Figure Captions

Figure 1:

Representative frames from dynamic MRI sequence of the knee during a flexion-extension cycle. Images were acquired using a 2D radial golden-angle gradient echo FLASH sequence, providing high temporal resolution to capture continuous knee motion. These frames serve as input data for subsequent semi-automated segmentation and kinematic analysis.

Figure 2:

Schematic overview of the semi-automated segmentation pipeline for tibiofemoral kinematic analysis. The process consists of four main steps: (I) Edge detection using the Canny algorithm to identify bone boundaries; (II) Connected-component labeling to isolate specific bone edges; (III) Extraction of reference points along the labeled edges; and (IV) Computation of transformation matrices to track bone movement across frames. The final panel illustrates the result of this process, showing the segmented tibia and femur overlaid on the original MRI image, similar to those seen in Figure 1.

Figure 3:

Result of the semi-automated segmentation process applied to a representative frame from the dynamic MRI sequence shown in Figure 1. The tibia (orange) and femur (blue) masks are overlaid on the original MRI image, demonstrating the algorithm's ability to accurately delineate bone boundaries throughout the flexion-extension cycle. This segmentation serves as the basis for subsequent kinematic analysis.

Figure 4:

Comparison of kinematic parameters derived from manual and semi-automated segmentation for an exemplary dataset during a knee flexion-extension cycle. (Left) Angle between the long axes of tibia and femur plotted against flexion cycle percentage, where -100% represents maximum flexion, 0% full extension, and +100% return to maximum flexion. (Right) Rate of change of angle (angular velocity) over the flexion cycle, with negative values indicating flexion and positive values extension. The semi-automated method (blue) demonstrates smoother trajectories compared to the manual method (orange) in both angle and angular velocity plots, potentially indicating more accurate representation of continuous knee motion.

Figure 5:

Comparison of kinematic analysis results between automatic and manual segmentation methods. (Left) Rate of change of the tibiofemoral angle throughout the knee flexion-extension cycle, aggregated across all datasets. The x-axis represents the flexion percentage, where -100% indicates maximum flexion, 0% represents full extension, and +100% indicates return to maximum flexion. Shaded areas represent one standard deviation from the mean. (Right) Coefficient of Variation (CV) for frame-to-frame angle changes. Each point represents the CV for one dataset.