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Novel Method facilitates Real-Time Tomosynthesis guided Breast Biopsy

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MOTIVATION

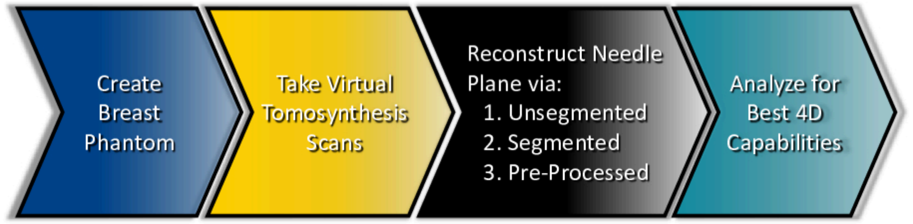
Tomosynthesis guided breast biopsy procedures can be uncertain, time consuming, and require significant pre-planning. In medical practice, a successful biopsy procedure is concluded after the biopsy specimen shows presence of the targeted lesion. Likewise, a failure, such as a target miss, is realized only after healthy tissue has been incorrectly excised, causing significant discomfort to the patient.

Real-Time Breast Tomosynthesis may mitigate these hazards by ensuring live-tracking of the needle advancement and any inadvertent movement of the target.

AIM

To examine **Novel Reconstruction Algorithms** in conjunction with **Advanced Tomosynthesis Acquisition Geometries** that offer Real-Time visualization of the biopsy needle while retaining accurate depiction of the surrounding breast tissue.

METHOD



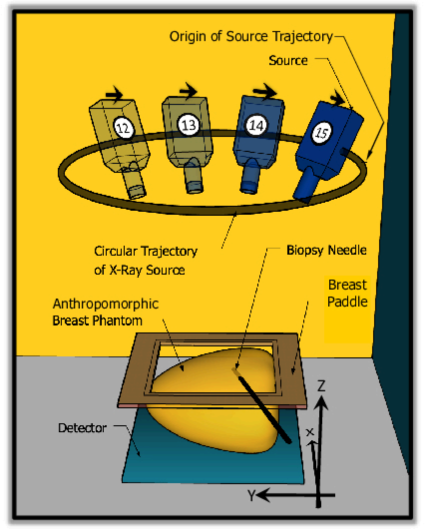


Fig 1 :Representative Diagram showing the Virtual Tomosynthesis acquisition geometry. The Needle inserted in a plane oblique to detector. The Anthropomorphic Breast Phantom is compressed craniocaudally. Not to scale.

Anthropomorphic breast phantoms[1] with central lesions were created simulating discrete timepoints of a 14-gauge flat-end cylindrical biopsy needle advancing to the lesion obliquely in 60 increments.

Virtual projections were acquired using the Open Virtual Clinical Trial[2] (OpenVCT) software, developed in-house, that constituted a:
Circular X-Ray Source Trajectory - Returns to origin after every 15 projections.

Needle plane image was generated through:
Multi-Planar Reconstruction - Performed with Piccolo™ 4.0.5 (Real Time Tomography, LLC, Villanova, PA)

Tomosynthesis images were reconstructed using three different algorithms:
Conventional - Utilizing all the past 15 projections for needle & background.
Segmented - Utilizing only the latest projection for needle, and all 15 for background.
Image Processed - Uses contrast enhanced projections for needle & background.

RESULTS

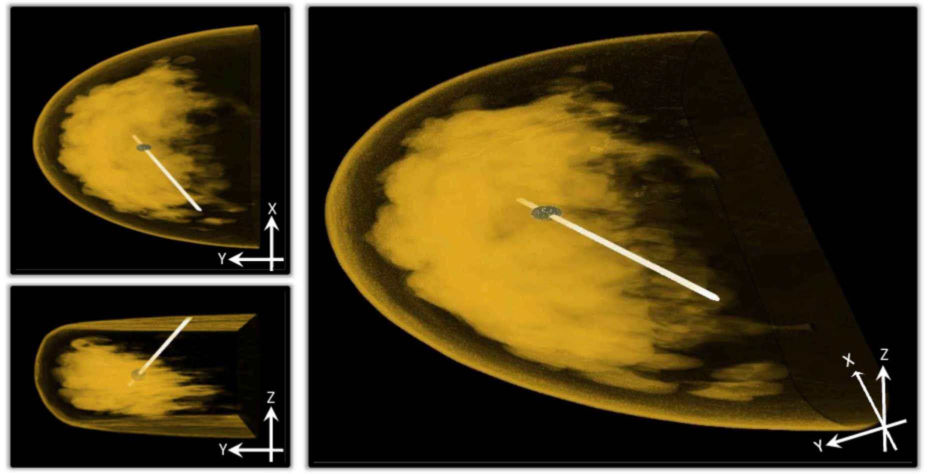


Fig 2: Maximum intensity projection (MIP) volume images of the Phantom for Projection #60 showing the Needle inserted completely through the Lesion.

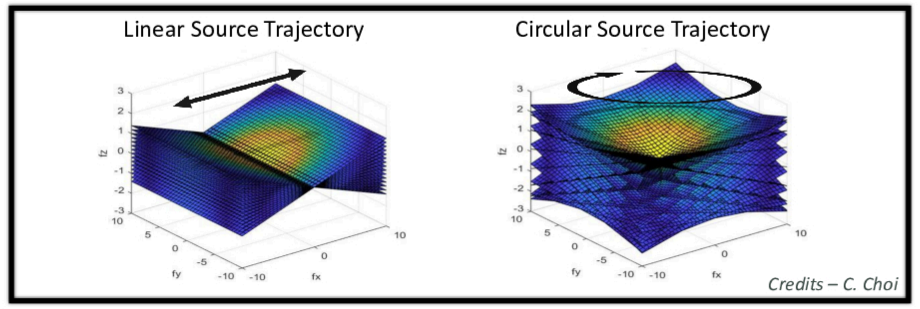


Fig 3: Fourier Slice Theorem Visualization. Each slice represents the frequencies sampled for a single X-ray projection in the Fourier domain. Compared to the conventional Linear Source Trajectory, the Circular Trajectory fills fx, fy, and fz more comprehensively, making the spatial resolution more isotropic and reducing out-of-plane artifacts.[4]

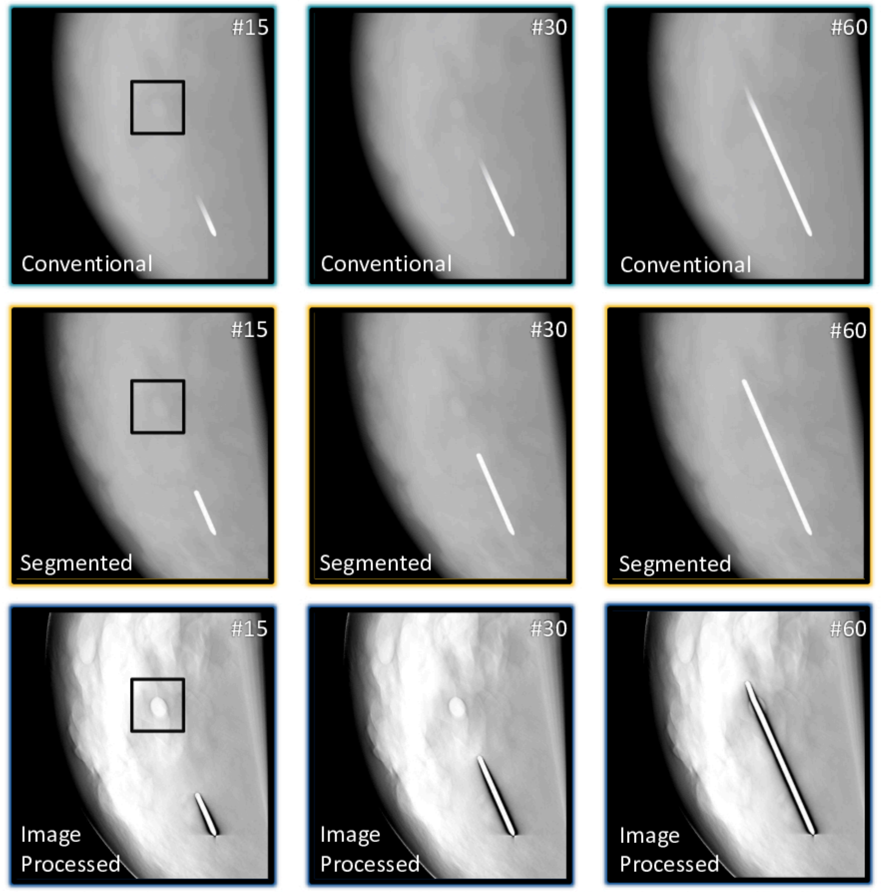


Fig 4: Multiplanar Reconstruction of the Needle plane followed by Conventional, Segmented and Image-Processed Algorithms at 3 time stamps, denoted by projection number (#15, #30 & #60). Dashed square box shows the location of the planted central Lesion.

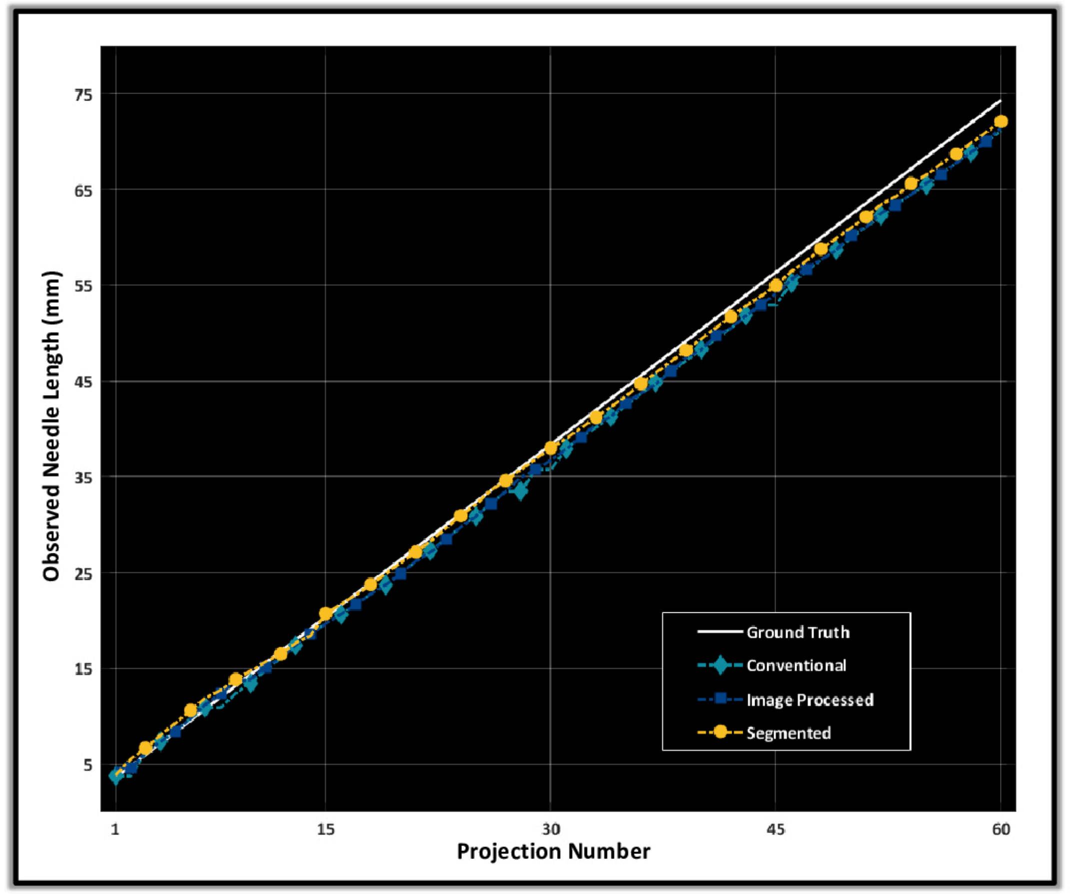


Fig 5: Observed Needle Length from Conventional, Segmented and Image-Processed Algorithms compared to the Ground Truth based on our created phantoms.

CONCLUSIONS

Comparative Parameters	Conventional	Segmented	Image Processed
Clarity of the Needle Tip	**No**, attenuating gradient appears	**Yes**	**Yes**
Accuracy of Observed Needle Length	**4.28%** error	**2.18%** error	**3.99%** error
Background Clarity	**Yes**	**Yes**	**No**, not around the Needle
Lesion Conspicuity	**Low**	**Low**	**High**, until the Needle reaches it

Acquisitional Improvements

Circular source trajectory, by filing in the 3D Fourier space more uniformly, allows for **Super-Resolution in both X and Y directions**.[4] It also makes continuous acquisition convenient by returning to its original position after every 15 projections.

Multi-Planar Reconstruction facilitates **Intuitive Visualization** of the needle and the lesion more so than in conventional Stereotactic or Digital Breast Tomosynthesis biopsy methods.

Reconstructional Improvements

Both Segmented and Image-Processed Algorithms overcome the attenuating gradient of previous needle projections seen in Conventional Tomosynthesis reconstructions and hence **Improve the Accuracy** of the needle's observed length.

While Image-Processed Algorithm worsens the clarity of background tissue immediate to the needle, it greatly **Improves the Clarity** of the lesion compared with the Conventional Algorithm.

REFERENCES

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