- **Title:** Acquisition of 3D Knee Geometry under Weight-Bearing Conditions using a C-Arm CT Scanner

- **Purpose**

  Recent developments in C-Arm CT provide a promising technique to characterize the knee joint under loaded conditions. We were able to acquire data in a horizontal scan plane for *the first time* using our C-Arm system. The remaining challenge is compensation for the involuntary tremor of the standing subject during a weight-bearing acquisition. We constructed the 4D Digital Extended Cardiac-Torso (XCAT)-based knee model, and controlled it to behave as a human patient does. Computationally efficient methods for generating 2D projections and volume reconstruction are presented.

- **Methods and materials**

  We used an 8-camera optical tracking system to capture 9 volunteers' motion at a rate of 120 Hz while standing with 60 degree of knee flexion. We scaled and transformed the knee model to a subject so that its motion with a 6 DOF subject-specific knee joint was synthesized to the subject. To avoid unrealistic wrinkles in the acute angle of the joint, weighting based on the proximity to the joint was applied. The model was tessellated to triangles and 191 projections were generated based on ray casting. Based on all intersections per ray, a monochromatic absorption model was evaluated. Reconstruction was performed using filtered back projection accelerated using graphics hardware.

- **Results**

  Average motion of 2.4 mm (+/- 1.6 mm) was seen at both knees which is about 7 times larger than the detector resolution in 2×2 binning (0.316 mm pixel size). As a comparison, the left leg volumes with and without a subject's tremor were reconstructed. The motion corrupted volume's deviation from the static volume, defined as the root mean square deviation normalized to the mean of each voxel value, is calculated as 41.1%. The motion corrupted slice subtracted from the static slice demonstrates motion artifacts.

- **Conclusion**

  We tracked multiple markers with a detailed subject-customized lower body model based on the XCAT and simulated efficiently realistic projection data. From the study, we can estimate potential motion artifacts before actually scanning a human patient. We expect artifacts in reconstructions to be significant for squat positions if no motion correction is applied; the effect will be even worse in patients with knee pain.

- **Clinical relevance/application (200 characters)**

  Accurate measurement of relative bone location (i.e. kinematics) in vivo during weight-bearing activities provides valuable insight into the functioning of healthy and injured joints.

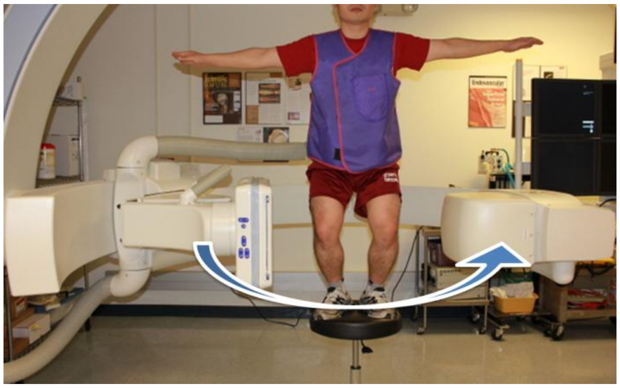
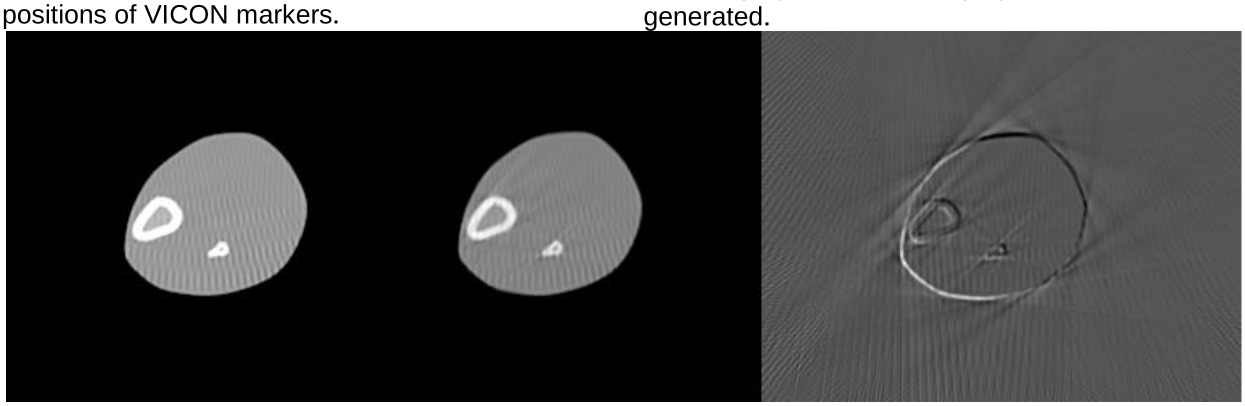


Figure 1. C-Arm CT system rotating in a horizontal scan plane with a patient standing in an upright position.

Figure 2. VICON optical tracking system with suitably placed markers to capture the motion of a lower body.

Figure 3(a). The XCAT-based lower body model were scaled and transformed based on the positions of VICON markers.

(b). The first 2D projection. The model was forward-projected and 191 projections were generated.



(c). The 2D projections were backward-projected and a 512×512×512 volume was reconstructed. <u>Left</u>: the central slice of the left leg volume image. <u>Middle</u>: the center slice of the left leg volume image motion-corrupted. <u>Right</u>: the difference between the left and middle images.