FMT-XCT – Work-package 2 advancement

FMT-XCT Year 3 Meeting
13-14/04/2011 – London

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Outline

- Work-package 2: year 3 activity summary
- FMT-XCT prototype construction and integration advancement
- Quantitative contrast enhancement strategies comparison
- Conclusion and future work
WP2 Objectives

Hybrid imaging system for small animal

\[\text{XCT} \leftrightarrow \text{FMT}\]

**XCT module should:**
- provide adequate accommodation of the optical components,
- eliminate X-ray interference with optical components,
- offer **improved contrast between organs** as is important for optimal use of XCT information as priors in the FMT inversion procedure (WP4).

**Enhanced contrast XCT strategies:**
- Dual-energy XCT
- Use of X-ray contrast agents
- *Double exposure technique*
- *X-ray Phase Contrast Imaging*
## WP2 Deliverables and Objectives: current state

<table>
<thead>
<tr>
<th>Objective</th>
<th>Title</th>
<th>Related deliverables</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>XCT Design</td>
<td>Milestone 2</td>
<td>Completed</td>
</tr>
<tr>
<td>2.2</td>
<td>Development prototype</td>
<td>2.2, 2.3, 2.4</td>
<td>Completed</td>
</tr>
<tr>
<td>2.3</td>
<td>Optimize dose and with multi-resolution code</td>
<td>2.4, 2.6</td>
<td>Completed</td>
</tr>
<tr>
<td>2.4</td>
<td>Minimize interference</td>
<td>2.5</td>
<td>Delayed</td>
</tr>
<tr>
<td>2.5</td>
<td>Research dual energy contrast</td>
<td>2.4, 2.6</td>
<td>Completed</td>
</tr>
<tr>
<td>2.6</td>
<td>Research contrast by contrast agents</td>
<td>2.6</td>
<td>Completed</td>
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<tr>
<td>2.7</td>
<td>Provide an optimal XCT design</td>
<td>2.7</td>
<td>Completed</td>
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<table>
<thead>
<tr>
<th>Deliverable</th>
<th>Title</th>
<th>Due for</th>
<th>State</th>
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<tbody>
<tr>
<td>2.1</td>
<td>Optimal design for X-ray CT system</td>
<td>1</td>
<td>Completed</td>
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<tr>
<td>2.2 + 2.3</td>
<td>Dual energy prototype &amp; software</td>
<td>15</td>
<td>Completed</td>
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<tr>
<td>2.4</td>
<td>Preliminary technical specifications</td>
<td>18</td>
<td>Completed</td>
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<tr>
<td>2.5</td>
<td>Measurements of scattered energy</td>
<td>21</td>
<td>Partial</td>
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<tr>
<td>2.6</td>
<td>Optimal contrast-enhancing strategy</td>
<td>24</td>
<td>Completed</td>
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<tr>
<td>2.7</td>
<td>Optimized system design</td>
<td>24</td>
<td>Completed</td>
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<table>
<thead>
<tr>
<th>Milestone</th>
<th>Title</th>
<th>Due for</th>
<th>State</th>
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<tbody>
<tr>
<td>2</td>
<td>XCT Design</td>
<td>1</td>
<td>Completed</td>
</tr>
<tr>
<td>5</td>
<td>XCT Dual energy vs. contrast agent</td>
<td>18</td>
<td>Completed</td>
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</table>
WP2: FMTXCT Installation @ Klinikum Rechts der Isar, Munich March 09, 2011
Some time later….
FMTXCT Final System Design

**Hardware:**

- Fully x-ray shielded (4mm lead)
- X-ray shielding and shutter for CCD camera (connected to safety interlock circuit)
- PLC controlled filter stage for up to 6 optical filters
- PLC control for digital and analog output (e.g. laser power)

**Software:**

- Standalone software to start a CT scan. The parameters can be freely modified (to e.g. scan with the parameters suggested by CEA-LETI)
- Interface driver to the HMGU Lab-View application
FMTXCT Possible Software Design

Acquisition Software
Select a FMTCT protocol

Scan Manager

Scanner

Data & Postprocessing / Reconstruction

Create a scan protocol for a combined FMTCT scan
Comparison of contrast enhancement strategies

- Compared 4 different techniques for contrast enhancement
  - Dual / Single energy
    - between them on CEA-LETI bench
  - 4 different contrast agent protocols
    - between them and with low energy protocol on FIHGM machine
  - Double exposure
    - tested on phantom
  - X-ray phase contrast imaging
    - feasibility study of the different techniques
    - basic simulation of one of them, no experiments
## Optimal acquisition protocols

<table>
<thead>
<tr>
<th>Low Energy settings</th>
<th>Contrast agent settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>35kV (40kV for CEA-LETI)</td>
<td>50kV</td>
</tr>
<tr>
<td>70µm Tin filter</td>
<td>1mm Aluminum filter</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>High energy settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>50kV (70kV for CEA-LETI)</td>
</tr>
<tr>
<td>30µm Lead filter (not used)</td>
</tr>
</tbody>
</table>

Commercial scanners suggested protocol: similar to contrast agent one
Dual/Single Energy Comparison

- Little contrast improvement of DE over SE
- $\alpha LE + \beta HE$: noise amplification
- DE: double acquisition time – increased dose
Low Energy / Intravenous Iopamiro

a) Low Energy
b) CA 5' after injection
c) CA 15' after injection
Low Energy / Intravenousous Fenestra

a) Low Energy
b) CA 5' after injection
c) CA 15' after injection
Low Energy / Intraperitoneal Iopamiro

a) Low Energy
b) CA 5' after injection
c) CA 15' after injection

Red profiles

Green profiles
Low Energy / Oral Iopamiro

a) Low Energy
b) CA 5' after injection
c) CA 15' after injection

Red profiles

Green profiles
Double exposure technique

- 2 acquisitions of the same object with 2 different exposures
- Allows extending the dynamic range of the detector
- Useful in presence of details with very different absorption properties
- Technique tested on phantoms

Single exposure  Double exposure
In-line X-ray Phase Contrast Imaging

- Many XPCI techniques in literature
  - some require synchrotron source
  - others complex interferometric grids
  - in-line technique: need only a very small focal spot size

- technique similar to phase contrast microscopy

- X-ray → waves:
  - contrast → n

- n contrast >> μ contrast

- needs very low E and very high fluxes

- need very high resolution detectors

- limited penetration depth
Suggested contrast enhancement technique

- **XPCI**
  - Not yet mature for routine application

- **Dual Exposure**
  - Complimentary technique for extending detector's dynamics
  - Useful for low contrast details in very heterogeneous objects

- **Low Energy / Dual Energy**
  - Reduced, but global, whole body contrast enhancement
  - DE contrast not bigger than LE one: LE preferable

- **Contrast agent**
  - Superior contrast enhancement depending on:
    - CA availability for target organ
    - CA diffusion dynamics
  - Limits:
    - CA washout time & eventual toxicity
    - Compatibility with optical acquisition (CA alters optical properties)?
Conclusions

- WP2 - Year 3 activity:
  - Contrast enhancement strategy comparison and choice (Deliverable 2.6 and Milestone 5) completed
  - Prototype construction and assembly completed
  - Measurement of scattered energy WP5

- Remaining activity:
  - Test and validate contrast enhancement strategies on final prototype when available (related to task 5.3)

- WP2 \(\rightarrow\) almost completed!