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Swarming Remote Piloted Aircraft Systems for Mosquito-borne Disease Research and Control

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ABSTRACT

Small Unmanned Aircraft Systems (sUAS) are an emerging application area for many industries including surveillance, agriculture monitoring, and vector-borne disease control. With drastically lower costs and increasing performance and autonomy, future application evolution will more than likely include the use of sUAS swarms. Several largely successful experiments in recent years, using off the shelf sUAS, have been conducted to address the long standing challenge of controlling and monitoring vector-borne diseases. In this paper we build on lessons learned from these prior efforts, and discuss ways in which swarms of sUAS could be deployed to place and monitor Autocidal Gravid Ovitraps for reducing the mosquito population.

CCS CONCEPTS

• **Software and its engineering** → **Software safety**;

KEYWORDS

Mosquitoes,UAS,AOG,RPAS,drone,UAV

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1 INTRODUCTION

Remotely Piloted Aircraft Systems (RPAS) are an emerging technology in sectors ranging from commercial engineering, various service and entertainment industries, to multiple research domains, including vector-borne disease control and monitoring [2, 8]. With significantly decreasing costs and increasing flight performance and autonomy, future application evolution across all applications will more than likely include the use of RPAS swarms. Here we address the potential of applying our research to the swarming of small Unmanned Aircraft Systems (sUAS) [1] to support monitoring, control, and research efforts regarding vector-borne diseases [2]. There are millions of cases of vector-borne diseases every year, resulting in hundreds of thousands of fatalities placing an immense burden on the health systems and economies of the world [6]. Approaches to addressing this problem generally focus on killing mosquitoes indoors, however, recent studies [4, 5] suggest that the distribution of tens of thousands of traps may be a necessary additional tool. We therefore propose a software system to support the use of sUAS in the deployment and monitoring of such a mass distribution of Autocidal Gravid Ovitraps (AGO).

Supporting the use of sUAS swarms in such scenarios requires both hardware and software solutions. Carefully developed software systems are needed to plan sUAS routes, manage their deployment, actively monitor flights, collect data that is either transmitted during flight or downloaded after landing, and provide analytic capabilities that are specific to vector-borne disease control applications. Furthermore, given that vector-borne diseases are prevalent in both rural and urban areas, hazards associated with flying sUAS in populated areas must be rigorously addressed throughout the entire software development process. A high-fidelity simulation environment that accounts for a heterogeneous ecosystem and unknown real world environment is necessary to perform "dry runs" of such complex missions prior to deploying physical sUAS.

2 sUAS SUPPORTED DISEASE CONTROL

In this work we try to bridge the gap between research in the area of Biology and Public health on the one hand, and the research work underway in both Software and Hardware Engineering that such an exercise would require. Based on a series of use case scenarios we present a high-level architecture of our proposed solution for leveraging swarms of sUAS for controlling mosquito populations in the fight against vector-borne diseases.

• **Autocidal Gravid Ovitrap deployment**
AGOs, such as in Fig. 1, with an *Attraction chamber*, attract female mosquitoes preparing to lay eggs. Once inside the upper *Capture chamber* they become stuck to a sticky lining and die. Deploying, and moreover maintaining tens of thousands of these traps on a large scale is extremely labor intensive and time-consuming.

[1]The FAA terms RPAS below 55lb as sUASAdministration [1]
[2]Vector-borne diseases broadly include: malaria, dengue, Zika, yellow fever, and west nile, with potentially dozens of other current and emerging diseases[7]

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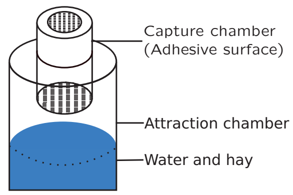

Figure 1: Diagram of an Autocidal Gravid Ovitrap used to attract and capture female *Aedes aegypti mosquitoes*

Here we focus on three specific use cases covering *(i) the precise placement, (ii) monitoring, and (iii) resupplying AGOs.* Achieving this vision comprises engineering, safety, and legal challenges associated with the use of sUAS in urban environments.

Given the known distances a species of mosquito travel in their life time, we envision a region being covered by a regular grid of 2D blocks, each of which contains a trap. This regular division of an area and associated tasks, is well suited to the flight planning, deployment, and task delegation to swarms of sUAS. Having a central control component further allows for sUAS flight and task allocation to be coordinated and dynamically adjusted as the real world context demands. Examples include adjusting a sUAS's target placement region given the placement of its nearest neighbors, or the re-tasking of a sUAS in response to a unexpected trap loss or disruption, if this is ultimately more efficient.

A swarm of sUAS might be deployed to initially identify suitable deployment sites, and then instructed to deliver traps (empty of water) accordingly. The traps, equipped with overflow outlets, will fill with rain water. Finally, when an AGO is deployed its location is recorded allowing a later maintenance and monitoring sUAS to fly directly to these traps. If not found, the sUAS will initiate a search mission within its allocated grid block, and if necessary, will recruit neighbouring sUAS to search their blocks.

• sUAS Architecture

Aside from hardware and regulatory challenges, a thoroughly designed and engineered software system facilitating management and control of sUAS, and providing analysis and processing capabilities for collected data needs to be developed. As an initial step towards our vision we propose a high-level architecture for swarm-based vector control (cf. Figure 2). Major components include the sUAS on-board sensors and processing capabilities, the sUAS flight management system, a user interface for controlling and planning missions, and an analysis component for data processing. On the sUAS hardware side on-board processing capabilities are required for real-time obstacle avoidance and carrying out trap related tasks such as deployment and inspection. This autonomy is, however, necessarily complemented by a central management and control software system, including procedures and algorithms to safely plan, dispatch and release sUAS when being sent on a designated mission. Several user interface components allow operators and scientific personnel to closely monitor the vehicles, and to take action in case of unforeseen, or potential dangerous situations. Finally, data processing and analysis components facilitate means to further analyze collected sensor and video data which may then be used for planning additional tasks (such as the scheduling of manual inspections of traps when necessary). The simulation capabilities built into our sUAS system allows us to create an extensive set

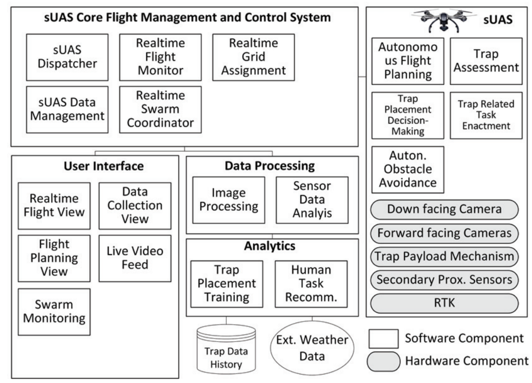

Figure 2: Architecture showing the proposed sUAS swarming system for deploying and monitoring AGO traps.

of simulations and test cases for AGO placement under realistic conditions, thereby enabling the assessment of the architecture and respective implementations for the described challenges. This simulation capability uses our own sUAS control and management system [3] which integrates a high-fidelity Software-in-the-loop (SITL) simulator and provides capabilities for monitoring sUAS in flight and capturing and storing data.

3 CONCLUSION

Vector-borne diseases are increasingly problematic for urban areas making eradicating or significantly reducing their occurrence a pressing public-health need. In this paper we have proposed a viable solution that leverages available technologies. Our solution requires a multi-disciplinary approach, in which Software, Hardware, and System Engineers must work closely with, scientists, and public health officials to deliver an effective solution.

ACKNOWLEDGMENTS

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