Technical Description

Overview

This frontier selection strategy employs a multi-factor scoring system integrated with adaptive path stability and an intelligent blacklisting mechanism to achieve autonomous exploration.

Core Strategy

1. Multi-Factor Evaluation Function

The algorithm evaluates each frontier candidate using weighted factors:

BFS Distance (Weight: 4.0): Prioritizes frontiers farther from the robot's starting position via BFS path distance. This encourages exploration of distant, uncharted areas and helps navigate around complex obstacles like U-turns.

Openness Score (Weight: 3.5): Analyzes a 5×5 neighborhood around each frontier, calculating a weighted ratio of free (1.0) and unknown (0.5) cells to avoid dead ends.

Heading Alignment (Weight: 1.5): Measures cosine similarity between the robot's current heading and the frontier direction to minimize unnecessary rotations.

Goal Proximity (Weight: 1.0): Applies inverse distance weighting to slightly favor frontiers closer to the final goal.

Robot Distance (Weight: -0.1): A minimal negative weight prevents myopic behavior by discouraging selection of the nearest frontier.

Attempt Penalty (-2.0): Penalizes frontiers attempted for over 5 steps to avoid repeated commitment to problematic targets.

Stability Bonus (+2.0): Awards a significant bonus to the current frontier when progress is detected, preventing oscillation between competing frontiers.

2. Path Stability Management

To reduce erratic frontier switching:

Progress Tracking: Monitors distance to the current frontier; maintains the path if the robot is within 2 cell sizes or making measurable progress.

Validity Checking: Verifies that the current frontier remains in the detection list and path progress continues before replanning.

Distance History: Tracks the last frontier distance to distinguish forward progress from stagnation.

Immediate Switching: Transitions to goal-seeking mode upon visibility confirmation.

3. Blacklist Mechanism

Prevents repeated attempts at inaccessible or problematic frontiers:

Step Limit: Blacklists frontiers requiring over 30 consecutive steps without completion.

Stuck Detection: Monitors position variance over the last 15 steps; spatial variance below 0.08m indicates circular movement.

Auto-Reset: Clears the entire blacklist when no valid frontiers remain.