PDC Project

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Section: C

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K-Shortest Path Ultimate Search

Introduction:

The K-Shortest Path Ultimate Search project is a collaborative effort by Muhammad Affan, Faraz Rashid, and Ahmad Hassan. The project aims to implement an efficient algorithm to find the K-shortest paths in a given graph. The project is implemented in C++ and utilizes concepts of parallel computing and graph theory.

Code Structure:

graphs.h:

- This file contains the declarations of classes and functions used in the project.
- It includes necessary C++ standard libraries such as iostream and vector.
- The file defines two classes: Node and Graph.
- Node represents a node in the graph, while Graph represents the entire graph structure.
- Various member functions and variables are declared within these classes to facilitate graph operations.

graphs.cpp:

- This file contains the implementation of the functions declared in the header file.
- Functions for reading graph data from files, initializing adjacency matrices, finding the number of neighbors for a given node, and finding K-shortest paths are defined here.
- The main function in this file demonstrates the usage of the implemented functionalities by reading graph data from files, computing K-shortest paths, and measuring execution time.

graphs_parallel.cpp:

- This file extends the functionalities of the original implementation to support parallel computing using MPI (Message Passing Interface) and OpenMP.
- It includes similar functionalities as the sequential implementation but parallelizes certain operations to improve performance.
- MPI functions are used for inter-process communication, allowing for parallel execution across multiple processes.
- OpenMP directives are used for parallelizing loops to leverage multi-core processors effectively.

graphs2.h:

- This header file contains declarations for two classes: Node2 and Graph2.
- Node2 Class: Represents a node in the graph. It contains a name (string) and vectors to store pointers to adjacent nodes (edge) and the corresponding weights (weights) of the edges.
- Graph2 Class: Represents the graph itself. It contains vectors to store nodes, indexes, and an adjacency matrix (AdjacencyMatrix) to represent edges and their weights. The graph class provides methods for adding edges, reading graph data from a file, printing edges, initializing the adjacency matrix, and finding the k shortest paths.

graphs2.cpp:

- This source file contains the implementation of the classes declared in graphs2.h. It defines methods for adding edges between nodes, reading graph data from a file, initializing the adjacency matrix, printing edges, and finding the k shortest paths in a serial manner.
- Reading from File: The readFromFile() function reads graph data from a CSV file, where each line represents an edge between two nodes along with its weight.

- Adjacency Matrix: The init_AdjacencyMatrix() function initializes the adjacency matrix based on the graph data. It iterates over the nodes and their edges to populate the matrix with edge weights.
- K Shortest Paths: The findKShortestSerial() function computes the k shortest paths using a modified Dijkstra's algorithm. It maintains a priority queue of nodes based on their distances from the source node.

graphs2_parallel.cpp:

- This source file extends the functionality of graphs2.cpp by introducing parallelization using MPI (Message Passing Interface) and OpenMP (Open Multi-Processing).
- MPI and OpenMP: MPI is used for distributed memory parallelism, allowing multiple processes to communicate and collaborate in finding the k shortest paths. OpenMP is used for shared memory parallelism within each process, leveraging multiple threads for parallel computation.
- Parallel K Shortest Paths: The findKShortestParallel() function parallelizes the computation of k shortest paths using MPI and OpenMP. It distributes the workload among multiple processes and utilizes parallel loops to explore different paths concurrently.

Mapping **Strategy:**

Our mapping strategy involved determining the number of neighbors for each thread by initially mapping each neighbor of the start node. By assessing the number of neighbors associated with each, we allocated a corresponding number of processes to efficiently explore these paths. However, given the requirement for random start and end nodes, we erred on the side of caution by allocating 1-3 processes, as some start nodes might have limited neighboring nodes.

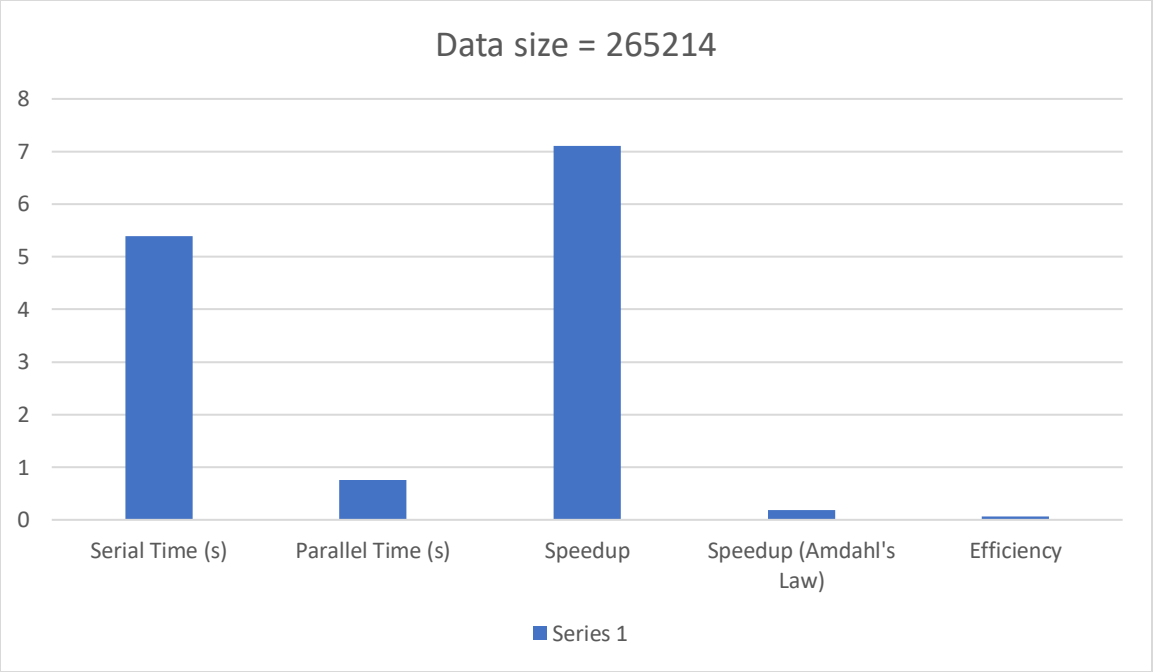
To prevent potential issues stemming from an excessive number of processes compared to available neighbors, we implemented a check to terminate the program early and display an error message if the processor count exceeded the number of neighbors.

Subsequently, after the threads had explored their respective paths, we aggregated their results and applied the Quick Sort algorithm, renowned for its efficiency, to sort the paths. This approach was chosen to mitigate communication and synchronization challenges inherent in inter-thread communication, thus streamlining the process.

Ultimately, our methodology aimed to efficiently derive the k shortest paths while also incorporating the distance from the start vertex to the neighboring vertex, optimizing the computational process.

Below are the running outputs of all the files read.
Each file is run 10 times and finally the Average is calculated.
Visual graphs are also illustrated for better view.

Size of data	Serial Time (s)	Parallel Time (s)	Speedup	Speedup (Amdahl's Law)	Efficiency	Processors in Parallel
265214	5.33253	0.79543	6.703958865	0.257178274	0.085726091	3
265215	5.32642	0.73892	7.208385211	0.17944537	0.059815123	3
265216	5.36967	0.719199	7.466181127	0.178272091	0.05942403	3
265217	5.37443	0.701341	7.663076877	0.178310003	0.059436668	3
265218	5.28681	0.781309	6.766605786	0.180269622	0.060089874	3
265219	5.61038	0.733508	7.648696401	0.170797616	0.056932539	3
265220	5.37791	0.737562	7.291468378	0.17781685	0.059272283	3
265221	5.3861	0.816711	6.594866483	0.176730371	0.058910124	3
265222	5.41609	0.815701	6.639798161	0.175809019	0.058603006	3
AVERAGE	5.386704444	0.759964556	7.109226365	0.186069913	0.062023304	3
36692	0.380267	0.341717	1.112812649	1	1	1
36692	0.374805	0.386713	0.969207138	1	1	1
36692	0.387539	0.354243	1.093991977	1	1	1
36692	0.351068	0.377773	0.9293094	1	1	1
36692	0.373273	0.412067	0.905855116	1	1	1
36692	0.420931	0.378135	1.113176511	1	1	1
36692	0.374986	0.347174	1.080109686	1	1	1
36692	0.34675	0.370234	0.936569845	1	1	1
36692	0.362716	0.379055	0.956895437	1	1	1
36692	0.354113	0.33563	1.055069571	1	1	1
AVERAGE	0.3726448	0.3682741	1.015299733	1	1	1
377	0.177231	0.22123	0.801116485	2.214901562	0.738300521	3
377	0.162653	0.214444	0.758487064	2.263628173	0.754542724	3
377	0.171677	0.262231	0.654678509	2.233216263	0.744405421	3
377	0.190039	0.22311	0.851772668	2.173790177	0.724596726	3
377	0.223127	0.224239	0.995041005	2.074324427	0.691441476	3
377	0.198425	0.195195	1.016547555	2.147689444	0.715896481	3
377	0.183105	0.214926	0.85194439	2.195855688	0.731951896	3
377	0.189167	0.20667	0.91530943	2.176540664	0.725513555	3
377	0.189176	0.191282	0.988990077	2.176512241	0.72550408	3
377	0.174012	0.214408	0.811592851	2.225479665	0.741826555	3
AVERAGE	0.1858612	0.2167735	0.864548004	2.188193831	0.729397944	3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8
7
6
5
4
3
2
1
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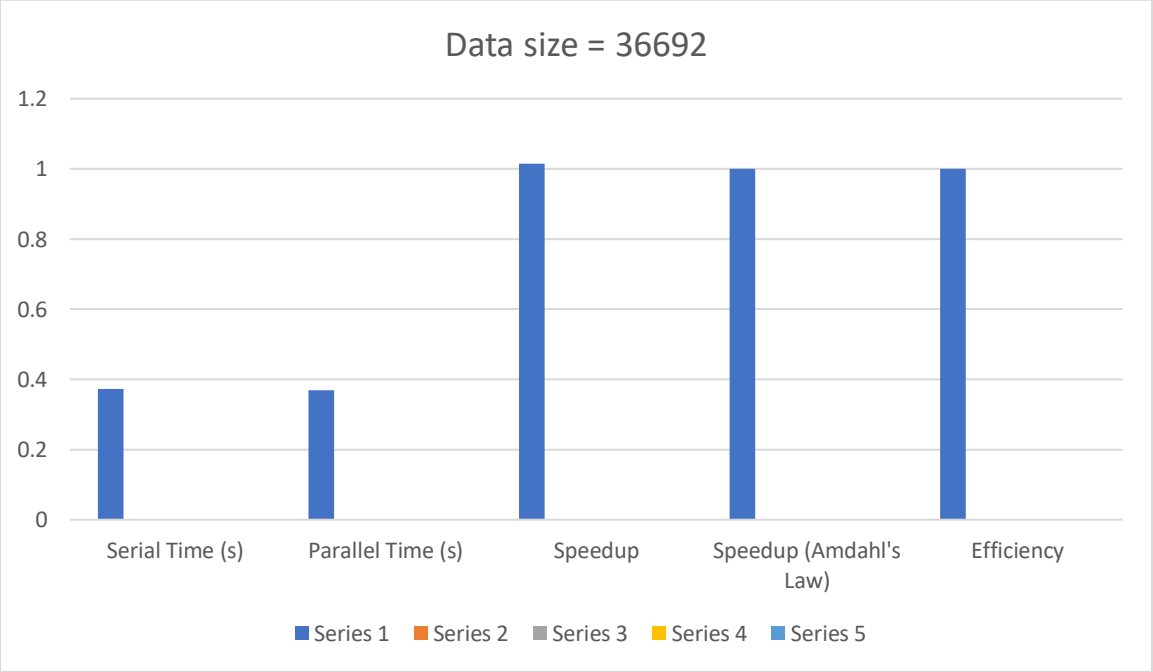
Serial Time (s)
Parallel Time (s)
Speedup
Speedup (Amdahl's Law)
Efficiency
Series 1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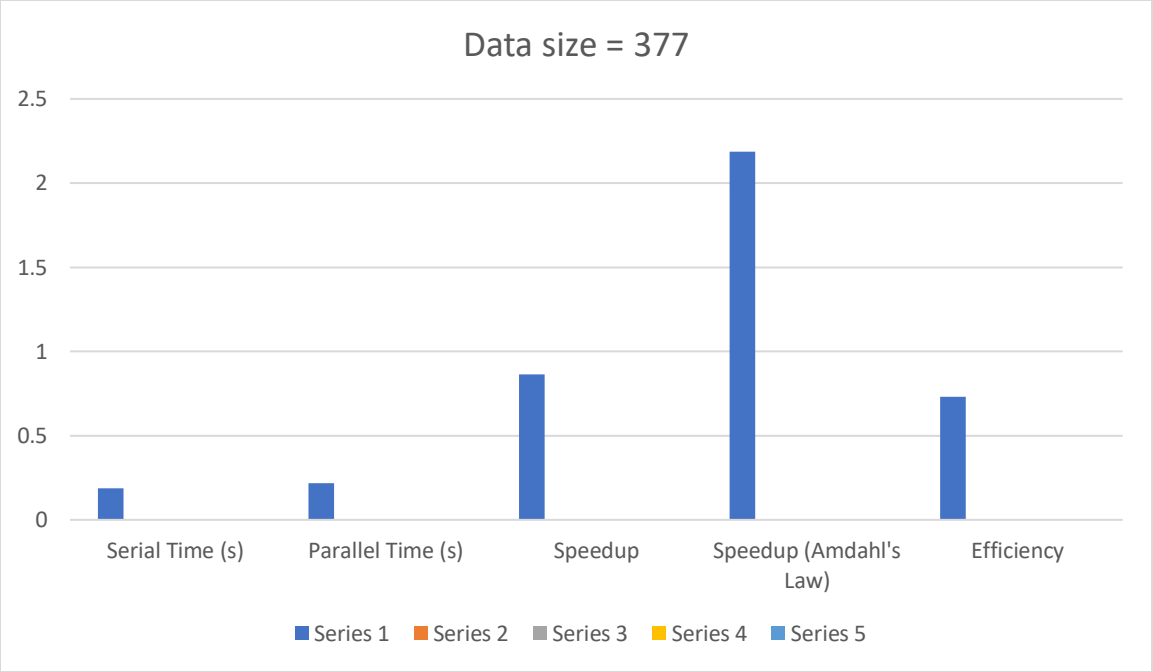
1
0.8
0.6
0.4
0.2
0
Serial Time (s)
Parallel Time (s)
Speedup
Speedup (Amdahl's Law)
Efficiency
Series 1
Series 2
Series 3
Series 4
Series 5



Conclusion:

Based on the results provided, it is evident that parallelization significantly improves performance for larger file sizes. However, the impact of parallelization diminishes for smaller files, as indicated by lower speedup values. Amdahl's Law highlights the importance of optimizing parallelizable sections of the program to achieve higher speedup. Additionally, the efficiency of parallelization depends on factors such as file size and the number of processors utilized. Overall, parallelization demonstrates its effectiveness in accelerating computation, particularly for large-scale data processing tasks.

Thankyou!