Environmental Sensor Assessment for a Light Quadcopter Drone

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Abstract. This paper presented drone design and environmental sensor assessment. The assessment was conducted for temperature and pressure. The measurements were performed offline and online. Offline measurement was by locating drone inside a controlled chamber, while online measurement was when drone is flying. Assessment shows that there were significant error differences in temperature, where offline drone exerted only 0.75% error, but online drone produced 6.23% error. Error increases as temperature increases. Pressure assessment exerted a slight error different between offline and online drone, 0.16% and 0.17%.

1. Introduction
Light drones have been popular being used for many applications such as toys, image retrieval, or even for farming applications [1]. Light drones are available from several dollars to thousands dollar depending upon the services provided. For specific or environmental monitoring, drone is usually equipped by some sensors [2]. Monitoring drones are mainly equipped by camera to take images from the air [3]. Temperature, pressure, humidity are some sensors to obtain environmental conditions at the surrounding of flying drones.

Drone is a smaller type of the unmanned aerial vehicle (UAV). UAV has been considered as a flying robot, as it requires control system as in robot. Drone design is dominated by propeller driven [4]. Military drones can fly several hundred kilometers, while small drones are usually restricted by local government, flying only up to several feet [5].

This paper examines environmental sensors attached on the designed drone that has been equipped by an obstacle avoidance system. The designed obstacle avoidance system makes use the ultrasonic’s sensors. Although camera based [6] and wind based [7] obstacle avoidance systems are exist, ultrasonic sensor was chosen for its simplicity. Fuzzy logic was employed to decide drone maneuver, instead of neural network [8], again for drone simplification. Those simplifications must be done as the intended designed drone is the light one, so that environmental sensors attached to it still allow drone to fly normally.

Environmental sensors as well as ultrasonic sensors are connected to arduino. Measurement data was transmitted through telemetry radio to ground station. Radio of 433 MHz was chosen rather than WiFi as the 2.4GHz spectrum is more crowded at the assessment location [9]. In order to measure environmental properties precisely, sensors were operated and validated by using some standard laboratory measurement equipment. Transmitted data that were received by the ground station were then compared to the standard value. Sensor deviation was measured to ensure valid monitoring data.

2. Drone design and measurement method
Drone design is shown in Figure 1. Ultrasonic sensors were attached to drone body, and continuously ping arduino. Arduino forwards control signal from remote receiver to flight controller based on sensor ping to apply collision avoidance. Meanwhile, environmental sensors were connected to arduino, arduino forwards measurement data to ground station by using 433 MHz telemetry radio.
Figure 1. Designed Drone System

Figure 2 shows the realization of the drone designed using four propellers. Drone uses frame 250 made from fiber, four brushless motor MT2204 and ES20, four units three blade propellers, CC3D circuit as flight controller, FS-I6 remote control module, HC-12 433 SI4463 for telemetry and Li-Po battery1500 mAh for drone power source. Temperature and pressure sensor uses BME 280, air quality sensor uses MQ135. The fiber frame 250 was chosen to produce total weight of only 800 grams, including additional battery for arduino and 433 MHz radio system.

Next step is to assess environmental sensor, in this case, temperature and pressure. Offline temperature sensor assessment uses temperature chamber and a standard temperature sensor fluke type 5615 with temperature variations of 20, 30 and 40 °C. Pressure validation uses pressure chamber and standard pressure sensor Vaisala type PTB 330 as shown in Figure 3.

Figure 3. Environmental sensor assessments
3. Assessment Results
Offline assessments by placing drone inside the chamber, setting some set points, and then comparing the telemetry data and the standard temperature gives values as shown in Table 1. There are slight differences between standard and the transmitted temperatures. Average temperature deviation is 0.23 °C, with the highest deviation is 0.38 °C. Deviation values increase to measured temperatures. This deviation produces measurement error 0.75% in average.

| Set Point | Standard Temperature (°C) | Measured Temperature (°C) |
|-----------|---------------------------|---------------------------|
| 20 °C     | 20.095                    | 20.21                     |
| 20.095    | 20.21                     |
| 20.095    | 20.21                     |
| 20.093    | 20.22                     |
| 20.093    | 20.22                     |
| 30 °C     | 29.861                    | 30.09                     |
| 29.859    | 30.09                     |
| 29.861    | 30.08                     |
| 40 °C     | 39.939                    | 40.31                     |
| 39.939    | 40.31                     |
| 39.938    | 40.30                     |
| 39.938    | 40.32                     |

Online assessments by flying the drone in a reachable height, measuring surrounding temperatures, and then comparing the received data and the measured temperature produces values as depicted in Table 2. Online measurements exert higher deviation than offline measurement. Average temperature deviation when drone fly is 1.88 °C, 7.19% higher than offline value. The highest deviation is 1.91 °C and measurement error is 6.23% in average.

| Standard Temperature (°C) | Online Assessment (°C) |
|---------------------------|------------------------|
| 30.2                      | 32.05                  |
| 30.2                      | 32.07                  |
| 30.21                     | 32.08                  |
| 30.21                     | 32.1                   |
| 30.22                     | 32.12                  |
| 30.22                     | 32.1                   |
| 30.24                     | 32.13                  |
| 30.24                     | 32.14                  |
| 30.26                     | 32.14                  |
| 30.26                     | 32.17                  |
The same experiments were applied for pressure which gave values depicted in Table 3 and Table 4. Average offline pressure deviation is 1.62 mBar with average error is 0.16%. Deviation and error increased when drone flies, producing deviation of 1.73 mBar and error of 0.17%.

| Set Point | Standard Pressure (mBar) | Measured Pressure (mBar) |
|-----------|--------------------------|--------------------------|
| 950 mBar  | 950.06                   | 951.62                   |
| 1000 mBar | 999.77                   | 1001.32                  |
| 1050 mBar | 1050.05                  | 1051.76                  |

| Standard Temperature (°C) | Online Assessment (°C) |
|---------------------------|------------------------|
| 1011.51                   | 1013.47                |
| 1011.51                   | 1013.3                 |
| 1011.51                   | 1013.18                |
| 1011.5                   | 1013.16                |
| 1011.5                   | 1013.15                |
| 1011.49                  | 1013.19                |
| 1011.49                  | 1013.21                |
| 1011.49                  | 1013.18                |
| 1011.49                  | 1013.22                |
| 1011.48                  | 1013.2                 |

4. Conclusions
This paper presented environmental monitoring drone with focus on temperature and pressure sensor measurement. The offline measurement in a controlled chamber gave errors 0.75% and 0.16% for temperature and pressure subsequently. Meanwhile, when drone flies, temperature error increased significantly to 6.23%, while pressure error is only 0.17%. The increment may cause by drone vibration and surroundings. These error increments should be consideration for those measuring these parameters using drone.

Acknowledgement
This research has been supported by TALENTA USU research grant 2020.
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