SPIX-LAB
towards SPeckle Imaging on X-ray LABoratory sources

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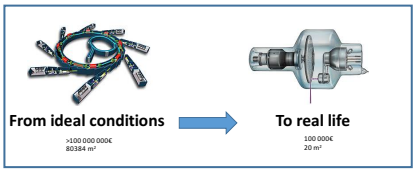
INTRODUCTION & OBJECTIVES

There is no imaging modality able to depict bone and soft tissues in a single image. X-ray Phase-Contrast Imaging (PCI) is an imaging modality using the refraction property of the X-ray instead of the absorption. PCI allows images with enhanced contrast of all the components.

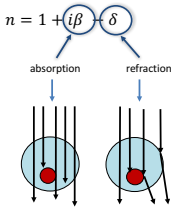
Most of the PCI methods require complex setup and/or synchrotron source. Speckle Based Imaging (SBI) forms a new class of X-ray PCI techniques where the experimental complexity is translated to the numerical processing side.

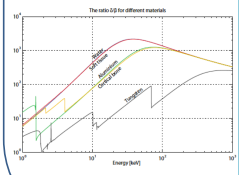
The aims of this PhD is to transfer SBI on conventional sources.



PRINCIPLE

Basis of PCI

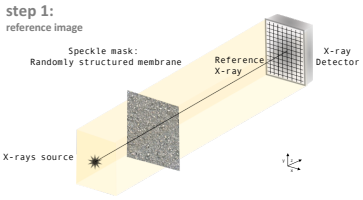


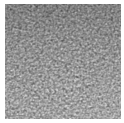


Refraction index > absorption factor (up to 1000 times greater)

Basis of SBI

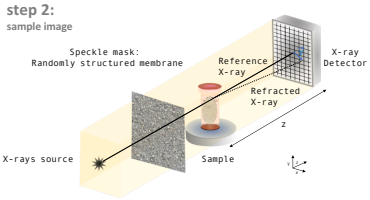
step 1: reference image

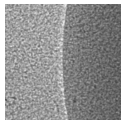




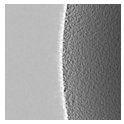
Reference Image

step 2: sample image





Sample Image



Normalization Image = Sample/Reference

Noise only in the part of the image where the sample is

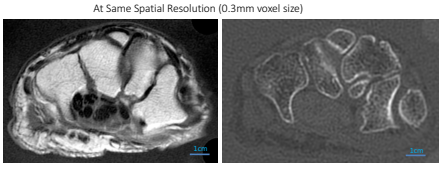
Direct measurement of the refraction

Speckle = random intensity pattern produced by interferences of the scattered waves with the transmitted beam

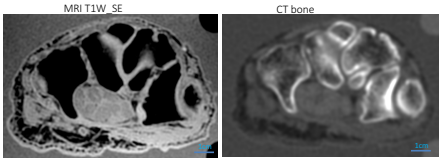
FIRST RESULTS

1. Interests of Phase Contrast Imaging for medical applications

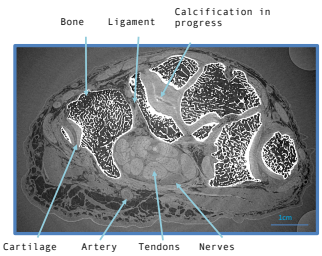
At Same Spatial Resolution (0.3mm voxel size)



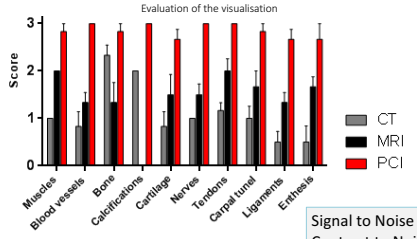
MRI T1W_SE | CT bone



MRI 3D WATSC | CT soft tissue



X-ray PCI using propagation based imaging



Score table:
0: undifferentiated from other structures
1: visible differentiation, blurry outlines and blurry internal structures
2: visible differentiation, sharp outlines and blurry internal structures
3: excellent visualization, sharp outlines and clear internal structures

Signal to Noise Ratio ↗
Contrast to Noise Ratio ↗
Global Image Quality ↗
Real improvement of the image quality for diagnosis

2. Algorithm optimization

Several phase retrieval

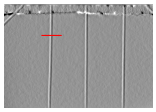
- Tracking algorithms :
  X-ray Speckle Vector Tracking (XSVT)
  Unified Modulated Pattern Analysis (UMPA)

$$\mathbf{v}(\mathbf{r}) = \arg\max_{\tau} \int f(\mathbf{r},\mathbf{p}) g(\mathbf{r},\mathbf{p}+\tau) d\mathbf{p}$$

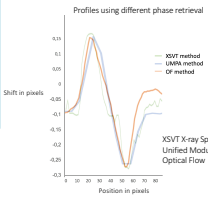
- Optical Flow algorithm (OF)

$$\nabla.\left[I_{(x,y)}.\nabla_{\perp}\varphi\right] + \frac{\delta I}{\delta t} = 0$$

Comparison



phase gradient in X direction
25 speckle projections
6µm pixel size

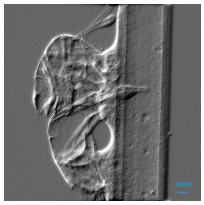


Comparison of the experimental setups and the associated phase retrieval methods at synchrotron to define the optimal conditions for transfer

3. Proof of concept on laboratory source

2D images of a fly obtained using an optimized phase retrieval algorithm

5µm pixel size



norm of the gradients

phase

Very promising 2D results of SBI on laboratory source

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CONCLUSION & PERSPECTIVES

- This simple setup provides a novel approach for bio-medical application with higher image quality and complementary information that can help diagnosis.
- Data processing technics comparison in different experimental conditions.
- Proof of feasibility on laboratory source.

- Optimization of experimental setup (time acquisition, dose deposition, diffusive membrane…) for pre clinical and clinical transfer.
- Optimization of tomographic reconstruction.

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