IIMP 6010 – Cross-Disciplinary Research Methods I

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Group ID	Group Six	
Group members	Qian Sun	qsunal@connect.ust.hk
	Fangzhou Xie	fxieah@connect.ust.hk
	Liangyawei Kuang	Lkuang@connect.ust.hk
	Haorong Dong	hdongao@connect.ust.hk

Project Proposal

1. Proposed topic

Path planning for mobile robot delivery system on HKUST GZ campus.

2. Purpose and Objective

We aim to design a food delivery system for the HKUST GZ campus. This system can provide both food delivery and package delivery services for students and staff on campus without human-to-human interaction. A well-designed mobile robot delivery system on campus with delicate path planning could make our campus more efficient and well-organized.

3. Expertise requirement breakdown

- (20% work) algorithm design: A* algorithms and multi-agent pathfinding techniques
- (30% work) programming: algorithms accomplishment on Python IDE
- (30% work) survey-supported policy design and constraints design for the problem setting
- (20% work) humanity, safety, and sustainability concerns with data-supported solutions

4. Background

As the incredibly increased demand for delivery service during the COVID-19 pandemic, a lot of unmanned delivery services came up to the catering industry and package delivery market. Looking backward and onwards, traditional delivery systems based on the human force are often facing high timeliness restriction and multi-task optimization problems, while unmanned systems are not only more efficient and cheaper but also more ecosystem friendly. We could see that unmanned delivery systems are much more powerful for after-disaster situations, and they will be used more often in the future.

5. Scope

In our project, the problem settings and limitations are on our HKUST GZ campus. We should consider weighted gates to the outer environment, as we may put different numbers of standing-by robots at different size gates. Moreover, we transfer height difference to weighted edges on our graph, because 2-dimension (2D) multi-agent pathfinding is already an NP-hard problem, considering height will force our problem on a 3-dimension graph, which is with much higher complexity compared with a 2D graph. We don't consider the delivery situation in buildings for the same reason.

6. Theoretical framework

The key part of our mobile robot delivery system is pathfinding. To be more specific, some multi-agent pathfinding (MAPF) techniques are useful in this project. In recent years, many related MAPF solvers have been created, some studies extend single-agent algorithm to large-scale multi-agent area, and some researcher use centralized control methods to solve some easy case problems with limited agents. In this project, we may use two frameworks to deal with our problems. One is Conflict-Based Search (CBS) (Sharon et al. 2015), which is one of the most state-of-art optimal MAPF solver. Another is call Cooperative A* (CA*) (Silver 2005), which is wildly used in real-world applications as it has small runtime, even it is suboptimal and incomplete.

7. Proposed method

We transfer our campus map to a networked weighted graph as our original problem setting. By setting the assumption that the food or package will be left at the main gates of the campus via manual delivery, we set the main gates and targeted buildings as nodes. To obtain the shortest path, we use the SPFA algorithm in a weighted directed graph as the beginning in this project. For CBS, it ignores other agents at first and starts with a root node that contains a shortest path for each agent. Then it chooses and resolves a collision by generating two child nodes, each with an additional constraint that prohibits one of the agents involved in the collision from being at the colliding location at the colliding timestep. Then it uses its lower level to replan the paths of the agents with new constraints. Considering collision avoidance and running time, we use CA* algorithm. Each agent is given a unique priority and computes, in priority order, the shortest path that does not collide with the (already planned) paths of agents with higher priorities.

8. Expected outcome

- A 2D weighted graph based on the HKUST GZ campus map
- A successfully designed multi-robot delivery system with optimization model which considers both multi-agent pathfinding and online assignments distribution
- Well-designed robot distribution strategies and movement policies based on humanity, safety, and sustainability consideration

9. Timetable

- Oct 21st: Project Proposal
- Oct 28th: Work allocation and 2D graph generation
- Nov 4th: Algorithm design and coding
- Nov 11th: Project improvement
- Nov 18th: Final report writing
- Nov 25th: Presentation

References

Li, J.; Tinka, A.; Kiesel, S.; Durham, J. W.; Kumar, T. K. S.; and Koenig, S. 2020c. Lifelong Multi-Agent Path Finding in Large-Scale Warehouses. In Proceedings of the International Conference on Autonomous Agents and Multiagent Systems (AAMAS), 1898–1900.

Sharon, G.; Stern, R.; Felner, A.; and Sturtevant, N. R. 2015. Conflict-Based Search for Optimal Multi-Agent Pathfinding. Artificial Intelligence 219: 40–66.

Silver, D. 2005. Cooperative Pathfinding. In Proceedings of the Artificial Intelligence and Interactive Digital Entertainment Conference (AIIDE), 117–122.'