WarehouseBot: Pick and Drop Optimization

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Abstract

The project aims to develop an optimization system for a single warehouse robot that performs parcel pick and drop operations efficiently. The objective is to minimize the total travel time and distance covered while ensuring that every parcel is picked before its respective drop-off. This problem works on a real-world warehouse automation challenge and can be viewed as an ***extended version of the standard Traveling Salesperson Problem*** *by introducing pickup and delivery pairs. The project will focus on heuristic search algorithms to find optimal task sequences and paths in a structured warehouse environment.*

I. PROBLEM DESCRIPTION

Nowadays, e-commerce companies rely heavily on autonomous robots in warehouses for logistics and material handling. A fundamental challenge for such robotic systems is deciding the optimal route for picking and dropping multiple parcels efficiently.

In this project, the problem involves a single robot starting from a station, collecting multiple parcels from shelves, and delivering them to their assigned drop zones. The route must respect precedence constraints (pickups before deliveries) and avoid unnecessary travel.

This project is interesting because it combines classical AI search concepts with a practical robotics application. It shows how heuristic and local search algorithms can be applied to real-world optimization situations encountered in warehouse automation.

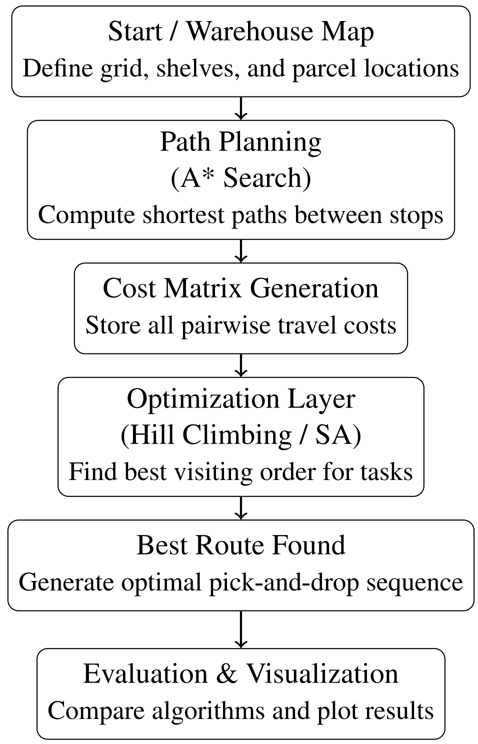
II. APPROACH AND SOFTWARE

The approach to this problem will be divided into two layers:

1. **Path Planning Layer:** The warehouse will be modeled as a 2D grid where each cell represents free space or a shelf (obstacle). The A* search algorithm will compute the shortest path between every pair of pickup, drop, and start locations. Different heuristics such as the Manhattan distance and Euclidean distance will be tested to observe their effect on search efficiency. The resulting travel costs will form a cost matrix, which then will be the input to the optimization layer.

2. **Task Sequencing Layer:** Using the cost matrix obtained from the previous part, local search algorithms such as Hill Climbing and Simulated Annealing will determine the most efficient order of visiting all pickup and delivery points while satisfying precedence constraints. Each algorithm will be evaluated for its solution quality and computation time.

The implementation will be done in **Python 3**, using standard libraries such as `numpy` for computations and `matplotlib` for visualizations. Development and testing will be carried out in **VS Code**.



III. EVALUATION

Evaluation for this system can be done based on:

- **Total path cost** (total distances/time to complete all tasks)
- **Algorithm runtime** (efficiency of Hill Climbing vs Simulated Annealing)
- **Improvement percentage** over baseline greedy methods
- **Visualization** of optimized routes and robot movement

Multiple simulations will be conducted using both static and randomly generated warehouse layouts to test robustness and generalization of the solution.

IV. TENTATIVE TIMELINE

- **Week 1 (Nov 5–11):** Design the warehouse grid and implement the A* based path planner algorithm to compute shortest paths between all pickup, drop, and start locations.
- **Week 2 (Nov 12–18):** Develop the optimization layer using Hill Climbing and Simulated Annealing and integrate it with the path planner.
- **Week 3 (Nov 19–25):** Run repeated tests on static and randomly generated warehouse layouts.
- **Week 4 (Nov 26–Dec 2):** Analyze generated results and prepare performance visualizations.
- **Final Week (Dec 3–8):** Refine the code, finalize documentation and complete the project report and presentation.

REFERENCES

1. Zhou, X., & Li, Y. (2014). *Routing Optimization of Intelligent Vehicle in Automated Warehouse*. Discrete Dynamics in Nature and Society, 2014, Article ID 972603. doi:10.1155/2014/789754. Available here

2. Wang, H., & Chen, W. (2021). *Task Scheduling for Transport and Pick Robots in Logistics: A Comparative Study on Constructive Heuristics*. Autonomous Intelligent Systems, 1(17). doi:10.1007/s43684-021-00017-9. Available here