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# SWARM ROBOTICS FOR LOGISTICS IN CONSTRAINED WAREHOUSE

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## MODEL DESCRIPTION

The presented project focuses on developing a swarm robotics system for logistical operations within constrained warehouse environments. This system leverages traditional multi-agent pathfinding algorithms and custom conflict resolution strategies to ensure efficient and coordinated goods movement in a space-limited setting.

### Pathfinding Algorithm

The pathfinding component of the system employs Dijkstra's algorithm, a traditional technique for finding the shortest path between nodes in a graph. The warehouse layout is represented as a graph, where nodes correspond to key positions such as pickup depots, drop-off depots, reservation nodes, and intersection nodes, while edges represent possible direction for robot traversal. Dijkstra's algorithm efficiently calculates optimal routes, ensuring minimal traversal time for each robot.

### Conflict Resolution Strategy

Given the complexity of navigating narrow aisles and the potential for path conflicts in a multi-agent environment, a custom conflict-based search (CBS) algorithm was developed. This approach draws inspiration from reservation-based parking and temporary docking point strategies for conflict resolution. The key features of the conflict resolution system are as follows:

- Reservation-Based Conflict Resolution:** Each robot reserves its intended path segments over time, creating a dynamic map of occupied paths. If a conflict arises—such as two robots attempting to occupy the same path segment simultaneously—the system identifies the conflict point and adjusts the timing or reroutes one or more robots to avoid collision.
- Docking Point Strategy:** Temporary docking points are introduced at strategic locations within the warehouse. These docking points serve as holding areas for robots waiting to resolve conflicts. This strategy minimizes idle times and ensures smooth traffic flow without causing significant delays in overall operations.

## System Design and Implementation

The swarm robotics system operates within a simulated and real-world test environment. The robots are equipped with the necessary communication modules to facilitate real-time data exchange and coordination. The system is designed to handle:

- Pickup and Drop-Off Tasks:** Robots are assigned specific tasks, such as picking up goods from pickup depots and delivering them to designated drop-off depots.
- Dynamic Traffic Management:** The system dynamically adjusts routes and schedules to adapt to changing traffic conditions and prevent bottlenecks.

## Evaluation

The system was tested in both simulated and real-world scenarios. Performance metrics included route optimization, traffic avoidance, and navigation efficiency. The results demonstrated that the integration of Dijkstra's algorithm with the custom CBS algorithm effectively resolved conflicts, minimized delays, and ensured the seamless movement of goods within constrained spaces.

## Conclusion

This project showcases the potential of swarm robotics combined with advanced pathfinding and conflict resolution techniques to optimize logistics in space-constrained warehouse environments. Future work may explore incorporating machine learning for predictive conflict resolution and enhancing the scalability of the system to handle larger robot fleets.