
ARTIFICIAL INTELLIGENCE
FIND THE SHORTEST ROUTE USING THE A*
ALGORITHM ON A REAL-WORLD MAP
Explore Now

MEET OUR TEAM

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OBJECTIVE

To develop an interactive simulation system that visualizes the A search algorithm* using live geographical data from OpenStreetMap (OSM).

THE POWER OF A

- Combines the optimality of Dijkstra with the speed of Greedy Best-First Search.
- Uses the evaluation function: $f(n) = g(n) + h(n)$.
- $g(n)$: Actual cost from start to current node.
- $h(n)$: Heuristic estimate (straight-line distance) to the goal.

REAL-WORLD CONTEXT

1. Logistics & Fleet Management: Optimizing delivery routes to minimize fuel costs and travel time.
2. Autonomous Systems: Enabling self-driving cars and warehouse robots to navigate dynamic environments safely.
3. Games & Virtual Simulations: Guiding NPCs through complex, obstacle-filled maps with realistic movement.
4. Emergency Services: Routing ambulances and fire trucks via the fastest paths to save lives.

TECHNICAL FRAMEWORK & SYSTEM ARCHITECTURE

01

Core Technologies

- Leaflet.js: Open-source library for interactive map rendering and layer management.
- OpenStreetMap (OSM): Extracted real road data (Nodes & Ways) via the Overpass API.
- JavaScript (ES6+): Handles the graph logic, A* execution, and UI interactions.

02

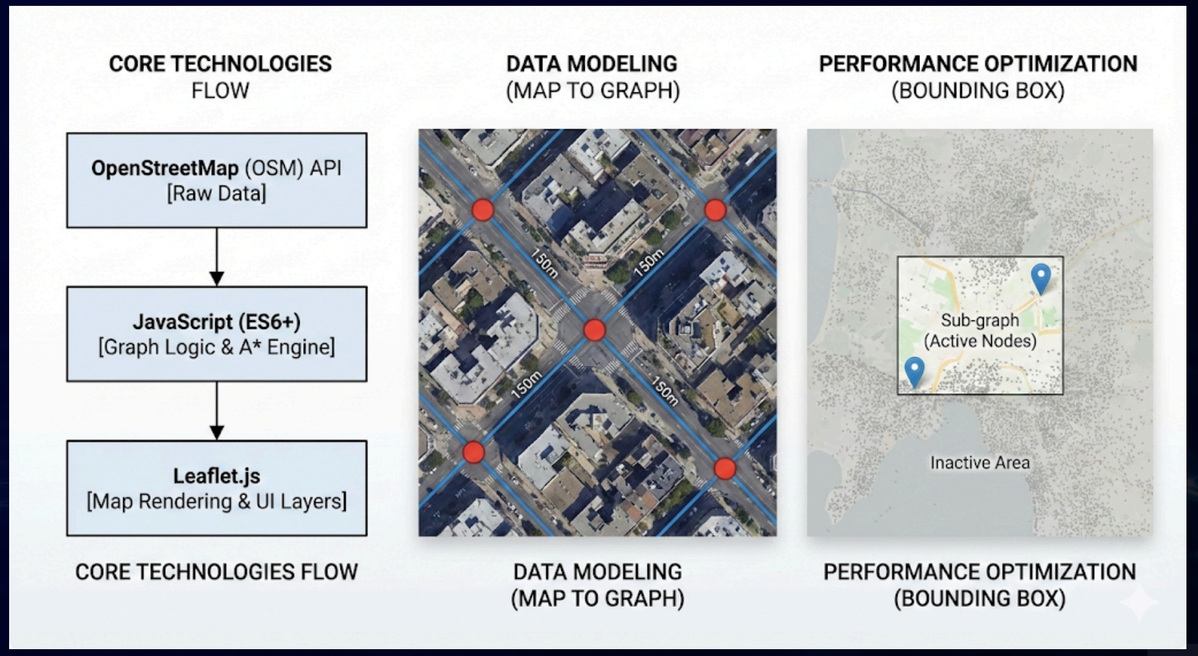
Data Modeling

- Nodes: Intersections or road points (ID, Lat, Lng).
- Edges: Road segments between nodes with weights calculated by geographic distance.

03

Performance Optimization

- Bounding Box (BBox): Filters the search space to a specific area between two user-clicked points.
- Sub-graph Extraction: Dramatically reduces the number of nodes processed, ensuring smooth browser performance.



ALGORITHM IMPLEMENTATION & VISUALIZATION

THE VISUALIZATION LOGIC

- Frontier (Yellow): Nodes currently in the priority queue (Open Set) awaiting expansion.
- Visited (Orange): Nodes already processed and expanded (Closed Set).
- Optimal Path (Blue): The final shortest route generated after reaching the goal.

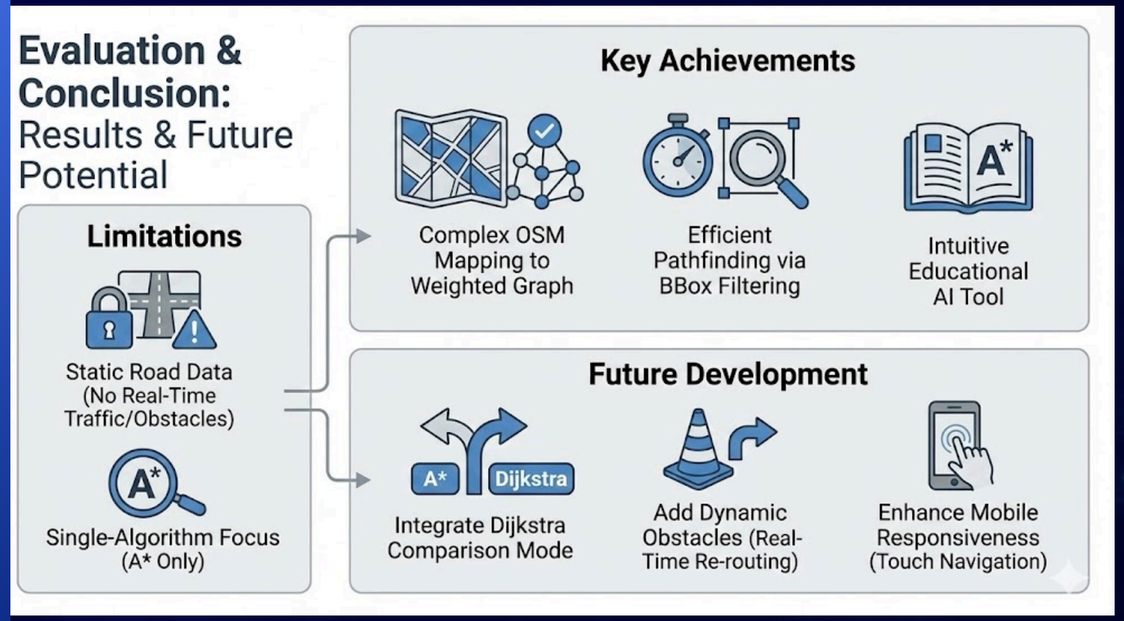
ANIMATION SYNCHRONIZATION

- runId Mechanism: A unique ID for each search session to cancel old animations if a user clicks new points rapidly.
- Sequential Rendering: Uses setTimeout with incremental delays to simulate the "wave-front" expansion of the algorithm.

INTERACTIVE UI

Users can select any two arbitrary points on the map, and the system snaps them to the Nearest Node in the graph.

RESULTS & FUTURE POTENTIAL



01

Key Achievements

- Successfully mapped a complex OSM dataset into a functional weighted graph.
- Achieved efficient pathfinding even on large-scale maps using BBox filtering.
- Created an intuitive educational tool for understanding AI pathfinding.

02

Limitations

- Currently limited to static road data (no real-time traffic or dynamic obstacles).
- Single-algorithm focus (A* only).

03

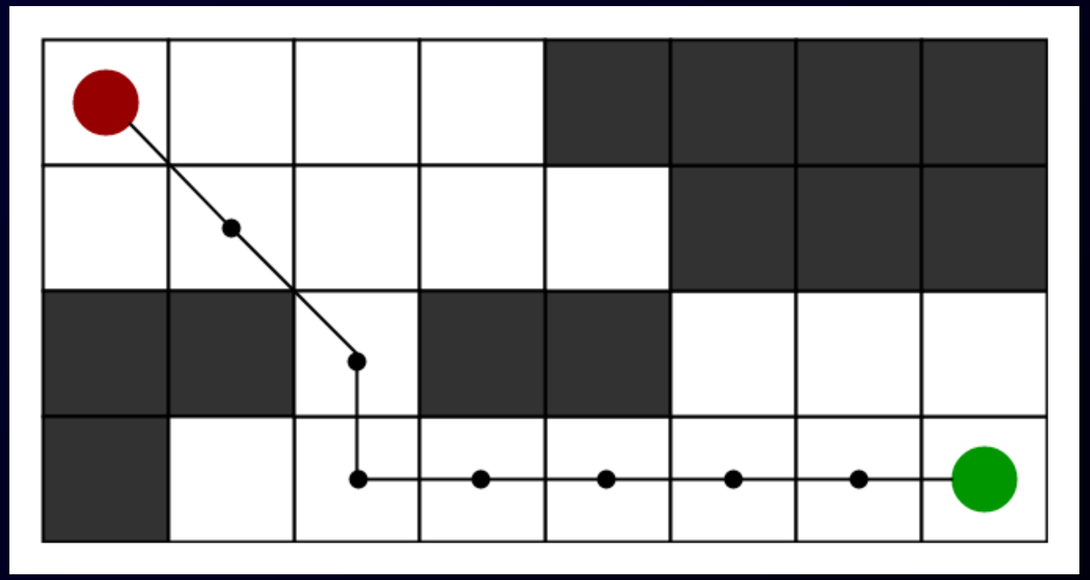
Future Development

- Integrate Dijkstra comparison mode to show efficiency differences.
- Add dynamic obstacles (construction, roadblocks) for real-time re-routing.
- Enhance Mobile Responsiveness for touch-based navigation.

A* ALGORITHM OVERVIEW

The A* algorithm is one of the most optimal and efficient shortest-path search algorithms, widely applied in:

- Mapping systems,
- Autonomous robotics,
- Game AI,
- Intelligent navigation systems.



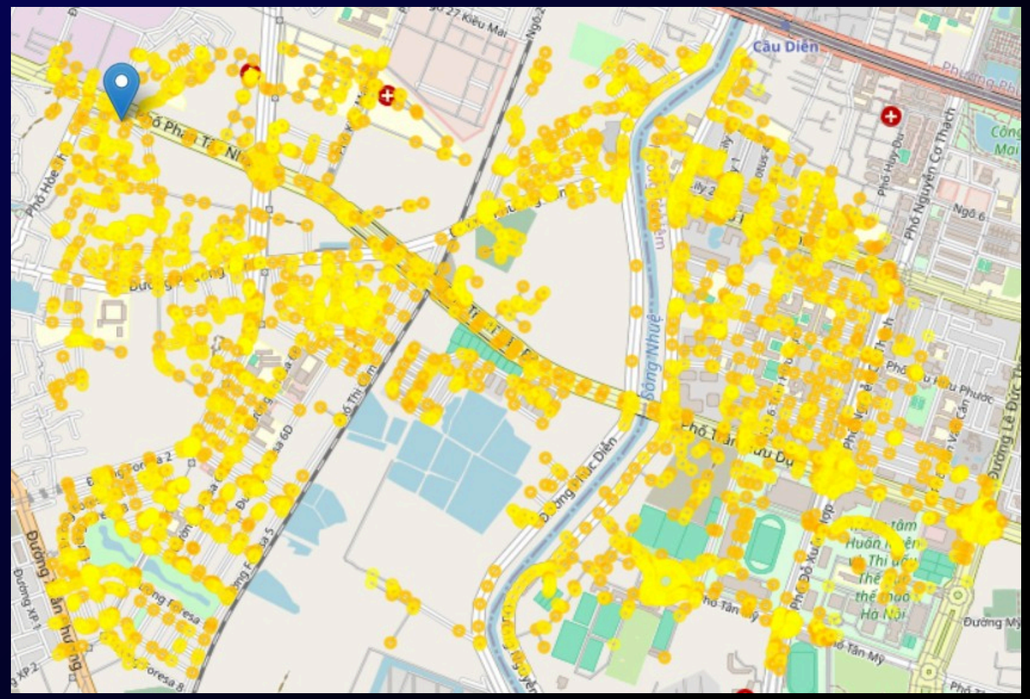
Core evaluation formula

$$f(n) = g(n) + h(n)$$

- g(n): Actual cost from the starting point to the current node
- h(n): Estimated (heuristic) cost from the current node to the goal

  → If h(n) is good (never wish too high), A* will find the shortest and fastest path.

A ALGORITHM OVERVIEW*



Reconstruct path using **cameFrom** map

(Track parent nodes to build path backwards from goal to start)

Visited nodes (expanded) → **Orange**

Frontier (open set) (awaiting expansion) → **yellow**

SYSTEM DESIGN

Main modules

- buildGraph(): Build graph from OSM data (nodes + bidirectional edges)
- aStarTrace(): Execute A* with tracing visited/frontier
- subGraphFromBBox(): Create subgraph limited to bounding box

Speed optimization with Bounding Box

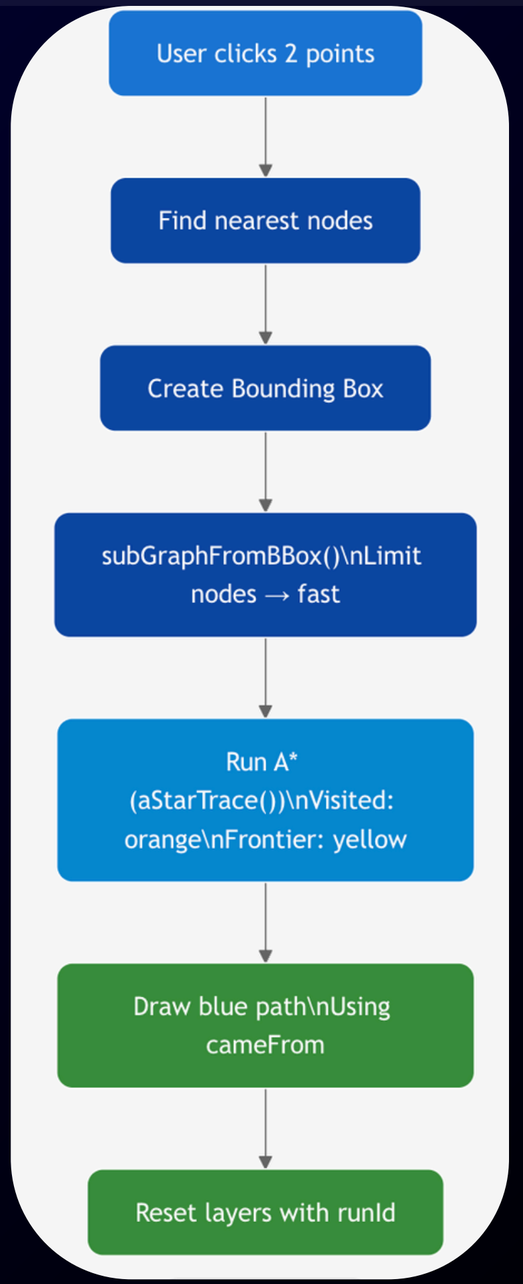
- Limit search area around the 2 clicked points
- Reduce nodes from thousands to hundreds → avoid lag

User interaction

- Click 2 points on the map → automatically find nearest nodes
- Trigger A* → display animation (visited orange, frontier yellow)
- Draw final path in blue after animation

Modular design

- Separate layers (visited, frontier, path, marker) → easy to clear & reset
- runId to cancel old animations when clicking quickly



ANIMATION & UI ARCHITECTURE

Layer Management (Leaflet.js)

- Separated *L.LayerGroup* for distinct visual elements:

visitedLayer (Orange):
Processed nodes

frontierLayer (Yellow):
Nodes in priority queue

pathLayer (Blue):
Final shortest path

- **Benefit**: Modular control, easy to clearLayers() on reset.

Asynchronous Animation:

- Uses *setTimeout* with incremental delay (i * 10ms) to simulate "wave-like" expansion.

```
visited.forEach((id, i) => {
  const n = subGraph.nodes.get(id);
  setTimeout(() => {
    if (runId !== currentRun) return;
    L.circleMarker([n.lat, n.lon], {
      radius: 3, color: "orange", opacity: 0.5
    }).addTo(visitedLayer);
  }, i * 10);
});
```

Concurrency Control (*runId*):

- Problem: Rapid user clicks cause animation conflicts.
- Solution: A unique *runId* increments on every click.
- Logic: *if (runId !== currentRun) return;*

→ Immediately cancels outdated animations.

EXPERIMENTAL RESULTS

Workflow Visualization:

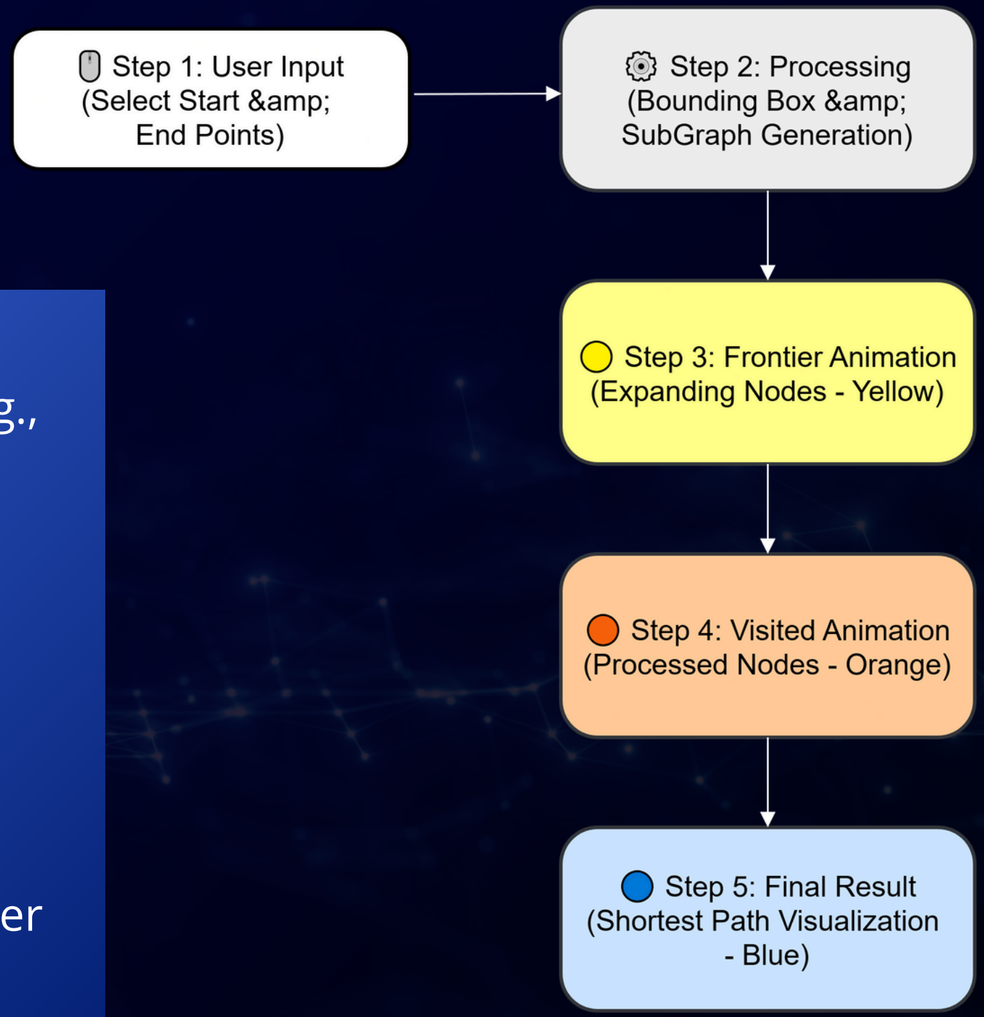
1. Input: User selects 2 points anywhere on the map (e.g., Nam Tu Liem district).
2. Processing:

- Calculates Bounding Box.
- Finds nearest graph nodes.

3. Execution:

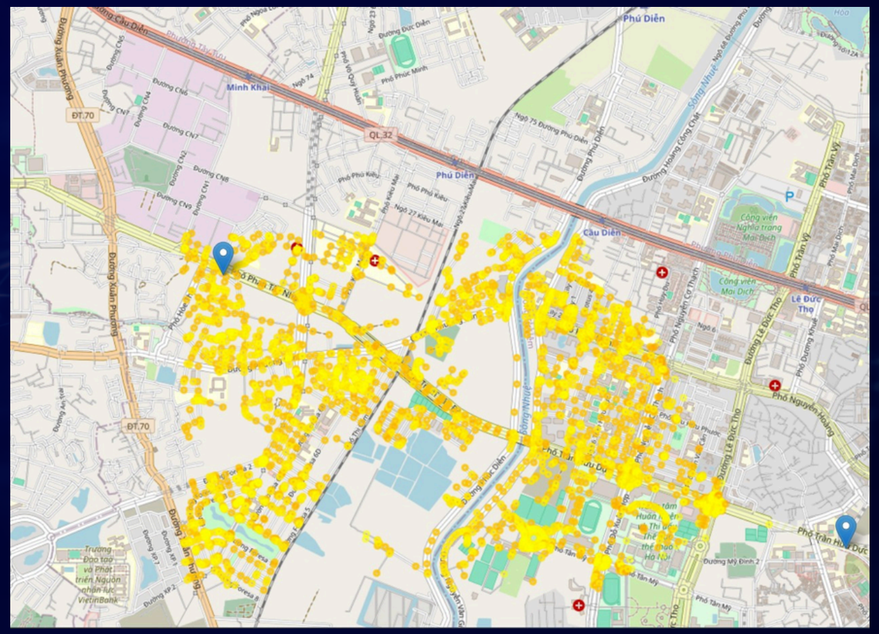
- Frontier (Yellow): Expands towards the target.
- Visited (Orange): Marks explored areas.

4. Output: The shortest path (Blue polyline) is drawn after search completion.

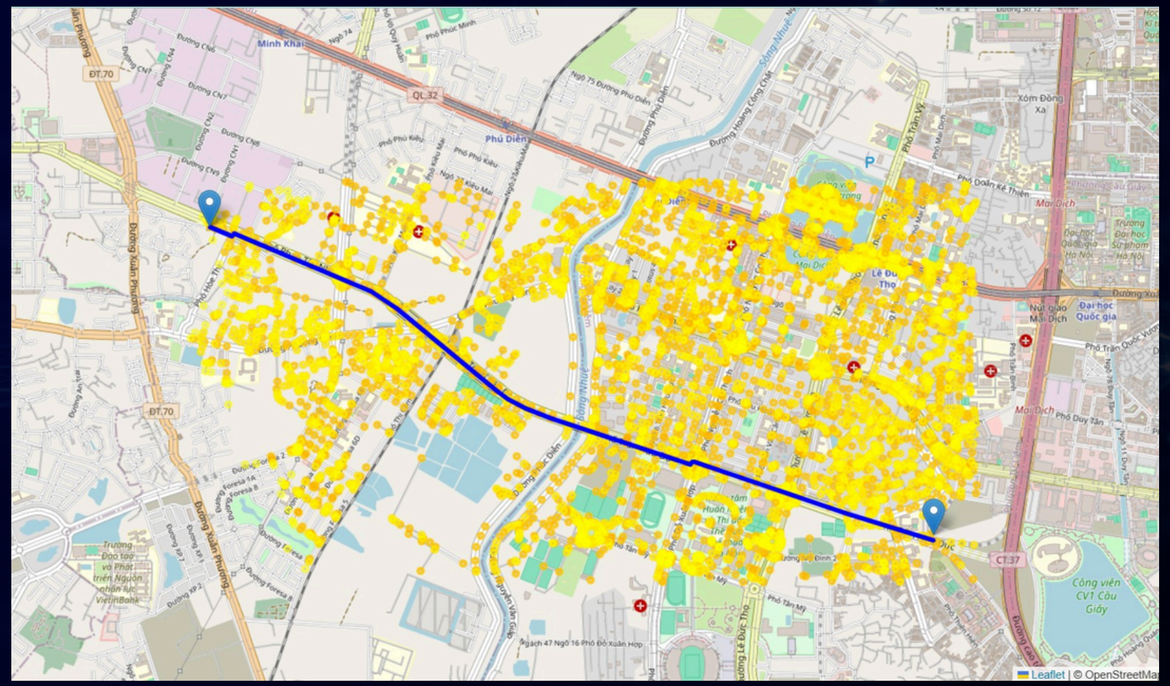


PERFORMANCE

- Smooth rendering on browser.
- Fast computation due to Subgraph extraction (Bounding Box).



EXPERIMENTAL RESULTS



EVALUATION & FUTURE WORK

Strengths:

- Educational: Visually demonstrates how A* works (f(n) = g(n) + h(n)) via color coding.
- Optimized: Efficient subgraph extraction prevents browser lag.
- Robust UI: Handles race conditions effectively.

Limitations:

- Single Algorithm: Lack of comparison with Dijkstra or BFS.
- Static Graph: Does not account for dynamic obstacles (traffic jams, construction).
- Platform: Not fully optimized for mobile touch interfaces.

Future Development:

- Integrate Dijkstra mode for performance comparison.
- Add Dynamic Obstacles (allow users to block roads).
- Implement Responsive Design for mobile devices.

THANK YOU