AUTOMATIC KNEE OSTEOARTHRITIS PARAMETERS MEASUREMENT BASED ON X-RAY IMAGE

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Abstract: Knee Osteoarthritis (OA) is one of the most common body complaints worldwide. As prevalence of knee OA increases with age, the overall burden of the disease is expected to increase with the ageing of the population. To assist doctors to accurately and reproducibly derive the knee OA parameters in clinical diagnosis, we proposed an approach to calculating the geometric parameters between the tibia and the femur in an anterior-posterior knee radiograph with free manual measurement. The experimental results show our system can derive these parameters accurately and efficiently.

Introduction

Knee Osteoarthritis is one of the most important causes of pain and disability in aging population [1-2]. Patients with knee OA report pain and difficulty with functional activities such as prolonged sitting, walking and rising from a chair. Ultimately these limitations lead to a loss of functional independence and reduced quality of life. Since the older people are more and more in demand of a pain-free active life, the proper diagnosis and management of knee OA have become major clinical and economic issues in health care [3]. In the literature, most studies on the knee osteoarthritis analysis focus on imaging modalities such as computer tomography (CT) and magnetic resonance (MR). In fact, the plain radiography is the most primary investigation in the clinical diagnosis and assessment of osteoarthritis of the knee. The radiological features of OA include osteophyte formation, joint space loss, subchondral sclerosis and cyst formation. The most important factor in defining the presence of osteoarthritis is the presence of osteophyte. And, the joint space narrowing is the most significant factor in defining the progression of the knee OA. For the present clinical diagnosis, these assessment parameters are fully manually or semi-manually derived from the radiograph such that it tends to be time consuming and subjective. Besides, the reproducibility of these parameters is low. To the best of our knowledge, there is seldom paper discuss how to automatically extract the assessment parameters about the knee OA. In this paper, we propose an automatic approach to calculating the geometric parameters, including distances and angles, between the tibia and the femur in an anterior-posterior knee radiograph. We utilized the anatomical knowledge of the knee such that only simple image processing algorithms were used instead of complex ones. The experimental results show our method can derive these parameters accurately and efficiently. In section 2, we explain the image processing steps. In section 3, we show the experimental results. We make conclusions in section 4. Section 5 is our future work.

Materials and Methods

To simplify the analysis, the input image is divided into three parts including the upper part (***UP***), the middle part (***MP***) and the lower part (***LP***). The upper and the lower parts focus on processing the femur and the tibia individually. As to the middle part concentrates on dealing with the femur-tibia joint. For the distal femoral articular surface and proximal tibial articular surface finding. The Canny edge detector is first applied to ***MP***. To exclude those edges outside bones the edge image ***E*** is ANDed with the thresholded image ***T*** derived by thresholding the input image. Usually, the detected edges are fragmentary. To reduce the fragmentation, the dilation operation with a 3x3 structure element is employed to ***R***. Then, the edge linking procedure is utilized to link up these fragmental edges to boundaries. Subsequently, the summit edge point (***SEP***) around the middle axis is first sought out. The boundary tracing process starts from the ***SEP*** and proceed forward and backward individually. The traced boundary with the maximum length is viewed as the distal femoral articular surface. For the proximal tibial

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articular surface finding, it is similar to the previous stage except that the starting point is produced by looking for the second articular surface point downward from the ***SEP***. The detected boundaries in this step are employed as the initial boundaries. Based on these initial boundaries the ASM (Active Shape Model) can be utilized to locate the real boundaries. Figure 1 shows the detection results.

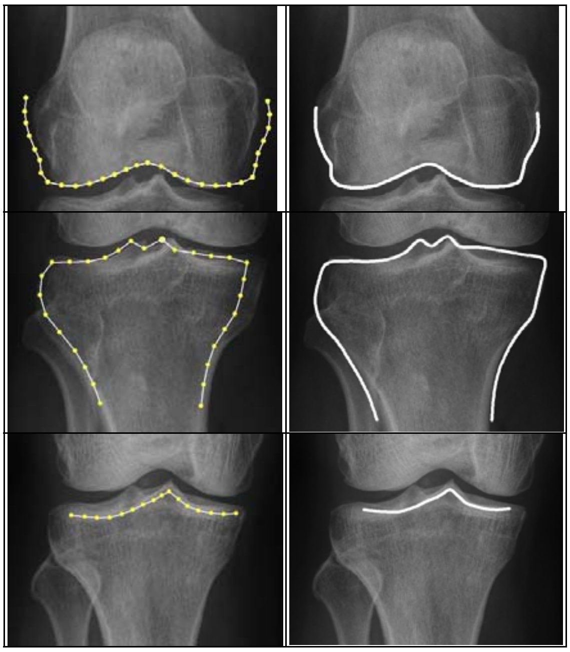
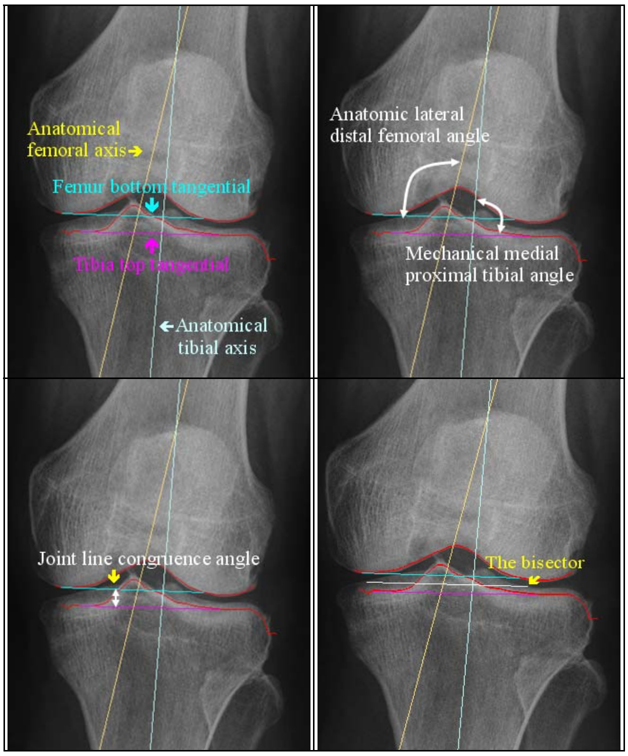


Figure 1: the ASM initial boundaries and the final detected boundaries. The left column corresponds to the initial ones and the right column corresponds to the final results.

Before deriving the geometric parameters we have to acquire the femur bottom tangential, the tibia top tangential, the anatomical femoral axis and the anatomical tibial axis on the original bones' boundaries. Both the anatomical femoral and the tibial axes are estimated from the straight parts of the bones. For the femur, the upper part is straighter than the lower part, whereas the lower part is straighter than the higher part for the tibia. The medium axis of the straightest part, cropped from the top of the femur to two centimeters below, is adopted as the anatomical femoral axis. The anatomical tibial axis is derived in the similar manner except that the straightest part is cropped from the bottom of the tibia to two centimeters above. The femur bottom and the tibia top tangentials are derived from the distal femoral articular surface and the proximal tibial articular surface with excluding the middle parts, individually. Along the left perpendicular line of the anatomical femoral axis from top to bottom we can find out the lowest intersection point with the distal femoral articular surface. Similarly, along the right perpendicular line of the anatomical femoral axis from top to bottom we can find out another lowest intersection point with the distal femoral articular surface. By connecting the two lowest points, the femur bottom tangential can be obtained. We can acquire the tibia top tangential in the same way except that the highest intersection points are sought and the searching process is from bottom to top.

Now, the anatomical femoral axis, the anatomical tibial axis, the femur bottom tangential and the tibia top tangential are available (as shown in Fig. 2). The anatomic lateral distal femoral angle and the mechanical medial proximal tibial angle can be straight calculated. The joint line congruence angle can be straight calculated also. The bisector of the two tangentials, denoted as the BST, can be computed at the same time. Both the anatomical femoral axis and the anatomical tibial axis intersect with the tibia top tangential called Pf and Pt. The mechanical axis deviation is defined as distance between Pf and Pt. The distance between the femur and the tibia is derived by measuring the distances between the corresponding points of the distal femoral articular surface and the proximal tibial articular surface. The corresponding points are the intersection points of the perpendicular line of the BST and the distal femoral articular surface and the proximal tibial articular surface, individually. For each side of the knee joint, three distances are calculated such as the maximum distance (MXD), the minimum distance (MND) and the average distance (AVD). Hence, we can get six distance values for each leg.



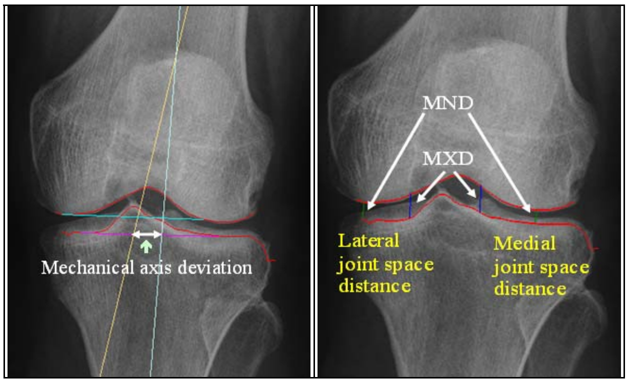


Figure 2: The knee joint parameters indications.

Results

The size of the radiograph is 1270x2160. The experiments proceeded on the personal computer with Pentium CPU, 2.4GHz clock rate and 512MB main memory. The accuracy of the system is evaluated by matching the detected boundary ***B*** with that drawn by the doctor ***D***. There are two approaches to matching ***B*** and ***D***, either based on ***B*** or based on ***D***. Eq. (1) and (2) are the corresponding formulas. The boundary detection error ***BE*** is the average of the both types errors like Eq. (3). In addition to the boundary detection error, we quantify the accuracy of the joint space distance by calculating the absolute difference between the detected version and the sketched version.

$$E_1 = \frac{\sum_{i=1}^{N} \min_j \overline{B_i D_j}}{N} \qquad (1)$$

$$E_2 = \frac{\sum_{j=1}^{M} \min_i \overline{B_i D_j}}{M} \qquad (2)$$

$$BE = \frac{E_1 + E_2}{2} \qquad (3)$$

We have collected sixty cases consisting of 24 normal cases and 36 abnormal cases. Table 1 demonstrates the error analysis result for the normal cases. As to the abnormal cases, the error analysis result is shown in Table 2. In the first columns of Table 1 and Table 2, the words min, mean and max indicate the joint space distance is defined as the ***MND*** or the ***AVD*** or the ***MXD*** between the two articular surfaces. In the first rows of Table 1 and Table 2, the words ***Min***, ***Max*** and ***Average*** represent the minimum value, the maximum value and the mean value of errors. These results indicate that our system can derive the geometric parameters from the knee radiograph accurately for either the normal cases or the abnormal cases.

Table 1: The error analysis result of the normal cases

Normal Cases				
	Min	Max	Av	Unit
Distal femoral articular surface	2	6.6	4.3	Pix
Proximal tibial articular surface	4.4	16	8.6	Pix
Femoral-Tibial angle	0	2.9	1.4	Deg
Anatomic lateral distal femoral angle	0	3.1	1.3	Deg
Mechanical medial proximal tibial angle	0	6.3	2.7	Deg
Joint line congruence angle	0	4.7	1.8	Deg
Mechanical axis deviation	0	65	26.6	Pix
Medial joint space distance (mean)	0.6	13.6	6.8	Pix
Lateral joint space distance (mean)	1	27.1	8.8	Pix

Table 2: The error analysis result of the abnormal cases

Disease Cases				
	Min	Max	Av	Unit
Distal femoral articular surface	2. 5	7.4	4.4	Pix
Proximal tibial articular surface	3.3	16.9	9.2	Pix
Femoral-Tibial angle	0	4.2	1.4	Deg
Anatomic lateral distal femoral angle	0	4.9	1.8	Deg
Mechanical medial proximal tibial angle	0	9.5	2.5	Deg
Joint line congruence angle	0	7.0	2.1	Deg
Mechanical axis deviation	0	110	31.1	Pix
Medial joint space distance (mean)	0.3	17.1	8	Pix
Lateral joint space distance (mean)	0.6	29.2	9. 4	Pix

Conclusions

In this paper, we proposed an automated approach to computing the knee joint parameters from a knee radiograph for assisting the clinical diagnosis of the knee osteoarthritis. We took advantage of the anatomical knowledge of the knee such that only simple image processing algorithms are used instead of complex ones. The experimental results demonstrate that our method can analyze the knee joint accurately and efficiently. They also prove that the proposed method lends itself to the clinical applications.

Acknowledgments

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