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Stable Diffusion in Digital Rock Analysis: Applications, Challenges, and Future Prospects

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Digital rock analysis has shown promise in visualizing geological microstructures and elucidating transport mechanisms in subsurface rocks, particularly in unconventional reservoirs such as tight sandstone and shale. Accurate image reconstruction techniques, which provide valuable insights into the pore network, grain distribution and connectivity, are essential to capture the intricate features and heterogeneity present in digital rock samples.

Stable diffusion (SD), a new hotspot in the field of artificial intelligence-generated content (AIGC), holds promising potential for the production of high-quality digital rock images. The SD is a deep learning model based on diffusion techniques, and has revolutionized the field of computer vision by generating highly realistic images from textual prompts, since its first release in 2022. While it is already being used in fields such as illustration, game design and electronic-commerce, its application in the digital core field is still in its early stages.

In this study, we examine the primary applications of SD in the field of digital rock analysis. Specifically, we explore its potential in enhancing image resolution, improving image quality through denoising and deblurring techniques, segmenting images into multiple regions, filling in missing sections, extending images in any direction using outpainting, and reconstructing 3D digital rocks based 2D images. Furthermore, this research highlights certain limitations of existing pre-trained models such as WebUI, Midjourney, and DALL-E. These limitations come from the fact that their databases do not encompass digital rock images obtained from scanning electron microscopes (SEM) or computed tomography (CT). Therefore, it is imperative to fine-tune the existing models or develop new ones specifically tailored to the realm of digital rock analysis, which deserves further attention and investigation.

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