Technical Explanation

1. Problem

The original frontier-selection logic, based mainly on heading projection and distance ranking, often caused oscillation and stagnation in random maze environments.

2. Design Concept

The new method follows the principle of information-driven yet goal-oriented navigation. The frontier decision is reformulated as a multi-factor weighted-score problem:

- Maintain smooth local motion by favoring frontiers aligned with the current heading.
- Guide long-term progress by weighting proximity to the ultimate goal.
- Encourage exploration by estimating local information gain from surrounding unknown cells.

The original framework and function interface remain unchanged

3. DImplementation Method

- **Frontier Detection and Fallback Mechanism**

The system first checks the frontier array. If the robot is within 2.5 × arrival tolerance of the goal, the system directly plans a path to the final goal to prevent idle wandering.

- **Feature Functions**

`heading_alignment()` – cosine similarity between robot heading and vector to frontier, promoting forward continuity.
`goal_progress()` – negative Euclidean distance from frontier to goal, encouraging global convergence.
`proximity()` – negative BFS distance, favoring reachable, nearby frontiers.
`unknown_ratio()` – proportion of unknown cells in a 3×3 neighborhood, approximating information gain.

- **Composite Scoring Function**

A weighted sum balances exploration and goal seeking:
`Score=2.0×Alignment+1.0×Proximity+1.5×Progress+2.0×UnknownRatio.`
The highest-scoring frontier is selected; if its distance to the goal is below 1.5 × tolerance, it is snapped directly to the goal.

- **Path Planning and State Update**

The chosen frontier cell is stored as `state.frontier_goal`, and `plan_unknown_world()` generates a new path assigned to `state.path`. A flag `frontier_lock_active` is set to preserve consistency.

4. Results and Conclusion

Tests with seeds 6, 243, and 463 showed smooth exploration and successful goal arrival with no oscillation. The weighted frontier-selection method achieves balanced exploration and goal-driven navigation, enhancing stability and efficiency without altering the system framework.