# *Weighted backprojection: a reconstruction technique for dynamic micro-CT*

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**Summary:** Dynamic high-resolution CT scanning or 4D-$\mu$CT is a tool to study dynamic processes in situ on the micro-scale. These scans need to be performed fast to capture the dynamics accurately. However, a good quality reconstruction needs a slow scan. We propose a technique to make an iterative reconstruction converge with less data, thus allowing for faster scanning while still maintaining reconstruction quality.

## 1. INTRODUCTION

Visualizing and analyzing dynamic processes in 3 dimensions is an increasingly important topic, e.g. in geosciences [1], [2]. High-resolution CT-scanning is a suitable technique for this, as it is non-destructive and therefore does not hinder the dynamic process while it is ongoing.
In order to reconstruct a 4D-$\mu$CT scan, i.e. create a 4D volume from the projection images of the CT scan, the set of projection images is divided into smaller subsets, each representing a small time frame. Each subset is reconstructed separately with a traditional CT reconstruction technique, which yields a 3D volume. The combination of all these 3D reconstructions is the resulting 4D volume.
However, these reconstruction techniques assume a static sample. Motion artefacts are introduced when this assumption is invalid, which is the case for the small time frames over which each 3D volume is reconstructed. To minimize the motion artefacts, the scan is performed at high speed and therefore suffers from lower statistics hence higher noise. The resulting reconstruction quality for the 4D volume is insufficient for fast processes.
One method to improve reconstruction quality is using a priori knowledge. Of the two most used reconstruction algorithms, the iterative reconstruction scheme is best suited for this. In this research, the simultaneous algebraic reconstruction technique or SART [3] is used and adapted to take prior knowledge into account.
The most well-known way to incorporate prior knowledge into an iterative reconstruction algorithm is an initial volume. The iterative reconstruction will not start from an empty volume, but from an already known volume resembling the sample. This can be a high quality CT scan from before the dynamic process was initiated or a model for for example a 3D printed sample. Using an initial volume instead of an empty volume already presents a great improvement [4].
Other forms of a priori knowledge, such as the continuity of changes [5] or the incompressibility of a fluid combined with static regions in the sample [6], can also be included. In this work, we supplement the initial volume with the prior knowledge of the locations in the sample where the dynamic process is most likely to occur, while also leaving some room for error in this prior knowledge.

## 2. EXPERIMENTAL METHOD

In order to include the locations of change in the reconstruction, we use a weight volume. This is a 3D volume of the same size as the reconstruction volume. Each voxel has a weight, a number that indicates how likely this voxel is present in a dynamic region. This weight determines what fraction of the backprojection of an X-ray

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is assigned to this voxel as compared to the other voxels on the path of that X-ray. A higher weight means the voxel receives more of this backprojection and therefore this voxel will change more from its value in the initial volume.

We demonstrate weighted backprojection on a 4D-$\mu$CT dataset from geological research.

This dataset considered fluid flow through a Bentheimer sandstone. This experiment was performed to investigate the intrusion of oil into a water-filled porous rock, with relevance to the study of groundwater pollution and petroleum reservoirs [1, 8]. The sandstone was shaped roughly cylindrical, with a height of about 10 mm and a diameter of about 6 mm.

The experimental data from this sandstone were acquired using the EMCT micro-CT scanner [7]. One initial high quality scan of the porous rock was used as a basis for the weight volume, since the dynamic process occurs inside the pores.

## 3. RESULTS

In figure 1 a weighted backprojection reconstruction is compared to a normal reconstruction and one from an initial volume. It is clearly visible that the weighted backprojection already shows filled pores (black), while both other reconstructions need more data. Therefore, the weighted backprojection converges much faster and can handle having less projections available.

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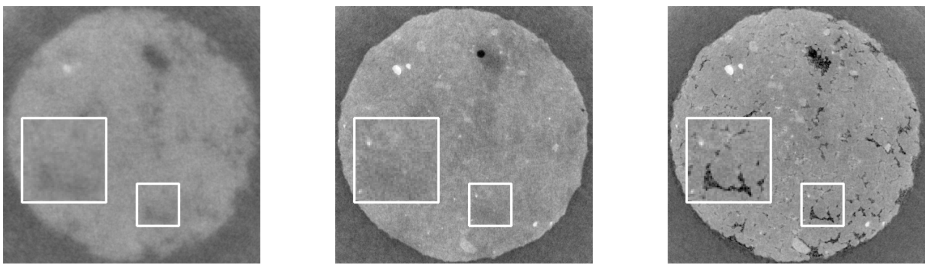

(a) (b) (c)

**Figure 1:** (a) Normal reconstruction (b) Reconstruction from an initial volume (c) Weighted backprojection