Stationary Digital Tomosynthesis
Using
CNT X-Ray Source Array

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Outline

- Motivation
- Advances in the CNT x-ray source array technology
- Breast tomosynthesis
- Dental tomosynthesis

Current Digital Tomosynthesis Scanners

- Mechanically moving an x-ray tube over a finite angular range to collect the
  projection images for reconstruction
- Focal spot motion blurs the image, reduces detection sensitivity
- Long imaging time, patient motion further degrades image quality
Stationary Tomosynthesis

Enabling Technology: Distributed X-Ray Source Array with Carbon Nanotube (CNT) Field Emitters

Advantages
- Field emitted electrons -> Electronically controlled radiation
- Easy physiological gating
- Flexible array configuration

Challenges
- Tube current (mA)
- Energy (kVp)
- Source-to-source consistence
- Reliability
X-Ray Tube Current
- CNT emitters can generate high current needed
- X-ray tube power is limited by anode heat management, no different from a regular x-ray tube
- Current fixed anode design limits the maximum output to what can be achieved with a conventional fixed anode thermionic x-ray tube

![](image)

1 A emission current from a CNT cathode

X-Ray Tube Energy
- The unipolar design makes high-voltage more challenging
- Significant improvement in high voltage stability
- 160kVp CNT x-ray source array fabricated

![](image)

Source-to-Source Consistency
- Inconsistency from variations in CNT cathodes, and manufacturing tolerance
- Variation in the x-ray flux readily regulated through an automatic feedback loop in the extraction voltage.
- Variation in the focal-spot sizes are within a reasonable range.
**Flexible Array Configuration**

- Source array configuration can be tailored for specific system need
- Allow novel geometries for CT and tomosynthesis

**Lifetime**

- Depending on the current, current density, vacuum…
- Accelerated lifetime performed for equivalent of 7 yrs (breast tomo) and 5 yrs (dental tomo) tubes

**Stationary Breast Tomosynthesis**

Anticipated clinical benefit

- Higher spatial resolution
- Better sensitivity for micro-calciﬁcation
- Shorter scanning time
- Wider angular range
- Less Z-axis artifact
- Less dose (tomo only)
**Stationary DBT (s-DBT)**

Prototype device in NC Cancer Hospital

[Image]

https://clinicaltrials.gov/ct2/show/NCT01773850

**Stationary DBT (s-DBT) System**

System developed by retrofitting CNT linear source array to Hologic Selenia Dimensions system

- 31 x-ray focal spots
- 30° angular span
- 40 kVp
- Dose matched to conventional DBT systems
- 2.6 to 4.5 second imaging time
- Images reconstructed on RTT workstation

**Comparison with commercial systems**

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<tr>
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<th>s-DBT</th>
<th>Hologic</th>
<th>GE</th>
<th>Siemens</th>
</tr>
</thead>
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<tr>
<td>Scan angle (degrees)</td>
<td>Up to 30 (40°)</td>
<td>15</td>
<td>25</td>
<td>45</td>
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<tr>
<td>Acquisition time (sec)</td>
<td>2.5-4.5 (1.5 – 3.5°)</td>
<td>4</td>
<td>7</td>
<td>25</td>
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<tr>
<td># of projection images</td>
<td>Up to 31</td>
<td>15</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td>Scan motion</td>
<td>Stationary</td>
<td>Continuous</td>
<td>Step and shoot</td>
<td>Continuous</td>
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* 2nd generation s-DBT tube
Improved System Resolution

Higher Z-axis resolution


Comparison of ACF for Different Angular Spacing

30% improvement in system resolution

Irregular Speculated mass

2D FFDM RMLO

2D DBT RMLO

Tumor extension to skin is not visible on conventional imaging

LMO view
Dental Imaging: Unmet Clinical Needs

2D Intraoral Panoramic CBCT

Low sensitivity
• Caries: most common dental conditions, sensitivity < 50%
• Root fracture: early detection is difficult
• CT does not improve diagnosis accuracy

Prior Works on Dental Tomosynthesis

• Webber, et al. invented Tuned Aperture Computed Tomography (TACT)
  – Fiducial marker
  – Manual translation of a conventional dental x-ray tube
  – Significant improvement in the diagnostic accuracy for fractures, periodontal diseases
  – Results on caries are inconclusive

• TACT is not used clinically
  – Long imaging time
  – Require fiducial marker
Intraoral Tomosynthesis with CNT X-Ray

- Linear CNT x-ray source array @ 70kVp x 7mA (clinical standard setting)
- Standard intraoral sensor, 35.52mm x 26.64mm (1920 x 1440 pixels, 18.5µm x 18.5µm each).
- Total dose from a tomo scan is the same as one 2D x-ray (PSP detector)
- Iterative reconstruction

Phantom Imaging: 3D vs 2D

Increased visualization of dental anatomy, caries, and tooth fractures compared to standard 2D image

Reader Study

Objective: Compare 3D intraoral with clinical 2D x-ray for caries detection
Specimen: Extracted human teeth
Ground truth: Micro-CT
Observers: 8 experienced dentists from UNC Dentistry
Conclusion: 36% increase in sensitivity for caries detection
Ongoing Patient Imaging Study

Objective: Conventional Bite Wing Radiography vs 3D Intraoral

100 patients from UNC Dental Clinic.

(https://clinicaltrials.gov/ct2/show/NCT02873585)

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