LU 4 - Individual Assignment: A* Heuristics

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19 November 2024

Assignment Overview

This assignment presents an analysis of the impact of different heuristic functions on the performance of the A* pathfinding algorithm. Specifically, it compares the Manhattan distance heuristic and the Euclidean distance heuristic in the context of a grid-based environment, where diagonal movement is allowed. The following sections provide detailed responses to the questions posed.

Answers

A. Why does the Manhattan distance heuristic expand fewer nodes than the Euclidean heuristic?

The **Manhattan distance heuristic** calculates the distance between two points by summing the absolute differences in their x and y coordinates:

$$d_{\text{Manhattan}} = |x_2 - x_1| + |y_2 - y_1|$$

This heuristic is inherently aligned with environments that restrict movement to horizontal and vertical directions, as is often the case in grid-based systems. In these scenarios, the Manhattan distance function tends to prioritize grid-aligned paths, which results in fewer nodes being expanded. Since the heuristic does not account for diagonal movement, it avoids exploring unnecessary paths, focusing on those that are more likely to lead directly to the goal.

Conversely, the **Euclidean distance heuristic**, defined as:

$$d_{\text{Euclidean}} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

takes the straight-line (or diagonal) distance into consideration. While this can be advantageous in environments where diagonal movement is permissible, it often leads to the exploration of a larger number of nodes. This is because the Euclidean heuristic may favor paths that include diagonal segments, potentially leading the algorithm to expand nodes in areas that are not immediately relevant to the goal, especially in grid-based layouts with obstacles.

Therefore, the Manhattan distance heuristic tends to expand fewer nodes in grid-based environments, as it limits the search to paths that follow horizontal and vertical lines, which is more appropriate for such environments.

B. Under what conditions would the Euclidean metric be preferable?

The **Euclidean distance heuristic** is particularly advantageous in the following situations:

- **When diagonal movement is permissible or optimal**: In environments where diagonal paths are either allowed or preferred, the Euclidean heuristic provides a more accurate estimate of the shortest path since it directly reflects the straight-line distance between points.
- **In open environments with few obstacles**: In relatively obstacle-free areas, the Euclidean heuristic allows the algorithm to take more direct routes, potentially reducing the number of turns and generating shorter paths. This is particularly useful in less structured environments where the shortest path may not strictly adhere to grid lines.

In conclusion, the Euclidean heuristic is most effective in open, unobstructed spaces where diagonal movement is feasible, whereas the Manhattan heuristic is better suited for grid-based systems that require right-angle turns due to obstacles or structural constraints.