Non-Rotational Tomography for Luggage Scanning using Krylov Methods

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to develop a non-rotational tomography approach for the purpose of achieving CT results in environments constrained by space and power.

Motivation
- Computed tomography has been at the forefront in providing detailed, quality 3D imagery in medical and security fields.
- X-Ray CT demand immense power and space requirements.
- Not all scenarios can afford to provide such requirements (i.e. carry-on luggage inspection, field clinics)
- Current machines such as the GE CTX9000 (Fig. 1) are too massive for carry-on applications and are confined to large rooms for checked bags

Reconstruction Challenges
1) Inconsistent Geometric Spacing
   - Standard fan-beam projections have consistent spacing from projection to projection (Fig. 4).

2) Limited-Angle Tomography
   - One projection is similar to cone beam setups
   - Linear geometry vs rotational geometry causes inconsistent ray spacings between projection data
   - Direct methods such as Feldkamp-Davis-Kress (FDK) no longer apply.

Solution Approach
The set of ray traces from equation 1 are stacked together to form the whole system of equation (Eq. 3).

Eq. 3: \( r^T = A^T Ax \)

Efficient inversion via Krylov methods such as generalized minimal residual method (GMRES)[3] are used to solve the normal equations in equation 4.

Eq. 4: \( A'Ax = A'r \)

Results
The suitcase data had a voxel resolution of 512x512x260.

Research to Reality
Next steps:
- Simulations with established phantoms.
- Physical implementation to acquire actual data.

Conclusion
We have shown that this geometry is feasible using conjugate gradient on the normal equations. The suitcase was reconstructed somewhat adequately but 150 iterations still requires a significant amount of time. Our reconstructive technique is able to work with real problem sizes, but unfortunately takes significant amount of time to process the data.

We have tested this problem setup with conjugate gradient but other iterative methods should also be explored. In addition a preconditioner needs to be established to speed up the convergence rate. In addition the limitations of the geometry are not well established and such a parameter search would also be beneficial.

References: