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Dynamic X-ray computed microtomography imaging of multiphase flow in porous media using deep learning

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Dynamic imaging of multiphase flow in porous media using X-ray microcomputed tomography (micro-CT) has been a technique exclusive to synchrotron-based systems. With the emergence of deep learning, however, the lower X-ray flux from a standard micro-CT system, and thus lower signal and higher noise under dynamic imaging conditions can be compensated for by use of convolutional neural networks with a *priori* knowledge of the imaged domain and the noise signature.

In this work, a cycle consistent generative adversarial network (CycleGAN) based on the principle of unpaired image-to-image translation is utilized for transforming noisy micro-CT images to clean images. The two main objectives of this study are to assess the levels of noise that would be prevalent during dynamic imaging, and to design a DL network to denoise these images. To obtain the relevant data, fast and slow scans were performed at set saturation levels in the sample. The examined two-phase flow system consisted of air and water (the latter doped with potassium iodide –KI). The sample in consideration was a Bentheimer sandstone sample and the experiment was conducted with a custom-built benchtop micro-CT system located at Oregon State University. To obtain ground truth (GT) images for the training of the CycleGAN model, a high-quality dry scan of the sample was acquired before the KI doped water was injected. Once the fluid was injected, subsequent fast scans were acquired, and finally, a high-quality multiphase scan was captured.

The results from denoising micro-CT scans indicate that the proposed workflow is robust and capable of improving the quality of images with good accuracy and ease of implementation. The fastest scan was conducted at 1min43s while the high-quality scans were acquired at 1hr24mins. Three fast scans with varying scan times of 1min43s, 2min45s, and 3min26s were tested. It was observed that when subjected to the CycleGAN network, the denoised images of 1min43s were adding features (often called hallucinations) in the generated results indicating that the images were too noisy as a starting point. On the other hand, 2min45s and 3min26s scans showed promising results. The accuracy of denoising was then validated by pixel-wise accuracy of the segmented denoised images.

In multiphase flow imaging, it is often not practical to acquire paired images for denoising. With the implementation of cycleGAN, the proposed research not only enhances image quality, but also indicates that the acquisition time can be decreased by more than 25 times from hours to minutes (as low as 2min45s) for dynamic imaging in standard benchtop systems.

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Primary author: MATHEW, Eric Sonny (University of New South Wales (UNSW))

Co-authors: WILDENSCHILD, Dorthe (Oregon State University); Dr JACKSON, Samuel (CSIRO); MOSTAGHIMI, Peyman (University of New South Wales); TANG, Kunning (University of New South Wales); ARMSTRONG, Ryan (University of New South Wales)

Presenter: ARMSTRONG, Ryan (University of New South Wales)

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