Practical Assignment: Report on a Paper

Graph Measures

Module Code: 5FTC2093
Submission Date: 4/1/2025
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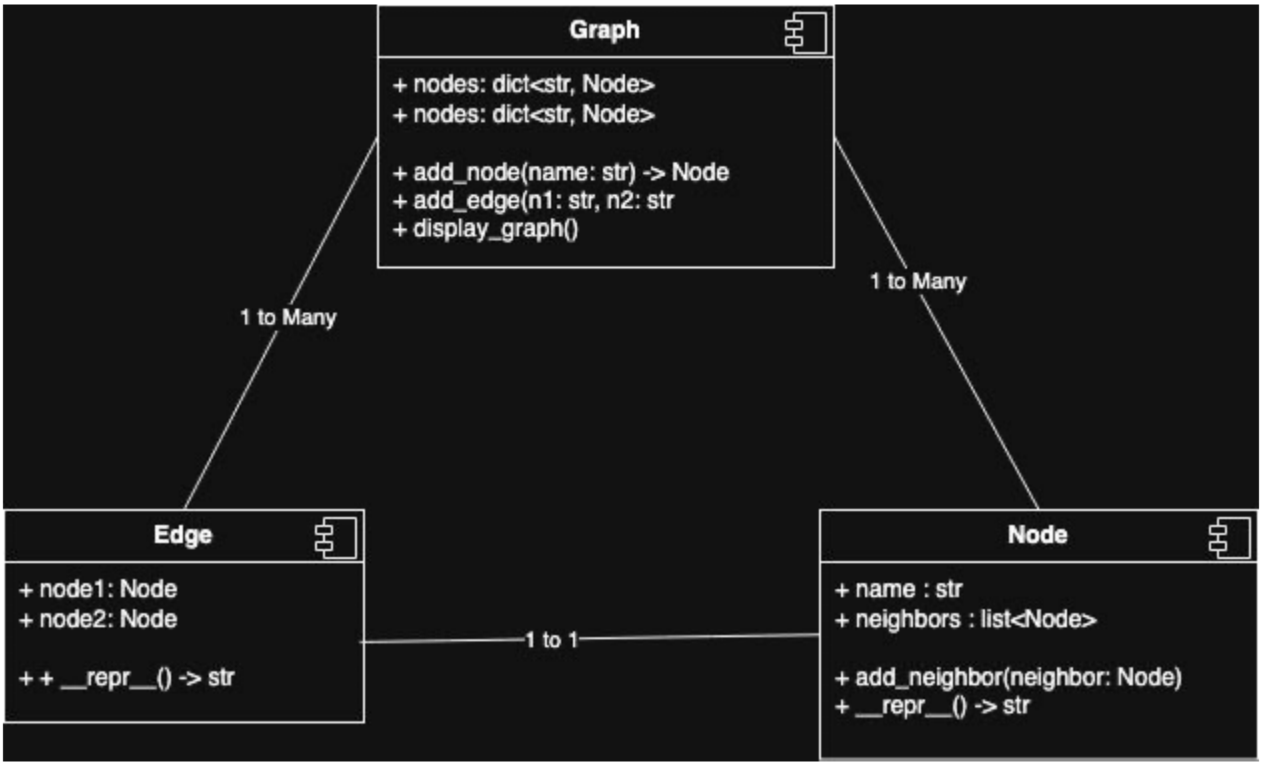
Introduction

This report explores the design, implementation, simulation, and evaluation of an autonomous agent navigating an undirected graph. The study is based on Clements' (2019) research on graph-theoretic centrality, empowerment, and relevant goal information in navigation-based decision-making. By applying key principles of graph theory and agent-based modeling, this project investigates how agents behave in structured environments.

World Design

UML Diagram:



Design Choices

The graph structure is designed using three main classes: Node, Edge, and Graph. This modular setup simplifies expansion and maintenance. The Node class includes properties such as its name and a list of neighboring nodes, with the add_neighbor method facilitating new connections. The Edge class represents the relationships between nodes, while the Graph class manages the collection of nodes and edges. This separation ensures efficient data management and retrieval.

World Metrics

GraphMetrics Class

The GraphMetrics class implements three centrality measures: degree centrality, closeness centrality, and betweenness centrality, following the methodology outlined by Clements (2019).

Shortest Path Computation

The GraphMetrics class calculates degree, closeness, and betweenness centrality. A breadth-first search (BFS) algorithm is employed in the all_shortest_paths function to determine the shortest paths for betweenness centrality, ensuring accurate and efficient computation.

Agent Design and Simulation

Agent Design

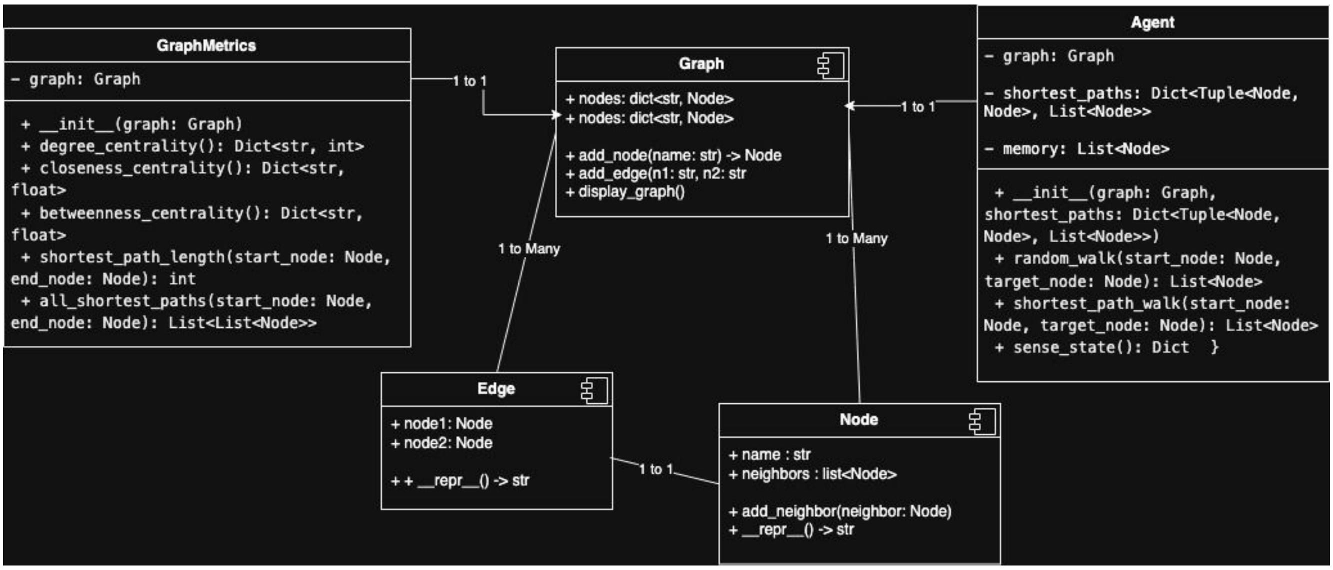
The Agent class represents an entity capable of navigating the graph through two movement strategies:

Random Walk: The agent randomly selects a neighboring node and moves to it.

Shortest Path: The agent follows a precomputed shortest path to reach a target node.

Additionally, the agent maintains memory, tracking previously visited nodes within an episode. At the start, shortest paths between all node pairs are precomputed and stored in a dictionary for quick access.

Updated UML diagram:



Simulation

The simulation involves multiple episodes, where the agent is assigned a random starting node and a target node. The agent navigates the graph, and the number of visited nodes per episode is recorded. A total of 1,000 episodes are conducted to gather sufficient data.

Evaluation

To analyze performance, data from the first 10 episodes of the random walk were assessed.

Comparison of Movement Modes:

Metric	Random Walk	Shortest Path
Average Nodes Visited	14.3	3.0

Movement Mode Analysis:

As expected, the shortest path strategy results in fewer nodes visited since the agent follows an optimized route. Conversely, the random walk method explores the graph arbitrarily, increasing the number of visited nodes.

Centrality Measures vs. Simulation Results

Node	Degree Centrality	Closeness Centrality	Betweenness Centrality	Average visits (Random Walk)	Average visits (Shortest Path)
A	2	0.56	8.0	1.7	0.5
B	2	0.56	8.0	1.2	0.4
C	3	0.71	14.0	2.7	0.5
D	3	0.71	14.0	2.4	0.6
E	2	0.56	8.0	2.0	0.3
F	2	0.56	8.0	1.4	0.7

Analysis of Results

Nodes with higher centrality values (e.g., nodes C and D) are visited more frequently in both movement strategies. The data confirms that central nodes play a significant role in navigation, particularly in shortest path strategies where the agent naturally prefers high-centrality nodes.

Conclusion

This project successfully implemented an agent-based system for graph navigation. The evaluation demonstrated expected variations in movement modes and reinforced the relationship between graph centrality measures and agent navigation behavior. The findings align with Clements' (2019) research, emphasizing the importance of graph structures in decision-making and agent behavior modeling.

References

Clements, M. (2019). Empowerment and Relevant Goal Information as Alternatives to Graph-Theoretic Centrality for Navigational Decision Making (MSc by Research). University of Hertfordshire.