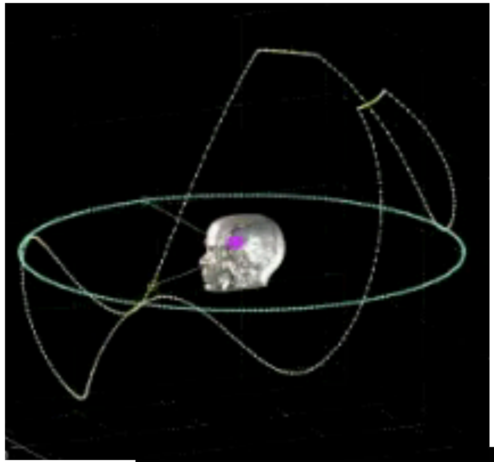
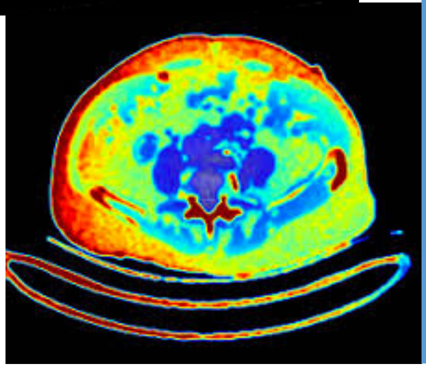


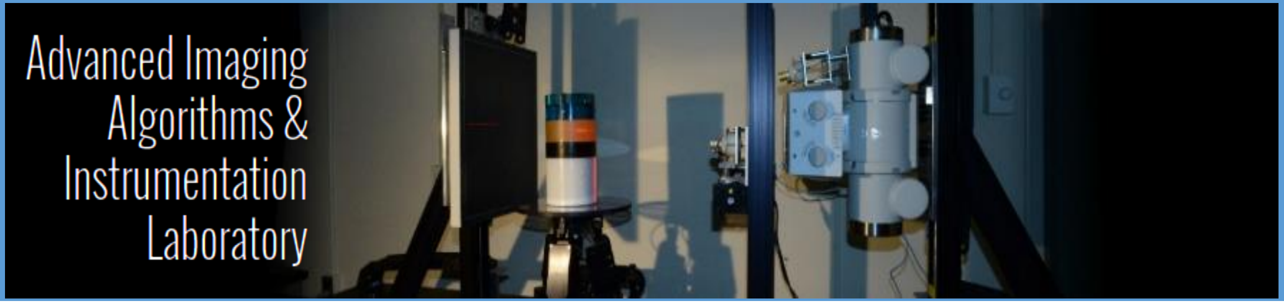


Dynamic x-ray beam positioning for low-dose CT

Computer Integrated Surgery II

Andrew Mao, William Shyr

Mentor: J. Web Stayman Ph.D.



AIAI Lab

JOHNS HOPKINS BIOMEDICAL ENGINEERING

JOHNS HOPKINS MEDICINE

JOHNS HOPKINS
BIOMEDICAL ENGINEERING

Team Members

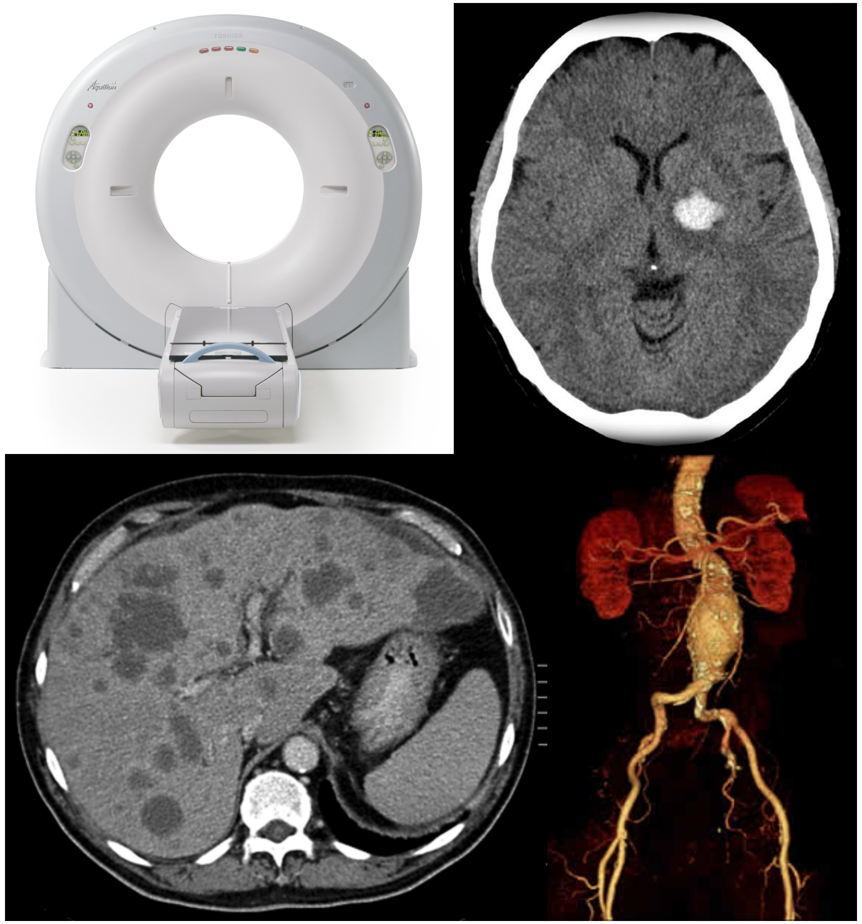
Andrew Mao

William Shyr

Dr. Web Stayman

Motivation

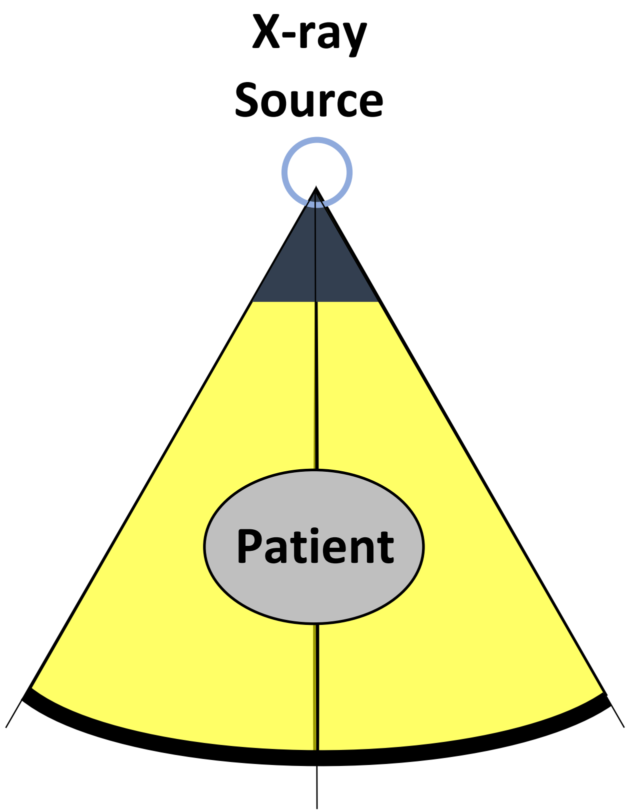
- CT has vast diagnostic utility in medicine
- # procedures growing >10% per annum
- 15% of all radiological exams, but 50% of effective dose
- Publicly recognized need for dose reduction methods
- “One size fits all”
- Fluence field modulation (FFM) strategies promise dose reduction without loss of image quality

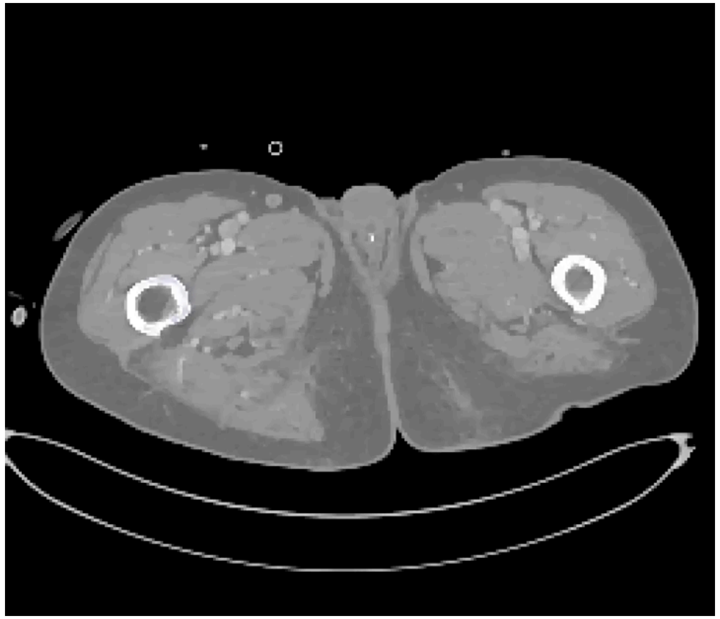


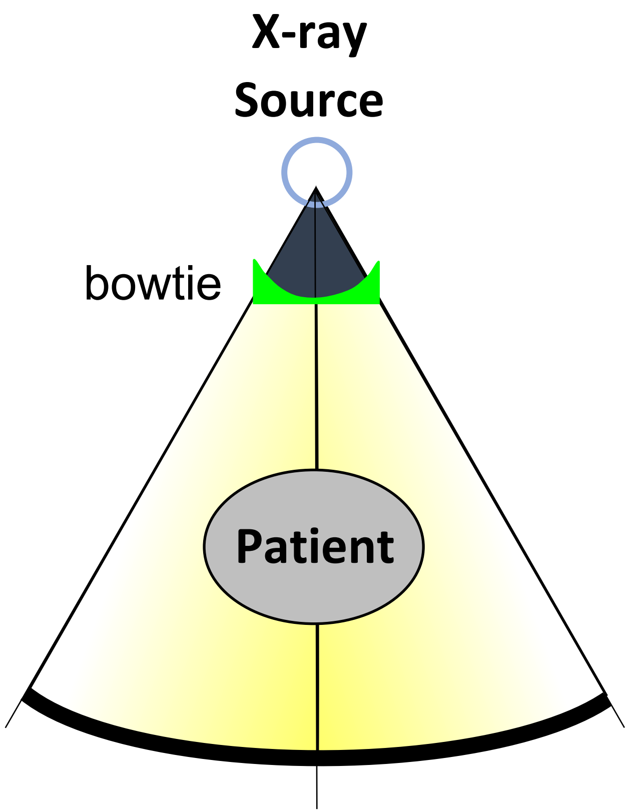
Background

Beers-Lambert Law

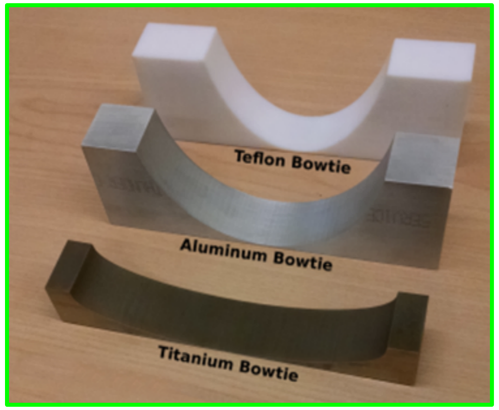
$$I = I_0 e^{-\mu \ell}$$

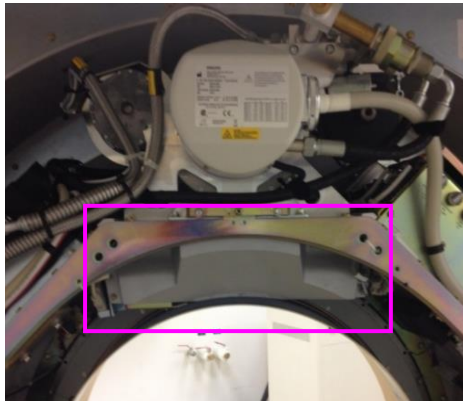


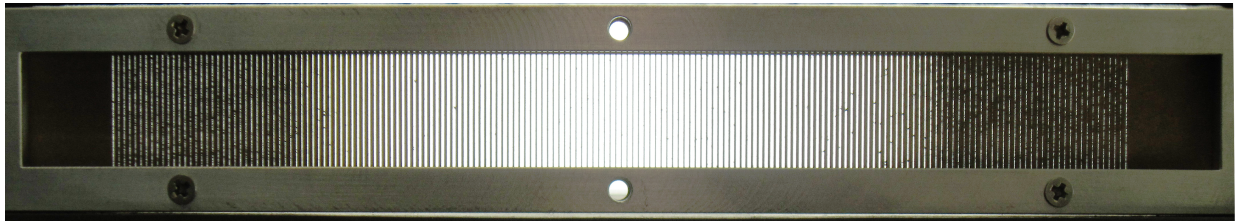




Background







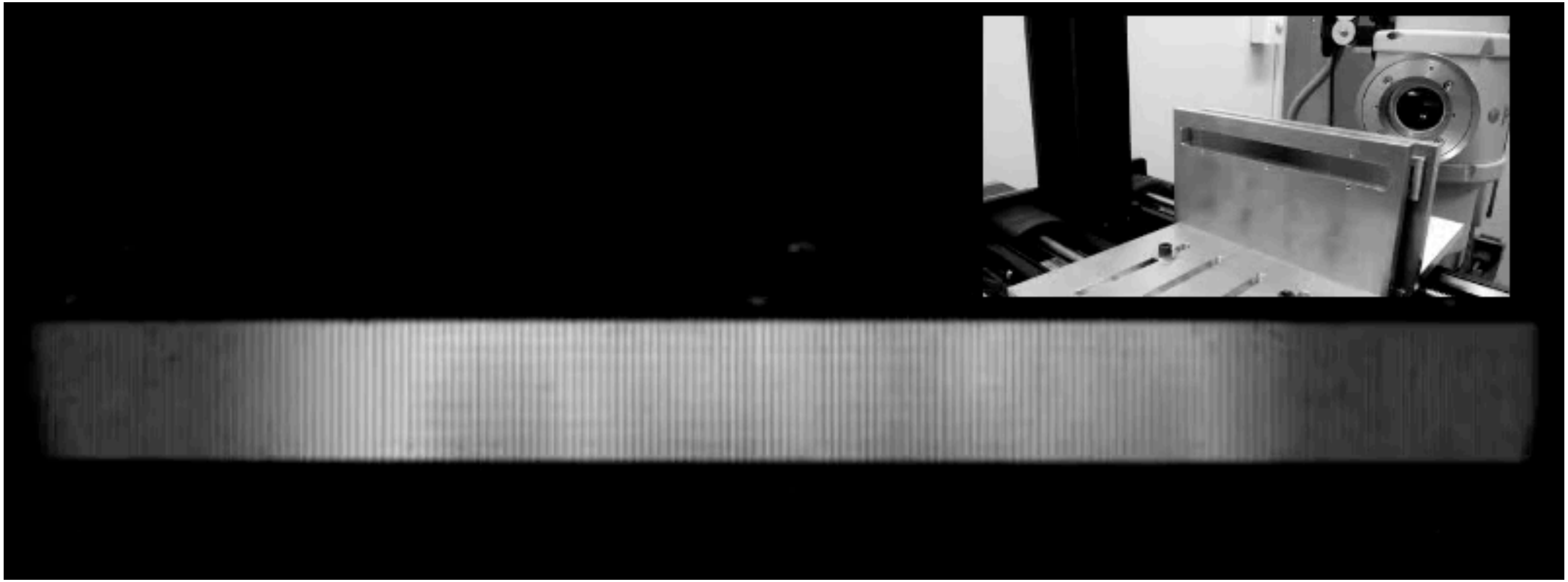
Bowtie filters

- Shape via variable thickness
- Variety of possible materials
- Reduce dynamic range of data
- Help to homogenize noise

Multiple aperture device (MAD)

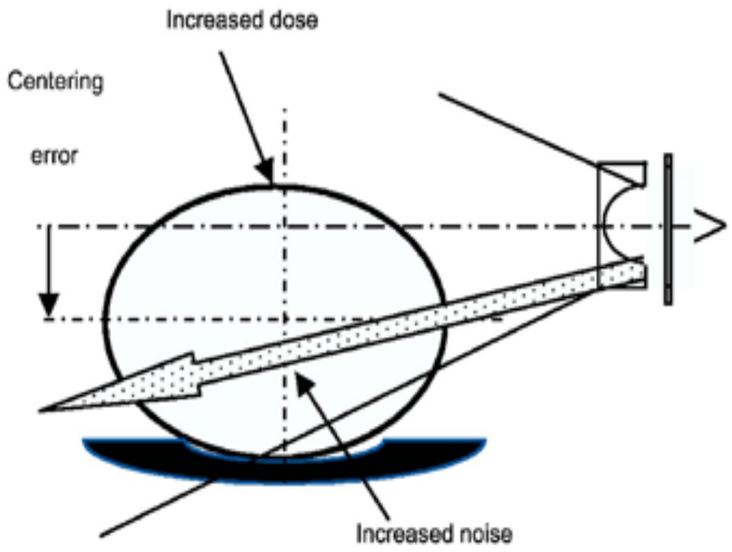
- Binary filter (0% or 100% pass)
- Spectrally neutral
- Compact design (few mm of tungsten)
- Large scale shaping with small actuation

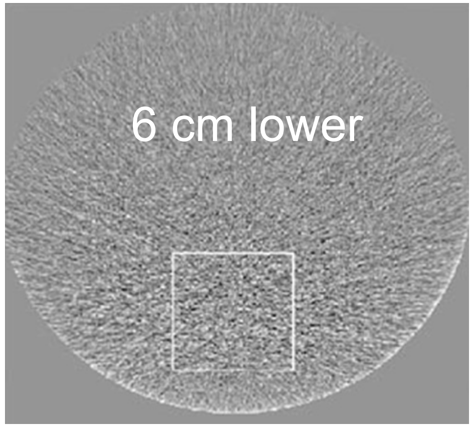
Background



Need & Significance

- Patient often miscentered within bore
  - Average 3cm below center
  - 25.8% dose increase
  - up to 22% noise increase
- Dose and image quality consequences
- Requires repositioning and retaking images
- Impractical in emergency medicine
- Bowtie filters often simply removed -> increased dose





Toth et. al. Med. Phys. 2007
Habibzadeh et. al. IFMBE Proceedings, 2010

Project Goal

To achieve dynamic x-ray beam positioning in low-dose CT acquisitions and quantitative performance assessment for arbitrary patient positioning in emergency medicine applications

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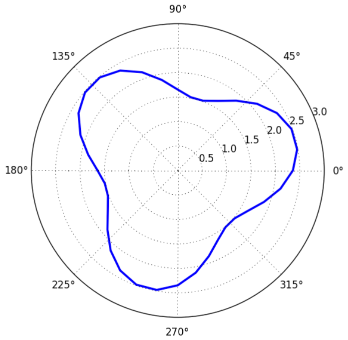
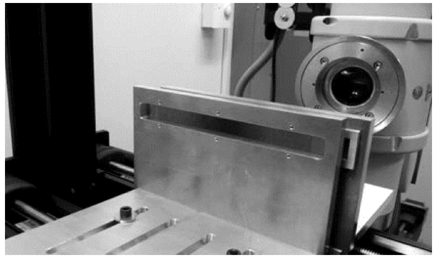
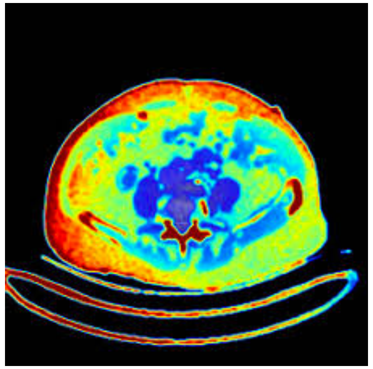
Technical Approach

2D Scout Scans → Compute filter trajectory → Projection data with beam filter actuation → Reconstruction → Performance Assessment







Calibration & Optimal Trajectory

- Object assume to be ellipse
- Parameter vector $\vec{x}$: ellipse center, width, height, μ
- $\arg\min_{\vec{x}} ||P\vec{x} - g||^2$
- P is forward projection operator, g is the data
- Filter trajectory computed via optimization on bowtie translation to obtain flat fluence at detector at each angle

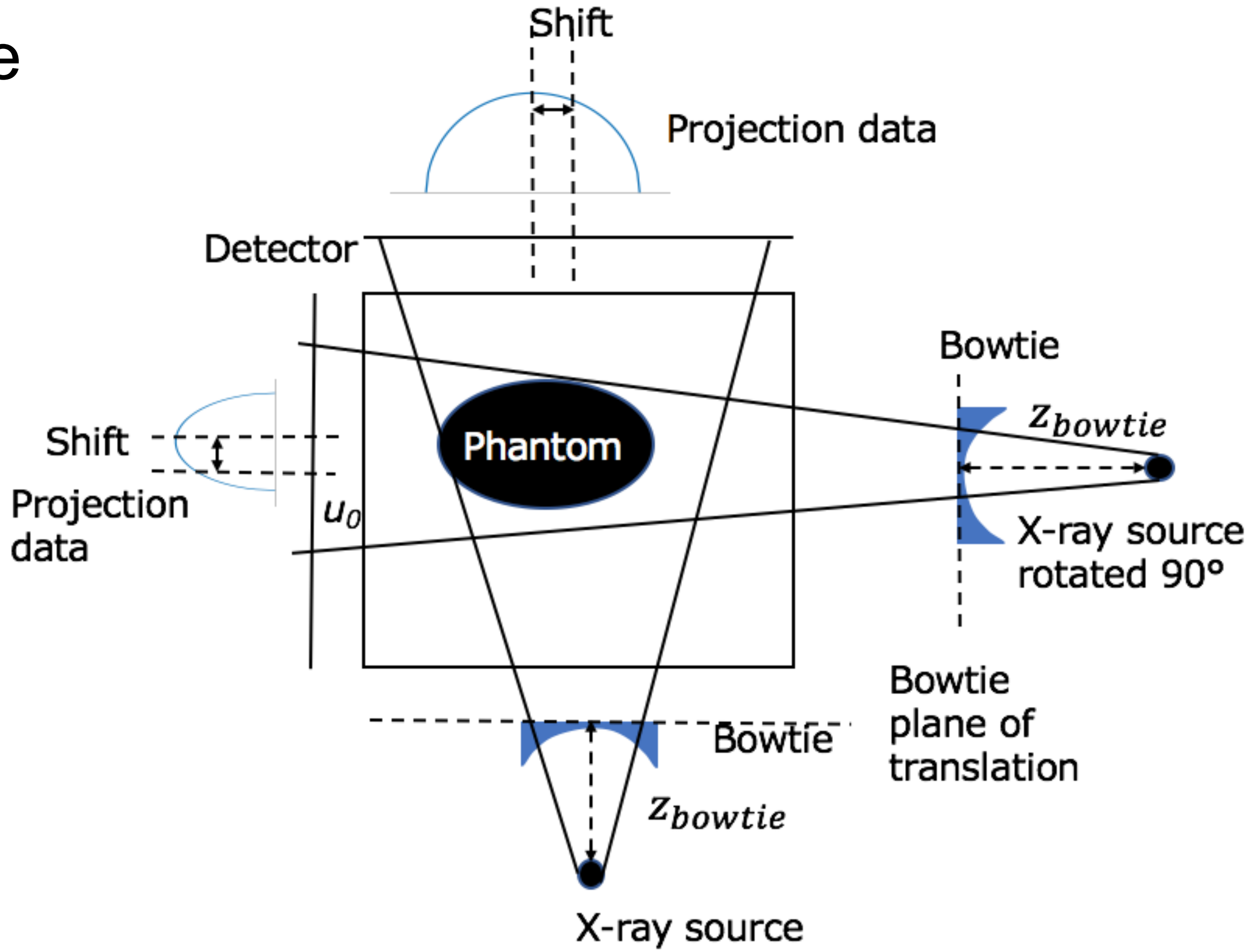
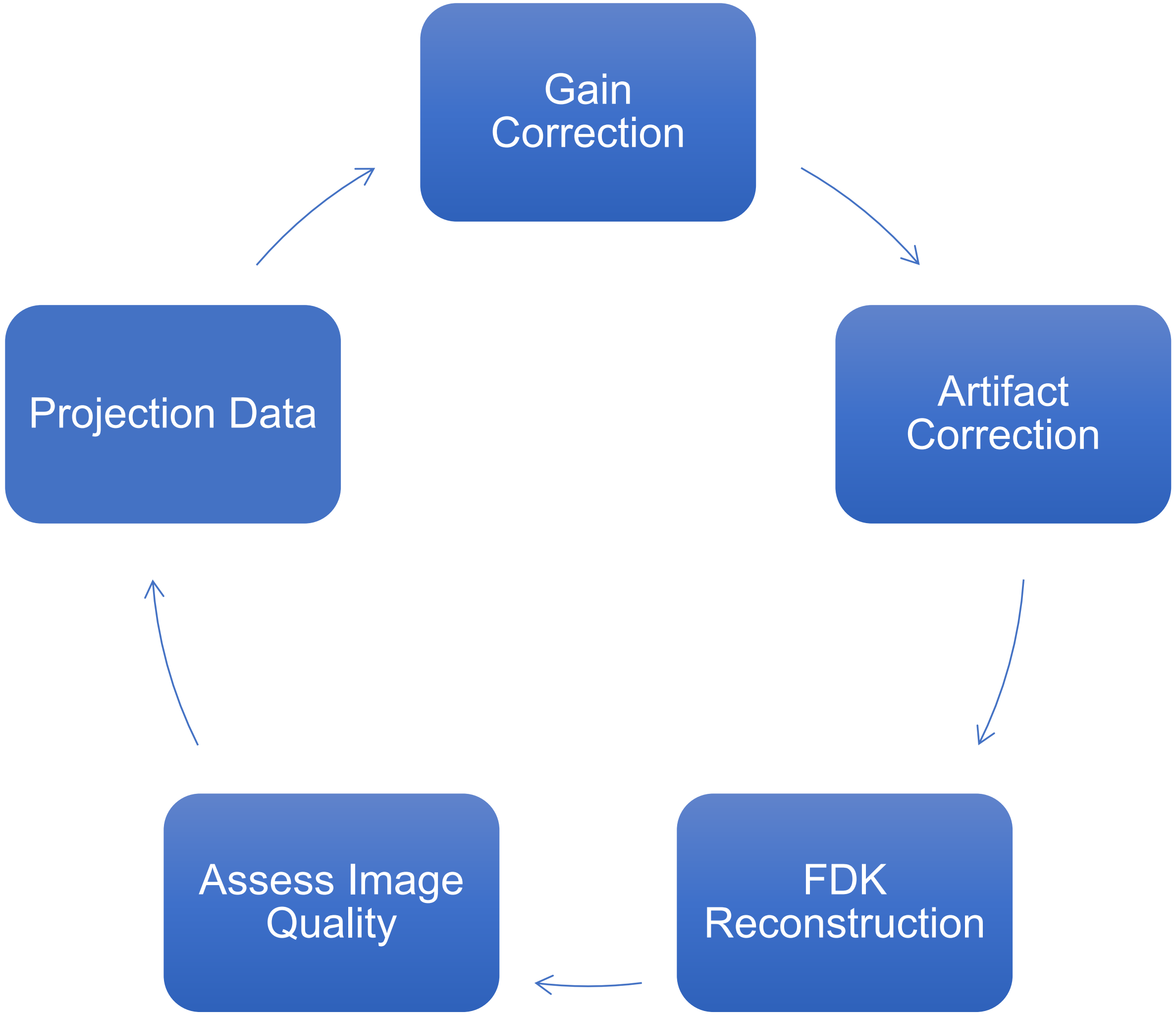


Image Acquisition & Reconstruction



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Deliverables

Minimum

- Constructed test bench setup & control software
- Working dose assessment and image reconstruction frameworks
- Calibration of object position in FOV using multiple view low-dose scans
- Computed beam filter trajectory for 360° acquisition

Expected

- Simulated image reconstructions on digital phantoms
- Performance assessment on phantom acquisitions using bowtie filters

Maximum

- Artifact correction for MAD imaging (*potential pitfall)*
- Performance assessment on phantom acquisitions using a single MAD

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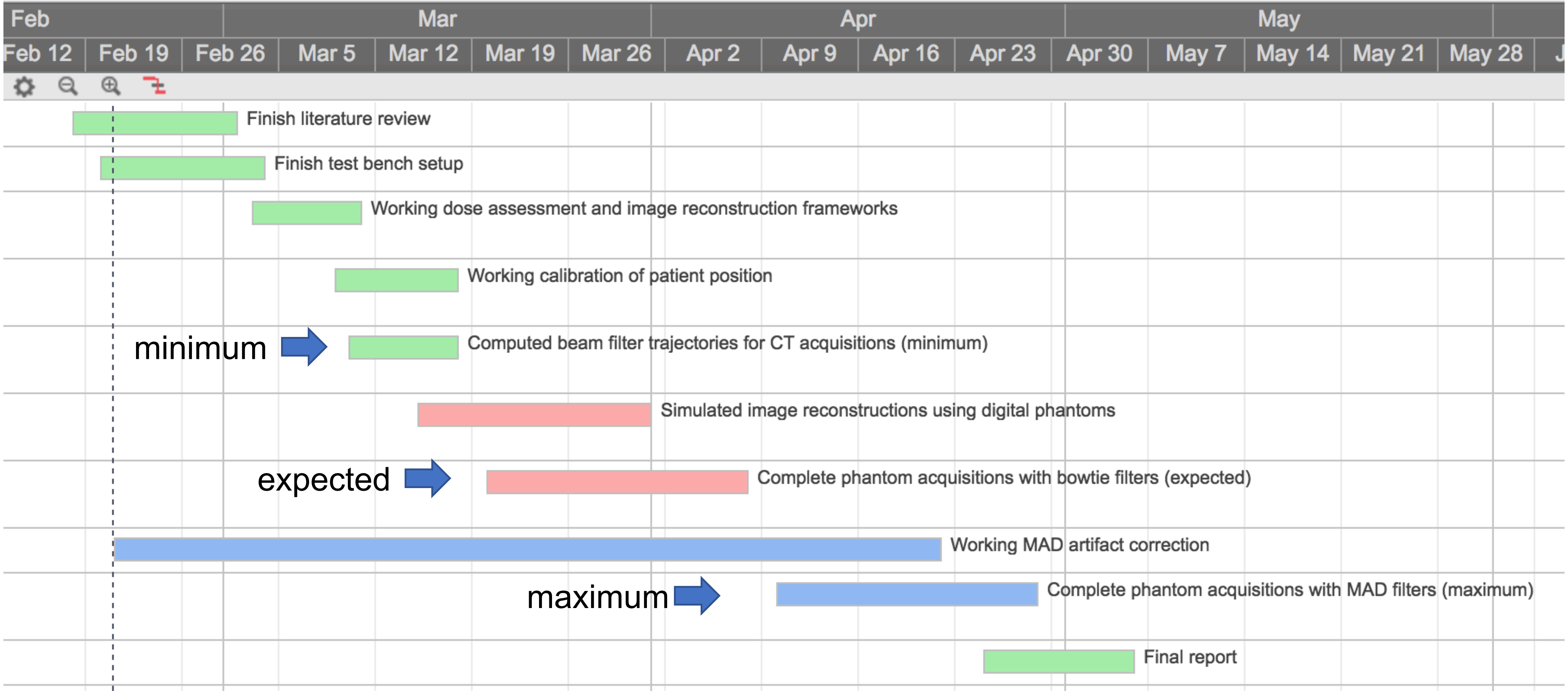
Dependencies

- Dependencies for simulations and image reconstruction
  - Access to GPU workstation (Met)
  - Access to CUDA tools (Met)
  - Digital phantom data (Met)
- Dependencies for physical phantoms
  - Access to prototyping facility (Met)
  - Access to beam filters (Met)
  - Access to CBCT test bench (Met)
- Advising dependencies
  - Mentor availability (Met)
    - Weekly meetings on Friday 2-3pm

Timeline



Feb
Mar
Apr
May
Feb 12
Feb 19
Feb 26
Mar 5
Mar 12
Mar 19
Mar 26
Apr 2
Apr 9
Apr 16
Apr 23
Apr 30
May 7
May 14
May 21
May 28
Finish literature review
Finish test bench setup
Working dose assessment and image reconstruction frameworks
Working calibration of patient position
minimum
Computed beam filter trajectories for CT acquisitions (minimum)
Simulated image reconstructions using digital phantoms
expected
Complete phantom acquisitions with bowtie filters (expected)
Working MAD artifact correction
maximum
Complete phantom acquisitions with MAD filters (maximum)
Final report

Milestones

Date	Description
3/1/17	Finish literature review
3/3/17	Finish test bench setup
3/10/17	Working dose assessment and image reconstruction frameworks
3/17/17	Working calibration of patient position
3/17/17	Computed beam filter trajectories for CT acquisitions (**minimum**)
3/31/17	Simulated image reconstructions using digital phantoms
4/7/17	Complete phantom acquisitions with bowtie filters (**expected**)
4/21/17	Working MAD artifact correction
4/28/17	Complete phantom acquisitions with MAD filters (**maximum**)
5/5/17	Final report

Management Plan

Andrew	Will
Image reconstructions	Scout scans & filter trajectories
Phantom acquisitions	Performance assessment protocol
Test bench setup & control software	
MATLAB functions for each step of technical approach	
Version Control using Git	
Weekly Mentor Meetings	
10+ hours at JHMI per week	

Reading List

1. Stayman, J. Webster, Mathews, Aswin, Zbijewski, Wojciech, Gang, Grace J., Siewerdsen, Jeffrey H., Kawamoto, Satomi, Blevis, Ira, Levinson, Reuven (2016): Fluence-field modulated x-ray CT using multiple aperture devices. *In: Kontos, Despina; Flohr, Thomas; Lo, Joseph (Ed.): SPIE Medical Imaging, pp. 97830X,International Society for Optics and Photonics 2016.*
2. Mathews, Aswin, Tilley II, Steven, Gang, Grace J., Kawamoto, Satomi, Zbijewski, Wojciech, Siewerdsen, Jeffrey H., Levinson, Reuven, Stayman, J. Webster(2016): Design of dual multiple aperture devices for dynamical fluence field modulated CT. *In: 4th International Conference on Image Formation in X-Ray Computed Tomography, pp. 29– 32, 2016.*
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6. Habibzadeh MA, Ay MR, Kamali AR, Ghadiri H, Zaidi H. The Influence of Patient Miscentering on Patient Dose and Image Noise in Two Commercial ct Scanners. 2010:327- 330.
7. Pari V. Pandharipande, Andrew T. Reisner, William D. Binder, Atif Zaheer, Martin L. Gunn, Ken F. Linnau, Chad M. Miller, Laura L. Avery, Maurice S. Herring, Angela C. Tramontano, Emily C. Dowling, Hani H. Abujudeh, Jonathan D. Eisenberg, Elkan F. Halpern, Karen Donelan, and G. Scott Gazelle. CT in the Emergency Department: A Real-Time Study of Changes in Physician Decision Making. Radiology 2016 278:3, 812-821
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