Using Unmanned Vehicles With Instrumented Bug Zappers To Detect & Eliminate Mosquitoes

Mary C. Burbage, An Nguyen, Kyle Walker, Nhan Phung, Vinh Truong, Erik Van Aller and Aaron T. Becker

***Abstract*— Mosquitoes are a vector for several deadly diseases, including the Zika virus that is currently spreading rapidly in Latin America. Mosquito-borne diseases kill millions of humans each year. Popular methods to control mosquitoes such as pesticides or adulticides are effective, but they introduce long-term damage to the environment. Traditional electrified screens (bug zappers) use UV light to attract pests, but have an large bycatch of non-pest insects. This paper introduces techniques using a electrified screens (bug zappers) mounted on unmanned vehicles to autonomously seek out mosquitoes in their breeding grounds and eliminate mosquitoes. Instrumentation on the bug zapper logs the GPS location, altitude, weather details, and time of each mosquito elimination. Mosquito controllers can use this information to analyze the insects' activities. The device can be mounted on a remote controlled or autonomous unmanned vehicle. If autonomous, the vehicle can use the data collected from the electrified net as feedback to improve the effectiveness of the motion plan. This paper examines design considerations, presents a working prototype system of drone and instrumented bug-zapper, and introduces a simulator for swarms of mosquitos and a mosquito-eliminating drone.**

I. Introduction

Mosquito-borne diseases kill millions of humans each year. Popular methods to control mosquitoes such as pesticides or adulticides are effective, but they introduce long-term damage to the environment. Traditional electrified screens (bug zappers) use UV light to attract pests, but have a large bycatch of non-pest insects. This paper introduces techniques using bug zapper mounted on unmanned vehicles to autonomously seek out mosquitoes in their breeding grounds such as ponds and swarms and effectively eliminate mosquitoes. Instrumentation on the bug zapper log the GPS location ,altitude, weather details, and time of each fried mosquito. Mosquito controllers can use this information to analyze the insects' activities. The device can be mounted on a remote controlled or autonomous unmanned vehicle. If autonomous, the vehicle can use the data collected from the electrified net as feedback to improve the effectiveness of the motion plan.

This is accomplished by simulating a large number of mosquitoes within a rectangular area. Each mosquito obeys a biased random walk flight pattern. Each mobile robot is capable of eliminating any modeled mosquito that intersects its path. The mobile robots can detect the time each mosquito is eliminated, share this information with neighboring drones, and use this data as feedback for a motion policy.

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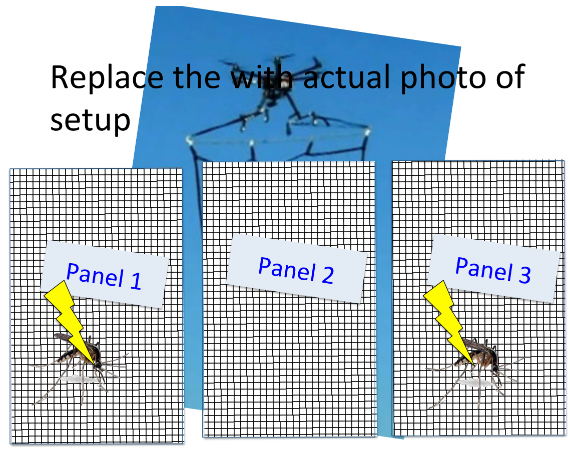

Fig. 1. A multi-copter drone carrying a high-voltage, instrumented bug-zapping screen. An onboard microcontroller monitors the voltage across the screen and for each mosquito strike records the time GPS location, altitude and weather information.

II. Related Work

A. Mosquito Control Solutions

we need someone to read these papers (saved in the github) and give 1 sentences summaries of each.

For an overview, see [1]
larvicide [2]
genetic [3] [4]
mosquito-electrocuting traps [5] What is this?

B. Robotic Pest Management

Eradication mosquito breeding sites: [6]
Photonic (active laser) fence for mosquitos [7], [8]
A wireless sensor system for monitoring mosquito populations [9]

C. Robotic coverage

Robotic coverage has a long history. The basic problem is to design a path for a robot that ensures the robot visits within r distance of every point on the workspace. For an overview see [10]. This work has been extended to use multiple coverage robots in a variety of ways, including using simple behaviors for the robots [11], [12]. The key difference in mosquito coverage problem is that the mosquitos can move and so a cleared area can again become contaminated. We instead have a probability of coverage, as in [13] This

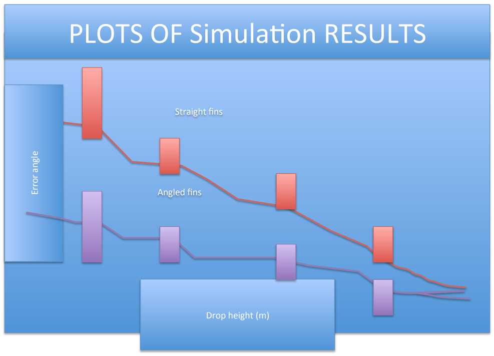

Fig. 2. Circuit diagram of bug-zapper and probe circuit.

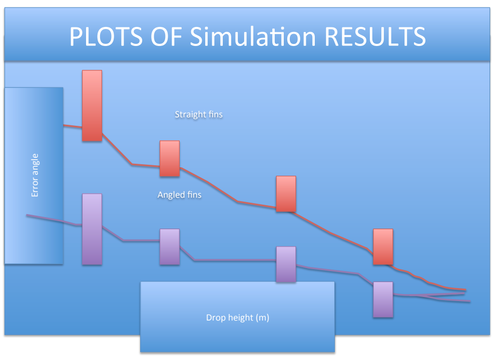

Fig. 3. Block diagram of microcontroller and bug-zapper

is closely related to the art gallery problem [14], but with limited range of visibility.

III. Design

A. Electronics

Circuit diagram of bug-zapper and probe circuit
block diagram of microcontroller and zapper
Oscilloscope trace from mosquito elimination
Math describing the size of screen that can be caried

B. Energy Budget

how many mAh to keep an LxL screen charged? How many mAH to kill one mosquito: describe the experiment procedure and extrapolate the results

C. Location of screen

The drone must carry the bug-zapping screen, and the location of this screen determines the efficacy of the mosquito drone, measured in mosquitos eliminated per second of flight time.

To hover, the drone must push sufficient air down with velocity v_d to apply a force that cancels the pull of gravity. The drone has mass m_d and has a square-shaped cross

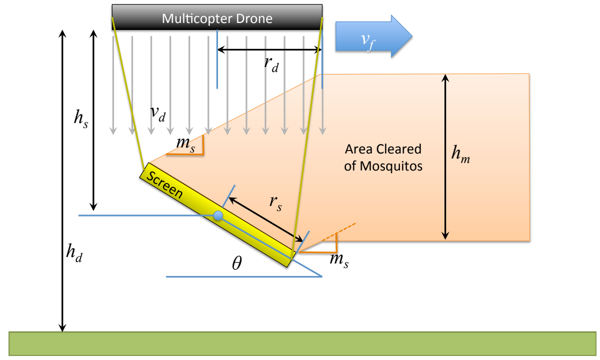

Fig. 4. The drone suspends a square bug-zapping screen beneath it. Propwash pushes incoming mosquitos downwards, and the drone clears a volume $h_m \times 2r_s \times v_f$.

section of size $d_d \times d_d$. The mass flow of air through the drone's props is equal to the produce of the change in velocity of the air, the density of the air ρ_a, and the cross section area. We assume that air above the quadcopter is quiescent, so the velocity change of the air is v_d m/s.

$$\begin{aligned} \text{Force gravity} &= (\text{mass flow}) \cdot \text{air velocity} \\ m_d g &= (v_d \cdot \rho_a \cdot d_d^2) \cdot v_d \qquad (1) \\ \text{kg} \cdot \frac{\text{m}}{\text{s}^2} &= \left(\frac{\text{m}}{\text{s}} \cdot \frac{\text{kg}}{\text{m}^3} \cdot \text{m}^2\right) \cdot \frac{\text{m}}{\text{s}} \end{aligned}$$

This means the velocity of air beneath the drone (the propwash) is

$$v_d = \sqrt{\frac{m_d g}{\rho_a d_d^2}} \qquad (2)$$

The drone testing site in Houston Texas is 15 m above sea level. At sea level the density of air ρ_a is 1.225 kg/m^3. The 3DR Solo drone weighs 2 kg with diameter 0.71 m[1]. The acceleration due to gravity is 9.871 $\frac{m}{s^2}$. These values in (2) give $v_d = 5.6$ m/s.

For manufacturing ease, the electrified screen is square, size $d_s \times d_s$. The mosquito species we are initially targeting are low altitude flyers, so the screen is suspended a distance h_s beneath the drone flying at height h_d. Suspending this screen beneath the drone also requires less weight that a rigid frame to hold the screen above the drone. This screen can be suspended at any desired angle θ in comparison to horizontal, as shown in Fig. 4. A key question is what distance h_d the screen should be suspended from the drone, and the optimal angle θ. The goal is to clear the greatest volume of mosquitos per second, a volume defined by the drone forward velocity v_f and the cross sectional area $h_m \times d_s$ cleared by the screen, as shown in Fig. 5.

Due to propwash, a mosquito in level flight will fall relative to the drone at a rate of v_d/v_f. As shown in Fig. 4,

[1]https://3dr.com/solo-gopro-drone-specs/

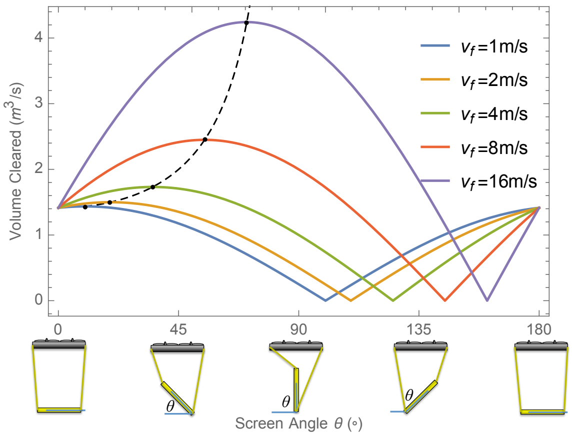

Fig. 5. The volume cleared by a drone is a function of screen angle θ and forward velocity v_f. The dotted line shows the optimal angle given in (4).

we can extend lines with slope v_d/v_f from the screens trailing edge to h_{top} and from the leading edge to h_{bottom}

$$h_{top} = h_d - h_s + \frac{d_s}{2}\sin(\theta) + \frac{d_d + d_s\cos(\theta)}{2}\frac{v_d}{v_f}$$

$$h_{top} = h_d - h_s - \frac{d_s}{2}\sin(\theta) + \frac{d_d + d_s\cos(\theta)}{2}\frac{v_d}{v_f}$$

$$h_m = d_s\left(\frac{v_d}{v_f}\cos(\theta) + \sin(\theta)\right) \tag{3}$$

The optimal angle is therefore a function of forward and propwash velocity:

$$\mathrm{ArcTan}\left(\frac{vf}{v_d}\right) \tag{4}$$

To ensure the maximum number of mosquitos are collected, the screen must be sufficiently below the drone $h_s > \frac{d_s}{2}\sin(\theta) + \frac{d_d+d_s\cos(\theta)}{2}\frac{v_d}{v_f}$ and the bottom of the screen must not touch the ground, $h_d > h_s + \frac{d_s}{2}\sin(\theta)$.

Mosquitos are not distributed uniformly vertically. Gillies and Wilkes performed a series of experiments measuring the number of mosquitos caught in suction traps at 0,0.5,1,1.5,2,3,4,5,6m above ground. the traps were operated in open grassland in the Gambia from 20:30 to 2:00 during the night [15]. The *Mansonia spp.* flies close to the ground, while the *Cx. poicilipes* prefers to fly higher in the air. Changing the flying height of our drones will target different mosquito populations.

IV. Simulation

V. Experiment

VI. Conclusion

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Fig. 6. The drone.

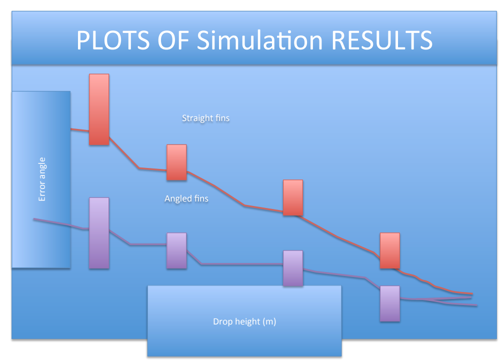

Fig. 7. The drone.

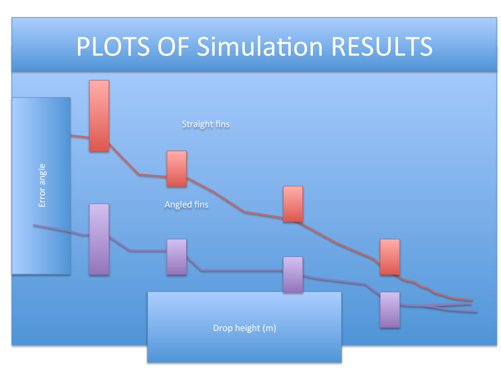

Fig. 8. To calibrate the system, three instrumented bug-zappers were carried on a 2.5 m pole.

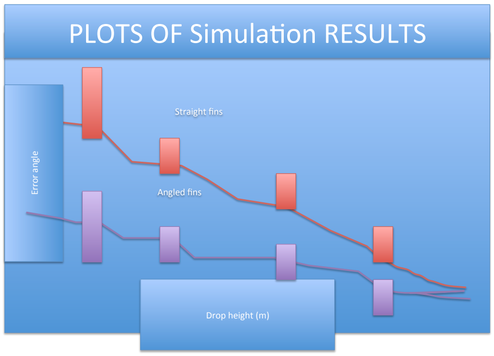

Fig. 9. map with GPS path and kill locations superimposed

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