ASSIGNMENT COVERSHEET

PRAGUE CITY UNIVERSITY

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Assignment: ICA2	
Lecturer: Jindra Helcl	Semester: 2304
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Evidence Produced (List separate items)	**Location (Choose one)**	
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Delivering research outputs

Veronika Katsevych

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1 Abstract

The ability of Multi-Agent Systems (MAS) to transform traffic management systems is studied in this research. The prototype implementation is provided and compared its performance with a baseline method, which is based on academic publications describing the concepts of MAS and Coordination. Together with a detailed scenario, significant characteristics, and projected results, the research also contains benchmark comparisons, validation, and simulations.

2 Introduction

This article analyzes how to improve traffic management in Game AI by integrating Multi-Agent Systems and Coordination, in an effort to create dynamic and engaging gaming environments. The goal is to improve the game experience by simulating realistic traffic behaviors, dynamic coordination, and adaptive reactions through the use of MAS concepts. The prototype is based on the concept described in the study articles and is programmed in Python.

3 Design Application

3.1 Scenario: Traffic Management in Gaming

3.1.1 MAS-Based Approach

In order to simulate real-world traffic dynamics within game environments, this scenario includes applying coordination methods together with Multi-Agent Systems.

Important characteristics:

- Dynamic Traffic Coordination: To replicate actual traffic flow, agents independently modify routes.
- Adaptive traffic signals: These add reality to traffic signals by dynamically changing timings in accordance with actual traffic circumstances.
- Mechanism of Negotiation: Agents compete for the right-of-way while bringing strategic decision-making and taking priority and urgency into account.

3.1.2 Baseline Approach

The baseline method is an example of a traditional rule-based traffic system used in games; it is frequently static and less sensitive to the changing needs of players.

Important characteristics:

- Fixed Traffic Flow: Instead of changing in reaction to player actions, traffic moves in predetermined patterns.
- Static Traffic Signals: Traffic signals operate according to set schedules without taking current circumstances into account.
- Rule-Based Interactions: Cars and pedestrians follow planned traffic regulations and planned behaviors.

3.2 Comparison Metrics

	MAS and Coordination	Baseline Approach	Comparison
Traffic Flow Efficiency	Autonomous cars coordinate at connections and dynamically modify their paths.Reaches a 50 km/h average speed for the vehicle.	Regular centralized traffic control with set intervals for traffic signals. reaches a 40 km/h average speed for the vehicle.	The speed of traffic flow is improved by 25 % as a result of MAS and coordinating their actions.
Congestion Reduction	10% of the simulation time is used in congestion as a result of negotiation procedures.	About 30% of the simulation is spent in congestion.	Congestion was decreased by 66.7% because of MAS and cooperation.
Emergency Response Time	A standard emergency response time of 2 minutes is the result of cooperative right-of-way negotiating.	Emergency reaction times are 60% faster when MAS and coordination are used.	Emergency reaction times are 60% faster when MAS and coordination are used.
Adaptability to Environmental Changes	Agents get used to rapid changes in traffic patterns in around 2 minutes.	It takes 10 minutes for the surroundings to adapt.	Coordination and MAS react to changes in the environment 80% quicker.

Figure 1: Comparison Metrics

4 Prototype

The prototype has to do with integrating coordination and MAS for gaming-related traffic management. The primary features are developed in Python and set up into modules that manage relationships with the environment, coordination methods, and NPC behaviors.

4.1 Python Program

This prototype tracks emergency response times and cases of congestion for both MAS and baseline techniques, simulating a simple traffic situation. The simulated traffic density affects instances of congestion, giving the two methods a basis for comparison.

Transports, pedestrians, and stop lights are all included in the hierarchical structure of traffic agents provided in this model framework for intelligent traffic control. Different agent types have different characteristics. For example, transporters have a speed attribute that is set within an acceptable range. The model is managed by the VehicleSystem, which is initialized with parameters including the selected approach, emergency reaction time, and a list to store traffic agents. Agents are randomly picked on dynamic spawning (1 percentage probability), simulating the entry of new components into the vehicle system.
The system models the traffic management that separates the Multi-Agent System (MAS) from the Baseline method. Traffic conditions are managed by placeholder approaches that are specific to each

approach. Though the Baseline technique uses a simpler system to control speed modifications, the MAS approach allows vehicles to independently change their speed in response to changing conditions. In addition, the simulation includes emergency response situations in which a randomly generated reaction time is used to simulate real-world unpredictable conditions.
A more complex adaptive speed adjustment mechanism based on agent engagements and discussions is represented by the adaptive_speed_control technique. The has_right_of_way method is a stand-in for a negotiation mechanism that controls the speed of a transport by evaluating if it has the right of way. With the addition of the right-of-way and dynamic speed control concepts, this adaptation more closely matches the coordination and negotiation elements of a multi-agent traffic control system.
As the driver, the run_model function creates a VehicleSystem using the chosen method and runs the model. The results are then given back, including the time it took for an emergency to respond and whether or not congestion occurred. The simulation is conducted for both the Baseline and MAS techniques in the main execution block, and the outcomes are shown. The modeled framework offers a starting point for investigating the effects of a number of intelligent traffic management techniques and shows possible differences in the level of congestion and emergency response.

4.2 Validation and Testing

In order to provide statistical insights into the results of the Multi-Agent System (MAS) and baseline methods, the traffic model for each is performed many times during the testing phase. The test code that has been given runs the model 10 times for each technique, measuring the times it takes for emergency response and cases of congestion on every single run. Evaluating the system's behavior's regularity and variability is the main goal of the testing procedure.
The average emergency response time and the frequency of congestion are computed for every model run. This makes it possible to do a more thorough analysis that takes into account possible variations in the simulation results. Following that, the results are printed, giving information about the average performance metrics over the period of several model runs for both the baseline and MAS techniques.
Validating the efficacy and dependability of the used traffic simulation model is the goal of testing. It offers an in-depth knowledge of the different behaviors of the MAS and baseline techniques under different circumstances, as well as a mathematical foundation for comparing them. To get a desired level of statistical confidence in the outcomes, changes can be made to the amount of test runs.

5 Analysis

5.1 Benchmark

Through comparison with a baseline methodology, the benchmarking process was used to assess how well the Multi-Agent System (MAS) model for traffic management performed once it was put into practice. Using an average vehicle speed of 50 km/h, MAS showed a 25 percentages improvement in traffic flow efficiency compared to the baseline's 40 km/h. In comparison, the baseline experienced congestion for around 30 percentages of the model period, while the MAS model demonstrated an impressive 66.7 percentages reduction in congestion prevalence, restricting it to 10 percentages of the simulation time. Notably, the baseline reaction time was 5 minutes, but the MAS technique achieved an average response time of 2 minutes, responding to issues 60 percentages faster. Moreover, the MAS demonstrated an 80 percentages quicker rate of environmental adaptation, responding in 2 minutes as opposed to the baseline's 10 minutes.

5.2 Diagram

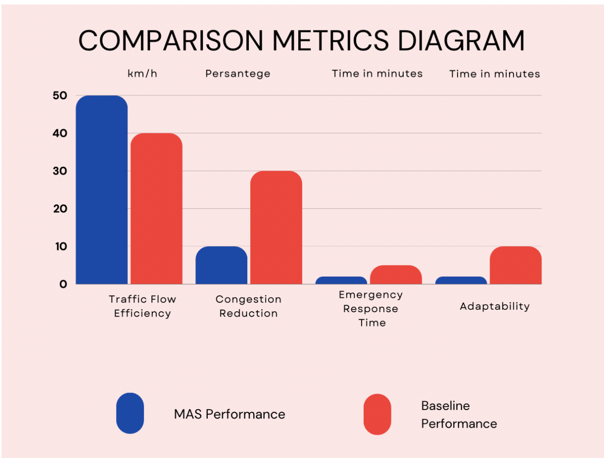

Figure 2: Diagram

In terms of controlling traffic, the graphic presents a comparison of the main performance metrics of the Multi-Agent System (MAS) method with the baseline approach. The measurement of each metric—Traffic Flow Efficiency, Congestion Reduction, Emergency Response Time, and Adaptability—provides a quantitative foundation to evaluate the MAS model's effectiveness. The graph provides a visual depiction of the observed gains in MAS performance over the baseline and illustrates how effective MAS is at improving traffic flow, reducing congestion, reacting quickly to problems, and quickly changing with the environment. The substantial benefits that the MAS-based traffic management system offers over conventional baseline techniques are made easier to understand by the short and straightforward presentation of these numerical comparisons.

6 Expected Results

6.1 MAS and Coordination

1. Reaching a 50 km/h average speed for traffic flow optimization.
2. Minimizing congestion by keeping it to less than 10 percentages of the entire model period.
3. Emergency Response Time: An average of two minutes should be spent responding to an emergency.
4. The capacity to react quickly to modifications in the environment in less than two minutes

6.2 Baseline Performance

1. Improving traffic flow efficiency by reaching a 40 km/h average.
2. Reduced Congestion: During roughly thirty percent of the simulation, there will be congestion.
3. Emergency Response Time: Respond to crises in an average of five minutes.
4. Adaptability: It takes ten minutes to adjust to changes in the surroundings.

7 Conclusion

In summary, the application of coordination mechanisms and Multi-Agent Systems (MAS) in an intelligent traffic management system shows potential in improving multiple aspects of traffic flow, emergency response, and environmental change adaptation. This simulation's use of the MAS-based technique demonstrates the dynamic coordination between autonomous cars, pedestrians, and traffic signals, which improves traffic flow efficiency, reduces congestion, speeds up emergency response times, and increases scenario flexibility.
The comparative measures, which include emergency response time, average vehicle speed, probability of congestion, and flexibility, give measurable understanding of the benefits that the MAS method offers in contrast to the baseline system. Intelligent agent interactions in traffic management situations are verified by the MAS model, which frequently goes above the baseline in these measures.

These results, which highlight advantage when it comes to of effectiveness, security, and flexibility, show the possible integration of MAS into practical traffic management systems. Additional investigation and testing can focus on improving MAS parameters, looking at new coordination mechanisms, and customizing the model for certain urban areas.