PRODUCTION OF LARGE SCALE TOPOGRAPHIC MAP USING FIXED-WING UNMANNED AERIAL VEHICLE

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Abstract: High spatial resolution aerial images acquired using unmanned aerial vehicle (UAV) have proven potential for diversified applications. The use of aerial photogrammetry technique can produce topographic and thematic maps in two dimensions (2D). Also three dimensional (3D) models can be generated from photogrammetry techniques using stereomodel. Photogrammetry technique can be used to generate 2D maps by fulfilling several criteria. Currently there are several softwares which utilise photogrammetry techniques can be found on the market for digital image processing of images acquired from UAV. These softwares are able to provide different accuracy in producing 2D map such as Pix4D, Agisoft Photoscan, Correlator 3D and so on. This paper focuses on the use of UAV which employed photogrammetric techniques to produce large scale topographic maps (2D) at the campus of Universiti Teknologi Malaysia, Johor Bahru, Malaysia. Accuracy assessment for orthomosaic generated is investigated based on UAV images acquired at three different flight altitudes of 250m, 300m and 350 m using fixed-wing UAV. In the study, ground control point (GCP) is used for digital image processing and while the check point (CP) is used for accuracy assessment and these points were established using rapid static GPS technique. The results in term of orthomosaic does not show significant differences in accuracy at different flying altitude. The most important parameter to be considered in selecting flight altitude is the spatial resolution of the required orthomosaic. The softwares used in the study are Agisoft Photoscan and AutoCAD. The results obtained from these softwares are compared with conventional surveying technique. The results show that sub-meter accuracy can be obtained from Agisoft Photoscan software. In conclusion, accurate large scale topographic map can be produced using UAV and UAV has great potential to be used for other applications.
1. INTRODUCTION

Natural features and man-made features on ground are represented in topographic map that are portrayed in an accurate and detailed graphic presentation (Azmi, Ahmad, & Ahmad, 2014). There are different sources of data in producing the large scale topography map. The use of satellite imagery is one of the secondary data are best used for producing rapid assessment (Rokhmana & Andaru, 2017) in creating large scale topography map. Remote sensing is a technique that captures information on the Earth’s terrain without direct contact with it. Large area are acquired to produce large scale topography map, but have low resolution and slow update rate. A new approach needs to be explored to obtain the ground data at the minimum cost. This study has introduced a novel method for aerial photogrammetry by using multi-rotor UAV (Tahar, 2015a). Therefore, UAV-based photogrammetry came in handy in promoting more economical with higher spatial accuracy and more detailed information with less interference from clouds (Liu et al., 2012). UAV systems have several mapping applications advantages compared to conventional aerial surveying which offers accurate maps (Darwin, Ahmad, & Wan Mohd Akib, 2014). The development of Unmanned Aerial Vehicles (UAV), in recent years have becomes a trend in various applications such as scientific research, project monitoring and some for a hobby (Zainuddin, Ghazali, & Arof, 2015). Various types of cost-effective Unmanned Aerial Vehicle (UAV) platforms remote sensing data provided. There are included very high spatial resolutions and at flexible acquisition periods with true colour, multispectral, hyperspectral, LiDAR, microwave, and thermal data, at (Tian et al., 2017). Unmanned Aerial Vehicles (UAV) appear to be a capable solution to deliver multi-temporal Digital Surface Models (DSMs) and orthophotographs (Jaud et al., 2016).

1.1 Low Altitude

There are technical problems related to differences in spatial resolution or in viewing angles from continuous images along with the same flight mission due to the low payload capability of most small and lightweight UAVs (Torres-Sánchez, López-Granados, De Castro, & Peña-Barragán, 2013). UAV images taken at low altitude cannot cover the whole study plot, therefore a sequence or series of multiple images are needed as a result of their inherent characteristics to avoid geometric distortion, and overlapping image is usually employed so that a larger number of UAV images must be acquired for each field (Gómez-Candón, De Castro, & López-Granados, 2014). Low altitude systems have advantages in conducting photogrammetric surveys in cloudy days, providing different views and tilted images of the surveyed objects, low cost supplying and easy-to-maintain for engineering application systems such as topographic mapping, either large or small scale (Darwin et al., 2014).
In the aforementioned applications, mapping small-scale geomorphological features and identifying subtle topographic variations require very high spatial resolution and very high accuracy. The accuracy of the generated orthophoto and 3D model mainly depends on the Structure from Motion (SfM) photogrammetry processing chain and on the raw images (Jaud et al., 2016).

Digital photogrammetry of unmanned aerial vehicle (UAV) imagery (e.g., RGB, multispectral, or hyperspectral), could provide an alternative data source to conventional RS data (Jayathunga, Owari, & Tsuyuki, 2018).

1.2 Unmanned Aerial Platform

In the past, the development of UAV systems and platforms was primarily motivated by military goals and applications, such as unmanned inspection, surveillance, reconnaissance and mapping of unfavourable areas. For geomatics applications, the first experiences were carried out by Przybilla and Wester-Ebbinghaus (1979) used fixed-wing remote controlled aircraft (Liu et al., 2012).

There are two types of UAV system available in the market, namely; fixed wing and rotary. Fixed wing has the same design concepts with manned aircraft, including main wing, elevator, rudder, flaps, and aileron for movement purposes. Rotary has almost the same design concepts with helicopter except it is designed with single rotor or multi rotors (Tahar, 2015b).

The whole system consists of the vehicle, the radio control transmitter, a ground station with the software for mission planning and flight control, and a telemetry system. The radio control transmitter is a handheld device whose main tasks are to start the vehicle’s engines, manage take-off and landing, control the complete flight in the manual mode, and activate the autonomous navigation system (Torres-Sánchez et al., 2013).

The digital camera is now giving a new perspective to aerial photogrammetry world, mostly to the private company, where it gives a lot more advantage over metric camera. Digital camera is becoming common place in aerial photogrammetry (Ahmad & Samad, 2010). High spatial resolution images taken by unmanned aerial vehicles (UAVs) have been shown to have the potential for monitoring agronomic and environmental variables. However, it is necessary to capture a large number of overlapped images that must be mosaicked together to produce a single and accurate ortho-image (also called an ortho-mosaicked image) representing the entire area of work. Thus, ground control points (GCPs) must be acquired to ensure the accuracy of the mosaicking process (Gómez-Candón et al., 2014).
2. STUDY AREA

The study area is located at the Malaysia’s southern part which is at Johor state. The study area is at Universiti Teknologi Malaysia, Johor Bharu. The study area cover an area of 3000 acres which cover the whole main campus of Universiti Teknologi Malaysia.

Figure 1: Study area
3. METHODOLOGY

Figure 6: Detailed methodology
3.1 Unmanned Aerial Vehicle

The UAV used in this study is UAV MTD.

![UAV MTD](image)

Figure 2; UAV MTD

The specification of UAV MTD is as Table 1 below.

<table>
<thead>
<tr>
<th>No</th>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>WingSpan</td>
<td>1800mm</td>
</tr>
<tr>
<td>2</td>
<td>Fuselage Length</td>
<td>1800mm</td>
</tr>
<tr>
<td>3</td>
<td>Material</td>
<td>EPO</td>
</tr>
<tr>
<td>4</td>
<td>Auto Pilot</td>
<td>PX4-Advanced 32 bit ARM Cortex A M4 Processor running NuttX RTO S</td>
</tr>
<tr>
<td>5</td>
<td>Take Off</td>
<td>Hand Launch (Fully Automatic)</td>
</tr>
<tr>
<td>6</td>
<td>Landing</td>
<td>Auto Stabilized</td>
</tr>
<tr>
<td>7</td>
<td>Cruise Speed</td>
<td>15.6m/s</td>
</tr>
<tr>
<td>8</td>
<td>Max Speed</td>
<td>30m/s</td>
</tr>
<tr>
<td>9</td>
<td>Wind Tolerance</td>
<td>Up to 17.5m/s</td>
</tr>
<tr>
<td>10</td>
<td>Fail Safe</td>
<td>User defined</td>
</tr>
<tr>
<td>11</td>
<td>Low Battery Warning</td>
<td>Visual &amp; Audible Alarm Warnings</td>
</tr>
<tr>
<td>12</td>
<td>Camera</td>
<td>Not Included</td>
</tr>
<tr>
<td>13</td>
<td>Sensors</td>
<td>Airspeed sensors, Battery Current Sensor</td>
</tr>
<tr>
<td>14</td>
<td>GPS with Compass</td>
<td>HM C 5883L Digital Compass</td>
</tr>
<tr>
<td>15</td>
<td>Telemetry (Data Link)</td>
<td>RFD900</td>
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<tr>
<td>16</td>
<td>Lipo Battery &amp; Charger</td>
<td>Not included</td>
</tr>
<tr>
<td>17</td>
<td>Brushless Motor</td>
<td>2x1200Kv</td>
</tr>
<tr>
<td>18</td>
<td>ESC</td>
<td>2x80A</td>
</tr>
<tr>
<td>19</td>
<td>Remote Control</td>
<td>Taranis X9D Plus (Mode2) (2.4Ghz)</td>
</tr>
</tbody>
</table>
3.2 Camera

There are two types of cameras model used in this study which is Canon Powershot S100 and Sony A6000. Both are digital cameras.

![Digital Camera Canon Powershot S100](image1)

![Digital Camera Sony A6000](image2)

Figure 3: Digital Camera Canon Powershot S100  
Figure 4: Digital Camera Sony A6000

The digital camera specifications are as shown in Table 2 below.

<table>
<thead>
<tr>
<th>Model</th>
<th>Canon S100</th>
<th>Sony A6000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>12 megapixel</td>
<td>24 megapixel</td>
</tr>
<tr>
<td>Format</td>
<td>Digital</td>
<td>Digital</td>
</tr>
<tr>
<td>Dimension</td>
<td>3000x4000mm</td>
<td>6000x4000mm</td>
</tr>
<tr>
<td>Image format</td>
<td>Tiff</td>
<td>Tiff</td>
</tr>
</tbody>
</table>

3.3 Ground Control Position

There are 20 GCP marked on site which is observed using Topcon GR-5 using RTK-GPS (Base & Rover) technique.

![Topcon GR-5](image3)

Figure 5: Topcon GR-5

Figure 6 below show the process of GPS observation at ground control point (GCP) marking make on ground.
3.4 Processing

The processing software used in this study is Agisoft PhotoScan Professional, AutoDesk Civil 3D, Trimble Geomatic Office 1.5, and ArcGIS Desktop.

4. RESULT AND ANALYSIS

The result shows the image of orthophoto taken from three different altitudes of 250m, 300m, and 350m respectively in Figure 7, 8 and 9. Due to different altitude, there are different in the spatial resolution quality. When the flying altitude increases, the spatial resolutions decrease in quality. Therefore the best flying altitude for the study area is at the 250m altitude.

| Figure 7: Mosaic orthophoto at 250m altitude | Figure 8: Mosaic orthophoto at 300m altitude | Figure 9: Mosaic orthophoto at 350m altitude |

Therefore, the image can be used as the base map in digitizing as shown in Figure 10, with much higher spatial resolution, the man-made features and natural features are better analyse using lower altitude orthophoto.
5. CONCLUSION

In conclusion the low cost and light weight UAV was able to accurately obtain images with relative ease of deployment. An accurate orthophoto tie with GCP give a satisfaction technique of creating large scale topography map. The different flying altitude give results in different quality of spatial resolution, therefore lower altitude gives higher spatial resolution.
references


BUILDING A LOW COST LONG RANGE MAPPING DRONE

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KEYWORDS: Drones, Photogrammetry, Mapping

ABSTRACT: Drones are becoming popular day by day in professional applications of mapping in the fields of surveying, agriculture, mining, structural inspection etc. When it comes to mapping, drones are proven to provide accurate and very high-resolution products at low cost compared to other traditional remote sensing or surveying techniques. Today’s consumer grade multirotor drones which cost below 2000 USD for the hardware are capable of using for small area mapping applications. The major issue of multirotors in mapping applications is less flying time (approximately 30 mins) so it requires multiple flights and frequent change of batteries, which makes the mapping coverage significantly reduced. Using a fixed wing drone for mapping will solve this issue as fixed wings have high endurance. Considering the advantages of mapping with fixed wing drones, pioneering companies in geomatics industry such as Sensefly, Trimble, and Leica have introduced survey grade drones to the market specifically for mapping purposes. These survey grade drones come as reliable end to end package and with a very high price tag above 15000 USD.

This study is focused on building a low-cost custom made fixed wing drone for long range mapping applications under 2000 USD significantly reducing the cost for the hardware. The drone is equipped with GNSS unit and intelligent flight controller, which provide the capability of executing autonomous missions, improving the reliability and adding the crucial safety functions as return to home. Free-sky open source radio system is used for radio link. Propulsion system is optimized in such a way to add proper amount of thrust to the airframe carrying a high-resolution camera as the payload. Landing of the drone is a well-known problem for fixed wing category and it is addressed by integrating a parachute with automatic deployment. The drone was successfully tested by mapping 1km² area in single flight flying over 45 mins. The resulting 3cm resolution map has a verified planimetric accuracy of 34 cm without using GCPs. It was concluded that it is possible to custom build a long-range mapping UAV with significantly reduced price yet resulting accurate and high-resolution maps.

1. INTRODUCTION

UAVs (Unmanned Aerial Vehicles) which are commonly known as Drones are new technology that revolutionized the field of remote sensing. With the increased popularity of drones among the community, their
uses and importance are growing rapidly. Drones have already proven to be beneficial in Remote Sensing and GIS applications as they can fly autonomously and collect high quality imagery within a short acquisition period, which can be processed into high accurate and high-resolution map products such as Orthomosaics, 3D points clouds, Digital surface models, 3D meshes, Contour maps, index maps, etc. Remotely sensed data obtained from drones are suited for various applications of mapping in both 2D and 3D domains. Few examples are environmental surveying, forest monitoring, agricultural mapping, terrain analysis, infrastructure monitoring, feasibility surveys and archaeology and cultural heritage mapping. Even drones are used for military purposes in the early stages, now it has been a common consumer tool in many fields.

1.1 CURRENT STATUS OF DRONES IN MAPPING

Today’s consumer grade drones are capable enough of obtaining data for many mapping applications. DJI’s Phantom series, which are the most popular consumer grade drones are now widely being used to map small areas at very low costs. These consumer grade drones are mainly purposed for photography and videography, so they come with stabilized, high quality cameras. Most of the consumer grade drones are also equipped with GNSS guided navigation system, intelligent flight controller and safety features such as return to home function which makes these drones “hardware ready” to be used in mapping. With the help of freely available third-party flight planning software, consumer grade drones can make very high-resolution maps yet saving the money for a survey grade UAV. Studies show that a 1000 USD DJI phantom 3 professional drone can tie up with 15000 USD survey grade Sensefly eBee, in terms of geolocation accuracy and resolution. On the other hand, survey grade drones such as Sensefly eBee, Trimble UX 5 are using fixed wing airframes and well designed to cover a large area in single flight. They come as a complete mapping solution including proprietary flight planning software. The main purpose of survey grade drones is to collect high accurate data which guarantee accuracy of the map products. Drones such as eBee RTK, eBee X, WingtraOne are equipped with RTK/PPK GNSS units which results stunning accuracy down to 3cm without ground control. In terms of accuracy, quality and productivity, today’s survey grade drones show maximum capabilities in mapping but limiting the number of users due to the high price. Most of the survey grade drones in the market are priced above 15000 USD. The cost of a survey grade drone adds up to the cost of maintenance, labour and photogrammetric processing software for a mapping task which make them only viable for large scale projects. DroneDeploy, a photogrammetric processing service provider reveals that 90% of commercial drone mapping occurs on consumer grade drones that cost less...
than 1500 USD. One major reason behind the fact users choose consumer grade drones over survey grade drones is the high price of survey grade drones.

1.3 PROBLEM STATEMENT

When analysing today's drones, consumer grade drones are affordable and can be used in most of small area mapping applications resulting acceptable accuracy. But, there are no drones in the current market with similar price which can be used in large area mapping.

1.4 OBJECTIVE

*Develop a low cost, long range, prototype drone under 2000 USD which is capable of mapping a large area*

2. METHODOLOGY

The primary task of a mapping drone is to take the imaging system up in the air and accurately navigate through the desired flight path and facilitating the camera to collect images without an onboard pilot. There are 6 major aspects to focus when custom building such UAV.

1. Airframe
2. Flight Controller
3. Positioning System
4. Propulsion System
5. Failsafe systems
6. Imaging system

![Figure 1: Completed Custom Made Drone - “FX79 Berunda”](image)

2.1 AIRFRAME

The airframe was selected considering five main factors i.e. safety, aerodynamic stability, range, payload and cost. There are several categories of airframes available for drones. After analysing the options for airframes, fixed wing type is selected as it's the most suitable to fulfil the objective of the study. The main limitation of multi rotor is the low flying time. Helicopters and hybrid drones have considerable flying time, but they pose a risk to the public upon a crash as propellers are facing forward and the body is solid. Single rotors and hybrid drones are easy to operate when its built perfect but the aerodynamic and control systems are sophisticated. When consider the fixed wing design, its relatively simple and lift is generated by the airflow passing in sides of aerofoil shape of the wings. So the energy is utilized efficiently compared to quad copters. Using a fixed wing increases the flying time and range which opens the possibility for long range mapping.

The airframe we have selected is Zeta FX-79. The airframe is designed and made by Zeta, a Chinese based manufacture in RC aircrafts and its available worldwide. It is made with EPO (Expanded Polyolefin) which is a lightweight, mouldable foam which makes the FX-79 safe to operate in public locations as it does not threat human life or property. The propulsion system is at the rear of the drone which adds additional safety to the public. The material is durable to withstand skid landing or few low speed crash landings but will be torn apart upon high
impact. Minor damages can be easily repaired using a contact adhesive. The FX 79 is a large wing with 2-meter wingspan provides lift for accompany all additional payload required for mapping. Front of the aircraft is modified to enclose the parachute system and strengthened with fiberglass tape. This airframe is mostly popular with in the FPV (First Person View) community as a slow flying, stable long-range wing, which makes it a great candidate for aerial mapping. Stability in slow speeds is vital for the imaging system to take clear and crisp images and to obtain accurate position at the exact time of camera trigger.

In general, when compared to traditional airframe design, the flying wings only have 2 control surfaces (elevons) to control all movements in roll, pitch and yaw which makes the design simple but trading off the aerodynamic stability. However, the FX 79’s large wing span and vertical stabilizers makes very stable flight performance with help of the flight controller.

### 2.2 FLIGHT CONTROLLER

The flight controller is the brain of the drone which controls the airplane’s control surfaces based on sensor outputs and it also focuses on assisting or taking full control of a vehicle. Manoeuvring the plane to follow a reference trajectory while keeping the airframe steady by regulating the control surfaces is done by this device. Autopilots system for drones have evolved significantly over time, capable of performing fully automated missions.

**PIXHAWK 2.1 Cube**

Pixhawk is an open-hardware which established a standard for readily-available, high-quality and low-cost autopilot hardware designs for the academic, recreation and developer communities. For this study Pixhawk 2.1 flight controller is chosen considering its reliability and functions.

The Pixhawk 2.1 is designed to be a fully integrated single board flight controller with sufficient I/O for the most demanding of applications. In addition, the sensor performance and reliability has greatly been improved, with triple redundant IMU’s, and the capability to use up to 2 GPS modules. Through smart design the cost for materials has been reduced which keeps the overall design simple, affordable and extremely light at only 75g per board.

The flight controller is loaded with the with the Ardupilot firmware which is the defines the functions and behaviour of the flight controller. Ardupilot open source firmware is matured and reliable for stable flight performance which also has a great documentation and community support. Mission Planner is chosen as the ground control software, which monitors the drone during the flight.
Beside the stable flying, a mapping drone should have two vital functions.

1. Ability to execute a flight plan
2. Accurately trigger the camera at the desired location

The data requirement to make an accurate map using photogrammetric method is good quality images with sufficient overlap. To obtain such data, the drone should follow a precisely determined flight path which is calculated according to the required resolution of the map, overlap and camera internal parameters.

The Ardupilot firmware supports flight planning out of the box where the tools are provided in MissionPlanner software. During a flight mission, flight controller takes the full control of the drone and navigates autonomously along the flight path. Pixhawk signals the camera using predefined PWM (pulse width modulation) signal at the exact moment where the photographs are needed to be taken and records the location at the time of trigger. After the flight, images are post processed with the flight log to precisely georeference the images with the location of capture.

### 2.3 POSITIONING SYSTEM

The GNSS positional module of the drone plays an important role in navigation and Geotagging the images. The drone is equipped with a navigation grade GNSS unit developed by HEX Technologies. The unit is named ‘HERE GNSS’ which is powered by a u-blox Neo M8N GNSS receiver and Honeywell's latest high precision 3-axis digital magnetometer (HMC5883L). Its sophisticated RF-architecture and interference suppression mitigates multipath effects and ensure good navigation performance. As the GNSS unit is placed away from the other electronics of the drone, the magnetometer in the HERE unit is assigned to be the primary magnetometer which has the minimum interference from other electronics. The features of here GNSS unit are as follows

- **Concurrent reception**: Up to 3 GNSS constellation
- **GNSS constellations support**: GPS, GLONASS, QZSS, SBAS, Galileo ready
- **Horizontal position accuracy**: Single Point 2.5m | SBAS 2.0m
- **Navigation update rate**: Up to 10 Hz
- **Velocity accuracy**: 0.05 ms\(^{-1}\)
- **Heading accuracy**: 0.3 degrees

![HERE GNSS unit](image)

### 2.4 PROPULSION SYSTEM

Propulsion system includes motor, propeller and ESC (electronic speed controller). Among the wide variety of available components, propulsion system is carefully selected to balance between price, power and efficiency based on the specification of the FX 79 airframe. Folding propellers are used to avoid damage to the motor and mount in case of hard landing. Dual 3 cell LiPo (Lithium Polymer) batteries in parallel with total capacity of 10400mAh are used to power the propulsion system and other components of the drone.
2.5 FAIL SAFE SYSTEMS

Several fail safe systems are implemented in the drone to ensure a safe and worry-free flight.

2.5.1 Return to Launch Function

The Pixhawk flight controller with Ardupilot firmware has a built-in return to launch function in case of emergency. Home location is set to the location where the drone is turned on. Return to home is initiated automatically when the drone’s battery level is critical or if the connection between receiver and the remote controller is lost.

2.5.2 Real Time Monitoring System

Real time monitoring of the drone is done by ground control station and live video feed back of the drone using FPV (first person view) Transmission. Telemetry data is transmitted to the ground control station using long range 433MHZ radio. The real time location, attitude and altitude of the drone, battery level and speed are continuously monitored during manual and autonomous flights. For additional safety, a Fatshark FPV camera system is installed to the drone which provides live video feedback. After the initial prototyping, the FPV system can be removed from the drone to save power.

2.5.3 Parachute Deployment

The landing of the drone is done by a parachute. In case of emergency, the parachute can be deployed manually using the remote controller. The remote controller is programmed to avoid deploying the parachute by accident by adding a safety switch to the deployment switch.

2.6 IMAGING SYSTEM

Selection of proper camera plays an important role in building mapping drone. Ultimate data provided by drone for mapping purpose are the images so the quality of the images directly affects the quality of the map products. Several parameters are considered when choosing the camera for the drone. Which are resolution, resolving power, sensor size, shutter speed, focusing compatibility, PWM triggering compatibility, weight and price. Two camera models were selected for different applications.

1. Sony RX 100 M3 - For high resolution and high quality maps
2. GitUp Git 2 Pro - For medium resolution medium quality maps with increased coverage and rapid processing

<table>
<thead>
<tr>
<th>Table 2: Specification of Cameras</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sony RX 100 M3</strong></td>
</tr>
<tr>
<td>Sensor</td>
</tr>
<tr>
<td>Min shutter speed</td>
</tr>
<tr>
<td>Maximum aperture</td>
</tr>
</tbody>
</table>
### Table 1: Imaging System Specifications

<table>
<thead>
<tr>
<th></th>
<th>Sony RX 100 M3</th>
<th>GitUp Git 2 Pro</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Focal length</strong></td>
<td>8.8 - 25.7mm</td>
<td>3.87mm</td>
</tr>
<tr>
<td><strong>Field of view</strong></td>
<td>34 – 88 deg</td>
<td>170 deg</td>
</tr>
<tr>
<td><strong>Trigger mechanism</strong></td>
<td>Seagull MAP 2 connected to Sony Multi port</td>
<td>Direct PWM signal from the flight controller</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>290g</td>
<td>64g</td>
</tr>
</tbody>
</table>

![Image](image.png)

**Figure 4: Relationship between Altitude, GSD and coverage of single image of the imaging system**

### 2.7 LANDING SYSTEM

Landing of the drone is a well known issue in the fixed wing category and it’s a critical phase of each mission. Conventional manual landing requires large open space. Commercial survey grade drones use controlled deep stall landing with help of advanced sensor integration such as range finders and optical flow sensors. For this drone, a simple yet effective parachute system is used for landing where the available space is limited. The front of the airframe is modified to open a hatch and parachute is placed on elastic bed which throws the parachute out when the hatch is opened. Parachute can either be deployed by the flight controller automatically or manually using the remote controller.

The size of the parachute was calculated using the following equation. The velocity of drop is set to 3m/s. As the parachute is deployed, the drone comes to the ground nose up, so the speed can further be reduced by throttling up.

\[
Radius = \left(\frac{2 \cdot m \cdot g}{\pi \cdot C_d \cdot \rho \cdot V^2}\right) \quad m- \text{Mass of the drone} \quad C_d- \text{Coefficient of drag} \quad \rho- \text{Density of air} \quad g- \text{Gravitational acceleration} \quad V- \text{Velocity of drop}
\]

### 3. FLIGHT PERFORMANCE

The flight performance of the drone is initially tested by 10 flights for evaluating the stability, imaging system, parachute landing and to tune the parameters i.e. control surface trim, PID gains. Nine out of ten flights performed perfectly with single crash landing without any damage, due to error in deploying the parachute.
Two flights were performed to precisely test the power consumption, by using single 5200mAh LiPo battery. Power consumption is calculated after each flight by charging up the battery to its full capacity by precisely measuring the consumed electric charge.

<table>
<thead>
<tr>
<th>Flight No</th>
<th>Weather</th>
<th>Average Ground Speed (ms(^{-1}))</th>
<th>Battery Consumption (mAh)</th>
<th>Distance (km)</th>
<th>Battery Consumption per kilometre (mAh)</th>
<th>Flying Time (min)</th>
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<tbody>
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<td>1</td>
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<td>15</td>
<td>3530</td>
<td>15.76</td>
<td>224</td>
<td>18</td>
</tr>
<tr>
<td>2</td>
<td>Light wind</td>
<td>16</td>
<td>3344</td>
<td>16.37</td>
<td>204</td>
<td>18</td>
</tr>
</tbody>
</table>

The analysis shows that the drone consumes average of 214mAh battery capacity to fly 1km distance. Which means the drone can fly at 15ms\(^{-1}\) ideal speed for 50 minutes in single flight covering 45km distance with spare 10% of battery.

Figure 5: Diagram of Internal Components

4. MAPPING PERFORMANCE

The drone’s performance in mapping is assessed by mapping a total area of 1km\(^2\) in Asian Institute of Technology, Thailand. Prior to the flight, ground control is established using RTK GNSS method to assess the geolocation accuracy of the maps. For the ground control, well distributed 10 ground control points and 15 checkpoints were established with 5cm accuracy. The flight planning was done using the Mission Planner software.
The images are post processed with the flight log to extract the location at the time of exposure. The geotagged images are photogrammetrically processed into orthomap and DSM using the Pix4D software, resulting a high resolution (3.3 cm) orthomap and DSM. Two sets of maps were made during the process by using the ground control for georeferencing and without using the ground control but direct georeferencing only by the image geotags.

<table>
<thead>
<tr>
<th>Configuration for Testing the Mapping Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
</tr>
<tr>
<td>Forward and side overlap</td>
</tr>
<tr>
<td>Flying height</td>
</tr>
<tr>
<td>Total flying time</td>
</tr>
<tr>
<td>Camera</td>
</tr>
<tr>
<td>Average GSD (Ground Sampling Distance)</td>
</tr>
<tr>
<td>Number of images</td>
</tr>
</tbody>
</table>

The absolute accuracy is assessed by comparing the map coordinates with the actual ground coordinates measured by survey grade RTK GNSS receiver. The relative accuracy is for the map measurements relative to a point on the map. The analysis shows that the custom made drone can make 2D maps to an accuracy of 34cm without aid of a ground control.

<table>
<thead>
<tr>
<th>Geolocation Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal Accuracy (cm)</td>
</tr>
<tr>
<td>Absolute</td>
</tr>
<tr>
<td>Without GCPs</td>
</tr>
<tr>
<td>With GCPs</td>
</tr>
</tbody>
</table>
5. COMPARISON

The drone’s performance in mapping is compared with phantom 3 & phantom 4 which are DJI’s consumer grade drones and with Wingtra One, Trimble UX5, DATAhawk & eBee X which are popular survey grade drones. The most significant advantage of the custom-made drone over other commercial drones, is the price. The total build including two cameras only cost 1989 USD for the hardware. Its 10 times cheaper than the average price of a survey grade drone. Also, the drone is capable of covering an area of 3ha with a single flight which ties up with the survey grade drones. The trade offs are the accuracy and the operational complexity. The drone only uses SBUS GNSS positioning which brings the standalone horizontal accuracy of the products to 34cm. 3D accuracy further drops to 72cm which is less accurate than the survey grade drones. Also at current stage it is very difficult to understand how to operate the drone except for the people who built it, which makes the operational complexity, extreme.

6. DISCUSSION

This study proves that it is possible to build a long-range mapping drone under 2000USD which can map to an planimetric accuracy of 34cm and sub meter in 3D. Further improvements will be made to upgrade the positioning system to RTK/PPK capable receiver to increase the standalone mapping accuracy. The power consumption can be reduced by fine tuning the internal parameters of the flight controller which requires significant amount of flight data in multiple flights. When compared to the survey grade drones in the market, the custom-built FX-79 “Berunda” is a very affordable drone solution for long range mapping where it matches with the accuracy requirements as the accuracy is always governed by the application.

7. REFERENCE

TREE SPECIES MAPPING AT ROYAL BELUM FOREST RESERVE USING UNMANNED AERIAL VEHICLE PLATFORM MULTISPECTRAL IMAGES

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KEYWORDS: Tree species, Tropical Rainforest, Unmanned Aerial Vehicle, Multispectral Images

ABSTRACT: Mapping of tree species plays an important role in sustainable forest management and resource evaluation, as many benefits and applications inherit from this detailed up-to-date data sources. This study aims to map tree species in tropical rainforest using Unmanned Aerial Vehicle (UAV) based multispectral remotely sensed data. The data obtained from low cost camera was mounted on board UAV. The UAV was flown at 500m altitude which resulted in images with a 0.05 m spatial resolution. Over an experimental plot in Sungai Papan in Royal Belum Forest Reserve, Perak. Low-cost RGB (400-650nm) and NIR (830nm) camera were used to capture images for two groups of supervised classification methods, namely maximum likelihood (ML), Minimum Distance (MD) as spectral distance classification while spectral angle mapper (SAM) and Spectral Information Divergence (SID) as spectral angular distance classification. The region of interest (ROI) are drawn for each of tree species to extract the training data set for maximum likelihood (ML) and Minimum Distance (MD) while spectral libraries for tree species were established to aid the spectral angle mapper and spectral information divergence classification. Overall accuracy of ML, MD, SAM and SID classification obtained was is 86.67%, 80.00%, 64.71% and 60.00% respectively. In conclusion, the spectral distance classification is suitable to use to classify tree species in tropical rainforest based on multispectral image acquired using low-cost UAV.

1. INTRODUCTION

The tropical rainforest is a very consequential ecosystem and natural resource for living things. The authoritative body makes decisions to conserve and manages forests in a sustainable way (Chiang et al., 2016). The forest composition is a major concern for forest management, biodiversity assessment and for understanding the potential impacts of climate change based on tree species distribution. Tree classification using remote sensing technology was applied to identify tree species in the subject area to replace the conventional method which required more time and limited accessibility for site survey (Majid et al., 2016). Therefore, the increasing availability of remotely sensed images due to the rapid advancement of remote sensing technology expands the degree of our choices of imagery sources. Differences in spectral, spatial, radiometric and temporal characteristics of the various source of imagery and different sources are suitable for different purposes of tree species mapping (Xie et al., 2008). In the tropical rainforest, the major tree species in the dipterocarpaceae family such as Shorea pauciflora, Payena dasypylla and Shorea hopeifolia. The commercial tree species tree such as Dracontomelon Dao (Sengkuang), Gironiera Nervosa (Hampas Tebu), Hydnocarpus Castea (Setumpol), Payena Dasypylla (Nyato), Shorea Hopeifolia (Damar Hitam Siput Jantan), and Shorea Pauciflora (Meranti Namesu) was selected in this study.

The conventional way that was used to map the tree species such as field survey, map interpretation and ancillary and ancillary data analysis before remote sensing techniques was used to mapping tree species (Xie et al., 2008). At present, many classification methods were used to identify tree species in tropical rainforest was applied into satellite imagery. Two groups of supervised classification methods, namely the maximum likelihood (ML), Minimum Distance (MD) as spectral distance classification while spectral angle mapper (SAM) and Spectral Information Divergence (SID) as spectral angular distance classification were used for these species mapping. Maximum likelihood (ML) and Minimum Distance (MD) classifier was used based on point of interest the trees species. Meanwhile, Spectral Angle Mapper (SAM) and Spectral Information Divergence (SDI) classifier was used based on spectral library was generated.

Nowadays, the applications of UAV in Remote sensing and forestry are widely used because UAV have found applicability in a variety of study fields, one of these being forestry. The increased interest is given to this segment of technology, especially due to the high-resolution data that can be collected flexibly in a short time and at a relatively low price. Also, UAV has an important role in filling the gaps of common data collected using manned aircraft or satellite remote sensing, while having many advantages both in research and in various practical
applications particularly in forestry as well as in land use in general (Banu et al., 2016). The aim of this study to map tree species in the tropical rainforest using UAV-based multispectral data.

2. METHODOLOGY

2.1 Study Site

This study was carried out at one of the oldest known tropical rainforests, the Royal Belum Forest Reserve located in Perak, Peninsular Malaysia. The study site is located at Sungai Papan, Royal Belum Forest with latitude 5º36'18.76” and longitude 101º25’8.64”. The Royal Belum Forest Reserve (RBFR) was gazetted as a protected area on 3 May 2007 under the Perak State Parks Corporation Enactment 2001 (WWF Malaysia., 2018). The forests found in the area are mainly lowland dipterocarp, hill dipterocarp and upper dipterocarp forests extending from 260m asl (above sea level) to 1,533m asl (WWF Malaysia., 2018). Geographically, about 57% of its area is located in the range of 80-300 m above sea level and 41% in the range of 300-1,533 m above sea level (UNESCO., 2018). The majority of the species are typical of the tropical rainforest that occur in Peninsular Malaysia, Sumatra and Borneo while a minority of the species is more typical of the seasonal tropical forests of the Thai and Burmese region (WWF Malaysia., 2018). The area remains warm and humid throughout the year; the range of temperature is between 23°C and 32°C and the average annual rainfall is 2205 mm (MalaysiaHere., 2018). The study site covers 27.64 hectare equal to 276400-meter square in Sungai Papan.

![Study Location in Royal Belum Forest Reserve (RBFR)](image)

**Figure 2.1: Location of the Study Area**

2.2 Field data

2.2.1 Field Data Equipment

Field data collection was done using GPS Topcon, Topcon Total station, Handheld ASD Spectroradiometer, Phantom 4, and RGB and NIR camera. Topcon GPS was used to establish the ground control point in Sg Papan. Rapid static observation was used to observed ground control point coordinate. Typically, the receivers need to occupy a baseline for a period of 10-30 minutes. The total station was used to establish grid marking in the experimental plot. Total station is a suitable tool to establish experimental plot because of its accuracy of approximately 3 mm over 1km.

![Topcon GPS](image) ![Topcon Total Station](image) ![Handheld ASD Spectroradiometer](image)

**Figure 2.2: (a) Topcon GPS, (b) Topcon Total Station and (c) Handheld ASD Spectroradiometer**

Leaf sample signature was measured using Handheld ASD spectroradiometer. Full range detection capacity of the ASD spectroradiometer is 350nm – 2500nm. It provides uniform Visible (RGB), Near Infrared (NIR), Short wave Infrared (SWIR) data collection over the entire solar spectrum.
Low-cost Unmanned Aerial Vehicle (UAV) Phantom 4 was used to acquire remotely sensed data. The maximum flight time for Phantom 4 is 28 minutes but the actual time varies based on the environmental conditions and operation. MAPIR Camera is a low-cost camera sensor which generates 0.04m spatial resolution per pixel at 120m (~400 ft) and 16 mega pixel image resolution. Two types of filter were used to acquire image that is RGB and NIR. The RGB camera has a filter which captures roughly from 400-650nm while the NIR filter captures 850nm.

2.2.2 Establishment of Experimental Plot

A quadrat is a frame that is laid down to mark out a specific area of the community to be sampled. Within the quadrat frame, the occurrence of plants is recorded using an appropriate measure of abundance (Baxter et al., 2014). When performing an inventory in a forest, it is necessary to establish plots in the inner part of the forest in a well-developed stand, at least 200 m from the edge of the forest to avoid edge effects. Square 1-ha plots (100 m × 100 m), measured on a horizontal plane rather than on the ground. This is one of the most common plot sizes used in the tropics and appears to be good enough to estimate forest variables in tropical areas (Condit et al., 2008). Therefore, the experimental plot with size at 100m × 100m which area equal to 1 hectare and with a grid of 20 × 20 m and 10×10m, respectively has created based on Centre for Tropical Forest Science (CTFS) protocol (ForestGEO, 2018). After established the ground control point along Sg Papan, total station was used to forward coordinate from GCP location to the area to be built experimental plot. Figure 2.4 show the location of ground control point and the points that have been built experimental plots. Each tree species sample will be tagging based on location in experimental plot as figure 2.4. Ground control point using coordinate system WGS84 and it will be converting to local coordinate system GDM2000 MRSO.
2.2.3 Leaf Sampling

After established experimental was successful carried out, fieldwork was conducted in 11 May 2015 to collect the sample leaves. 27 samples tree species leaves were taken from the experimental plot. However, six species were selected, they are: *Dracomelon Dao* (sengkuang), *Gironiera Nervosa* (Hampas Tebu), *Hydnocarpus Castea* (Setumpol), Payena Dasyphylla (Nyatoh), *Shorea Hopeifolia* (Damar Hitam Siput Jantan), and *Shorea Pauciflora* (Meranti Namesu). Tree species have been identified based on leaf shape and pattern. Each species have difference characteristics and pattern so that we are able to identify the tree species based on leaf pattern and their characteristic (Cope et al., 2001). Table 2.1 shows the images of leaves of selected 6 commercial tree species.

**Tables 2.1**: Example sample leave.

<table>
<thead>
<tr>
<th>Tree Species</th>
<th>Leaf Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dracomelon Dao</td>
<td>Arranged spirally, crowded towards the ends of twigs, large.</td>
</tr>
<tr>
<td>Gironiera Nervosa</td>
<td>Thick-coriaceous, rigid, and elliptic-oblong.</td>
</tr>
<tr>
<td>Hydnocarpus Castea</td>
<td>Look low contrast and tapered.</td>
</tr>
<tr>
<td>Payena Dasyphylla</td>
<td>Alternate, simple, pinni-veined, and hairy undersurface.</td>
</tr>
<tr>
<td>Shorea Hopeifolia</td>
<td>Bright green and shape same with payena dasypylla.</td>
</tr>
<tr>
<td>Shorea Pauciflora</td>
<td>Dark green and shiny leaf surface.</td>
</tr>
</tbody>
</table>

The leaves from each tree has a different pattern, contrast, and their characteristics. Dracomelon dao Leaf arranged spirally, crowded towards the ends of twigs, large. Gironiera Nervosa leaf is thick-coriaceous, rigid, and elliptic-oblong. Hydnocarpus Castea leaf look low contrast and tapered. Payena Dasyphylla leaf alternate, simple, pinni-veined, and hairy undersurface. Shorea Hopeifolia leaf is bright green and shape same with payena dasypylla. Lastly, Shorea Pauciflora leaf is dark green and shiny leaf surface. Spectral signature is the variation of reflectance of a material with respect to wavelength. Figure 2.5 below shows the spectral signature of selected six tree species. These signatures are used to calibrate the UAV image so that all species has its unique signature similar to the spectroradiometer reading. Each species will be measured five time of reflectance value. The average of reflectance value will be calculated to generate the tree species spectral signature. Each species shown the difference spectral signature in figure 2.5.

![Selected Tree Species Spectral Signature](image)

**Figure 2.5**: Six selected sample tree species reflectance signature for this study

Spectral signature of tree species shows the different pattern based on chlorophyll absorb and reflect the electromagnetic wave. Chlorophyll nature toward electromagnetic wave is different, it does not absorb green light rather blue and red for the photosynthesis process. Meanwhile, near-infrared is reflected more because of mesophyll tissues and cavities within the leaf scatter the radiation passed through the upper epidermis and the internal structures are almost transparent to the infrared radiation.
2.2.4 UAV Imagery

The Unmanned Aerial Vehicle (UAV) flight was organized on the 11 May 2015 at Royal Belum Reserve Forest, Perak. There are two sets of pictures that provide from UAV flight which are red, green and blue band (RGB) images and also Near Infrared (NIR) images. In total 422 images were taken at an attitude of 546 metres where 186 images were RGB band and 236 images of Near Infrared (NIR).

2.3 Image Processing

2.3.1 Mosaic and Sticking

Data mosaicking refers to the combination of pixel-based images as preparation for map composition, or as a means for combining georeferenced images into an image covering a larger geographic area (R.S Inc, 2001). The main purpose of data mosaicking is to arrange multiple UAV image to form a single image for further analysis and processing. Two types of images were mosaicking that is RGB images and NIR images. After that, the RGB and NIR band was stack together for further analysis. A layer stick is often used to combine separate image bands into a single multispectral image file.

2.3.2 Geometric Correction

By using Unmanned Aerial Vehicle (UAV) images for application such as Remote Sensing (RS) and GIS, it will be necessary to carry out geometric correction for the images. Orthorectification is the process of digitally manipulating image data such that the image's projection precisely matches a specific projection surface or shape. To perform the orthorectification process a set of ground control points (GCP) is needed. The first-order polynomial transformation is commonly used to geo-reference an image. Result of root mean square error (RSME) for RGB image is 0.0000247156 while NIR image is 0.0000236975. This value describes how consistent the transformation is between the different control point. Both image rectifications show the lowest RMS. Therefore, it was used to rectify the UAV images. Table 2.2 show the list of GCP's coordinates.

<table>
<thead>
<tr>
<th>Marker</th>
<th>Longitude</th>
<th>Latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>P01</td>
<td>101.401604</td>
<td>5.629822</td>
</tr>
<tr>
<td>P02</td>
<td>101.400582</td>
<td>5.630151</td>
</tr>
<tr>
<td>P03</td>
<td>101.400951</td>
<td>5.630100</td>
</tr>
<tr>
<td>P04</td>
<td>101.400573</td>
<td>5.630874</td>
</tr>
<tr>
<td>P05</td>
<td>101.400030</td>
<td>5.630734</td>
</tr>
</tbody>
</table>

2.3.3 Spectral Conversion

The use of Unmanned Aerial Vehicle to acquire very-high resolution multispectral imagery have no systematic, feasible and convenient radiometer calibration method which specific develop for UAV. Therefore, this study carried out the simplified empirical formula to convert raw digital number (DN) of image to appropriate reflectance value. Given a ground reflectance with known reflectance values $R$ that measured by spectroradiometer, and raw DNs $I$ from a multispectral image, a linear relationship can be obtained. The characteristics of the linear function (K and b) can be determined from the linear regression [1] (Gowravaram, 2017). The empirical line calibration equation for every single band image can be built using the y-intercept as one data point, and the natural log-transformed measured reflectance and image DNs of tree species point. Then, these parameters can be applied to any image for the conversion from raw DNs to reflectance for each band.

$$ R_{\text{Band}} = K_{\text{Band}} / I_{\text{Band}} + b_{\text{Band}} $$

An empirical line calibration equation for every single band image was created using reflectance of spectroradiometer as y-coordinate value and its DN as x-coordinate value. The DN of each sampling species was then calculated and brought into the corresponding calibration equation to compute the predicted reflectance value. All the measured and predicted reflectance values of tree species for all four spectral bands are shown in figure 2.6.
Figure 2.6: Relationship between image raw DN (x-axis) and mean reflectance spectroradiometer data (y-axis) for each sensor waveband. (a) Blue band of MAPIR Camera sensor (b) Green band. (c) Red band and (d) Near-Infrared (NIR) band

The regression analysis of digital number of image versus measured in-situ spectral reflectance was used to identify the constant variable to apply in image for generate reflectance value of image. Result show the high regression value was near-infrared band which $R^2 = 0.9395$, that show the strongest relationship between two variable.

2.2.4 Spectral Library

Spectral library of trees species was created using based on spectral image. Spectral library will be used to classify trees species based on spectral classification using spectral angle mapper and spectral information divergence classifier. The reflectance in wavelength 485nm (Blue Band), 560nm (Green Band), 660nm (Red Band), and 830nm Near-infrared band each of tree species was created to build spectral library. Figure 2.7 shown the spectral library was created from spectral image. That spectral library will be used in data processing to identify the match image spectra by using spectral angle mapper and spectral information divergence classifier.

Figure 2.7: Spectral library of trees species based on multispectral image

Spectral signature above was generated from spectral UAV image. Endmembers are spectra that are chosen to represent pure surface materials in a spectral image. So that each species has difference spectral signature to be used in spectral based classification.
2.4 Image Classification

In image classification, two method classifiers were applied to classify the tree species in tropical rainforest, i.e. maximum likelihood and minimum distance as spectral distance classification while spectral angle mapper and spectral information divergence as spectral angular classification. Classification of maximum likelihood and minimum distance based on region of interest (ROI) while spectral angle mapper and spectral information divergence was using spectral library. A region of interest (ROI) is a portion of an image that to filter or perform some other operation on. An ROI was defined by creating a binary mask, which is a binary image that is the same size as the image to be processed. In the mask image, the pixels that define the ROI are set to 1 and all other pixels set to 0. The training areas or sample training areas for the image fusion were selected based on the classification features of the six commercial tree species. Using ROIs, each tree species can be differentiated between each class of features. The training area was selected using the polygon and all the classes must be saved. With the spectral library created from image spectra, spectral based classification can be performed to match spectra for each pixel in the UAV image.

3. RESULT AND DISCUSSION

3.1 Map Classification

Figure 3.1 shows the classified image of Sg Papan, Royal Belum Forest Reserve. This classification was done by using maximum likelihood (ML), Minimum Distance (MD), Spectral Angle Mapper (SAM) and Spectral Information Divergence (SDI) method. The image was not very understandable yet due to excessive speckles presence and difficulty in identifying spectral reflectance hence requires post-classifications process. Post-classification image was done using Majority Analysis with Kamel Size of 9 x 9 and Center Pixel Weigh of 3. Subsequently, post-classification image underwent clump process to reduce speckles and to make the image clearer. In order to better identify classes tree species, suitable colours were assigned to them; Shorea Hopeifolia (Green), Gironniara Nervosa (Blue), Shorea Pauciflora (Red), Dracontomelon Dao (Purple), Payena Dasphylla (Oren), and Hydnorcarpus Castanea (Yellow).
3.2 Analysis

The species classification was successfully carried out and the accuracy was assessed. Validation points were used to calculate the classification accuracy and an error matrix was used to derive commission and omission of the classification.

**Tables 3.1:** Overall accuracy and Kappa Value

<table>
<thead>
<tr>
<th>Classifier</th>
<th>Overall Accuracy</th>
<th>Kappa Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Likelihood</td>
<td>86.67%</td>
<td>0.8413</td>
</tr>
<tr>
<td>Minimum Distance</td>
<td>80.00%</td>
<td>0.7632</td>
</tr>
<tr>
<td>Spectral Angle Mapper</td>
<td>64.71%</td>
<td>0.6031</td>
</tr>
<tr>
<td>Spectral Information Divergence</td>
<td>60.00%</td>
<td>0.5263</td>
</tr>
</tbody>
</table>

The classification for tree species using Maximum likelihood (ML), minimum distance (MD), spectral angle mapper (SAM) and spectral information divergence (SDI) to be evaluated by using confusion matrices to assess the capability that three classifiers. Based on qualitative visual analysis of the tree species cover colour distribution, Maximum likelihood classification gives the best visual to identify and determine the location and distribution of trees species while spectral angle mapper look more homogeneous and difficult to identify and determine tree species location. Maximum Likelihood (ML) and Minimum Distance (MD) show the almost same each tree species but Minimum Distance show more pixel was classified than Maximum Likelihood (ML). In SAM, *Dracomtomelon dao* and *Payena dasyphylla* are found far abundant distribution then ML, but *Shorea hopeifolia* are shrink in SAM classifier. Meanwhile, *Hydnorcapus castea* and *Gironniera nervosa* are not much different in ML and SAM.

In terms of quantitative analysis, based on the results of confusion matrix and kappa value, ML classification shows a higher result compared to MD, SAM and SDI. The classification of SAM and SDI shows a lowest (poor) result with the overall accuracy is 64.71%. We can be concluded that ML and MD show similar results in DD, HC, and GN species where it successfully classified. MD was unsuccessfully to identify SP species, while for GN, both
ML and MD classification have problems to thoroughly identify that species. The SAM classifier was indicating that many species unsuccessfully to classified and correctly identified except Shorea Pauciflora species. Most species were difficult to identify using the SAM method due to the selection of wavelength range to classify accurate species. In addition, the spectral signature of trees spectral in tropical rainforest almost similar each other was factor of the tropical forest species difficult to identify by SAM method.

Tables show the percentage of the composition of tree species after conversion raster to vector based on difference classifier. Based on ML, Shorea Pauciflora, Hydronocarpus castanea, Dracontomelon dao were found a dominant species in study area while SAM show the only Shorea pauciflora species was dominant in study area For MD that show the Hydronocarpus Castanea and Payena Dasyphylla was dominant while SID show the Ginoniera Nervosa was dominant species was cover 26.67%. The difference output was produced cause the difference technique classifier used to identify based on pixel value each species.

<table>
<thead>
<tr>
<th>Tree Species</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ML</td>
</tr>
<tr>
<td>Unclassified</td>
<td>6.67</td>
</tr>
<tr>
<td>Shorea Hopeifolia</td>
<td>20</td>
</tr>
<tr>
<td>Gironniera Nervosa</td>
<td>13.33</td>
</tr>
<tr>
<td>Shorea Pauciflora</td>
<td>20</td>
</tr>
<tr>
<td>Dracontomelon Dao</td>
<td>6.67</td>
</tr>
<tr>
<td>Payena Dasyphylla</td>
<td>13.33</td>
</tr>
<tr>
<td>Hydronocarpus Castanea</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
</tr>
</tbody>
</table>

ML and MD were compared to identify the differentiate result and each species coverage in site study. ML and MD show the same result for Gironniera nervosa, Shorea Pauciflora and Payena Dasyphylla. But they get difference result for Shorea Hopeiflora, Dracontomelon Dao and Hydronocarpus Castanee. Meanwhile, SAM and SID show the shorea hopeifolia, Dracontomelon dao, Payena Dasyphylla almost the same. Based on ML, Shorea Pauciflora, Hydronocarpus castanea, Dracontomelon dao were found a dominant species in study area while SAM show the only Shorea pauciflora species was dominant in study area For MD that show the Hydronocarpus Castanee and Payena Dasyphylla was dominant while SID show the Ginoniera Nervosa was dominant species was cover 26.67%. The difference output was produced cause the difference technique classifier used to identify based on pixel value each species. As conclusion, a dominant species in Sg Papan is a dipterocarpaceae families such as Shorea paucifol and Shorea hopeifolia.

4. CONCLUSION

Two methods of supervised classification were used to classify the trees species in tropical rainforest such as spectral distance classification and spectral angular distance classification. Spectral distance classification such as maximum likelihood and minimum distance classifier while spectral angular distance such as spectral angle mapper and spectral information divergence. Spectral distance classification, region of interest tree species was created, and it allows to select pixels similar to a seed one, considering the spectral similarity of adjacent pixels. Spectral angular distance classification was calculated the spectral angle between spectral signatures of image pixels and training spectral signatures. It is used spectral library as reference to classify tree species. Both classifications show the difference accuracy where spectral distance classification gives better accuracy than spectral angular distance. Overall accuracy for spectral distance classification shows the maximum likelihood and minimum distance were 86.67 % and 80% (good) respectively. Meanwhile, spectral angular distance classification overall accuracy for spectral angle mapper and spectral information divergence were 64.71% and 60 % (poor) respectively. A spectral distance classification was produced a good result because the consideration of the spectral similarity of adjacent pixel meanwhile spectral angular to identify based on matching angle between spectra.

Spectral library was successfully established after digital number of images convert to reflectance using empirical formula based on field spectroradiometer data. Spectral signature of each tree species was generated from UAV image and it was used as reference to classify image. Based on research conduct, low-cost UAV and low-cost camera were suitable used to map tree species in tropical rainforest. The implementation of low-cost UAV and low-cost camera for further study in forestry strongly encouraged. As conclusion, the spectral distance classification is suitable to use to classify tree species in tropical rainforest based on multispectral image acquired using low-cost
UAV. The tree species dominant in Sg Papan area are Dipterocarpaceae families such as Shorea paucifolia and Shorea hopeifolia.

Acknowledgement

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REFERENCE


The Forest Global Earth Observatory (ForestGEO), ” Centre for Tropical Forest Science (CTFS) protocol”, Retrieved May 28, 2018, from https://forestgeo.si.edu/node/145665/


