The Application of Motion Capture and SVM for Rapid Diagnosis of Shoulder Pain

Yu Hou, Tsutomu Fujinami
Japan Advanced Institute of Science and Technology,

Abstract:

The objective of this research is to discuss whether motion capture devices and SVM (Support Vector Machine) can effectively help doctors to diagnose shoulder pain. We focus on shoulder pain due to muscle injuries. Motion capture devices have been rarely adopted for medical diagnosis. It is more difficult than deciding on a treatment to diagnose causes of shoulder pains because it has to be diagnosed in greater accuracy. We propose a method to diagnose patients effectively using machine-learning technique. We employ several techniques such as random forest, sliding window and grid search to improve the performance of the classifier. We also employ a method called cross validation to prevent overfitting. The results were checked against the diagnosis carried out by a human doctor. Our approach is useful based on the evaluation result for medical diagnosis.

1.1 Background

Computer-aided medical diagnosis has made a great success in recent years. One such example is medical imaging. Few attempts have been done, however, for physical diagnosis. We employ a motion capture device to collect data and propose a method using SVM for diagnosis with a hope to help human doctors to carry out medical diagnosis.

There are fewer young, healthy individuals in the workforce because of the aging society. The shortage of worker force is evident for a variety of jobs, including jobs related to health care. The workloads for younger doctors are expected to increase greatly in the future. A computer-aided physical diagnosis may reduce doctors' workload if advanced technologies are employed in diagnosing patients. The increasing population means that the rehabilitation/physical therapy market is also expanding. It is, however, very difficult to fill the gap between the demand and supply with manpower.

Shoulder pain is a symptom of shoulder joint disease, which may result in a decrease in range of motion. Shoulder pain is age-related, thus it is rarely found among young people. This research focuses on the shoulder pain due to muscle injuries. We only consider pains due to problems with muscles, excluding other cases such as fractured bones. Muscle pain at shoulder can be caused due to many reasons. A fall or

accident may cause a shoulder pain by being injured. Stress from overuse or arthritis can be other causes. You could also overdo in long-term deskwork. Shoulder pain is sometimes felt in another condition such as arthritis.

1.2 Objective

The objective of our research is to discuss the possibility use of high-tech applications for medical diagnosis. We employ motion capture devices to collect data and apply a method using SVM to them to diagnose shoulder injuries. The method should help human doctors to reduce time as shown in Figure 1. We adopt active tests for clinical physical diagnosis to distinguish patients from healthy people. Our method is particularly useful for patients to go through the movements required for active test. The data of speed and angle are then analyzed to identify severe minor injuries of patients. Figure 1 illustrates the overview of our approach.

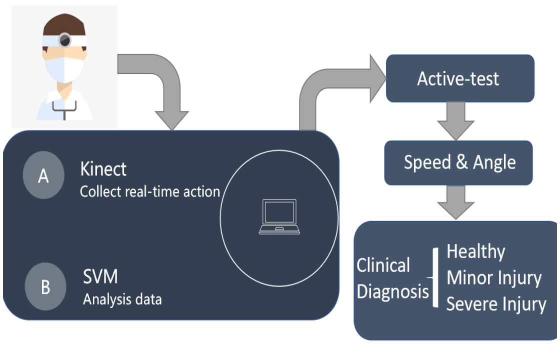


Figure 1 Objective

Kinect is employed to collect data real-time of patients' motions, whose data are analyzed using SVM. Active-test is a useful clinical measure for physical diagnosis. Speed of movements and angles between joints inform us of the different among subjects when they are tested with the same active test.

2. Related Research

2.1 Kinect 2 is used to collect patients' range of motion [1]. They collected the motion trajectory of patients. Researchers use the data to build a database to determine whether or not the patients are recovered.

2.2 Acceleration sensor is used to collect the acceleration of the patient's moving arm when they take part in a rehabilitation exercise [2]. SVM is used to examine deviations of data collected from patients to determine whether they are recovered.

3.1 Research work

In this research, Microsoft Kinect 2 was employed as a motion capture device to collect data of subjects' motions in real-time. The main diagnostic method of this research is active-test, a commonly used clinical examination method. The test is consisted of some basic motions of the shoulder joints, which includes horizontal abduction, adduction, vertical extension, adduction and internal, external rotation. Figure 2 shows the procedure employed for this research.

In this research, doctor used the passive-test (another commonly used clinical examination method, in which doctors ask patients to complete the checking actions) to determine the shoulder condition of the subjects. They were divided into three groups, the first of who is consisted of healthy people, the second of who people with minor injuries, and the third of who people with severe injuries. All the data are put into SVM to make a diagnosis classifier with the training data. The classifier can be used for clinical physical diagnosis after it is evaluated to be accurate though tests.

- Data collection: Subjects are asked to complete the active-test movements in front of Kinect 2.
- Data analysis: The motion data are processed into trajectory data and are fed into SVM as training data.
- Classifier: The accurate classifier is completed after testing stage.

Microsoft's Kinect 2(Figure 3) is employed as the research device to collect data of subjects. Kinect 2 is a marker-less, cheap technology recently introduced from the video gaming industry to dealing with our task of clinical diagnosis. Compared with other optical motion capture devices, Kinect does not require people to wear a special clothing nor markers on them.

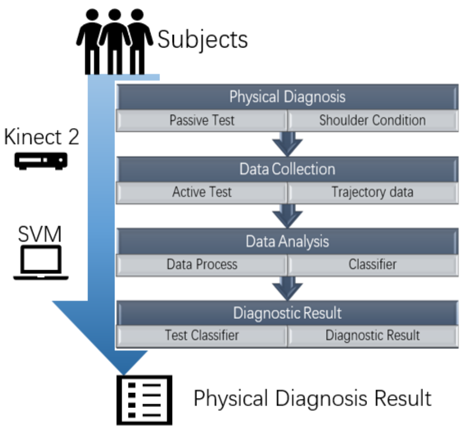


Figure 2 Research Form

https://www.ebay.co.uk/itm/OFFICIAL-Microsoft-XBOX-ONE-KINECT-2-2-0-V2-MOTION-SENSOR-FREE-UK-POST-/181539809075

Feature	Kinect 2
Color stream	1920*1280 at 30FPS
Depth stream	512*424
Depth distance	0.4m – 4.5m
Defined skeleton joints	25
Operation system	Windows 10

Figure 3 Kinect 2 and Performance Parameter

3.2 Behavior Model

Shoulder movements include stretching, rotation and adduction, as shown in the Figure 4. Complex movements require to combine different muscles to perform various movements in coordination with multiple muscle groups. The complexity of shoulder movement makes the shoulder more vulnerable to injury.

Peri-shoulder muscle

Peri-shoulder muscle is a general term for several muscles around the shoulder, including biceps, deltoid, trapezius, pectoralis major and latissimus dorsi. Its main functions are flexion, extension, abduction and adduction. Due to the complexity of the physiological structure of the shoulder, the function of the shoulder muscles cannot be completely explained separately.

Rotator cuff muscle

Rotator cuff, also known as shoulder cuff, is a dynamic and stable structure of shoulder joint, which is composed of supraspinatus muscle, infraspinatus muscle, subscapularis muscle and teres muscle. The rotator cuff muscle is relatively unitary in function. The rotator cuff muscle function is highly directional and easy to judge.

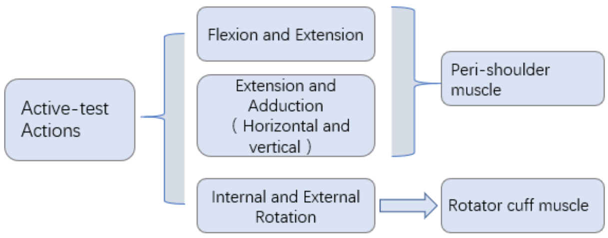


Figure 4 Active-test Actions

According to the above characteristics, we divide the shoulder movements into two types, namely, one is the abduction and adduction movement, which is mainly based on the peri-shoulder muscle function. The other one is rotational movement, which is mainly based on the rotator cuff muscle function. These two types of shoulder movements are examined for the diagnosis in this research.

4.1 Preliminary Experiment and Result

In order to make this research accurate, we focus on acceleration to analyze the conditions for shoulder movement because some researchers found a correlation between acceleration and muscle injury [3]. We thus adopt acceleration as a measure of shoulder movement. The purpose is to distinguish subjects into three groups based on three clinical conditions. The three conditions are whether they are healthy, whether they barely complete the active test, or they suffer from shoulder muscle injury. Through the analysis of acceleration, we can use acceleration to figure out the difference among healthy people, another people with minor injuries and other people with severe injuries. The results are as follows: healthy people showed high acceleration peak and the change of acceleration is obvious while patients showed low acceleration peak and the change of acceleration is weak as shown in the Figure 5.

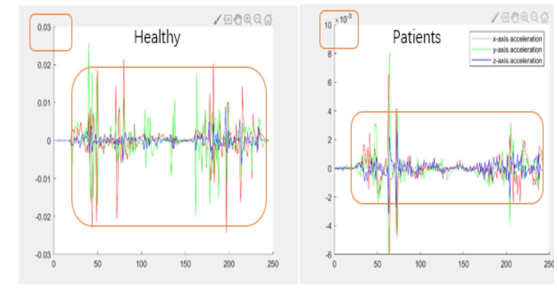


Figure 5 results of acceleration

4.2 Subjects

Shoulder movement data were collected from 30 subjects in this research. The subjects were all students and stuffs at JAIST, all of who suffer from muscle injuries due to long-term hard work or arthritis. We could not however find subjects who suffered from the shoulder pain caused by physical labor or sports injuries. We collected for each subject the motion data for about an hour. Active and passive tests were carried out separately of the data collection and required another one hour.

The results of diagnoses of subjects' shoulder conditions are shown as Figure 6.

- 4 are minor injuries severe injuries, 4 are severe injuries, and 22 are healthy people in the extension and adduction active-test.
- 4 are minor injuries severe injuries, 7 are severe injuries, and 19 are healthy people in the rotation active-test.

	Minor Injury	Severe Injury	Healthy
Peri-shoulder muscle	4	4	22
Rotator cuff muscle	7	4	19

Figure 6 Physical diagnosis results

4.3 Research process

We asked the subjects to stand 2 meters away in front of Kinect2. At the same time, subjects were asked to execute movements for the active test as explained below.

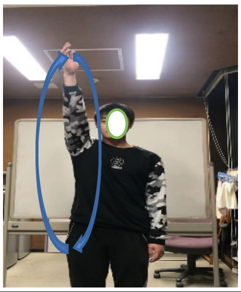
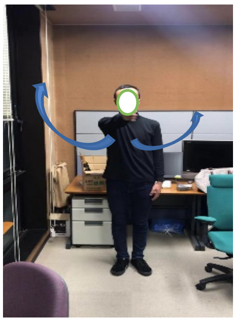
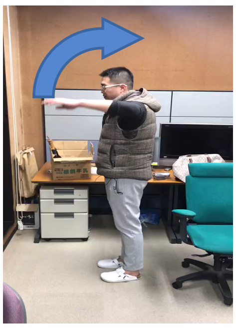
(1) Flexion and Extension: The straight right arm points down the ground, in which the angle is defined to be zero degree. He moves his right arm up to 180 degrees, pointing to the ceiling. After reaching the apex, the right arm is rotated and released back to the initial position as shown in Figure (7). Then, he executes the same action with his left arm.
(2) Vertical Extension and Adduction: With the right arm extended, he performs the vertical abduction to the head position. After reaching the peak, he moves his arm down

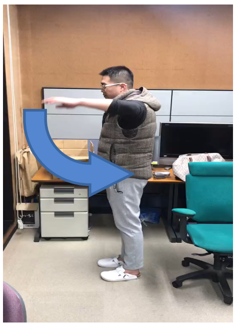
to the initial position (the vertical adduction) while the arm is kept as close as possible to the ear and the palm is kept downward as shown in Figure (8). Then, he does the same action with his left arm.

(3) Horizontal Extension and Adduction: With the right arm extended, he performs the horizontal adduction and abduction. After the adduction, he completes the abduction. At least 45 degrees of adduction and 90 degrees of abduction must be observed. The palm is perpendicular to the ground as shown in Figure (9). Then, he does the same action with his left arm.

(4) Shoulder External and Internal Rotation: The motion starts with a particular posture, that is, his elbow and forearm must form the right angle, that is, 90 degrees, the upper arm and the torso must from the right angle, the, fingers extended straight with the hand down, as shown in Figure (10). He is asked to move up vertically his right arm to point to the ceiling by rotating his shoulder and move it back to the initial position as shown in Figure (10). He is also asked to move down his right arm by 75 degrees from the initial position and he returns it to the starting position as shown in Figure (11). The subject is asked to turn his body to left by 30 degrees while he moves his right arm for this test. He turns to right when he moves his left arm similarly.

Subjects were required to perform these actions as slowly as possible, that is, for at least 3 seconds because Kinect 2 sometimes fails to capture quick motions., They are also asked to keep the speed constant to avoid catching noises due to failure of motion modeling by software. We collected real-time motion data from these subjects with a software developed using SDK. We collected data for each subject, each of who went through 5 active tests for the left and right sides, resulting in 10 data in total. The data can be used to show the conditions over trajectories of two arms concerning two muscle groups, one of which is the condition of peri-shoulder muscle group and the other is that of rotator cuff muscle group.

	Flexion and Extension Figure 7
	Vertical Extension and Adduction Figure 8
	Horizontal Extension and Adduction Figure 9
	Shoulder External Rotation Figure 10

	Shoulder Internal Rotation Figure 11

4.4 Workflow

The size of motion data collected is different among each subjects since the time required for the active test varies depending on subjects, We thus preprocessed the data so that each datum of a subject falls into a particular range of size. The preprocessed data allows us to compare them effectively. Preprocessed data are analyzed as follows:

1. Data reduction. We used a sliding window to segment the data into 500 items. This step reduces the data size significantly. Another method called random forest is further employed to identify possible features of data [4] while reducing the data size, too.
2. Prevent overfitting: Cross-Validation statistically divides data into subsets to prevent over-fitting due to complexities of models [5].
3. Testing Classifier: We verified that the classifier could accurately determine these subjects with injuries of shoulder muscles using another set of data collected from different subjects [6].

4.5 Result

We used data collected from five subjects to verify the classifier obtained with the method explained above. One of the five subjects was a person with and the other four were healthy people aged from 20 to 30 years old. Three of them were female and the other two were male. The first author, who is a doctor, examined physical conditions of each subject before collecting motion data. He also touched their muscles as part of physical examination to observe their ability to move shoulders.

The first author found through physical examination that the person with frozen shoulder could not lift his arm, in both abduction and rotation. His condition was more serious than the others. The other four subjects showed no significant stagnation or pains for any actions. The first author found by touching the subject that the person with frozen shoulder had some trouble in adhesion in rotator cuff while no abnormality was found in the other parts of his shoulder joint.

We verified through tests that our method could distinguish subjects with the shoulder muscle injury. The results of SVM's diagnosis were consistent with the doctor's physical examination. Our method can be applied to diagnose shoulder muscle injury.

5. Discussion

Our method can diagnose patients with the same accurate as human doctors without passive-test (Figure 12), thus saving 15 to 20 minutes for diagnosis. It can change physical diagnosis from time-consuming manual labor to time-saving and labor-saving computer work. Computers can be employed to complete preliminary, massive and repetitive diagnosis.

System	Active test	(15-20 minutes)
Doctor	Active test	Passive test

Figure 12 Contrast Result

6. Summary

We proposed to apply a motion capture device and SVM. We adopted several techniques in designing our method such as sliding windows, random forest and cross-validation. The method should release human doctors of the medical diagnosis of shoulder pains. There are however several limitations of our research. Firstly, the data size is not large enough to construct classifiers that accurately diagnose patients with pains.

7. Future Study

Shoulder joint is the most complex part of the human body. It can execute omnidirectional motion and rotational motion. We proposed a method employing a motion capture device and SVM to the examination of shoulder joints. The method can accurately detect problems with selected features enough for satisfying the requirements. We believe that our method can be applied to examining other joints, too. In future studies, however, I can get better and more convincing results by expanding the sample size of data, include physical labors and sportsmen.

Bibliography:

[1] Kinect Motion Capture Data for Rehabilitation Treatments. 2012 Fourth International Conference on Intelligent Networking and Collaborative Systems. The authors: Adso Fern'ndez-Baena; Antonio Susín ; Xavier Lligadas

[2] Intelligent Shoulder Joint Home-Based Self-Rehabilitation Monitoring System. Sep 2013 International Journal of Smart Home. The authors: Jiann-I Pan, Hui-Wen Chung, J. Huang

[3] Gait event detection using linear accelerometers or angular velocity transducers in able-bodied and spinal-cord injured individuals. Gait & Posture, Volume 24, Issue 4, December 2006, Pages 502-509. The authors:Jasiewicz JM, Allum JH, Middleton JW, Barriskill A, Condie P, Purcell B, Li RC.

[4][5] Random Forest and Support Vector Machine based Hybrid Approach to Sentiment Analysis Yassine AL AMRANI, Mohamed LAZAAR

[6] Support Vector Machines in a real time tracking architecture Benjamin Castaneda