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Development of IOT Based Hybrid Helium Drone for Flight Time Enhancement

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Abstract

In this paper, a new design of a IOT Based hybrid helium drone is proposed for the purpose of flight time enhancement. The purpose of this research paper is to show the possibility and usage of the drone with the help of latest technology. Firstly, there was a current drone literature in which we learn about usage and limitation in current drone technology. Later, we discuss about the most important element of this paper is design of the drone, electronic system and IoT technology. By connecting the drone with internet, we can explore many possibilities of IOT system. A new design of a helium-assisted hybrid drone is proposed for the flight time enhancement and high velocity movement in both vertical and horizontal direction. The main purpose of design for the hybrid drone has several benefits including easy to manufacture and a relatively cheaper when compared to other types of drones, due to which it enables the affordability option for end user. To validate the effectiveness of the proposed design, practical experiments were conducted.

Keywords: - Helium drone design, UAV, Drone analysis, IoT technology, Flight time enhancement.

1 INTRODUCTION

A "drone" is a term used to describe any unpiloted aircraft. Sometimes referred to as “Unmanned Aerial Vehicles" (UAVs), these crafts can carry out an impressive range of tasks such as wildlife and environment monitoring [10, 11], cellular network [12], military [13, 14], planetary exploration [15], entertainment [16, 17] and many more. Drones with VTOL (vertical take-off and landing) capabilities offer a wide range of applications since they can hover over a specific spot or region without requiring runways. As a trade-off, this type of drones (like quadcopters) can only fly in a relatively small amount of time (e.g., usually up to 20 mins [18, 19]) and can reach a certain amount of velocity (vertical or horizontal velocity) because of the fixed direction of propellers [20]. VTOL drones (such as quadcopter or hexacopter) uses motors to generate lifting force, which uses high amount of electricity, and radio transmitter and receiver to operate the drone, Because of the reason high performance parts required (such as bldc motors, li-po battery, wireless radio module and camera module) to make drone fly and communicate with the user, which directly affects the cost of the drone [21].

To increase the flight time, velocity and affordability of VTOL drones, there have been many approaches including fixed wing drones combined with VTOL capability [22], hybrid drones supported by extra lifting force [23, 24], use of a solar-power energy harvesting method [25], and many others. However, the previous approaches have several limitations such as their sizes and/or difficulty in manufacturing due to their unique designs. In what follows, we provide more detailed literature surveys on some related works to better understand what research have been done for this purpose, followed by the problem description and contribution of this research.

1.1 Literature survey

The “S-CLOUD” drone designed by Hwan Song et al. [6] posed a minimal risk to people near its flying radius because of its torus-shaped envelope. This envelope is created from thin polyethylene terephthalate that surrounds the co-axial rotors and 2-axis crossed flaps, which control the S-CLOUD drone. The torus shaped envelope is filled with helium to provide a lifting force such that the flight time of the drone is increased. The uniqueness of the design is that the on-board electronics such as the flight controller, LIDAR sensors, RC receiver, electronic speed controller, LiPo battery, servo motors, and coaxial brushless DC motors and rotors are located at the centre of the torus-shaped envelope. The total weight of the S-CLOUD is 550 g and the lifting power provided by the helium balloon is 490 g, which leaves 60 g to be lifted by the thrust from the rotors. This UAV has a flight time of approximately 63 minutes, which is more than that of standard VTOL drones such as quadcopters. The disadvantage of the design is that the torus shaped enveloped is difficult to construct due to its hollow shape and the aerial dynamics of the UAV are complicated.

Wan et al. [2] presented a 200.3 g solar-powered blimp for the purpose of increasing the flight time effciency of the UAV. Blimps are a type of lighter-than-air UAVs which rely on their neutral buoyancy to stay afloat. Some of the advantages of blimps are their low power consumption, ease of take-off and landing, and their capability for long endurance flights. Disadvantage of using a blimp is that it can be significantly larger in size when compared to a standard UAV, the blimp has a limited payload capacity and is difficult to control due to its characteristic sensitiveness to disturbances such as wind and temperature.

Gonzalez et al. [3] used a 200 g modified Plantago RC blimp with the goal of developing a low-cost autonomous indoor blimp. The blimp and its components were built to decrease the size of the blimp and the weight of the on-board technology due to its indoor application. To assist the blimp in travelling through two diverse surroundings, the authors designed a PID and fuzzy logic controller. One of the drawbacks of the blimp is its low payload capacity because it relies on its neutral buoyancy to stay afloat. Its low payload capacity restricted the choice of sensors that were used in the design.

Lonneville et al. [4] used helium balloons for aerial photography. The advantage of employing helium balloons is that they have no electronic components and can stay afloat until the majority of the helium has passed through the material. Because there is no way to stabilise the helium balloon due to its lack of control mechanisms, using just a helium balloon has the disadvantage of being easily influenced by outside forces such as wind. As a result, this simple design would be undesirable because there is no way to stabilise the helium balloon due to its lack of control mechanisms.

A blade-free drone that utilizes several micro blowers to generate a propulsive force that manoeuvres the drone in any direction in the three-dimensional space was developed in [5]. The disadvantage of this bladeless drone is that it is unable to conduct pitching and rolling rotations since the centre of gravity is located at the bottom of the airframe by design.

Due to a lack of technology capable of successfully supporting management activities, cities all over the world are failing to tackle water quality challenges [6]. Drones can solve this problem. This paper aims to provide a methodical overview drone-based sampling water payload. It ends with deliberating the problems and potential for possible examination and applications about drone-based water sampling payloads.

A conceptual design of HUAS (Hybrid Unmanned Aircraft System) which can be used in various fields of interest, from military to civil (search and rescue, environmental surveillance and monitoring, and entertainment) [7]. The mathematical models for weights estimation and balloon static performance analysis are presented, to compare with traditional quadcopter, which show 50% improvement of the flight duration.

This paper shows the cost of current drone flight and factors influencing the cost of UAV technology. There is weight to altitude ratio is taken to consideration for cost influence [3]. Multiple factors such as fuel, life cycle, operation cost, system support, personal, depot maintenance etc., cost is taken into account for drone cost matrices.

This paper proposes a new design for a helium-assisted hybrid drone to enhance flight time. This study aims to develop a hybrid drone system, where a helium balloon is used to provide a lifting force for this purpose [8]. Various analyses are conducted for the design of the hybrid drone system including the balloon shape and size, buoyant force, flight time, and connector design. Through the real experiments, it is proved that the hybrid drone can increase the flight time more than 2.5 times while guaranteeing stable motions.

In this research the amount of thrust can be generated by propeller is calculate with the help of theoretical and practical experiments [9]. This system was tested in air, nitrogen, carbon dioxide, argon, krypton, and helium at and below atmospheric pressure.

1.2 Problem description

For sustainable operations of drone system, it is necessary to increase the flight time [8]. Most of the conventional drones having hovering capability such as quadcopters and hexacopters can fly around 20 mins, which may not be enough for many missions requiring a long-time operation.

Drones transfer data using radio waves on specific radio frequencies, which are called bands. Radio waves are invisible waveforms on the electromagnetic spectrum and are measured in hertz (Hz). Frequency used by device, ranges from 20-kilohertz (kHz) to 300-gigahertz (GHz). Radio waves can travel at limited distance and can transfer small amount of data, Because of this reason conventional drones cannot be used for long range while providing high data transmition rate which limits their capabilities.

Drones with VTOL (such as quadcopter or hexacopter) is easy to move vertically because of the propellers vertical position but bit difficult to move horizontally, while blimp can move in horizontal direction easily but it’s difficult to move vertically.

Conventional drones (such as quadcopter or hexacopter) needed high performance parts such as bldc motor, li-po battery, radio transmitter and receiver, camera module, etc. Because of this reason the overall price of the drone is increases which makes them expensive for end users.

1.3 Contribution

In this work, we aim to develop a helium-assisted hybrid drone for the flight time enhancement while overcoming the major drawbacks of previous system designs. The contributions of our works can be summarized as follows:

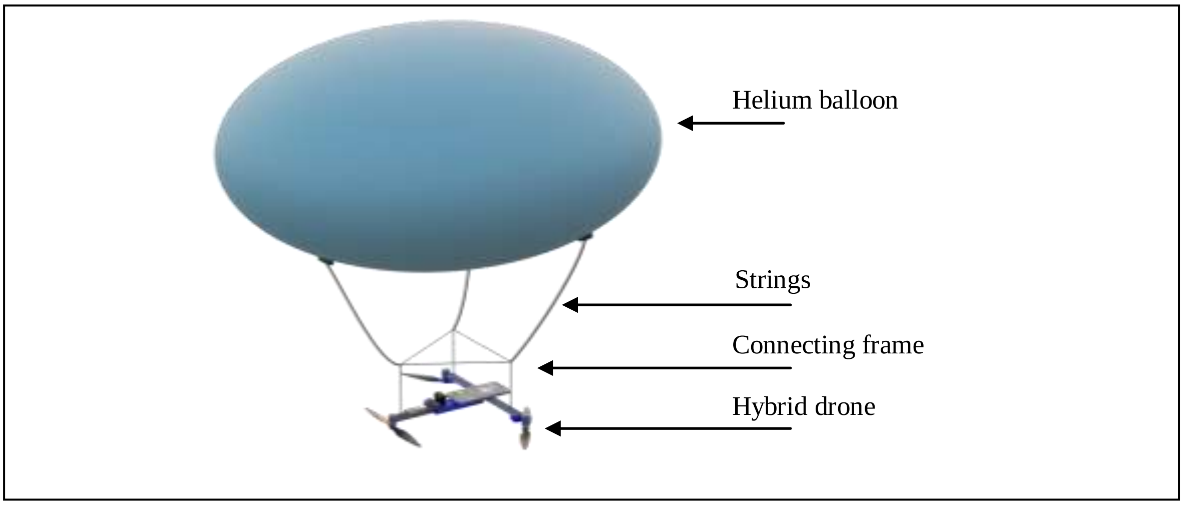

Fig. 1: Conceptual cad design of iot based helium hybrid drone

In the proposed concept, helium balloon will be attached to a top support frame. This top support frame will be then connected to the tricopter using some connecting part. The benefit of the proposed hybrid drone system is that it uses minimum things required for drone to fly. One of the benefits for the proposed design is that parts used in this drone can directly purchase from markets to build the hybrid drone without manufacturing them from scratch. The entire system architecture, with the fundamental component connecting the balloon to the drone, is what we propose in this study. And because the lifting force is generated by the helium balloons, helium drone can fly longer than conventional drones.

To control the drone and take live video output from drone, IOT (internet of things) system is used. Any smartphone can be placed on the drone, which provides internet to microcontroller and live video output to any device (such as smartphone, tablet, laptop, TV. Etc). with this connectivity drone can be control from anywhere over the internet. While we can use sensors which is in the smartphone to do desirable work such as camera to capture HD video and images, GPS to get drones location and many more.

Most of conventional drones has fixed direction of propeller. In this project we are using servo motors in which dc motors are directly connected to change the direction of dc motors by which drone can move vertically and horizontally with ease.

This drone is getting lifting force by helium balloons; thus, we need very little force to move drone from one direction to another, because of the reason the power requirement of the drone is less. For drone controls and video output we used cell phone which can be remove after use, so the cost of the cell phone is not include in this project. After evaluating all the aspect of the project, we conclude it is more affordable than conventional drones, while provides greater flight time, connectivity, and affordability.

2 PROPOSED NEW DRONE CONFIGURATION

2.1 Drone design and parts

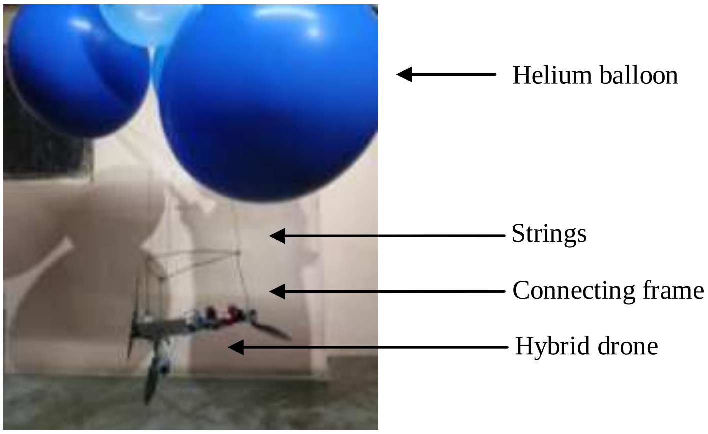

Fig. 2 Hybrid helium drone

As shown in fig. 2 the drone body is connected with the helium balloons by frame. All the lifting force required to lift the drone is generated by helium balloons, while propellers are used to move drone in any direction. To control the drone android application has been developed which send data to firebase Realtime database from where the microcontroller receives data and processes it. Microcontroller gives instructions to motor driver, servo motor and termination system.

The proposed design for the hybrid drone system is simple enough with a low manufacturing process and cost. One of the benefits for the proposed design is that any off-the-shelf VTOL drones and helium balloons can be directly purchased from markets to build the hybrid drone without manufacturing them from scratch. What we propose in this research is the whole system design with the core component connecting the balloon with the drone.

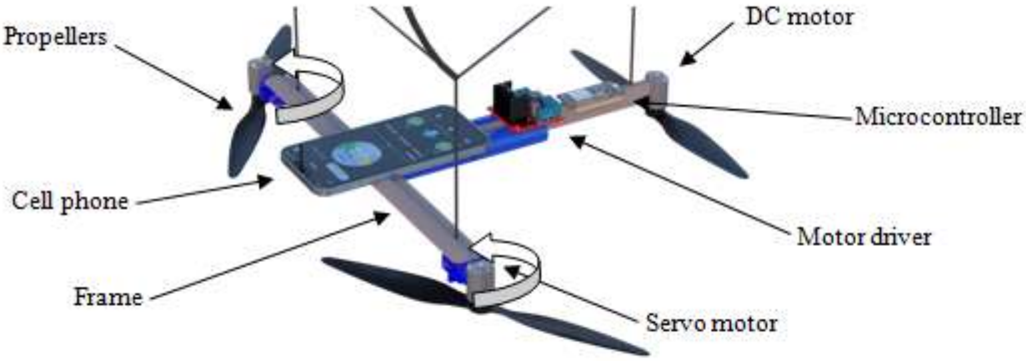

Fig. 3: Drone configuration CAD design

Standard tricopter configuration as shown in fig. 3 is use for drone, except Servo motors is used to change the direction of dc motor by which we can convert VTOL drone to horizontal motion blimp. By doing this we can move the drone at horizontal direction like blimp to achieve greater speed and accuracy with minimal energy.

Analyses on the balloon shape and size as well as the lifting force are provided. These results suggest an appropriate shape and size of the balloon while providing a corresponding lifting force for the system.

Following parts are required for this project:

Sr no.	Name of parts	Weight (grams)	Quantity	Total Weight (grams)
1	Microcontroller (ESP-32)	9.3	1	9.3
2	Dc motor (3v – 6v DC motor)	40	3	120
3	Servo motor (SG90)	9	2	18
4	Propeller (10 inch)	10	3	30
5	Cell phone (Any android phone)	180	1	180
6	Motor driver (L298N)	26	1	26
7	Frame (Plastic)	50	1	50
8	Battery's (2600mAh 18650 cell)	45	3	135
9	Connecting wire, insulating tape, threads, etc.	NA	NA	50
			Total Weight	600

Table 1: Parts used in drone and their weight

Each part has its function: - Microcontroller is used to reads data from firebase Realtime database and process it into instructions. Dc motors is used to rotate the propeller by which small amount of force generated which can be used to move drone. Servo motors is used to rotate dc motor direction by which we can decide the movement of direction (vertical or horizontal). Propellers is used to generate small amount of thrust to move drone. Cell phone serves two purposed 1st it provides live video output over the internet 2nd it provides internet to the microcontroller. Motor driver is used to operate 2 DC motors. All the parts are placed on the frame. Batteries are used to provide power to all the components.

2.2 Proposed drone connectivity

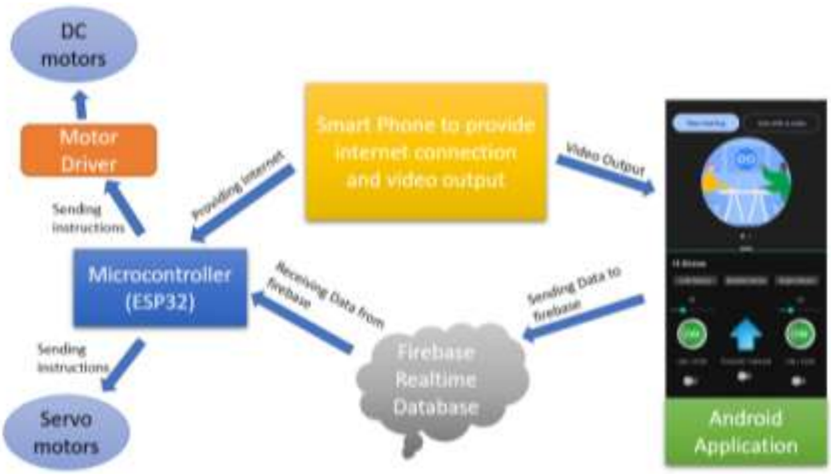

Fig. 4: IOT based connectivity structure of drone

IoT allows for the physical heterogeneous objects to connect with the network infrastructure has widely emerge to provide seamless services and applications [26]. The interoperability, distributed processing, real-time communication, and ubiquitous accessibility characteristics make the IoT a viable solution in every aspect of our daily life.

Firebase is Google's database platform which is used to create, manage, and modify data generated from any android application, web services, sensors etc. It's basically a mobile and web application development platform which has many services like Firebase cloud messaging, Firebase auth, Realtime database, etc. In firebase's Realtime database we can see, modify, and use the Realtime data on firebase cloud and can control any peripheral from anywhere using Internet.

We used firebase Realtime database to transfer data from cell phone to drone. There are two main system needed to be done. First android application which is connected with firebase is used to transfer data to firebase, and second microcontroller which is also connected with firebase to retrieve the data, the code for the system is present at https://github.com/Samyak404.

As you see in fig. 4, we created an android application to store data into firebase Realtime database from where it's readied by microcontroller. The microcontroller processed the data retrieved from firebase and work accordingly.

Live video output is provided by the cell phone placed on the drone's body which provides the live video output over the internet through android application (such as zoom or google meet).

Advantage of using iot system to control the drone over the internet opens immense possibility for the drone using. Iot based drone are much cheaper and gives more range than traditional radio frequency drones. It can be used from multiple devices.

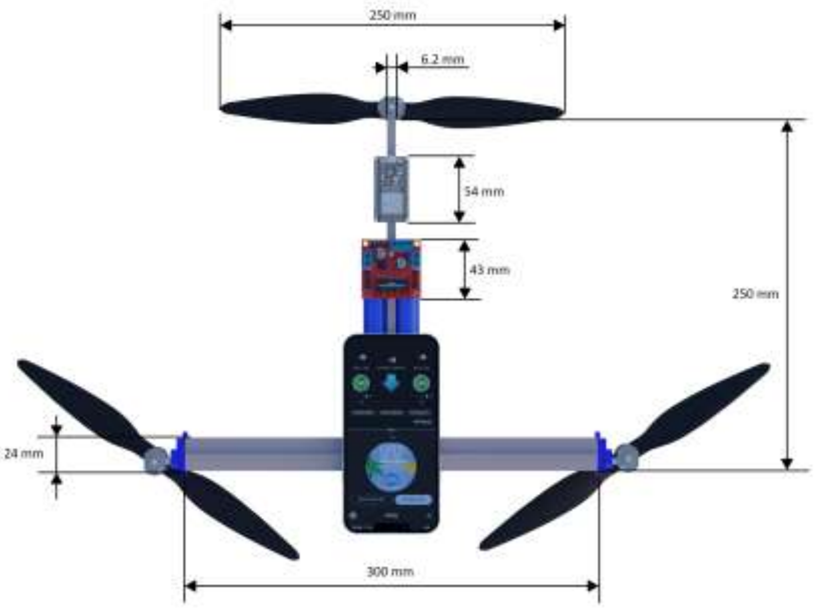

Fig. 5: Top view of drones CAD design with dimensions

2.3 Shape and size of helium balloons and drone

Among various shapes of the helium balloon such as cuboid or square as a candidate for the hybrid drone system, two major factors need to be considered: a size constraint and a lifting force. Although the size constraint depends on the application where the hybrid drone system will be applied, we used spherical shaped balloon with the diameter 36 inch. It is made of polyester which has volume approx. 400 cm^3.

In the fig. 5 dimensions are shown, any cell phone can be used to provide video output and internet connection for communication with microcontroller. The tricopter design is use for drone which is simple enough to make with low manufacturing cost. The two propellers with at the head of T frame moves at same direction while third propeller moves opposite direction in VTOL configuration to change the altitude. First two motors speed, rotation and direction can be controlled by motor driver and servo motor while third motor is fixed and can only move in one direction. Because of this configuration we can swich from conventional VTOL drone to blimp for smooth and stable movements while using minimal energy.

2.4 Power requirements of drone

Power requirement of the drone is as follows:

Sr no.	Name of parts	Quantity	On load (mA)	Stall current (mA)	Total on load power required (mA)
1	Microcontroller (ESP-32)	1	200	600	200
2	Dc motors (3v – 6v DC motor)	3	120	730	360
3	Servo motors (SG90)	2	100 - 250	650	500
4	Motor driver (L298N)	1	36	NA	36
		Average current required (avg. current)			Approx. 1100

Table 2: Power requirement of all the parts used in drone

Drone is getting lifting force by helium gas and gets its motion by 3v - 6v dc motor. Because of this, the power required to run the drone is less than conventional drone (such as quadcopter or hexacopter).

First battery pack consist of two 18650 cells with capacity of 2600 mAh at 3.7 volt each, which connected in parallel, means total voltage is 7.4 volt. This used to run one microcontroller, two servo motors, two dc motors and one motor driver. These two cells are connected in parallel which makes the total voltage of 7.4 volt with capacity of 2600 mAh. Thus, the total power of the first battery pack is (voltage * capacity) 19.24-watt hour.

And second battery pack consist of one 18650 cells with capacity of 2000 mAh at 3.7 volt is used to run third dc motor. Which makes its total power 7.4-watt hour. Termination switch is also connected with second cell, in case of any unwanted event, the mechanism is created which is powered by second cell to pop one of the balloons, to bring drone to the ground.

Battery backup calculations: -

For first battery pack (2600 mAh, 7.4 volt)
Backup Time (in hours) = Battery Capacity (in Ah) * Input voltage (V) / Total Load (in Watts)
= 2.6 * 7.4 / avg. $_{current}$ - current draw of 3rd dc motor* voltage required
= 2.6 * 7.4 / 1.1 – 0.12 * 7.4
= 2.65 (2 hours and 39 minutes)

For second battery pack (2000 mAh, 3.7 volt)
Backup Time (in hours) = Battery Capacity (in Ah) * Input voltage (V) / Total Load (in Watts)
= 2 * 3.7 / current draw of 3rd dc motor * voltage required
= 2 * 3.7 / 0.12 * 3.7
= 16.66 (16 hours and 39 minutes)

As per the theoretical calculation if we assume the 80% of power discharge ratio of the first battery pack, we get 2 hour and 7 minutes of battery backup.

2.5 Theoretical analysis of lifting force

The most frequent gases utilised to generate lifting force are hydrogen and helium. Despite the fact that helium is 2 times heavier than hydrogen, they are both much lighter than air, hence the difference is negligible.

Hydrogen appears to be the ideal to generate lifting force because it is the lightest existing gas (7 percent the density of air). It's simple to make big quantities, but it's highly flammable. The second-lightest gas is helium. As a result, it's also a good choice for lifting. This gas is non-combustible, which is a huge benefit.

Using the principle of buoyancy, the lifting power of hydrogen and helium in air can be computed as follows:

Helium has nearly double the density of hydrogen. Rather than their ratios, buoyancy is determined by the difference in densities (gas) and (air). As may be seen from the buoyancy equation, the difference in buoyancies is roughly 8%.

$FB = (\rho_{air} - \rho_{gas}) \times g \times V$

Where FB = Buoyant force (in Newton); g = gravitational acceleration = 9.8066 m/s2 = 9.8066 N/kg; V = volume (in m3). Therefore, the amount of mass that can be raised by hydrogen in air at sea level, equal to the density change between hydrogen and air, is:

$(1.292 - 0.090)\ kg/m^3 = 1.202\ kg/m^3$
and the buoyant force for one m^3 of hydrogen in air at sea level is:
$1\ m^3 \times 1.202\ kg/m^3 \times 9.8\ N/kg = 11.8\ N$
Therefore, the amount of mass that can be lifted by helium in air at sea level is:
$(1.292 - 0.178)\ kg/m^3 = 1.114\ kg/m^3$
and the buoyant force for one m3 of helium in air at sea level is:

$1\ m^3 \times 1.114\ kg/m^3 \times 9.8\ N/kg = 10.9\ N$
Thus, hydrogen's additional buoyancy compared to helium is:
11.8 / 10.9 ≈ 1.08, or approximately 8.0%

This calculation is at sea level at 0 °C. For higher altitudes, or higher temperatures, the amount of lift will decrease proportionally to the air density, but the ratio of the lifting capability of hydrogen to that of helium will remain the same. This calculation does not include the mass of the envelope need to hold the lifting gas

Lifting gas	**Density at sea level and 0^0C**	**Lifting force of $1m^3$ of gas**
Helium (He)	$0.178\ kg/m^3$	1.1115 kgf or 10.9 N
Hydrogen (H)	$0.090\ kg/m^3$	1.2033 kgf or 11.8 N
Air	$1.292\ kg/m^3$	NA

Table 3: Thermotical lifting force of gas

Given Data: -
diameter of balloon (D) = 36 inch = 91.44 cm = 0.91 m
radius of balloon (r) = 0.45 m
volume of balloon (V) = $0.41\ m^3$
total weight of drone (W) = appro. 650 grams

Calculations: -
Lift generated by one (36 inch) helium balloon = volume of balloon filled with helium * lifting force of gas

= 0.41 * 1.1115
= 0.45 kgf

By taking purity factor of helium and the weight of the balloon into consideration, we need 2 ~ 3 helium balloons to lift the 650-gram drone.

* Note. Temperature of the lifting gas is considered 0^0 c at sea level and density with 100% purity, in real life values can be different.

3 EXPERIMENTAL RESULTS

The total weight of the hybrid drone system including the drone, battery, support platform, and the balloon was 673 g. Depending on the volume of the helium filled in the balloon, the total weight of the hybrid drone system changes since it provides a lifting force. For the maximum lifting force helium balloons needs to be fully filled with the helium, which, however, may damage the balloon in the worst case, recalling that it is made from a thin polyester material.

Thus, it is indispensable to analyse how much the helium gas can fill the balloon with a corresponding lifting force. we determined that the actual balloon is filled to 94% of its capacity can resulting in the lifting force of 270 gram. Thus, we used 3 to 4 balloons to lift the drone.

By experimenting this drone system in close room, we get approximately 2 hour of flight time with stable motion. The maximum velocity of drone is calculated based on practical experiment which is approximately 10.8 km/h or 3 meter per second. As pre the battery backup, the battery lasted till the end of experiment.

4 CONCLUSION

This paper proposed a new IOT based hybrid helium drone system to enhance the flight time. Helium drones can be used in many purposed where long flight time require. Because the lifting force is generated by helium or hydrogen gas, the power requirements of the helium drone is lesser than conventional drones, because of this reason, we can use low performance parts (such as motor, battery, propeller, etc.) in drone, which directly reduces the cost of the drone. With the IOT based system it can be controlled by any device (such as smartphone, tablet, laptop, etc.) over the internet. While the live video output is provided by cell phone placed over the drone, we can get the best possible video quality.

By analysing the previous work on this topic, we came up with the new drone configuration. In this hybrid drone system, the shape of balloon, weight, battery backup and size of the drone was analysed together with the lifting force analysis. To calculate the theoretical flight time, the flight time calculation is provided, which guaranteed that this hybrid drone system can fly more than 3-4 times longer than the conventional drone.

There are some disadvantages of this drone system. Because the lifting force is generated by helium or hydrogen the volume of balloon gets bigger. It cannot be used in outdoor environment with ease. Flexibility is lower than conventional drones. But there are some advantages such as, more flight time than conventional drones, smooth and stable movements, affordable than others, works best at indoor, etc.

For the future research on this topic many things can be improved such as, by creating the custom board which can work as a microcontroller and motor driver the weight and power consumption can be reduced. Now a days phones with reverse charging can power the low power drone without any external power supply, with this approach the cost and the load of the drone will reduce significantly. While by using cell phone we can get the best possible camera output at best price.

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