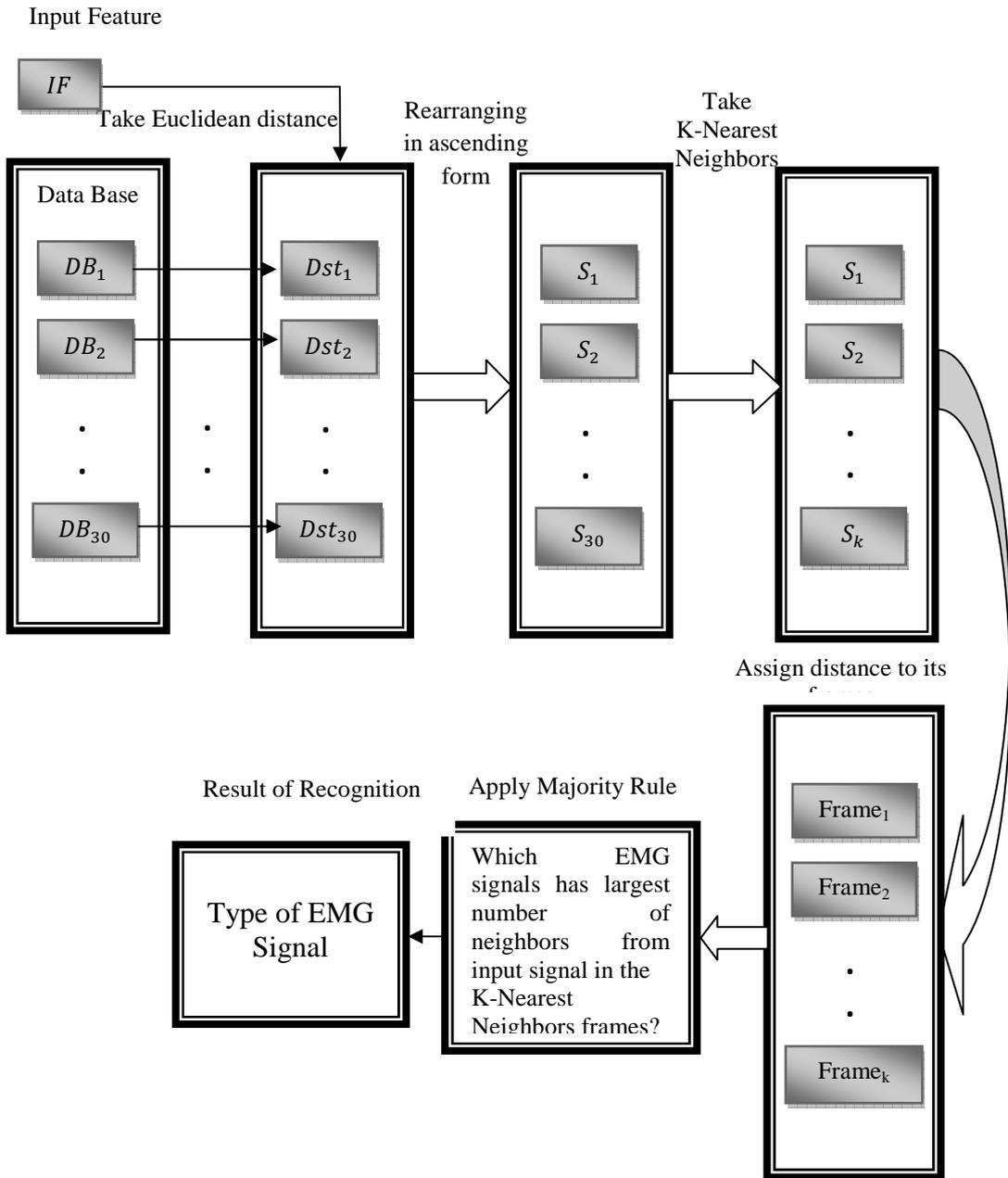


Figure 4. K-NN Classification Process

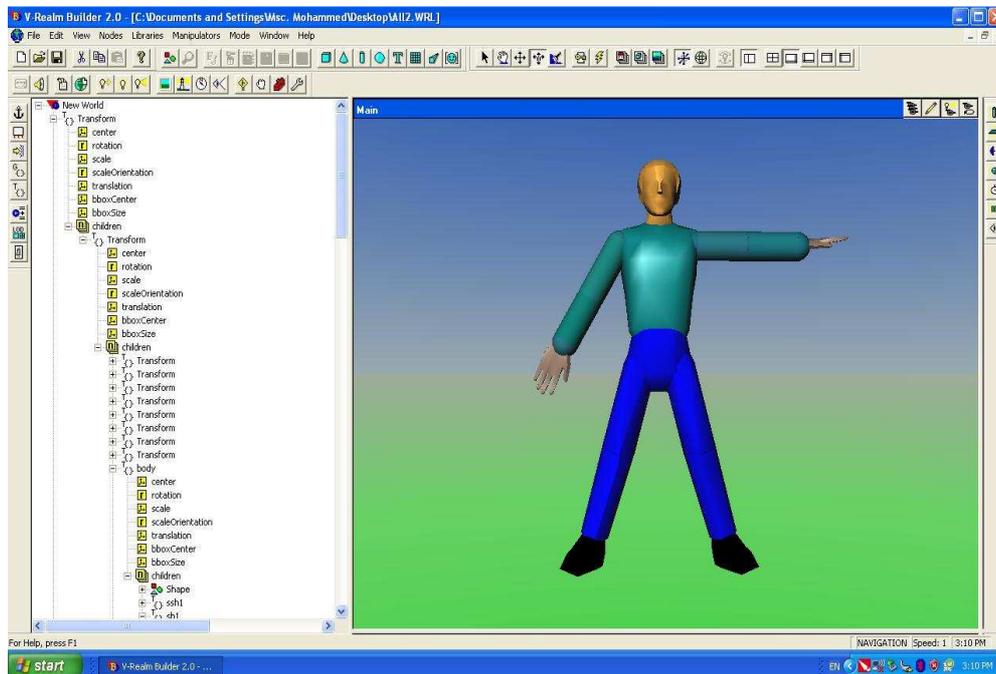


Figure 5. The VRML model of the Human arm

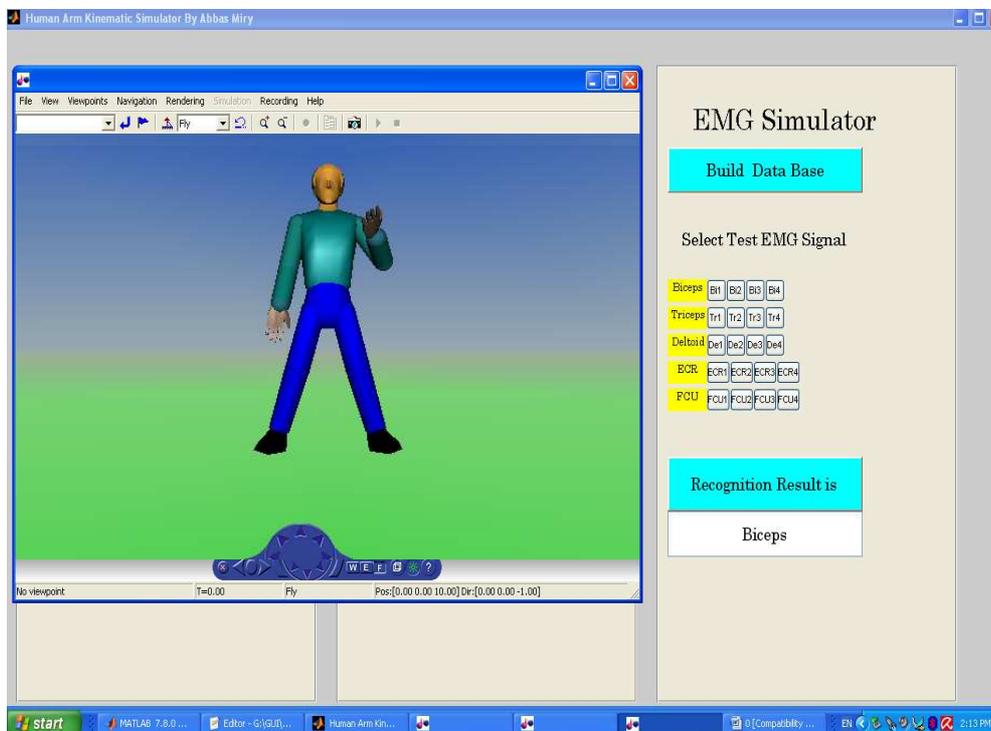


Figure 6 EMG Simulator Based GUI