Poster Abstract: Sprinkler-UAV Cooperative Active Scheduling System

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ABSTRACT

Urban particulate pollution presents considerable public health hazards, underscoring the need for effective control measures in various cities. A prevalent approach involves employing mobile sprinkling trucks. This paper proposes a Sprinkler-UAV Cooperative Active Scheduling System for enhanced efficiency in reducing particulate pollution. The system employs ground-based sprinkler trucks and airborne air pollution detection drones to actively explore and reduce PM2.5 in environments with dynamic and unknown pollution distributions. Preliminary experiments have demonstrated the effectiveness of using sprinklers for urban particulate matter control.

KEYWORDS

Sprinkling, Mobile computing, Scheduling system

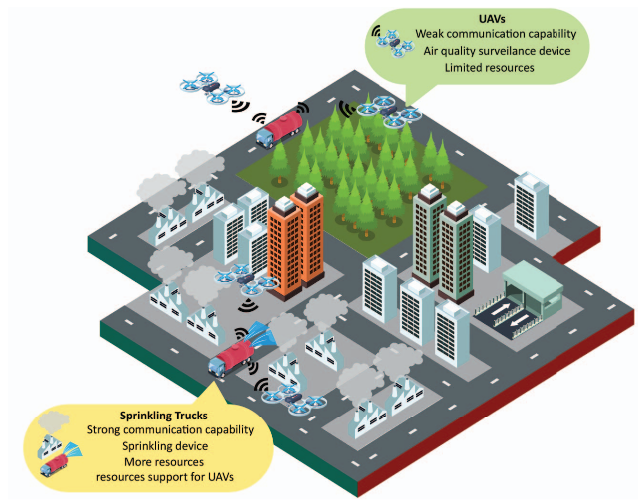

Figure 1: The scenario of collaborative scheduling for multiple sprinklers and UAVs.

1 INTRODUCTION

Urban air pollution, a silent yet potent threat, poses a formidable challenge to public health. In response, governments have enacted various policies to reduce the emissions of industry and transportation. Sprinkling trucks are favored as a cost-effective measure to stringent regulations due to their targeted and immediate impact. By installing sprinkling devices and water tanks on trucks, sprinkling trucks offer a scalable and flexible solution that can be deployed without the extensive infrastructure changes or long-term policy reforms associated with more rigid regulations.

Effective coordination of multiple sprinkling trucks is pivotal for enhancing air pollution mitigation. The effectiveness of fixed water spraying systems, which have demonstrated a reduction in particulate matter concentrations by up to 20%, serves as a benchmark for the potential of mobile sprinkling systems [1]. These mobile units extend the reach of pollution control efforts, providing a more dynamic and responsive approach to managing air quality in highly polluted areas.

However, precise scheduling of sprinkler clusters depends on a thorough understanding of the distribution of airborne particulate pollution, which is often unattainable in urban areas. Although it is possible to make the vehicle have active perception by installing sensors on the mobile sprinklers [2], the limited number of sprinklers determines the narrow perception range. Therefore, we consider the use of unmanned aerial vehicles (UAVs) to support environmental sensing. Virtually, UAVs have long been utilized for air quality surveillance and collaboration between heterogeneous agents has also proved feasible [3, 4]. There are also efforts to use non-dedicated drones for urban sensing missions, expanding the range of available drones [5].

This paper presents a Sprinkler-UAV Cooperative Active Scheduling System for unknown urban environments. As depicted in Fig. 1, the UAVs are equipped with air pollution monitoring equipment that can sense the distribution of pollution to provide mission guidance for sprinkling trucks. Installing low cost sensors on mobile agent has been shown to allow for relatively accurate field reconstruction [6]. The sprinkling trucks are equipped with sprinkling devices to reduce airborne particulate matter pollution. Additionally, its large carrying capacity can provide endurance support for the UAVs.

2 SYSTEM OVERVIEW

Our Sprinkler-UAV Cooperative Active Scheduling System is mainly characterized by two advancements: a non-central hierarchical air-ground cooperative scheduling algorithm for Sprinkler-UAV scheduling, and an efficient training data-saving model for the evaluation of sprinkling effects, tailored to the scheduling algorithm design.

2.1 Scheduling Strategy

Our scheduling algorithm employed a hierarchical scheduling strategy. In the upper-level scheduling process, the sprinkler and paired UAVs are considered as a work group. The different work groups

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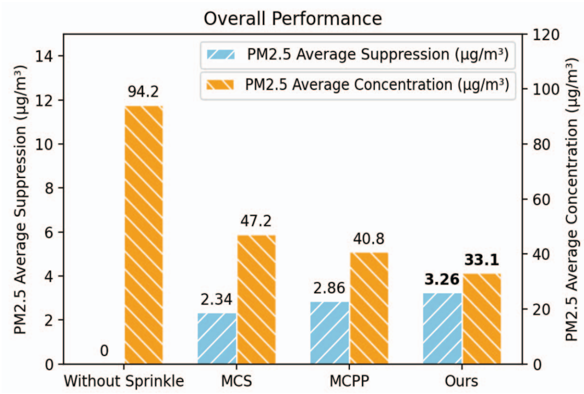

Figure 2: Preliminary result of the scheduling system.

are scheduled regionally based on MI-UCB with the principle of optimism under uncertainty [7]. After regional scheduling for each work group, the lower level scheduling process is implemented and the sprinklers and drones within each work group are collaboratively scheduled at a more detailed level. This process can be carried out through multi agent reinforcement learning [8]. For the online-planning framework, we use Dec-MCTS, a decentralised multi-robot planning algorithm that extends the well-known MCTS [9]. The Dec-MCTS framework compresses and fuses communication messages between agents, providing greater scalability with hierarchical scheduling policies. In order to perform long-period nonmyopic scheduling in unknown dynamic environments, temporally non-uniform information gains as well as time-discounted task gains are designed.

2.2 Sprinkling Effect Evaluation Model

To enhance the accuracy of sprinkler gain calculations, this paper introduces a physics-informed training method for developing the sprinkling effect model. The concept of enhancing the restoration quality of air pollution areas through physical regulations is based on the research conducted by Chen et al. [10], and we implement it in a deep neural network framework. Distinct from purely data-driven approaches that require extensive volumes of real-world training data, the training process for the proposed sprinkling effect model is grounded in a framework of air pollution propagation physical laws. The sprinkling effect evaluation model after training will become the basis of the calculation of sprinkling gains in the scheduling process.

3 PRELIMINARY RESULT

We tested the PM2.5 reduction effect of the sprinkler scheduling system in a simplified scenario. In this scenario, it is assumed that the pollution distribution in the environment is known in real time, while the role of drones is not considered. The results of the test are shown in Fig. 2, where MCS represents the maximum spatio-temporal coverage strategy and MCPP represents the MCTS-based strategy. We tested different strategies using two metrics which represent direct and target effects for overall PM2.5 reduction performance, and our strategy yielded the best results.

4 CONCLUSION AND FUTURE WORK

In this paper, we propose a Sprinkler-UAV Cooperative Active Scheduling System for urban particulate treatment and preliminarily verify the feasibility of using sprinklers in a simplified scenario. In the future, the system performance will be tested under unknown dynamic pollution distributions in a joint air-ground scenario. We will also do the actual deployment and testing in real systems.

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