A Non-Rotational Approach to Computed Tomography

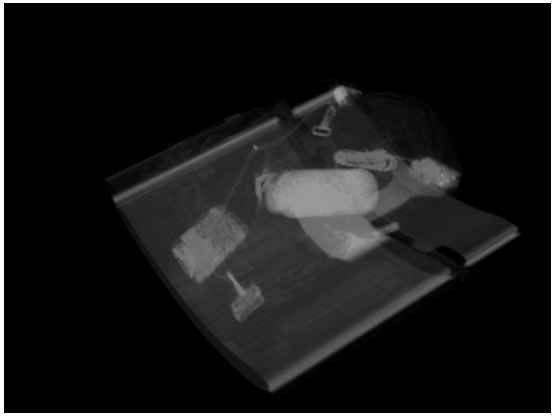
Zachary Sun, W. Clem Karl

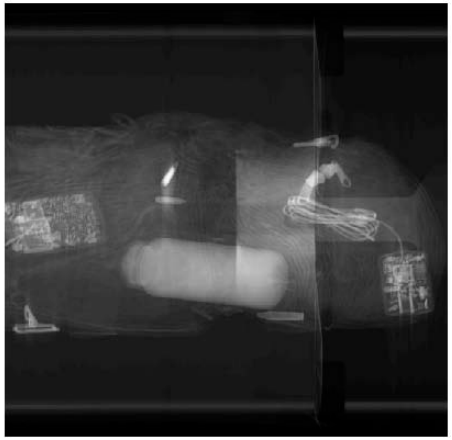
Boston University

Awareness and Localization of Explosive-Related Threats (ALERT)

Motivation

- Tomographic images produce 3D imagery which allow for higher accuracy in identifying targets/threats in luggage
  - All checked bags currently pass through CT machines such as the CTX9000
- Due to power and size constraints difficult for carry on
  - Currently rely on flat 2D images from line scanners
- Tomographic images for carry on bags would allow for better threat identification and thus increase passenger convenience
  - E.g. In the future you may no longer need to take out your laptop when going through security
- Analogic COBRA attempts to accomplish such a feat but still relies on rotational CT

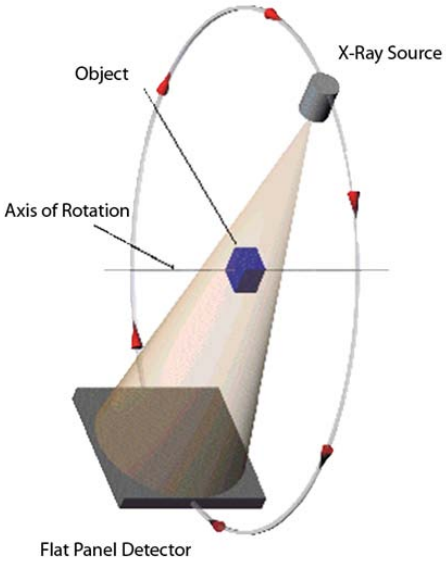




c) Analogic COBRA

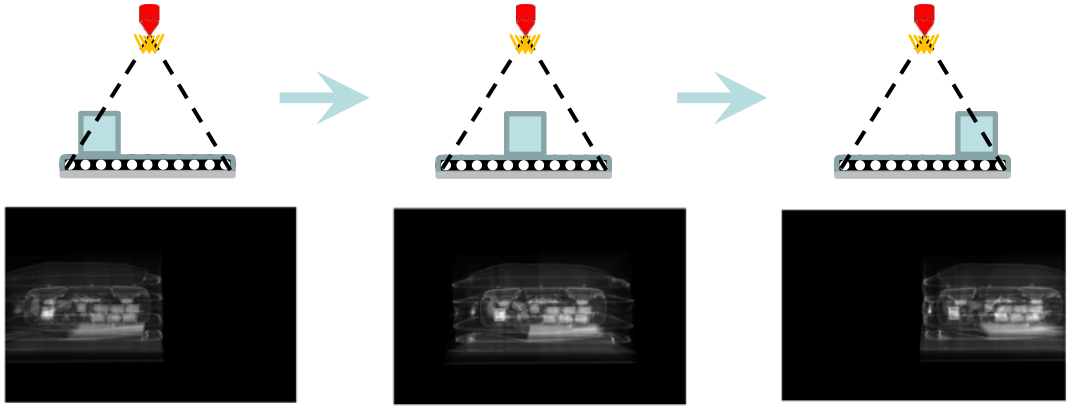
Cone-beam Computed Tomography

- Traditional tomography relies on a series of projections taken in a circular fashion.
- The need to rotate the source or object at high speeds results in big and expensive hardware.



Geometric Setup

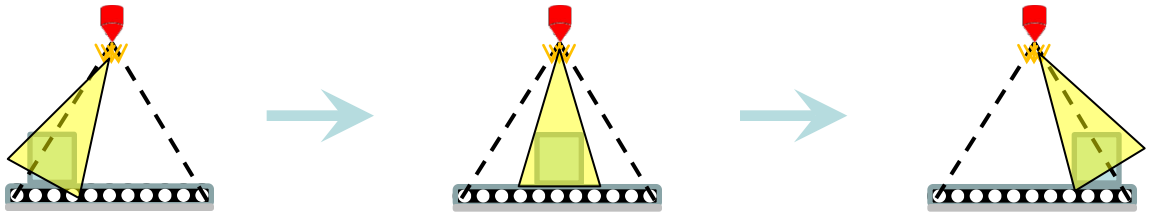
- Different views do not have to come from rotation
  - Can be achieved with linear motion
  - Object of interest moves linearly through a field of view
  - Each subsequent position provides a new perspective to the object



Position 1 Halfway Point Position n

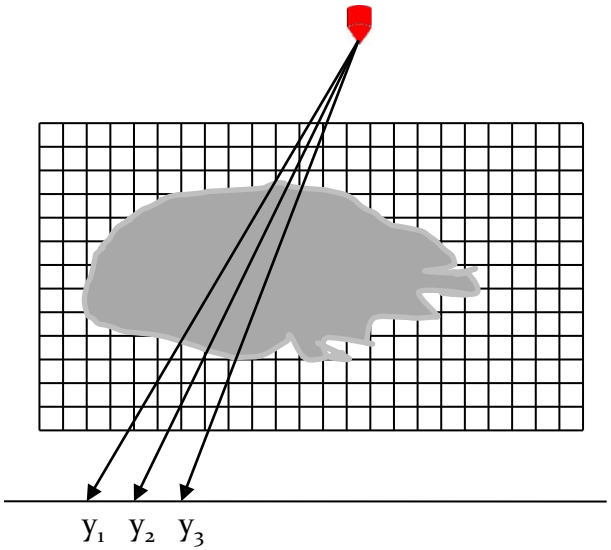
Limited Angle Tomography

- For full coverage need 180 degrees.
- Side views impossible with linear tomography unless object travels an infinite distance.
- Problem is forced to be a limited angle tomography
  - Direct methods such as Feldkamp-Davis-Kress no longer suitable
- Artifact Issues
  - Blooming
  - Ringing
  - Streaking



Model-Based Solution

- Without direct solution methods forced to use model-based approaches
- Tomography modeled as a linear system of equation, $y = Ax$
  - At a high level, each equation relates to the path an x-ray photon (y_1, y_2, y_3) travels

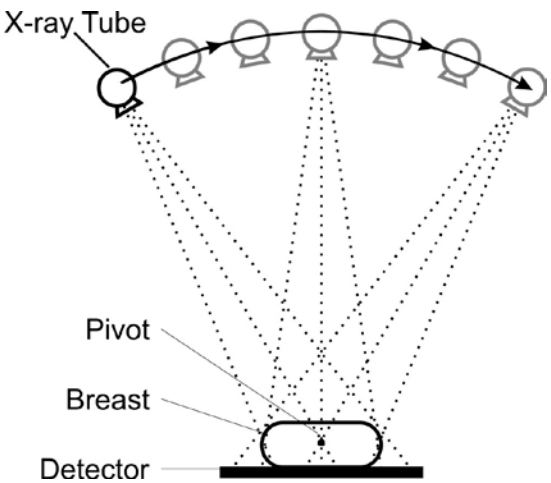


Computational Issues

- Matrix to describe tomography is very large and direct inverse is infeasible
  - Volumetric problems grow in size very quickly
- Many iterative methods where formation of the matrix is not necessary.
- Problem is also very parallelizable and so can leverage cluster computing and GPU based solutions.

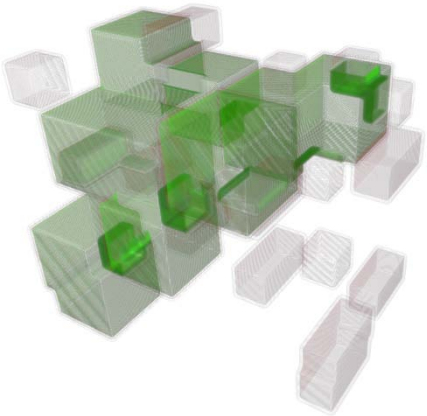
Connections to Tomosynthesis

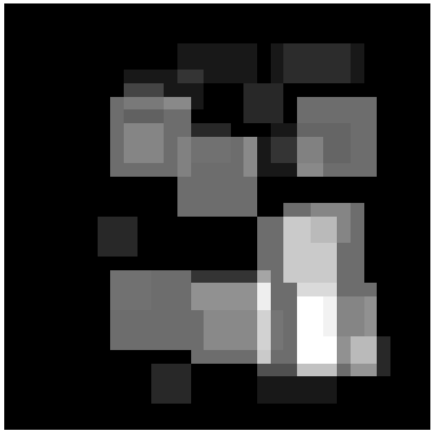
- Limited angle approach to 3D Mammography
- Source moves over a limited window of angles
- Has similar reconstruction artifact issues
- Artifact reduction solved in a variety of ways
  - Non-isotropic Resolution
  - Maximum Likelihood Estimator



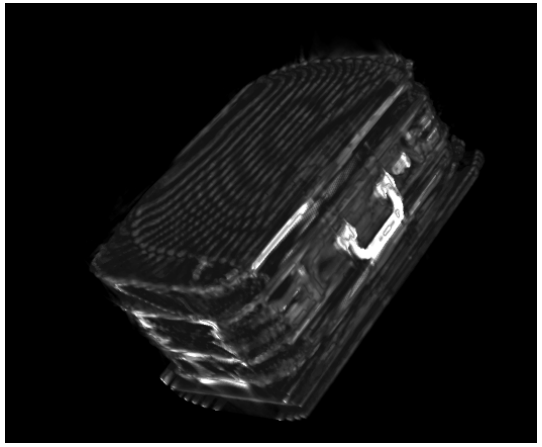
Initial Experiments

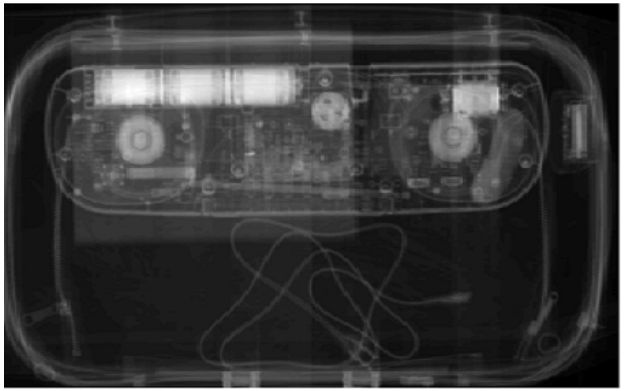
- Blocks





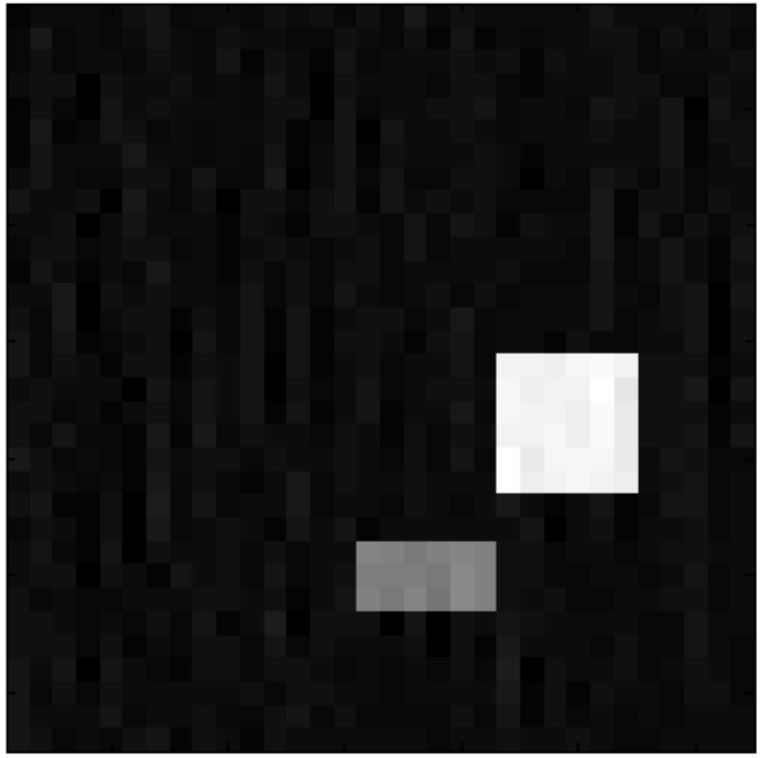
- Suitcase



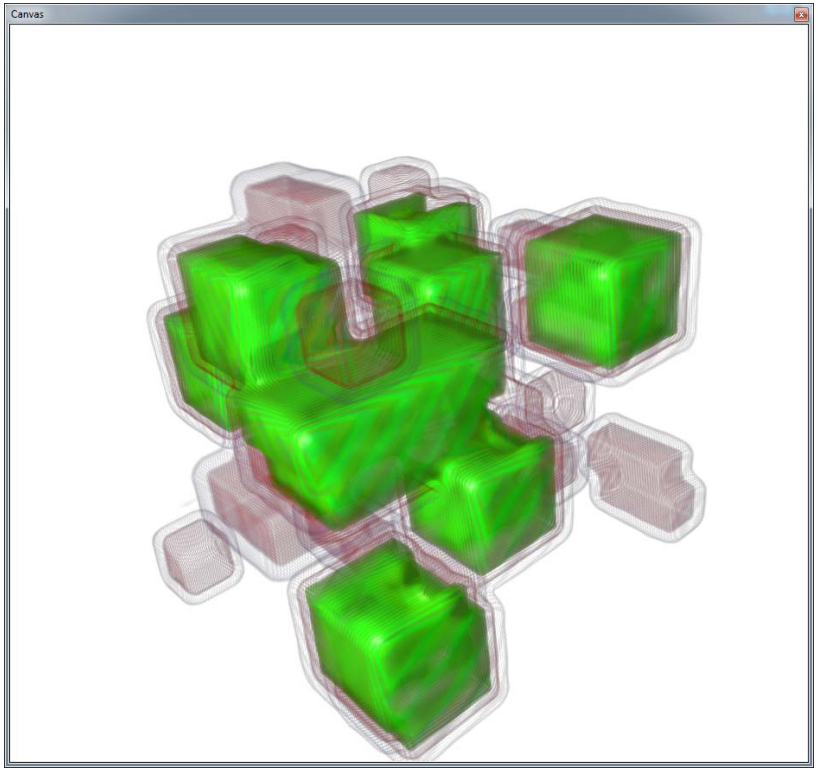


Results – Block Phantom

Reconstructed Slice

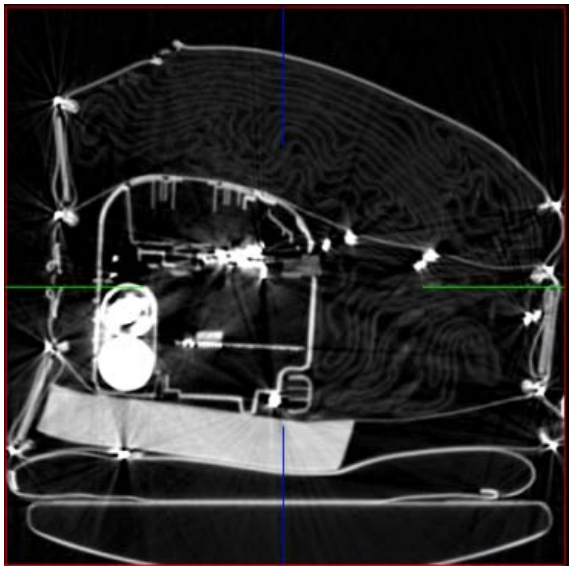


Reconstructed Render



Results - Suitcase

Original



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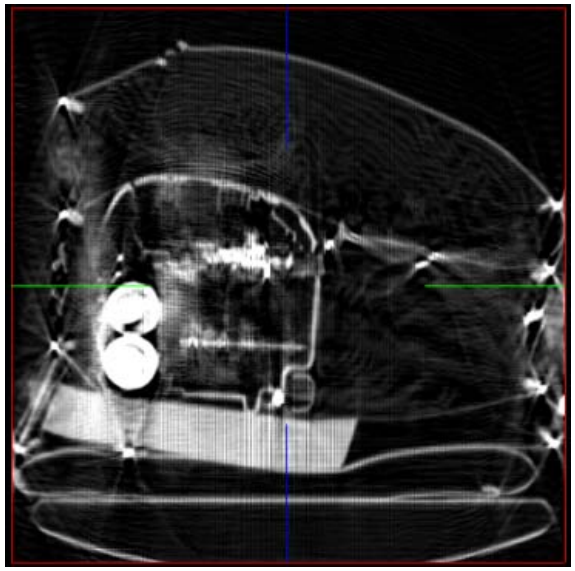

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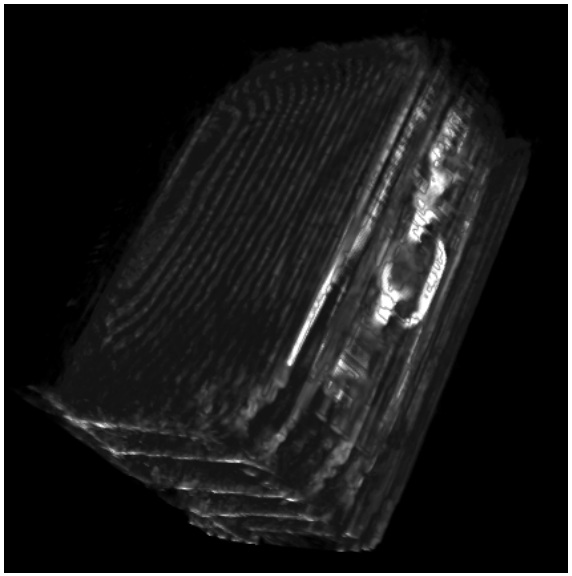

Summary

- Tomographic 3D images are possible without the need for large rotating gantries
  - Size, Power, Cost requirements can be lowered considerably
- Non-conventional geometry requires novel algorithmic approaches to produce images of comparable quality to conventional CT machines
- Computational complexity can be solved with developing hardware to create solutions in real time