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A Prototype Device for Pupal Parasitoids Distribution Using Unmanned Aerial Vehicle (UAV)

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Abstract

The cattle and dairy industry losses $2.2 billion a year due to the enormous amount of flies that grow in the manure and other substrates produced by animal feedlots. This condition generates a suitable environment for the development of flies. Biological control using a wasp species *Spalangia cameroni* is a promising alternative option to control the fly population. The distribution of pupal parasitoids, however, is done manually using nets, pans, buckets or pipes. This method is laborious and time-consuming. The objective of this study is to develop a device that can be attached to an Unmanned Aerial Vehicle (UAV) to distribute the pupal parasitoids in feedlots or pastures to control the fly population. A commercially available hand-crank spreader was modified and used in this study. The preliminary result showed that the distribution time decreases with the increase in the PWM output level. The decrease in distribution time is due to the faster motor speed caused by the increase in PWM duty cycle.The initial evaluation shows that the device is capable of distributing pupal parasitoids while attached to the UAV. This device is a promising technology that can be used in the biological control of flies, especially in large animal facilities such as feedlots and pastures.

Keywords: Arduino, Biological Control, Fly Pupae, Pupal Parasitoids, Unmanned Aerial Vehicle (UAV)

Introduction

Animal feedlots can produce massive amounts of manure and other substrates that can create conditions suitable for the development of flies [1- 3], which has become a widespread problem in the animal industry. The majority of fly larvae are found in uncompacted moist manure, feed, or vegetation [4, 5]. Once it develops into an adult fly, it can irritate the animals, which may cause production loss and health problems. The estimated loss in the cattle and dairy industry cause by stable flies is approximately $360 million for dairy cattle, $358 million for cow-calf herds, $1,268 million for pastured cattle, and $226 million for cattle on feed, amounting to more than $2.2 billion per year in 2005-2009 [6]. Also, the presence of an enormous number of flies in a community due to these facilities may cause complaints from the neighboring residential areas [7- 10]. These flies can also transmit pathogens that may cause diseases to humans [11-13]. Application of insecticides may be required to control the large population of flies. However, this kind of management strategy may cause potential environmental pollution, health, and safety-related issues. In addition, these pests might develop a resistance to such chemicals [14-18].

Several studies were conducted to develop efficient management programs to mitigate the flies' impact in the animal industry. These programs include improve sanitation [19, 20], biological control [21- 23], feedlot design [24], feedlot management strategies [25], and chemical control [24]. In these strategies, biological control is proven to control the fly population at a tolerable level [26-29].

Biological control is the use of natural enemies to control the pest population. A natural enemy can be a predator, pathogens, or parasites [30]. The potential of pupal parasitoids as control agents in the fly population has been studied intensively [31]. In dairy cattle farms, the release of a wasp specie Spalangia cameroni significantly suppresses the stable and house flies population density [23]. Using a biological agent in controlling the fly population also depends on the number of pupal parasitoids released and the area that it covers [32]. There are different methods to release the pupal parasitoids on the feedlots. These methods include the use of pans, buckets, and polyvinyl chloride (PVC) pipes. The containers are manually placed in random locations [23, 28, 33]. Though effective, these procedures are laborious and can only cover small areas. Also, the pupal parasitoids are only concentrated in the area where the pans, buckets, or pipes are placed and may not cover the whole facility. A small Unmanned Aerial Vehicle (UAV) may be utilized to distribute the pupal parasitoids easily to address this problem.

UAVs are now used in agricultural production, management, and planning due to their low cost, low elevation operation, lightweight characteristics, ground station control, efficient communication, and ease of operation [34]. In the animal industry, UAVs are used to monitor and inspect the animals' activity and movement. UAV equipped with temporal sensors is also used to detect the early symptoms of sickness [35]. UAV use also improved the coverage area when releasing *Trichogramma* species to control Asian corn borer [36].

Biological control of flies using pupal parasitoids is mostly conducted in a feedlot setting. There are also limited studies that use pupal parasitoids in the pasture area to control the fly population. Current technologies that are used to release natural enemies are mostly inefficient [37]. Hence, a device to improve the present methods of releasing the pupal parasitoids is necessary. The utilization of UAV technology may also enhance the efficiency of the distribution of the pupal parasitoids. Therefore, the study's objective was to develop a device that can be attached to the UAV to distribute the pupal parasitoids in the field.

Materials and Methods

A prototype of the device used to distribute pupal parasitoids in the field was developed by modifying a commercially available 1.5-Liter capacity hand-crank spreader (Chapin #84150, Chapin International, Inc, NY). An Arduino Uno microcontroller board, servo motor (TowerPro SG90 Micro Servo, Torq Pro & Tower Pro), and DC motor were also used in this study. The hand-crank spreader is usually used in the application of fertilizer and the broadcasting of seeds. The handle of the hand-crank spreader was removed, leaving only the sliding part of the trigger. The device was operated using a DC motor and servo motor controlled by a developed program in the Arduino UNO integrated development environment (IDE).

A program in Arduino IDE controlled the DC and servo motor using the Arduino UNO microcontroller board and the L298 motor driver. The Arduino UNO microcontroller board draws power from a 9V battery, while the L298 motor driver used a 2600 mAh 11.1V LiPo rechargeable battery to run the DC motor. A signal was sent by the Arduino UNO microcontroller board and the L298 motor driver to the DC motor. Setting the pin to HIGH will provide the maximum output voltage to the motor, while no voltage will be provided to the motor once the pin was set to LOW. The DC motor speed was varied by changing the PWM output level to distribute the pupal parasitoids.

The DC motor was attached to the device's shaft using a 6mm x 8mm flexible coupling. At the back of the device was the servo motor. The servo motor arm was connected to the slider that opens the hopper to allow the pupal parasitoids' flow and distribution.

The operation of the servo motor was also controlled using the Arduino UNO microcontroller board. The program turns the servo motor arm from its initial position of 0o (close position) to 90o (open position). A delay time was also set in the program so that the servo motor remains in its initial position. When the delay time was achieved, the servo motor opened the hopper to allow the pupal parasitoid distribution. After distributing the pupal parasitoids, the servo motor will return to its initial position to close the hopper. Figure 1 shows the wiring diagram of the components used in this study.

A 3D printed mounts were used to attach the device to the UAV. A platform was also created to hold all the necessary components to operate the device. Figure 2 shows the prototype of the device that can be used to distribute the pupal parasitoids to control the fly population. It weighs 1.58 kg and can be operated by uploading the program to the Arduino UNO microcontroller board.

The device was attached to the octocopter (DJI Spreading Wings S1000+ DJI, CA). The octocopter can carry a maximum take-off weight of 11.0 kilograms. The device's ability to distribute the pupal parasitoids while attached to the UAV was evaluated by determining the time it takes to distribute the pupal parasitoids at three different PWM output levels.

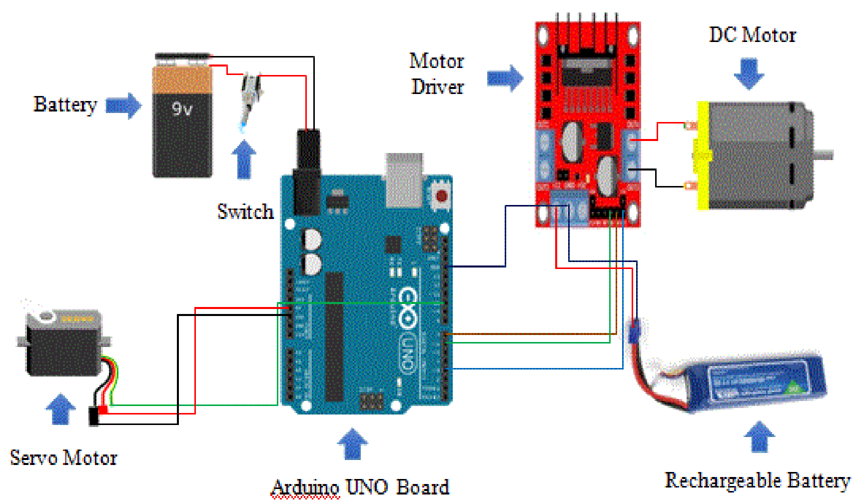

Figure 1: Wiring diagram of the components used in the development of the prototype

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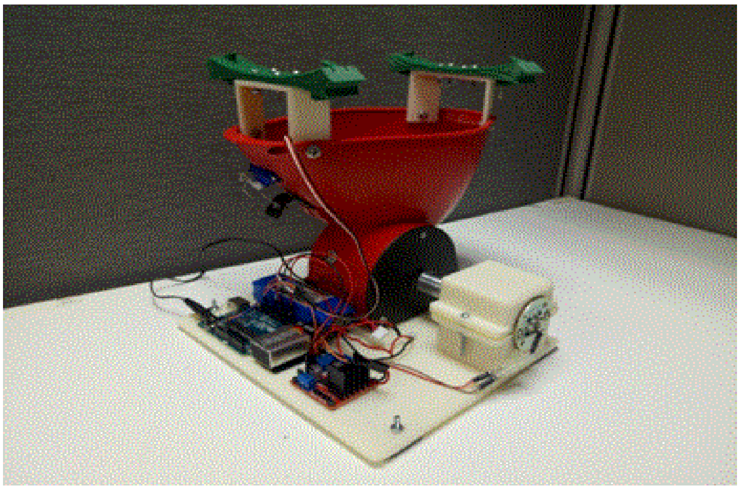

Figure 2: The prototype pupal parasitoid distribution device

Results

Performance Evaluation

Preliminary testing of the prototype was conducted to evaluate its ability to distribute the pupal parasitoids (Figure 3). The lowest PWM output level that the DC motor can rotate the device impeller was 190. Therefore, it was selected as the lowest PWM output level during the preliminary testing. The device was evaluated using three PWM output levels (190, 225, and 255). Three replications were conducted to determine the time it takes for the device to distribute 15,000 pupal parasitoids.

Figure 4 shows the result of the preliminary evaluation of the prototype. At the PWM output level of 190, the device took 135.67 seconds to distribute the pupal parasitoids while it only spent 85.33 seconds to release 15,000 pupal parasitoids at the PWM output level of 225. The shortest distribution time was obtained when the PWM output level was set to 255. The device only took 78.33 seconds to distribute the pupal parasitoids. The preliminary testing result shows that as the PWM output level increases, the distribution time of the pupal parasitoids decreases. This outcome can be attributed to the fact that the PWM output level was related to the rotation of the DC motor that was used to operate the device. In a DC motor, the strength of the armatures electromagnetic field was controlled by managing the current flow through the DC motor windings. This results to a stronger or weaker interaction and therefore a faster or slower motor speed. The PWM signal controls the motor with a series of ON-OFF pulses and varying the duty cycle. The duty cycle is the amount of time that the output voltage is in the "ON" state as a percentage of time to complete a cycle while keeping a constant frequency [38]. The PWM output level controls the DC motor rotation by changing the PWM duty cycle or PWM pulse width. A 0.0% duty cycle indicates that the DC motor will stop completely due to zero voltage difference. In a 50.0% duty cycle, the DC motor rotates at half the speed of the maximum motor speed because the voltage is half the full voltage. When the PWM is in 100.0% condition, the motor rotates with maximum speed due to the continuous PWM output [39].

Figure 3: Preliminary testing of the prototype

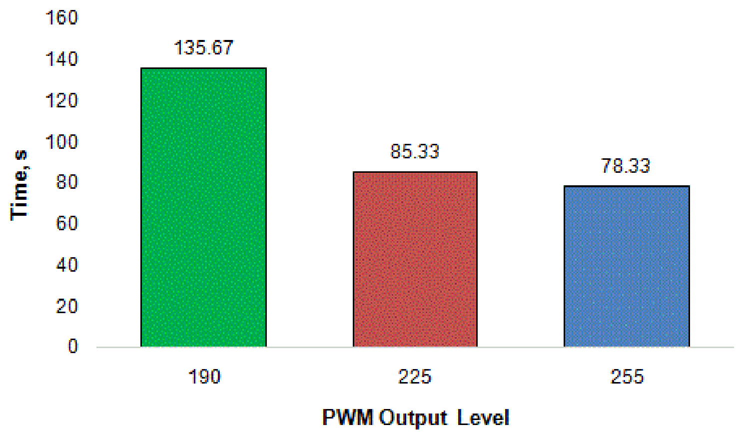

Figure 4: The average time it takes for the device to distribute the pupal parasitoids at different PWM output levels

Field testing was conducted to evaluate its capability to distribute pupal parasitoid while attached to the UAV. The device was mounted to the UAV, and necessary adjustments were conducted. A test flight was performed to check the possible problems regarding the weight distribution caused by the device to the UAV. After the test flight, the pupal parasitoids were loaded to the hopper. The UAV with the prototype device attached to it was flown and successfully distributed the pupal parasitoids, as shown in Figure 5.

Figure 5: The prototype attached to the UAV distributing pupal parasitoid

Conclusion

The objective of this study was to develop a prototype device that can be used to distribute pupal parasitoids in feedlots and pastures to control the fly population using a UAV. The prototype device was developed by modifying a commercially available hand-crank fertilizer/seed spreader. An Arduino UNO microcontroller board, L298 motor driver, servo motor, and DC motor were used to operate the device. The servo motor was utilized to manage the hopper's opening and closing that allows the flow of the pupal parasitoids. The DC motor attached to the modified spreader's shaft rotates its impeller and distributes the pupal parasitoids. The opening and closing of the hopper and the speed of the DC motor were controlled by the program created in the Arduino UNO IDE. The preliminary evaluation of the prototype showed that the distribution time decreases with the increase in the PWM output level. This is because the PWM output level is linearly related to the DC motor speed. Increasing the PWM output level increases the DC motor speed while decreasing the PWM output level slows the DC motor speed.

The prototype device is a promising technology that can distribute the pupal parasitoids either in feedlots or pasture areas. It can be attached to the UAV, making the distribution of the pupal parasitoids a lot easier, especially in large areas. The pupal parasitoids will also be distributed across the feedlots or pasture and will not be concentrated in just a particular area compared to manual distribution. This device will also help the farm workers to cover a large area when distributing the pupal parasitoids.

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