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UNITED STATES DEPARTMENT OF VETERANS AFFAIRS

2D-3D Registration via Accelerated Computation of Digitally Reconstructed Radiographs (DRRs)

Duane Storti, Grant Marchelli, and Brian Fabien
Mechanical Engineering, UW Seattle

We present initial results from a marker-free system for measuring bone motion by registering computed 2D projections of 3D bone geometry with stereo pairs of 2D fluoroscope images. Bone geometry is obtained by segmenting 3D CT scan data, and simulated projections (DRRs) are computed using the CUDA-accelerated DRRACC software demonstrated at GTC2013. Bone motion is determined by optimizing correlations of corresponding simulated (DRR) and measured (fluoroscope) 2d image pairs. Results include animations of bone motions, validation of measurement accuracy, and timings for processing data sets.

Data Acquisition

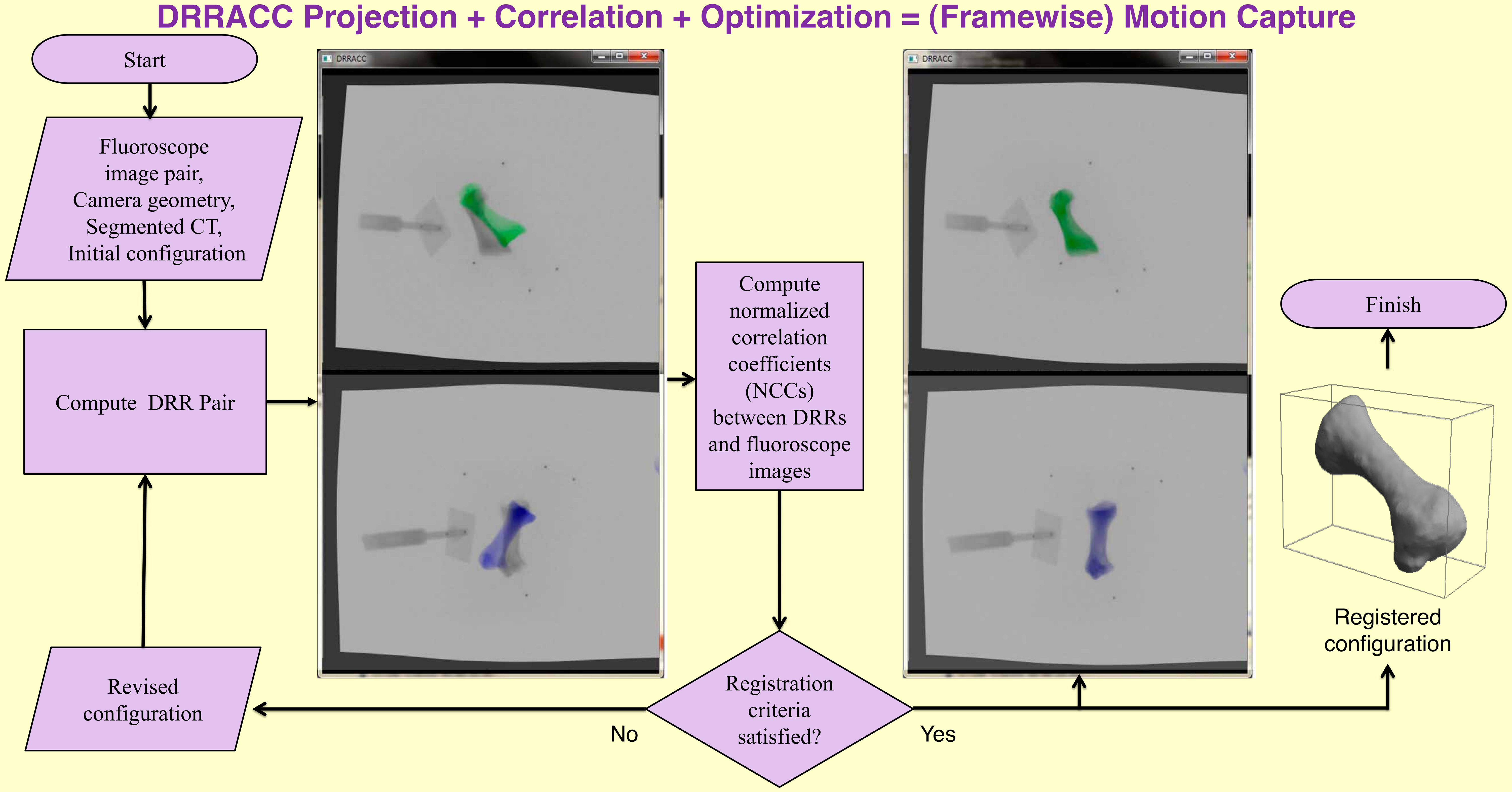
3D: CT scanner

CT data is segmented to identify voxel set for each bone.
Intensity file and label file comprise the motion capture inputs from the 3D imaging system.

2D: Bi-plane Fluoroscope

Imaging of calibration block defines camera geometry (source and screen locations).
Dual fluoroscopes capture synchronized stereo image pairs.
Camera geometry and stereo image pairs comprise the motion capture inputs from the 2D imaging systems.

DRRACC Projection + Correlation + Optimization = (Framewise) Motion Capture



Summary of Results

- Demonstrated feasibility of non-invasive, marker-free motion capture based on registration of projections of 3D CT imaging with 2D stereo pairs of fluoroscope imaging.
- Sub-millimeter accuracy based on validation with motion generated by calibrated translational stage.
  (10 position stage translation mean absolute error = 0.01 mm)
- Cuda's 3D texture capabilities support efficient memory access and interpolation for computing projections of full CT data set.
- Implementing pixel computation using thread-level parallelism accelerated DRR computation by ~ 250X.
  (700 msec CPU vs 2.8 msec GPU)
- Computation time for registration to a complete stereo fluoroscope imaging sequence reduced from 15 hours to ~1 hour by parallelizing the DRR and normalized correlation coefficient (NCC).

Publications

[1] Marchelli, G., Haynor, D., Ledoux, W., Ganter, M., and Storti, D., Graphical User Interface for Human Intervention in 2D-3D Registration of Medical Images, Proceedings of the 9th International Conference on Multibody Systems, Nonlinear Dynamics and Control, Paper #DETC2013-13659.

[2] Marchelli, G., Haynor, D., Ledoux, W., Tsai, R., and Storti, D., A flexible toolkit for rapid GPU-based generation of DRRs for 2D-3D registration, SPIE paper #8669-47, 2013.

[3] Storti, D., and Marchelli, G., Real-time Interacttion with 3D Medical Imaging using 3D Textures, GTC 2013 P01790, http://www.gputechconf.com/gtcnew/on-demand-gtc

[4] Fabien, B. C., Parameter optimization using the L-infinity exact penalty function and strictly convex quadratic programming problems, *Applied Mathematics and Computation*, vol. 198, pp. 834-848, 2008. http://bas-5.me.washington.edu/snlp/index.html

[4] Hu,Y., Haynor,D. , Fassbind,M., Rohr,E., and Ledoux,W., "Image Segmentation and Registration for the Analysis of Joint Motion from 3D MRI," Proc. SPIE **6141**, pp. 133-142, *Medical Imaging: Visualization, Image-Guided Procedures,&Display*, 2006.

Further information and Acknowledgment

Please contact *storti@uw.edu*.

The authors gratefully acknowledge support by VA RR&D Grant A6973R and significant contributions from collaborators David Haynor of UW Radiology and William Ledoux, Joseph Iaquinto, and Matt Kindig of the Seattle VA Center of Excellence for Limb Loss Prevention and Prosthetics.