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Development of a Helium Gas Balloon Flying System for Aerial Photographing and Observation

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***Abstract*—This paper describes the implementation of a helium gas balloon flying system equipped with a camera and tracking subsystem for aerial photography. This is partially the results of a successful project conducted in November 2012 by a group of electrical and electronic students from the University of Johannesburg. The goal of this project was to take aerial pictures at the highest possible altitude above the sea level from the flying system while tracking its position in real-time. The solution proposed was based on a low cost unmanned system for a reliable and optimal aerial observation and tracking, suitable for start-ups companies or research groups.**

Keywords-Helium gas balloon; flying height; aerial observation; tracking subsystem; flying payload

I. INTRODUCTION

The aerial observation of the atmosphere became a very relevant topic nowadays that demands a lot of inputs. Considering the fact that it is difficult and even not advisable for helicopters to fly at low altitude (less than 300 meters) because of diverse reasons like weather conditions, mountain areas, island areas, strong winds; It is preferable to operate unmanned systems like helium gas balloons systems or Unmanned Aerial Vehicles (UAVs) also known as drones.

This last approach is safer, more accurate, faster and lower cost. Such systems have many benefits, for instance they can be used in case of earthquake, volcano, tsunami, typhoon, to survey disaster areas, and send real time information to the base station; they can served in photographing and observation from high or low altitude for vegetation survey and weather predictions.

Many systems have already been developed by scholars for aerial photographing and observation. Some of them are based on balloon and others based on robot or unmanned helicopters. UAV systems are able to perform attitude stabilization endurance and autonomous control but cannot fly for long time [1]-[3]. On the other hand, balloon based systems can fly continuously for undetermined periods, reach steady buoyancy, suitable for high altitude, but the system control is very unstable due to light weight of the payload and lack of stabilization system [4]-[6].

However depending on the target application, one can opt for balloon or robot based systems. In our case, the objective of this research was to perform aerial photography at the highest possible altitude above sea level. Therefore the helium gas balloon was chosen because this gas is less heavy than air, so the helium balloon due to less weight should ascend quicker in the atmosphere according to Archimedes principles. Also helium is an inert gas, environmentally friendly and less explosive than hydrogen or methane. Many more details about the design, advantages and calculations on the helium gas balloon can be found in [7] and [8].

In this paper, an approach for achieving flying observation system is proposed. We will focus more on the aerial photography and tracking system of the payload than the design of the helium gas balloon. The rest of this paper is structured as follows: Section II presents the system design and requirements. The system implementation is detailed in Section III. Then Section IV shows the results obtained as well as some important analysis and discussion on the system. Finally we provide a conclusion in Section V.

II. SYSTEM DESIGN AND REQUIREMENTS

The overall system is made of a helium gas balloon connected by a rope to the payload containing 2 subsystems: the tracking and the sensing systems.

A. *Helium Gas Balloon*

Fig. 1 presents the design of the balloon. The balloon is designed to carry a payload of less than 1 kg, with an internal diameter of 1.4 m and it is made of latex TA200. The payload box dimensions are 20m x 15m x 15m with a thickness of 10 cm. The rope passes through the centre of the parachute of area dimensions 1.5m x 1.5 m. After the burst of the balloon at the highest point, the payload will pull the mechanism down and the parachute will open automatically due to air pressure, this is to minimise the damage of the payload returning back to the ground. The polystyrene box provides built-in insulation to the payload.

B. *Sensing and Tracking Subsystem*

The design is based on low cost components with reliable functionality. Fig. 2 presents the design of the tracking and sensing subsystems. The sensing subsystem is designed to read the temperature and the atmospheric pressure at regular intervals. In order to achieve this, the following components were used:

- Arduino Uno R3 board with an operating voltage of 5V; ATmega328 micro-controller; 14 Digital I/O pins (of which 6 provide PWM output); 6 analog input pins and clock speed of 16 MHz [9].

- BMP085 biometric pressure sensor, this device can measure the temperature and the atmospheric pressure. Pressure sensing range is 300–1100 hPa (9000m to -500m above sea level), the operational temperature range is between -40 to +85 C [10].
- BOB00544 data logger, this is an interface to store data into the SD card. Data are saved periodically throughout the entire flight [11].

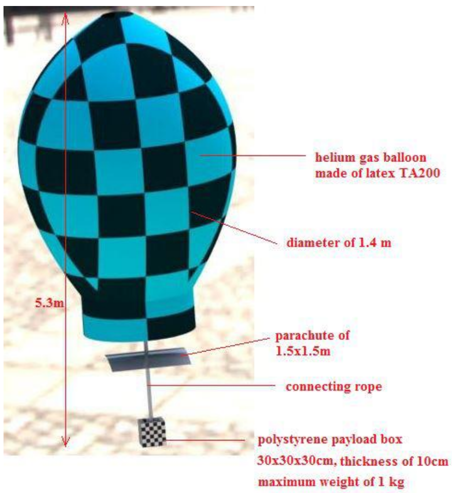

Figure 1. Balloon design

The tracking part is essentially based on a Samsung Galaxy Ace smart phone GT-S5380, this cellphone is relatively cheap and has many features. 3G network HSDPA 900/2100; GPRS; Speed HSDPA of 7.2 Mbps; Camera 5 MP; 2592x1944 pixels autofocus, LED flash; Video VGA at 24 fps; CPU 800 MHz ARM 11; GPS Adreno 200; Sensors: accelerometer, proximity, compass; OS Android 2.3; SMS (threaded view); MMS; Email; GPS with A-GPS support; Battery Li-Ion 1350 mAh. This smartphone is used for the following reasons [12].

- Tracking the GPS location of the payload through 'MTN WhereRU' which is an MTN (telecommunication company) service tracking a specific Subscriber Identity Module (SIM) card within a certain range of communication.
- Recording the altitude again as a backup of the sensing mechanism via the appropriate sensor.
- Sending regular text messages to the base station computer containing data information, while there is network coverage.

According to the BMP085 biometric pressure sensor datasheet, the relationship between the atmospheric pressure and the altitude is as follow [13]:

$$altitude = 44330 * (1 - (\frac{p}{p_0})^{\frac{1}{5.255}})$$

where p is the sensing pressure and $p_0 = 101325 \ Pa$ is the pressure at sea level.

Since the objective is to capture images at highest altitude above sea level, the sensing and tracking subsystems serve as backups to each other in the sense that both of them record the altitude of payload during the flight simultaneously.

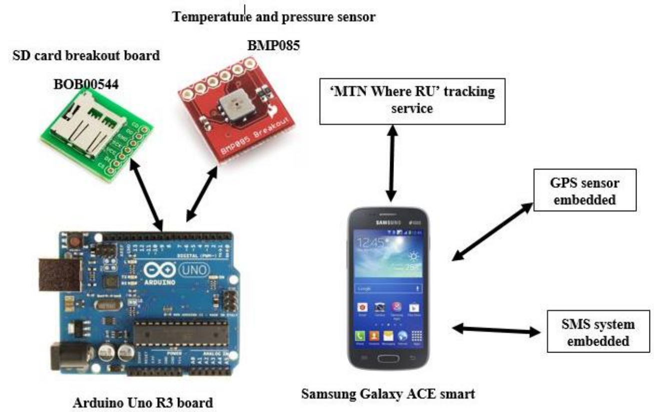

Figure 2. Sensing and tracking system

III. System Implementation

A. Tracking Subsystem

The Galaxy Ace smart phone is Android based. Python scripts were written and deployed on the phone for recording the altitude of the payload and also for taking photos at different intervals of time and geo-referenced.

For the Python scripts to run on Android platform, the following applications were installed to set up Python environment: *SL4_r6.apk* and *PythonForAndroid_r4.apk*. The *wakeLockAcquirePartial()* function was used to keep the phone awake at all times but allowing the Android phone screen to go off, while the script keeps on running; This was to minimise energy usage. The *startLocating()* is used for obtaining GPS position from the Android platform as follow [14].

```
import android
import time
droid=android.Android()
droid.wakeLockAcquirePartial()
droid.startLocating()
```

For the photo recording, the *cameraCapturePicture()* function was used for taking a photo and save it to a specific directory as follows:

```
while(x==x):
locpic='sdcard/Flight/'+str(x)+'.jpg'
droid.cameraCapturePicture(locpic,True)
 time.sleep(1000)
```

The mechanism was programmed to record a photo and the corresponding GPS coordinates with the same file name every 10 seconds.

The 'MTN WhereRU' tracking service was used to track the location of the payload after landing. Although, the network signal was lost at a certain altitude, this service served to obtain the location of the payload within network coverage, especially after landing. There are two ways for retrieving the payload location. The first one is by USSD, user dial **120*911*cellphone_number#*, to receive the location of the payload. The second is tracking via MTNs website from the payload SIM card account [15].

B. *Sensing Subsystem*

This part was implemented to retrieve the temperature and atmospheric pressure data of the payload at regular interval of time. This data is saved on the SD card. Fig. 3 presents the layout connections of the sensing system.

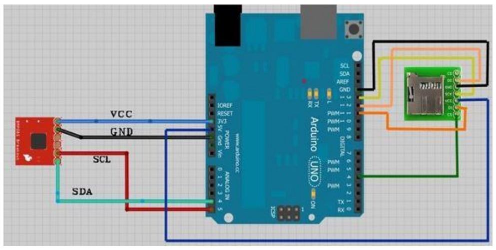

Figure 3. Layout connection of sensing system [9]

Arduino scripts were deployed on the micro-controller to establish communication with the BMP085 barometric pressure sensor using the initializing functions *bmp085Read()* and *bmp085ReadInt()*. Once the communication is established, the sensor has to be calibrated and every value from the BMP085 address stored in a global variable to be accessible by the code. The temperature and pressure values are calculated according to the sensor datasheet.

The sensing and tracking subsystems were implemented and deployed independently. This means that they were running on two different timers. The sensing subsystem data (temperature, pressure and altitude) were saved in a text file every 10 seconds, each data point having a unique ID. The tracking subsystem script outputs an image and the corresponding data text file containing (GPS coordinates, speed, altitude, time) with the same name or ID every 10 seconds. Fig. 4 presents some contents of output text files from the sensing subsystem (at the left) and tracking system (at the right).

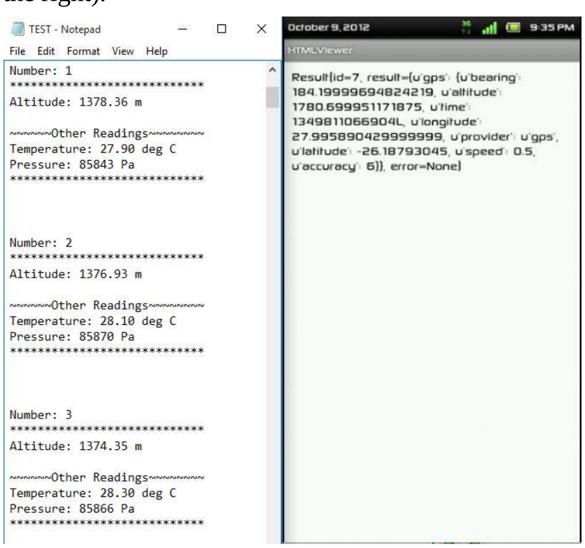

Figure 4. Text files from sensing and tracking subsystems

IV. System Results and Analysis

The system was implemented according to the design and requirements mentioned above. Fig. 5 presents the final system ready for launch.

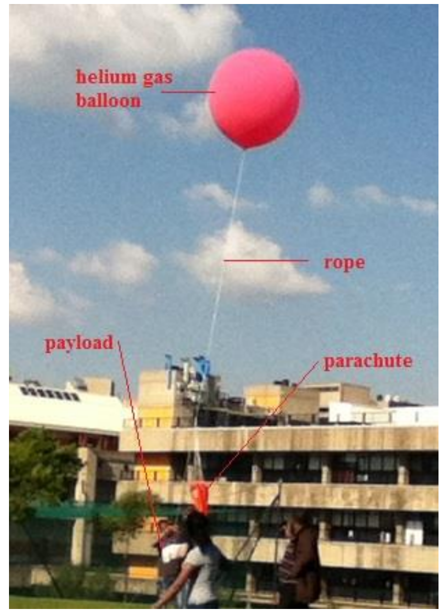

Figure 5. Implemented system ready for launch

The system was launched on a safe grass field area in Parys, Free State, South Africa, around the point (latitude: -26.97, longitude: 27.31 and altitude: 1443 metres above sea level) on the 3rd November 2012, (wind direction SE, cloud cover 0/7, atmospheric pressure 104.7kPa, average temperature 24 C). The payload was found at beginning of December 2012 in the outskirts of Vereeniging (Gauteng Province, South Africa) around the point (latitude: -26.40, longitude: 27.55 and altitude: 1479 metres above sea level), this is approximately 125km away from the launching position.

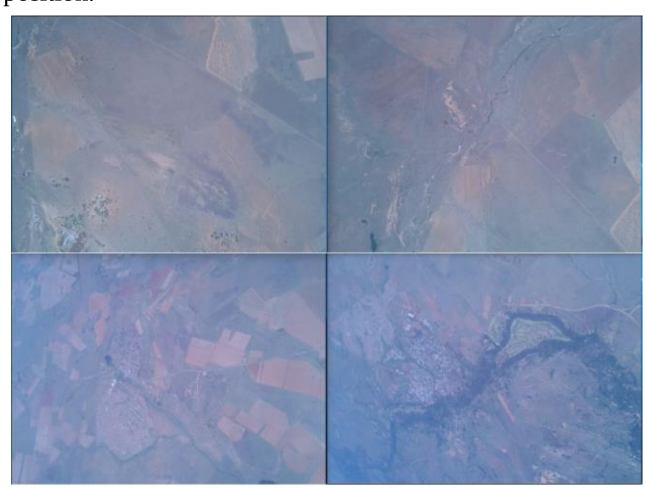

Figure 6. Aerial photos from the payload

Fig. 6 presents some aerial photos during the assent of the payload. According to the text files, the payload was ascending up with an average velocity of 5.5m/s. There are some measures taken to ensure the success of this event. A sufficiently strong rope was used to connect all parts of the mechanism to avoid tearing off during flight. The batteries or power supplies of the tracking and sensing subsystems were fully charged before the flight. Many tests were conducted to ensure that the parachute can open after the bursting of balloon. The system design was based on computerised simulation of the flight for a maximum altitude of 30 km (98425 feet) which lies in the stratosphere part of atmosphere. The tracking subsystem was surrounded by insulation materials to avoid temperature dissipation at high altitude. The BMP085 sensor was exposed to outside in order to have good readings of pressure and temperature.

The highest altitude was recorded at an altitude of 13.7821km equivalent to 45216.86 feet above sea level at a point of latitude -26.69 and longitude 27.47. Fig. 7 presents some photos recorded around the highest altitude reached by the payload.

Fig. 8 presents the graph of atmospheric pressure (measured in Pascal) vs. altitude (in meters) recorded during the flight.

Fig. 9 presents the recorded data from the sensing subsystem of the temperature (in C) versus altitude (in meters) recorded during the flight. According to the data, the temperature start increases immediately after the launch for about half a kilometre before starting decrease.

However, the BMP085 sensor determines the altitude based on the local atmospheric pressure which varies according to the local weather, therefore the reading obtained are not perfectly accurate, as result of no QNH correction. According to this sensor datasheet, the offset range is around $\pm 2\%$.

Figure 7. Aerial photos at the highest point about 13.7821 km above sea level

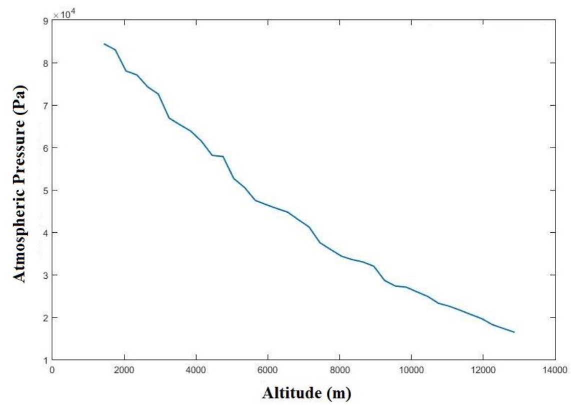

Figure 8. Pressure vs. altitude during flight

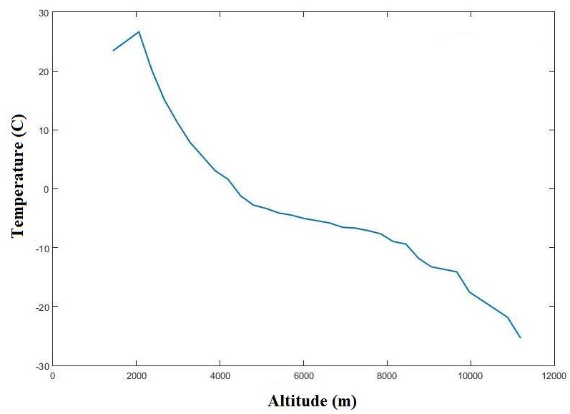

Figure 9. Temperature vs. altitude during flight

V. CONCLUSION

An approach for aerial photography and observation based on a helium gas balloon flying system was presented in this paper. The mechanism aimed to obtain the highest altitude aerial photo from the payload. In order to achieve this task, two electronic subsystems were developed; The sensing subsystem based on an Arduino board that served to record data about the pressure and temperature during the flight; And the tracking subsystem based on a simple Samsung Galaxy Ace phone, used for taking photos, recording GPS coordinates and altitude of the payload. The objective was performed and the payload reached a highest altitude of 13.7 km above sea level. The world record of helium gas balloon flying system is about 30 km. Although our mechanism achieved less than the record, we believe that it is ideal for university projects or research laboratories in order to expose young engineering students to more practice as this design was based on low cost components.

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