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Bimodal imaging with neutrons and X-rays

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Summary: Combining imaging modalities has the advantage that the strength of each modality can be exploited while the impact of weaknesses is reduced. We describe the different configurations for bimodal imaging using neutrons and X-rays available at the neutron imaging beamlines are Paul Scherrer Institut and show some applications where this combination is useful.

1. INTRODUCTION

Neutrons and X-rays are common radiation types to make imaging experiments for material science. Typical applications are found in porous media research for geology and civil engineering. Also, functional testing of mechanical devices or pieces from the cultural heritage can be considered. Each modality has its strengths and weaknesses and the users mostly have to choose which single modality will benefit their experiment. In the past, when users had access to both modalities it was often as ex-situ experiments where the sample had to be transported between two different facilities. This is often inconvenient as many experiments where bimodal imaging is required also involve samples that are badly suited for transportation or even require simultaneous acquisition to be able to observe ongoing processes. A reasonable solution to this problem is to add the ability to acquire X-ray images at neutron imaging beamlines as this is the rarer modality of the two.

The neutron imaging beamlines NEUTRA[1] and ICON[2] at Paul Scherrer Institut have both been equipped with X-ray sources and dedicated detector systems that allow in-situ experiments using both neutrons and X-rays. The implementation of the second modality is different for the two NI beamlines with different advantages as described below.

2. EXPERIMENTAL METHOD

The beamline of the second modality can be installed either inline with the neutron beamline or it can be installed across the neutron beamline. The inline approach was chosen at NEUTRA with a 350kV X-ray source located remotely from the detector to provide similar beam geometry for both modalities[3]. This has the advantage that the same detector system can be used for the image acquisition of both modalities. The acquired images in this configuration don't have to be registered as the same geometry and detector is used. The disadvantage of the inline configuration is that it is not possible to use both modalities simultaneously as the X-ray source is placed in the line of sight for the neutron beam. This limitation is addressed by a configuration with the X-ray beam across the neutron beam which is the preferred configuration of the more recent installation at ICON [4]. The 150kV X-ray source at ICON has a cone beam and the images are acquired using an amorph silicon flat panel detector. In this configuration it is possible to acquire CT time series simultaneously. Registration is required as the two detectors does not provide aligned data and the pixels have different sizes. The X-ray beamline is designed to allow magnifications up to ten times which will provide voxels of a similar size as the so called micro setup at ICON. The X-ray options at ICON is now ready for user experiments.

We are currently working on developing calibration routines and to evaluating methods for augmented or mutual bimodal reconstruction using methods like [5] but also traditional CT reconstruction using filtered back-projection for parallel or cone beam geometry. Next steps are to evaluate and develop methods for image

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registration between the two modalities and further to fuse the data sets to provide new insights from the study of different samples and processes.

3. RESULTS

Bimodal imaging is now a standard option of the neutron imaging beamlines NEUTRA and ICON. Figure 1 shows an example of a bimodal CT of a stone coated by a sedimentation. In the X-ray image, it appears that the sediment has a higher density than the stone while the neutron data shows the heterogeneity of the stone. In the future, we will continue to investigate different samples that benefit from the information provided by an additional modality and also develop a catalog of analysis methods to support the neutron imaging users in their analysis.

References

[1] E. H. Lehmann, P. Vontobel, and L. Wiezel. Properties of the radiography facility NEUTRA at SINQ and it's potential for use as European reference facility. *Nondestructive Testing and Evaluation*, 16(2-6):191–202, 2001.

[2] A.P. Kaestner, S. Hartmann, G. Kuehne, G. Frei, C. Gruüzweig, L. Josic, F. Schmid, and E.H. Lehmann. The ICON beamline - A facility for cold neutron imaging at SINQ. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, 659(1):387 – 393, 2011.

[3] P. Vontobel, D. Mannes, A.P. Kaestner, F. Schmid, and E. H. Lehmann. The x-ray option at the neutra imaging beamline of the spallation neutron source sinq. *Nuclear Instruments & Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors, and Associated Equipment*, submitted 2015.

[4] A.P. Kaestner, J. Hovind, P. Boillat, C. Muehlebach, C. Carminati, and M. Zarebanadkoukiand E.H. Lehmann. Bimodal imaging at ICON using neutrons and X-rays. *Physics Procedia*, 2017.

[5] Daniil Kazantsev, Sebastien Ourselin, Brian F Hutton, Katherine J Dobson, Anders P Kaestner, William R B Lionheart, Philip J Withers, Peter D Lee, and Simon R Arridge. A novel technique to incorporate structural prior information into multi-modal tomographic reconstruction. *Inverse*, 30(6), 2014.

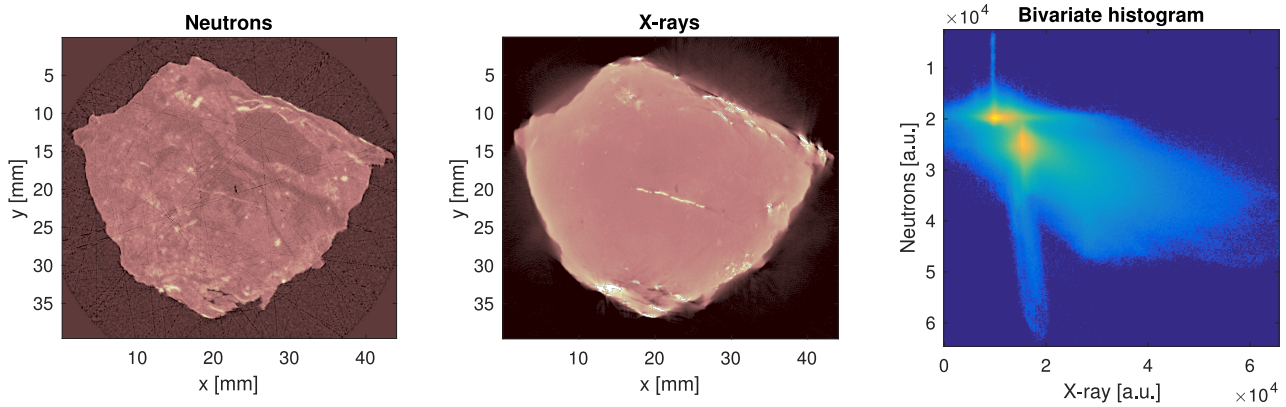

Figure 1: CT slices of a stone with sediments entering the pores using Neutrons (left) and X-rays (center). The bivariate histogram (right) shows different trends in the response from the two modalities.