Low-cost UAV for Visible, NIR and Thermal Sensors Platform

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***Abstract*—Low-cost UAVs have a limit on the sensor payload in dimension and acquire a higher number of aerial images in terms of image resolution and produced less accurate results. Therefore, accurate calibration will improve the quality of the image data. The objectives of this research are to develop fully autonomous low-cost hexacopter UAV, perform an accurate calibration of the multispectral sensor and develop a technique to monitor the vegetation cover using modified NDVI and thermal derived data. These studies cover components calibrations, diagnose problem, and flight planning using fully autonomous vertical take-off and landing capabilities and reduce the line-of-sight telemetry. The total cost of the Hexacopter UAV system is USD 2000, which is far cheaper than commercial UAV, with a weight less than 4kg and sensor payload up to 1.5 kg. The sensor calibration used were RGB (Canon SX230 RGB), NIR (SX230 670nm to 750nm, SX260 above 750nm, Tetracam 520 nm to 920 nm) and Thermal (MobIR M8 8 to 14 µm).**

Keywords—* *UAV; hexacopter; sensor; calibration; lightweight

I. INTRODUCTION

Low-cost and light-weight UAVs have been used widely in 3D geo-data mapping [1-3], air quality monitoring [4,5] and agriculture [6-9]. The research cost is about one-tenth of the cost of UAVs sold commercially such as Parrot AR Drone [10] and DJI Phantom [11]. Lars *et al.* [12] describes low-cost UAVs as relatively inexpensive and readily available. Spare-parts are available from alternative brands, open source hardware, and software which is supported through community groups, easy to attach sensor payloads without alternating the body and require a short time to set up.

Low-cost UAVs limit the sensor payload in dimension and weight and acquire a higher number of aerial images in terms of image resolution and coverage compared to those with high-end sensors. Low-cost sensors are less stable, and this reduces image quality when compared to high-end sensors. A lightweight sensor payload used for lower weight navigation fly affects the orientation of the sensor and produces less accurate results.

Normally, commercial lens sensors are laboratory-calibrated, where the Complementary Metal-Oxide Semiconductor (CMOS) based sensors are non-uniform magnification between the sensor and plane detector. Its calibration raises some issues. Accurate parameters for sensor calibration are needed to determine the interior and exterior orientations. Among the issues related to interior and exterior parameters are flying height, focal length, pixel, spatial resolution and also a change in the attitude of whatever component parts of the earth's surface weather that includes sensor orientation, relief distortion and radial distortion [13]. For more accurate results, calibration of field samples can validate images under lab condition [14,15].

Using a suitable gimbal sensor, a low-cost multispectral sensor such as visible, NIR and thermal was placed on lightweight Hexacopter UAVs to perform aerial acquisitions of oil palm plants at a very low altitude. Reliability data analysis was then generated from the correction of undesirable and sensor defect characteristics. Here, sensor corrections and calibrations include geometric, radiometric, vignetting, resolution and directional effects. For the multi-temporal or multi-sensor image analysis, a relative *DN*-to-radiance radiometric calibration was performed.

II. UAV COMPONENTS SYSTEMS

A. Brushless Motor

For UAVs, brushless motors are controlled by the electronic speed controllers. A motor with a higher KV has less torque or acceleration, but delivers more top speed. The KV rating refers to the RPM motor per volt with no payload.

B. Arm

The The frames of the Tarot Pro680 hexacopter are made from 16mm 3K hollow pure carbon fibre that is light and very strong than the aluminum version, and this hexacopter can easily be folded for storage as in Fig. 1.

Fig. 1: Arm made from carbon fiber

C. Propeller

The The frames of the Tarot Pro680 hexacopter are made from 16mm 3K hollow pure carbon fibre that is light and very strong than the aluminum version, and this hexacopter can easily be folded for storage as in Fig. 2.

Fig. 2: Propeller balancing

D. Electronic Speed Control (ESC)

ESC is specially designed to vary the speed of the electric motor and its direction and acts as a dynamic brake, with +5V power for the flight electronics. In this research, Afro ESC 30A OPTO that provides a 3-phase voltage energy, suitable for electric powered radio controlled models was used.

E. Gimbal

For commercial gimbals, DJI Company [11] designed a plastic gimbal for the lightweight GoPro cameras, and Photohigher Company [13] used carbon fiber for larger cameras up to 1.8 kg. Since both commercial products are expensive, a creative hobbyist used plywood as gimbals. This experiment used a sensor gimbal with two axes tilt mount which provides a stable picture and video recording capability to the hexacopter UAV. The gimbal was made using high-quality carbon fibre, and for vibration-dampening, rubber grommets were used to ensure high picture and video quality. In this research, two types of gimbal were used. The first type is the RGB / NIR sensor camera while the other one is a thermal sensor, as shown in Fig. 3 and Fig. 4.

F. Flight Check and Planning

In general, examinations were done on pre-flight check flight modes such as stabilizer, Altitude Hold, Loiter and Autopilot mode from its current position to hover above the home position. A pre-flight test was conducted in the UPM Golf course. Fig.5 shows the stabilizer mode calibration results and Mission Planner setting waypoints at 30 m altitude. The maximum flight time was calculated from the flight data results.

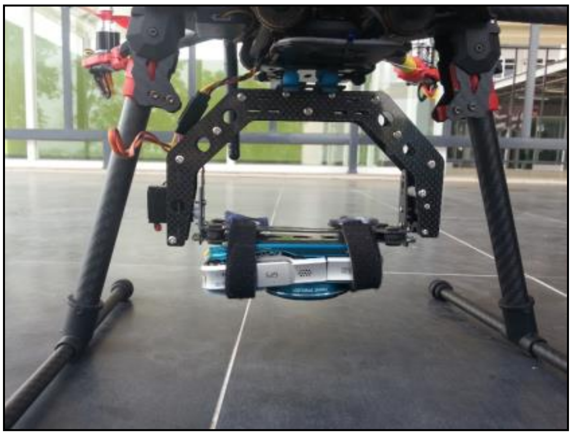

Fig. 3: RGB/ NIR Gimbal

Fig. 4: Thermal Gimbal

Fig. 5: Waypoints setting.

III. SENSORS

For the visible sensor, Canon PowerShot SX230 HS, weighing 210 grams and equipped with a GPS, a wide-angle of 28mm and an optical zoom of 14x, a 12-megapixel back-illuminated CMOS and focal length of 5.0 to 70.0 mm was used.

For NDVI, the modified from Canon SX230 HS RGB that converts the camera into a 3-band vegetation stress filter spectrum sensitivity (Figure 3.39) by replacing the IR Cut Filter, ICF (Kodak Color Infrared Film Aerchrome Type 1443) with a high-quality glass custom-manufactured filter, FSQ-WG280. It is more practical, more useful and less expensive than the Chlorophyll Meters and Chlorophyll Fluorometers.

Finally, for the thermal sensor, the Uncooled TIRS MobIR M8, weighing 350 grams with a long-wave infrared (8-14µm) temperature ranging from –20 °C to 250 °C was used. The detector type is 160 x 120 pixels with 25um uncooled FPA microbolometer, 60 Hz frequency while the thermal sensor sensitivity range is ≤0.1℃ at 30℃.

IV. RESULTS

For RGB, Fig. 6 shows a sensitivity result between the image centre and the corners of the raw and vignetting flat field, with a correction factor image radius 255 and sigma 382.

For NIR, vignetting correction from SX230 NIR is shown in Fig. 7 where the raw and vignetting flat field was derived correction factor imagery with radius 255 and sigma 482.

For thermal, image data were divided into thermal and visible objects. Visual objects were captured with a 320 width x 240 height pixel resolution while thermal objects were captured with 160 width X 120 height pixel resolution as shows in Fig. 8.

Fig. 6: RGB Image

Fig. 7: NIR Image

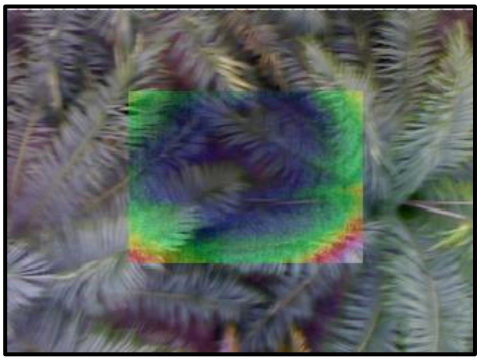

Fig. 8: Thermal Image

V. CONCLUSIONS

A low-cost and fully autonomous Tarot Ironman 680 was successfully developed with a 2-axis gimbal for image stabilisation using fully autonomous flight control.

With regard to sensors, with a sensitivity of less than 0.1 °C, the uncooled thermal sensor can detect temperature differences between areas from the image generated. Environmental data such as humidity, ambient temperature or the gap between the measured object are the most important for an accurate reading of thermal calibration.

A low-cost multispectral sensor such as visible, NIR and thermal together with a suitable gimbal was installed on the lightweight Hexacopter UAV. The aerial vehicle flew at a very low altitude to gather data on oil palm yield. For Canon SX230 sensor with near-infrared ranging between 670 nm and 750 nm, Canon SX260 above 750 nm and Tetracam NIR sensor between 520 nm and 920 nm were used. Meanwhile, for the thermal sensor, long-wave infrared 8-14 µm with temperature ranges from –20 °C to 250 °C was used.

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