Advances in Intelligent Systems and Computing 670

Bijaya Ketan Panigrahi
Munesh C. Trivedi · Krishn K. Mishra
Shailesh Tiwari · Pradeep Kumar Singh
Editors

Smart Innovations in Communication and Computational Sciences

Proceedings of ICSICCS 2017, Volume 2

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Preface

The International Conference on *Smart Innovations in Communications and Computational Sciences (ICSICCS 2017)* has been held at Moga, Punjab, India, during June 23–24, 2017. ICSICCS 2017 has been organized and supported by the "North West Group of Institutions, Moga, Punjab, India."

The main purpose of ICSICCS 2017 is to provide a forum for researchers, educators, engineers, and government officials involved in the general areas of communication, computational sciences, and technology to disseminate their latest research results and exchange views on the future research directions of these fields.

The field of communications and computational sciences always deals with finding the innovative solutions to problems by proposing different techniques, methods, and tools. Generally, innovation refers to find new ways of doing usual things or doing new things in different manner but due to increasingly growing technological advances with speedy pace *Smart Innovations* are needed. Smart refers to "how intelligent the innovation is?" Nowadays, there is massive need to develop new "intelligent" "ideas, methods, techniques, devices, tools." The proceedings cover those systems, paradigms, techniques, technical reviews that employ knowledge and Intelligence in a broad spectrum.

ICSICCS 2017 received around 350 submissions from around 603 authors of 9 different countries such as Taiwan, Sweden, Italy, Saudi Arabia, China, and Bangladesh. Each submission has gone through the plagiarism check. On the basis of plagiarism report, each submission was rigorously reviewed by at least two reviewers. Even some submissions have more than two reviews. On the basis of these reviews, 73 high-quality papers were selected for publication in proceedings volumes, with an acceptance rate of 20.8%.

This proceedings volume comprises 33 high-quality research papers in the form of chapters. These chapters are further subdivided into different tracks named as "Smart Computing Technologies," "Web and Informatics," and "Smart Hardware and Software Design."

We are thankful to the speakers: Prof. B. K. Panigrahi, IIT Delhi; Dr. Dhanajay Singh, Hankuk (Korea) University of Foreign Studies (HUFS), Seoul, South Korea; and Dr. T. V. Vijay Kumar, JNU Delhi; delegates, and the authors for their

participation and their interest in ICSICCS as a platform to share their ideas and innovation. We are also thankful to Prof. Dr. Janusz Kacprzyk, Series Editor, AISC, Springer, and Mr. Aninda Bose, Senior Editor, Hard Sciences, Springer, India, for providing continuous guidance and support. Also, we extend our heartfelt gratitude and thanks to the reviewers and Technical Program Committee Members for showing their concern and efforts in the review process. We are indeed thankful to everyone directly or indirectly associated with the conference organizing team leading it toward the success.

We hope you enjoy the conference proceedings and wish you all the best!

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Part I
Smart Computing Technologies

Classification of the Shoulder Movements for Intelligent Frozen Shoulder Rehabilitation

Shweta, Padmavati Khandnor, Neelesh Kumar and Ratan Das

Abstract Frozen shoulder is a medical condition leading to stiffness in the shoulder joint and also restricting the range of motion of the shoulder joint. The paper compiles the details about the four basic movements of the shoulder joint, namely the flexion/extension, abduction/adduction, internal rotation and external rotation movements. Shoulder movements of 150 subjects were recorded, and the data was further analyzed and classified using the K-nearest neighbor algorithm, support vector machine, and also using logistic regression algorithm. The data is recorded using a module consisting of a triaxial accelerometer, a HC-05 Bluetooth module and triaxial gyroscope. SVM shows an accuracy of approximately 99.99% over the classification of the four shoulder movements and is proved to be better than other classifiers. Classification of the shoulder movements can be further used to classify an individual as either a patient suffering from frozen shoulder or a normal individual.

Keywords Signal processing · Pattern recognition · Machine learning
Bioinformatics · Frozen shoulder

1 Introduction

Recognition of the human body movements has proved to be utterly important in various sectors of life like sports activities, bioinformatics [1], medical diagnosis, rehabilitation purposes. [2]. The tracking of movements of spheroidal joint like

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shoulder joint is of great significance in the field of medical diagnosis and rehabilitation for the problem of adhesive capsulitis. Adhesive capsulitis or frozen shoulder is a medical condition leading to the stiffness of the shoulder joint as well as leading to reduction in the active and passive range of motion [3]. The shoulder movements are majorly divided into four types, namely shoulder flexion, shoulder abduction, internal rotation, and external rotation. Figures 1, 2, 3, and 4 show the various shoulder movements. Table 1 shows the details of the movements of the shoulder joint.

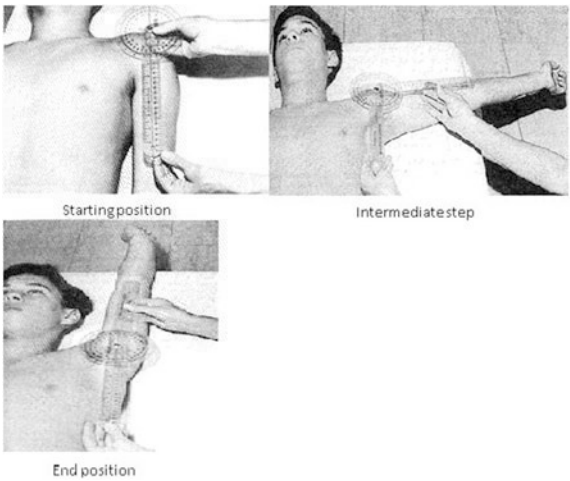

Fig. 1 Abduction movement [4]

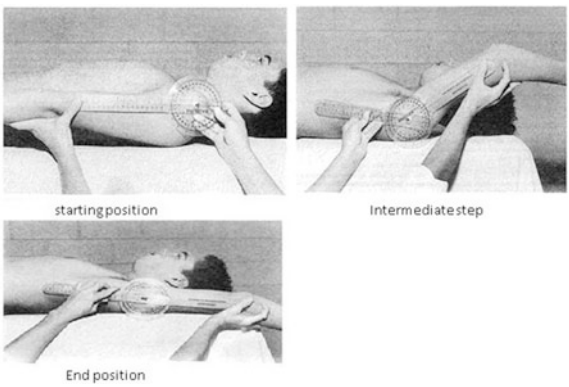

Fig. 2 Flexion movement [4]

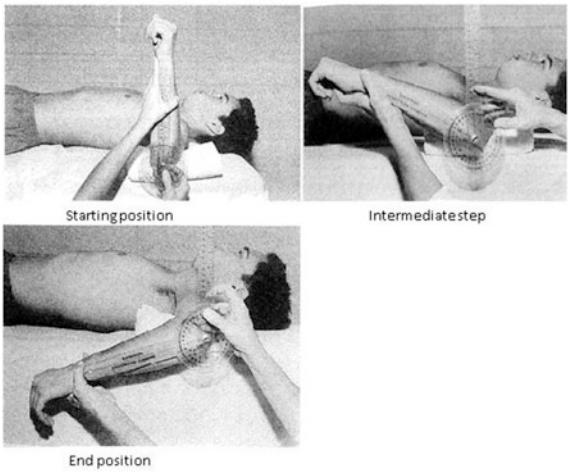

Fig. 3 Internal rotation [4]

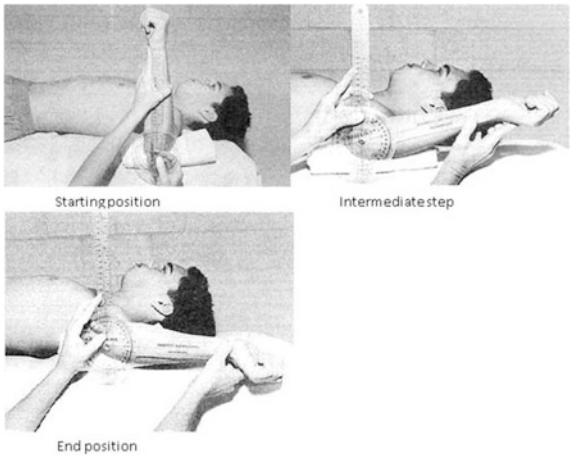

Fig. 4 External rotation [4]

Table 1 Details about the shoulder joint movements

S. No.	Shoulder movement	Mean angle (°)
1	Abduction	180
2	Flexion	180
3	Internal rotation	70
4	External rotation	90

2 Related Work

A self-controlled rehabilitation system to monitor the shoulder joint is the need of the hour for managing the problem of adhesive capsulitis [3, 4]. A virtual reality-based approach for the assessment of shoulder joint for its rehabilitation purposes has been presented in [3]. The authors also detail the analysis about the shoulder joint movement and motor functionality of the shoulder joint. To monitor the patients suffering from frozen shoulder or upper arm problems, a track of movements is made and accordingly the physical therapy is provided to assist the patients in increasing range of motion (ROM) and relieving the pain in shoulder joint [5]. The patients are guided with the proper exercises like stretching, rotation according to their rehabilitation progress. Activity recognition has been performed to recognize various activities like running, walking, standing, climbing stairs in the past. Inertial measurement unit (IMU) like accelerometer, magnetometer, and gyroscope are used to assess the activities of human motion following steps like extracting the features, selection of the higher accuracy features, and the classification of activities. Various supervised machine learning algorithms such as Naive Bayes (NB) [6], hidden Markov model (HMM) [6], support vector machine (SVM) [7], K-nearest neighbor (K-NN) [8], decision trees, or the combination of one or more algorithms have been used for classification in the past. Many algorithms which are semi-supervised or unsupervised are also used for the purpose of classification of activities. Likewise, these classifiers can also be used to classify the shoulder movements and help in the vision of smart rehabilitation of frozen shoulder.

3 Methodology

This work is done using a wireless inertial sensor-based wristband module which comprises of a triaxial accelerometer [9], a HC-05 Bluetooth chip and a triaxial gyroscope. The data is sent using the Bluetooth module to the central system using the serial port communication. The frequency of the sensor module is 20 Hz. For the experiments, we have used just the triaxial accelerometer and the biaxial gyroscope to measure the gravitational acceleration (m/s^2) in *x*, *y,* and *z* directions as well as the angular velocity in the x and y directions. For the analysis of the shoulder joint motion, we focus on the four elementary motions as mentioned below.

1. Action A: Keeping the arm straight in the vertical plane and then moving the arm in the sagittal plane along the socket joint (flexion and extension of the shoulder joint);
2. Action B: Keeping the arm straight in the vertical plane and then moving the arm in the coronal plane along the socket joint (abduction and adduction of the shoulder joint);

3. Action C: Keeping the angle between the elbow joint as 90° and moving the forearm toward the central axis of the body (internal rotation);
4. Action D: Keeping the angle between the elbow joint as 90° and moving the forearm away from the central axis of the body (external rotation).

The experiments were performed using the normal subjects having age in the range of 15–70 years. The ROM of the subjects is measured using the wristband of all the right dominant subjects. The training database is generated from 100 normalized subjects by making them perform all the above-mentioned actions (Action A, Action B, Action C, and Action D). The testing of the data is done using one-tenth of the database.

3.1 Data Processing

The elementary steps involved for the processing of data of an individual are specified in the flowchart in Fig. 5.

Data Gathering and Data Pre-processing Phase
The inertial sensor-based wristband is used to gather the data from the shoulder joint movement of the normal subject. The data communication is established with the central system via a HC-05 Bluetooth chip in the sensor module. The raw data from the band is filtered by applying a band-pass filter having a frequency of 0.1 Hz to remove the noise. In feature extraction phase, various feature combinations or sets like the frequency domain or time domain have been used in [10]. Application of the accelerometer and gyroscope signals for the identification of upper arm movements comes into focus because of the variability and uniqueness of the two signals [11]. For our research work, we had considered over a mix of frequency- and time-domain features. Each triaxial accelerometer signal and each triaxial gyroscope signal is considered to derive a feature set comprising of following:

1. Weighted mean for the duration of the shoulder movement;
2. Standard deviation for the duration of the shoulder movement;

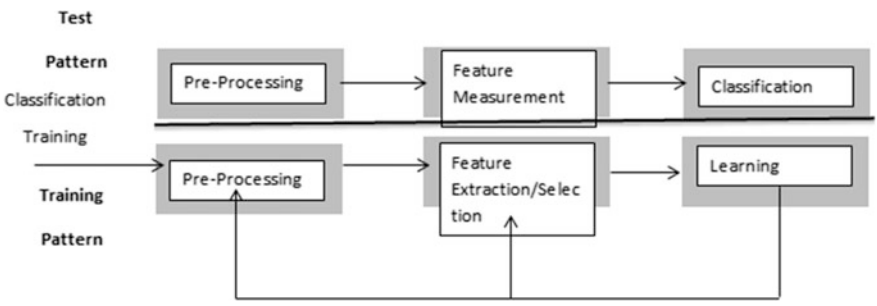

Fig. 5 Flowchart showing the process of classification

3. Kurtosis—to predict the 'peakedness' of the signal;
4. Skewness—to determine the symmetry of the signal [12];
5. Root mean square (RMS value);
6. Entropy of the signal—to measure the randomness of the signal;
7. Absolute difference between maximum and minimum values of the signal;
8. Index of dispersion.

Along with the following above derived features, the module was programmed to calculate the angle in x and y directions. Using the angle values, maximum and minimum angle values in x and y directions are calculated, respectively. ROM is measured by taking the difference between maximum and minimum angle values. For the ROM, the mean angular velocities along the x, y, and z directions are measured. Kurtosis and skewness are the variables to know the probability distribution of the data, whereas maximum amplitude is used to assess the motional capacity of the shoulder joint. Hence, a set of eight features on each accelerometer signal (accx, accy, accz) and each gyroscope signal (gyrox, gyroy, gyroz) are computed.

Feature Selection Phase
This phase of the entire analysis reflects on selecting the perfect group of features to get the desired accuracy. Clamping algorithm [13], principal component analysis (PCA) [14], RELIEF algorithm [15] are the most widely and most used algorithms for feature selection. In our experiments and analysis of data, we have used PCA to give the best results.

Classification
Some of the classification algorithms constitute of generalized linear models like logistic regression [16], linear discriminant analysis (LDA), SVM [17], Naives Bayes [18], K-NN [19]. In our analysis, we have implemented the K-NN, logistic regression, and the SVM to classify the four shoulder movements. The principle of working of K-NN is to find the 'K' number of nearest training points to the tested sample of data and therefore predict the label of the tested data. All the implementation of the programming code is done using Python in Enthought Canopy.

3.2 Results and Analysis

The average accuracy is the score given by the classifier for its successful prediction of the test data. In multiclass scenario, there are certain problems of class inseparability, thereby affecting the sensitivity of data [20]. Sensitivity of a class 'A' is defined as the number of true positives (TP) classified as class A divided by the number of actual values of class 'A' as defined in Eq. 1. Figures 6, 7, 8, 9, 10, 11, 12 and 13 show the plot of the acceleration and gyroscope signals for the actions A, B, C, and D.

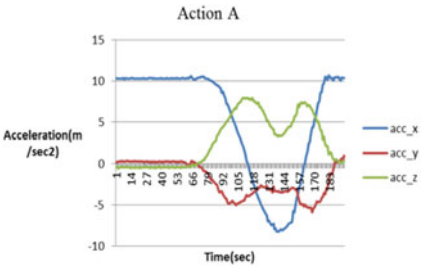

Fig. 6 Action A acceleration signal

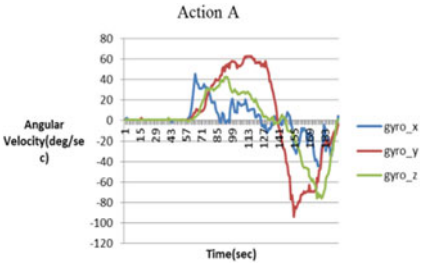

Fig. 7 Action A gyroscope signal

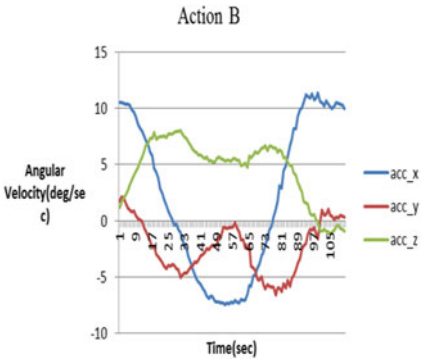

Fig. 8 Action B acceleration signal

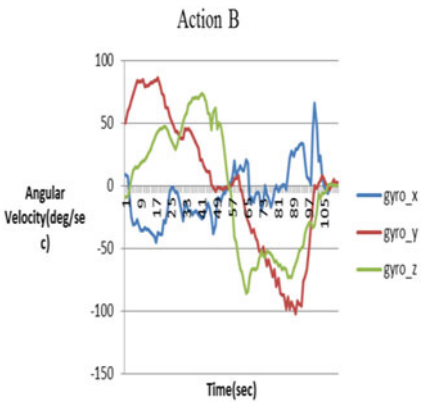

Fig. 9 Action B gyroscope signal

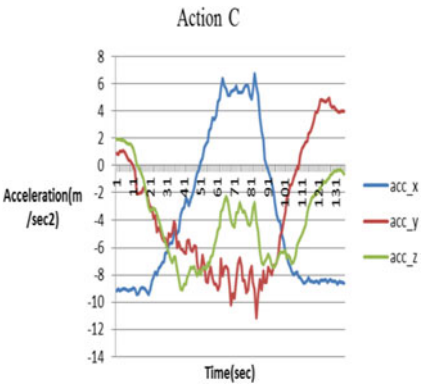

Fig. 10 Action C acceleration signal

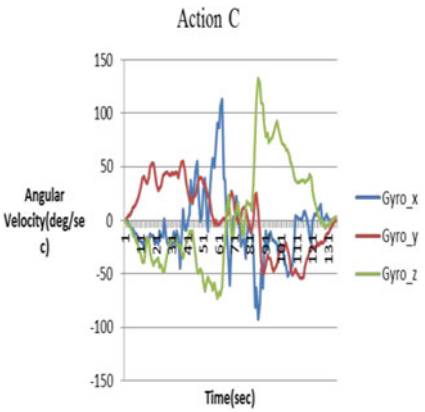

Fig. 11 Action C gyroscope signal

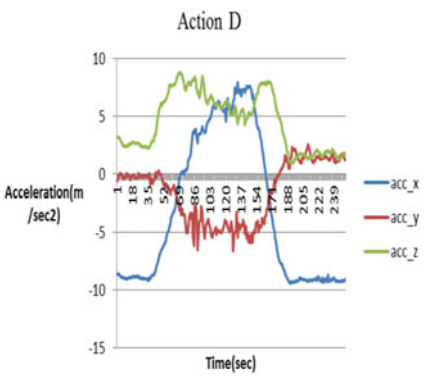

Fig. 12 Action D acceleration signal