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DEVELOPMENT OF ANTERIOR CRUCIATE LIGAMENT (ACL) DIAGNOSIS SYSTEM USING IMAGE PROCESSING

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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 image processing system 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 crucial tear (CT), partial tear (PT) and normal classes. The analysis of results based on comparison between the system and medical experts' opinion reveals an accuracy of 92%.

Keywords: anterior cruciate ligament (ACL);diagnosis system, image processing, magnetic resonance image (MRI).

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1. INTRODUCTION

1.1. Anterior Cruciate Ligament

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 [1]. 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 [2]. 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 [3].

In this research study, 750 MRI sampling MR images are used which cover 3 level injury that is rest, treatment and serious. All samples undergo 3 phases of processing discussed before. The first phase is image pre-processing and the process involve is resizing, cropping, adjust contrast, median filter, binary conversion and labeling. As for the second phase is image segmentation which cover process of threshold, dilation, erosion, trace boundaries, region props, centroid, determine perimeter, obtain horizontal x-axis and vertical y-axis, compute matrices, rescale and display output.

1.2. Knee Injuries Diagnosis System

There are several types of diagnostic techniques in classifying the types and conditions of knee injuries [4]. 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.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 usingnaked eyes [5]. Fig.1 shows the process flow of knee injury diagnosis.

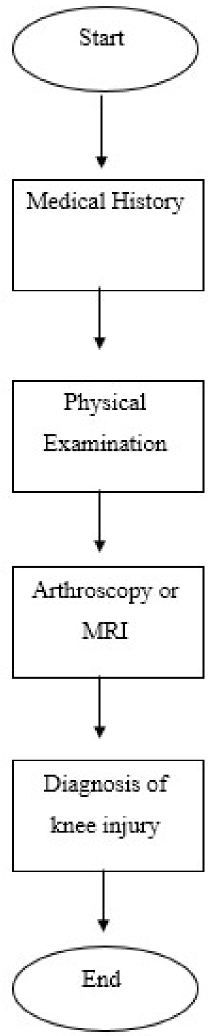

Fig.1. Process flowchart of knee injury diagnosis

1.3. 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 [6].

1.4. 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 [6]. 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. If several symptoms recognize from the examination, patient are confirm suffer from ACL in obtaining the details injury [7].

1.5. Arthroscopy

In arthroscopy, the doctor manipulates a small, lighted, optic tube in Fig.2 that has been inserted into the joint through an incision in the knee. Images 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.

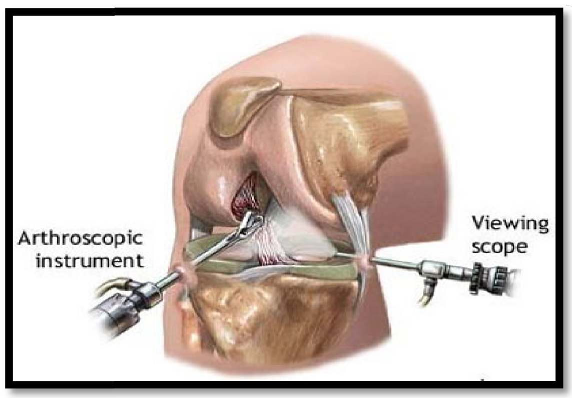

Fig.2. Arthroscopy

1.5. Magnetic Resonance Image (MRI)

Magnetic Resonance Image (MRI) is a non-invasive type of diagnosis. In MRI, an accurate diagnosis for ACL test could be obtained [8]. MRI is the best technique in evaluating the knee joint since its sensitivity is 90% due to high intensity ultra violet used. Thus, it is suitable for use instead of the diagnostic arthroscopic examination. Fig. 3 shows a sample of ACL MRI image, 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 [9]. 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.

Fig.3.ACL MRI images

3. EXPERIMENTAL

The image processing used for this research study contain of 2 processes, which are pre-processing and segmentation. In pre-processing, the process starts with a raw MRI image as input, resizing into certain fixed limitation. The cropping technique was used at the specific region on the images during the process. In adjusting the contrast clear resolution view of the image is obtained, median filter is used to filter the noise present in the image. The following process is binary conversion, used to translate gray scale image into binary black and white pixel. Last process in image pre-processing is labeling, each pixel are label for image segmentation process [10].

In the segmentation process, threshold process get input image from labeling process. Dilation process takes place in the morphological techniques and erosion process used to eliminate noise based on pixel assigned in binary image. The following step is trace boundaries, used for identifies edge region in binary ACL image. Region props function to measure set of properties for each pixel assigned. Next step is centroid, this process is to identify center value in the image for easy process further. Compute perimeter as area, perimeter and average pixel are done in this process. Obtaining several features as horizontal and vertical image value take place. Compute matrices used to state computation value in order and rescale all value is to scale down data. Lastly, display output image with features extraction data as in Fig. 4.

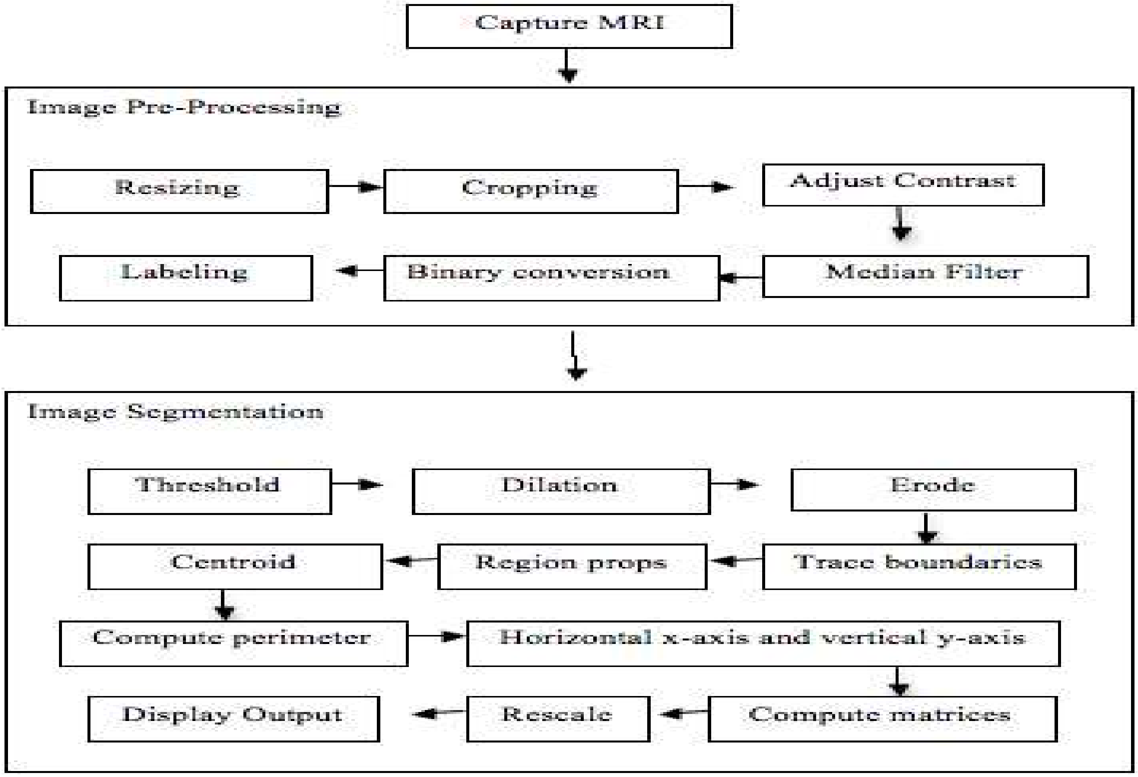

Fig.4. Process flow for image processing technique

3. RESULTS AND DISCUSSION

3.1. Feature Extraction

After the ACL has been successfully segmented, certain parameters or properties are extracted from the images. This feature will be used for the classification process. From the black and white binary image segmented, 5 features are considered to extract which is the area, perimeter, average pixel, horizontal x-axis and vertical y-axis of the image. These features are classified as follows:

Area: Value that gives the actual number of overall ACL pixel. It is obtained by the summation of areas of pixels in the image that is assigned as 1 in the binary image obtained as explain in Fig.5.

1	1	1
1	1	1
1	1	1

Fig.5. Example set of pixel occurs in the image

From these sets of image, the area is the sum of all the pixels occur in set of pixel. Which means, 1+1+1+1+1+1+1+1+1 = 9 pixels.

Perimeter: Value that gives the actual number of outline of the registered pixel in the binary image. Fig.6 shows an example set of pixel in the binary image.

1	1	1
1	1	1
1	1	1

Fig.6. Example set of pixel occurs in the image

From these sets of image, the area is the sum of all the pixels occur in set of pixel. Which means, 1+1+1+1+1+1+1+1+1 = 8 pixels.

Average Pixel: Value that gives the mean number of outline of the registered pixel in the binary image. Fig.7 shows an example set of pixel in the binary image.

1	1	1
1	1	1
1	1	1

Fig.7. Example set of pixel occurs in the image

From these sets of image, the average pixel is the mean of all the pixels occur in an ACL image. Which means, (1+1+1+1+1+1+1+1+1) / 9 = 1 pixels.

Horizontal Pixel: Value that gives the actual number of outline of the registered pixel horizontally in the binary image. Fig.8 shows an example set of pixel in the binary image.

1	1	1
1	1	1
1	1	1

Fig.8. Example set of pixel occurs in the image

From these sets of image, the horizontal pixel is the all pixel occur in an ACL image. All pixel are categorized into horizontally group set as state:

H1: 1+1+1 = 3 pixel

H2: 1+1+1 = 3 pixel

H3: 1+1+1 = 3 pixel

Vertical Pixel: Value that gives the actual number of outline of the registered pixel in the binary image. Fig. 9 shows an example set of pixel in the binary image.

V1	V2	V3
1	1	1
1	1	1
1	1	1

Fig.9. Example set of pixel occurs in the image

From these sets of image, the average pixel is the mean of all the pixels occur in an ACL image. All pixel are categorized into horizontally group set as state:

V1: 1+1+1 = 3 pixels

V2: 1+1+1 = 3 pixels

V3: 1+1+1 = 3 pixel

3.2. Normal ACL

The end result in Fig. 4 shows the feature extraction of the normal ACL injury. These procedure 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. Fig.10 shows normal ACL injury process image.

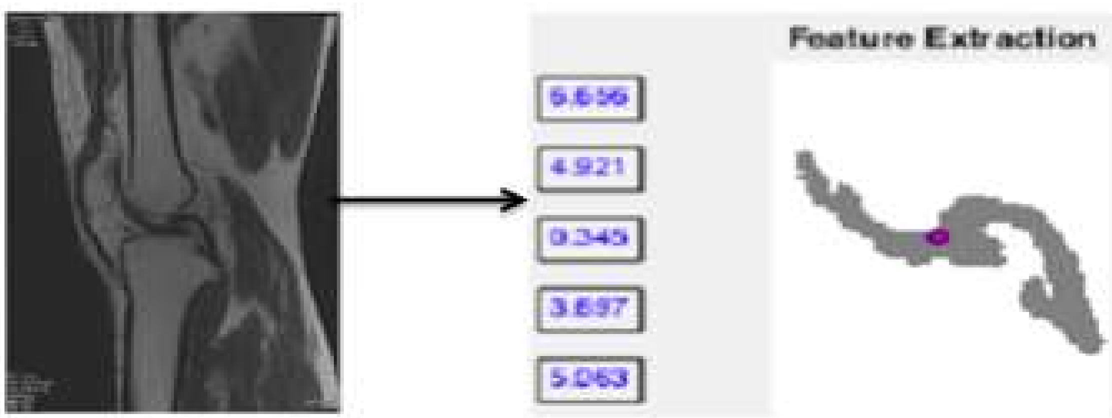

Fig.10. Normal ACL injury

3.3. Partial Tear ACL

Result in Fig. 5 shows the feature extraction of the partial 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. Fig.11 shows normal ACL injury process image.

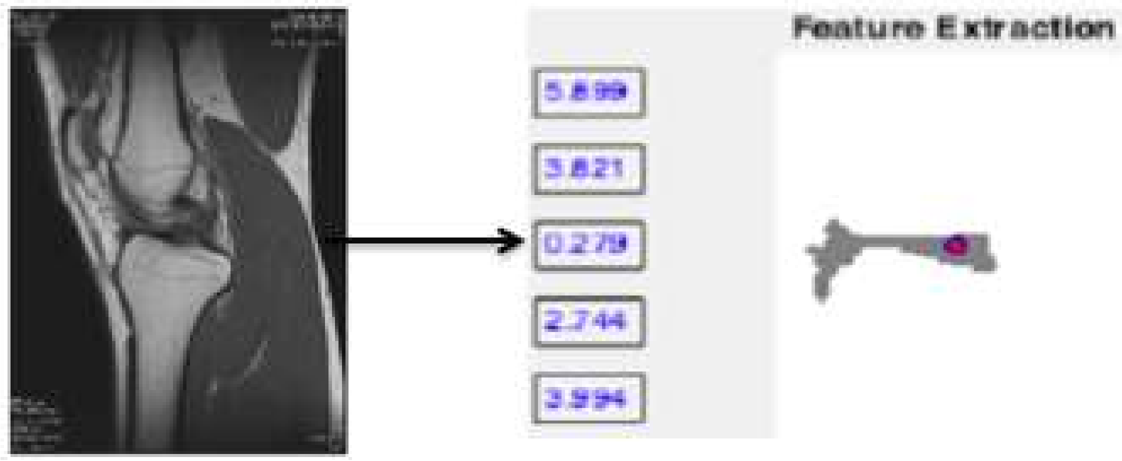

Fig.11. Partial ACL injury

3.4.Crucial Tear ACL

The continuous result in Fig. 6 show the feature extraction of the crucial 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. Fig.12 shows normal ACL injury process image.

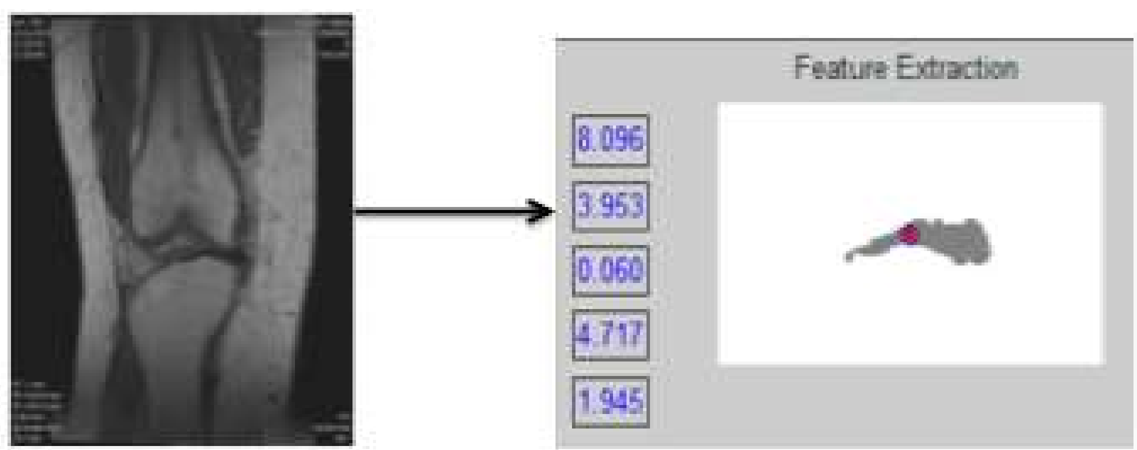

Fig.12. Crucial ACL injury

3.5. Analysis of Results

The segmented images are submitted to the medical expert for validation. The medical expert in the imaging department approved the images. As for treatment, the experts in the orthopedic department clarify the actions for further treatment. Table 1 shows the comparison of the results between the study and the medical expert opinions.

Table 1. Comparison ACL MRI result between the image processing experiment and medical expert opinion

No Case	Experiment Result	Medical Expert Result
1	Normal	Normal
2	Normal	Normal
3	Partial	Normal
4	Crucial	Partial
5	Partial	Partial
6	Partial	Partial
7	Crucial	Crucial
8	Crucial	Crucial
9	Crucial	Crucial
10	Crucial	Crucial

From Table 1, it can be seen that there are some differences. These are highlighted in case numbers 3 and 4 (shaded) over 10 samples.

4. CONCLUSION

Overall comparison results between the medical expert opinion and classification system show that the system performance of 97.0%. Besides that, this system could reduce wrong interpretation using naked eye human error and analyzing up to approximately 92% of accuracy. The system can save time and medical expert effort. According to the standard procedure analyzing Anterior Cruciate Ligament (ACL) Magnetic Resonance Image (MRI) approximately between 3 to 4 hours. It is due to limited medical expert and equipment used for analyzing. Using the image processing system, analysis can do in several minutes

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DrAzharare responsible getting MRI and consultancy from time to time.This collaboration leads into new research area in diagnosis of ACL from MRI images and it assist saving time medical expert.

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