

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

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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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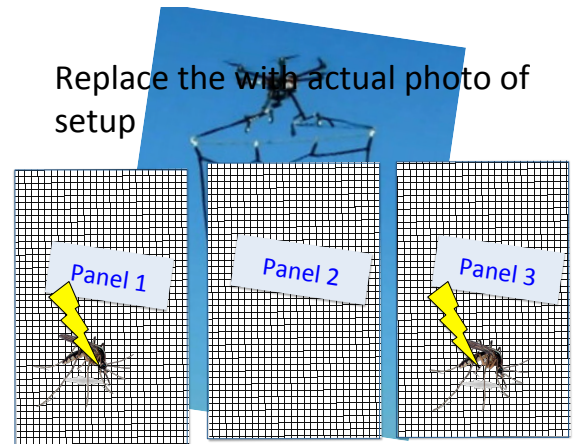


Fig. 1. A multi-copter drone carrying a high-voltage, instrumented bug-zapping screen. An onboard microcontroller monitors the voltage across the screen and for each mosquito strike records the time GPS location, altitude and weather information.

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

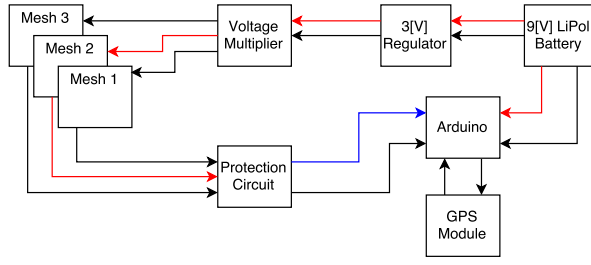


Fig. 2. Block diagram of microcontroller and bug-zapper: The system is powered by a 9 [V] Lithium Polymer battery applied directly to the power jack of the Arduino. The 9 [V] is also regulated down to 3 [V] where it is applied to the voltage multiplier circuit that will power the mesh of the net, as shown in Fig. 3. The net outputs a high voltage that is brought down by a protection circuit to a suitable level for the ADC of the Arduino. The Arduino will utilize a GPS shield for

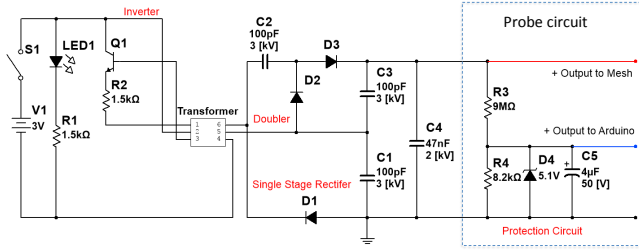


Fig. 3. Circuit diagram of bug-zapper and probe circuit. **Bug-zapper:** (from left) using a BJT (Q1) and center tap transformer a DC input voltage is inverted to AC and applied to the primary winding of the transformer where it is stepped up (1:1000). The voltage at the secondary winding of the transformer is boosted and rectified to a high voltage output capacitor that is applied to the inner layer of the mesh. **Probe:** (right) a voltage divider is used to lower the voltage so that it can be monitored by the microcontroller and a Zener diode (D4) is placed in parallel to protect the ADC input.

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

III. DESIGN

A. Electronics

block diagram of microcontroller and zapper Fig. 2
Circuit diagram of bug-zapper and probe circuit Fig. 3

Oscilloscope trace from mosquito elimination

Math describing the size of screen that can be carried

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 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

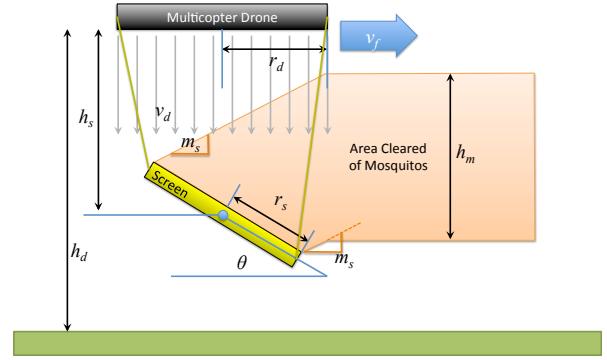


Fig. 4. The drone suspends a square bug-zapping screen beneath it. Propwash pushes incoming mosquitos downwards, and the drone clears a volume $h_m \times 2r_s \times v_f$.

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.

Force gravity = (mass flow) \cdot air velocity

$$m_d g = (v_d \cdot \rho_a \cdot d_d^2) \cdot v_d \quad (1)$$

$$\text{kg} \cdot \frac{\text{m}}{\text{s}^2} = \left(\frac{\text{m}}{\text{s}} \cdot \frac{\text{kg}}{\text{m}^3} \cdot \text{m}^2 \right) \cdot \frac{\text{m}}{\text{s}}$$

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

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

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/m³. The 3DR Solo drone weighs 2 kg with diameter 0.71 m¹. The acceleration due to gravity is 9.871 $\frac{\text{m}}{\text{s}^2}$. 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, we can extend lines with slope v_d/v_f from the screens

¹<https://3dr.com/solo-gopro-drone-specs/>

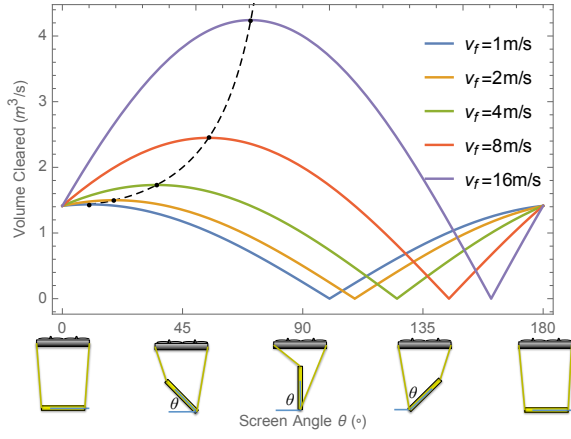


Fig. 5. The volume cleared by a drone is a function of screen angle θ and forward velocity v_f . The dotted line shows the optimal angle given in (4).

trailing edge to h_{top} and from the leading edge to h_{bottom}

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

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

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

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

$$\text{ArcTan} \left(\frac{v_f}{v_d} \right) \quad (4)$$

To ensure the maximum number of mosquitoes 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, $h_d > h_s + \frac{d_s}{2} \sin(\theta)$.

Mosquitoes are not distributed uniformly vertically. Gillies and Wilkes performed a series of experiments measuring the number of mosquitoes 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

REFERENCES

- [1] R. Peter, P. Van den Bossche, B. L. Penzhorn, and B. Sharp, "Tick, fly, and mosquito control—lessons from the past, solutions for the future," *Veterinary parasitology*, vol. 132, no. 3, pp. 205–215, 2005.
- [2] W. H. Organization, "Guidelines for laboratory and field testing of mosquito larvicides," *WORLD HEALTH ORGANIZATION COMMUNICABLE DISEASE CONTROL, PREVENTION AND ERADICATION WHO PESTICIDE EVALUATION SCHEME*, 2005.



Fig. 6. The drone.

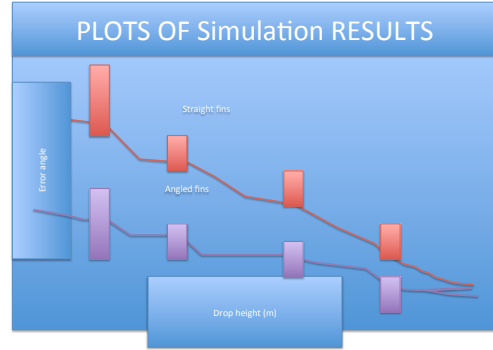


Fig. 7. The drone.

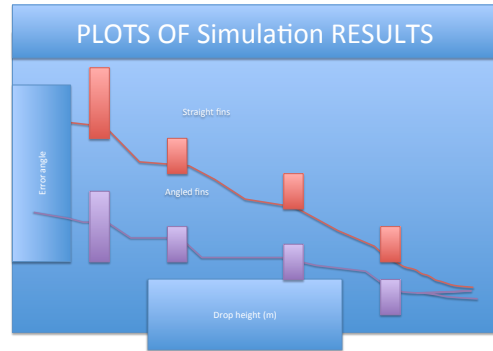


Fig. 8. To calibrate the system, three instrumented bug-zappers were carried on a 2.5 m pole.

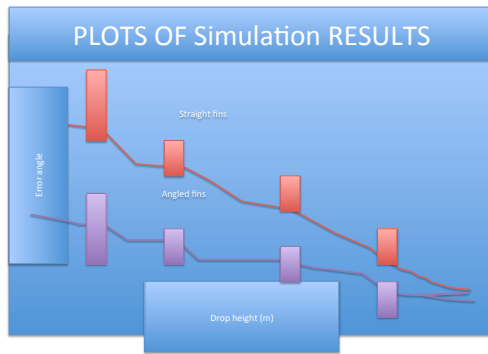


Fig. 9. map with GPS path and kill locations superimposed

- [3] C. A. Hill, F. C. Kafatos, S. K. Stansfield, and F. H. Collins, "Arthropod-borne diseases: vector control in the genomics era," *Nature Reviews Microbiology*, vol. 3, no. 3, pp. 262–268, 2005.
- [4] J. M. Marshall and C. E. Taylor, "Malaria control with transgenic mosquitoes," *PLoS Med*, vol. 6, no. 2, p. e1000020, 2009.
- [5] D. V. Maliti, N. J. Govella, G. F. Killeen, N. Mirzai, P. C. Johnson, K. Kreppel, and H. M. Ferguson, "Development and evaluation of mosquito-electrocuting traps as alternatives to the human landing catch technique for sampling host-seeking malaria vectors," *Malaria journal*, vol. 14, no. 1, p. 1, 2015.
- [6] P. Anupa Elizabeth, M. Saravana Mohan, P. Philip Samuel, S. Pandian, and B. Tyagi, "Identification and eradication of mosquito breeding sites using wireless networking and electromechanical technologies," in *Recent Trends in Information Technology (ICRTIT), 2014 International Conference on*. IEEE, 2014, pp. 1–6.
- [7] J. Kare and J. Buffum, "Build your own photonic fence to zap mosquitoes midflight [backwards star wars]," *IEEE Spectrum*, vol. 5, no. 47, pp. 28–33, 2010.
- [8] C. Boonsri, S. Sumriddetchkajorn, and P. Buranasiri, "Laser-based mosquito repelling module," in *Photonics Global Conference (PGC), 2012*. IEEE, 2012, pp. 1–4.
- [9] B. Hur and W. Eisenstadt, "Low-power wireless climate monitoring system with rfid security access feature for mosquito and pathogen research," in *Mobile and Secure Services (MOBISERVICES), 2015 First Conference on*. IEEE, 2015, pp. 1–5.
- [10] H. Choset, "Coverage for robotics - a survey of recent results," *Annals of Mathematics and Artificial Intelligence*, vol. 31, no. 1-4, pp. 113–126, October 2001.
- [11] D. Spears, W. Kerr, and W. Spears, "Physics-based robot swarms for coverage problems," *The international journal of intelligent control and systems*, vol. 11, no. 3, 2006.
- [12] S. Koenig, B. Szymanski, and Y. Liu, "Efficient and inefficient ant coverage methods," *Annals of Mathematics and Artificial Intelligence*, vol. 31, no. 1, pp. 41–76, Oct. 2001.
- [13] C. Das, A. Becker, and T. Bretl, "Probably approximately correct coverage for robots with uncertainty," in *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, vol. 1, San Francisco, CA, USA, Oct. 2011, pp. 1160–1166.
- [14] D.-T. Lee and A. K. Lin, "Computational complexity of art gallery problems," *Information Theory, IEEE Transactions on*, vol. 32, no. 2, pp. 276–282, 1986.
- [15] M. Gillies and T. Wilkes, "The vertical distribution of some west african mosquitoes (diptera, culicidae) over open farmland in a freshwater area of the gambia," *Bulletin of entomological research*, vol. 66, no. 01, pp. 5–15, 1976.