Development of a gimbal for the Parrot Sequoia multispectral camera for the UAV DJI Phantom 4 Pro

R Kurbanov¹ and M Litvinov¹,²

¹Federal Scientific Agro Engineering Center VIM, 109428, Russia, Moscow, 1st Institutsky proezd, 5
E-mail: ²litvvinov.max@yandex.ru

Abstract. Crop monitoring with air monitoring tools on the basis of different types of unmanned aerial vehicles with a payload allows to identify problem areas in the field and make timely management decisions. Such complexes suggest a simple and cheap method of collecting information about agricultural biological objects. Every season, due to the lack of timely and accurate information about the condition of farmland, agricultural producers lose profits. The use of UAV platforms in agriculture ultimately allows to predict yields and reduce losses. Consequently, the integration of multispectral cameras on UAVs becomes an actual and important task. The main goal of this work is to develop a gimbal for installing the Parrot Sequoia multispectral camera on the DJI Phantom 4 Pro UAV and connecting it to the standard power plant. During the development, a gimbal was made that takes into account all sensors and has dampers for the camera, a method for powering a multispectral camera from the UAV's onboard power supply, flight tests were conducted that showed stable work of the UAV with additional attachments.

1. Introduction

Multicopter UAVs are widely used in various industries where it is necessary to monitor vegetation, soil and create digital terrain models (Evşen Yannmaza et al., 2018). Currently, many UAV prototypes are being built and their effectiveness has been shown for indoor and outdoor flights (Banzi, 2008, Buchi, 2011, Pounds et al., 2010). The use of attachments on serial copters is difficult due to the lack of ready-made solutions (Dandois and Ellis, 2013, Nicol et al., 2011, Alberto Valea, Rodrigo Venturab, Paulo Carvalhoc, 2017). The DJI Phantom 4 Pro quadcopter is a serial model popular among agricultural producers, breeders, agronomists and researchers (Senlin Guan et al., 2019), due to the low cost of acquisition, further maintenance, repair, ease of use and transportation, the presence of obstacle sensors and, accordingly, high flight safety, the ability to take off and land in cramped conditions, the presence of a 4K camera with a resolution of 20 MP and a mechanical shutter. The ability to install various types of suspended equipment (multispectral cameras, sensors, sensors) on the UAV allows you to monitor (Zhiyao Zhao, Quan Quana, Kai-Yuan Cai., 2017) farmland. At the same time, in most cases, the suspension equipment used does not have a suspension in its configuration for installation on the body of an unmanned aerial vehicle.

There are foreign and domestic solutions for attaching a multispectral camera to a DJI Phantom 4 Pro quadcopter, but they have a number of disadvantages:
• the camera is located under the body on the legs of the UAV, thereby overlapping the height control sensors;
• the presence of a battery to power the multispectral camera increases the weight of the installed equipment and negatively affects maneuverability, as well as reduces flight time (Daniel C. Gandolfo et al., 2017);
• most existing suspensions do not provide dampers in their design, which is why the vibration from the UAV is transmitted to the installed equipment, which contributes to the appearance of extraneous noise and distortion in the received data;
• too low position of the multispectral camera led to physical contact with the ground, as a result of which the camera optics were damaged;
• the design does not allow you to pack the UAV together with the suspension in a standard case for transportation and the suspension has to be removed. This takes time, and the attachment points of both the suspension and the UAV are worn out.

2. Materials and Method

2.1. Descriptive Analysis

Parrot Sequoia is the most popular multispectral camera for monitoring agricultural fields. Digital field maps are generated from images processed in Pix4DMapper software, which can be used to calculate vegetation indices that allow rational use of fertilizers and pesticides, as well as to analyze the state of plants (Jannoura et al., 2015, Vega et al., 2015, Pérez-Ortiz et al., 2015). The use of Sequoia on UAVs will allow you to quickly assess the state of crops, make timely management decisions and significantly increase productivity.

Due to its small weight and size, Sequoia can be connected to any drone, both multi-rotor and airplane. Parrot Sequoia consists of two sensors. The first sensor is a multispectral camera that has 4 1.2 MP monochrome cameras: green, red, red edge, near infrared, and 16 MP RGB cameras. The second sensor is a light sensor that registers the intensity of sunlight.

The camera has a built-in GPS antenna, which significantly improves the accuracy of shooting, without the need to connect an external antenna. Image files contain information about the height, speed, and position of the camera.

There are gimbals for the Parrot Sequoia multispectral camera for the DJI Phantom 4 Pro unmanned aerial vehicle (UAV), which consist of a camera bracket, a sensor bracket and a battery case (“2 Axis Parrot,” n.d.), (“Parrot Sequoia mount,” n.d.), (“DRON Expert Sequoia,” n.d.). The disadvantage of these gimbals is the large weight and overlap of the UAV sensors, and the displaced center of gravity.

3. Results

The technical task of the proposed solution is to balance the UAV and maintain functionality, facilitate the installation of a multispectral camera due to the collapsible design of brackets and quick-release mounts, technological holes for sensors.

In accordance with the technical task, a gimbal was developed (Figure 1), which consists of a rear bracket 1 with technological holes for UAV sensors. In the slots of the bracket 1, a damper platform 2 is installed with holes for rubber dampers 3, the platform 2 is fixed on the bracket 1 with locks 4. The dampers 3 are fixed in the holes of the cover 5 of the camera body 6 and the platform 2. The base of the camera body 6 and the cover 5 are made with grooves for fixing them. The front bracket 7 contains a stand with a platform 8 for the camera's light sensor.
Figure 1. Gimbal for Parrot Sequoia multispectral camera for UAV DJI Phantom 4 Pro.

The implementation of the bracket 1 with technological holes for the sensors of an unmanned aerial vehicle helps to preserve the functionality of the UAV, since the sensors work smoothly. The design of a collapsible housing in the form of a cover 5 and a base 6 provides easy installation of the multispectral camera. The implementation of a collapsible bracket 7 with a stand 8 for the sensor, and a stand with a platform 8 for the sensor with grooves makes it possible to quickly mount the sensor, and also allows you to place the UAV in the case that comes with the kit, without modifications. The location of brackets 1 and 7 at the back and front of the unmanned aerial vehicle, respectively, makes it possible to maintain the center of gravity. Mounting the gimbal brackets to the UAV is carried out using self-tapping screws on plastic. Figure 2 shows the installed mounting brackets of the suspension.

Figure 2. Mounting brackets to the UAV.

4. Discussion
To operate the Parrot Sequoia camera, it was decided to use power from the UAV battery via a voltage Converter. This decision is due to the fact that this method of powering the camera eliminates the external battery, which makes the gimbal structure heavier, and also affects the UAV's handling and thereby significantly reduces the flight time.

To connect power from the battery of the UAV was performed a partial disassembly to get to the controller Board power supply. Pins for desoldering were determined using a multimeter (Figure 3).

Figure 3. Power pins.
The operating voltage of the DJI Phantom 4 Pro battery is 15.2 V, which must be lowered to the USB port voltage of 4.9-5.2 V using a Converter.

In accordance with the specification of the Parrot Sequoia camera (“Parrot Sequoia User Manual,” n.d.), a 5-18V IRBIS MPA 15A pulse voltage Converter was selected (Figure 4), which produces a stable current of 3 A and a voltage of 5V. A cheaper analog of the HW-676 did not cope with its task, since this Converter outputs a current of 3A only in peak mode, which causes overheating and drops the current to the nominal 2A, as a result of which on the Parrot Sequoia camera the shooting process was interrupted.

![Figure 4. Voltage converter Irbis MPA 15A.](image)

The use of attachments significantly affects the flight characteristics of the copter. There is a rule that ensures the stability of the UAV flight – the half thrust of the engine group must be at least the weight of the entire UAV system (Stanisław Anweiler, Dawid Piwowarski, 2017).

To calculate the recommended take-off weight of the system, use the inequality

\[
\frac{1}{2} T_{PG} \geq M_{UAV} + M_G + M_{Cam},
\]

where \(T_{PG}\) – traction force of the propeller group, 
\(M_{UAV}\) – mass of the UAV, 
\(M_G\) – mass of the gimbal, 
\(M_{Cam}\) – mass of a multispectral camera.

The mass of the copter is \(M_{UAV}=1380\) grams, the weight of the suspension – \(M_G=120\) grams, the mass of the multispectral camera Parrot Sequoia with a light sensor – \(M_{Cam}=105\) grams.

Based on calculations in the ecalc.ch calculator the maximum thrust-to-weight ratio of the DJI Phantom 4 pro is 2.7.

The thrust-to-weight ratio (T/W) is the ratio of the thrust of the propeller group in grams to the mass of the aircraft. As a result, the tractive effort developed by the propeller group is equal to

\[
T_{PG} = \left(\frac{T}{W}\right) \cdot M_{UAV}.
\]

\(T_{PG}=2.7 \cdot 1380=3726\) g.

Substituting all values in the inequality, get

\[
0.5 \cdot 3726 \geq 1380 + 120 + 105
\]

\[
1863 \geq 1605
\]

The UAV flight stability rule has been observed.

Testing of flight characteristics with the developed gimbal was carried out in the field (Figure 5).
During the tests, the operation of UAV stabilization sensors and maneuverability with load were checked.

When monitoring the state of the copter during the flight via the DJ GO 4 app, no errors related to sensor overlap were detected. Takeoff and landing took place completely automatically. Compared with analogues, a UAV with a developed gimbal has better maneuverability due to reduced inertia and load mass.

5. Conclusion
The design solution made it possible to avoid the following problems:

- the gimbal with the camera does not cover the height control sensors;
- the gimbal with the camera is located above the legs, so the installation of additional supports to avoid physical contact with the ground is not required;
- the stand with the light sensor is positioned in such a way that it does not overlap the UAV obstacle monitoring sensors;
- the distribution of the payload weight is performed evenly due to the separate placement of elements of suspended equipment on the UAV body;
- reduced payload weight by eliminating external battery packs by powering the payload from the UAV battery;
- the camera is attached to the gimbal body via dampers, which reduces camera vibration during flight;
- the mass of a rake with a multispectral camera does not exceed the recommended half-thrust condition for a stable UAV flight.

The payload is powered by the UAV’s onboard network. The operating voltage of the DJI Phantom 4 Pro battery is 15.2 V, which is lowered by a Converter to the power supply voltage of the multispectral camera of 5.2 V.

Acknowledgment
According to the developed suspension, the Russian Federation patent for invention No. 2728846 was obtained “Gimbal for the parrot sequoia multispectral camera for the DJI Phantom 4 pro unmanned aerial vehicle”.

References
[1] Yanmaza E, Yahyanejadb S, Rinnerec B, Hellwagnerd H and Bettsstetter C 2018 Drone networks: Communications, coordination, and sensing Ad Hoc Networks 68 1
[2] Banzi M 2008 Getting Started with Arduino (Sebastopol: O’Reilly Media)
[3] Buchi R 2011 Fascination Quadrocopter. (Zurich: Books on Demand GmbH)
[4] Pounds P, Mahony R and Corke P 2010 Modelling and control of a large quadrotor robot Control Eng. Pract. 18 (7) 691e699.

[5] Dandois J P and Ellis E C 2013 High spatial resolution three-dimensional mapping of vegetation spectral dynamics using computer vision Remote Sens. Environ. 136 259e276

[6] Valea A, Venturab R and Carvalhoc P 2017 Application of unmanned aerial vehicles for radiological inspection Fusion Engineering and Design 124 492e495

[7] Guan S, Fukami K, Matsunaka H, Okami M, Tanaka R, Nakano H, Sakai T, Nakano K, Ohdan H and Takahashi K 2019 Assessing Correlation of High-Resolution NDVI with Fertilizer Application Level and Yield of Rice and Wheat Crops using Small UAVs Remote Sens. 11 112

[8] Zhaoa Z, Quana Q and Cai K Y 2017 A health evaluation method of multicopters modeled by Stochastic Hybrid System Aerospace Science and Technology 68 149

[9] Gandolfo D C, Salinas L R, Serrano M E and Toibero J M 2017 Energy evaluation of low-level control in UAVs powered by lithium polymer battery ISA Transactions 71 (2) 563

[10] Nicol C, Macnab C J B and Ramirez-Serrano A 2011 Robust adaptive control of a quadrotor helicopter Mechatronics 21 927e938

[11] Jannoura R, Brinkmann K, Uteau D, Bruns C and Joergensen R G 2015 Monitoring of crop biomass using true colour aerial photographs taken from a remote controlled hexacopter Biosyst. Eng. 129 341e351

[12] Perez-Ortiz M, Pena J M, Gutierrez P A, Torres-Sanchez J, Hervas-Martinez C and Lopez-Granados F 2015 A semi-supervised system for weed mapping in sunflower crops using unmanned aerial vehicles and a crop row detection method Appl. Soft Comput. 37 533e544

[13] 2 Axis Parrot Sequoia+ Micro NDVI Gimbal for DJI Phantom 4 Standard. (n.d.) Retrieved from https://copterlab.com/2-axis-parrot-sequoia-multispectral-sensor-camera-stabilized-gimbal-for-dji-phantom-4-standard

[14] Parrot Sequoia mount for Phantom 4 and Phantom 4 Pro (n.d.) Retrieved from https://zcopters.com/en/product/parrot-sequoia-mount-for-phantom-4-and-phantom-4-pro/

[15] DRONExpert Sequoia mount (n.d.) Retrieved from https://dronexpert.nl/en/parrot-sequoia/

[16] Parrot Sequoia User Manual (n.d.) Retrieved from https://www.manualslib.com/manual/1321911/Parrot-Sequoia.html?page=10#manual

[17] Stanislaw Anweiler and Dawid Piwowarski 2017 Multicopter platform prototype for environmental monitoring. Journal of Cleaner Production 155 208

[18] Gorodnichiev M, Marsova E, Gematudinov R, Dzhhabrailov K 2020 Technical vision for monitoring and diagnostics of the road surface quality in the smart city program E3S Web of Conferences 164 03013 doi:10.1051/e3sconf/202016403013