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REAL-TIME FOREST FIRE MONITORING SYSTEM USING UNMANNED AERIAL VEHICLE

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Abstract

The main focus of this research is to develop a real-time forest fire monitoring system using an Unmanned Aerial Vehicle (UAV). The UAV is equipped with sensors, a mini processor (Raspberry Pi) and Ardu Pilot Mega (APM) for the flight controller. This system used five sensors. The first is a temperature sensor that served to measure the temperature in the monitored forest area. The others sensors are embedded in the APM. There are a barometer, Global Positioning Sensor (GPS), inertial measurement unit (IMU) and compass sensor. GPS and compass are used in the navigation system. The barometer measured the air pressure that is used as a reference to maintain the height of the UAV. The IMU consists of accelerometer and gyroscope sensors that are used to estimate the vehicle position. The temperature data from the sensor and the data from GPS are processed by the Raspberry Pi 3, which serves as a mini processor. The results of the data processing are sent to the server to be accessible online and real-time on the website. The data transmission used the Transmission Control Protocol (TCP) system. The experimental setup was carried out in an area of 40 meters × 40 meters with 10 hotspots. The diameter of the hotspots is 0.4 meters with a height of 0.5 meters. The UAV is flown at a constant speed of 5 m/s at an altitude of 20 meters above the ground. The flight path is set by using a mission planner so the UAV can fly autonomously. The experimental results show that the system could detect seven hotspots in the first trial and nine hotspots in the second trial. This happened because there is some data loss in the transmission process. Other results indicate that the coordinates of hotspots detected by the UAV have a deviation error of approximately 1 meter from the actual fire point coordinates. This is still within the standard GPS accuracy as this system uses GPS with a range accuracy of 2.5 meters.

Keywords: APM, Hotspots, Raspberry Pi, Real-Time UAV.

1. Introduction

Forests are an important component in maintaining the balance of nature. The forests cover about a third of Earth's surface and are home to two-thirds of the world's terrestrial species. Forests are the source of biodiversity on the Earth. Unfortunately, every year, forest fires destroyed millions of hectares of forests and hundreds of millions of dollars are spent to extinguish these fires [1]. Although wildfires help to create new forests, it is difficult to ensure the uncontrolled fires do not spread to places that threaten the ecological system of the forests and human life. A forest fire has become a serious natural hazard. Therefore, early prevention of forest fires is crucial [2].

This issue has been the subject of research for many years. There are a number of solutions that have been developed to address this problem. One of the ways used to prevent forest fires is the development of early fire detection systems in the forest. Massive efforts have been made to monitor, detect, and extinguish the fire quickly before it gets too large. Traditional fire monitoring and detection methods use humans to monitor the forests unremittingly. But this method requires a high cost and is not safe for humans. Recently, remote sensing systems have become one of the most effective methods of forest monitoring. The development of electronics, computer science, and digital camera technology have enabled computer-based remote sensing systems for forest fire monitoring and detection. Remote sensing approaches for forest fire monitoring and detection can be grouped into three categories: land-based systems, manned air-based systems, and satellite-based systems. However, each of these systems presents a variety of technological issues and practices. Ground measurement equipment has very limited coverage. Satellite systems are less effective for large numbers of hotspots. Manned air vehicles are usually large and expensive. In addition, pilot safety is also a part to be considered [3].

Unmanned aerial vehicles (UAVs) with computer-based remote sensing systems are an increasingly becoming an attractive and realistic option. Besides being faster and mobile, UAVs are also relatively cheaper to continuously monitor and detect forest fires. The integration of UAVs with remote sensing techniques can also add value to pre-existing methods. In addition, UAVs are able to operate in hazardous areas that cannot be safely reached by humans. These are the reasons that have made UAVs one of the solutions that are currently attracting the world's attention to overcome forest fires [4-9].

In the beginning, the UAV system for forest fire detection was developed by the United States Forest Services (USFS) Forest Fire Laboratory (Wilson and Davis 1988). Furthermore, the USRP and National Aeronautics and Space Administration (NASA) developed a project called Wildfire Research and Applications Partnership (WRAP), which aims to develop underserved forest fire applications [10]. A team of researchers from the University of Cincinnati supported by the West Virginia Department of Forestry (WVDF) used a UAV system called UAV Marcus "Zephyr" to test the system's ability to detect forest fires [11].

This research develops a real-time forest fire monitoring system using a UAV. The UAV is equipped with sensors, a mini processor and Ardu Pilot Mega (APM) for the flight controller. Data from both the temperature sensor and GPS are processed by the Raspberry Pi 3, which serves as a mini processor. The results of the data processing are sent to a server to be accessible online and real-time on the website. The data transmission used the Transmission Control Protocol (TCP) system.

This paper is organized as follows: Section 1 is introduction while Section II is system model. Numerical result and discussion are explained in Section III and lastly, Section IV is the conclusion.

2. System Model

The purpose of this research is to develop a real-time forest fire monitoring system using an Unmanned Aerial Vehicle (UAV). The configuration of the system can be seen in Fig. 1. The UAV is equipped with sensors, a mini processor (Raspberry Pi) and Ardu Pilot Mega (APM) for the flight controller. There are five sensors used in this system. The first is a temperature sensor that serves to measure the temperature in the monitored forest area. The temperature sensor uses a Non-Contact Infra-Red Sensor. The principle of the Non-Contact Infra-Red Sensor is like a conventional thermal camera, with 2 × 2-pixel resolution and a Field of View (FOV) of five degrees. The other sensors are embedded in the APM.

There is a barometer, Global Positioning Sensor (GPS), an inertial measurement unit (IMU) and compass. The GPS and compass are used as the navigation system. The barometer measures the air pressure that is used as the reference to maintain the height of the UAV. The IMU consists of accelerometer and gyroscope sensors that are used to estimate the vehicle's position. The data from both the temperature sensor and GPS are processed by the Raspberry Pi 3, which serves as a mini processor. The communication between the UAV and ground station uses telemetry data link with a frequency of 433 MHz. The Raspberry Pi 3 sends data to the web server to be accessible online and real-time on the website. The data transmission uses the Transmission Control Protocol (TCP) system.

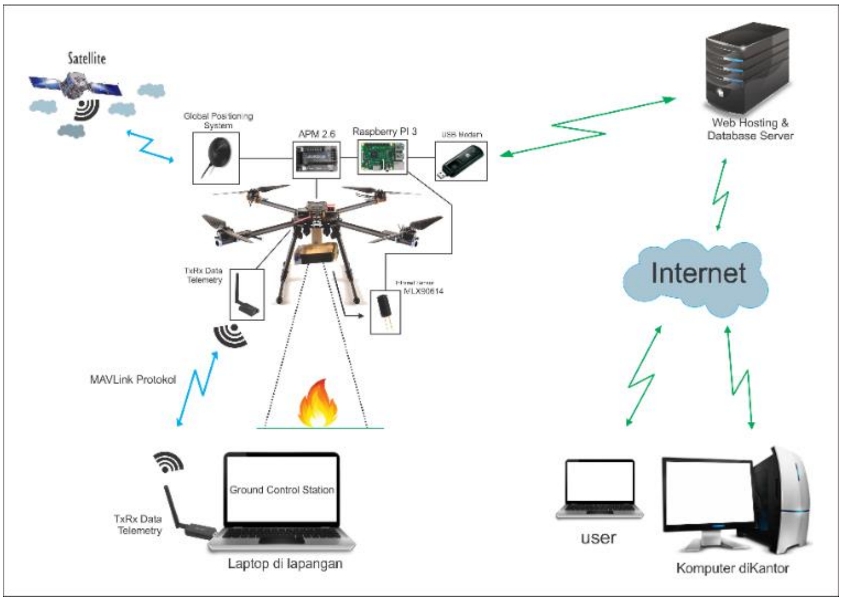


Fig. 1. System configuration.

The forest fire information system website was developed by using CodeIgniter, Grocery CRUD, PHP: Hypertext Preprocessor (PHP), Cascading Style Sheets (CSS) [12] and jQuery [13]. The information system on the website shows the number of hotspots, the coordinates of hotspots and the temperature of hotspots. The website is integrated with Google Maps so the user can more easily pinpoint the location of the hotspots. The flowchart of this system can be seen in Fig. 2.

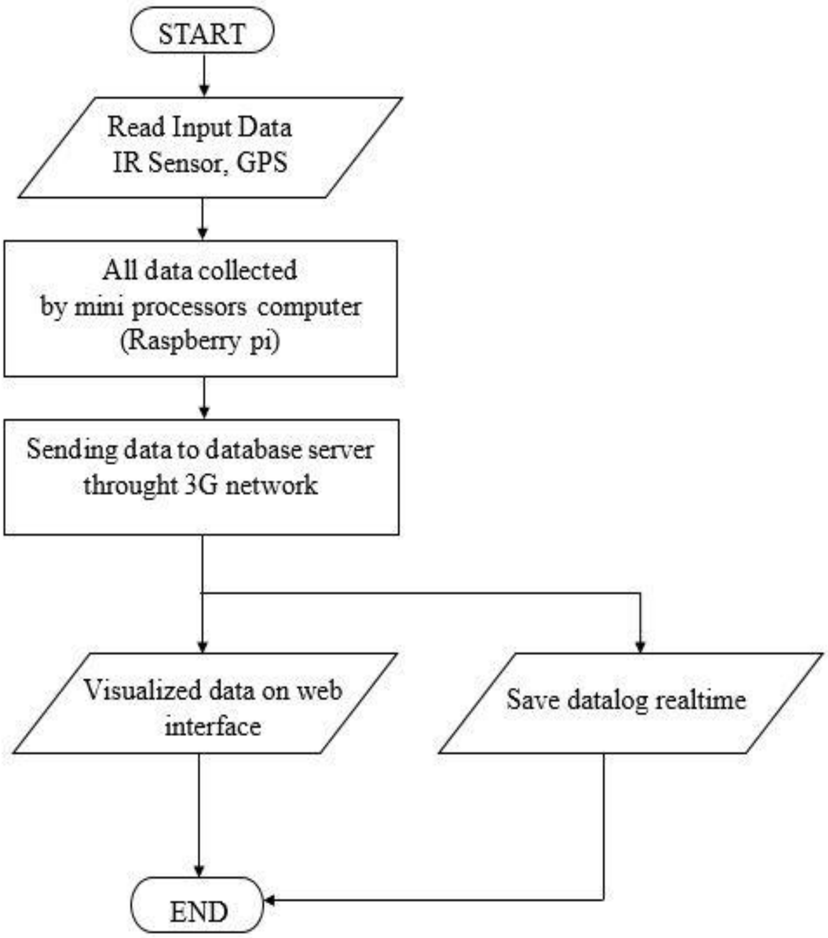


Fig. 2. Flowchart of the system.

3. Numerical Result and Discussion

The experimental setup was carried out in an area of 40 meters × 40 meters with 10 hotspots, as shown in Fig. 3. The diameter of the hotspots is 0.4 meters with a height of 0.5 meters. The UAV flies at a constant speed of 5 m/s at an altitude of 20 meters above the ground. The flight path is set by using a mission planner so the UAV can fly autonomously. The flight paths flown are shown in Fig. 4.

On the first flight, the drone can detect seven from 10 hotspots that have been created. On the second flight, the drone can detect nine from 10 hotspots. This happens because of the difference of timeout on the first flight and the second flight. The first flight has a timeout of 0.2 seconds and the second flight uses a timeout of 0.5 seconds. The smaller timeout value means more data is sent to the server. Unfortunately, more data sent to the server also means more data lost. This is because of the instability in the data transmission process. Another reason is the wind speed, which makes the drone shifts slightly from the flight path. This issue will be tackled in future works.

Figure 5 shows the display of UAV location on the website in real-time. If the drone detects a temperature that exceeds the threshold in a certain coordinate, then the display on the website will put a marker in this location.

The temperature data of the sensor is also displayed in the form of a contour map so that the user can see in detail the temperature at each coordinate. This can be seen in Fig. 6.

Fig. 3. The experimental setup.

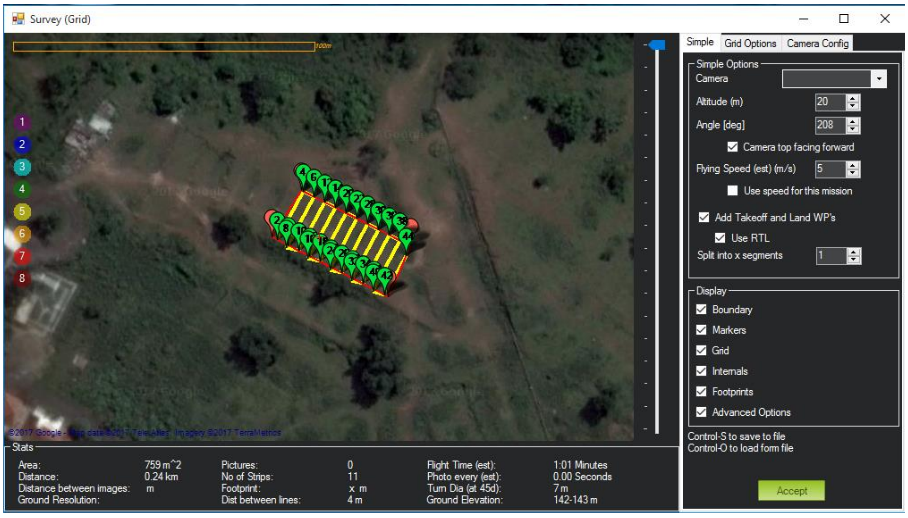
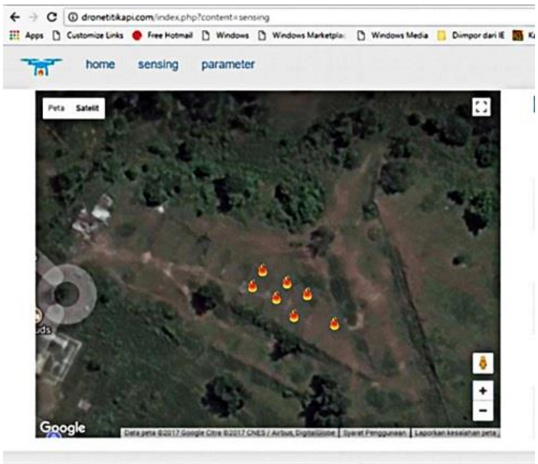
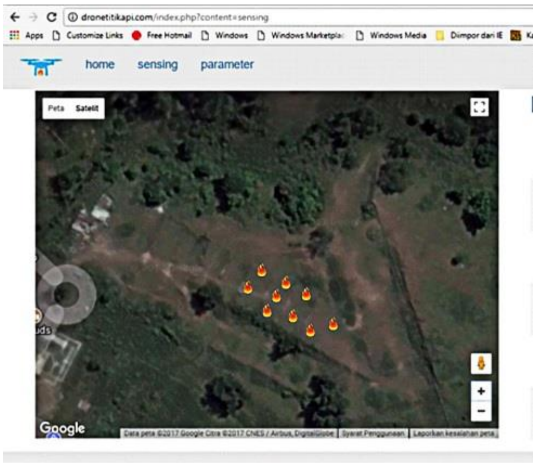


Fig. 4. Flight paths.

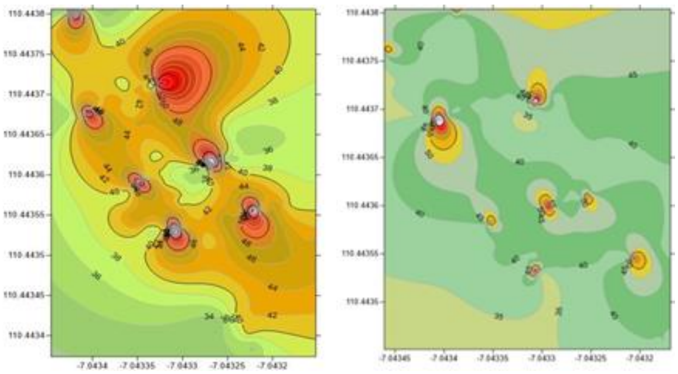


(a) Flight 1



(b) Flight 2

Fig. 5. Real-time website visualization.



(a) Flight 1 **(b) Flight 2**

Fig. 6. Contour map visualization.

Figure 7 shows the coordinates of hotspots detected by the UAV. There is a deviation error of approximately 1 meter from the actual fire point coordinates. This is still in the range of GPS accuracy because this system uses GPS with a range accuracy of 2.5 meters.

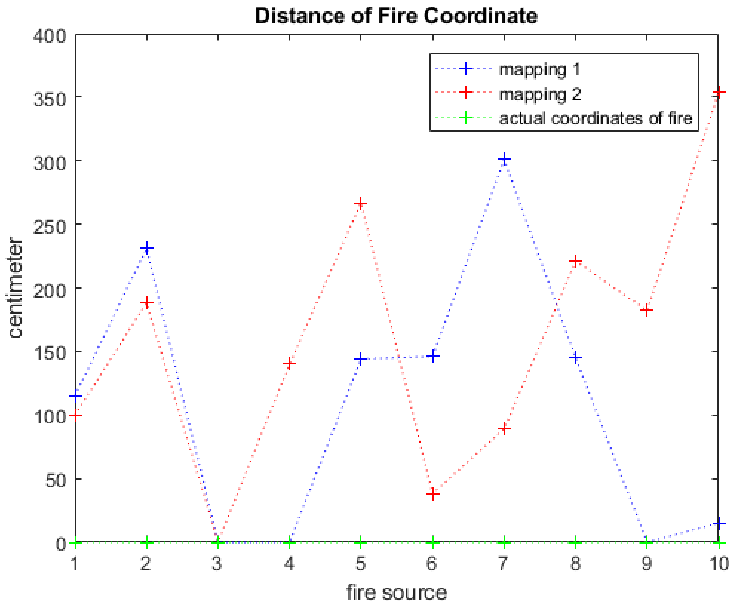


Fig. 7. Comparison of distance errors for mapping 1 and 2 to the original coordinates.

4. Conclusion

A real-time forest fire monitoring system using an Unmanned Aerial Vehicle (UAV) or drone has been developed. The drone can detect ground surface temperatures from a height of 20 meters above the ground. The drone flies at a constant speed of 5 m/s. The drone can also send the measured data to a web server to be displayed on a forest fire information system website. The results also indicate that the coordinates of hotspots detected by the drone have a deviation error of approximately 1 meter from the actual fire point coordinates. This is still within the standard GPS accuracy because this system uses a GPS system with a range accuracy of 2.5 meters. Among the future works of this research is how to mitigate data loss during the data transmission from the drone to the web server.

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