K. J. Somaiya College of Engineering, Mumbai-77

Batch: B1	**Roll No.: 16010121045**
Experiment / assignment / tutorial No. 8	

Title: IEEE Case study on learning/planning techniques

Objective: Case study on AI System (learning/planning techniques) based paper published in IEEE/ACM/Springer

Expected Outcome of Experiment:

Course Outcome	After successful completion of the course students should be able to
CO4	Analyse applications of AI and understand planning & learning processes in advanced AI applications

Books/ Journals/ Websites referred:

Pre Lab/ Prior Concepts:

A learning agent is **a tool in AI that is capable of learning from its experiences**. It starts with some basic knowledge and is then able to act and adapt autonomously, through learning, to improve its own performance.

Artificial intelligence is an important technology in the future. Whether it is intelligent robots, self-driving cars, or smart cities, they will all use different aspects of artificial intelligence!!! But Planning is very important to make any such AI project.

Even Planning is an important part of Artificial Intelligence which deals with the tasks and domains of a particular problem. Planning is considered the logical side of acting.

Everything we humans do is with a definite goal in mind, and all our actions are oriented towards achieving our goal. Similarly, Planning is also done for Artificial Intelligence.

For example, Planning is required to reach a particular destination. It is necessary to find the best route in Planning, but the tasks to be done at a particular time and why they are done are also very important.

Note: A minimum of two papers should be selected based on the AI application of learning or planning concepts and summarized as follows.

Title : *Deep Reinforcement Q-Learning for Intelligent Traffic Signal Control with Partial Detection*

Abstract of the paper :

This paper introduces a deep reinforcement Q-learning model designed to optimize traffic signal control at an isolated intersection in environments where only a portion of vehicles are detected, thanks to the emergence of connected vehicles. Unlike most literature that assumes complete vehicle detection at intersections, this model works under the realistic scenario of partial detection. It incorporates a novel state representation for partially observable environments, a new reward function tailored for traffic signal control, and presents a detailed network architecture with tuned hyper-parameters.

Proposed Architecture / System:

The proposed architecture includes a detailed deep reinforcement Q-learning model with several innovative components:

- **Partial DTSE (Discrete Traffic State Encoding)**: A new state representation that captures the partially observable environment of the intersection, focusing on connected vehicles.
- **Total Squared Delay Reward Function**: A new reward function designed to minimize the total travel time through the intersection by emphasizing fairness and efficiency.
- **Convolutional Dueling DQN (Deep Q-Network)**: The network architecture, utilizing convolutional neural networks (CNN) for handling the state representations, is specifically tuned for the task of traffic signal control under partial vehicle detection.

Results:

The model was tested against traditional actuated traffic signal controllers like Max Pressure and SOTL in various simulation scenarios. It demonstrated superior performance, particularly in scenarios with more complex intersection configurations and varying traffic demands. Notably, the model showed robustness and adaptability to different levels of vehicle detection, with significant improvements in traffic flow and reduced delays, even at low detection rates of connected vehicles.

Conclusion:

The study concludes that the deep reinforcement Q-learning model significantly outperforms existing actuated traffic signal controllers in environments with partial vehicle detection. It sets new performance thresholds for acceptable and optimal operations based on the rates of connected vehicle detection, advocating for the deployment of such models at intersections to improve traffic flow and reduce congestion. The paper also outlines several avenues for future research, including exploring probabilistic estimation methods for uncertain vehicle detections and extending the model to decentralized multi-agent systems for coordinated traffic light control across multiple intersections.

Title:

LLM-ASSIST: Enhancing Closed-Loop Planning with Language-Based Reasoning

Abstract:

This study investigates the integration of Large Language Models (LLMs) like GPT4 and Llama2 with rule-based planning for autonomous driving to address the limitations of existing learning- and rule-based planners in handling diverse driving scenarios. A novel hybrid planner is proposed, which combines a conventional rule-based planner with an LLM-based planner. By leveraging the commonsense reasoning of LLMs, the approach navigates complex scenarios with well-reasoned outputs, achieving state-of-the-art performance on the nuPlan benchmark across various metrics. The code for this project will be made available online.

Proposed Architecture / System:

The architecture introduces a hybrid planning method that utilizes a state-of-the-art rule-based planner, PDM-Closed, for common scenarios, and an innovative LLM-based planner for high-uncertainty scenarios. The system dynamically engages the LLM-based planner based on the base planner's performance metrics. It involves two modes of LLM assistance: **LLM-ASSISTUNC**, which allows the LLM to directly generate a future trajectory for the ego vehicle, and **LLM-ASSISTPAR**, where the LLM suggests parameters for the base planner to safely navigate the scenario.

Results:

Extensive evaluations on the nuPlan benchmark demonstrated the superior performance of the LLM-assisted planner in both reactive and non-reactive settings, outperforming existing learning- and rule-based methods. The approach notably improves safety, reducing the number of dangerous driving scenarios by 11%. Ablation studies and qualitative analyses further underscore the effectiveness of leveraging LLMs for planning in complex driving environments.

Conclusion:

LLM-ASSIST represents a significant advancement in autonomous driving planning, showcasing the potential of combining traditional rule-based planners with the cognitive and reasoning capabilities of LLMs. The approach not only sets new benchmarks in performance but also offers insights into future research directions, emphasizing the need for further improvements in LLM grounding, multimodality, and processing speeds to fully harness their potential in real-time, safety-critical applications like autonomous driving.