**Figure 1:** Dynamic MRI frames of knee motion during a full flexion-extension-flexion cycle. Each frame represents a 2-degree increment in knee angle. Frame 0 shows maximum flexion, with subsequent frames progressing through extension and returning to flexion in the final frame.

**Figure 2:** Schematic overview of the semi-automated pipeline for bone shape tracking. The process includes: (I) Canny edge detection for detection of bone boundaries; (II) Connected-component labeling to isolate edges; (III) Extraction of reference points along edges; and (IV) Reference point transformation of the tibia, illustrating the binary edge (white) with initial reference points (orange dots) displaying misalignment due to bone movement, and after applying the estimated optimal transformation parameters (green dots)

**Figure 3:** Example of semi-automatically tracked segmentation of the tibia (blue) and femur (orange) at different points during the knee motion cycle overlaid on the base CINE frames.

**Figure 4:** Comparison of relative bone motion parameters during knee flexion-extension cycles using semi-automatic and manual segmentation. Panels show anterior-posterior (left) and superior-inferior (right) centroid distances between tibia and femur. Top row represents extension phase (flexed to extended), bottom row shows flexion phase (extended to flexed). Shaded areas indicate variability across subjects: orange for manual and blue for semi-automatic segmentation.