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AgentChat: Feasibility Of Large-scale Multi-agent Based Coordination For Freight Co-loading

Project Team

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What is the project?

Freight co-loading increases the utility of freight capacity by including shipments from multiple shippers on to the same freight to travel between close shipment locations. Benefits of freight co-loading may include reduced carbon, cost of shipment and congestion at receiving locations. Yet, in the UK and Europe only 63% of journeys carry useful load and average vehicle utilisation is under 60%. Although the idea of freight co-loading is not new, it has never been fully implemented. Freight co-loading is a hard problem because:

- Co-located or close suppliers do not know whether they are sending items to similar locations at similar times. For them to know, someone needs to tell them.
- For the retailers, orchestrating co-loading involves transaction costs. The benefits of truck co-loading does not necessarily outweigh the costs of paying for manual orchestration.
- For logistics providers to be the orchestrator, suppliers would need to use the same logistics providers, creating a lock down effect, not suitable to sporadic journeys.
- For a third-party mediator to orchestrate, multiple suppliers need to sign up and pay for it.

What did the project achieve?

We created an automated solution to freight co-loading, so information between the actors involved in co-loading can be shared and optimal routing solutions can be found, without the associated transaction costs. Additionally, to incentivise stakeholders to co-load, an automated negotiation and value sharing solution was developed. Finally, the related problem of optimal container packing has been explored, such that optimal or near-optimal solutions could be found in real time. The feasibility of the approach was tested with our industrial partner VCL. The key technology toolbox developed is multi-agent systems with Reinforcement Learning. Whilst other industrial applications implemented multi-agent system solutions in manufacturing, supply chain and logistics solutions have been lacking. Key challenges we investigated included appropriate agent architectural configurations and how to keep agent learning scalable.

How we did it

As there are tens of thousands of independent local carriers across the UK, the total number of the agents that are needed to represent each carrier can become huge, thus a scalable, efficient and effective agent architecture is a key component to the success of handling collaborative logistics in realistic settings. We investigated this problem by first identifying various types of template agents that define the basics of supply

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chain entities; and second creating a simplified simulated collaborative logistics environment in which agents can be customised and automatically generated according to a given configuration file;and finally, experiments were run on this platform for studying the relationship between agent architectures, the number of agents and time taken to reach solutions. Additionally, a demonstrator was created for showcasing agent configuration and the follow-up collaborative vehicle routing solutions built upon this environment. While this simulated environment is at its initial stage and can only accommodate up to a hundred agents in a consumer-grade laptop, it is a promising attempt to shed light on agent-based collaborative logistics and we are expecting to create a more mature platform in our follow-up research.

Another key challenge we focussed on is "collaborative vehicle routing", which is concerned with:

a) efficient routing to maximise container utilisation whilst respecting constraints such as goods compatibility, and loading / off loading constraints and axle weights. And,
b) gain sharing e.g. if a company collaborates, how much should it get paid?

> *"We very much enjoyed working with the Connected Everything project - the clarity of the approach and rigour with which colleagues have researched the topic. The project outputs certainly enabled us to understand and leverage the multi-agent architecture design approach as well as possible methodologies behind gain share evaluation and allocation mechanisms."*
> Value Chain Lab

For (a) a reinforcement learning (RL) based algorithm has been developed that converts a 3D packing problem into a 2D problem through image processing. This then improves the scalability of an NP hard, combinatorial problem space, so that solutions can be approximated in a relatively shorter time. Our approach has proven to be more scalable than existing approaches in literature (Schoepf et al 2022). For (b) we found that traditional approaches from game theory, such as Shapley values, do not scale as it requires access to the "characteristic function" which is computationally expensive to calculate. We alleviated this problem through using neural networks to approximate the characteristic function instead (Mak et al., 2021).

Future plans

In future work, we hope to further investigate the scalability of our proposed approach and develop a testbed environment for supporting experimental studies, as well as applying it to more realistic data distributions. We also anticipate incorporating learning methods into the work of designing agent organisations, and creating an open source distributed, decentralised collaborative logistics platform for both academic and industrial use.

AgentChat laid the foundations for solving the challenging problem of collaborative vehicle routing - using AI technology, we showed that both optimisation and incentivisation could be built in algorithmically, through automated value sharing. The project also mapped technical challenges to potential solution areas, and offered a roadmap for further research. We are now in the process of building a consortium with industrial and academic partners for a larger research project proposal.

References & Publications

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