Forest Fire Monitoring and Warning System by Quadcopter

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***Abstract*— Forest fire occurs seriously in Vietnam and has been considered as one of the major causes of forest lost and degradation. It is urgent for Forest Fire Prevention Departments to adopt a monitoring system that can predict the occurrence and spread of forest fire so as to reduce the loss caused by forest fire. This paper designs a forest fire monitoring system based on monitoring and controlling by the completely automatic quadcopter and 3G network. The developed system is composed of three major components: Control Quadcopter diagram, Fire detecting and lacating unit, the server and website.**

Keywords*— Forest fire; quadcopter; 3G network; Raspberry; TM4C1294NCPDT; long range RF.

I. Introduction

Urban forests can provide economic, environmental, and social benefits. Economic benefits such as lower heating and cooling costs and higher property values are fairly well recognized. Urban forests can increase carbon sequestration and reduce the urban heat island effect [1]. However, forest fire hazards ecosystems and causes the loss of human life and property [2]. In Viet Nam, in dry season there are about 6 millions ha of forest and plant vegetable (about 50% of total forest area) with high potential of forest fire risk, located in 48 different provinces and cities [3]. In 2012, a serious fire destroyed 100ha of forest land on Hai Van Mountain Pass in Lien Chieu District. In 2016, fire damaged a 5ha log farm near Ba Na – Nui Chua Nature Reserve in Hoa Vang District, 25km away from the central city's centre yesterday, the city's forest management department said [4].

While the traditional forest fire monitoring and early warning methods are manly based on ground patrolling, watching tower, aerial patrolling, long-distance video monitoring, satellite monitoring , they are often prone to miss the best time to extinguish the fire. We can greatly reduce, or even avoid the occurrence of forest fires if we make effective monitoring and early warning [5].

In order to effectively prevent forest fire, this paper designs a forest fire monitoring system based on monitoring and controlling by the completely automatic quadcopter and 3G network through which monitoring system can make it easy to implement the connection of monitoring field with remote monitoring server.

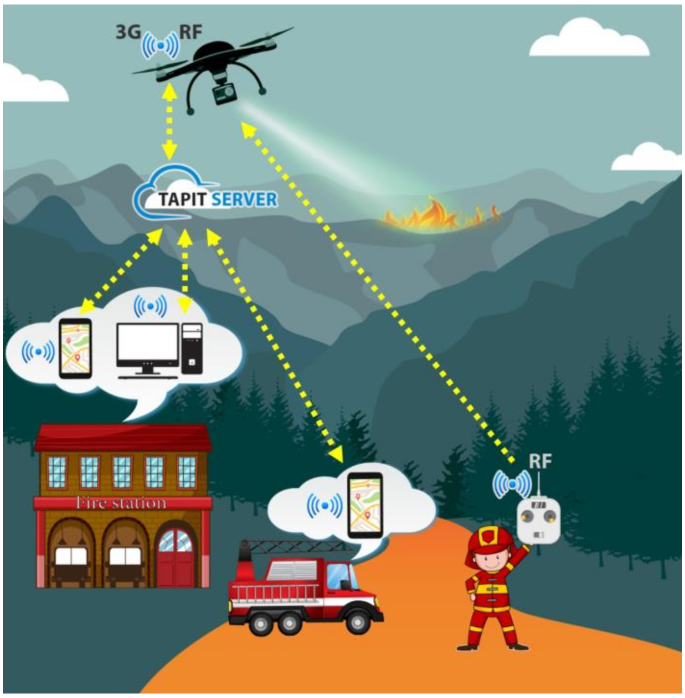

Fig. 1 The schematic diagram of the Forest Fire Monitoring and Warning System by Quadcopter

II. Quadcopter Controller

The Quadcopter control unit consists of sections: the transmitter and receiver RF, Sensor, a Tiva™ C Series ARM

Cortex-M4 microcontroller, module 3G connecting with Server, Movement and Power.

In order for the quadcopter to reach a certain height and balance itself, we use the RF transmitter to transmit this high-altitude signal in conjunction with the sensor values fed into the Tiva microcontroller. From there, the Tiva microcontroller performs calculations and outputs the signal to active the movement block. In addition, Tiva microcontrollers combine the transmission with the Fire Detecting And Locating Unit to retrieve coordinates, fire video, and warning signals for upload to the server via 3G network. The block diagram of the Quadcopter controller is shown in Fig. 2.

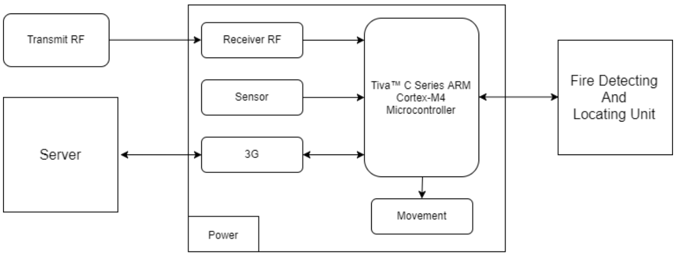

Fig. 2 Block diagram of the Quadcopter controller

A. The motion theory of the Quadcopter

The Quadcopter is designed as a plus sign. It has two pairs of opposing wings, with wings placed opposite one another on the same side. In addition to contributing to the thrust of the quadcopter, the wings also make the movement of the quadcopter around the center. Increasing and decreasing the speed of the symmetric motors together will result in the torque making the aircraft tilting at an angle. From there we can control the moving plane in the horizontal or vertical direction as compared to the direction of the plane.

The operational principle of the Quadcopter is based on the movement of the air flow generated by the wing, the airflow moves downward making the object flies upward and the adjustment of the speed of each engine will change the direction of the Quadcopter [6].

B. Transmitter và Receiver RF

This is an RF transmitter and receiver that controls the quadcopter at 2.4GHz including 10 channels and transmits up to 2km. Among them, TX is Devition Devo 10, RX is RX-1002 Devo 10.

Fig. 3 Transmitter and Receiver RF

C. Tiva ™ C Series ARM Cortex-M4 Microcontroller

The Quadcopter model requires a powerful processor to manually adjust the balance and handle interference signals and the Texas Instrument Tiva ™ TM4C1294NCPDT can handle that. Microcontroller use the highest clock frequency of 120MHz to improve processing efficiency and use a 12-bit ADC [7] to read the sensor's signal. After the kalman filter output, the corresponding control signal is sent to each motor through four 16-bit independent PWM channels that can handle the signal well. Calculate 3 PID controllers consisting of 3 separate parameters controlling 3 stages: proportional, integral and derivative. Get location information and fire images from the Fire Detecting And Locating Unit and upload to Server via 3G network.

Fig. 4 Kit Tiva™ TM4C1294NCPDT

D. Sensors

Sensors used to interface with microcontrollers are the GY85 9DOF module including tilt-acceleration sensor three axis acceleration ADXL345; Angular velocity sensor three axis Gyroscope ITG3200; magnetic sensor three axis Magnetometer HMC5883L[8] and pressure sensor Pressure BM180. It has the function of inputting the angles, axes corresponding to each type of sensor into the microcontroller for processing, thereby adjusting the self-balance for the Quadcopter.

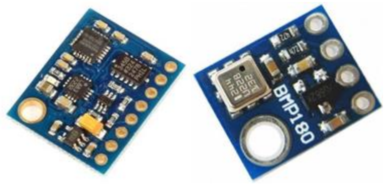

Fig.5 Module GY85 and Pressure Sensor BMP180

E. 3G network

Sim5320A 3G module, aimed at high-speed data transmission applications [9] to put coordinates, fire video and warning signal to the server.

Fig.6 Module Sim5320A

F. Movement

The components that are important for the Quadcopter to fly are 4 ESC Platium 30A Opto and 4 Motor SunnySky. The ESC takes signals from the RF through the microcontroller that handles the signal for each operating motor, thereby pushing the Quadcopter up and automatically adjusting the balance.

Fig.7 ESC Platium Oppo 30A Opto

Fig.8 Motor SunnySky

G. Power

To provide stable power to the Tiva and Raspberry Pi microcontrollers (5v - 3A), we use the TPS54386 IC with 4.5 to 28V Input, Dual 3A Output, 600kHz Step - Down Converter with Internal Compensation of Texas Intruments [10].

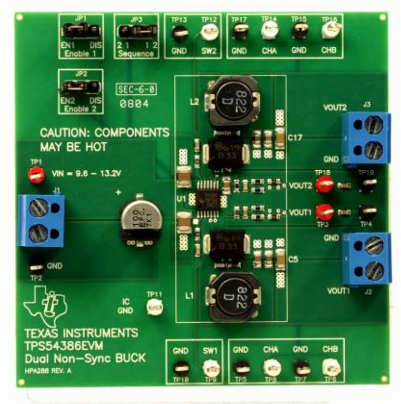

Fig.9 Power supply circuit using IC TPS54386

III. Fire Detecting and Locating Unit

Fire detecting and locating unit includes parts: a Record video, a Video record device, Locate for Quadcopter and Fire and a Embedded Computer.When the quadcopter flies to a certain height, a camera recording panoramic around. Every second the captured camera is processed and identified the location of the fire in the video by Raspberry, based on the height and angle of the camera, it is possible to determine the distance from the quadcopter to the fire. The coordinates of the fire are determined based on the coordinates of the quadcopter and the distance to the fire. The fire detecting and locating unit sends the warning signal, coordinates and fire video to the Quadcopter Control Diagram from which the signal is sent to the server using the 3G module. The block diagram of the Fire detecting and locating unit is shown in Fig. 10. Flowchart of Fire detecting and locating is shown in Fig. 11.

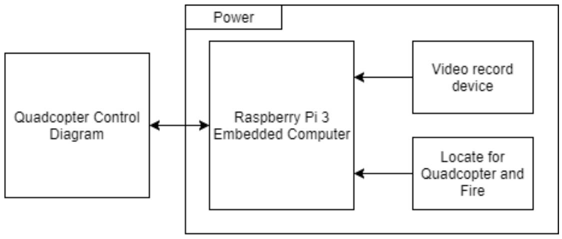

Fig.10 The structure diagram of the Fire detecting and locating unit.

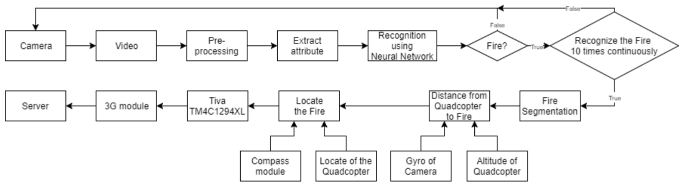

Fig.11 Flowchart of Fire detecting and locating unit

A. The Video record device

A video record device is responsible for recording the images around the quadcopter and they are used as processing and identification data. A video record device uses Pi NoIR Camera v2 [11] capable of recording at night with video quality up to 1080p30, which is an integral part of the whole product, like the eyes of a quadcopter. In addition, the Video record device has an anti-vibration component of the Quadcopter, which makes the camera more stable, the Gimbal 2 axis, is a combination of two servos to control the X and Y axes showed in Fig.12 . The combination of components in the video record device helps to create a more stable video record quality.

Fig.12 2-Axis Gimbal using 2 servo

B. Locate for Quadcopter and Fire

Locate for Quadcopter and Fire returns the coordinates of the location on the Quadcopter's map. Based on the distance and direction from the Quadcopter to the fire, it is possible to locate the location of the fire. Locate for Quadcopter and fire uses NEO-6 GPS module [12]. Maximum error for coordinate positioning is 2.5 m. Locate for quadcopter and fire using UART communicate to embedded computer.

Fig.13 NEO-6 GPS module

C. *Raspberry Pi 3 Embedded Computer*

Raspberry Pi 3 is responsible for processing, identifying and locating fires from images recorded by the video record device (with 15FPS) and from quadcopter coordinates determinded by Locate for quadcopter and fire. A buffer containing 10 frames is recorded continuously by the video record device and changes as new frames are input into the image processing and fire identification system. Frames are balanced by the brightness of the image, which prevents the sun's light from changing through pre-processing. Then they continue to be extracted objects using Color Analysis [13] and extracted attribute based on changes in the shape of objects. These properties are the input of the Neurol Network model (one of the Machine Learning algorithms) has 2 layers, 7 inputs with 2 outputs corresponding to the result: fire not not fire. This model has the task of identifying the appearance of fire in the 10 frames. If this model identifies there is burning 10 times in succession (continuous translation of 10 more frames), it will concluse that there are fire and partition these fire. Send the control signal to the Video record device's Gimbal 2-Axis to move the burning part to the center of the frame. When determining the angle X of Gimbal in conjunction with the height of the Quadcopter taken from the pressure sensor, we get the distance from the Quadcopter to the fire (as shown in Fig.16), so that we determine the location of the fire. Information about fire alarms, coordinates, and fire images is transmitted through the Quadcopter control diagram. Information about fire such as coordinates, images and alarm are transmitted through the Quadcopter control diagram.

Fig.14 Fire changes between frames

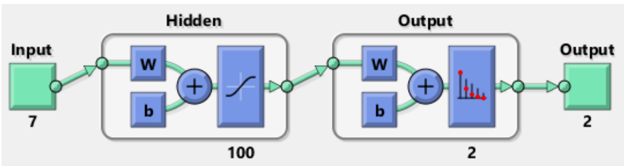

Fig.15 Neurol Network model

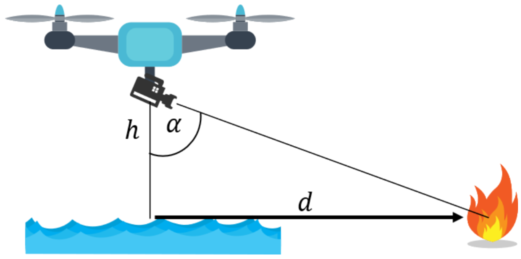

Fig.16 Calculate the distance to the fire

Fig.17 Identification and partition fire

IV. THE SERVER AND WEBSITE

The function of the server is to collect data from the quadcopter, the data will be saved and displayed on the web browser. The information contained herein is the location, the current coordinates of the fire and the quadcopter; raw data such as temperature, altitude, battery capacity, etc. In addition, the information will be updated on the website so that people, managers can capture that. Users can interact with quadcopter via web browser. All information will be saved to Google Drive in excel file. The demo of website is shown at http://rgb.tapit.vn.

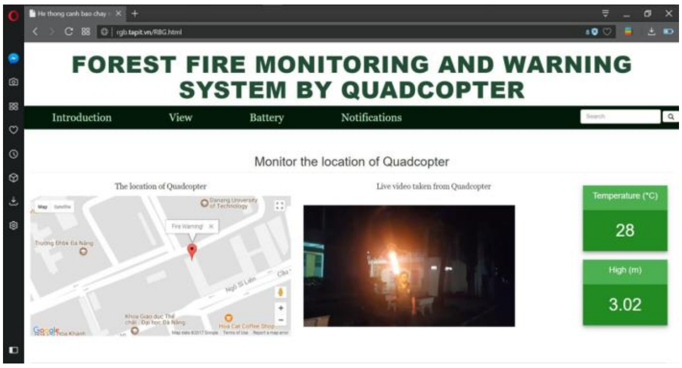

Fig.18 The website functionality

V. CONCLUSION

We have completed almost all of the components on the Quadcopter, the fire detecting and locating unit and also communicated with the website. However, the biggest obstacle of our Quadcopter is its balance as well as its rudimentary form. Other drawback is that our algorithm is not optimal.

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