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# 1.Introduction:

## 1.1 Background：

Now that [1] Japanese society is ageing, there are fewer young, healthy individuals in the workforce. [2] It's going to be higher and higher relative to the previous doctor. New doctors' workloads are going to increase greatly according to...when compared to doctors in the past. If computers and advanced technology can be used to complete preliminary, massive and repetitive diagnosis, this can reduce the doctor's workload. In China, we have a huge population, but unfortunately, [3] China is also ageing from the < China Population and Labor Report >. The large population means that the rehabilitation/physical therapy market is very large. However, it is almost impossible to make up the gap in the market through manpower. For these reasons, we must begin to look for new solutions.

To begin, with the development of artificial intelligence technology, AI is replacing human workers in many different tasks. In many automobile companies, a large number of robots are replacing human workers to finish their jobs. While jobs disappear due to AI, more people are choosing to become engineers and designers by learning new technologies. So that workers may avoid the primary processing work for earning a higher income. This means that with the progress of technology, human beings are creating more wealth and having more time to enjoy their life at the same time. In the medical field, no revolutionary technology has been produced due to the limitations of previously existing artificial intelligence technology. When you enter the hospital, you find many nurses and doctors busy all the time, many enterprises work on this aspect, but the effect is not obvious. In China, the shortage of medical talents has become a serious social problem. In the countryside and many underdeveloped areas, many people do not receive adequate medical support or treatment. The training of doctors, however, takes long time. It generally takes from 5 to 10 years of work to complete the initial education of doctors. I think if advanced technology can be applied to preliminary medical diagnosis, the purpose is to complete a large number of complicated preliminary medical diagnosis. This gives doctors more time to learn new things.

Secondly, there is a phenomenon/problems of communication between doctors and patients. Doctors have different learning backgrounds than ordinary people. Different professional knowledge leads to obvious problems in their communication. A doctor may only tell the patient the condition of his disorder or not carefully explain the cause of the disease and the specific treatment plan. But patients want more information about their disease. They want to know more about themselves and their illness. This means that in the long-term treatment, patients have doubts and negative feelings towards the treatment method due to the ignorance of their own situation. Doctors and nurses do not have enough time to explain each stage of the disease. But computers are different. They patiently introduce patients to each stage of the disease and explain to the patients the progress and status of treatment. This repetitive work does not make the computer impatient. It looks like a robot on a growth line,

Thirdly, over the past decade or so, interactive games have become a significant part of the gaming market. Both Sony and Microsoft have made great progress in this area. Kinect, a product of interactive device by Microsoft company, has much more expansibility than SONY's similar products. Many studies have applied this device to capture motions. Many studies use different SDK to achieve their goals. Software Development Kit (SDK) is generally a collection of development tools used by software engineers to build applications for specific software packages, software frameworks, hardware platforms, operating systems, etc. More and more SDKs also make Kinect more accurate and noise-reducing. In related studies, Kinect was used to capture the movement track of subjects between 2 meters and 5 meters away, and the accuracy was accurate enough to judge the tiny movements of subjects. Devices from either SONY or Microsoft can be accurate enough to carry out research work. At the same time, within the range of about 2 meters, it is also the distance for doctors to make physical diagnose for patients. The human eye at this distance performs essentially the same function as the RGP camera. With the use of depth cameras, the accuracy of the machine is far greater than that of the human eye. With the function of data saving and data reading, human judgment has obvious errors. It is indisputable that human memory is error prone. Do you remember what time you had breakfast yesterday? However, computers can remember every patient's results. These results are presented as data to patients. Patients can intuitively observe the changes in their muscle conditions during treatment. Meanwhile, as technology improves, a small box can be placed anywhere that a doctor wants to use it. Such a convenient, fast and effective diagnostic device can be used in medical diagnosis, thus saving a lot of work.

The system consists of motion capture device and SVM， which can achieve professional medical diagnosis in shoulder pain, thus greatly reducing the work of doctors. At the same time, this system allows people without any medical background to obtain professional and effective diagnostic results. This device is very convenient to carry and store. It is suitable for both families and community hospitals. Professional, effective medical diagnoses are available when people use them. The modern people who pursue speed and efficiency all the time, need its professional judgement more after taking exercise. This is a very promising commodity. It will be a good doctor's assistant. The value of this research lies in the concentration of multiple advantages. For these reasons, I envisage an advanced technology device being used in primary diagnosis.

## 1.2 Objective：

The objective of this research is to discuss whether the computer can be used to carry out the diagnosis of shoulder pain. So how can computers replace human doctors to perform accurate shoulder muscle injuries?


Figure 1Purpose sketch

The real-time actions of the human shoulder are collected by the motion capture system, and the trajectory data and acceleration data are obtained through a software. After that, the data are input into the diagnosis classifier for data analysis, so that an accurate diagnostic result can be obtained.

The purpose is for doctors to be released from time-consuming repetitive activities through artificial intelligence technology. In order to reduce the doctor's workload and improve work efficiency, our method makes the tedious work of diagnosis easy and simple.

The accuracy of diagnosis is paramount to our research. That is the aim of my research. When compared with standard diagnosis, computers are unable to judge muscle condition by touch. However, computers allow us to diagnose shoulder muscle condition by analyzing trajectory.

In this way, how to obtain accurately trajectory data and how to correctly process data become the problems of this research.

# 1.3 Target:

With the advent of the ageing society, the faster pace of life and more onerous work, physical health has become a new consumer market. With the popularization of computer, work efficiency has improved, but physical fitness less so. young people today have more skeletal and muscle diseases than they did 30 years ago. Frozen shoulder(五十肩), once acquired only at the age of over 50 years old, is more and more common among young people. Lack of time for exercise has become an excuse for young people to reduce their exercise. Long periods of inactivity or inadequate exercise intensity result in reduced muscle function and muscle strength. However, short periods of intense exercise may damage their muscles. These are two very common situations when people exercise.

How to correctly judge their muscles has become a difficulty for young people nowadays. Recently, my classmates and I are busy writing our final papers. I often hear them talking about neck pain, shoulder pain and back pain. There are even toothaches, leg aches and stomachaches. The pain caused by intense work is very different from that caused by illness. At least these kinds of pain from long-term hard work does not cause a loss of muscle function. It is just that feelings of fatigue can lead to negative emotions. On the contrary, the pain caused by illness, such as sports injury, can cause a partial or complete loss of muscle function, so that makes it very difficult to perform even a very simple action. For example: brushing hair, brushing teeth, washing face or other daily actions, etc. All kinds of pain appear around us, which reminds me of my research significance. I hope this research can be both innovative and practical.

① For doctors. As a doctor, I hope this research can reduce the work intensity of doctors. Thus, doctors are freed from a lot of tedious and repetitive work. They may devote more time for effective treatment and achieve twice the results with half the effort. I try my best to relieve my colleagues from heavy work.

② For patients. This device can satisfy the desire of patients with no medical background for medical knowledge. The muscle can be described in detail to everyone who uses it. And can be given accurate diagnostic result in each use, like a professional doctor.

③ For athletes. For athletes or people who love to exercise. The system can give detailed historical results. The results of each diagnosis can be queried and compared one by one.

The shoulder joint is the most complex joint in the human body. It can be realized in a three-dimensional environment exceed 180 ° rotation. This characteristic leads to its incomparable mobility, at the same time, to its extreme vulnerability. As we all know, joint activity is actually muscle tension and relaxation. The joints perform one action after another due to working together with many muscles. The relationship between muscle and bone is similar to that between steel and cement in reinforced concrete buildings. Bones are steel skeletons, muscles are cement. Most functional activities are actually done by muscles. Because that the health situation of the muscles determines the activity of the whole joint. The accurate and effective physical diagnosis can often

provide effective preventive measures in the early stage of a disease.

## 1.4 Composition:

Because this study used a large number of clinical physical diagnosis. So in chapter 3, I spend a lot of time talking about physical diagnosis. The subject research begins in chapter 4, which introduces how I complete the collection of real-time actions. In the fifth chapter, I have carried on the preliminary processing to the data. Get the relationship between the physical diagnosis and the acceleration. And explain. Starting from chapter 6, the process of using sliding window method to process data and using SVM to classify data. In chapters 8 and 9, I discuss the significance of this experiment and point out the shortcomings. And hope that in the future research can make up for the lack of this experiment.

# 2.Related Research:

[4] <Biomechanical Validation of Upper-body and Lower-body Joint Movements of Kinect Motion Capture Data for Rehabilitation Treatments> Published in 2012 Fourth International Conference on Intelligent Networking and Collaborative Systems. The authors are Fern'ndez-Baena ; Antonio Susín ; Xavier Ligadas.

Kinect is a markerless, very cheap technology recently introduced from the video gaming industry. Compared with other optical motion capture devices, Kinect does not require people to wear an special clothing nor markers on them. In this research, the accuracy of joint angle calculation between Kinect and optical motion capture system is compared. They obtained new procedures that guarantee enough precision for most clinical rehabilitation treatments. In this way, an easy and cheap validation of these treatment methods can be obtained automatically, thus ensuring the quality control process for patients' rehabilitation. From the powerful game industry, new devices such as Kinect have emerged, allowing real-time interaction with game consoles. Kinect can be thought as a 3D markerless motion capture system because it gives us a simplified skeleton in real time. No especial clothing or other equipment is required. The skeleton is composed of 15 joints. Because of its simplification, it cannot be used for very accurate research at present. Therefore, their goal is to use it without the need for such accuracy, such as clinical rehabilitation. In this case, the correctness of the motion can be verified without extreme accuracy. For such applications, in this paper, researchers consider the validation of Kinect data by joint angle during motion. The main limbs are involved. Researchers compare these data with professional motion capture devices and calculate the errors in the whole motion capture process. The achieved accuracy of angle joints is enough for most of the rehabilitation exercises in rehabilitation treatment.

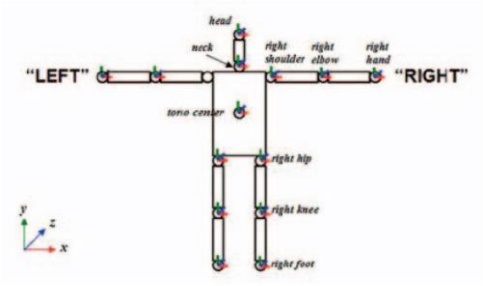



Figure 2OpenNI joint specification

[5] <Detection of Gait Events and Assessment of Fall Risk Using Accelerometers in Assisted Gait > Published in 2014 11th International Conference on Informatics in Control, Automation and Robotics (ICINCO). The authors are A. Tereso, M. Martins, C. P. Santos, M. Vieira da Silva, L. Gonçalves and L. Rocha.

Thirty years ago, it was suggested that accelerometers should be installed to monitor human motion. Recently, such system has become a viable alternative to the standard motion analysis system, using active or passive body mounting tags to watch through the camera. Therefore, an acceleration sensor system has been developed for gait analysis in order to have a practical system. The use of acceleration/angular rate in this system has important clinical and research applications. An important and necessary condition of acceleration system is that it can provide motion information about gait. Motion data (angle, velocity and acceleration) can prove important insights into gait abnormalities. Information that collected includes various measurements describing landing patterns. These measurements include stride and stride length, pace (step/minute), stride speed, single support time and percentage of double support time, etc. These measurements provide an objective assessment of gait. The core and important requirement of each gait analysis system is able to accurately and reliably detect foot end contact (EC) and initial contact (IC) events.

Our analysis shows that for normal subjects, the three event detection methods have the same accuracy in detecting IC and EC events, and all events are recognized. Compared with normal subjects, we found that the accuracy of EC and IC measurements using leg angular velocity in Asian D subjects was significantly lower than that using footline acceleration or sagittal angular velocity of the foot.

After many improvements and modifications, kinect2 can now accurately record the movement of volunteers' shoulders. This includes recording the movement track of shoulder, pausing recording, continue rerecording and saving data. These programs are added to the SDK provided by the window to record valid data or to delete invalid data. Because the purpose of my research is to provide an effective diagnostic method, therefore, the data in the record should be as accurate and effective as possible to prepare for the judgment result. In my research, volunteers have to fully communicate with researchers, so that volunteers without medical background can accurately complete the active experiment, thus improving the accuracy of this research. Therefore, with the help of my friend, I finished the software on the basis of Microsoft SDK, so that it can better complete the work of motion trajectory acquisition.

# 3. Association Knowledge:

## 3.1 Medical Knowledge:

There are many causes of shoulder pain. Endogenous arthritis and exogenous muscle injury are the most common. It is also the main basis of clinical diagnosis. In this research, I used motion capture device to define the symptoms of different causes. [5]"Collision injury of subacromion", [6]"Rotator cuff injury" and [7] "Frozen Shoulder" are distinguished by motion capture devices. The differences are: Inability to abduct and adduction caused by peri-shoulder muscle injury; Inability to shoulder internal rotation and shoulder external rotation by rotator cuff muscle injury; Frozen shoulder, an endogenous arthritis that causes shoulder can neither complete abduction movement nor rotation movement. In the data, I used "minor injury" to represent the single injury of peri-shoulder muscles or rotator cuff muscles, while "severe injury" to represent the simultaneous injury of the peri-shoulder muscles or rotator cuff muscles.

Shoulder movements include stretching, rotation and adduction. The combination of different muscles to complete different movements, in coordination with multiple muscle groups, achieve complex movements. The complexity of shoulder movement makes the shoulder more vulnerable to injury. Shoulder injuries are characterized by peri-shoulder joint pain and limited movement, which can seriously affect the normal life and work of patients. If not timely diagnosed and treated, it is likely to have a serious impact on the functional activities of the shoulder joint. X-ray examination is a common examination means, at the same time, experienced doctors often go through the method of active and passive tests check and judge the patient's shoulder movement. There are many kinds of shoulder injuries, including sports injuries, frozen shoulder and trauma.

Sports injury refers to all kinds of injuries that occur in the process of sports, and it is a kind of situation that affects human sports ability. Shoulder injury is more common in over - top athletes. Pain, weakness and limited movement are the main symptoms. No stiffness of shoulder joint was found in athletes. The over – top movement is also called overhead movement， that is hands over the head, such as badminton, tennis, freestyle, etc. In the process of raising the shoulder, the collision or friction between the acromion and the greater tubercle of humerus, coupled with the rotator cuff tendon lack of blood supply, may lead to rotator cuff injury, serious rotator cuff tear. In addition, as in cleaning home window glass, chandeliers, ceilings, etc. also belong to the over – top movement.

Acute injury occurred less than subacute and chronic injury. Shoulder bearing heavy sports load is the main cause of injury.

1. "Collision injury of subacromion ", proposed by Neer in 1983, is a general term for a series of symptoms characterized by shoulder pain and dysfunction. At present, the mechanism of its occurrence is not completely clear. Summarizing the existing research results, we believe that: one is endogenous anatomical factors. That is chronic tendinitis and fibrous degeneration of

bursa. The repeated subacromial impact causes fibrous degeneration of bursa, thickening of the wall of the bursa, and chronic tendinitis of tendons, usually accompanied by fibrosis and edema. It is summarized as aseptic inflammation; the other is exogenous dynamic factors. The main pathological changes were partial or complete rupture of the supraspinatus tendon and biceps brachii muscle by repeated injury and degeneration. About 1/2 of the patients had a history of trauma, and a few of them had a significant or severe history of trauma.

Figure 3Collision injury of subacromion
https://uprighthealth.com/pain-trying-lift-arm-side/

This shows that most of them are chronic injuries. Most studies believe that athletes suffering from subacromial shock syndrome are mostly caused by exogenous long-term heavy exercise load. The pathogenesis restricts shoulder movement.

2. Rotator cuff injury was first proposed by Smith, and it is more common in over – top movement. Over – top movement is the general name of a kind of sports events in which the hand moves over the plane height of the head in the process of movement. This kind of movement is easy to be the rotator cuff muscle group in a continuous overload state, causing muscle injury, is the main cause of rotator cuff injury.

Figure 4Rotator cuff injury
https://www.drcarofino.com/services/frozen-shoulder

Rotator cuff injury is a common degenerative disease of shoulder joint. Rotator cuff injury is also common among people over the age of 60 and increases with age, the study found. Lifting heavy objects, or falling down are common causes of rotator cuff injury in older people. The main clinical manifestations are: (1) shoulder and neck pain, (2) shoulder joint weakness and (3) limited range of motion. The most typical pain is at shoulder and neck at night and over - top movement pain. The duration was accompanied by radiation pain in the neck and upper limbs.

3. Frozen Shoulder is also called scapulohumeral periarthritis, commonly known as 五十肩 in Japanese, a long-term shoulder disease. The chronic and specific inflammation of the shoulder capsule and its surrounding ligaments, tendons and bursa is mainly manifested by shoulder pain, night pain, activity limitation and aggravated shoulder joint activity, gradually relieved after a certain degree, and finally completely recovered. There are three clinical stages: acute stage, adhesions stage and convalescence stage. The main manifestation of acute stage is pain, mostly chronic and persistent pain. Some patients experience a sense of restraint. They cannot move their shoulder very freely or feel heavy on their shoulder joint. Some patients describe this feeling as carrying a very heavy bag on their back. Pain often occurs in the anterolateral shoulder, involving the scapula, upper arm and forearm. This pain is aggravated when putting on a jacket or brassiere. Symptoms during shampooing, washing face and other movements feel laborious. Pressing shoulder pain is obvious.


Figure 5Frozen Shoulder
https://www.youtube.com/watch?v=8Zm2LMjWwBQ

In the adhesion period, patients with Frozen Shoulder rate the pain as being a second less intense while they are moving their aims. But the moving ability of the shoulder joint is significantly reduced. Joint contracture and muscle atrophy are observed, which showed obvious frozen state. The moving ability of shoulder joint in all directions is reduced by 20%-25% compared with the normal state. In severe cases, dressing, combing, raising hands and other simple movements cannot be completed independently. Muscle atrophy and loss of function occurred in the shoulder muscles, but tenderness was relieved or disappeared. However, pressing pain relieved or disappeared. In convalescence stage, shoulder pain basically disappeared and joint activity gradually recovered, but it could not be restored to the healthy state.

Frozen Shoulder is a common disease characterized by shoulder pain and mobility inconvenience. The predisposing age of this disease is about 50 years old. The incidence of this disease in women is slightly higher than that in men, and it is more common in manual workers. Without effective treatment, it may seriously affect the functional activities of shoulder joint. Also, it can appear the atrophy of deltoid muscle of different level. Even when the patient recovers, the muscles are noticeably atrophied, and the ability to move is reduced relative to the healthy state, but there is no pain. Frozen Shoulder is also a common clinical disease at present.
Shoulder trauma is a partial loss of function after shoulder surgery. In my research, limited mobility

and pain of shoulder joint caused by shoulder trauma and other diseases were not involved.

The diagnosis of sports injury and frozen shoulder was discussed to improve the accuracy of this research. That is to say, the diagnosis of shoulder diseases with limited shoulder movement and pain symptoms is discussed on the premise of normal shoulder mobility. In addition, there are shoulder pain and mobility limitations caused by cervical spondylosis. Shoulder injuries caused by cancer and surgical trauma are not considered in this research.

## 3.2 Materials: Kinect 2 and System Setting

### 3.2.1Kinect 2:

Kinect - based crowdsourcing technology quickly spread from the original gaming industry to medicine, architecture, and the web. In the medical field, Kinect motion-sensing technology is currently mainly used in medical rehabilitation, medical imaging and psychology. Especially in the field of medical rehabilitation, Kinect motion-sensing technology has developed very rapidly.

Figure 6Kinect2
https://www.ebay.co.uk/itm/OFFICIAL-Microsoft-XBOX-ONE-KINECT-2-2-0-V2-MOTION-SENSOR-FREE-UK-POST-/181539809075

In the field of medical rehabilitation, Kinect motion-sensing technology is currently mainly used for active sports training and rehabilitation treatment of patients, and it is applicable to community and family rehabilitation. The patients can use Kinect at home to complete rehabilitation exercises.

Optical motion capture is used to monitor and track specific points of light on the target. Theoretically, as long as a point in space can be seen by two cameras at the same time, its position in space can be determined according to the images and camera parameters are taken by two cameras at the same time. When the camera is shooting continuously at a high enough rate, the motion trajectory of the point can be obtained from the image sequence. The advantage of optical motion capture is that the performer has a wide range of activities, no cable, mechanical device restrictions, the performer can freely perform, very convenient to use. Its high sampling rate can meet the needs of most high-speed motion measurement. The disadvantage of this method is that the system is

expensive. Although it can capture the real-time movement, the post-processing (including the identification, tracking of the marker and the calculation of spatial coordinates) requires a large amount of work. It has certain requirements for the lighting and reflection conditions of the performance venue, and the calibration of the device is also complicated. Especially, when the motion is complex, the marker of different parts may be confused and occluded to produce wrong results, and manual intervention is required in the post-processing process. From the perspective of technology, the essence of motion capture is to measure, track and record the trajectory of an object in three-dimensional space.

In recent years, some video game researchers have shown increasing interest in using video games for physical and psychological therapy. Many physiotherapies involve repetitive physical movements that are analyzed to determine the range of motion of a particular muscle group. This process is done without any external intervention. In medicine, this kind of physical examination performed by patients is called active test. For some diseases, the duration of the disease is long, and active test will make the patient lose patience and motivation, and the treatment will become slow and frustrating. I want to design a diagnostic tool similar to the video game. A low-cost, easy-to-use motion-capture system captures the patient's movement. The movement status of patients can be judged by analyzing their movements. The tool can also be used in patients' homes. However, the system is limited by its motion-capture capabilities. To improve the capture accuracy, other methods are used to track the user's movement using sensors. Kinect2 greatly improves the performance of low-cost motion capture systems, enabling a new approach that is low-cost, easy to use, and portable.

Traditionally, most physical therapy and rehabilitation assessments for stroke patients are based on the observation and judgment of therapists. The assessment method relies heavily on the therapist's visual assessment that patients are performing standard diagnosis or classically clinical examinations. This process requires a trained physiotherapist (PT) or occupational therapist to treat patients one-to-one. However, assessments are often inaccurate for several reasons, one of which is the accuracy of these clinical examinations and the subjectivity of the therapists in conducting clinical assessments. Sensors and computing technology can be used in medicine in the past few years, and motion capture technology has made remarkable progress. Motion capture system can record high accuracy and high-reliability data of human body's motion data. Two major kinds of sensor are usually used for human motion capture in rehabilitation medicine, and they are optoelectronics and non-optoelectronics sensors. The optical system tracks the marker points to obtain the body's trajectory. At the same time, also can obtains joints' position and direction. In markerless systems, image features such as colour, edge, shape and depth are used to interpret motion. Compare with the other optical motion capture devices, Kinect doesn't need people to wear especial clothing, that have a marker on them. Non-optoelectronics sensors include inertial, mechanical and magnetic systems. Non-vision systems usually use one or a group of sensors to measure and track human motion. For example, the Wii telecontroller or remote control is a system that uses inertial and optical sensors to measure human motion.

Figure 7Using Kinect 2

Depth imaging device may use the skeletal tracking to determine joints' position and direction such as Microsoft Kinect. Depth-based systems can also use depth segmentation and computer vision algorithms to detect and track human body from depth image sequences. This paper mainly shows the application of motion capture system based on striking contrast in rehabilitation, especially in depth imaging technology. Because computing the load required to extract human skeleton from RGB (red, green, and blue) images, the real-time interactive system based on contrast is not reliable. Sometimes errors appear in human body's motion. Especially when the feature points are blocked, however, devices have depth imaging such as Kinect are more reliable to developers because they provide so many software development kit (SDK), which provides access to skeletal tracking data and can be directly used in rehabilitation game development. Since the advent of Microsoft Kinect, many rehabilitation engineers have used Kinect in their systems. These studies aimed at upper and/or lower limb rehabilitation, balance monitoring/training, and range of motion exercises among physical and cognitive examination, showed that patients and therapists had received Kinect-based rehabilitation systems.

With the precision of Kinect2, we can use this device. Relative to kinect1, kinect2 has a resolution of 1920×1080 and a depth resolution of 512×424. The number of human feature points identified has also increased from 20 to 25. It uses a depth-sensing camera to capture the user's full body movement in 3D space. The system does not require the user to hold an interface device or move it on a mat as the source of interaction in the game. Therefore, it is more convenient than other devices and easy to use. Compared with the motion-capture system in Fujinami laboratory, it can collect patients' movements without wearing specific clothes. Instead, the machine automatically tracks the movements of multiple users' bodies in three-dimensional space. Kinect2 uses USB3.0 to connect to a PC. Because kinect2 itself is a low-cost motion-capture system, its accuracy is not high. The accuracy of the time will be a problem, so I added part of the program. That is, in the event of a sudden sharp jump in the trajectory of the collected feature points, the data will be discarded, preventing the accuracy of the results from being affected. The data with runout points and outliers equal to conventional skeleton points are removed to improve the reliability and stability of skeleton data, enhance the matching rate and reduce errors.

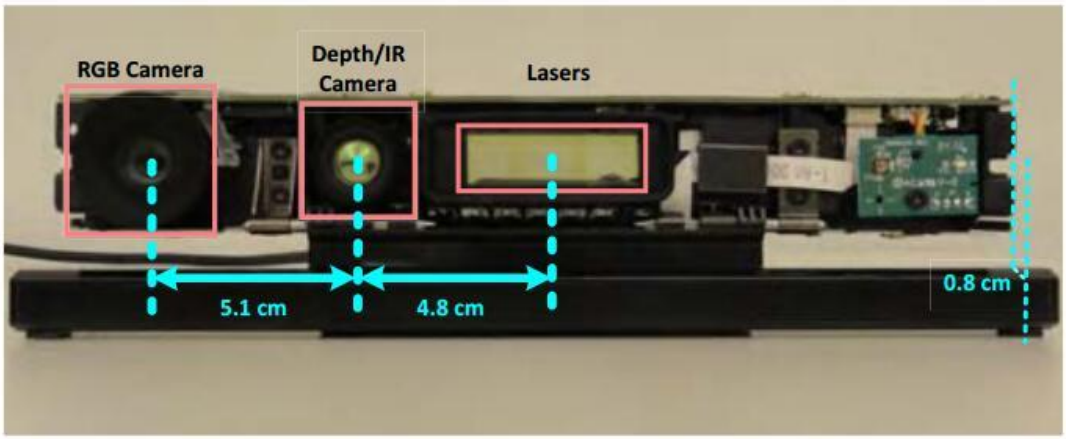



Figure 8Structure diagram of Kinect 2

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

## 3.2.2Kinect 2：System Setting

Using the Unity3D engine, I developed a game-based inspection system of shoulder muscle movement, aiming to trigger specific diagnostic actions when controlling the virtual avatar to achieve in-game goals. In the early prototype phase of the game, subjects faced the kinect2 with certain motions, as shown in figure（1）, including flexion, extension, horizontal abduction and adduction, vertical abduction and adduction, inward rotation and outward rotation. After the initial calibration of the virtual body, the collected results are compared and analyzed with the data in the database to ensure the goal of the game is achieved. That is to say, the shoulder muscles are judged by the subjects' active test movements. The functionality of the game-based app also allows the subject or clinician to select tasks (for example, make appropriate analyses when making a diagnosis and output the results of the active test).

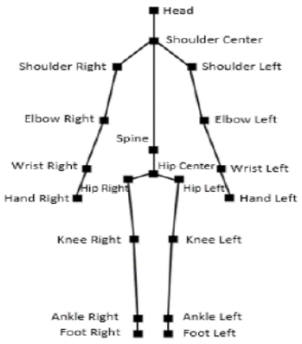



Figure 9Kinect human virtualization nodes

Prototype development：

Current game-based rehabilitation tools are conceived and developed through a series of stakeholder

interviews with clinicians, researchers, and major patient groups to explore the need for balanced exercises and major development functions based on computer games. This program is developed by the author by considering the actual needs of doctor, which can not only reduce the workload of doctors but also clearly explain the condition. The study was supported by the stakeholder groups and provided specific needs/requirements, including changes of the moving ability levels and tasks of different patients, the ability to record interactive data, and incentives and games that encourage the appropriate practice. In November, after the initial development of the prototype in figure 10, preliminary tests were conducted in an informal setting on five people with or without sports injuries. These participants provided informal feedback about the game prototype. Participants are encouraged to provide feedback on technical elements of the game, such as precision, object, and action collection. Again, informal discussions
Comments and feedback were compiled and reviewed. Feedback was incorporated into the design and relevant and appropriate changes were made to the game prototype.

Prototype evaluation：

To assess the initial availability of the system, several volunteers with motor injuries and shoulder pain were recruited at JAIST. Volunteers were asked to perform certain movements. The movements are flexion, extension, horizontal abduction and adduction, vertical abduction and adduction, inward rotation and outward rotation. Participants in the exercise used Microsoft Kinect's depth-sensing camera to control virtual characters to perform a task based on a design. The participants were given a preliminary clinical diagnosis and then watched as they completed the prescribed actions. These movements are the clinical active examination. The analysis was carried out after the volunteers completed the voluntary inspection. After the interaction, participants were asked to complete a second clinical examination to identify the injured muscle and to record it. Game performance and researcher observations were analyzed.

Figure 10Printman


Figure 11Time Control System

After many improvements and modifications in figure(10), kinect2 can now accurately record the movement of volunteers' shoulders. This includes time-control system (figure 11) to record the

movement track of shoulder, pausing recording, continue rerecording and saving data. These programs are added to the SDK provided by Microsoft company to record valid data or to delete invalid data. Because the purpose of my research is to provide an effective diagnostic method, the data in the record should be as accurate and effective as possible to prepare for the judgment result. In my research, volunteers have to fully communicate with researchers, so that volunteers without medical background can accurately complete the active experiment, thus improving the accuracy of this research. Therefore, with the help of my friend, I further completed the SDK of Microsoft, so that it can better complete the work of motion trajectory acquisition.

# 4 .Research Plan：

## 4.1 Physical Diagnosis:

Before the formal test, I made a physical diagnosis of each subject to determine their shoulder condition. In order to make the research data more accurate, I used passive test and touch test to ensure that the shoulder condition of the subjects would not be missed.

Passive test is also called passive movement. That is the patient be asked to fully relax and allow doctor to move their arm instead of himself. That is a common clinical skill for every doctor. The patient is warned if he experience any pain they should let doctor know immediately. Doctor repeat the passive test movements to feel for any crepitus during movement of the joint.

After passive test, I recorded the detail condition of the subjects' shoulders. Used a file to record the data, size as Form 1.

| NAME: | | |
|---|---|---|
| ROTATION: | Left | Right |
| UPWARD: | Left | Right |

Physical Diagnosis Result Form (1)

## 4.2 Setting Diagnostic Action:

In human motion, bones support and stabilize body. They can be compared to steel skeleton of a reinforced concrete building. Complex movements performed by contracting and stretching muscles. I want to make this relationship clearer here; there are agonistic muscle and antagonistic muscle. Human muscles tend to appear in pairs, their activity inversely proportional to the completion of movements. That is, when one muscle stretches, other muscle contracts, as muscles do in pairs. For example, when bending the arm, the biceps brachii contracting and triceps brachii relaxing; when stretching arm, triceps brachii contracting and biceps brachii relaxing. In this way, the two muscles work together to achieve complex movements. In general, I divide all muscles of the shoulder into peri-shoulder muscles and rotator cuff muscles. The basic movements of the shoulders perform together, including flexion, extension, horizontal abduction and adduction, vertical abduction and adduction, internal rotation and external rotation.

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, show in form 2. Its main functions are flexion, extension, abduction and adduction. The deltoid muscle is also involved in the external and internal rotation movements. The rotator cuff muscle is relatively unitary in function. The rotator cuff muscle function is highly directional and easy to judge. When different muscles are injured, their movement changes are obvious. Peri-shoulder muscle besides motion function, still have fixed function. For example, the deltoid muscle, its fixed function is obvious, if the deltoid muscle injury, will appear "square shoulder" symptoms. The latissimus dorsi plays a major role in the abduction of the shoulder joint. Pectoralis major plays a major role in horizontal adduction of shoulder joint. The trapezius occurs in the vertical abduction of the shoulder. Due to the complexity of the physiological structure of the shoulder, the function of the shoulder muscles cannot be completely explained separately. If patients with frozen shoulder do not receive timely treatment, their deltoid atrophy will be very obvious.

| Peri-shoulder muscle |
| --- |
| biceps |
| deltoid |
| trapezius |
| pectoralis major |
| latissimus dorsi |

Peri-shoulder muscle Form (2)

In addition, sports injuries mostly occurred in biceps, trapezius, latissimus dorsi and pectoralis major.

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, in form 3. Functionally as a whole, rotate the upper limb and stabilize the capitulum humeri and pelvis together. When the arm moves to different positions, each muscle plays a specific role in manipulating the motion direction of the humeral head. Without rotator cuff dynamics to stabilize the joint, the humeral head will collide with the surrounding bone structure, causing joint capsule, tendon, blood vessel and nerve damage. Supraspinatus muscle plays a role in stabilizing the upper shoulder joint, which can make the shoulder joint abduct and depress caput humeri； Infraspinatus and teres minor serve to stabilize the shoulder and rotate it outward; Subscapular muscle has the function of internal rotation of shoulder joint. Supraspinatus muscle, infraspinatus muscle and subscapularis muscle are injured in the rotator cuff, and any structural damage will cause pain, weakness and limited mobility to varying degrees, which will seriously affect the daily life of patients.

| Rotator cuff muscle |
| --- |
| supraspinatus |
| infraspinatus |
| subscapularis |
| teres |

Rotator cuff muscle F Form（3）

# 4.3 Data Collection:

I asked the subjects to stand 2 meters in front of Kinect2, which is the best distance for Kinect2 to work. At the same time, subjects were asked to complete the active test movements. The movements of active test are described in detail below.
[6]Diagnostic actions of people in research are:

(1) The right hand under the conditions of straight, from the body really face up to 180 ° in figure (12). After reaching the apex, the hand is rotated and released from the side of the body back to the initial position. (1-1) Left hand in straight, from the body really face up to 180 °. After reaching the apex, the hand is rotated and released from the side of the body back to the initial position.

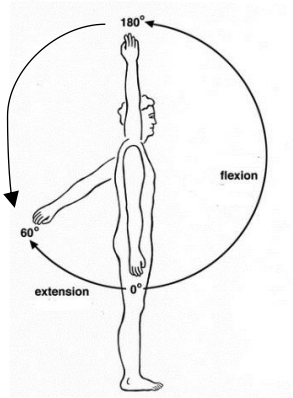



Figure 12Flexion action
http://coretrain.blogspot.com/2017/02/cpbl.html

(2) With the right hand extended, perform vertical abduction to the head position. After reaching the peak, do the vertical adduction to the initial position, requiring the palm downward, as close as possible to the ear, in figure (13). (2-1) With the left hand extended, do vertical abduction to the head position. After reaching the peak, do the vertical adduction to the initial position, requiring the palm downward, as close as possible to the ear.

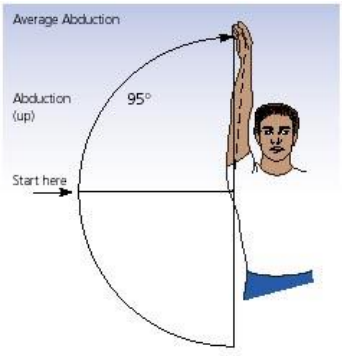



Figure 13Vertical adduction and abduction action
http://coretrain.blogspot.com/2017/02/cpbl.html

(3) With the right hand extended, do horizontal adduction and abduction. After the adduction, complete the abduction. At least 45 degrees of adduction and 90 degrees of abduction are observed. Palm is perpendicular to the ground, in figure(14). (3-1) The left hand in a straight state, horizontal adduction and abduction movement. After the adduction, complete the abduction. At least 45 degrees of adduction and 90 degrees of abduction are observed. The palm is perpendicular to the ground.

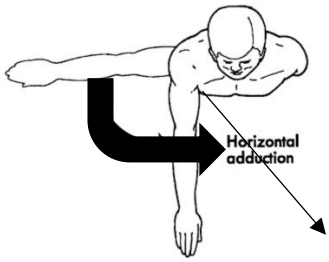



Figure 14Horizontal adduction and abduction action
http://coretrain.blogspot.com/2017/02/cpbl.html

(4) [7]The subjects were asked to 30 ° rotating to the left, to check the right movement. Elbow 90 degrees, shoulder 90 degrees, finger forward, hand down, as shown. Begin with an upward shoulder roll and return to the starting position. Do the downward shoulder rotation again and return to the starting position, in figure (15).

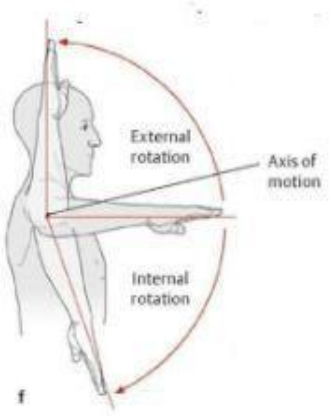



Figure 15 Rotation action, right hand
http://coretrain.blogspot.com/2017/02/cpbl.html

(5) The subjects were asked to 30 ° rotating to the right, check again on the left side of the movement. Elbow 90 degrees, shoulder 90 degrees, finger forward, hand down, as shown. Begin with an upward shoulder roll and return to the starting position. Do the downward shoulder rotation again and return to the starting position, in figure (16).

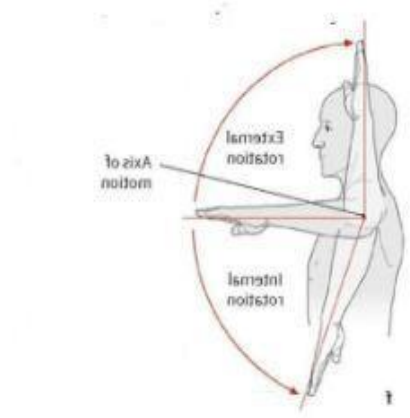


Figure 16Rotation action, left hand

[10]Throughout the research, due to the accuracy of Kinect 2, subjects were required to perform these actions as slowly as possible, for at least 3 seconds. At the same time, participants were asked to try to keep a constant speed to find the acceleration in motion. I collected real-time motion data from these subjects with kinect2, after the software was completed. I collected 5 active tests from left and right sides, a total of 10 data each people. The data can be used to show the moving condition of two different muscle groups. Respectively is shown the condition of peri-shoulder muscle group and rotator cuff muscle group.

## 4.4 The Subjects

After the system was developed, the physiotherapists divided the subjects into A and B. Group A was the healthy group, and all the active tests could be completed. Group B is the test group, in which subjects are divided into two parts: the first part is unable to complete the stretching exercise; The second part is that the rotation cannot be completed. The data of shoulder movement trajectory of subjects in group A and group B were collected for further study. Several subjects were invited to participate in the study. For instance, the subjects were JAIST students and staff, including dancers who had practised for years, fitness enthusiasts who had been active, basketball enthusiasts. In the test group, some people had just been injured and people who had been suffering from injuries for a long time. The subjects ranged in age from 20 to 60. Among them, I found two Chinese mothers who held their children for a long time. It was essential to me that they had significant limitations in both their shoulder movements. Because relative to the patients with frozen shoulder, often only one side, that is, limited action of the affected side. However, the limitation of both sides of these two maternal subjects can better improve my classifier. In addition to they have been ordered to undergo physical therapy as soon as possible.

Patients with frozen shoulder, their one hand range of motion and muscle endurance are significantly higher than the other hand. Their healthy side also had far more muscle function than the other side. Therefore, I hope they could try to complete the active test. Although it is very painful, I know, but as far as possible to achieve the patients' motion situation. This method can let me more clearly judge their injury situation. Compared with machine diagnosis, manual diagnosis can better understand the patient's condition, but only for patients with frozen shoulder. Because their constant pain can seriously affect the range of motion in their shoulders, it reduces the accuracy of machine diagnosis. In this process, I was communicating with subjects in order to achieve their cooperation.

[11]Both two groups of subjects had no experience using Kinect2. Beside, the names of subjects in the research have been changed to protect their privacy.

# 5. Preliminary Experiment: Acceleration

## 5.1 Purpose：

In order to make this research more accurate. I used acceleration to analyze shoulder movement conditions. The reason is that in related researches, [13]the researchers have shown a clear correlation between acceleration and muscle injury. I use acceleration as a measure of shoulder movement. The purpose is to distinguish three common clinical conditions. The three conditions are healthy people, unhealthy people who could complete the active test, and patients with shoulder motor ability.

## 5.2 Research Process：

In the collected data, I made a preliminary grouping. Subjects were divided into three different categories: A, B and C. Group A is a group of healthy people, and they have no problem in completing the active tests. They have no muscle injury. Group B subjects had sports injury or felt significant pain while moving their shoulders. And the subjects in group C were patients with shoulder muscle injury. Most of the subjects were long-term patients. In my study, I did clinical examinations of all subjects to ensure the accuracy of the research.

Based on the results of relevant studies, I know that patients will have significant acceleration changes compared with healthy people. Previously, I guessed that the patient's acceleration would fluctuate apparently due to pain. That is to say, the shoulder acceleration of patients should be higher than that of healthy people. But what I observed was the opposite. It was the peak of shoulder acceleration of patients that is lower than that of healthy people.

I chose the two most representative actions, which are raising hands to the limit and rotating shoulder to the limit — the results shown that the peak acceleration changes most obviously in the raising up action. Since most of my subjects had a right side muscle injury, I used my right hand up to the limit to illustrate my observation.

When they completed the right-hand raise, I collected their movement data and analysed them through the program. We can clearly find that the peak acceleration of this group is very high. The range is between -0.06 to 0.06 and -0.03 to 0.03. Shows as Figure(17.18.19.20).

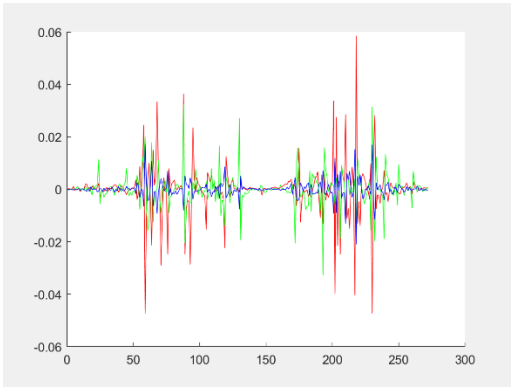



Figure 17Acceleration data for healthy people 1

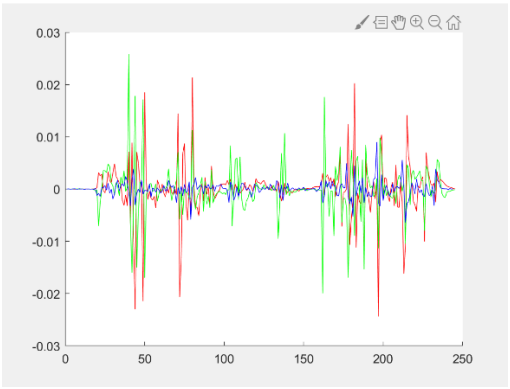



Figure 18Acceleration data for healthy people 2

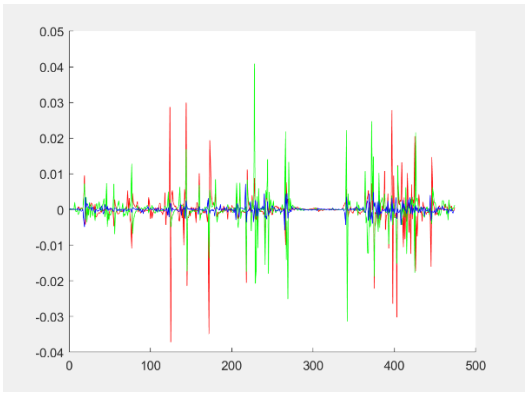



Figure 19Acceleration data for healthy people 3

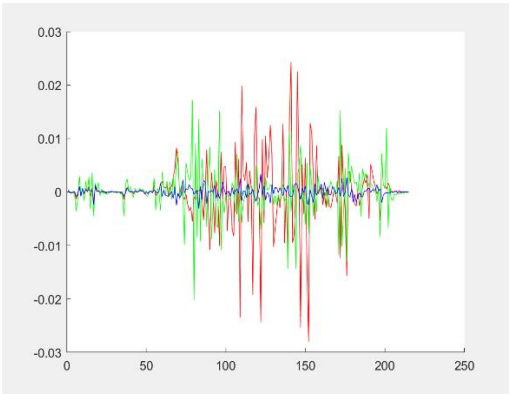



Figure 20Acceleration data for healthy people 4

I took four random samples to illustrate this point. You can clearly observe the drastic changes of peak accelerations.

In group B, we can observe the difference in peak acceleration. We already know that group B was muscle injured just now or just felt muscle pain. Most people are members of basketball clubs. Regular exercise allows them to endure muscle pain and complete their exercise. I also checked their muscles to make sure they were functioning properly. The subjects in this group are sports injury and feel shoulder muscle pain caused by long-term hard work. Although there is no collective experimental time required, most people can still complete the active test action within 2 to 10 seconds. Some people show significant pain when they complete the action. But I also try to ask them to complete the active test action as possible as they can.

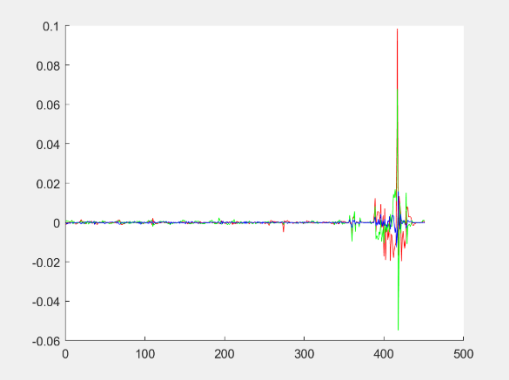



Figure 21Acceleration data for unhealthy people 1

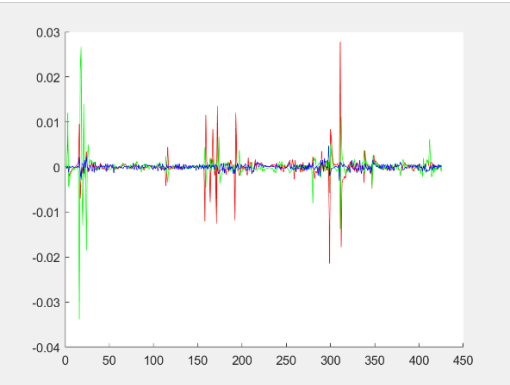



Figure 22Acceleration data for unhealthy people 2

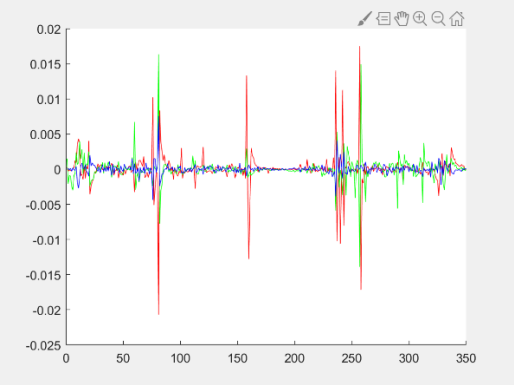



Figure 23 Acceleration data for unhealthy people 3

I randomly sampled three samples. Because there were not many samples of shoulder muscle injuries, I reduced the number of samples proportionally. The subject whose data is shown in the first figure has a sport injury. The acceleration changes very averagely throughout the raising hand action. Only when the hand reaches the limit, the peak acceleration changes dramatically. Careful observation shows that most of the peak acceleration is between -0.02 and 0.02.The result shows in figure(21.22.23).

The second picture is from a pregnant Chinese woman. She just had a baby. Chinese people are accustomed to holding their babies, so the pain in her shoulder muscles is very obvious. In the figure, we can find that most of the time, her peak acceleration is also very low.

Picture 3 is from a traffic accident. Years ago, he had a minor accident. The right side of his body was injured in the accident, and although all the muscles are now fully functional, the pain is still with him. During research, the peak acceleration of the shoulder is also affected by the pain.

In group C, I get a much different change in peak acceleration. The subjects in group C were patients with shoulder muscle injury. They need professional treatment because some of muscles have lost their function. The symptoms of pain and limited mobility were evident. Using the motion capture device, it can be clearly identified. I randomly select two patients to prove it. One is a patient with frozen shoulder, and the other is a muscle injury caused by overtraining. Compare with the other two groups; we could easily find that the acceleration of patients with shoulder muscle injury is

abnormal. The range of acceleration is no longer between -0.1 and 0.1. It's in a new scale. The new scale is between -0.015 to 0.015. I remember that they could not finish the active test because of the intense pain. The result shows in figure(24.25).

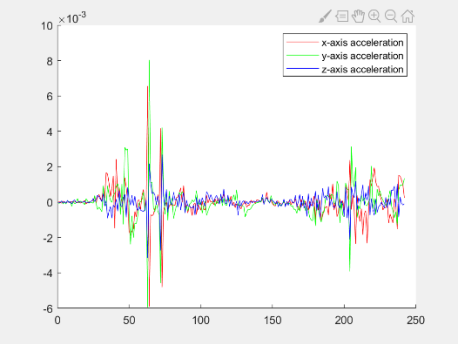



Figure 24 Acceleration data for patients 1

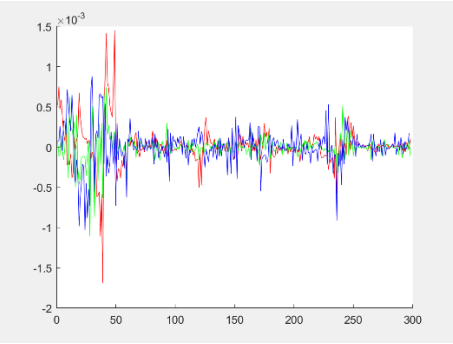


Figure 25 Acceleration data for patients 2

I asked one of my subjects to practice for a week. I hope to get different data. However, there was no significant change. The severe pain still makes him unable to complete the active test. Moreover, and in the new data, we can find that only the movement time is shorter than the last test that he finished one week ago.

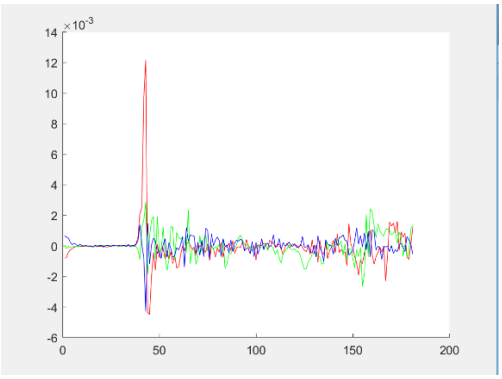


Figure 26 Acceleration data for patients 3

One obvious difference you can find in this picture that is the peak acceleration suddenly increases at one moment, compared with the image a week ago. But this dramatic change disappeared very soon, probably because of painful, I think. Shows in figure(26).

## 5.3 Research Result and Significance:

I have used Matlab to calculate the data I collected. The program is pasted at the end of the article. I used this program to calculate the action acceleration of everyone that as subjects in my research and observed a phenomenon. That is, in patients with shoulder muscle injury, the maximum acceleration of shoulder movement is less than that of ordinary people. And I used pictures to

explain what I find. At the same time, I observed the change of acceleration in healthy people is more pronounced than that in patients. The range of acceleration from patients are small than that in healthy people. You can find between the healthy people and patients, the range is different. The peak of acceleration from healthy is 0.06， beside， the peak of acceleration from patients is just 0.014. At the same time, the change of acceleration from patients are more average than it from healthy people. The same phenomenon is also appeared in unhealthy people. Just not so obvious.

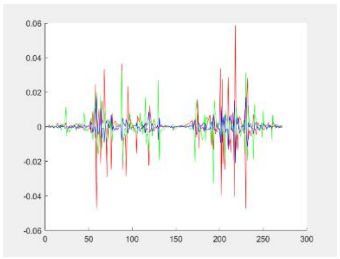


Figure 27 The healthy result of acceleration data

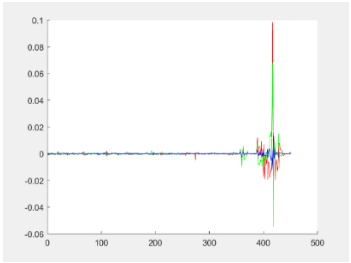


Figure 28 The unhealthy result of acceleration data

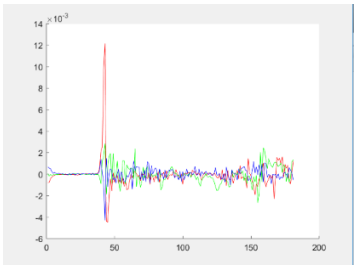


Figure 29 The patient's result of acceleration data

Through the analysis of acceleration, I found a problem. That is I can use acceleration to figure out the three cases that in my original mind map. The three cases are the shoulder moving condition in healthy people, the moving condition in mildly injured and the moving condition in severely injured. [14]But the acceleration is computed by the trajectory of the motion, so whether I can use the acceleration directly to analyse the three cases. After getting the professor's advice, I completed a new mind map. That is to put the trajectory directly into the classifier, and then analyse the three cases. To achieve this goal, I also improved the SVM classifier. The new assumption is made by modifying the previous two monomial equations into a polynomial. The mind map is shown below.

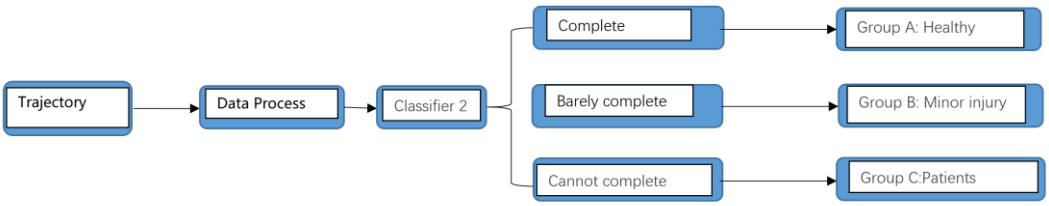



Figure 30 Mind Mapping

# 6. Data Processing:

## 6.1 Sliding window:

[16]The sliding window is a common partition method for time series analysis method, and the data collected changes relatively little. Currently, Convolutional Layer is not required. I collected many pieces of data, which were the shoulder movements. Then divide each shoulder movement data into 500 intervals, which is equivalent to 500 small movements. Using the sliding window method, the average value of 500 specific movement data in each partition was calculated. For example, I did 500 partitions for a total of 10000 data. Then using the sliding window, I calculated the average of 500 specific data in each partition. The accuracy and robustness of trajectory detection data are guaranteed by sliding window.

For the detection of abnormal behaviours of people with shoulder muscle injury, the characteristics and rules of active test behaviours of patients and normal people were analyzed, and the motion trajectory of the active test was sampled and quantified, and the training and detection were conducted through the feedback sliding window. The research results show that the motion trajectory can be used as an important description of shoulder muscle injury and shoulder disease with the development of artificial intelligence, computer vision, the technology of target tracking and behaviour analysis. Whether human beings can be replaced by machines has aroused people's extensive concern and become a new research hotspot. For example, when the elderly living alone with service robots are in abnormal behaviour due to falls or sudden diseases, they often lose the ability to call for help by themselves or control the robot to call for help. Therefore, the robot must have the ability to detect the abnormal behaviour of the elderly in a timely, active and effective manner.

In many specific cases, the target behaviour can be extracted by analysing the target trajectory. In the intelligent traffic monitoring, motor vehicles generally drive along fixed roads and specified directions. By learning the distribution pattern of these standard tracks, violations such as going against the traffic and crossing the street can be detected automatically. The target motion in the home environment is more complicated than the vehicle trajectory. However, for accurate medical diagnosis, the time and location of indoor active testing activities are relatively regular. Therefore, the distribution pattern of its trajectory can be regarded as an essential representation of the characteristics of active test behaviour. To analyse the action trajectory of normal people and patients, to obtain the method to distinguish abnormal trajectory. It is feasible to judge the abnormal trajectory as the main basis of the negative factors of behaviour. In recent years, location-based behaviour analysis has attracted extensive attention from scholars at home and abroad, and a variety of algorithms have been proposed. In essence, target behaviour analysis based on motion trajectory is a classification problem of multi-dimensional sequence data. Its key is how to find the same kind or search for exceptions from the trajectory, ensure that the classification algorithm can deal with and adapt to slight changes of motion trajectory in space and time scale.

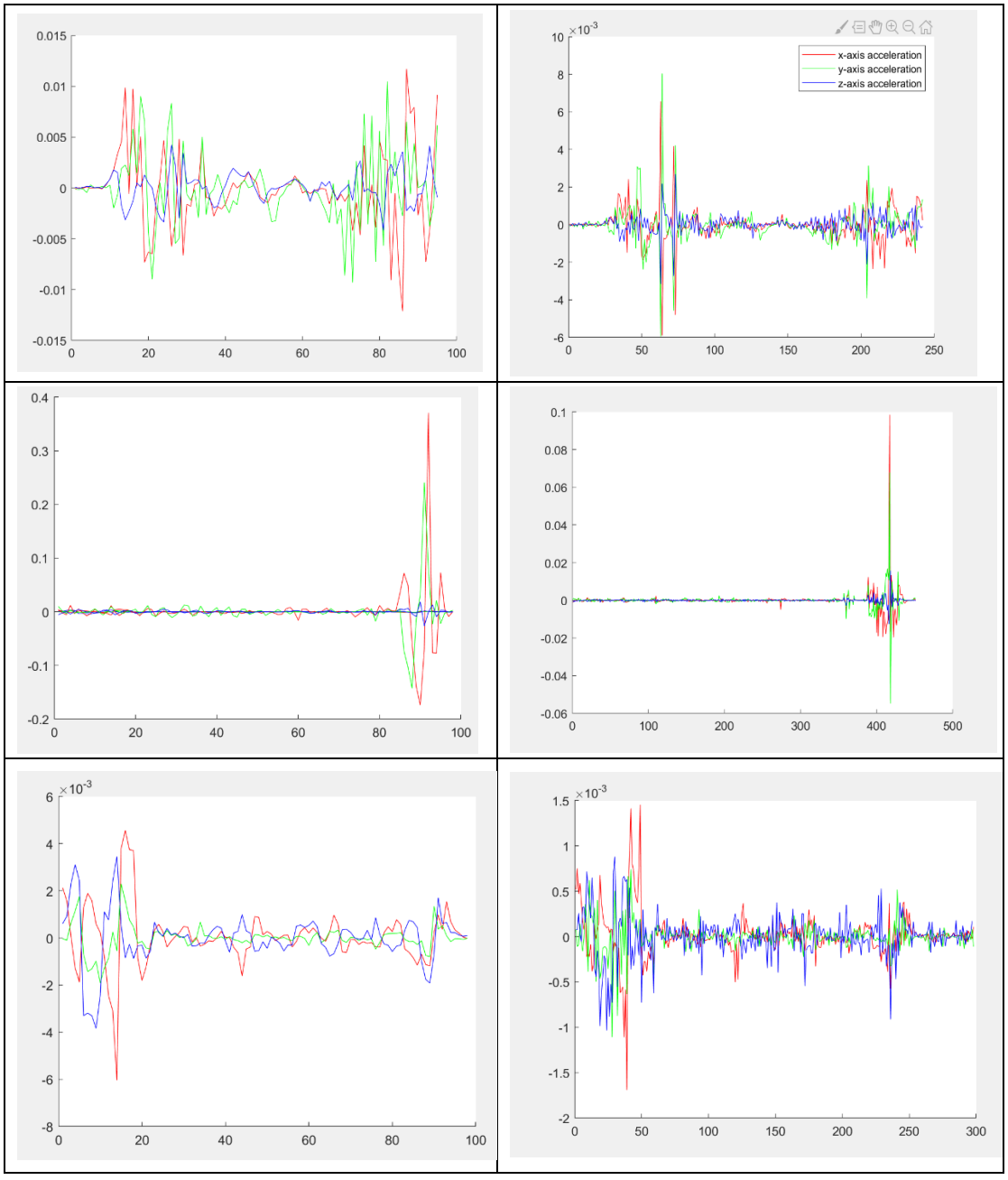
People's movement trajectory in the family environment is messy and significantly affected by time, location and other factors. Many methods have many shortcomings in solving this problem. In this paper, a Hidden Markov Model-based method for trajectory distribution pattern extraction and anomaly detection is proposed. The accuracy and robustness of trajectory detection are guaranteed by the feedback sliding window, which proves the validity and feasibility of the diagnosis method. Hidden Markov Model. First, let's see what kind of problem can be solved using the Hidden Markov Model. When the HMM model is used, our problem generally has these two characteristics: 1) the problem is sequence-based, such as time series or state sequence. 2) there are two types of data in the problem. One type of sequence data can be observed, namely, observation sequence; The other kind of data cannot be observed, that is, hidden state sequences, or state sequences for short. HMM trajectory model considering the actual monitoring system, the target motion is affected by many factors, even if it is to belong to the same type of behaviour mode 2 paths, its difference is huge, so there are many limitations with traditional sequence comparison method, and the HMM can not only effectively solve the identification process of time and space is not neat, you can also to direct quantitative recognition results, good response pattern similarity between sequences. The collected motion data are processed. The length of the data collected varies according to the subjects' activity ability and the experimenters' operation in the test. However, such data cannot be directly applied by SVM.

## 6.2 Data processed for SVM

This is where I had my problem before, and it bothered me for a long time. [15]The time dimension of collected data is different, which leads to the low accuracy of the classifier. Later, with the help of friends, I improved the data calculation. In this way, the accuracy is greatly improved, and the ultimate goal of the research is finally achieved. The motion track data of people collected through Kinect2, together with the time of movement, are too high to be used by SVM. The data of human motion trajectory collected by Kinect2, together with the time of movement，so that data dimensions are too high to be used by SVM. Therefore, such a large size must be reduced through program operation. The way to handle this is to use the sliding window method. The collected data is divided into 500 parts on average, and the average value of each partition is obtained so that the original data becomes a fixed data set with 500 dimensions. This data set is put into SVM for training to get accurate classifier. Since the previous data is the data of different lengths composed of 3d coordinates and time, the data after the calculation is the data of the fixed length of the average value of a 3d coordinate. So, the time dimension disappears here. Then, the data of each subject is spliced together as a new data and imported into SVM for training data training classifier.

I used sliding window to perform the preliminary calculation for data of some subjects. The results are compared with the acceleration calculated from the trajectory. [17]You can see that the data in the two sets (figure 31.32)of images are consistent regarding the robustness of the data. At the same

time, the number of peak accelerations in the data is reduced, making it easier to compare. [18]An obvious problem with the trajectory is that the time of each data is different. For SVM, different data lengths cannot be compared in one classifier. As for the sliding window method, each data is 100 partitions. Consistent in the amount of data, and the characteristics of the data. Through the sliding window, data can be directly inputted to SVM for classification.



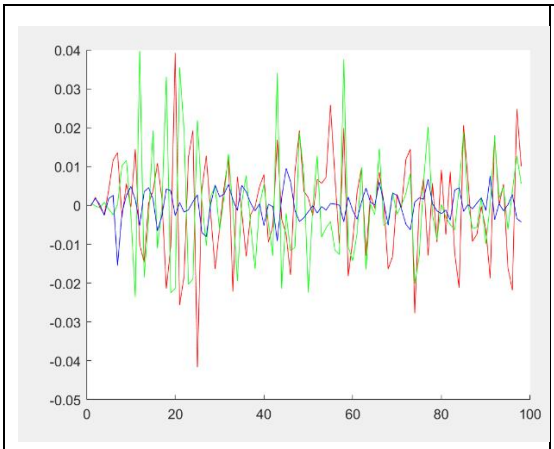



Figure 31Data processed by sliding window. Maintain the stability and robustness of the data

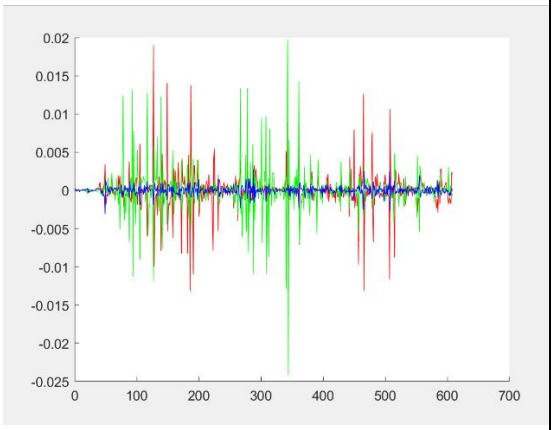



Figure 32 Original data of real-time action

Data processed by sliding window. Maintain the stability and robustness of the data.

# 7. SVM

Support Vector Machines (SVM) is a general machine learning method. Based on the principle of Structural Risk Minimization (SRM), it overcomes the limitation of empirical Risk Minimization in traditional learning methods and still performs well in classification under the condition of small samples. It from the linearly separable case evolved the optimal classification plane, meet the conditions of kernel function instead of a nonlinear mapping, the sample point in the input space can be mapped to a high-dimensional feature space, and in the space linear separable, and then constructs an optimal hyperplane to approximate the ideal classification results, the basic idea can be used two dimensional case to illustrate.

I focus on the advantages and disadvantages of machine learning for comparison. Because the data samples in this study are few and the dimensions are high. So I use SVM as a method of machine learning.

Advantage and Application

| Name | Advantage | Disadvantage | Application |
|---|---|---|---|
| Decision tree | 1.Decision tree is easy to understand and explain, can be visualized analysis, easy to extract the rules.<br>2.Decision trees can handle | 1.It is difficult to deal with missing data.<br>2.Prone to overfitting.<br>3. Ignore the correlation of attributes in the dataset. | 1.Enterprise management practice<br>2.Enterprise investment decision<br>3.Good analytical |

| | | | |
|---|---|---|---|
| | both nominal and numerical data.<br>3.The running speed is relatively fast.<br>4.Be good at extended to a large database, and its size is independent of the database size. | 4.Feature that the result of ID3 algorithm is biased towards more numerical values when calculating information gain. | ability of decision trees<br>4.More applications in the decision-making process |
| KNN (k-NearestNeighbor) | 1. KNN is an online technology in which new data can be added directly to the data set without retraining<br>2. KNN theory is simple and easy to realize | 1. It is difficult to calculate large samples.<br>2. When the sample is unbalanced, the error is relatively large.<br>3. KNN performs a global operation again for each classification.<br>4. Selection of k value. | 1. Text classification<br>2.Pattern recognition<br>3. Cluster analysis<br>4.Multiple classification areas |
| Support vector machine (SVM) | 1.Solving machine learning problems with small samples.<br>2.Solve non-linear problems.<br>3.No local minimum problem.<br>4.Processing high-dimensional data sets.<br>5.Strong generalization ability. | 1. The interpretation of kernel functions is complex.<br>2. Sensitive to missing data. | 1. Text classification<br>2. Image recognition<br>3.Field of dichotomies |
| Naive Bayes | 1. High speed for large quantity training and query.<br>2. Support incremental operation.<br>3. Naive Bayes is easy to understand the interpretation of results. | The assumption of sample attribute independence is used. | 1. Text classification<br>2. Fraud detection |
| Nerve net | 1. High classification accuracy and strong learning ability.<br>2. Strong robustness and fault tolerance to noise data.<br>3. Associative ability. | 1. Neural network has many parameters, weights and thresholds.<br>2, black box process, cannot observe the intermediate results.<br>3. The learning process is relatively long and may fall into a local minimum. | 1. Computer Vision<br>2. Natural Language Processing<br>3.Speech Recognition |

Comparison between SVM and other machine learning From (4)

As the chart shows, the advantage of SVM is that it can perform high-latitude operations with small samples (from 4). Therefore, I choose to use SVM to complete this study. The goal is to be able to

classify more accurately.

## 7.1 Introduction of the SVM

Support vector machine (SVM) is a binary classification model. In simple terms, a simple SVM is just straight line that perfectly separates two types of data. But this line is not a normal line, this is the best line from the infinite number of classifiable lines that can be used to divide these data. Because it appears to be between two sets of data. It's the same distance from each point in the two kinds of set. The points closest to the boundary are called support vector. The straight line that can perfectly separate the two types of data is called the hyperplane. In a two-dimensional plane, the hyperplane is a line that can divide two types of data perfectly. But in a three-dimensional model, this line becomes a plane. The distance from the hyperplane to the boundary is called margin. Meanwhile, the hyperplane is unique. With the change of training data, the hyperplane also changes.

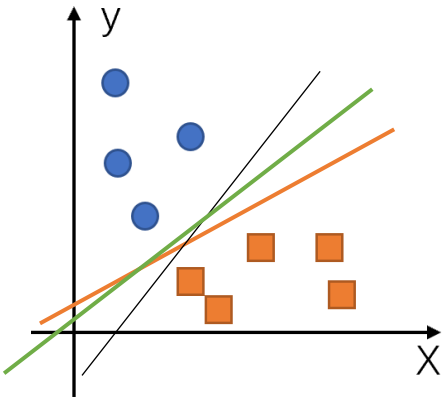



Figure 33 SVM

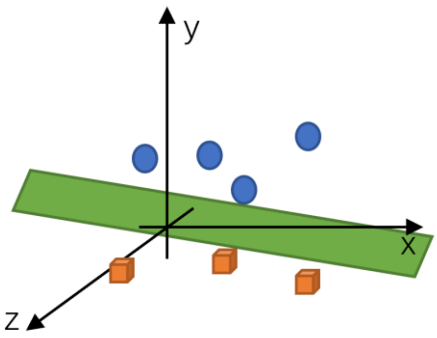



Figure 34 SVM hyperplane

SVM classification algorithm

Training sample set that can be linearly separable: $S = \{(x1, y1), \ldots(xi, yi), i = 1, 2\ldots, n\}$, $xi \in Rd$, $yi \in \{+1, -1\}$ as shown in the figure 33. The circular point and the square

point represent two kinds of samples, and the middle line is the classification plane. Classification plane can completely divides two types of data into two different sets of data. The samples on both sides are the samples closest to the classification line in all kinds of samples, and the straight lines are parallel to the classification line, and the distance between them is called margin. The distance between them is called the classification interval (margin). The separating hyperplane requires that the classification plane not only separates the two kinds of samples correctly and perfectly but also maximizes the margin of classification.

The equation of the hyperplane can be expressed as: $y = w^T x + b$ Figure 34

The training sample set is satisfied by normalization operation: $y^i(w^T x_i + b) - 1 \geq 0$ Figure 35

At this point, the classification margin is equal to $||w||^2/2$. If you want to maximize the classification margin to be equivalent to minimizing $||w||^2/2$. The separating hyperplane is the classification plane that appears when we get the minimum value of $||w||^2/2$. When classifying a data point, the greater the "margin" between the hyperplane and the data, the greater the confidence of classification is. Therefore, in order to maximize the confidence of the classification, we need to find maximize "margin". The "margin" that we need to look for is "maximum margin classifier". This time, the distance between boundary line and support vector is the shortest.

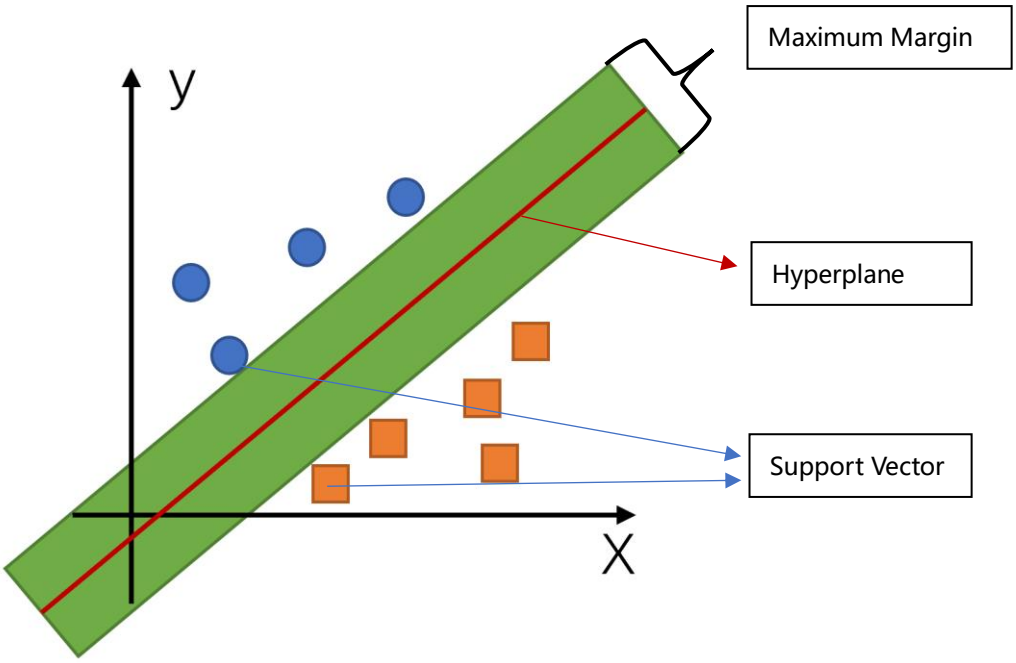



Figure 35 Working sketch of SVM

Using the Lagrange multiplier method can be reduced to a quadratic programming problem, to produce an optimum solution. In other words, only when the formula satisfies this condition, the classification plane we get is the optimal segmentation hyperplane. That's the constraint:

The $a_i$ is the multiplier of Lagrange multiplier corresponding to each constraint expression in the above problem. This is an inequality constrained quadratic function to find the optimal solution, and there is a unique solution. Easy to prove. In general, only a small part of the solution ai is not zero, and the corresponding sample is the support vector. The optimal classification function obtained after solving the above problems is:

$$L(w \cdot b \cdot a) = \frac{\|w\|^2}{2} - \sum_{i=1}^{N} a_i(y_i(w^T \cdot x_i + b) - 1)$$

From this, we can get the indicator function of the sample by solving the optimal solution of the quadratic programming, and then get the classification hyperplane of the sample. However, since the characteristic space of samples is not necessarily linear, we use the kernel function to map these samples in space and make them linearly separable.

## 7.2 Establishment of Behavior Model

Aiming at the application requirements of video analysis in medical diagnosis, this paper studies an effective identification method of abnormal behaviours based on motion capture system. This article is based on the target object skeleton feature model (SDK). [19]The design and generation of behaviour model, combined with SVM support vector machine, is used to realise the detection of

abnormal shoulder activities in the video frame sequence. This model can be applied to interactive games, which is helpful to improve the intelligence of the system and enhance the ability to diagnose shoulder muscle injury.

AI diagnostic devices have always been the focus of social attention. The accuracy of electronic doctors has been questioned. But machines are hedging more accurate than humans at diagnosing accuracy. The traditional video monitoring method is mainly used by staff for monitoring and data comparison. This method has a large workload, challenging to find, and easy to miss some abnormal behaviours. To solve the shortcomings of such systems, improve the diagnostic efficiency of video, reduce the system's dependence on human work to the greatest extent, and honestly realise the real-time observation of medical examination behaviour and automatic extraction of abnormal behaviours, motion capture technology is required as the support.

Intelligent video monitoring is a new monitoring technology. It refers to using computer vision and video analysis technology to automatically analyse the image sequence recorded by the camera and judge the target's behaviour without manual intervention, to realize automatic target detection, tracking, behaviour recognition, abnormal record and abnormal analysis. Among them, behaviour recognition is based on low-level processing of video image sequence to further study the nature of each target in the image and the relationship between them and to understand the meaning of image content. The technology mainly involves the detection and extraction of moving targets, moving target recognition, moving target analysis and understanding and other aspects of the content, so gradually become a research hotspot in the field of computer vision.

The visual analysis of human movement is mainly for the analysis and processing of human action video, which generally follows several basic processes such as feature extraction and motion representation, behaviour recognition and understanding. Among them, motion detection belongs to the visual processing part of the bottom; Feature extraction and motion representation is to match the motion features extracted from the motion information of the target with the reference sequence on the basis of the processing of the bottom and middle layers, such as target detection, classification and tracking, so as to judge which behaviour model the current action is in. High-level behaviour and understanding to identify the understanding of complex behaviours on events by combining the information and relevant domain knowledge of behaviours.

## 7.2.1 Characteristics of abnormal actions

One of the key technologies to be solved by the system is the automatic identification of abnormal behaviours, including behaviour modelling and behaviour classification. Abnormal behaviour refers to any behaviour that does not conform to a given environment, and varies according to the environment and set requirements. There is no clear data that can be used by a computer because of the difficulty in summarizing abnormal behaviour. In order to complete this study, according to the analysis of relevant medical data, the abnormal shoulder behaviour can be simply defined as the

following characteristics, showing in figure(36)： [1] : the abnormal behaviour of peri-shoulder muscle (1) the arm fails to raise to the medical standard;(2) horizontal abduction behaviour fails to the medical standard; (3) horizontal adduction behaviour fails to the medical standard; (4) vertical abduction behaviour fails to the medical standard; (5) vertical adduction behaviour fails to the medical standard.[2] : abnormal rotator cuff muscle behaviour (1) shoulder internal rotation fails to the medical standard; (2) shoulder external rotation fails to the medical standards. In the diagnostic environment, the subject stands. The range of all kinds of action is significant, and durative action is much. For example, frequent movement of hands on both sides and in front of the body, a slight deflection of the head, slight movement of the shoulder and so on in normal conditions. The abnormal behaviour of the shoulder is the movement track with limited movement. Even if the motion amplitude is the same and the duration is short, the detection system can accurately and effectively detect the micromotion.

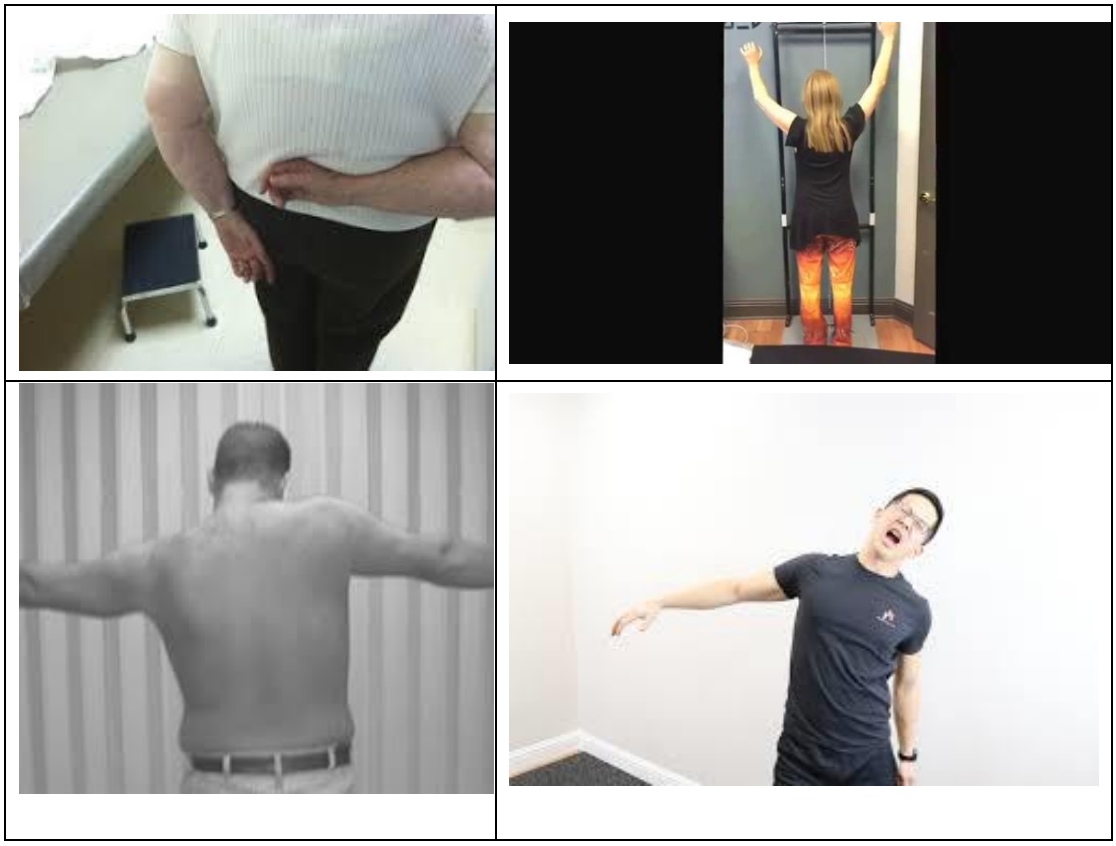


Figure 36 Schematic diagram of abnormal behavior

## 7.2.2 Abnormal behaviour diagnosis

The diagnosis of shoulder movement abnormality should firstly model the human body behaviour and then carry out classification detection. In this study, kinect2 was selected to collect the motion trajectory data of the human body, and these motion trajectories were divided into ten particular

actions to be collected separately. Then, the motion trajectory data of each movement is divided into 500 partitions, which is equivalent to dividing a complete movement into 500 small movements. For each partition, the sliding window method was used for data processing to obtain the average of the movement track. The result is a set of 500-dimensional data sets, which are then spliced together. For example, the active tests to check whether the rotation is abnormal are shoulder internal rotation and shoulder external rotation. Splicing action 4, action 4-1, action 5 and action 5-1. Form a complete data set. The data is represented as a matrix.

### 7.2.3 Identification of abnormal behaviours

To extract human body movement, using support vector machine (SVM) class classifier was carried out on the characteristics of training and learning in the study of shoulder movement behavior of three kinds of training, and to choose kernel function to extract features of human movement space transformation, the low-dimensional nonlinear characteristic of the human body movement can be divided into feature space into higher dimensional linear can be divided into space. Because of the characteristic of the kernel function, the inner product operation of high dimensional characteristic space is equivalent to the inner product operation of low dimensional characteristic space, which reduces the high computation amount brought by space transformation. The human motion model is generated through the learning of the support vector machine. When the data for the human motion track to be diagnosed are input, the same sliding window is used for data to match the model. The matching process is to input the movement track to be diagnosed into the support vector classifier and return the classification result.

## 7.3 Feature Selection and Feature Extraction

### 7.3.1 Random forest

[20] The random forest is a particular bagging method that uses the decision tree as a model in bagging. First, m a training set is generated by the bootstrap method, then, for each training set, constructing a decision tree, in the node to find characteristics were falling apart, cannot find the characteristic of all indicators (such as information gain) of the largest, but in the random part of characteristics, in the middle of the smoke to the characteristics of the find the optimum solution, is applied to the node, to split. The method of random forest can avoid overfitting because bagging, namely the idea of integration, is equivalent to sampling both samples and features.

Importance of random forest feature: Random forest has become one of the most popular machine learning methods because of its relatively good accuracy, robustness and ease of use. It also provides two straightforward methods of feature selection: mean decrease impurity and mean decrease

accuracy.

Random Forest algorithm and extra-trees algorithm. Both of these algorithms combine the popular idea of tree design: perturb-and-combine. This approach creates a set of diverse classifiers by using randomization in the construction of classifiers. The prediction of such ensemble method can give the average prediction of each classifier.

The advantage of random forest: Able to process data with high dimensions (many features) without feature selection. After the training, it can give out which features are important or not. The training is fast and easy to be parallelized. In the training process, mutual influence between features can be detected. For unbalanced data sets, it can balance errors

### 7.3.2 Prevent overfitting

In this research, the sample size is too small. To prevent overfitting. I made a lot of improvements to make the data more accurate. Apart from using the sliding window for data processing, I also used the method of feature extraction and Cross-Validation to complete the classifier. Using the sliding window, the simple explanation is to divide a complete moving track into 500 parts. The aim is to break a coherent movement into 500 smaller movements and average them. Because each data time is different, cannot use SVM to undertake classification directly. Compared with a large number of data, small sample data in such a high characteristic, still cannot get accurate results. Random forest is used to extract the most variable features.

### 7.3.3 Cross-Validation

Cross-Validation, which is used to prevent over-fitting caused by too complex models, is a practical method to statistically divide data samples into smaller subsets. Therefore, some subsets can be analyzed firstly, and the other subset can be used for subsequent confirmation and verification of this analysis. The initial subsets are called the training set. The other subset is called validation set or test set. Cross-Validation is the generalize ability of a statistical analysis, machine learning algorithm to a data set independent of training data.

The basic idea of cross-validation is to group the original data (dataset), one part as the training set to train the model, the other part as the test set to evaluate the model. ( Figure 37)

Why use cross-validation?

1. Cross-validation is used to evaluate the predictive performance of the model, especially the performance of the trained model on the new data, which can reduce overfitting to a certain extent.

Overfitting has two situations: first, the model learns too much noise; Second, the model has poor generalization ability. At this point, the model performs well on the training set, but poorly on the test set.

2. You can also extract as much useful information as you can from limited data. It helps us to evaluate the quality of the model

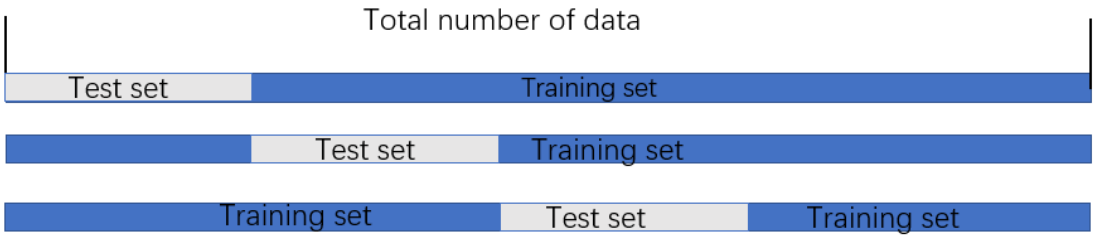



Figure 37 Schematic diagram of cross-validation

## 7.4 Test Classifier:

[21] Linear classification is a simple and effective method, but many classification problems cannot be solved by the linear classifier. SVM in handling the nonlinear classification problem, with the help of kernel functions to map sample input space to a high-dimensional feature space, which can be linearly separable, and then in the new feature space structure, the optimal linear classification hyperplane, shape into sample classification decision rules, to solve the problem of nonlinear classification provides a very unique ideas and methods.

During the training, the data of healthy people were treated as positive, and the system output was 0. The data of people who could barely complete the active test actions were minor injury, and the system output was 1. The patient data was severe injury. They couldn't complete the active test actions and the system output was 2. The data are minor_injury and severe_injury, because Python system cannot input spacebar.

I use several common kernel functions for analysis. Including: linear, RBF, polynomial and KNN method test the testing data. The testing data include two conditions. The one is problem in peri-shoulder muscle. The other one is problem in rotator cuff muscle. I divide the two result in different picture to show.

| Rotation | | Upward | |
|---|---|---|---|
| Linear | 0.86 | Linear | 0.92 |
| RBF | 0.74 | RBF | 0.83 |
| Poly | 0.78 | Poly | 0.61 |

| | | | |
|---|---|---|---|
| KNN | 0.85 | KNN | 0.90 |

Compare the results of kernels. Form(5)

I verified the data using different kernel functions. The result obtained (Figure 38) from them is that the linear kernel function has a high fraction value, so I chose the linear kernel function as the kernel function in my research. The reason for this may be the small sample size. In future studies, it is hoped that the accuracy of classifier can be further increased by increasing the sample size.

```
The Accuracy of the classifier is: 0.86
result [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 2. 1. 1. 1. 1. 2. 2. 2. 1. 1.
 1. 1. 1. 1. 1. 1. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2. 2.]

Process finished with exit code 0
```

Figure 39 The accuracy of the classifier

After the classifier is complete. I used five data as test sets to verify whether the classifier could accurately determine the shoulder muscle injury of these subjects. One of the the testing subjects is a patient with frozen shoulder, and the other four are healthy people aged between 20 and 30 years old. Three women and two men. I gave each of the subjects an accurate physical examination before collecting their trajectories. In addition to observing their ability to move, I also take physical check to ensure the accuracy of the test by touching muscle situation.

The results of physical examination showed that the patient cannot complete the lifting, abduction and rotation. It's more serious. The other four subjects showed no significant stagnation or painful in any action. The result of the patient showed that there was obvious adhesion in rotator cuff and no abnormality in the other part of shoulder joint by touching examination.

After testing the classifier. The results are shown below (Form6). We can clearly find that the computer can clearly distinguish the shoulder muscle injury of the subjects through motion trajectory analysis. The results of SVM's diagnosis are consistent with my physical examination of them. This system, consisting of motion capture equipment and SVM, can be used to diagnose shoulder muscle injury.

| Upward | Rotation |
|---|---|
| 1: positive<br>2: severe injury<br>3: positive<br>4: positive<br>5: positive | 1: positive<br>2: severe injury<br>3: positive<br>4: positive<br>5: positive |

Result of testing data.Form(6)

# 8. Result and Discussion:

This research discusses the application of motion capture device and SVM to finish professional medical diagnosis. In order to achieve this goal, I must obtain enough accurate data and process the data correctly, so as to establish a complete and effective classifier and complete the diagnostic activity of shoulder muscle injury. During this period of time, I completed the system design, device setting and program development. In order to improve the accuracy of my research, I used many operational methods. For example, sliding Windows, random forest and cross validation are used to reduce dimensions and select features. According to <Random Forest and Support Vector Machine based Hybrid Approach to Sentiment Analysis>, we can know that the random forest method can effectively improve the accuracy of the classifier, but how to deal with the original data for random forest selection. I use the sliding window method to complete data processing, dividing a trajectory data into 500 pieces on average, making it into a 500-dimensional matrix. In my research, I first made physical diagnosis for all the subjects to obtain the condition of these subjects, and then analyzed the data of the subjects through SVM. The results were compared to determine whether the system can satisfy the requirements of clinical diagnosis. After testing, I found that the system composed of kinect2 and SVM could complete the diagnosis of shoulder muscle injury. And there was no difference between the SVM's diagnosis and the human doctor's diagnosis. This is exactly what I want to get.

Significance of my research: 1. Give doctors an objective evaluation standard. This system is composed of Kinect 2 and SVM, which can be used not only for the diagnosis of shoulder muscle injury, but also for the diagnosis of other joint muscle injuries. It turns the previous subjective judgment into objective evaluation, which reduces the workload of doctors. 2. Change physical diagnosis from time-consuming manual labor to time-saving and labor-saving computer work. Computers can be used to complete preliminary, massive and repetitive diagnosis. 3. Compared with other studies, the main purpose of this research is to use computers to complete accurate medical diagnosis rather than for treatment. 4. Provide a portable, accurate method for diagnosing shoulder muscle injuries. Easy to use and easy to move are the advantages of this system, people can use it at home. 5. Sliding window was used to process the motion trajectory data and keep stability and robustness of the motion trajectory data.

Originality:

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.

Because in my opinion, it is a trend for machines to completely replace human beings to complete

some complicated and tedious work. Since the shoulder is the most complex joint in human, this research proves that this system can be used to the diagnosis of shoulder muscle injury. Similarly, this system will also be suitable for other joint muscle injuries. Medical diagnosis has its characteristics, that is, the high demand for accuracy. In this regard, the computing power of the computer has become a major advantage over human beings. At a distance of 2 meters, kinect2 can detect subtle movements of the human body with precision. This is crucial. The accuracy of the classifier is better reflected by the application of different kernel functions in SVM. In my opinion, the current result is not convincing, because the sample is too concentrated. Most of the subjects are students and basketball fans, and some of them are university staff. The high similarity of occupations leads to the excessively high similarity of results. This can have an impact on the results of data analysis. However, I think in future research, this problem can be solved by expanding the sample size of data.

In addition, in this study. I found that acceleration can also be used to determine shoulder muscle injury. The specific result was that the peak acceleration and acceleration change of the patients were lower than that of the healthy people. There is no acceleration sensor for this research. The acceleration is calculated by program. Therefore, this result is only applicable to the environment of this research and does not involve other situations.

In the absence of existing models and classifiers, I adopted the method of data collection and data analysis to verify the possibility of motion capture technology and SVM for medical diagnosis. The research method I used is data comparison and analysis. Compared with human doctors, the computer can complete medical diagnosis with sufficient accuracy through algorithm optimization.

In the future, computers will be able to perform more complex medical diagnoses without any human assistance. In this way, the complex and tedious diagnostic activities can be truly replaced by human beings.

# 9.Future Study:

Shoulder joint is the most complex joint in human body. It can complete omnidirectional motion and rotational motion. These complex activities are performed by different muscles , which function or rotate or abduct. In the cooperation of different muscles, the shoulder joint to complete a variety of movements. The system composed of motion capture system and SVM can be applied to the examination of shoulder joint, indicating that the accuracy of detection and the ability of feature selection can satisfy the requirements. So that means that it can be examined in other joints. For example: elbow joint and knee joint. In the examination of muscle injury, the examination of subtle movements is the key to correct diagnosis. In machine learning, abnormal parts are trained as negative variables. After a lot of training, SVM can find the eigenvalues that change the most and classify them into a classifier for data analysis. At this point, the learning ability of SVM is much higher than human being. At present, the sample size of data I used is too small to give a convincing result. However, in future studies, I can get better and more convincing results by expanding the sample size of data.

I am a doctor with 5 years of clinical experience. With my experience and requirements to develop the system will be more practical. When developing the program, I design it according to all practical requirements. And will be clinically common situation, that is, someone will be completed in front of the active test action based on the development of this system. Future research will always focus on the theme of clinical requirements. In my opinion, machines will completely replace people to complete such activities as medical diagnosis and space exploration in future. These dangerous and complex activities will be carried out by high-tech machines. There is no doubt that machines have the advantage of high accuracy over human.

At the same time, the machine learning speed is also very fast. It takes at least 10 years to train a young person to become a qualified doctor. Within days, the machine learned how to assess shoulder muscle damage. This will save a lot of time on initial training. More high-tech jobs will be offered.

This device can be used not only by doctors. It can also be used by ordinary people, they are who don't have any medical background. When they at home, they could receive professional medical examinations the same as in hospital. It can reduces the time to go to the hospital.

For acute injuries, this device can be used for the first-time examination. Acute injuries are usually accompanied by bleeding and internal bleeding. In patients with bleeding, this system can judge whether the function of the active muscle is good or not to determine whether surgical treatment is needed. In patients with internal bleeding, it is possible to accurately determine which muscle is injured by data analysis that from motion trajectory, so as to avoid overtreatment and wrong treatment.

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