

Mesh Normalisation, Quantisation & Reconstruction

Niyati Siju

1. Introduction

The goal of this project was to process 3D meshes using normalisation, quantisation, and reconstruction techniques. We evaluated how much geometric information is preserved after each step by calculating reconstruction errors (MSE/MAE) and visualising the meshes.

All work was done in a single Kaggle notebook using Python, Trimesh, NumPy, and Matplotlib.

2. Methods

2.1 Normalization

We used two normalisation techniques:

1. Min–Max Normalisation

Each coordinate axis is scaled independently to the range 0–1. This can distort the mesh if one axis has a different range than the others.

2. Unit Sphere Normalisation

The mesh is centred around its centroid and scaled uniformly so that the farthest point is at a distance of 1. This preserves the overall shape.

2.2 Quantization

After normalisation, vertex coordinates were quantised using 1024 bins.

This reduces precision but maintains consistent storage.

2.3 Reconstruction

To reconstruct:

1. Dequantize the values back to the normalised range
2. Apply the inverse of Min–Max or Unit Sphere normalisation

Reconstructed meshes were saved and visualised using point clouds.

3. Results

3.1 Visualizations

We visualised:

- Original meshes
- Min–Max normalised
- Unit Sphere normalised
- Min–Max quantised
- Unit Sphere quantised
- Min–Max reconstructed
- Unit Sphere reconstructed

XYZ point cloud visualisations were used for a stable Kaggle display.

3.2 Reconstruction Error

We computed per-axis Mean Squared Error (MSE) and Mean Absolute Error (MAE).
The results clearly show:

- Unit Sphere normalisation gives lower error than Min–Max
- Min–Max creates uneven scaling across axes, causing a larger reconstruction error
- Quantisation error is small and consistent in both methods

Task 3 error plots and the CSV file confirm these observations.

4. Conclusion

- Unit Sphere normalisation preserves mesh shape better because it scales uniformly.
- Min–Max normalisation distorts geometry, especially when axis ranges differ.
- Quantisation with 1024 bins adds small but acceptable noise.
- Reconstructed meshes using Unit Sphere normalisation are visually the closest to the original.

Overall, the combination of Unit Sphere and Quantisation is the best for preserving mesh structure.

5. Deliverables Included

- Normalized meshes
- Quantized meshes
- Reconstructed meshes
- Visualisations (PNG)
- Error CSV
- Notebook
- README
- Final report