An Electrostatic Model for Assessment of Joint Space Morphology in Cone-Beam CT

Computer Integrated Surgery II – Project 11

Mini-Checkpoint Presentation

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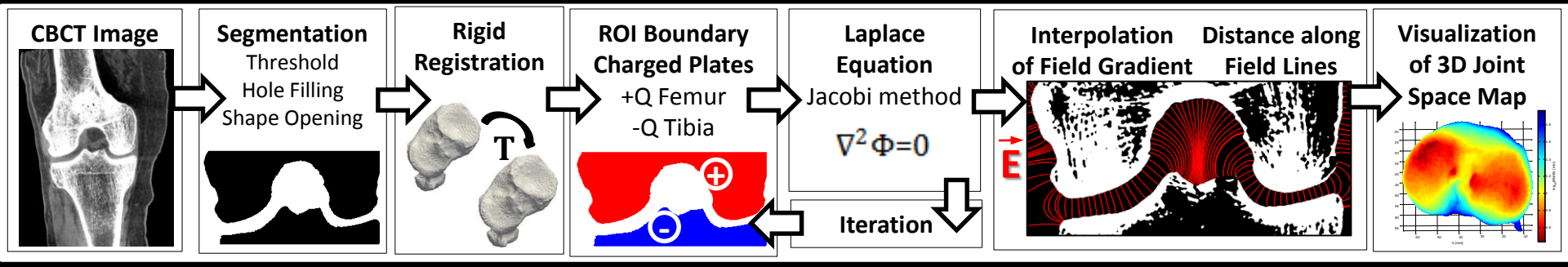
Mentor: Jeff Siewerdsen

Goals

1. To develop an efficient method of mapping joint space width in CBCT volumes using electrostatics.



2. To apply the method to the analysis of osteoarthritic (OA) knees and non-OA knees under weight-bearing and non-weight-bearing conditions. (Identify regions of subtle morphological change, cartilage erosions)

62 Scans Total: 31 knees in sitting and standing position, 18 OA, 13 non-OA.

Final Deliverables

Minimum Deliverable (Expected by 03/01/2014)

1. A set of prototyped MATLAB functions for joint space mapping using the capacitor model. ✓
2. A set of prototyped MATLAB functions for segmentation. ✓
3. Documentation of existing code. ✓

Expected Deliverable (Expected by 04/01/2014 → PUSH BACK TO 06/01/2014)

1. A set of validated MATLAB functions for joint space mapping using the capacitor model. ✓
2. A refined MATLAB function for segmentation. ✓
3. Detailed analysis of algorithm performance (convergence characteristics, accuracy, speed etc). ✓
4. MATLAB routines for visualization of the analysis results (volume rendering + GUI) in VTK. ✓
5. Provide relevant documentation for code hand-off. (80% complete)
   (Need to organize into a central document)
6. Conduct a phantom study to compare the algorithm with existing closest-point method. ✓
7. Apply the analysis pipeline to the analysis of OA and non-OA knee joints under load-bearing (standing) vs non-load-bearing (sitting) conditions (62 CT Volumes). (? % complete)
   (Need to discuss with Prof. Siewerdsen)

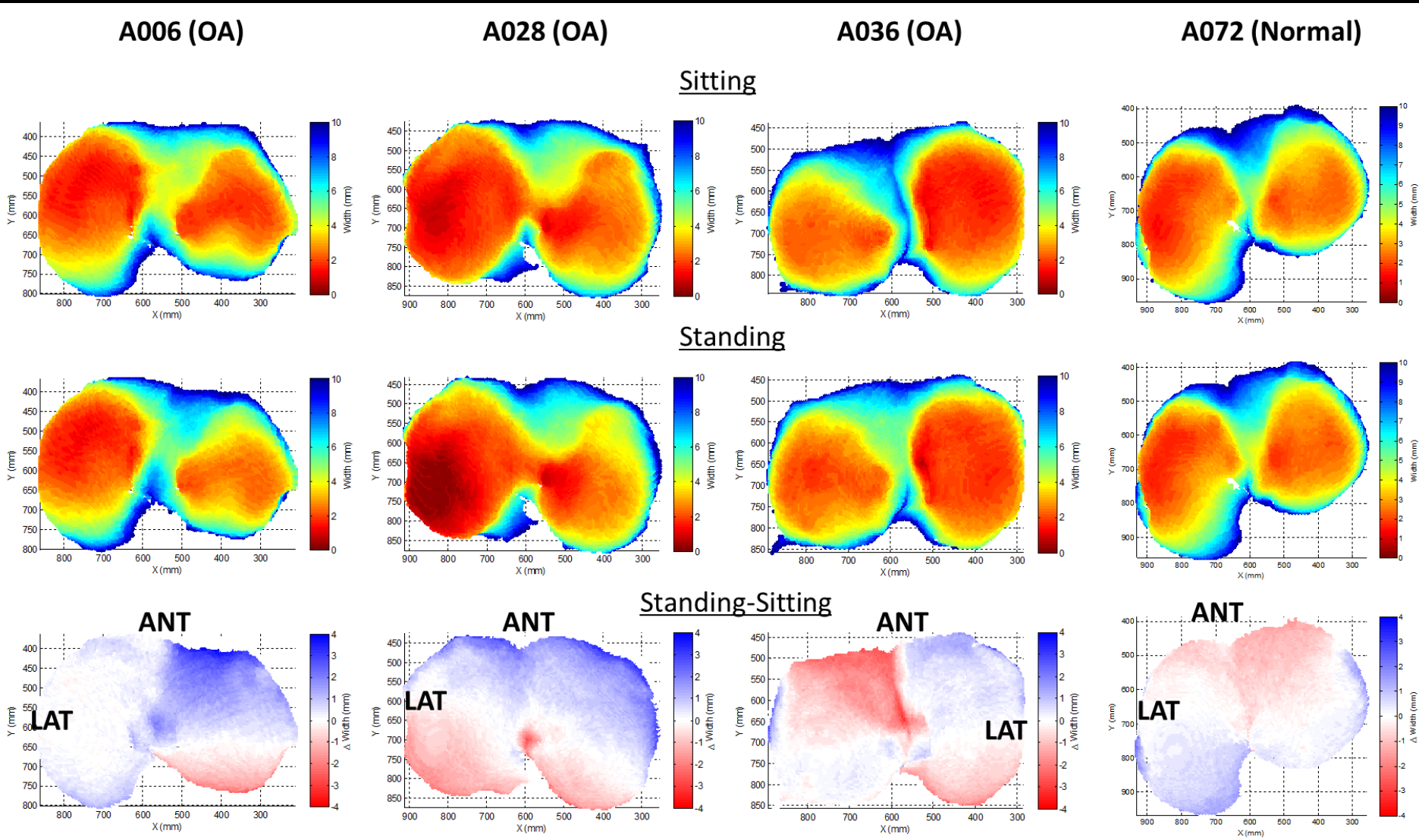
Maximum Deliverable (Expected by 07/01/2014)

1. Submit abstract to the American Association of Physicists in Medicine (AAPM) annual meeting. ✓
   (Abstract accepted, oral: Q. Cao, G. Thawait, G. J. Gang, W. Zbijewski, T. Riegel, S. Demehri, and J. H. Siewerdsen, "An Electrostatic Model for Assessment of Joint Space Morphology in Cone-Beam CT," The 56th Annual Meeting of the AAPM. July 24th, 2014, Austin TX**)**
2. Submit a technical paper.

Final Timeline

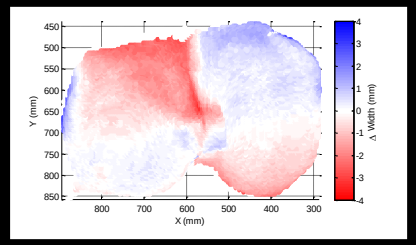
Stage	Task	6-Jan	13-Jan	20-Jan	27-Jan	3-Feb	10-Feb	17-Feb	24-Feb	27-Feb	3-Mar	10-Mar	17-Mar	24-Mar	31-Mar	7-Apr	14-Apr	9-May	1-Jun	1-Jul
Preliminary Experimentation	Literature Review				✓															
	Problem Formulation					✓														
	Method Selection						✓													
	Synthesize Toy Data									✓										
	Experiment with Methods for Knee Volume Segmentation							✓												
	Prototype Algorithm for Joint Space Analysis											✓								
	Experiment with Visualization Toolchain (Volume Rendering, etc)									✓										
	Preliminary Profile and Benchmark								✓											
	Project Proposal Presentation										✓									
	Milestone #1																			
Algorithm Validation and Refinement	Refine and Test Segmentation Method														✓					
	Apply Joint Space Analysis Algorithm to Knee Data																			
	Algorithm: Consider alternative boundary conditions										✓									
	Algorithm: Characterize error												✓							
	Algorithm: Characterize Rate of Convergence															✓				
	AAPM Abstract														✓					
	Phantom Study																			
	Tweak, Debug, Profile, Document																✓			
	Project Checkpoint Presentation (TBA)															✓				
	Milestone #2																			
	Finalize Visualization Toolchain (MATLAB wrapper etc)																✓			
Documenta	Finalize documentation																			
	Milestone #3																			
	Final Presentation																			
	Technical Paper																			

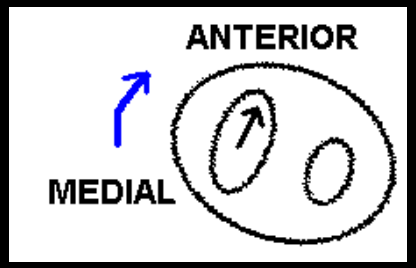
Deliverables (Goal 2)

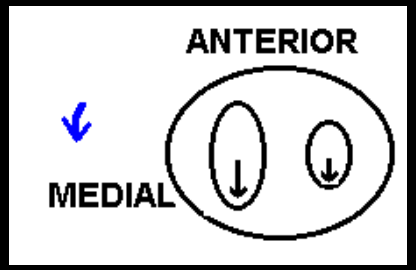


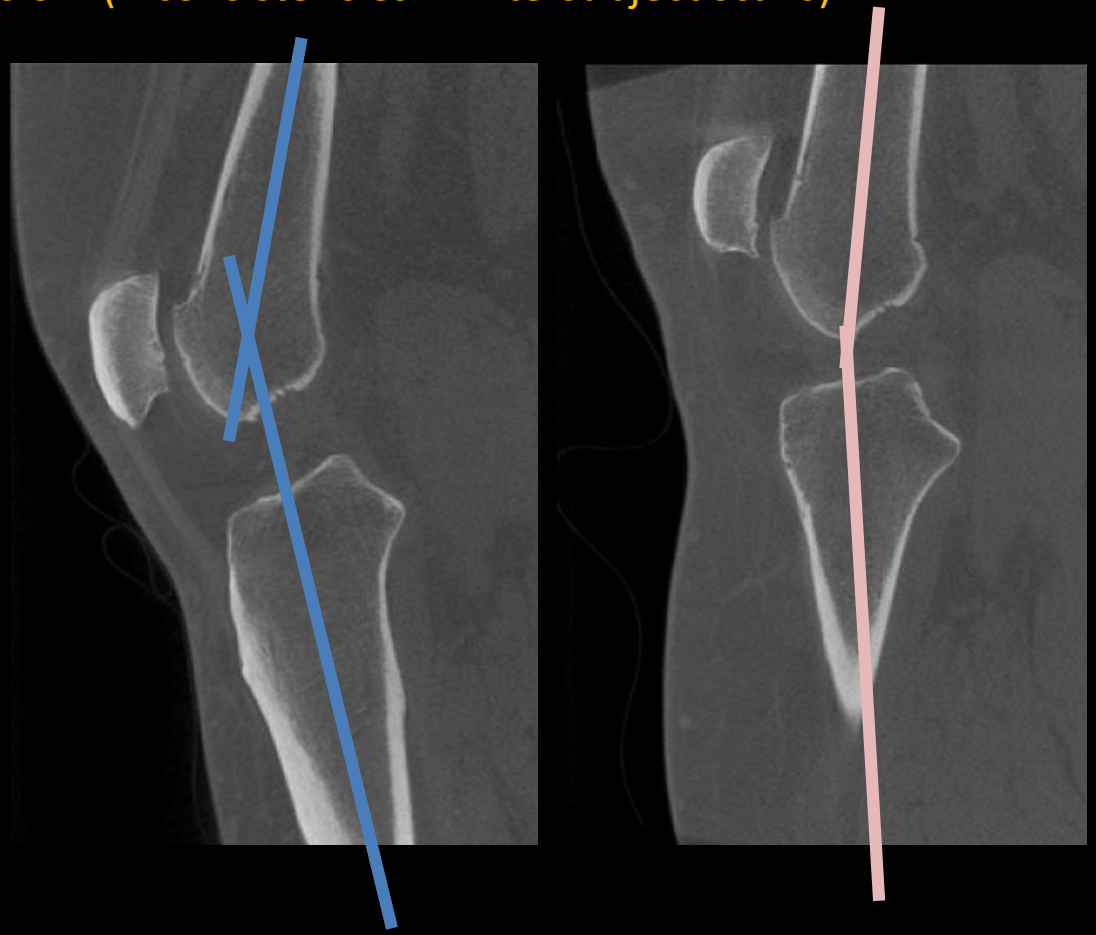
Data Normalization

Screw-Home Mechanism: External rotation of the tibia during the last 20 degrees of knee extension. (Inconsistencies in intersubject scans)





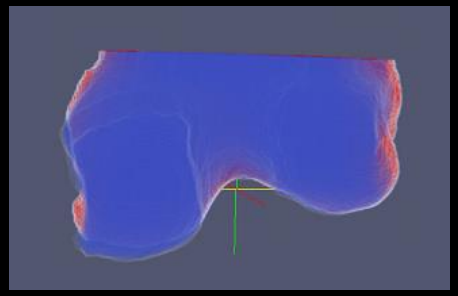




Data Normalization

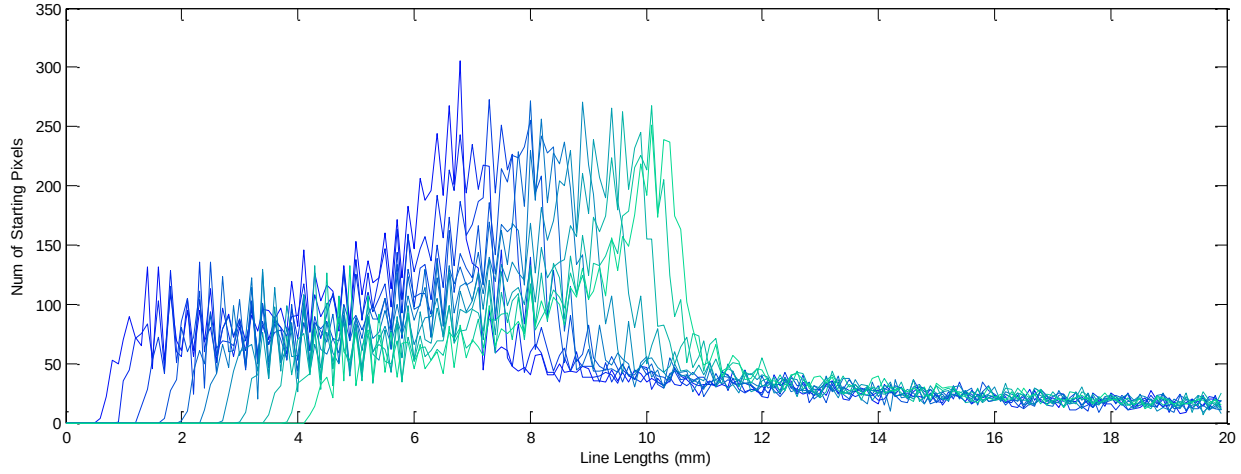
Possible strategies?

1. Correct for rotation, x-y motion with a 5-DOF rigid transformation



$$T|_{sit}^{stand} = \begin{bmatrix} a & b & c & x_t \\ d & e & f & y_t \\ g & h & i & z_t \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} a' & b' & c' & x_t \\ d' & e' & f' & y_t \\ g' & h' & i' & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & z_t \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

2. Analyze the data as-is. Find patterns in feature space.



Thanks!