Optimization Project Proposal

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I. LITERATURE REVIEW

Multi-agent systems involve robots, such as drones or self-driving cars, working together as a team to tackle complex tasks more efficiently than a single robot could manage. Researchers draw inspiration from various sources to create methods for enabling robots to communicate, coordinate their actions, and make decisions collectively without relying on a single leader. This review explores the fundamental concepts, challenges, and real-world applications of multi-agent teamwork in the field of Unmanned aerial vehicles (UAVs) and autonomous vehicles.

UAVs offer significant potential in various public and civic domains. Lately, UAVs have primarily been used in situations where human presence is either impossible or dangerous. Using a swarm of small UAVs for tasks can be more efficient and cost-effective than relying on a single large UAV. However, there are numerous challenges that need to be addressed before creating stable and dependable multi-UAV networks.

There have been multiple research on the optimization of UAVs, the study in [1] focuses on using UAVs for tasks in hazardous areas. They introduce a coordinated optimization algorithm that combines Genetic Algorithms (GA) and cluster algorithms to determine the right number of UAVs and plan their paths efficiently. Simulation results confirmed the effectiveness of this approach in task assignment. Additionally, when compared to GA, the coordinated optimization algorithm showed superior performance.

There has been another Study in [2] that generalized the problem of task allocation to include robots. The paper delves into the computational complexity of multi-robot task allocation, focusing on tasks with specific robot requirements. It addresses the Max-Task-Within-Task-Budget problem, particularly when each task needs at most two robots. The study introduces several approximation algorithms, and outlines lower bounds for these approximations.

Several task allocation algorithms have been developed for UAV networks, and the paper in [3] comprehensively surveys them, exploring their core concepts, operational characteristics, advantages, and limitations. These algorithms are then compared in terms of their key attributes and performance factors. Furthermore, the paper discusses unresolved issues and challenges and proposes potential directions for future developments in task allocation algorithms.

On the other hand, Cooperative Merging of Connected Vehicles at Highway On-Ramps cited in [4] is a traffic management challenge that leverages advanced communication and sensor systems in connected and autonomous vehicles (CAVs). The problem involves coordinating the merging of vehicles from an on-ramp onto a highway to optimize traffic flow efficiency. CAVs exchange data like speed, position, and intentions, allowing a centralized or decentralized control system to make real-time decisions about merging. This approach minimizes congestion, reduces delays, enhances safety, and promotes environmental sustainability by optimizing merging strategies and vehicle speeds.

The study in [4] presents a cooperative merging strategy for intelligent vehicles on highways, optimizing travel time and on-ramp merging. A genetic algorithm is used, showing better performance in MATLAB simulations than a velocity-based approach, especially in high-demand scenarios. This strategy proves effective for merging in congested traffic conditions.

Another study in [5] also aims to improve fuel efficiency and traffic flow during highway ramp merging for connected and automated vehicles (CAVs). It introduces a graph-based approach that categorizes vehicles into groups and utilizes an optimized shortest-path algorithm to identify the most fuel-efficient merging sequence. Simulations confirm that this method reduces fuel consumption, enhances traffic efficiency, and facilitates vehicle platooning after merging.

II. TASK ALLOCATION FOR MULTIPLE UAVS

Task allocation for multiple Unmanned Aerial Vehicles (UAVs) is a complex challenge in robotics and autonomous systems. At its core, this problem entails the strategic assignment of a group of UAVs to a set of tasks, considering a multitude of constraints and objectives. In the input phase, key components include the set of available UAVs, each possessing unique capabilities, the set of tasks to be accomplished, each with distinct requirements, and various constraints. For example, the Constraints may encompass UAV-specific factors like current state, operational costs and task-specific details like compatibility and time windows for completion. The ultimate goal of the problem is to formulate an optimal assignment strategy, detailed in the output phase, which specifies which UAV should be assigned to which task while maximizing a chosen performance measure, such as maximizing tasks completed, minimizing total time, or minimizing overall operational costs, all within the boundaries of the specified constraints. These constraints span the spectrum, including

UAV constraints (one task per UAV, adherence to UAV capabilities), task constraints (suitable UAV assignment based on requirements), compatibility constraints (aligning UAVs with tasks), resource constraints (e.g. number of available UAVs), and time constraints (adherence to task completion time windows).

We consider a scenario where the number of Unmanned Aerial Vehicles (UAVs) available is limited and fewer than the total number of tasks at hand. Our objective is to find the most efficient task allocation strategy for each UAV to complete all tasks in the shortest possible time and with minimal travel distance. This problem bears similarities to the well-known multiple traveling salesman problem.

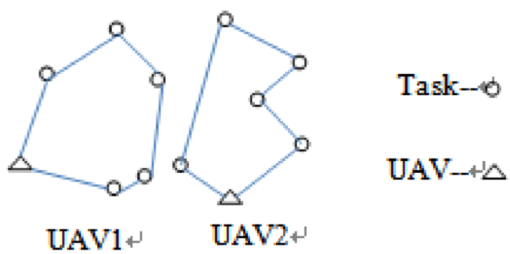

Fig. 1. Task allocation for two UAVs [1]

Solving the task allocation problem for multiple UAVs is of paramount importance in various real-world applications, such as surveillance, delivery, agriculture, disaster response, and military operations. Efficient resource allocation not only ensures improved mission success and resource utilization but also enhances the overall effectiveness of these applications, as it maximizes the utilization of UAV assets while taking into account the intricate interplay between UAV capabilities, task requirements, and operational constraints.

Keywords— ***Multi-robot, Unmanned Aerial vehicles (UAV), Autonomous systems, Task allocation, Multiple Traveling Salesman Problem (mTSP), Genetic Algorithms***

III. Merging of Connected Vehicles at Highways

Merging vehicles onto a highway is a critical traffic management problem that requires efficient coordination to maintain smooth traffic flow and minimize congestion. When vehicles from an on-ramp need to merge into the main traffic flow, the process can often lead to disruptions, slowdowns, and even accidents if not managed effectively. The challenge is to determine how and when vehicles from the on-ramp should merge onto the highway, considering factors such as vehicle speed, spacing, and the flow of existing traffic. This problem becomes more complex when a mix of human-driven and autonomous vehicles is involved, each with different driving behaviors and capabilities.

The problem of merging vehicles on a highway involves optimizing the speed and position of each merging vehicle to minimize traffic congestion, reduce travel time, and maximize traffic flow efficiency. Decision variables include the speed and position of each merging vehicle, determining their behavior during merging. The objective is to find the optimal combination of vehicle speeds and positions that minimize delays, prevent collisions, ensure a smooth transition onto the main highway, and adapt to real-time traffic conditions and driver behavior. we will only consider one single lane which is the closest lane to the merging point for the merging sequence.

This optimization problem aims to enhance overall highway safety and efficiency, considering factors such as vehicle-to-vehicle communication and the presence of both human and autonomous drivers.

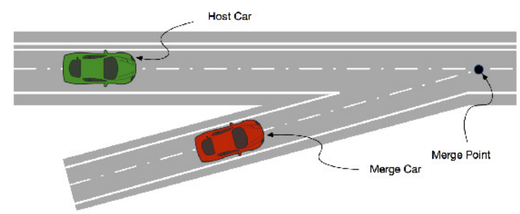

Fig. 2. On ramp Merging

Keywords: ***Merging vehicles, Coordination, Traffic flow, On-ramp, Optimization, Traffic congestion, autonomous vehicles.***

References

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