An Automated Method for Scan Geometry Planning for MR Knee Imaging

X. Tao[1]
[1]Imaging Technologies, GE Global Research Center, Niskayuna, New York, United States

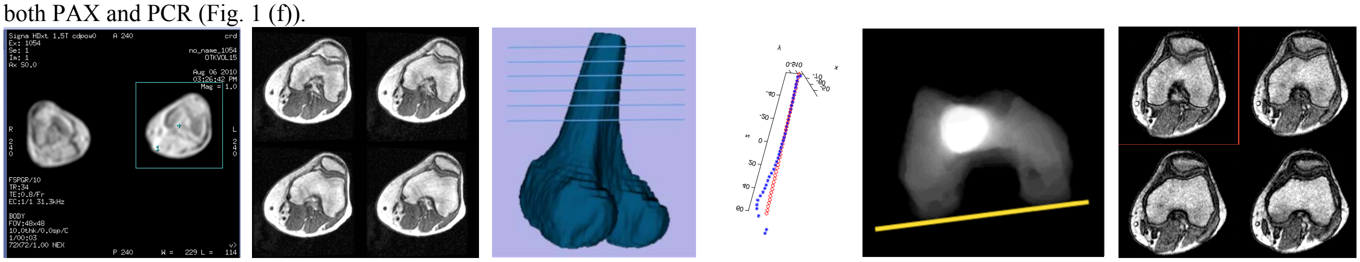
Introduction

Clinical MR knee exams typically start with a three-plane localizer of the knee joint. An operator then prescribes the scan geometry (center of the field-of-view, orientation of the scan plane, and coverage) of the diagnostic scans after determining the anatomy in the localizer images. This process requires extensive knowledge of the joint anatomy and experience in MR imaging from the operators. The consistency of the diagnostic images is not guaranteed. Automatic alignment algorithms have been reported either for scan plane planning using landmark identification [1] or as a post-processing step using femur segmentation [2]. We developed an automated algorithm for scan plane prescription using femur segmentation from a 3D axial localizer. The scan geometry for diagnostic exams is defined based on the position and orientation of the femur bone. We have incorporated this approach in a clinical MR system and demonstrated its usefulness in automatically obtaining consistent imaging planes across examinations irrespective of subject position. The automated scan geometry prescription system can relax the requirement on operator's experience level, improve scan throughput, and facilitate straightforward longitudinal analysis.

Methods

Data Acquisition: A single slice 2D axial localizer is first acquired using a fast spoiled gradient echo sequence (TR/TE 34/1 ms, Flip 10^o, Matrix 72x72, FOV 48cm, slice thickness 10mm) at the landmark level. This slice is used to determine the center of the knee to be scanned in the axial plane. A 3D axial localizer is then acquired with another SPGR sequence (TR/TE 4.1/1.4 ms, Flip 12^o, Matrix 96x96, FOV 18cm centered at the knee center, 60 slices at a thickness of 3mm).

Femur Segmentation: In order to prescribe the 3D localizer to have the right FOV containing enough information for the subsequent process, we analyze the 2D localizer to determine the center of the knee of interest (Fig. 1 (a)). This is done by a thresholding followed by a connected component analysis. When Body coil is used, both knees appear on the slice. In this case, the location of the knee to be scanned is determined by comparing the centers of the two largest connected components. To segment the femur bone, we first identify a seed point inside the femur from the superior section of the volume, where the femur cortex is thick and its contrast to marrow is large. A statistics flow is computed on the localizer volume to drive a fast marching algorithm to segment the femur [3] (Fig. 1 (c)). Once the femur is segmented, we define an anatomical coordinate frame using the following steps: 1. Determining the patient axial plane (PAX) as a plane perpendicular to the direction of the femur, $\mathbf{V}_{FB}$, which is computed from a linear fitting of the centers of the femur body (Fig. 1 (d)). 2. Determining the patient coronal plane (PCR) as a plane parallel to the line tangent to the back of the condyles and perpendicular to PAX. The posterior edges of the lateral and medial condyles are detected from a projection of the 3D femur label in the direction of $\mathbf{V}_{FB}$ (Fig. 1 (e)). And 3. Defining the patient sagittal plane (PSG) as the plane perpendicular to both PAX and PCR (Fig. 1 (f)).



(a) (b) (c) (d) (e) (f)

Figure 1. The process of automated scan plane planning for knee MRI. (a) Single slice localizer with knee center and FOV determined. (b) Slices from 3D localizer. (c) Segmented femur model with locations of axial slices of femur body indicated. (d) Centers of femur body (blue points) and linear fitting (red line). (e) Projection of femur label in the direction of femur body with line of posterior condyles indicated. (f) Slices from diagnostic exam indicating the standard axial orientation (note the protocol is selected to demonstrate scan plane, rather than optimized for diagnosis).

Results

The algorithm was implemented using ITK library [4] and integrated into a GE Signa scanner (GE HealthCare, Milwaukee, WI). Fourteen subjects were scanned for both knees (32 knee scans total) on GE Signa 1.5T systems with three types of receiving coils (Body coil, HD TRknee PA, and QuadKnee) under an IRB approved study. On a typical scanner, the 2D localizer takes 3 seconds, the 3D localizer takes 25 seconds, all computation takes about 7 seconds. The time before the first diagnostic image is between 1 and 1.5 minutes depending on the type of study. For the 32 knee scans, an operator manually determined the desired orientations and measured the errors of the automatically determined scan geometry. The statistics of the errors are shown in Table 1, with angles reported in degrees and distances reported in millimeters. We note that the mean errors represent bias, while the standard deviations represent consistency in the scan geometry definition. From Table 1, we can conclude that the proposed method can achieve high consistency as compared with inter-operator errors as reported in [2].

Table 1. Error statistics of automatically determined geometry.

	Left Knee		Right Knee	
	Mean	Std	Mean	Std
Roll	0.20	0.55	-0.11	0.56
Pitch	-0.61	0.97	0.85	0.62
Yaw	0.29	1.10	1.14	0.85
Trans_X	1.4	1.29	0.05	1.46
Trans_Y	-2.66	2.30	-2.58	2.16
Trans_Z	3.33	1.07	-3.64	1.83

Conclusion

We have presented an automated algorithm for defining the position and orientation of the femur bone from the MR images of knee joints. The algorithm achieves high consistency and repeatability as compared to a human operator. This algorithm can be used in a system of automated scan geometry prescription to arrive at consistent and repeatable scan planes.

References

[1] *SPIE Med. Imag.* 2007. [2] *ISBI* 2010: 940-943. [3] *Med. Imag. Anal.* 2004, 8(3): 267-274. [4] http://www.itk.org.