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Small Scale Aerial Monitoring for Human Body Temperature Measurement Using Rotary Wing Drone

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Abstract*— In Indonesia, the COVID-19 pandemic has had an impact on a variety of sectors. Using all available technology for disaster mitigation is critical for pandemic prevention and control. Recent studies have uncovered the advantage of Unmanned Aerial Vehicle (UAV) or drones, particularly those with rotary wings, in dealing with the pandemic. Much effort has been devoted to developing a rotary-wing drone system as a flying platform for aerial monitoring. However, several factors must be considered when visually observing a specific region, i.e., the area's size, topographic contours, locations of special interest inside the area, approach points to the area, and the observation timeframe. Since fever is a common symptom of COVID-19, human body temperature monitoring is highlighted for fever screening, with the objective of minimizing people with high body temperatures going to the crowd. A major challenge is creating a system that can provide accurate body temperature data, which is critical for fighting the pandemic. The purpose of this paper is to present a rotary wing drone application for aerial human body temperature measurements. The paper also proposed an alternative solution based on using a portable, low-cost, Forward-looking Infrared (FLIR) thermal imaging camera. The FLIR thermal camera is incorporated into the drone's electronic system. Furthermore, thermal image data are transmitted into the ground station via a radio telemetry transceiver to allow flexible surveillance by the operator. Indoor and outdoor experiments reveal that the system has been effectively installed and provide data collection for further research. The results show that the system can be used for small-scale area aerial monitoring.

***Keywords*— COVID-19; drone; FLIR; aerial; temperature; monitoring; small scale.**

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I. Introduction

Currently, drones have been commonly used in various applications. Unmanned Aerial Vehicle (UAV) or drone is an unmanned flying vehicle that in the last decade, has grown rapidly in the realm of unmanned system research in the world. Not only those in the realm of the defense department or research agencies, including universities that conducted research and development, but the industrial world and the civil sector have also begun to use this unmanned system technology a lot in supporting their daily activities. Real-time monitoring and mapping of critical areas such as strategic areas such as mining areas, maritime affairs, inter-state borders, natural disaster damage assessment, plantations, etc. are objects of great potential for the utilization of these unmanned systems [1]–[5]. Drones are also used for indoor aerial monitoring [6].

Since 2020, all corners of the globe have been affected by the COVID-19 pandemic. The mitigation strategy is implemented by limiting travel and minimizing spreading risk in public space [7]–[10]. On the other hand, investigating how to use drones as a fighting platform for combating the pandemic presents an intriguing study [11], [12]. The use of drones in the emergency and fight against the pandemic in another previous study have included the following six schemes: visual monitoring, thermal body detection, using an onboard loudspeaker for communication, delivery of basic needs, health items, and disinfectant spraying [13], [14]. The most common drone application is area monitoring or aerial surveillance, which is utilized in routine and special operations to combat COVID-19. Area monitoring or aerial surveillance was implemented in all nations where unmanned aerial vehicle applications were reported. When visually watching a specific region, several factors must be considered: locations of special interest inside the area, the area's size, contour condition, approach points to the area, and the observation timeframe. Point monitoring may be adequate in smaller or open regions. In the other hand, the operation of numerous aerial vehicles that coordinated in a network is required [15]. In the latter case, the flight altitude can affect the flight patterns because it increases the visible area, allowing the flight time or flight path to be shortened. Other conditions, such as the area's edge, remain unchanged in this case. If the flight altitude remains unchanged but the camera-viewing angle increases, the situation remains the same.

Since fever is a common symptom of COVID-19, several studies have highlighted the use of thermal cameras for fever screening to minimize travelers with high body temperatures [16]. Even when other influenza-type epidemics, such as SARS and MERS were spreading, body temperature regulation was already a standard technique [17]–[19]. Thermal imaging or infrared thermography is a technology used to measure or "see" infrared, the wavelengths emitted from objects, and then convert the temperature information into an image [19]. For a special mission, the drone's onboard camera can be replaced with a thermal imaging camera [20]. The drone can also be equipped with a wireless video transmission system that can transmit real-time video and photos to operators on the ground [21], [22].

Some studies show that there are several methods to detect human temperature since thermal-based cameras or sensors are now widely available and affordable [23], [24]. Considering major factors contributing to the heterogeneity of previous findings, this paper addresses a design and implementation of a small-scale rotary wing system for aerial human temperature fighting COVID-19 pandemic. The monitoring system sends the video from the onboard visual camera with thermal imaging capability in the rotary wing to the ground station.

II. Materials and Method

The proposed system consists of three parts: a basic rotary wing configuration system, an onboard camera system, and a proposed rotary wing configuration system. In Fig. 2, the configuration block diagram of the proposed system is shown. Generally, the basic rotary wing configuration consists of a flight system, propulsion system, and communication module, which monitor and control the six motors.

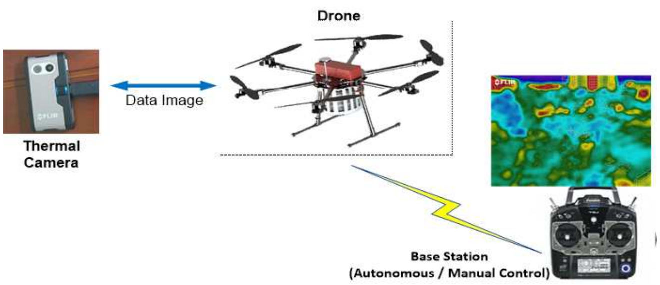


Fig. 1 Aerial Monitoring Configuration System.

Ground-based controls and accessories are necessary for a drone to work like any other electronic remote device. The drone's RF-based remote controller, which enables remote control of the UAV, is the most crucial component [25]. The drone will send the data by using a telemetry transceiver. In this system, RC receiver functions as a receiver that receives a command from the ground station on how the rotary wing move.

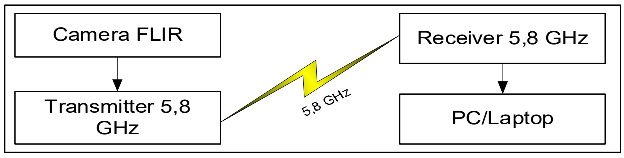


Fig. 2 FLIR camera configuration.

Even though mobile high-quality video drone has grown popular, it is critical to maintain video transmission systems as simply as possible [26]. The camera's configuration on board in the rotary wing consists of a camera 600 TTL, which will transmit the video using a 5.8 GHz transmitter, and the video can be seen in a ground station in a personal computer (PC).

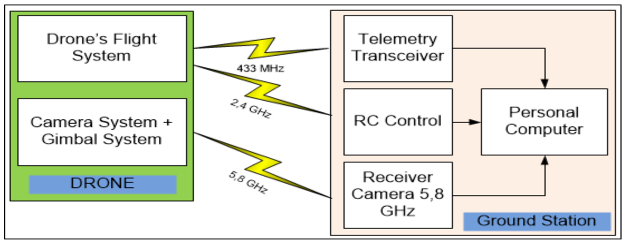


Fig. 3 Proposed Rotary wing Configuration System.

In this research, the proposed system's configuration is shown in Fig.3. In this figure, every data and video is sent to a personal computer. The personal computer will process the data and video and show it as information, and the video processed in a personal computer will show human temperature data. Infrared imaging technology advancement has provided low-cost and mobile IR camera equipment. Nevertheless, low-cost IR cameras have a restriction in the form of fluctuating inaccuracies [27].

TABLE I
Thermal Camera Specifications

No.	Specification	Value
1	Object Temperature Range	-20°C — 120 °C
2	Thermal Resolution	80 x 60
3	Thermal Sensitivity (MRDT)	150 mK
4	Accuracy	±3°C or ±5%
5	Adjustable MSX distance	0.3m – Infinity
6	Focus	Fixed 15cm – Infinity
7	Visual resolution	Saved as 1440x1080 pixel

This paper uses low-cost IR cameras like FLIR One Gen 3. A thermal camera that used in this experiment is FLIR One Gen 3 (Fig. 4). It is attached to an Android-based smartphone or Linux-based mini-PC, i.e., Raspberry Pi series. The technical specification is shown in TABLE [28].

Fig. 4 FLIR One Thermal Camera.

III. Results and Discussion

Fig. 5 shows the rotary wing frame, which used six motor and a control system using Ardupilot. The motors have a specification 1100 kV, which means there is 1100 RPM (rotation per minute) per volt. With this motor using 4 cell battery (approximately 14,8 volt), the rotary wing can lift its weight up to 3 kg. The processor is used in Arduflyer 2.5.2 board for an autonomous flight controlling system. The Inertial Measurement Unit (IMU) is embedded in the system. IMU consists of 3-axis accelerometer and gyroscope. The accelerometer is used to measure the Earth's acceleration vector, while the gyroscope is needed to measure the rate of rotation around an axis. An external GPS, as used as a position sensor, is connected to the flight controller. This external GPS is also integrated with a digital compass.

All sensor integrated into the flight controller in drone's system is guided with an open-source APM Copter firmware. Mission Planner, an open-source application from ardupilot.org, is installed in the ground station. This application enables the flight controller to fly in autonomous mode and send flight information to the ground station.

Fig. 5 Rotary Wing Drone Platform.

A. Indoor Test

Fig. 6 shows the test configuration in an indoor environment with the thermal camera only. The camera is not installed on drone yet. The FLIR camera is connected to an Android-based smartphone and initialized using camera's default app. Things to note that smartphones are also heat sources, and the processor and battery are the heat-generating components. For comparison a thermometer gun is also used to compare the results. When considering a mobile device as a tool, the heat generated by the device must also be considered as the environment temperature. The device was directed towards the reference object to calibrate the FLIR camera. At the same time, the thermometer is used to obtain the comparable temperature.

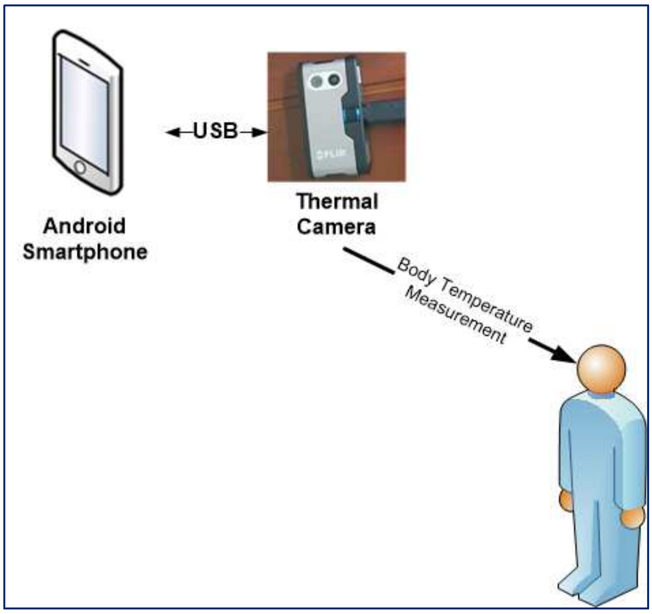


Fig. 6 Body temperature measurements using a Thermal Camera.

To evaluate the performance of the thermal camera, Figure 6 shows temperature measurements from a stationary object obtained using the thermal camera. The thermal camera utilized in the research is the FLIR One Gen 3, which has an accuracy of +/-3°C or +/-5 percent, a thermal resolution of 80x60, and a thermal sensitivity of 150 mK. It is chosen because of its relatively low cost, decent thermal resolution, and dual-lens (visible and thermal) imaging system. A test series was performed using people's temperature by comparing the FLIR One to a regular thermometer gun to measure people's temperature to verify the camera's reliability. It was determined that the value was comparable to the thermometer result by comparing the temperature measured through infrared images at the target of a known temperature. The results in TABLE indicate that both of them show similar results.

TABLE II
COMPARISON OF THERMO GUN AND FLIR CAMERA MEASUREMENTS

Thermal Camera View	Thermal Image Temp. (ºC)	IR Thermometer Gun (ºC)
	36.2	36.5

According to the results of this test, the FLIR One is considered a reliable unit when operating within the specified temperature range, and accurate temperatures can be perceived when the scene is tuned based on the target.

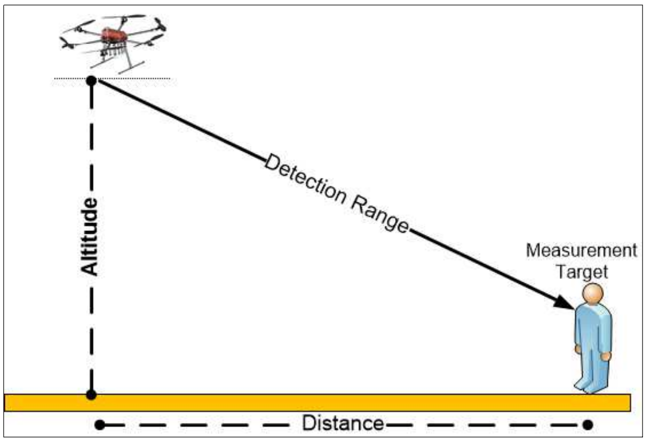


Fig. 7 Measurement test setup.

To evaluate the system, the FLIR camera must be tested aboard the drone in both indoor and outdoor environments. From TABLE , with the camera specification known, the user may estimate the smallest item detectable at a certain range. If the target object's size is known, the drone's flying height can be adjusted so that the object stays observable at the operational flight altitude. The experimental setup for the measurement test is shown in Fig. 7.

The system is tested inside four story building shown in Table 3. The drone's camera coverage was assumed to be point-like [29]. Then, Pythagorean Theorem can be useful in this case. The detection range can be determined if the altitude and distance are 7.5 meters and 9 meters, respectively. The calculation is shown in equation (1) to (3).

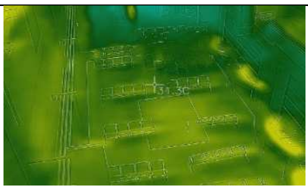
$$Detection\ Range = \sqrt{(Altitude)^2 + (Distance)^2} \quad (1)$$

$$Detection\ Range = \sqrt{(7.5)^2 + (9)^2} \quad (2)$$

$$\boldsymbol{Detection\ Range = 11.72\ meter} \quad (3)$$

The results demonstrate that measuring human temperature from this distance was problematic. The result in **Error! Not a valid bookmark self-reference.** shows there is a significant gap between thermal camera temperature and thermometer gun value.

TABLE III
INDOOR AERIAL TESTING

Thermal Camera View	Thermal Image Temp. (°C)	IR Thermometer Gun (°C)	Gap (°C)
	31.3	36.5	5.2
	31.9	36.6	4.7

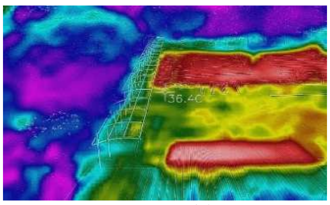
B. Outdoor Test

The findings from indoor tests provide information about the effective range of FLIR thermal cameras. Therefore, a significant decrement is implemented in drone altitude settings. For the outdoor test, the altitude is set at 6-meter value maximum, and it's more than the minimum range limit of drone-human interaction in public space [30]. The drone's altitude is set higher than the chosen target to ensure flight safety and psychological effect. Fig. 8 shows that the drone is taking off to the holding altitude. The test is conducted in a relatively open area. TABLE IV significantly affects the thermal camera's accuracy related to altitude change, and a deviation varies with a small range between 0.1 – 1.8 °C.

Fig. 8 Drone Taking Off for Aerial Monitoring Test.

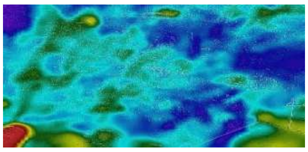
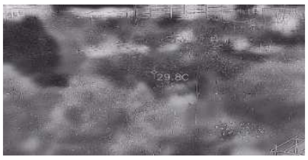
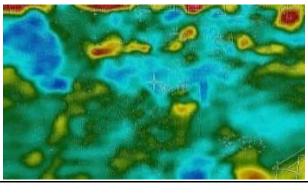
After taking off, the system will map the "hotspot" position. The position is usually the highest temperature measured in the area. Typically, the system will perform a rescaling process. The picture is divided into 15 segments into horizontal and vertical pixels. If a target is detected, then the measured temperature's position is shown in which segment. The problem with using this algorithm in this experiment is that the change in ambient light's brightness can interfere with the camera's ability to detect the object. An experimental setup where the temperature can be monitored and controlled is necessary to examine the errors.

TABLE IV
OUTDOOR AERIAL TESTING (OPEN AREA)

Thermal Camera View	Thermal Image Temp. (°C)	IR Thermometer Gun (°C)	Gap (°C)
 Floor	39.2	41	1.8
 Human Subject	36.4	36.5	0.1

The effects of obstacles have also been documented to provide a better understanding. The experiment results show the limitation of the thermal camera with the presence of an obstacle. The thermal camera did not provide a substantially better reading of human body temperature behind foliage, and this result may not be accurate due to the complexity of heat absorbed by the foliage. A specific method, fusion with visual and thermal images, or object recognition, has been used to distinguish areas of interest. The issue with these techniques is that they cannot ignore the thermal effect of background heat on the actual interest area. By considering how thermal images, particularly those captured by FLIR cameras, should be adjusted and processed, a reliable image that accounts for variation in background heat can be displayed. Also, in Table 5, there is a significant gap between data from a thermal camera and a thermometer gun.

TABLE V
OUTDOOR AERIAL TESTING (FOLIAGES AREA)

Thermal Camera View	Thermal Image Temp. (°C)	IR Thermometer Gun (°C)	Gap (°C)
	32.1	36.6	4.5
	32.1	36.5	4.4
	29.8	36.5	6.7
	30.1	36.5	6.4

In Fig. 9, the drone's capacity on monitoring area can be easily calculated. The effective detection range of the drone is 8.49 m and the distance is 6 m. Assuming the area in square form, the monitoring area is 12 x 12 m or equal to 144 m^2 (Table 6). Therefore, observed areas are more limited e.g., campus or city park, traditional markets, and other open public places. In such circumstances, the restrictions are usually still mild. Aside from thermal camera resolution, the ability to modify the temperature value is also crucial.

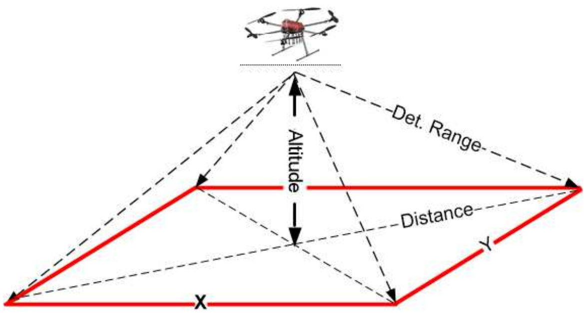


Fig. 9 Drone Monitoring Area.

TABLE VI
DRONE MONITORING AREA SCALE

Altitude (m)	Distance(m)	Detection Range (m)	Monitoring Area (m^2)
6	6	8.49	144

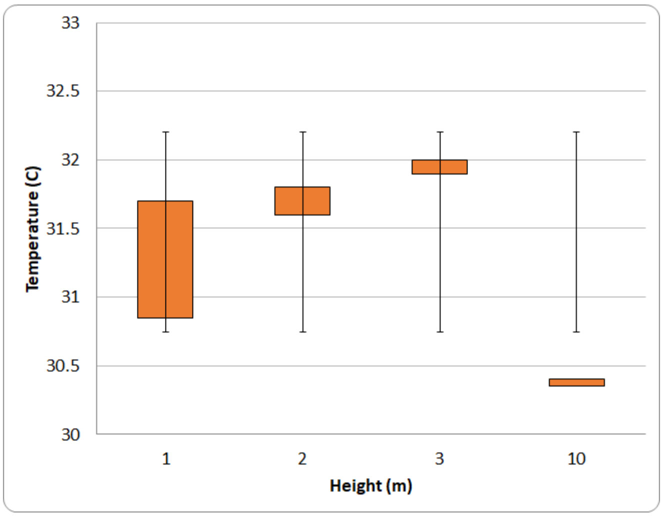


Fig. 10 Box and whisker plot of temperature reading by height.

The average temperatures for each sample are shown in Fig. 10. Height, or drone altitude appeared to be the most contributing factor to target's temperature measurement. Boxes indicate the lower and upper quartile of measured data. Above the effective detection range, the minimum and maximum temperature recorded from the sensor are between 30.4 – 31.6 °C, below the normal people's temperature range. The data support a lower range of temperature measurement. The system may function in a somewhat narrow range. The causes of inaccuracies are unclear and may reflect differences in the way in which measurements were performed. Nevertheless, the possibility of portable thermal cameras for aerial monitoring can't be excluded.

IV. CONCLUSION

A proposed system for aerial monitoring of human temperature has been developed utilizing an Unmanned Aerial Vehicle (UAV) or drone combined with a thermal camera. The suggested device can detect human body heat from a distance of several meters above the ground. It was able to send data to ground control and measured human temperature. In general, the experiment on the camera system is held on indoors and outdoors. Another interesting issue worth exploring is how to follow up if the suspected person is detected. Issues that occur include what kind of procedure or measure needs to be taken, e.g., who contacts the detected person and how to report the authority.

Several improvements can be done in this system by providing a more accurate FLIR camera to improve the accuracy. The paper presented here shows several points: combining a drone, and FLIR thermal camera can be an alternative solution for fighting the COVID-19 pandemic. The results also suggest that the system works well for a small-scale area of 144 m^2. This research could be expanded to include correction for thermal camera temperature data using computational methods, i.e., Artificial Neural Networks or Machine Learning.

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