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Automated workflow for Core Saturation experiment

1. Introduction

This tutorial will detail how to develop and use an automated workflow for a core flooding experiment.

The workflow consists of a recipe including all image processing operations.

Optionally, a python or TCL script defining the data access and output results in order to apply the workflow automatically to a series of acquisitions can be developed.

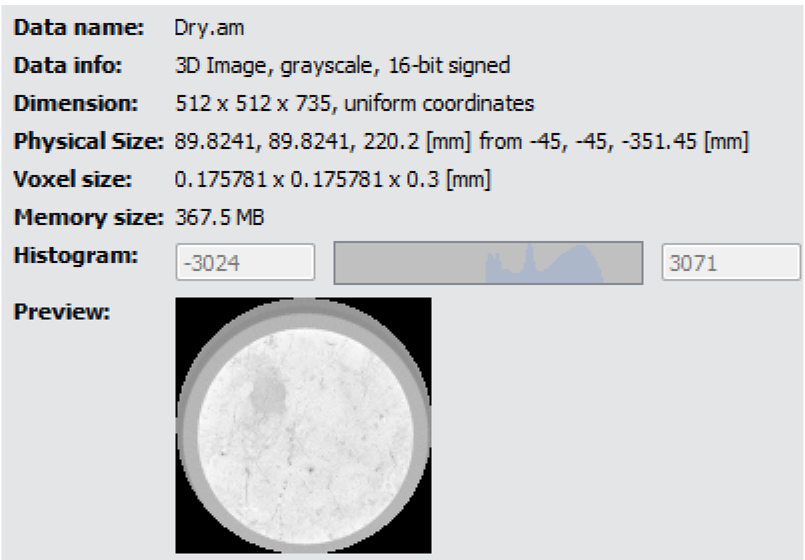

Figure 1 Original core data

2. Samples and workflow definition

The samples consist of multiple series of 10cm plugs CT scans acquired at different levels of imbibition. For each series, we have :

- 1 water-saturated sample
- 1 oil-saturated sample
- multiple plugs with different degrees of saturation

The image processing workflow consists of:

- Registration of the water-wet sample against the oil-wet sample

For every plug:

- Removing the core barrel and correcting the tilted orientation with *Crop Core*
- Beam hardening correction
- Automated bulk volume mask computation
- Registration of the plug against the wet sample
- Computation of the saturation with an Arithmetic module and the formula:
  - (data – Oil) / (Wet – Oil)*1000

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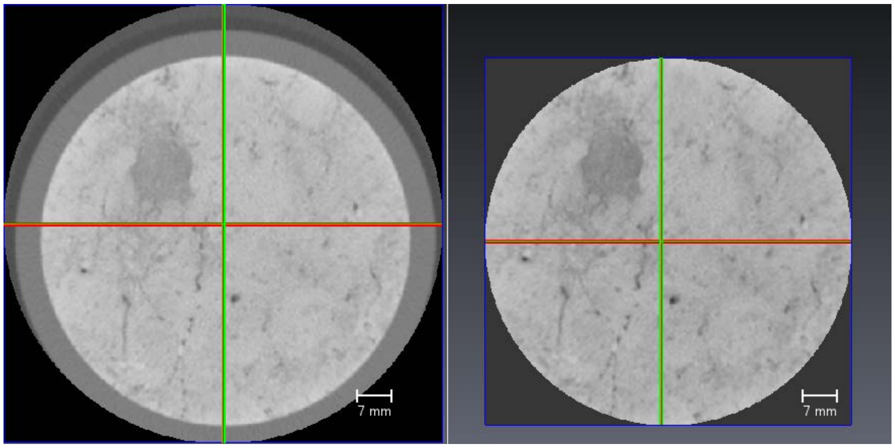
3. Workflow implementation

The implementation will be defined once, and saved as a recipe, so that it can be applied to multiple samples.

Removing the core barrel and correcting the tilted orientation

The crop core module will remove the core barrel, re-center and re-align the core



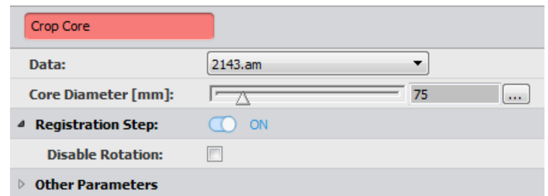
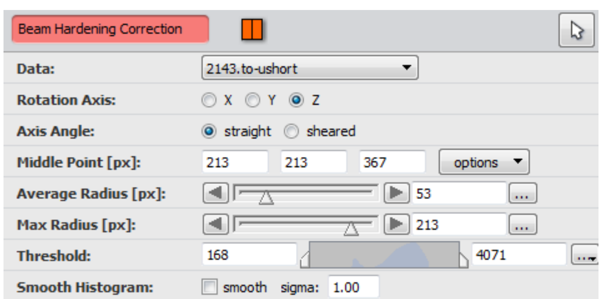
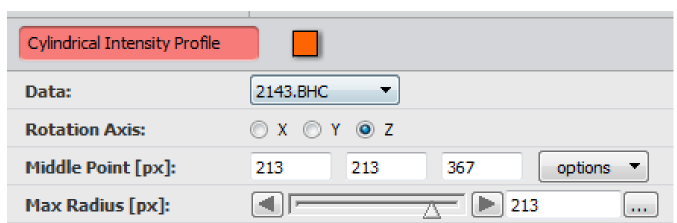


Figure 2 Original Core (not centered with barel) - corrected core

Beam hardening correction

The Beam hardening correction module will correct the beam hardening. A validation of the intensity correction is obtained by comparing the cylindrical intensity profiles.





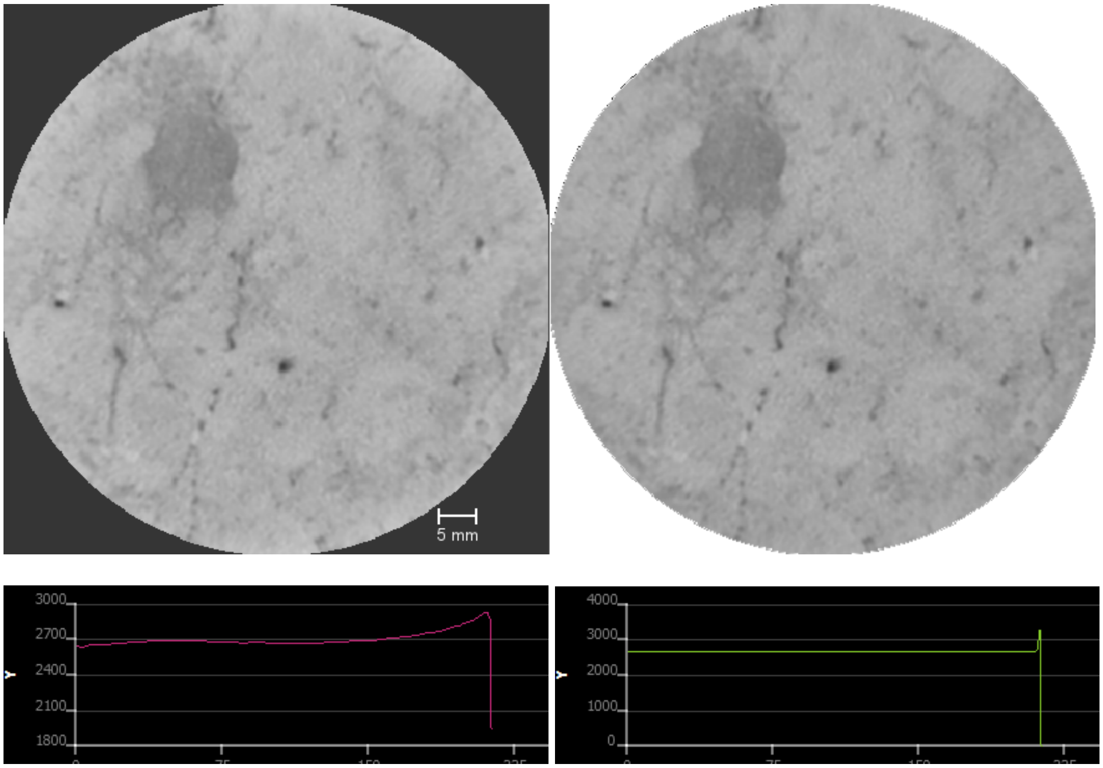


Figure 3 Cropped Core vs Beam Hardening corrected core, and associated cylindrical intensity profiles

Mask computation

The mask is computed with an *Auto thresholding* module followed by a *Fill Holes* module, and a 2D erosion with a circular kernel, in order to remove the bordering pixels, often the cause of artefacts.

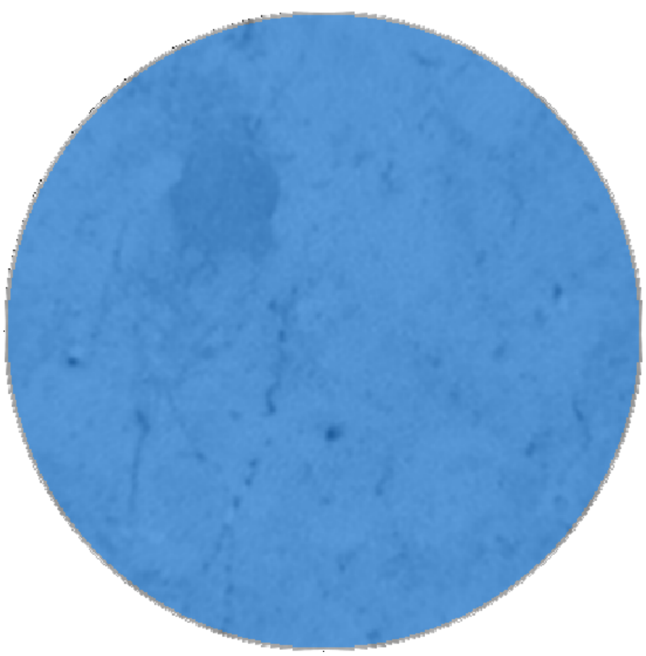
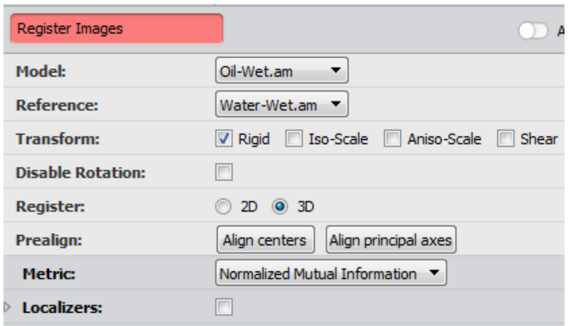


Figure 4 Computed mask on top of the greyscale image

Registration of the oil-wet sample against the water-wet sample

This automatic operation is only done once, with a *Register Images* module.



Note : although the samples seems properly aligned to each other, there is always a tiny displacement that needs to be corrected

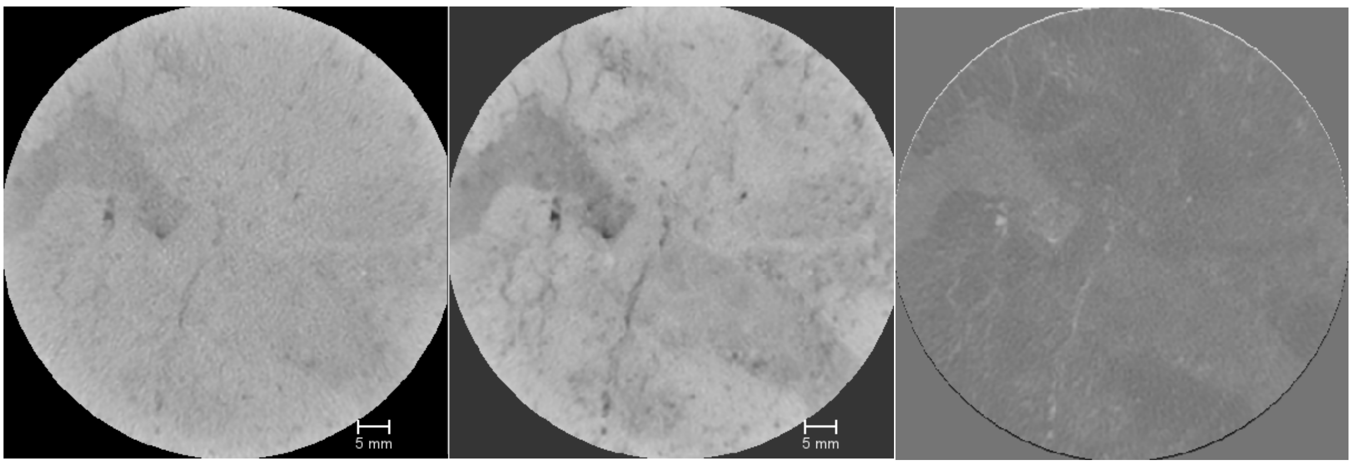


Figure 5 Water, Oil wet samples and arithmetic difference with bordering pixels highlighting the displacement

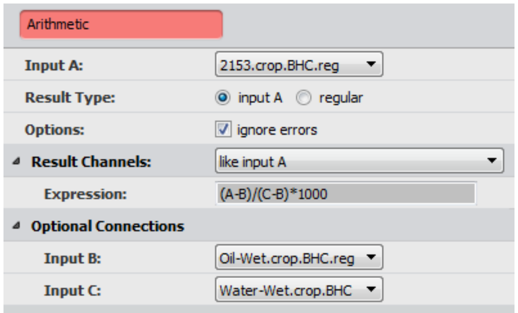
Registration of each sample against the water-wet sample

In order to correctly compute the saturation, every sample is registered to the water-wet sample, prior to the saturation computation.

Note: since the Arithmetic module supports transformations, there is no need to Resample the data after the registration step

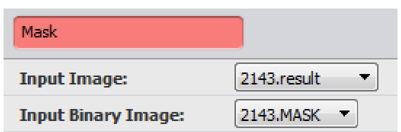
Computation of the saturation

An Arithmetic module with the formula (data – Oil) / (Wet – Oil)*1000 is applied to the corrected sample.



Masking the result

The saturation result can optionally be masked by either a fixed mask for all different sample, or computed every time with the workflow described above.



Saving the recipe

Note : prior to saving the recipe, the models (water-wet, oil-wet) need to have a cleared history. This can be achieved through the *Clear History* button of the home panel, resulting in no log of the Crop Core and Beam Hardening Correction.

The recipe is saved and stored in order to be applied further

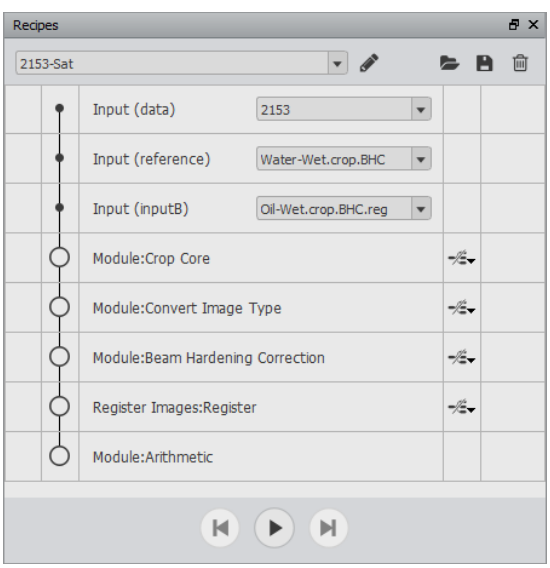


Figure 6 Saturation recipe

4. Application to multiple series

Application to multiple series requires a bit of scripting. The image processing is handled via recipes, and the script just focuses on loading/unloading the data.

Many possibilities exist for outputting results :

- Saving the computed saturation cores as a 3D tiff data
- Saving snapshots of 2D slices or 3D volume renderings
- Saving intensity profiles as .csv files. The intensity profiles can be obtained after applying a *Global Analysis* module in XY mode on the binary mask and greyscale core data.

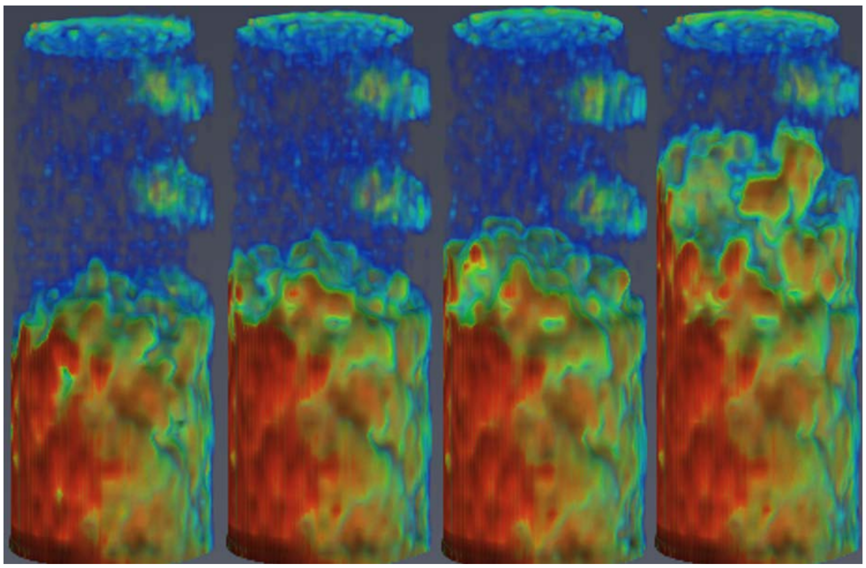


Figure 7 Saturation results at different levels of imbibition