ICL-ESE-MSc Advanced Programming Coursework 2 – 2023/2024

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Overview of Implemented Optimisations: Significant improvements have been made to the mesh mapping system, including introducing spatial partitioning via an octree, Gaussian RBF interpolation, and data management through DataFrame structures. These optimisations target both computational efficiency and the accuracy of mesh mappings.

Changes to Data Structures: Octree is introduced as the updated structure for the storage of data. It is an efficient way to find nearest neighbours by reducing computational complexity. The minimum and maximum bounds are calculated to create the octree. Each point insertion involves recursively dividing the space until the leaf nodes are reached. The search for the k nearest neighbours is done using a priority queue. The complexity of the search is O(logn+k). However, the performance can degrade to O(n) in worst-case scenarios. The initial setup is O(nlogn) due to the O(logn) insertion complexity. Comparingly, the unoptimised dummy search method has a minimum complexity of O(n^2) when searching for the nearest value. During the search, pruning was performed on the octree, reducing computational complexity. Introducing a DataFrame structure for handling CSV input and output streamlines data management and facilitates easier manipulation of mesh data. This change enhances the code's flexibility in dealing with different data sources and formats, making it easier to extend the mesh processing capabilities to include additional variables or to adapt to different mesh formats. The CSV file default has 5 elements per row. The first three are the coordinates of the node, and the fourth and fifth ones are the corresponding temperature and pressure.

Changes to Functions: The **MeshMapper** has been enhanced with the adoption of Gaussian Radial Basis Function (RBF) interpolation, representing a substantial improvement in mapping accuracy, especially for irregularly spaced data. Compared to simpler methods like barycentric interpolation, this method provides a more flexible and accurate approach to interpolating values across the mesh. The use of RBF can capture the nuances of complex value distributions across the mesh, leading to higher fidelity in the mapped results. Furthermore, functions have been added to the **main** for error calculation and performance metrics, allowing for a quantitative assessment of improvements.

Quantification of Performance: Implementing the octree and Gaussian RBF interpolation has led to a noticeable improvement in computational efficiency and mapping accuracy. Performance benchmarks indicate a reduction in execution time and increased accuracy in mapped values compared to the original implementation. The original implementation is a weighted sum of k nearest neighbours, and the search method is a simple tree search.