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ScienceDirect

Physics Procedia 88 (2017) 348 – 353

Physics Procedia

8th International Topical Meeting on Neutron Radiography, Beijing, China, 4-8 September 2016

A freeware path to neutron computed tomography

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Abstract

Neutron computed tomography has become a routine method at many neutron sources due to the availability of digital detection systems, powerful computers and advanced software. The commercial packages Octopus by Inside Matters and VGStudio by Volume Graphics have been established as a quasi-standard for high-end computed tomography. However, these packages require a stiff investment and are available to the users only on-site at the imaging facility to do their data processing. There is a demand from users to have image processing software at home to do further data processing; in addition, neutron computed tomography is now being introduced even at smaller and older reactors. Operators need to show a first working tomography setup before they can obtain a budget to build an advanced tomography system. Several packages are available on the web for free; however, these have been developed for X-rays or synchrotron radiation and are not immediately useable for neutron computed tomography. Three reconstruction packages and three 3D-viewers have been identified and used even for Gigabyte datasets. This paper is not a scientific publication in the classic sense, but is intended as a review to provide searchable help to make the described packages usable for the tomography community. It presents the necessary additional preprocessing in ImageJ, some workarounds for bugs in the software, and undocumented or badly documented parameters that need to be adapted for neutron computed tomography. The result is a slightly complicated, but surprisingly high-quality path to neutron computed tomography images in 3D, but not a replacement for the even more powerful commercial software mentioned above.

Peer-review under responsibility of the organizing committee of ITMNR-8

Keywords: Neutron Radiography; Neutron Imaging; Neutron Computed Tomography; Tomography; Reconstruction; Software

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Peer-review under responsibility of the organizing committee of ITMNR-8
doi:10.1016/j.phpro.2017.06.047

1. Introduction

Very few freeware packages for computed tomography and 3D viewing are available in the internet, and they (nearly) all originate from the X-ray and synchrotron world, relying on conditions different from what is required for neutron imaging, so some pre-processing is required. For this, the freeware package ImageJ (1) is the best and most widespread solution. The most important difference is that X-ray software always relies on a fully illuminated detector, while in neutron imaging, beam limiters are often used to reduce the beam size to roughly the sample size in order to keep background and activation of detector components low. The resulting dark edges in the projections cannot be processed by most X-ray software, and have to be cut off using ImageJ first.

Different softwares require different naming conventions, some of them requiring the numbering of projections to start at zero, some at one. Renaming of an image stack can either be done by loading into ImageJ and saving with a different numbering scheme, or by using the powerful ‘Bulk rename utility’ (2). The biggest problem during data transfer from one package to another arises where programming conventions were not followed, making standard data formats unreadable. The company Bruker MicroCT graciously provides one reconstruction package and two data viewing packages for free (3), but these cannot read ImageJ output directly – see below.

Two CT reconstruction packages were picked from the review article published in (4) for testing, one more from the neutron community, plus three 3D viewing packages. It is assumed that the reader is familiar with general data processing path for computed tomography from using professional software packages at a CT installation, so these are not repeated. A link to a comprehensive step-by-step description is given at the end of the paper. In addition, no explicit comparison is done to commercial software, as both descriptions would go beyond the possible scope of this paper. Instead, the focus lies on a compact description of the required additional steps. For initial test hardware, a simple tomography controller with control software that can interface nearly every camera plus stepper motors for a rotation and a translation stage is described in (5).

2. General preprocessing

As mentioned in the introduction, dark edges in neutron images must be removed before the data can be used. For this, the projections, dark frames and open beam images should be loaded into a single common stack in ImageJ, then cropped to the illuminated size. It is recommended to run the ‘despeckle’ and possibly the ‘remove outliers’ noise filter on all images to remove small gamma spots before saving the stack as an image sequence with the original file names. The common stack operation makes sure that dark frames and open beam images are cropped to the same size and position as the projection files.

3. Tomographic reconstruction

3.1. CT reconstruction with H-PITRE

Scientists at the synchrotron in Trieste have developed the reconstruction package PITRE (phase-sensitive X-ray image processing and tomography reconstruction) (6) and its successor H-PITRE (7). PITRE uses the free IDL runtime engine (8) and runs on the CPU, while H-PITRE runs standalone on an advanced graphics card.

PITRE and H-PITRE were developed for attenuation and phase contrast measurements at synchrotrons, implying low-contrast samples and parallel beam geometry. For monochromatic parallel beams, 180 degree rotation is sufficient, but for polychromatic radiation and large-contrast samples, a 360 degree scan would be helpful to reduce beam hardening artefacts, however, this is not implemented in H-PITRE. H-PITRE can read 8 and 16 bit integer and 32 bit float data in TIFF, PNG and BMP. It requires a fixed naming and four digits numbering convention starting at 0001 with the names tomo_0001, flat_0001, dark_0001. Fig. 1 shows a screenshot of H-PITRE.

H-PITRE will do a dark frame and flat field correction, but the center of rotation must be found manually if it deviates from the image center. After converting all projections to sinograms, single slices can be reconstructed. Small semicircles at edges are a sign for incorrect center of rotation; the correct value has to be found manually by trial and error. If the rotation axis is tilted, test slices must be reconstructed at top and bottom of the data set, and with the option ‘dynamic rotation center’ set (see Fig.1), the resulting values must be filled into the appropriate fields for ‘RoCenter’ (Fig.1). For this, the reconstruction range SinoSN(B-E) must be set to the same value for