Development of an Internet-of-Things-Based-Container for UAV Payload Transport Application in Disaster’s Location

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Abstract. Natural disaster often occurs nowadays all around the world resulting in environmental damage and broken infrastructure which prevent logistics transportation for the evacuees. Therefore, it has been developed a payload transport UAV based on Internet of Things (IoT) for transportation of goods (foods, clothes and medicines) to the disaster location. The transport system consists of a relatively small (52.5 cm, 52.5 cm and 26.5 cm of length, width and height respectively) container (as the main part of the system) lifted by an UAV using a rope, servo motor and a pulley which are controlled by IoT Platform for user friendly access through a smartphone, tablet, laptop or computer. The system is equipped with automatic door and lock system, ultrasonic sensor system for distance measurement and pulley system with 17 N cm torque servo motor 360° for loading and unloading mechanism. Lolin Node (Microcontroller Unit) MCU v3 using Message Queuing Telemetry Transport (MQTT) protocol of IoT for WiFi and GSM networks has been used for the system for control and communication application. Hereinafter, the pulley system has been successfully tested to lift until 9.27 kg of load, 50 cm of distance motion with 6.3 cm/s upward velocity and 11.4 cm/s downward velocity.

Keywords: Internet of Things, UAV, disaster, payload transport, MQTT

1. Introduction

Natural disasters including volcanic eruptions, earthquakes, floods, tsunamis, hurricanes, tornados and other geologic processes, often occurs nowadays all over the world. Large amount of energy released from the source to other places through seismic wave in earthquake. Flood also transfers energy from the source through water overflow the usually-dry submerge land. Larger energy transferred through water happened in tsunami as well as in hurricanes and tornados. Meanwhile in volcano, energy transferred through combination of seismic wave, water or lahars, heat and gasses or other materials released during the eruption. The energy transferred could be damage to human, animals, buildings and environments.

To overcome these disasters, there are researches for minimizing the loss from the disasters including fatalities, infrastructures, agriculture, livestock and etc. For example, an early warning system has been developed for volcano eruption [1-10]. When the disaster occure, it sometimes prevents the logistic transportation for the evacuee. In this situation, UAV technology has a good prospect to solve this problem. Some researches has used UAV to lift a load such as Lidar 2-3 kg for mapping the specific area [11-13], and an UGV for volcano monitoring application [14]. Therefore, we have been developing a low cost UAV payload transport for transportation of goods (foods, clothes and medicines) to the disaster location. The transport system consists of a relatively small container (the main part of the system as the focus of the research) lifted by an UAV using a rope, servo motor and a pulley which are controlled by IoT Platform [15] for user friendly access [16].
2. Methodology

2.1 Payload transport UAV module

In this research, it has been designed a small container for payload transportation from acrylic 2.5 mm (the base is covered with 0.05 cm aluminum sheets) with iron frame to sustain up to 7 kg load (Figure 1). This box shape container has 3.9 kg total mass with dimension 52.5 cm, 52.5 cm, 26.5 cm for length, width, and height respectively when the door is closed and 68 cm, 52.5 cm, 26.5 cm when the door is opened. The system is equipped with a controlled door system to open and close the door as well as a controlled lock system, a 4-pulley (2 cm of outer diameter and 0.8 cm of inner diameter) system connected to a modified (360° rotation) Tower Pro MG996 servo motor at 6 Volt using a X16009E1 step-up (connected to eight 600 mAH 3.7 V Li-ion Ultrafire GRC 18650 batteries) from 5 Volt Lolin Node MCU v3 module (supplied by a 10,000 mAH Robot RT130 power bank). These pulleys connected with 0.3 mm nylon rope for lifting loads up to 20 kg, move simultaneously to pull up and down the container from UAV to be attached to. The system is controlled and communicated through WiFi and GSM using Lolin Node MCU v3. Meanwhile, HC-SR04 ultrasonic sensors are used for distance measurement between the container and the ground/surface where it will be landed [17-20]. This sensor is connected to microcontroller through trigger and echo pins.

![Figure 1. The container design: Controlled door system (1), Ultrasonic sensor (2), Microcontroller (3), Hook (carabiner) to be attached to the UAV (4), Controlled Lock System (5), Rope (6), Servo motor and pulley (7)](image)

This container is sustained by 12 inner frames, 2 plate (72 cm, 2.3 cm, 0.2 cm of length, width, and height respectively) horizontal frames along the diagonal of the base, a plate (51.5 cm, 2.3 cm, 0.2 cm of length, width, and height respectively) horizontal frame along the width of the base, 2 plate (72 cm, 2.3 cm, 0.2 cm of length, width, and height respectively) horizontal frames over the top and 7 vertical iron solid cylindrical frame (0.6 cm of diameter) (Figure 1). The left and right side of the wall have 40 cm X 3 cm ventilations for reducing the wind interference during the flight.

2.2 Door system

Mechanically, the door is connected directly to nylon rope at the end of its pulley-servo motor [21] controlled through digital-D2 pin of microcontroller according to the comment from user. The door will be opened when the motor rotate clock wisely, and vice versa (Figure 2). This system is suitable for the container because of its limited space (only needs the space in front of it) and more efficient because it uses only 1 motor.
To open and close the door, the system should first connect to Wi-Fi or GSM networks. Furthermore, user should publish the command through MQTT broker to open or close the door after subscribed to specific topic (door system), hence the microcontroller translate the command for the servo motor to pull up or down the rope for opening or closing the door.

### 2.3 Lock system

The lock system is designed for the goods/objects inside to be in the same position through the flight. User will subscribe to a specific topic in MQTT broker to publish the command to lock or open the key through the microcontroller to move the gear to move the rod slides up or down (Figure 3).

![Figure 3. The Lock system](image)

### 2.4 Pulley system

In this system, the motor control the pulleys which are move in the same time to pull up or down the rope after MQTT publish desired topic inserted by user. Therefore, the container will also move up or down.

### 2.5 Distance measurement system

There are 2 ultrasonic for distance measurement system. First, it is mounted on the lower part of the base to measure the distance between the container and the ground or surface where it will be landed [22] (Figure 4 (a)). The last is mounted on the inside part of the wall parallel to the door to know the goods is already inside the container (Figure 4 (b)) [23].

![Figure 2. The door mechanism](image)
2.6 MQTT broker for controlling the system

Before user input or publish the command to open or close the door, open or lock the key, pull up or down the rope, to measure the distance between the container and the ground or surface or measure the distance between the backside of the container and the goods inside container, the system should have been connected to MQTT broker through Wi-Fi or GSM networks. Therefore, user could subscribe to the specific topic to control servo motors or ultrasonic sensor through the microcontroller to do the specific works.

3. Result and Discussion

The system implementation is presented in Figure 6, where the lock system, door system and ultrasonic sensors are shown in the picture. The lock system has been successfully tested by the user to be opened and locked as well as the door system. However, the time for open (7 s) and close (11 s) the door was different, because of its different angular velocity to rotate clockwise and counter clockwise after calibration process.
The distance measurement system has been also tested and compared to the manual measurement using a metal ruler to know the distance between the container and the landing surface, which yielded the same result for both measurements. Before calibration, the sensor has a 2 cm zero offset, therefore the measurement could not be less than this distance. However, all the measurement in this paper are used the sensors which have been calibrated.

Before the system is being controlled, it has to be connected to the Wi-Fi or GSM network and send the notification of this successful connection through MQTT broker [24-25]. All the connection in this research has no delay both in subscribe or publish the topics.

Servo motors for pulling up and down the container have been also tested to know their range of torques. The motor was connected with varies loads which were added gradually for each 245 gr through a nylon rope from empty to the maximum load (2,250 gr (Figure 7)) could be pulled by the system (Inset of Figure 7). In this system, rope tension \( T = 22.05 \text{ N} \) could be calculated by Equation 1 (assumed there was no external forces affected the system)

\[
T = mg
\]

where \( g = 9.8 \text{ m/s}^2 \), while torque magnitude (Equation 2) for radius \( R = 1 \text{ cm} \) is 22.05 N.cm (maximum torque assumed for each motor).

\[
\tau = mgR
\]

For the empty container (4.39 kg of total mass - measured by Newtech Wtl-AO8 with 10 gr of uncertainty) the total torque of the rope for this pulley (\( R = 1 \text{ cm} \)) is 43.02 N.cm or 10.75 N.cm for each torque. Therefore, the range of the torque for each servo motor to be loaded by goods to be transported is between 10.75 N.cm (empty) and 22.05 N.cm (fully loaded).

Average speed of the rope without load is 7.7 cm/s and decreases almost linearly according to the load, until the motor could not lift the load (average speed 0 cm/s) at 2,250 gr of mass.
The range of torque for each motor could be used to estimate the range of load (up to about 9 kg for 43.02 N.cm maximum of total torque) to be transported by the system. A testing has been successfully conducted to know the maximum load to be transported, which is 9.27 kg in minimum average upward velocity (6.6 cm/s), while the maximum’s is 8.3 cm/s for empty container (Figure 8) to be moved up until 50 cm of height (distance measurement could be up to 4 m). On the other hand, the container moved down with 9.1 cm/s without any load. It is shown that gravity force has significant effect in this downward motion as well as when the load is maximum with average velocity is 11.4 cm/s (Figure 9).

Figure 7. The Result of servo motor testing for various loads and the mechanism of this testing (inset picture)

Figure 8. The container controlled to move up with various load
Figure 9. The container controlled to move down with various load

4. Conclusion

The container for UAV payload transport system has been developed, equipped with ultrasonic sensor, door system, lock system and pulley system. Lolin Node (Microcontroller Unit) MCU v3 MQTT protocol of IoT for WiFi and GSM networks has been used for the system for control and communication application. Hereinafter, the pulley system has been successfully tested to lift until 9.27 kg of load, 50 cm of distance motion with 6.3 cm/s upward average velocity and 11.4 cm/s downward average velocity. In the near future, we will attach the system to our UAV (load capacity up to 15 kg) and test for payload transport application in Laboratory.

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