GRID-BASED PATHFINDING

Problem overview:

In real life and in areas like robotics, video games, or navigation systems, we often face the need to find a **path from a start point to a goal** in an organized and efficient way.
For this project, I'm working with a **two-dimensional grid**, where each cell can be:

- **Open:** can move through it
- **Obstacle:** cannot move through it
- **Start or Goal position**

The main task is simple: get from the start to the goal while avoiding obstacles. Movement is only allowed in **four directions** (up, down, left, right), and each step has the same cost.

The real challenge is that some obstacles might block the direct path, so the algorithms have to find alternative routes. Also, the goal isn't just to reach the target, but to see **which algorithm performs best** in terms of speed, memory usage, and path quality (finding the shortest path).

In short, this project gives us a chance to see **how each algorithm behaves when solving a grid-based pathfinding problem**, and lets us compare them to understand which one works best in different situations.

Project Objective:

The main objective of this project is to implement, evaluate, and compare six fundamental search algorithms in artificial intelligence by applying them to solve a practical pathfinding problem in a two-dimensional grid environment. The project will provide hands-on experience in algorithm implementation, performance evaluation, and comparative analysis, highlighting the strengths and weaknesses of each search strategy in various scenarios.

Problem Definition:

Core Problem:

The project addresses the pathfinding problem: Given a two-dimensional grid with obstacles, a start cell, and a goal cell, the task is to find an optimal or near-optimal path from the start to the goal while avoiding obstacles. This problem is highly relevant to applications such as robotics, navigation systems, video games, and logistical planning.

Problem Components:

1. **Environment Representation:**

   Grid of size N × M, where each cell can be:

   - Free (traversable)
   - Blocked (obstacle, non-traversable)
   - Marked as Start or Goal
1. **Input Parameters:**
   - Grid dimensions (N rows × M columns)
   - Start and Goal positions
   - Obstacle density (default 20%)
   - Allowed movement directions and uniform movement cost
2. **Output Specifications:**
   - Sequence of coordinates representing the solution path (if one exists)
   - Quantitative performance metrics for each algorithm
   - Optional visualization of paths and exploration patterns
3. **Problem Constraints:**
   - Movement is allowed only in four cardinal directions (up, down, left, right)
   - Each move costs 1 unit
   - Start and goal are distinct cells
   - Obstacles are immovable
   - Some grids may be unsolvable if obstacles block all paths

Algorithms we use:

The project will implement and compare the following search algorithms:

- Breadth-First Search (BFS)
- Depth-First Search (DFS)
- Depth-Limited Search (DLS)
- Iterative Deepening Search (IDS)
- Uniform-Cost Search (UCS)
- A* Search

Note: Detailed explanation of each algorithm will be included in the project implementation and final report.

Team Roles and Responsibilities:

youssef :

- ▢ Built the grid environment alongside Mohamed.
- ▢ Implemented A* search with Manhattan heuristic.
- ▢ Tested A* and ensured proper integration with the grid.

salma :

- ▢ Implement Depth-Limited Search (DLS).
- ▢ Managed depth limits and tested algorithm accuracy.
- ▢ Prepared and organized the project proposal.

huda :

- ▢ Implemented Breadth-First Search (BFS).
- ▢ Tested BFS on the grid and ensured correct pathfinding.
- ▢ Prepare the final report and conclusions.

yomna :

- ▢ Collect results from all algorithms.
- ▢ Perform the comparative analysis between algorithms.
- ▢ Implemented Uniform-Cost Search (UCS).

mahmoud :

- ▢ Implemented Iterative Deepening Search (IDS).
- ▢ Reviewed all algorithms and helped with debugging.
- ▢ Ensured proper integration, visualization, and overall system functionality.

mohammed :

- ▢ Implemented Depth-First Search (DFS).
- ▢ Built the grid environment alongside Youssef.
- ▢ Assisted in testing and visualization of all algorithms.

All Members: worked together on understanding the problem, building the environment, testing the algorithms, and comparing the results, in addition to their individual responsibilities.

Evaluation Measures:

The project will assess each algorithm using the following metrics:

1. **Time Complexity:** Number of nodes expanded during search
2. **Space Complexity:** Maximum number of nodes stored in memory
3. **Solution Optimality:** Whether the shortest path is found
4. **Path Cost:** Number of steps in the solution path

Expected Outcomes:

- Successful implementation of six search algorithms
- Comparative analysis highlighting differences in efficiency, memory usage, and solution quality
- Clear visualization of exploration patterns for each algorithm
- Insights into which algorithms are better suited for different types of grid-based pathfinding problems

github link : GitHub - youssef-darrag/grid-pathfinding-algorithms