Malaysian Journal of Industrial Technology, Volume 1, No. 1, 2016
ISSN: 2462-2540

A DEVELOPMENT OF ANTERIOR CRUCIATE LIGAMENT (ACL) DIAGNOSIS SYSTEM USING FUZZY INFERENCE SYSTEM

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ABSTRACT: Knee injury is one of the most common injuries in sports activities or events. Failure to detect it would jeopardize the athletes' future. Knee image processing is studied for the development of an aided system to identify knee injury. However, medical experts analyze the MRI images using their naked eyes. This increases the possibilities for false analysis. To overcome the problem, this study aims to develop an intelligent system which involves a Fuzzy Inference System (FIS) to assist the medical experts in making decisions to decide on the types of ACL knee injury. The end results in the identification of ACL injury is in the form of a classification based on complete tear (CT), a partial tear (PT), and normal classes. The analysis of results based on comparison between the FIS and medical experts' opinion reveals an accuracy of 92%.

Keywords: Anterior Crucitate Ligament (ACL) Diagnosis System.

I. INTRODUCTION

The knee is the largest joint in the human body, specifically in the leg and it is the easiest part of the body to be injured. Knee injuries can be caused by a sudden injury, an overused injury or by an underlying condition. The treatment depends on the cause and type of injury. Early symptoms of knee injury can include pain, swelling, and stiffness. Most people have had a minor knee problem at one time or another. Most of the time, normal body movements do not incur injuries. As a result, knee injuries are common in sports such as soccer, football, and basketball, most of which involve frequent sudden stop movements among athletes. At all levels, an injury is a constant threat for all injuries, those of the knee are athletes' greatest fear as they would have to rest for quite a long time.

Combination between medical and engineering technology could lead into new perspective. Image processing used to analyze the Magnetic Resonance Image (MRI), several techniques such as adjust contras, filtering, image conversion, and etc. applied to the image. Feature extraction technique could provide the data from the processing image and tell us level of ACL injury.

II. LITERATURE REVIEW

a. Knee Injuries Diagnosis System

There are several types of diagnostic techniques in classifying the types and conditions of knee injuries. Currently, the method used is diagnostic tests. The doctor uses one or more tests to determine the nature of a knee problem. In most cases, patients are given a primary diagnosis based on their medical history, physical examination, and imaging or other procedures [7]. There are several steps or process in determining the ACL diagnosis system. The process starts with a medical history, where the patient's history is reviewed for further action.

This is followed by physical examination, whereby the medical expert will ask the patient to make some movements in order to detect the injury. Arthroscopy or MRI technique involves the medical expert to evaluate the injury using their naked eyes

[11]. Figure 1.0 shows the process flow of knee injury diagnosis.

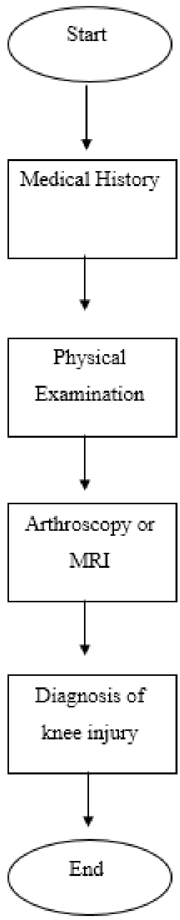

Figure 1.0: Process flowchart of knee injury diagnosis.

b. Medical History

The medical history of a patient may lead to a high likelihood of knee injury. In Australian Rules football, the most common injury was the hamstring tear (13%), which also involves the knee and lower muscle strain injuries, a proportion of which were recurrences, with a significant incidence during training sessions. In rugby, fractures and knee ligament injuries are rampant [19]. A study from Chang [5] showed that the knee is the most commonly injured joint in soccer with rugby having the highest risks.

c. Physical examination

For physical examination, doctors will perform some movement to the patient's knees or lower limbs such as bending, straightening, rotating (turns), or pressing on the knee to evaluate the injury and discover the limits of movement and the location of pain. Doctors may ask the patient to stand, walk, or squat for detailed diagnoses. In diagnosing the most frequent knee injuries, ACL injuries will be inspected through physical examination. Later, to obtain the details about the injury medical imaging ie. the arthroscopy or MRI is then used.

d. Arthroscopy

In arthroscopy, the doctor manipulates a small, lighted, optic tube (in Figure 2) that has been inserted into the joint through a incision in the knee. Images of the inside of the knee joint are projected onto a television screen. While the arthroscopic is inside the knee joint, removal of loose pieces of bone or cartilage or the repair of torn ligaments is also possible. Arthroscopy is an invasive type of diagnostic test [7].

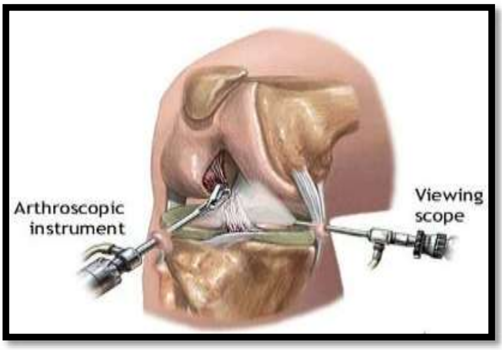

Figure 2: Arthroscopy

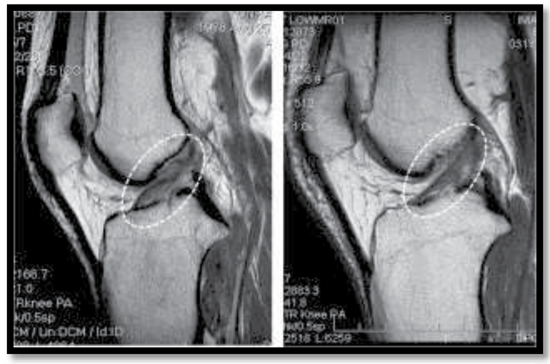

Figure 3: ACL MRI images.

e. MRI

MRI is a non-invasive type of diagnosis. In MRI, an accurate diagnosis for ACL test could be obtained [17]. MRI is the best technique in evaluating the knee joint since its sensitivity is 90%. Thus, it is suitable for use instead of the diagnostic arthroscopic examination [5]. Figure 3 shows an ACL MRI image, from a sample obtained from a resource used in this study. The advantage in using MRI is that the patient does not suffer from any injected scope compared to arthroscopy. On the other hand, the disadvantage is that the medical expert makes a decision based on the images and relies on the MRI machine accuracy, which creates high possibility of making the inaccurate decision.

III. METHODOLOGY

The full process for the ACL image processing shown in procedure shown in Figure 4. The process starts with a raw MRI image in, cropping technique used to a specific region of the process. In adjusting the contrast clear resolution view of the image is obtained, average filter is used to filter the noise present in the image. Next process is segmentation binary conversion used to convert grayscale to binary image, inversion binary process to convert pixels inversely from black (0) to white (1). Dilation process takes place in the morphological techniques and erosion process used to eliminate noise based on pixel assigned in binary image. Lastly, is the image extraction used to be obtained the parameters ie. area and perimeter. All of these processes are shown in Figure 4.

The ends result from Figure show the feature extraction of the ACL injury. These steps show the exact region of ACL injury. The first data shown here is the area of affected injury and the second data is the ACL injury perimeter. The center point is allocated in the middle of the image. As for normal ACL, the range of area is 16 to 30 and the range for perimeter is 600 to 1000. Values which fall between these ranges are classified as normal.

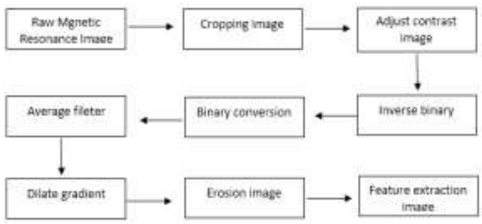

Figure 4: Process flow for image processing technique.

a. Normal ACL

The ends result from Figure show the feature extraction of the ACL injury. These steps show the exact region of ACL injury. The first data shown here is the area of affected injury and the second data is the ACL injury perimeter. The center point is allocated in the middle of the image. As for normal ACL, the range of area is 16 to 30 and the range for perimeter is 600 to 1000. Values which fall between these ranges are classified as normal.

b. Partial Tear ACL

Result from Figure 4 show the feature extraction of the ACL injury. These steps show the exact region of ACL injury. The first data shown here is the area of affected injury and the second data is the ACL injury perimeter. The center point is allocated in the middle of the image. As for partial tear ACL, the range of area is 12.5 to 22 and the range for perimeter is 250 to 280. Values which fall between these ranges are classified as partial tear.

c. Complete Tear ACL

The continuous result from Figure 4 show the feature extraction of the ACL injury. These steps show the exact region of ACL injury. The first data shown here is the area of affected injury and the second data is the ACL injury perimeter. The center point is allocated in the middle of the image. As for complete tear ACL, the range of area is 0 to 15 and the range for perimeter is 0 to 500. Values which fall between these ranges are classified as complete tear.

IV. RESULT

a. Analysis of Results

The segmented images are submitted to the medical expert for validation. The images were approved by the expert in the imaging department. As for treatment, the experts in the orthopedic department clarify the actions for further treatment. Table 1-1 shows the comparison of the results between the study and the medical expert opinions. Meanwhile table 1-2 show ten (10) sample images underdo the process.

Table 1-1: Comparison between the medical expert opinion and the results obtained from the FIS.

No. case	Expert Opinion	FIS Results
1	Treatment	Treatment
2	Treatment	Treatment
3	Treatment	Rest
4	Treatment	Rest
5	Rest	Rest
6	Rest	Rest
7	Rest	Rest
8	Operation	Operation
9	Operation	Operation
10	Operation	Operation

From Table 1-1, it can be seen that there are some differences. These are highlighted in case numbers 3 and 4 (shaded in grey).

Table 1-2: Results for 10 Sampling Images

No. Sample	Area	Perimeter	Fuzzy Output Value	Results
1	19 122.000	650.000	0.549	Treatment
2	18 010.010	667.000	0.564	Treatment
3	20 000.000	824.000	0.653	Rest
4	20 032.210	834.000	0.653	Rest
5	24 453.290	764.000	0.738	Rest
6	29 105.380	973.000	0.882	Rest
7	29 581.560	934.000	0.882	Rest
8	12 295.280	294.000	0.124	Operation
9	12 223.450	305.000	0.126	Operation
10	13 492.740	320.000	0.285	Operation

From the results, there are three different types of outputs from the classifier. All the output classifiers range between 0 to 1, which include REST, TREATMENT and OPERATION. The first portion is REST, whereby the output fuzzy is from 0.655 to 1.000 which is normal cases. There are no injuries to be worried about.

Value starting from 0.111 to 0.999 is TREATMENT, which means the patient need to see the medical officer for further treatment. At this stage, the percentage of injury is in the range of 20% to 50%, any delay may incur serious injury to patients.

Lastly, is OPERATION, which range from 0 to 0.355. At this range, patients may suffer from more serious injury from 51% to 100%, and these levels of injury need urgent medical attention for operation. According to the medical expert opinion, the period for the worst condition to be completely healed is usually around 6 to 12 months. Besides that, patients who may suffer from previous operations, chances for them to be active in sports again would be low. These types of ACL patients are afflicted with weakness in their knee ligament connection.

V. CONCLUSION AND DISCUSSION

This work is to develop an intelligent diagnostic system for the detection of knee injuries. It has been successfully developed and tested. All of the objectives that are selecting the image processing steps that are suitable in knee injury detection based on area and perimeter of ACL and classify the types of different ACL using FIS have been achieved throughout this work.

Image processing techniques used are image contrast adjustment, filtering, cropping, binary conversion and binary inversion. In these phases, images are processed from raw MRI image to binary image. The second phase is image segmentation, whereby processes such as dilation, erosion and feature extraction are involved. These are used to extract value of area and perimeter of the ACL injury. These values of area and perimeter are used as input for the FIS. As for normal ACL, range of area is 16 to 30 and range for perimeter is 600 to 1000. All range falls between these ranges are classified as normal. In partial tear ACL, range of area is 12.5 to 22 and range for perimeter is 250 to 800. All values which fall between these ranges are classified as partial tear and for complete tear ACL, the range of area is 0 to 15 and range for perimeter is 0 to 500. All values, which fall between these ranges, are classified as complete tear.

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