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A HARDWARE-IN-THE-LOOP DDDAMS SYSTEM FOR CROWD SURVEILLANCE VIA UNMANNED VEHICLES

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ABSTRACT

Recent advancements in small unmanned vehicles and their capability in collecting dynamic data using onboard sensors make them key players in a wide variety of applications such as mapping, monitoring, search, and rescue. Specifically, monitoring in the border environments using unmanned air vehicles (UAVs) and unmanned ground vehicles (UGVs) is the focus of this research work. In this regard, we design, develop, and demonstrate a simulation-based planning and control system for surveillance and crowd control via collaborative operation of UAVs and UGVs through three phases. At the first phase, a dynamic data driven adaptive multi-scale simulation (DDDAMS)-based planning and control framework is designed and developed. Next, in the second phase a testbed is implemented using agent-based hardware-in-the loop simulation. Finally at the phase three, using the developed framework and testbed in previous phases, different control architectures as well as UAV and UGV team formation are addressed.

1 INTRODUCTION

Planning and control of unmanned vehicles play a major role in multi-vehicle systems since accomplishing challenging missions requires not only extensive decision-making process but it also demands realization of the execution of those decisions based on the received sensory information. Simulation-based planning and control has been studied by researchers in various disciplines such as manufacturing and shop floor control (Son and Wysk, 2001). In this work a simulation-based planning and control system is designed, developed and demonstrated for surveillance and crowd control via collaborative operation of UAVs and UGVs. Three phases are considered, where a comprehensive system level framework is designed at the first stage. The second phase then describes details of constructing an integrated testbed involving hardware and software, and finally the third phase demonstrates two types of analyses on various control architectures and team formation of unmanned vehicles using the developed framework and testbed.

More specifically, at phase 1, a dynamic data driven adaptive multi-scale simulation (DDDAMS)-based planning and control framework is designed and developed, where the major components include 1) integrated planner, 2) integrated controller, 3) decision module for DDDAMS, and 4) real system (Khaleghi et al., 2013 (a)). Moreover, crowd detection, crowd tracking and motion planning modules are implemented in this framework to perform surveillance and crowd control mission. This frame work adopts dynamic data driven application system (DDDAS) paradigm (Darema, 2004), where the integrated planner is invoked on a temporal or event basis to incorporate dynamic data from onboard sensors of unmanned vehicles into the simulation and select the best control strategy.

At phase 2, a testbed is designed and constructed using agent-based hardware-in-the loop simulation, which involves various hardware components (e.g. real UAVs and UGVs containing on-board sensors and processors), software components (agent-based simulation, hardware interface), and human components (e.g. individuals in the crowd). In this regard, various models needed to simulate the considered scenario (surveillance and crowd control via UAVs and UGVs) are developed (Khaleghi et al., 2013 (b)). They are 1) social force model to mimic crowd movement, 2) agent-based model to represent the considered environment (e.g. terrain; GIS information), UAVs, UGVs, and individuals in the crowd. The constructed testbed is used to test scalability and robustness of the proposed planning and control platform, where alternative algorithmic approaches are evaluated for various modules such as detection, tracking and motion planning.

At phase 3, different control architectures (e.g. centralized, hierarchical, distributed, and hybrid) are addressed using the developed framework and testbed. Pros and cons of those control architectures are compared in term of computational performance due to the limited onboard resources such as sensors, battery lifetime and processing units (Khaleghi et al., 2014(a)). In addition, a DDDAMS-based UAV and UGV team formation is discussed using crowd clustering, followed by determining required team sizes based on the geometry of the generated clusters (Khaleghi et al., 2014(b)). This approach is used during the splitting behavior of the crowd into different groups, where existing team of unmanned vehicles is not able to continue monitoring all the groups due to the long distance among them.

In conclusion, we believe this work has a profound impact on both research community and practitioners using unmanned vehicles. The developed hardware-in-the-loop DDDAMS system has the potential to be deployed in real world scenarios such as border patrolling to evaluate different control strategies of autonomous systems.

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