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Knee Deformity Recognition and Deform Angle Measurement

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ABSTRACT

This paper proposes a software approach using MATLAB to measure the angular deformity as well as recognizing the type of deformity present. This can give a meaningful approach to measure the most accurate deformed angle due the Valgus and Varus knee deformity. The proposed software aids the orthopedic surgeons in knee surgeries, knee implantation and correcting the deformed knees. Thus it will revolutionize the knee surgeries and speed up the process, avoiding delay in treatment and a great relieve to the patient. Based on the deformed angle doctor can decide whether surgery is needed or not.

General Terms

Deformity Recognition, Knee Deform Angle, Affine transform Algorithm, Non-rigid Algorithm, Image Registration, Image Pre-processing, Valgus and Varus.

Keywords

Q Angle, area of interest, Miss-aligned Knee.

1. INTRODUCTION

In present scenario, the overweight and growing age of human is being considered a big problem, As far as concerned with the knee structure. The knee anatomy is widely senses as a tibio-femoral joint which is made up of four bones. These are the femur, tibia, fibula and the patella. The major movement is takes place here. A hard and smooth cartilage is used in between each of the bone so as to keep friction less hence helps in smooth movement. The femur is the thigh bone which is attached to the tibia with the help of capsule, cartilage and ligaments. Fibula is lower bone of a leg which runs along the tibia up to the ankle joint. The patella known as knee cap and it lies between the indentures of the lower end of the femur.

Fig 1: The Knee Anatomy

Another key term is load bearing axis of the knee. This the line joining the centre of the hip joint passes through the knee joint to the ankle joint. This line is called as mechanical axis of the knee. In a normal knee it is a straight line passing through the mid of the knee joint. Without knowing the concept of the knee deformations it is less likely to understand the deform angle measurement. The figure shows the normal alignment and the alignment of the Valgus and Varus. When the mechanical axis of the knee mal aligned, deformities come into play. There are two types of deformities present i.e. Valgus and Varus. Varus occurs when the mechanical axis of the tibio femoral joint shifts causing more stress and strain on inner compartment. Valgus occurs when the mechanical axis of the knee joint moves outside causing more stress and pain in outer compartment. In the knee deformity correction, surgeons must know the location, position and physical characteristics of the knee joint and soft tissue. The correct posture of knee joint and ligament transfers the load force across the knee joint [10].

In recent years, Valgus deformity of a knee can be corrected by the pie crusting technique, which makes use of TKA for correction. In this technique also our approach can be beneficial to give the tibio-femoral deformed angulations [8]. The total knee arthoplasty is a simple but time consuming and high cost method, here too presented approach can aid in terms to reduce the time as well as make simpler for surgeons to give them accurate angulations of deformations hence accurately aligned knee [1]. The presented approach also suited in llizarov method to correct the deformities present in knees by giving the Q angles [2].

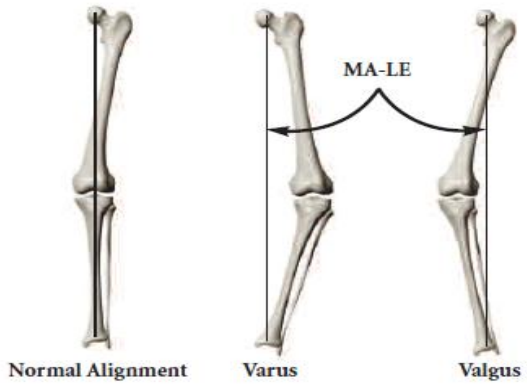

Fig 2: Mechanical axis of normal and deformed tibio-femoral joint

The x ray of a Varus and Valgus deformity is shown below in figure 3

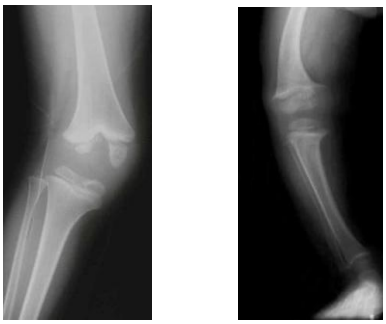

Fig 3: X ray of the Varus and Valgus deformity

2. OVERVIEW

We in this paper are concentrating on measuring the angle of deformity of the knee which can also tell the kind of misalignment that is Varus or Valgus. Before going to the mechanism designed we would like to explain basics of angle measurement and certain transformations which are needed to be carried out before we can extract the angle from the x ray images.

2.1 Deform Angle Measurement

There are several terms which are useful to measure the deformed or Q angle of the tibio femoral joint [6] [12-14]. These are mentioned below.

2.1.1 *MAF and FShA*

Mechanical axis of the femur which is a line joining the mid of the femur head and mid of the knee joint.

Fig 4: Mechanical Axis and Shaft Axis of Femur

2.1.2 TShA and MAT

Mechanical axis of the Tibia which is a line joining the mid of the knee joint and the mid of the ankle joint.

Fig 5: Shaft and Mechanical Axis of Tibia

2.1.3 Mechanical Tibiofemoral Angle

When we considered a deformed knee, the mechanical axis deviates by an angle obtained by the femur and tibia mechanical axes. The subtended angle at the tibio-femoral joint is deformed angle and it is supplement with normal angle of knee alignment. This subtended angle indicates the extent of the mal alignment of the knee due to the deformity.

Fig 6: Mechanical Axis Deviation of Tibio-femoral joint leading to deformity

2.2 Measurement of Deformity in Knee

The Q angle or the deform angle is measured via MATLAB. The below figure gives the conceptual way of measuring the theoretical deform angle.

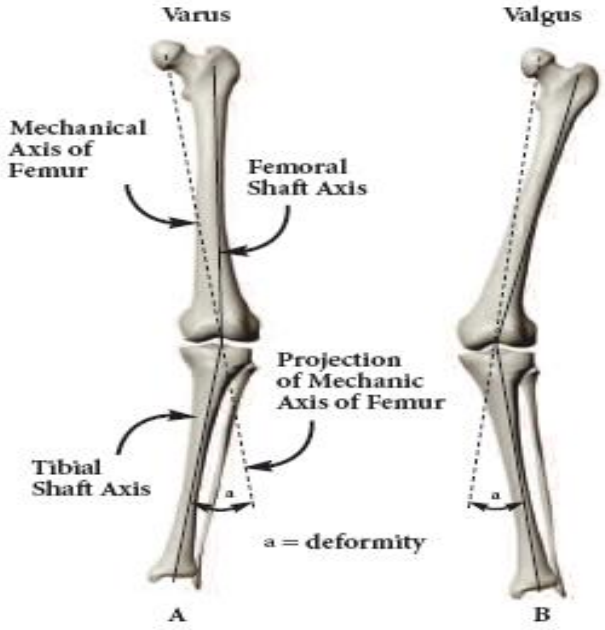

Fig 7: Measurement of Deformity

2.3 Affine Transformation

We can define the A abd B matrices to perform the Affine transform operations.

$$\begin{vmatrix} x_2 \\ y_2 \end{vmatrix} = A \times \begin{vmatrix} x_1 \\ y_1 \end{vmatrix} + B$$

For translation we can define A and B matrix given below-

$$A = \begin{vmatrix} 1 & 0 \\ 0 & 1 \end{vmatrix}, B = \begin{vmatrix} b_1 \\ b_2 \end{vmatrix}$$

For rotation, A and B can be defined as

$$A = \begin{vmatrix} cos(\theta) & -sin(\theta) \\ sin(\theta) & cos(\theta) \end{vmatrix}, B = \begin{vmatrix} 0 \\ 0 \end{vmatrix}$$

And for Scaling the A and B are given as

$$A = \begin{vmatrix} a_{11} & 0 \\ 0 & a_{22} \end{vmatrix}, B = \begin{vmatrix} 0 \\ 0 \end{vmatrix}$$

2.4 Non Rigid Transformation

Non Rigid Transformation includes local transforms in addition to the global affine transform. It does not preserve distance, planarity, parallelism or the angle. It is typically used to compensate for longitudinal tissue changes and deformation.

3. MECHANISM DESIGNED

The first step is to get the images of the tibio-femoral joint. The leg image can be collected by the scanograph. We can use also the digital x-ray images for this work. The input images of the knee joint are acquired in the MATLAB. It is done by using a MATLAB image processing tool command "imread()" . After image acquisition the images are registered using affine and non rigid transformation algorithms. Image registration is a necessary task in medical image processing. Image Registration is a process which transforms the input image's set of intensity values into a referenced coordinates. It widely finds the applications like automatic target recognition, medical imaging, computer vision, analysis and compilation of images or data in satellite communication. Registration makes possible to compare the input data with the referenced data so as to get the valuable measurements.

Next step is the pre-processing of the registered image. In pre-processing what we have done is resizing, denoising, deblerring; filtering, dilating, filling etc operations are carried out for further processing. The last stage is the deformed angle measurement or calculation. This deformed angle is also known as Q angle; which is calculated via MATLAB. The results of each stage is obtained and shown in the respective section.

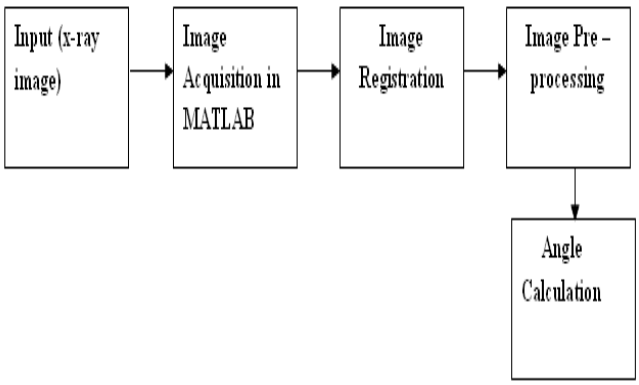

Fig 8: Block Diagram of System

3.1 Image Acquisition

The first stage of the process is to acquire an x ray image or scanograph image of the deformed knee from the database. The database consists of aligned and misaligned knee images.

3.2 Image Registration

Image registration [7] can be based on feature and intensity based algorithms. In this process we have to give an image which act as a reference image and other is an input image. Registration processes spatially transform the input image in such a way that the input image aligns as it is the reference image. The feature based registration translates the features such as lines, points etc correspondence to the reference image. Here the selected control points are only transformed from the image. This method creates a correspondence among the control points. On these control points then transformation can be done to map the input image with respect to the reference image. The feature based image registration uses the linear transform, in this paper we are using affine transform [9] which include translation, rotation, scaling and shearing.

Where as in intensity based registration the intensities of the pixels of the input and reference image is compared by taking correlation between them. Intensity based registration register the entire image or part of an image. Intensity based registration uses the elastic or non-rigid transformations. These algorithms can locally transform the input image into the reference image so that input image can align perfectly. In medical, image registration has a vital role in analyze the disease, aging factors, development process etc. here for this purpose affine in parallel non rigid transform is used for registration of an image. This is best approach for the registration for the computers having parallel processors [5].

3.3 Image Preprocessing

Here we do the Pre-processing of the registered image. In pre-processing what we have done is resizing, denoising, deblerring; filtering, dilating, filling etc operations are carried out for further processing. This is really important for accurate and angle measurement and the overall efficiency of the mechanism relies on the quality of image. We need to filter out unwanted regions and highlight area of interest.

3.4 Angle Calculation

The last phase is to extract angle of deformity and misalignment of the leg because of defect in the knee. The method to extract this is to find the axis of the upper and lower leg and then measuring the angle between axis and the horizontal line passing the centre of the knee. The angle computed also indicated direction of the shift that is whether the misalignment is Valgus or Varus.

4. RESULTS

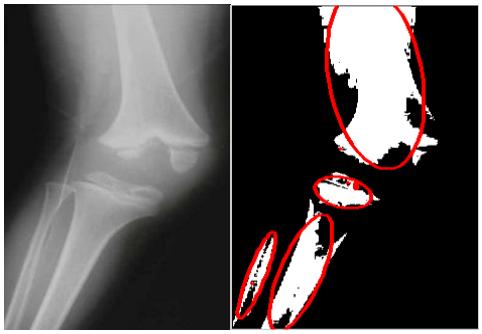

Fig 9: Knee1

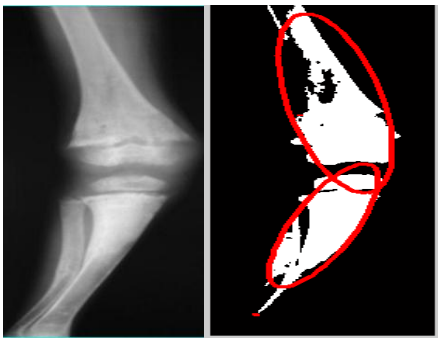

Fig 10: Knee2

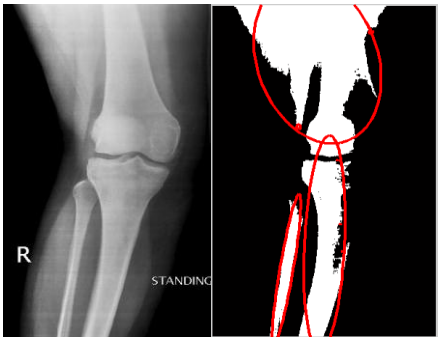

Fig 11: Knee3

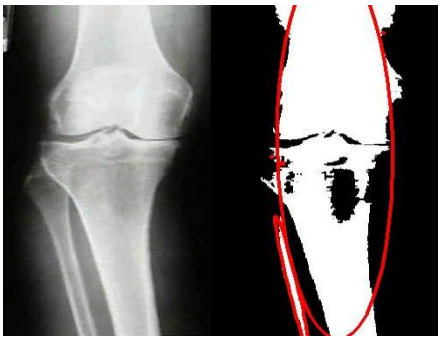

Fig 12: Normal Knee

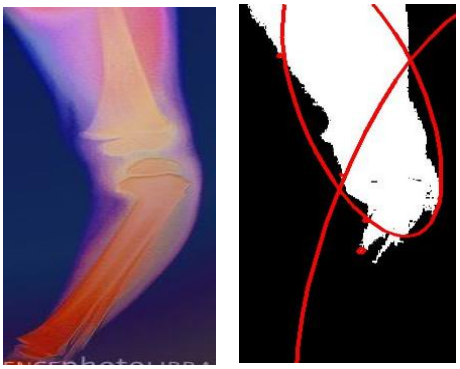

Fig 13: Knee5

Table 1. Type and angle of Deformation

Picture	Deformity type	Theoretical axis angle_quad I to IV	Theoretical Q angle	Practical Q angle	Error
Knee1	Valgus	97,83,90,90	30°	29°	1°
Knee2	Valgus	102,78,76,102	24°	21°	3°
Knee3	Valgus	105,75,90,90	13°	11°	2°
Normal knee	Normal	95,85,90,90	4°	1°	3°
Knee5	Varus	100,80,120,60	35°	30°	5°

5. CONCLUSION AND FUTURESCOPE

The problem of Leg misalignment because of knee deformity caused by overweight and aging effect is the topic of great concern in the field of medical science. The Valgus and Varus deformities can also arise at the time of birth too. Here in this paper we have designed a mechanism for measuring the angle of deformity or misalignment to aid the surgeons and doctors in treatment. The amount of deformation decides the therapy or treatment to be carried out. The results obtained show that the mechanism designed provides a good approximation of the angle of deformation with good precision. So, it can help the cause well.

The future work may comprise of providing better enhanced images to the angle calculation module in order to enhance the system we have registered images with a combined affine and non rigid transformation so the image alignment is not an issue. A new highly précised affine transform can be used for image registration instead of using the traditional methods. This method provides a robust and more accurate to mismatch points presented in an image [3].

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