Multi-Agent Coordination in Autonomous Vehicle Routing: A Simulation Based Study

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Introduction

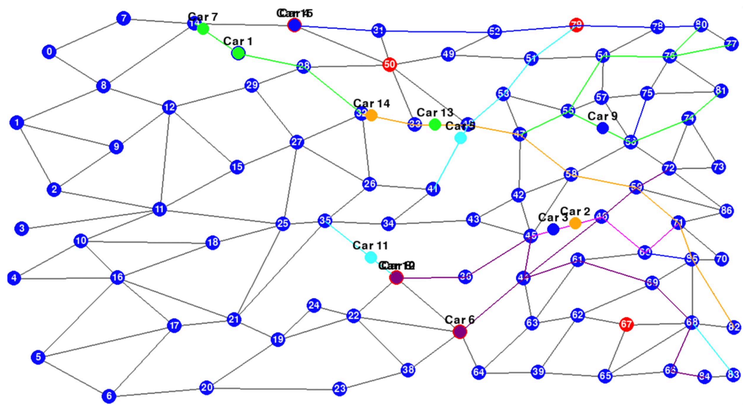
This study investigates how multi-agent coordination strategies, such as communication and memory, improve navigation efficiency in Autonomous Vehicle networks. We use a graph-based simulation to test how agents reroute, avoid obstacles, and learn from past decisions.

Research Question

To what extent does inter-agent communication improve travel efficiency and reduce delay in multi-agent autonomous vehicle systems navigating obstacle-rich environments?

Methodology

- Developed a graph-based simulation to model AV navigation in a controlled network.
- Graph contains 86 nodes and 161 edges representing intersections and roads.
- Vehicles are deployed with:
  - Rerouting logic after 8s of delay
  - Communication channels (V2V)
  - Memory mechanism for storing past obstacles (OMM)



Key Experiments

- Six experiments: 15, 35, and 55 vehicles
- Tested with/without rerouting, memory, and communication
- Up to 20 obstacles per simulation
- Measured travel time, wait time, and routing behavior

Special Finding

- Without memory, two vehicles were trapped in an infinite loop, repeatedly rerouting into previously blocked paths.
- This highlighted the critical need for memory-aware routing.

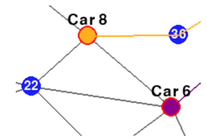


Figure 4.15: Faced 1st Obstacle

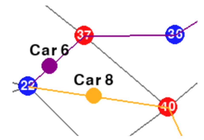


Figure 4.16: Rerouting after 8s

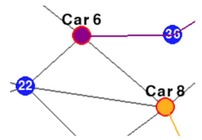


Figure 4.17: Faced 2nd Obstacle

Figure 4.18: Rerouting to Blocked Route

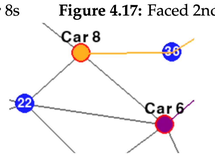
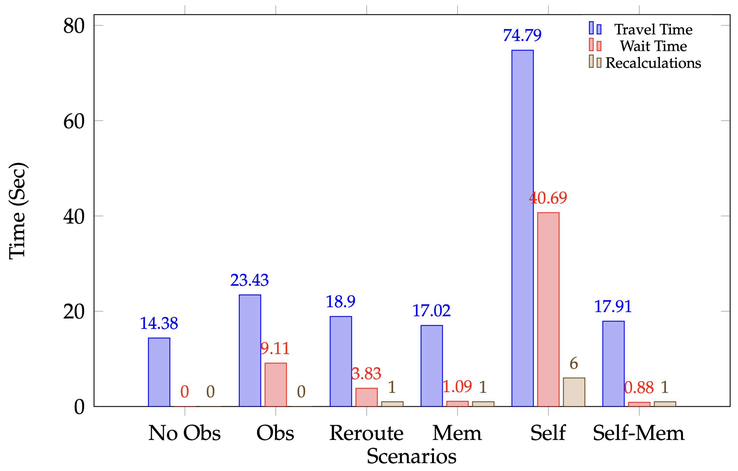


Figure 4.19: Faced 1st Obstacle again

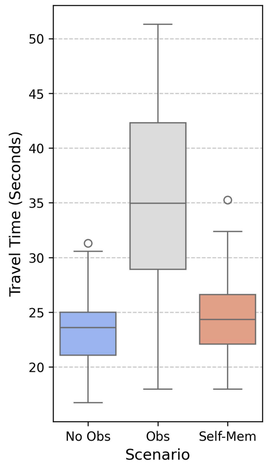
Figure 4.20: Illustration of Car stuck in an Infinite Loop

Results Summary

- Coordination and memory-aware systems consistently improved travel efficiency across all experimental conditions.
- Self-rerouting without memory led to significant inefficiencies and decision loops.
- Object Memory Management (OMM) enabled agents to avoid previously blocked paths and reduced unnecessary rerouting.
- Memory combined with communication provided the most consistent and robust performance under heavy obstacle conditions.



Average travel time, wait time, and number of recalculations across coordination strategies for 55 cars. **Without memory, travel time spikes and delays are severe.**



Distribution

- Travel time distribution for 55 cars across three scenarios. Memory-enabled coordination leads to more consistent and efficient travel.

Talking Point

- Even with obstacles, “Self-Mem” performs close to baseline.
- Shows robustness, not just average improvement.

Conclusion

- Multi-agent communication and memory significantly improve AV performance
- OMM prevents decision loops and redundant routing
- Decentralized coordination leads to globally efficient behavior

Future Work

- Apply to real-world traffic graphs
- Simulate partial communication loss
- Add adaptive learning and memory decay strategies

References

- [1] Jiaxun Cui et al. “Scalable multiagent driving policies for reducing traffic congestion”. In: arXiv preprint arXiv:2103.00058 (2021) (pages 11, 19, 21, 28).
- [2] Alberto Petrillo et al. “Adaptive multi-agents synchronization for collaborative driving of autonomous vehicles with multiple communication delays”. In: Transportation research part C: emerging technologies 86 (2018), pp. 372–392 (page 18).