

Fiducial marker-based motion compensation for the acquisition of 3D knee geometry under weight-bearing conditions using a C-arm CT scanner

Innovation/Impact: Today's diagnostic methods to investigate knee pathology are limited either to a supine or prone position in MR and CT scanners, or have limited ability to image bone tissue (open magnet systems). A suitable system to investigate this would be a flat-panel angiography system because it has high spatial resolution (0.3x0.3 mm pixel size in 2x2 binning) and good bone contrast. Moreover, it is highly flexible in terms of angulation which allows data acquisition under weight-bearing conditions. However, images acquired while scanning a patient in an upright position are particularly vulnerable to motion. The proposed methods reduce the motion artifacts.



A volunteer was scanned while standing in a C-Arm CT. The C-Arm rotates in a horizontal plane. One-mm Tantalum markers were suitably attached around knee.

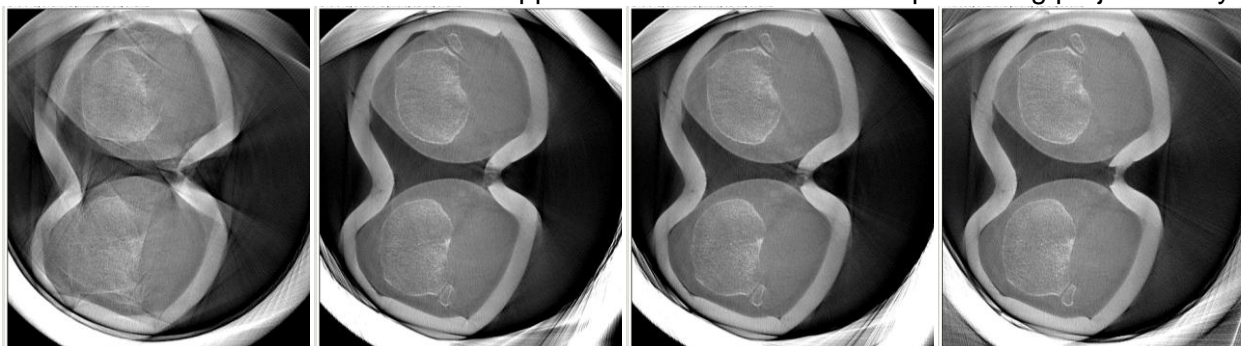
Motion correction methods: The static mean 3D position of a marker can be determined by identifying its location in several projections [1]. Eight markers were used as references to correct time-variant motion. The reference estimation in a C-arm CT system with arbitrary trajectories can be done using a projection matrix and identified markers in projections. Three corrections approaches were compared:

- 1) Simple projection shifting in 2D:** The references in 3D were forward-projected onto a projection. The projection was shifted the amount of the difference (Δu , Δv) between the mean of forward-projected references and the mean of detected markers.
- 2) Deformable projection warping in 2D** using approximate thin plate spline mappings [2]: The detected markers were mapped smoothly onto the forward-projected references. Due to noise of the control point locations, the exact spline interpolation was relaxed.
- 3) Rigid body warping in 3D:** A 3D transformation matrix performs 3 rotations and 3 translations in x, y, and z directions. The 6 parameters for the matrix were optimized to minimize the distance of transformed references from the identified markers in a projection.

For the purpose of image quality comparison, we used the Euclidean distance between the average locations of the identified markers and the projected references after

| | No | 1) 2D | 2) 2D | 3) 3D |
|------------------|------------|----------|----------|----------|
| Methods | correction | Shifting | Warping | Warping |
| Error (pixel/mm) | 10.8/3.24 | 3.7/1.11 | 1.4/0.42 | 1.5/0.45 |

transformation as error measure. The error measures are comparable for deformable 2D warping and 3D warping (see table). The image quality with 3D warping, however, is better since the 3D correction can correct for opposite motions at different depths along projection rays.



No correction

1) Projection shifting 2D

2) Projection warping 2D

3) Warping 3D

References

- [1] T. E. Marchant, A. M. Amer, and C. J. Moore, "Measurement of inter and intra fraction organ motion in radiotherapy using cone beam CT projection images," *Physics in Medicine and Biology*, vol. 53, p. 1087, 2008.
- [2] G. Donato and S. Belongie, "Approximate thin plate spline mappings," in the 7th European Conference on Computer Vision, 2002, pp. 531-542.