DEVELOPMENT OF PEST'S BIOLOGICAL CONTROL TOOL USING VTOL UAV SYSTEMS

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Abstract

This project presents a tool focused in biological agent's distribution to combat agriculture pests, in order to improve the agriculture production without the use of poison. Actually the pests combat is based at the use of chemical products (poisons like pesticides, fungicides, etc), which your regular use results in elevated production cost, negative impacts to the environment and takes health risks from the farmers until the consumers, because the composition based on toxic components. This research is an alternative tool, to be employed on the pest's combat using the biological control. This method consists in large amounts of pest's natural enemy, distributing them on the fields to eliminate the pests and impeding their damages for the agriculture production. Consequently gradually decreasing the economic loses and increases the food quality. Specifically, these pests are caterpillars who "attack" deferent's types of crops and has as your natural "predator" a parasitoid wasp. This wasp use the pests as a way to reproduce, them put their eggs inside the caterpillar (host), and the new wasps born from caterpillar killing it. The affectivity of these waps are very close, no more than 10 meters of radius, for this reason is necessary to establish one efficient method to distribute it on the farm, task who takes time and spend a lot of money, if considering the ground distribution. To simplify this process, considering the crops types (soybean, corn, etc), the coverage area access in some cases is practically impossible by the ground, for these reason we are proposing a tool to perform the distribution considering the aerial way and using UAV Systems. In specific this UAV is a small size Quad copter (rotary wing – VTOL system), electric powered, designed considering the modular concept and a dedicated payload installed above of the aircraft fuselage, loaded with small capsules made with biodegradable material, contemning wasp eggs. The biological distribution agents occurs autonomously during the UAV's flight, in a previously defined route and target points, unloading small capsules with wasp eggs, on the target, who will born and haunt the caterpillars in a close future. NDVI or regular cameras are used to mapping and generate maps of the flight areas (GIS), to monitor and improve next flight. This is an ongoing project that has prototypes developed and it is on a field test stage. For the preliminary result is possible to observe that the waps distribution was satisfactory considering this scope.

1 Introduction

Actually the pests combat is based at the use of chemical products (poisons like pesticides, fungicides, etc), which your regular use results in elevated production cost, negative impacts to the environment and takes health risks from the farmers until the consumers, because the composition based on toxic components [2].

This research is an alternative tool, to be employed on the pest's combat using the biological control. This method consists in large amounts of pest's natural enemy, distributing them on the fields to eliminate the pests and impeding their damages for the agriculture production. Consequently gradually decreasing the economic loses and increases the food quality.

Specifically, these pests are caterpillars who “attack” deferent’s types of crops and has as your natural “predator” a parasitoid wasp called by Trichogramma Pretiosum. This wasp use the pests as a way to reproduce, them put their eggs inside the caterpillar (host), and the new wasps born from caterpillar killing it [3].

The natural cycle is interrupted when no more pests and waps rest, closing the combat cycle.

The affectivity of these waps are very close, no more than 10 meters of radius, for this reason is necessary to establish one efficient method to distribute the waps on the farm, task who takes time and spend a lot of money, if considering the ground distribution [5]. To simplify this process, considering the crops types (soybean, corn, beans, etc), the coverage area access in some cases is practically impossible by the ground, for these reason we are proposing a tool to perform the distribution considering the aerial way and using UAV Systems [1].

In this works we are considering only the use of the Trichogramma Pretiosum applied over soybean crops, but other types of biological agents can be used with the same UAVS, to be used over others crops types, as corn, beans e etc.

2. Development

2.1 System Overview

Here we describe the development of a tool focused in biological agent’s distribution to combat agriculture pests without the use of poison. This tool is an electrical UAV VTOL UAV system, composed of rotary wing aircraft (quad copter), ground station, a specific payload and field support equipment.

This system allows the operator to create specified missions over the crops, setting aircraft route and the points to drop the biological agent’s. Remotely and in real time, the operator can fly and control the aircraft and payload from a one-man portable ground station.

In terms of setup and performance, the aircraft is an electric small sized rotary wing UAV VTOL System, composed by four electric engines (quad copter setup), 6 lbs of weight, and flight autonomy of 20 minutes (typical).

The airborne system is composed of a complete autopilot system where the navigation is performed considering a 9DOF Inertial System (IMU) and GPS with data fusion. Cryptographic and telemetry system, specific electronic boards, actuators and cameras in charge of all needed system integration functions between the sensors, in order to provide the aircraft stabilization and payload control in any atmospheric condition.

Considering a modular concept design, the Payload can be interchanged according with the mission profile. The Payload has a onboard control board to control the distribution according to mission profile.

The ground station is a one-man portable design, composed of a tablet computer equipped with interfaces that provide real time acquisition of image and telemetry from the aircraft. Through the ground station software the operator can constantly control, monitor and makes in real time adjusts at aircraft, their route and poison’s target points, it’s can take-off and land automatically using pre-defined functions.

2.2 Aircraft

The mini Hornet UAV prototype, displayed in Figure 1, is a complete UAV system developed by the author. It operates either in fully automatic mode, since take-off until the landing, monitored in real time from their ground station ([4] [9]).

The aircraft is modular in design for simple maintenance and replacement of components. The airframe is made of composite materials which makes it very strong, lightweight and modular, with ample compartments for systems installation and payload packaging.

The total aircraft weight (aircraft + payload) is around 6 lbs.

The configuration has four electric power plant engines, installed symmetrically and located at aircraft arms. Each engine works as an aircraft fixed wing surface command to provide Pitch, Yaw and Roll Axis stabilization.

Portable, easy to assemble and to transport, radio controlled in LOS (Line-Of-Sight) whose operation can be manually or automatically controlled through a ground station. Some features such as automatic and autonomous [6] are present in this VTOL system, for example, waypoint automatic navigation, Position / Altitude hold, and return to launched point (RTL) in case of emergency.

Figure 1 shows the UAV test prototype used in this application.

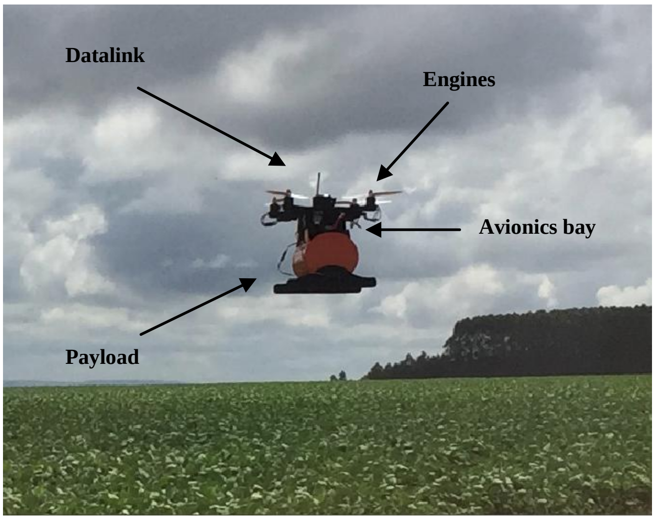

Fig. 1. Mini Hornet prototype.

The UAV VTOL system technical specifications are shown in Table 1.

Table 1. UAV Technical Specifications

Model	**BRV-VESPINHA (MINI HORNET)**
Engine	Electrical
Class	Agriculture
MTOW	6 lbs
Take-off	Vertical
Landing	Vertical
Transport	Case or Bagpack
Concept	Rotary wing
Navigation	Automatic
Software interface	protocol NMEA-183 and proprietary
Mission payload	Default camera (RGB) Thermal camera NIR camera High resolution camera (12 Mpixel) Biological control

Technical characteristics of the UAV VTOL System used as a testing platform are:

Performance and Operational Envelop

The aircraft typically operates at an altitude from 10 to 30 feet above the local terrain, with a cruising speed of 20 km/h and an operational speed range between 15 and 25 km/h of maximum speed.

Comparing with Hornet fixed wing aircraft [10], where The aircraft typically operates at an altitude from 20 to 400 feet above the local terrain, with a cruising speed of 80 km/h and an operational speed range between 60 and 110 km/h of maximum speed, this system will be used at short range applications, very low altitude and at small crops.

It can perform slow over flights and has Position hold function (common at VTOL System) that allows the hover over specific points increasing the distribution process for punctual target.

The choice of aircraft is subject to the mission purpose (GIS mapping or biological control) and crop size.

Embedded Systems

Considering the modular concept design, that allows the replacement of mission payload according to each mission profile, the embedded systems are divided by two groups, the aircraft control and the aircraft mission equipment (payload), similar to Hornet aircraft [10].

The aircraft controls are compounded by aircraft basic controls and aircraft automatic controls.

The basic control is the group of electronics equipments that keep the aircraft flying through the control of four electric engines (similar to deflection action of the primary flight controls), e.g., aircraft basic controls, pitch, roll and yaw axis control, and throttle [9]. The platform control considers the variation of rotation of each engine which results at push generation in each engine to stabilize and control the platform navigation [11].

The automatic control is a group of electronics equipments that keep's the aircraft flying automatically on a route, defined by the mission profile. In this case an autopilot system is used to navigate the aircraft and in the same board used to integrate the payload control with the navigation scope.

The mission equipment group is the group of electronics equipments responsible for mission equipments, e.g., payload control, imagery sensors, mission data link and theirs integration.

All the airborne system allows the operator to remotely fly, monitors and control the aircraft and its systems through a ground station.

The GPS and 9DOF Inertial System (IMU), with data fusion, are used to improve the platform navigation with high accuracy. In general, the aircraft's main mission is to follow the trajectory (route / path), previously created by the ground station mission planner software, and activate the payload according to pre-defined positions (targets).

The two ways communication in real time between the aircraft (telemetry), payload (control and images) and ground station, is made by telemetry links. All the time the operator can monitor and if necessary change the flight and/or payload parameters remotely, using the ground station.

As described in [10], the same development methodology used on Hornet prototype aircraft, is considered to this development. We are using COTS equipment to build the avionics systems, e.g., a GPS, and Inertial Measurement System board (IMU), data link telemetry and video boards, a RX Control Module (RX-CM) etc, the system integration is fundamental to allow the communications between these equipment / sensors. In the case described here, proper interfacing had to be developed.

The interfacing device developed was denominated integration box. It is a dedicated micro-processed board. Considering a modular design, it is possible to upgrade the avionics architecture in order to install or remove each sensor to adapt the avionics systems to the aircraft mission.

The integration box allows the communication between the boards / sensors and manages the connection and the communication of airborne equipment in real time. Inside the mini Hornet aircraft there are an integrated packaged of boards and sensors necessarily to control, to navigation and to monitor the aerial platform and their payload ([7], [8] and [11]). From there information is established a two way communication digital datalink between the aerial platform and systems with the ground station.

In the ground station, all information related to navigation and payload status is showed on a specific and customized screen. In real time the current aircraft position, the planed mission (path and waypoints), real time video, sensors status and etc are shown, and then the pilot can manages the aircraft's route to correct its position, and make changes, if necessary.

Figure 2 shows the mini Hornet prototype onboard equipment and the integrations.

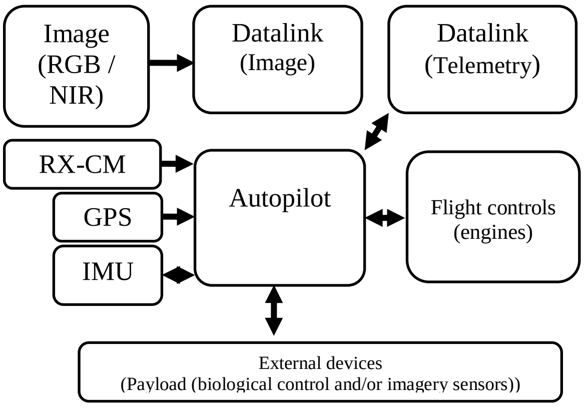

Fig. 2. The onboard equipment integration diagram.

Payload

In this works are considered one payload type, customized with biological agents devices.

The imagery equipments (cameras) are installed at camera bay, located in front of quadcopter. These equipments shall be used at same time of payload devices without replacing the biologic agents payload.

The imagery devices are specific cameras, e.g., RGB or NIR, cameras are used in order to take pictures over the crops and after that create specified digital maps.

Figure 3 shows a RGB, NIR and NDVI [12] image application example considering the payload equipped with imagery sensors.

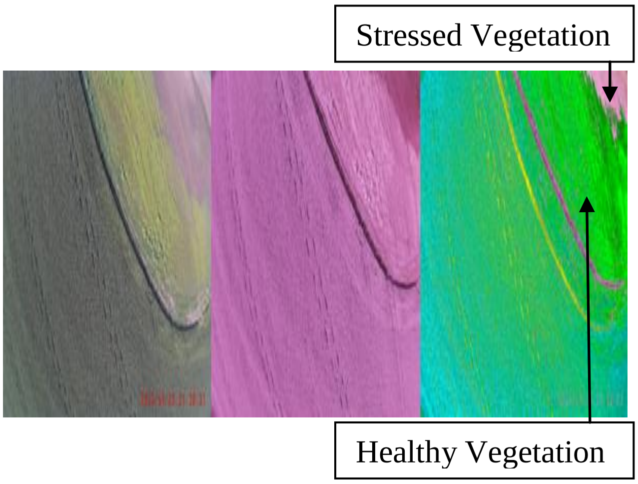

Fig. 3. RGB, NIR and NDVI image, generated by mini Hornet

Figure 4 shows the trichogramma pretiosum wasp (biological agent) used on payload equipped with devices that allows the drops of biological agents over the crops.

Source: Internet

Fig. 4. The trichogramma pretiosum wasp (application example).

2.3 Ground Station

Ground Station devices

The ground station is a component of vital importance to support the UAV flight and mission. It is composed of a tablet computer, equipped with an device interface to support real time video (imagery devices), telemetry devices (digital data link with bi-directional communication), I/O device boards and specific software that allows the mission planning, the UAV remotely control and monitoring in real time.

The ground station software, installed on the tablet, is used to mission planning, during the mission brief stage of mission planning, the activation of platform and payload automatic functions, and the takeoff and land procedures during the mission operational stage. During the mission operational stage (e.g., during the flight) the ground station monitors in real time the aircraft flight and their sensors status (payload), if necessary the operator can modify the related flight parameters to adjust the platform according to mission's requirement.

The station software is fitted to one screen display operation with easy visual interface and commanded by touched screen buttons.

Through the auxiliary device, represented by the Auxiliary device box, it is possible the connection of other equipment to the ground station according to the mission requirements, e.g., a secondary moving map display, communication radio transceivers, GPS, FPV Glasses (HMD) etc.

A ground station block diagram is given in Figure 5. The actual hardware is shown in Figure 6.

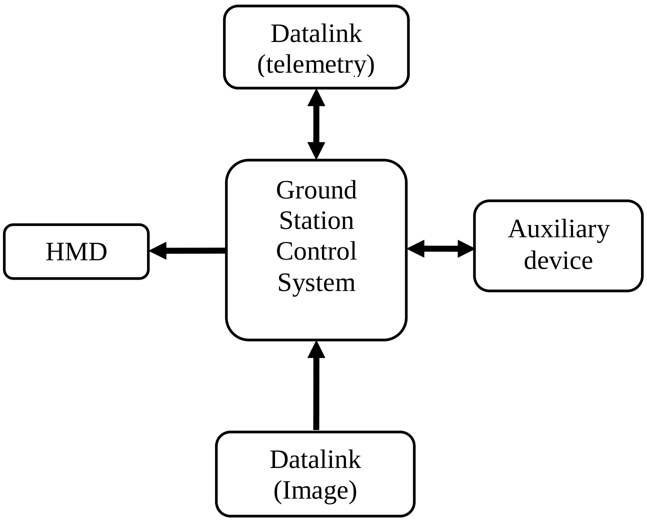

Fig. 5. Ground station equipment block diagram.

Fig. 6. Ground station hardware.

Ground Station Software

As described at [10], the Ground station developed architecture, consider the ground station as a monitor mode with mission planning over a graphical interface system (GIS), payload interface view and aircraft and payload control functionalities. The main focus of the ground station software is the mission planning, the real time monitoring and the aerial platform control.

During the flight, the software monitor in real time the aircraft and payload status, as the geographic position (latitude, longitude and altitude), speed, heading, signal status and other related information necessary to perform the mission.

In the ground station, all received information's are processed and showed at station screen, and if necessary the operator can send commands to aircraft in order to change some aircraft and/or payload parameters. In this scope, the navigation software can manage the acquisition of mission data (image and telemetry), perform aircraft position over a GIS map [9], shows the sensors status and upload commands remotely to aircraft.

All hardware devices connected on ground station are controlled by the ground station software.

If an auxiliary device (hardware or customized application software) is connected at ground station, the ground station software will identify the auxiliary device and connect it to the ground station device.

Part of this software was developed based on Open Source License GPL for research purpose.

Figure 7 shows the ground station software main screen.

Fig. 7. Ground station software, main display layout.

(1) Graphical aircraft current position (geotagged based)

(2) Navigation data

(3) Navigation HUD or Camera mission display

(4) Screen mode (Mission planner, navigation, payload control and reverse screen data)

(5) Aircraft coordinates

3 Experimental Results

To demonstrate the possibility of use Unmanned Aerial Vehicles for combat agriculture pests with a distribution of biological agent's over crops, a flight mission was created considering the operational envelop of mini Hornet UAV system.

This scenario was mapped previously using the Hornet aircraft [10], and it was generated a digital terrain model (DTM) and digital surface model (DSM), to help at mission plan process. This procedure is optional but can be used a base map from Google Earth.

The mission parameters as the maximum communication ranges, the mission flight altitude, flight speed, and disposal area of biological agents are considered according to mini Hornet performance. It can be modified according to the payload type and biological agents type, in order to represent the envelops in a real scenario with respect to the maximum operating range.

Considering this UAV VTOL aerial platform, the biological control process is performed in just one part, the flight and wasps disposal over the crops. n this case the mission plan is done using the Google maps database.

Optionally the Hornet aircraft can be used to flight over the target areas (crops), mapping them and generating aerial images with coordinates (GIS) (using regular cameras and/or NDVI [12]) and making digital maps (orthogonal mosaics) [10].

Starting from the Google maps database, on the ground station software, the flight plan is created, the distribution amount (targets) is a distribution function related to the crop status, according to the area degradation indices, e.g. a severe degradation indices, results in a large amount of agents deposited punctually.

The biological distribution agents occurs autonomously during the UAV's flight, in a previously defined route, unloading small capsules with wasp eggs, on the target, who will born and be haunt the caterpillars in a close future.

Figure 8 shows the biological distribution agents mission.

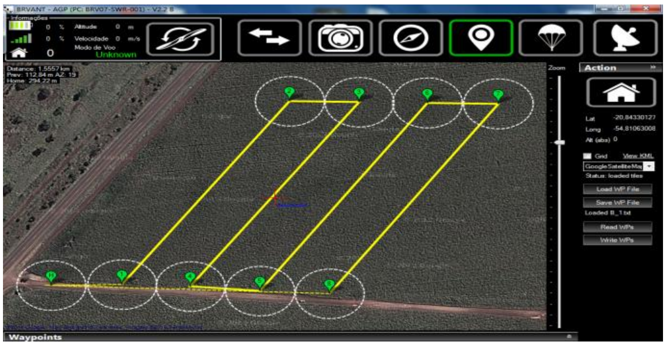

Fig. 8. Biological distribution agents mission scenario.

Basically, the UAV takes off automatically, enters into cruise mode and lands automatically. The automatic navigation functions are triggered since the take off when in a predefined altitude changes to navigation mode, which consists of flying to the point of "target", keeping the pre-defined route, point after point, throwing the biological agents on target during a specified route, and then returning to the base (RTL) and land.

All information obtained during the flight, as well as the aircraft navigation data, images and other related data, is stored in the ground station, thus creating a database for future reference.

4 Conclusions and Results

During the present work it was shown that there is the possibility of creating an UAVS distribution tools for pest's biological control to be employed in various crop types, in terms of sizes and types.

We develop two aerial solutions, the Hornet, presented at IEEE Aerospace Conference 2016 [10] and the mini Hornet, presented in this paper.

Some relevant factors must be considered in this development:

General view - This development is a conceptual demonstrator project with partial results.

Biological agents - The biological agent used was the Trichogramma Pretiosum wasp applied over soybean crops. In this case other biological agent's types could be used over other crops types considering the same methodology herein presented.

The operation of the UAVS shall be done considering a good weather conditions and a specific window time to apply the biological agents.

Considering both aerial platforms a mathematical distribution model was considered to uniform the biological distribution.

UAVS - Using an Unmanned Aerial Vehicle, it is possible to install customized payloads to allows the aerial "patrol" over the crops and beyond crops coverage area access, in a more quickly way and without damage (considering a ground inspection and access where the coverage area access in some cases is practically impossible by the ground) with a visual inspection in real time and using the automatic functionalities of UAV platform.

Considering the mini Hornet VTOL functionality, the automatic and vertical take off and land, the Position hold, the low altitude and flight speed, improved the operational logistics on small crops.

The aircraft stability is a main factor to increases the efficiency to following the mission route and the biological agents distribution process.

Through a portable ground station, it is possible to control, monitor and collect data of the UAV mission and payload in real time. Since the

With the use of imagery sensors, in this case RGB and NIR cameras, it is possible to fit the application operational needs, according to the each mission stage to improve the distribution process according to vegetation healthy.

The use of Digital Processing Images (PDI) and GIS tools in conjunction with a high precise UAV navigation system are fundamental to images processing (NDVI) and generate maps (GeoTiff mosaic). The PDI consequently increases the systems precision on mission planning and during the distribution process.

Final conclusion - The employment of this development at small crops, will fill the needs of small farmers. The aerial way method makes the pest's combat, using the biological agents, accessible, very efficient and safety for our health, consequently increases the food quality and our life.

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