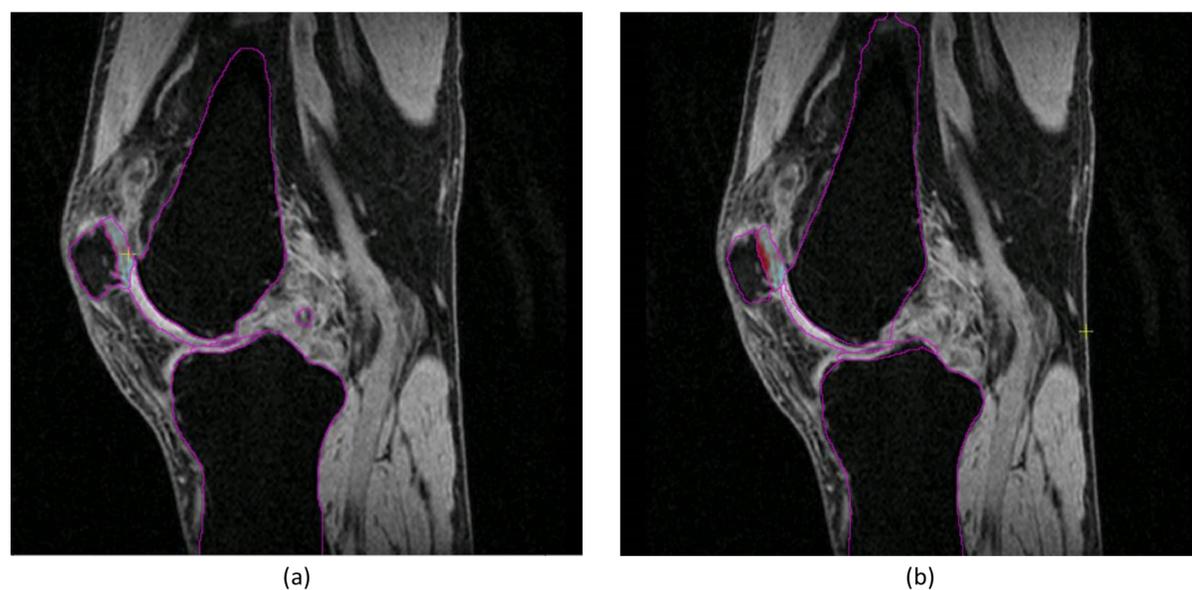


# Performance Assessment of an Automated Segmentation System for Knee MRI Scans

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**INTRODUCTION:** Surgical planning is crucial for patients who will undergo orthopedic surgery, such as knee replacement and anterior cruciate ligament reconstruction. Furthermore, the growing trend of high-quality, personalized patient care has led to the development of systems able to utilize custom positioning guides, modeled from magnetic resonance imaging (MRI) scans, which fit directly onto the unique anatomy of each patient, enhancing surgical efficiency. However, to do so, such systems rely on the manual segmentation of the knee anatomy. Here, a fully-automated segmentation system utilizing multiple anatomic atlases to generate accurate surface models of knee anatomy is presented and evaluated. The performance of such a system was assessed using a leave-one-out-like analysis to compare the unsupervised segmentation results to an expert manual segmentation.



**Figure 1:** One of the MRI scans used in this study with a purple outline denoting the (a) manual and (b) automated segmentations

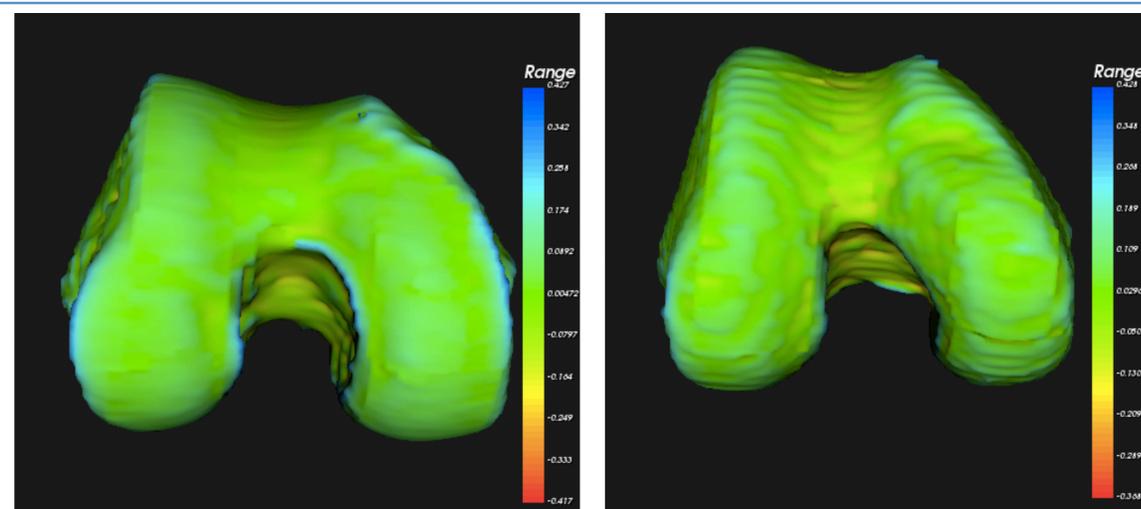
Image	Bone			Bone + Cartilage		
	Femur	Patella	Tibia	Femur	Patella	Tibia
1	0.968	0.927	0.950	0.958	0.903	0.943
2	0.959	0.908	0.949	0.947	0.850	0.943
3	0.963	0.924	0.947	0.951	0.915	0.942
4	0.957	0.953	0.963	0.943	0.929	0.955
5	0.956	0.892	0.962	0.933	0.786	0.956
6	0.956	0.893	0.957	0.945	0.867	0.953
7	0.959	0.943	0.964	0.948	0.917	0.956
8	0.961	0.941	0.965	0.952	0.912	0.960
9	0.933	0.924	0.956	0.919	0.874	0.950
10	0.931	0.961	0.958	0.924	0.954	0.951
<b>Average</b>	<b>0.954</b>	<b>0.927</b>	<b>0.957</b>	<b>0.942</b>	<b>0.891</b>	<b>0.951</b>

**Table 1:** The Dice similarity coefficient between automated and manual segmentations of the femur, patella, and tibia. Dice coefficient of 1.0 represent perfect overlap of segmented regions.

**METHODS:** Ten MRI knee scans from subjects undergoing total knee arthroplasty (TKA) and their corresponding manual segmentations, generated by an expert musculoskeletal radiologist, were used to evaluate the performance of the proposed system. To segment each image, the manual segmentations of the other nine images were regarded as anatomic atlases and were fed to the system. For each scan, the bone and cartilage of the femur, patella, and tibia were segmented. The Dice similarity coefficient (DSC) was used to evaluate the spatial overlap accuracy between the automated and manual segmented regions. The DSC ranges from 0 (no spatial overlap between two sets of segmentation results) to 1 (complete overlap), and was calculated as the intersection of the two segmented regions divided by their average size.

**RESULTS:** The automated segmentation system yielded promising results, averaging a DSC higher than 0.9 when evaluating the bone segmentations, reaching values up to 0.968. Only the patella segmentation had DSC values barely lower than 0.9, and such values were found in just two scans. When the comparison of the segmented structures included both the bone and the cartilage, the DSC values remained almost as high, with only the patella averaging a value under 0.9. Table 1 shows the detailed results from this analysis and Figure 1 shows an example of a manual and an automated segmentation.

**DISCUSSION:** The results showed that using this fully-automated system, the bone and cartilage segmentations of the femur, patella, and tibia from knee MRI scans were not significantly different from manual segmentations performed by an expert musculoskeletal radiologist. Thus, personalized patient care could benefit from this system by avoiding the need for manual segmentation for surgical planning needs. Additionally, the DSC values represent unsupervised segmentation results, and could be further improved with trained supervision, review and editing.



(a. Expert Radiologist Segmentation)

(b). Unsupervised Automated Segmentation

**Figure 2:** 3D Surface Models of the Expert Radiologist segmentation (a); and Unsupervised Automated Segmentation (b) showing distal femur with local bone surface curvature indicated by color (red = concave; green = flat; blue = convex).

**SIGNIFICANCE:** This analysis showed that an automated segmentation system could be of aid for orthopedic surgery, particularly in the case of knee replacement, where manual segmentation currently is used for creating custom positioning guides. The automated method decreases segmentation time significantly, and therefore increases throughput.