Real-Time, High Speed, High Resolution, 4D CT at Laboratory Setups

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ABSTRACT

Performing CT experiments on samples that are morphologically changing shape as a function of time is not straightforward, especially if the modifications happen in a short period of time and the altering structures are relatively small. These kind of experiments are challenging as large amounts of data are generated in a short amount of time and it is difficult to target the right time period where the change of interest can be observed. Additionally, hardware limitations in terms of acquisition speed and sufficient X-ray flux are problematic, especially at laboratory setups.
Here we present some CT-results where a time resolution of 1sec is achieved over a period of 2 min using a combination of hard- and software that is specifically designed for high speed, high resolution, 4D CT.

1. INTRODUCTION

While micro-CT is becoming an increasingly used technique for 3D visualisation of internal structures, there is still a certain threshold towards 4D measurements. The large amounts of data and the lack of dedicated software to perform such experiments are some of the limitations. Another reason is the time resolution which can be achieved at laboratory setups.

Performing one 3D CT scan already requires the acquisition of a large series of projection images. As a result, extending the acquisition in time to perform time resolved CT (4D) generates huge amounts of data. Performing reconstruction of each of these datasets is not only time consuming (even when automated) and requires large computational capacity but it also generates lots of data. In most cases not all of this data needs to be generated or stored to monitor the desired change in the sample. Being able to reduce the amount of data that is required and generated is therefore crucial to make 4D CT more practical. This can be achieved in several ways.
In a first step, the possibility to investigate the modification of the sample during the acquisition, hence *real-time*, permits to select only the time period where the targeted modification is occurring and therefore reduces the amount of produced data. This not only important to reduce data but it also offers a way to evaluate very rapidly the success of the experiment or the modifications that need to be performed to accomplish the experiment.
After the acquisition, a fast and easy method is needed to browse through all the generated data to select not only the desired time period within the entire acquisition but also the location of interest in the entire 3D volumes, hence a *4D browser*. Limiting the user interactions and the required pre-processing to browse through the 4D data makes it more user friendly reducing the threshold towards 4D CT.

Apart from the amounts of produced data, which is surmountable, laboratory setups often lack the time resolution which is required for 4D experiments, especially at higher resolution. This shortcoming is mostly caused by hardware limitations to acquire and store large amounts of data in a short period of time as well as the necessary X-ray flux to obtain good quality scans. Synchrotron facilities benefit from an abundant X-ray flux which makes such experiments more feasible but the access to such facilities is very limited. Being able to perform high speed acquisition at laboratory setups with sufficient quality is more difficult, but by optimising the hardware configuration and settings for each experiment it can be achieved. For this purpose hardware that is chosen and combined in a dedicated way with enough flexibility to alter some of the crucial parameters is mandatory.

Using a combination of hard- and software that is specially designed for 4D CT measurements, high speed and high resolution time resolved modifications can be observed and monitored using CT. For this abstract, the feasibility of this combination is illustrated on one specific sample.

2. EXPERIMENTS AND RESULTS

For the illustrated 4D experiment, a detergent foam was generated in a plastic container of approx. 3 cm in diameter. The container was placed in HECTOR, a UGCT-scanner (www.ugct.ugent.be/instruments) that was developed in collaboration with XRE (X-Ray Engineering bvba, www.XRE.be). HECTOR was modified both on the hardware and software level to accommodate the 4D experiment.
Several acquisitions and thousands of projections images were recorded over a period of 60 seconds while the sample was rotating. After the acquisition, the data was prepared and reconstructed using the in-house developed 4D software. The data results in slices of 1200x1200 voxels of approx (30µm)^3 that can be selected throughout the time period and scanned region.

In fig.1, four slices through a central region of the container are selected. The first three images illustrate the visible modifications that occur at a one second time interval (see enlargement). Small air bubbles change in shape and location as the foam deteriorates. The fast acquisition is necessary to overcome image artefacts that occur while the foam is changing and to be able to measure and observe even the smallest events. The images on the right illustrate the larger modification the foam has undergone after a period of 30sec.

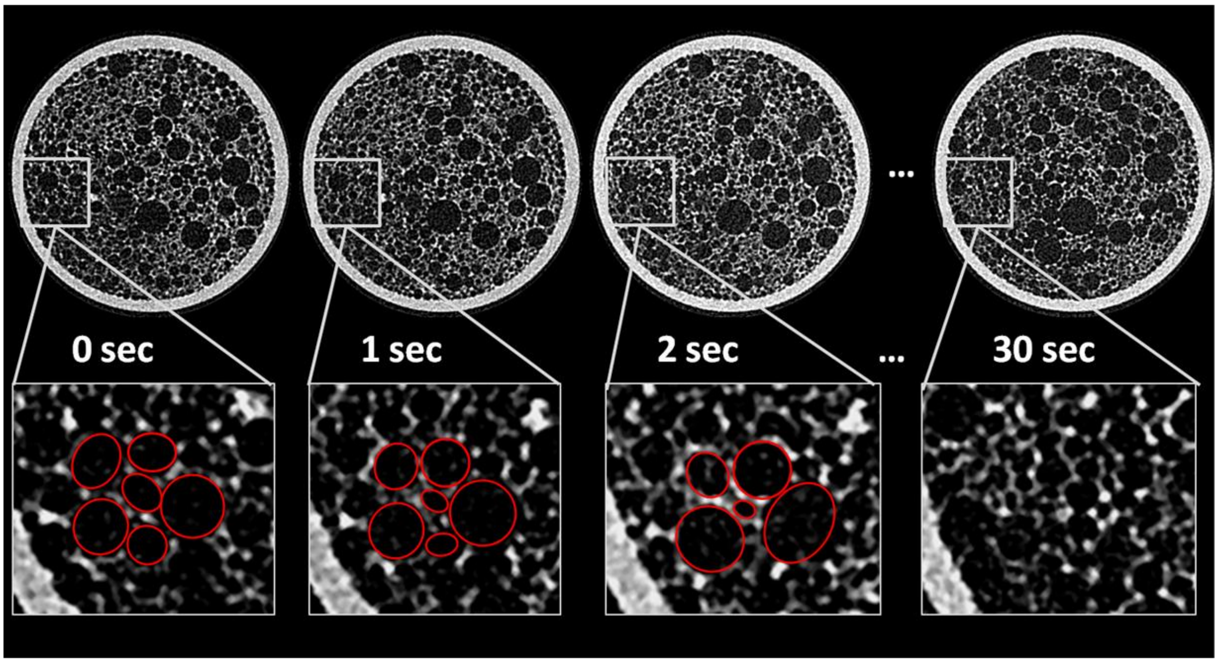

Figure 1: *Fours slices of the foam inside the container at different time intervals and an enlargement of a small region in each of the slices*

3. CONCLUSIONS

The selected experiment illustrates that it is possible to generate 4D CT scans at a laboratory setup where morphological changes that occur in 1 second can be appreciated, even at high resolution. This offers new and exciting possibilities towards the investigation of dynamic process. Combining dedicated soft-and hardware tools for 4D CT is crucial to achieve the best possible outcome and to improve the handling of the large amounts of data that are generated.