Assignment: Reconstruction of Porosity Distribution

March 2025

1 Objective

The objective of this assignment is to develop an efficient and robust method or algorithm to reconstruct the distribution of pores within a three-dimensional space, based on a given density factor.

2 Data Description

The dataset provides numerical representations of pore sizes and their spatial distribution within a unit cube (ranging from 0 to 1 in all dimensions). It can be accessed via the following link: `https://polybox.ethz.ch/index.php/s/mURsOKsnuRmFkkT`.

Each simulation instance is associated with a *density factor* between 0 and 1, indicating the proportion of the volume occupied by spherical pores. Higher values correspond to greater pore occupancy. Figure 1 illustrates an example distribution with a density factor of 0.2.

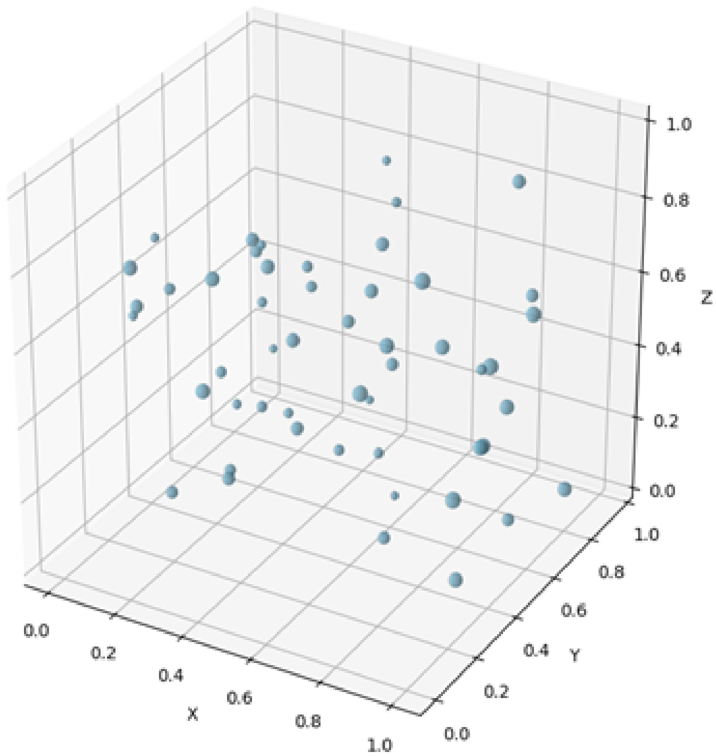

Figure 1: Example of a pore distribution with a density factor of 0.2.

The dataset files adhere to a standardized naming convention: `distribution_{index}_{density}.npy`, where `index` is a three-digit, zero-padded identifier representing the simulation instance, and `density` is a numerical value recorded to three decimal places. Each file contains a NumPy array representing a flattened 3D grid with a resolution of 30^3 (i.e., 30 grid points per axis). The data structure consists of rows, where each row includes four values: the `x`, `y`, and `z` coordinates, along with an occupancy flag (0 or 1) indicating whether the corresponding point is inside a pore.

3 Task Description

3.1 Core Requirements

Participants are required to develop an algorithm that reconstructs the porosity distribution efficiently based on the density factor while maintaining a high-resolution representation. The method should aim to:

- Minimize reliance on additional inputs beyond the given density factor.

- Achieve high computational efficiency, enabling rapid reconstruction.
- Accurately resolve even the smallest pores within the 3D space.
- Demonstrate robustness against variations in density factors and sphere size distributions.

3.2 Advanced Considerations

Outstanding submissions may further distinguish themselves by incorporating:

- Techniques for uncertainty quantification.
- Scalability analyses to larger spaces or higher-density scenarios.
- Comparative analyse between a conventional and machine learning based method.
- Visualization tools or interactive demonstrations of results.

In cases where computational constraints prevent full implementation, participants must provide a comprehensive theoretical description of their proposed method, including algorithmic details, pseudo-code, and expected performance characteristics. However, at least one working implementation is preferred.

4 Evaluation Criteria

Submissions will be evaluated based on the following criteria:

- Accuracy of pore reconstruction
- Computational efficiency and speed
- Innovativeness and robustness of the method
- Clarity and completeness of documentation
- Quality and comprehensiveness of the accompanying report

5 Submission Guidelines

Submissions must be completed by midnight on March 16, 2025.

Participants are required to create a GitHub repository, which is to be shared with `jpetrik@ethz.ch`, containing:

- Clearly structured and thoroughly documented source code.
- A comprehensive README file detailing instructions for running the code, specifying dependencies, and clearly describing the required computational environment.

- A PDF report that describes the methodology, justifies design choices, clearly presents results, discusses limitations, and proposes potential future improvements.

The implementation must be written in Python. If machine learning techniques are employed, the preferred framework is PyTorch, with an emphasis on explainability and interpretability.