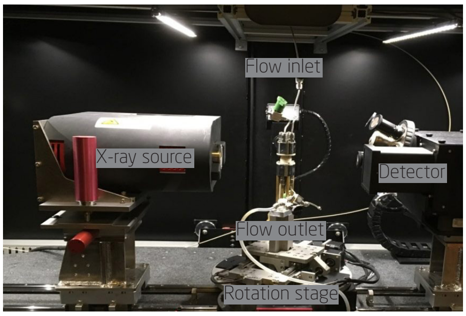
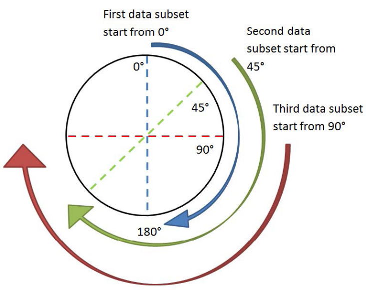
Improved time resolution in laboratory *in situ* µ-CT

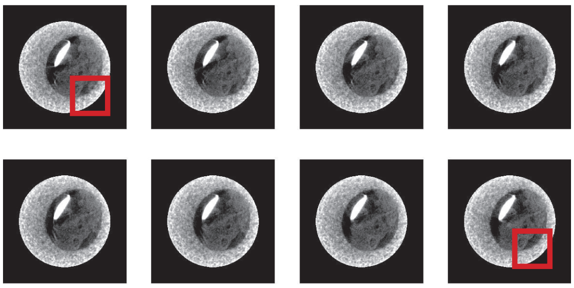
X-ray micro-Computed Tomography (X-ray µ-CT) is a method to image the 3D volume of a material non-destructively, e.g. the microstructure of carbonate rock. In conventional laboratory-based instruments, the limited intensity of the X-ray source, a cone-beam geometry of the imaging setup and the application of analytic reconstruction methods usually lead to a relatively long measurement time for achieving a good image quality. However, if *in situ* processes are studied, a long measurement time can lead to motion artifacts, if the subject under study changes within the timeframe of the measurement. In order to shorten the time required for an *in situ* scan, and thereby improve the time resolution, a special image reconstruction scheme was applied in this project and different reconstruction algorithms were tested. The studied system was a carbonate rock inside an *in situ* cell, such that water was constantly forced through the chalk leading to a dissolution of the chalk.



In situ setup used during the flow experiments.



Scheme used to obtain a higher time resolution. One dataset over 360 degrees is resampled into 8 individual datasets starting at different time steps shorting the time gap between two scans and therefore improving the time resolution.



2D images showing the same position with a time difference of 20 minutes between each image (left to right, top to bottom).

Project

The work is part of the research going on at the 3D Imaging Centre at DTU, which focuses on the development and application of X-ray Computed Tomography (CT). The project was part of the general development activities within the LINX project, in which researchers at leading Danish universities collaborate with scientists in industry to solve industry relevant problems using advanced neutron and X-ray techniques.

Challenge

As the CO_2 emissions into the atmosphere need to be reduced, one method is to inject it into geologic settings, e.g. carbonate reservoirs in the North Sea. First, a stable pore space needs to be generated in the reservoirs, which can be done by injection of water. To study this process, an *in situ* cell was used pumping water through a chalk sample. Though 8 consecutive µ-CT measurements were performed with each scan taking 2.5 hours, this time resolution is not enough to capture the chalk dissolution and pore evolvement. Therefore, we deciced to use a special reconstruction scheme reducing the time difference between the individual tomograms.

Results

For the reconstruction approaches applied in this work, an open reconstruction framework (*Astra toolbox*) was used and optimized accordingly. The application of iterative reconstruction methods in contrast to standard, analytic methods was found to improve the time-resolution by a factor of four. In addition, we applied a scheme in which one dataset was resampled into 8 datasets, where each subset starts at a different time step, was it is shown in the middle figure on the left. By this process, the time resolution was improved by a factor 8 such that the time difference between each individual tomogram was 20 minutes in contrast to 2,5 hours as required for the standard acquisition. With this improved time resolution we could follow the pore evolution over time, as shown in the bottom image, while the standard one would only have provided time-averaged information.
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3D Imaging Centre

The 3D Imaging Centre at DTU is a competence center for X-ray and neutron imaging. It houses a national X-ray infrastructure, DANFIX, and a regional centre for image analysis, QIM. The Centre is furthermore associated to an industry portal and has tight connections to large scale facilities such as ESS and MAX IV. The research conducted at the 3D Imaging Centre covers various research areas ranging from X-ray and computer sciences to biology, or cultural heritage.

https://3dim.dtu.dk/

DTU 3D Imaging Centre