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Potential of UAV Application for Forest Fire Detection

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Potential of UAV Application for Forest Fire Detection

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Abstract. Improved ground and aerial system technologies enable mapping and monitoring forests and land to mitigate forest fires. UAV plays a role in monitoring by collecting forest area images from the air, which could be processed into 2D and 3D images. They can be analyzed to identify land cover types and objects in forest areas. This image data collection uses the DJI Phantom 4 Pro UAV controlled automatically with a flight plan made with Pix4D Capture, which is then processed using Agisoft. The result of the mapping has an average GSD of 2,03 cm/px. The mapping result shows that the 3D image produced can show objects in various land cover types. Weather related parameters were measured using ground sensors both in forest and plain area. We had successfully gathered forest and plain area images in addition to weather related parameters in Tangkuban Perahu Mountain area.

1. Introduction

Forest fires occurrence are high in frequency especially during the dry season. Forest fire disaster observation and management play a crucial role and need to be supported by adequate equipment. Monitoring of forest fires becomes increasingly important as forest fires occurrence increases which is the case in the last decade. Forest and land fires have also occurred in parts of the world since the early 2000s, an estimated 50,000 fires occur each year in the Mediterranean basin, according to the Mediterranean Forestry Action Programme, in 2017, forest fires burned 442,400 hectares of rural and urban areas in Portugal [1]. In Australia, nearly 19 million hectares of forest are burned, more than 3,000 homes destroyed, and 33 people killed in 15,344 bushfires that occurred in 2019 – 2020 [2].

Researchers have used several methods to detect and monitor land fires, such as the aerial photography method using SAR Interferometry (Synthetic Aperture Radar) and combining it with satellite imagery. InSAR (RADARSAT) image is processed with an algorithm for mapping 3D trees. This method produces a higher resolution image that can penetrate the clouds. This method can provide information related to observations in a large area. Analysis of ERS SAR data at the test site in East Kalimantan showed promising results for detecting land cover change, illegal logging and detecting the intensity of fire damage [3]. Early Detection System for forest fire has been build by integrating Wireless Sensor Network (WSN) technology including satellite, air patrols and monitoring manual [4]. WSN technology utilizes wind as a source of electricity for devices and to monitors the spread of forest fires. Wind speed is determined by measuring the output voltage of the wind turbine generator (WTG). The research states that the developed WTG generates 7.7mW of electricity from a turbine speed of 3.62 m/s, which can be used to operate the 3.5mW WSN to detect the spread of fires [5].

A monitoring and detection system for land and forest fires based on the WSNs can provide warning messages and notification of fire locations using the cellular network. This system uses LM35DZ temperature sensor, MQ2 smoke sensor, and DHT2 humidity sensor on the WSN network which is considered cheap and requires low power. To make the system more effective, people who live near forest can send warning messages to firefighters using cellular phones [6]. Other research focuses on aspects of WSN structure, topology and security. WSN can identify smoke and temperature. Achievement of optimum delivery distance through embedded artificial intelligence. Fire positions are detected using GPS as well as gateways and public networks connecting to monitoring centers or alarm devices for real-time forest fire monitoring [7]. Land fire prediction has also been developed by Hafeeda [8] using the Fire Weather Index (FWI) system analysis to optimize the WSN system to get better results. Haifeng [9] created an algorithm to analyze big data, then used fuzzy logic to decide a situation for a potential fire to occur and quantitatively calculate the potential risk of fire. This system has been tested in Nanjing City, Jiangsu Province, China.

In the last decade, Unmanned Aerial Vehicles (UAVs) have increased their use due to their advantages (e.g., flexibility, high resolution, data obtained). Professionals around the world are using drones for mapping which boast quick data collection times, excellent accuracy, and safe operator experience. The method for making a 3D map of field and buildings used DJI Phantom 4 Pro has been made used different kinds of grid plans to collect map data of regions with buildings and a sport field in Institut Teknologi Bandung, Indonesia [10]. A low cost mobile volcano early warning system has been developed for Indonesian volcano. This low cost system consists of Wireless Sensor Network (WSN) for sensing, processing, distributing and transmitting the data, and a mobile robot for replacing a died sensor node in emergency situation [11,12]. A warning system based on Internet of Things using sensors, drone, mobile robot, and satellite has been developed and applied to monitor the physical parameter of the volcano of mount Kelud [13,14]. Arduino promini microcontroller process the data from mobile sensors and then sent to ESP8266 it's a wifi module to create an IoT which can be accessed on the web service page everytime [15].

Currently, the satellite is most used to take images of forests and land fire detection, but its drawback lay in its price and accuracy. UAV technology could solve the forest fire detection problem. UAVs can be used as a means of capturing forest and land fire imagery instead of satellite imagery. In addition, the difficulty in obtaining accurate data with high resolution requires a tele-operated device in forest areas so observation could be done in the same regions where operators remain safe. When fire occurs, sometimes there is no road access to the location of the fire, which make it difficult to be extinguished. This study proposes the ground sensors and UAV which can act as a fire detection and monitoring in the forest.

2. Method

The research is conducted on Mount of Tangkuban Parahu, Bandung Regency, West Java Province, in The Center for Volcanology and Geological Disaster Mitigation (PVMBG) observation post area at 6°46'21.2 " and 107°38'00.2" East Longitude. There are forests, agricultural land, and buildings at this location which are close to volcanoes, so the potential for forest and land fires to occur during the eruption is rather high.

In this study, two types of unmanned aircraft were used: the drone and the other is ground sensors. For drone, a quadcopter type of drone was used in this study is drone DJI Phantom 4 Pro. While the ground sensors used is an automatic robot that has been designed before (PRAWIRA). Drones are used to map and monitor the area from air. At the same time, ground sensors are utilized to monitor and acquire data on the ground field. A drone from DJI with battery 5870 mAh and 12 MP camera drone was used for this study. Phantom 4 Pro software from a smartphone was controlling this Phantom 4 Pro series with DJI GO Application. Data was imported to Pix4D mapper after geolocations data images, Ground Control Points and images have been collected to get a digital model of the area. Each coordinat of the spots in the images collected, saved and compared for image compatibility. The orthopoto of a model has been generated after point cloud and mesh steps was analyzed for its application. they were imported to the software to build 3D model and an orthophoto for further analysis.

The ground sensor (PRAWIRA) was used to acquire volcano parameter data (SO_2 CO_2, temperature and seismicity) with skid-steering mechanism of PID (proportional-integralderivative) controller, ROS (Robot Operating System), RTOS (Real Time Operating System) for kinematics and dynamics while either stop or moving mode. PRAWIRA has been designed with skid-steering control method for 4-wheel drive ground sensor. skid-steering on right and left sides motor concentrated to navigate ground sensor wich is connected with pulleys and belts relative velocities. This ground sensor able to turn to right or left, to move forward, backward and its has high maneuver by controlling its velocity in all terrain.

The ground sensors has dimensions of length × width × height: 450 × 445 × 220 mm. The ground sensor frame is manufactured using aluminium L with a thickness of 2 mm. The structure of the other parts of the ground sensor is formed using acrylic. After manufacturing and assembling the ground sensor, the weight of the ground sensor is 7 kg. The form of the ground sensor is symmetrical and straightforward. This ground sensor uses four wheels with a diameter of 22 cm. This architectural design process was carried out using Autodesk Inventor 2018 software. With this software, 3D designs and technical drawings of each part of the ground sensor frame are made. For wheels drive mechanism is implemented by two-24 volt-DC motor (PG 28) using pulley and belt. These motors are controlled by microcontroller STM32 Nucleo F446RE as secondary controller connected the motor with main controller, while robot main controller, Raspberry Pi 3 controls DC motors velocity and PID algorithm processing. The aluminum material was chosen because of its properties as a metal that is light and easy to fabricate and it's also durable against corrosion and non-toxic. Other part of the frame was made from acrylic, lighter than aluminum and other metals yet firm and flexible suitable for field application.

We took various stages to obtain the data. The first; we were preparing data collection facilities; the second step was collecting data. Third; it was processing data, while the fourth step was interpreting the collected data. The UAV system has several components that perform a role in data collection: drone, control systems, softwares, cameras. In this research, the softwares used are:

A. CTRL + DJI

CTRL + DJI version 1.9.6 from Pix4D on Android devices as a link between the DJI Phantom 4 Pro UAV and the Pix4Dcapture version 4.5.0 software. In this software, several indicators on the UAV are informed including connectivity between the UAV and Android devices; position x, y, z of the UAV; UAV speed; The remaining battery capacity in the UAV.

B. Pix4DCapture

Pix4DCapture on Android devices as the primary UAV control for retrieving data. At Pix4Dcapture, the flight plan and data retrieval process were carried out.

C. Agisoft on Windows-based computers.

This software is an image data processing tool from UAV to become 2D and 3D images. As a control other than the UAV controller, an Android-based smartphone, Vivo Y83 (4GB RAM and Android 8.1), was used. As for computer equipment, the MSI GL-62 7QF laptop (Intel Core i7, 12 GB RAM based on Windows 10) was used and the HP Pavilion Laptop 14-bf157TX (Intel Core i5, 8 GB RAM based on Windows 10). DJI Go 4-For UAVs since P4 version 4.3.20 on Android devices as control software over UAVs for manual flying. Manual flying was performed to measure the optimal altitude, take data in an area, and check the condition of the surrounding environment.

Research has been conducted with a flight plan at 70 m of an altitude from the ground and took 378 images for 25 minutes with 106 × 104 m^2 of area. GSD was set for 2.03 cm/px where 1 pixel of image shows 2.03 cm of real world. By making flight plan, the drone can automatically capture image data for optimal 2D and 3D maps and models following the flight plan from the application. The application could make regular flight plans with easily adjustment of photos overlay for better image data, while the

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other application could be programmed for circular flight plan. By combining both image data from flight of each app, we can get the optimal result of 2D and 3D maps and model in field and building region. By using grid pattern, each image overlaps with other image. The overlap is required to get better result of orthophoto and 3D map. Therefore, each image should overlap at least 90% with the previous image.

In this research, ground measurements were carried out for 12 seconds because it was in accordance with the needs and capabilities of the ground sensors battery. Ground measurements can be carried out in a longer time if using a battery with a larger capacity. While the UAV data collection is done in much longer time of 25 minutes because that was the time required for the UAV to fly to cover the area under study. In this study, ground sensors and UAVs cannot communicate directly, but both ground sensors and UAVs are connected to the control station.

3. Result and Discussion

Temperature and wind velocity were measured before performing any data collection in Tangkuban Parahu mountain. The measurement results of the weather at the research location were considered perfect at the time of the study, the average of temperature is 29.41° Celsius with standard deviation is 0.16° Celsius. The average of wind velocity is 0.66 m/s with standard deviation is 0.54 m/s. This condition making it possible for drone deployment.

The mapping area around the Mount Tangkuban Parahu PVMBG Post can be seen in Figure 1. For land mapping, drone flights are performed autonomically using the Pix4D Capture application with a flight plan that was set with a flying height of 70 meters, maximum speed (fast), camera angle of 70 degrees (vertical), and 90% overlap (height).

The flight was carried out for 25 minutes for two flights to cover the area around the PVMBG post, with each area mapped was 106 × 104 meters. Data in the form of images obtained from drones were processed using image processing software, namely Agisoft. The image was processed into 2D and 3D maps depicting the area around the research location. The maps obtained were then interpreted and analysed to identify land cover and vegetation types.

At the Initial Processing stage, intermediate quality of images was applied. There were two options, i.e., Point Cloud and Mesh. In the point cloud option, half image size and point of optimal density were used. While, in the mesh option, medium image resolution was worked.

Figure 1. Results of 3D image of the forest around PVMBG Post of Tangkuban Parahu mountain

In this study, as many as 378 images in JPG format were obtained with an average of 8.40 MB. The image processing result of the map are shown in Figure 3. The image covers 2.204 km^2 with a GSD of 2.03 cm/px. The image is a 3D image of the area around Mount of Tangkuban Parahu, precisely at the PVMBG Post. This image can be seen and classified as the types of land cover and vegetation in the area around Tangkuban Parahu mountain. The identification results based on the image show that most of the land in the PVMBG post area is forest, which is about 60%, agricultural land is 25%, roads are 8%, buildings are 4%, and the rest is empty land by 3%. The type of vegetation shown in the image varies significantly in terms of both leaf diameter and height. The results of the drone images show an excellent resolution of 2 cm compared to satellite resolutions ranging from 30-100 meters. This good resolution drone image makes it easier to analyze and identify land, so it is very suitable for monitoring forest and land fires.

The results of land monitoring in the Tangkuban Parahu Mountain area using a ground sensors can be seen in Figures 2 - 5. After the coordinates are mapped and data collection and processing are carried out, the coordinates for the PVMBG Mount Tangkuban Parahu post page are obtained as follows. After being analyzed, the area has an average slope angle of 4.69^o and an average coefficient of friction of 0.01228. However, the conflict coefficient is not evenly distributed because some of the environmental areas are mossy and some are not. In mossy area, the coefficient of friction can be greater than the average value.

Figure 2 is the result of 12 seconds measurement with an average temperature of 27.48 degrees Celsius. There is a decrease in temperature during the measurement process; this may be due to a passing cloud covering the sun so that the temperature drops rapidly. There was a decrease of about 1 degrees Celsius during the 12 second measurement process.

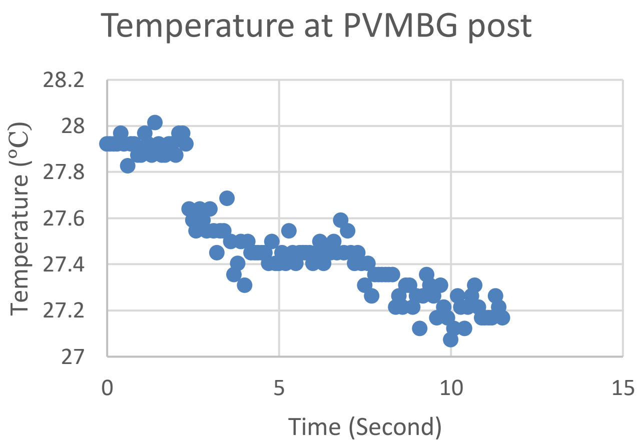

Figure 2. Result of temperature measurement using a ground sensor.

The ground sensor is proficient in measuring SO_2 concentration near the field around the PVMBG post area. The measurement results are exposed in Figure 3. The concentration of SO_2 is close to zero because the PVMBG post area is far away from the source of SO_2

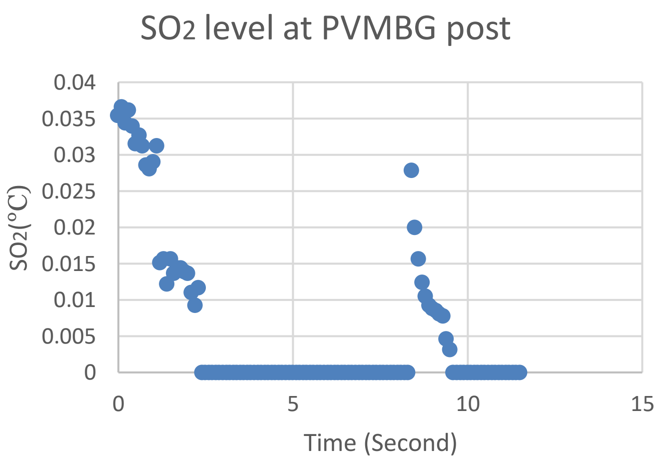

Figure 3. The SO_2 concentration detected by the ground sensor

The graph in Figure 4 is the result of MPU6040 sensor data. On average, the result was 0.0836 rad/s. Therefore, during the measurement process of about 12 seconds, the sensor in the ground sensor approximately rotates as fast as 0.0836 rad/s in the x-axis. Data fluctuation from 0.078 to 0.9 rad/s can also mean that the sensor is experiencing vibrations in the direction of the x-axis.

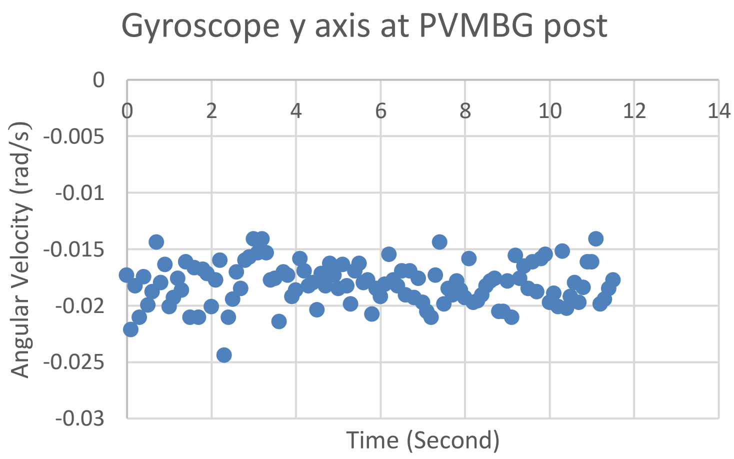

Figure 4. Result of gyroscope x-axis data using a ground sensor.

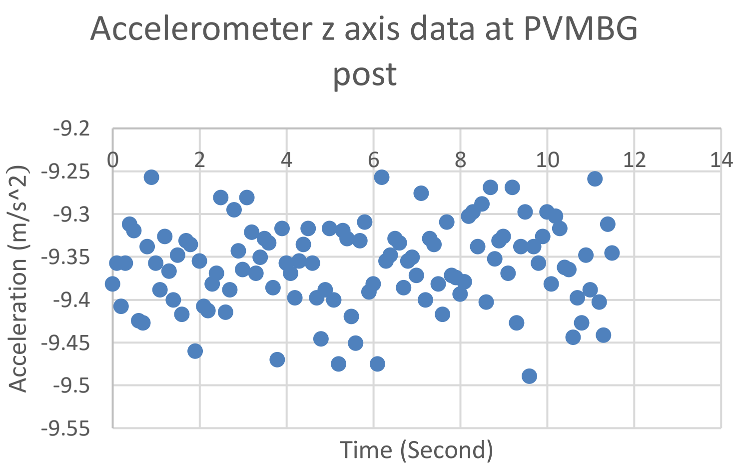

Figure 5. Result of accelerometer z-axis data using a ground sensor.

The graph in Figure 5 shows the amount of acceleration on the z-axis of MPU6040, with an average of -9.36 m/s^2. There should be no acceleration in the direction of the x-axis; there should only be an acceleration in the direction of the z-axis of about 9.8 m/s^2. If the sensor was parallel to the earth's surface, then the x and y-axis sensors will detect an acceleration of 0 m/s^2. In this case, it can be calculated with Pythagoras to get the angle of slope of the sensor, that is, by comparing the acceleration value obtained from the z-axis with the x or y-axis. Once calculated, the sensor tilt in the y-direction is -2.36 degrees, while the x-axis slope is 1.07 degrees.

4. Conclusion

The use of UAV drones and ground sensors for mapping and monitoring forests and land has been successfully carried out in the Tangkuban Parahu area. Drone image data processing produces a 3D map of the forest area at the PVMBG Mount Tangkuban Parahu post. This image has a higher resolution than the satellite image is GSD 2.03 cm/px, making it easier to identify land cover and vegetation types. Ground sensors can measure weather parameters in the Tangkuban Parahu area so that both drones and ground sensors could potentially be useful for monitoring forest and land fires.

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