Exploring the Opportunities of a Balloon-Satellite in Bangladesh for Weather Data Collection and Vegetative Analysis

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Abstract. For a third world country like Bangladesh, satellite and space research is not feasible due to lack of funding. Therefore, in order to imitate the principles of such a satellite Balloon Satellite can easily and inexpensively be setup. Balloon satellites are miniature satellites, which are cheap and easy to construct. This paper discusses a BalloonSat developed using a Raspberry Pi, IMU module, UV sensor, GPS module, Camera and XBee Module. An interactive GUI was designed to display all the data collected after processing. To understand nitrogen concentration of a plant, a leaf color chart is used. This paper attempts to digitalize this process, which is applied on photos taken by the BallonSat.

1. Introduction
The Space Age began with the development of space researches that begin in the mid nineteen hundred with the launch of Sputnik [1]. During that time, there was a competition going on mainly between USA and Russia. Soon, other countries had joined in this space race. Nowadays, space research is a very rich and emerging topic of science and engineering. Satellites play an important role in field of space study. These are man-made devices purposefully placed into the Earth orbit for numerous reasons. The cost of setting up a satellite is in the range of millions of dollars. For a developing country like Bangladesh, it is very difficult even to build a small satellite and without a practical satellite, space research will not be able to attract students [2]. Table 1 shows the cost and the development time required to build several small-scale satellites [3].

| Satellite   | Country     | Year | Mass  (kg) | Development Time  (years) | Development Cost (US Dollars) |
|-------------|-------------|------|------------|---------------------------|-------------------------------|
| UoSAT-1     | Great Britain | 1981 | 60         | 2.5                       | 850,000.00                    |
| UoSAT-2     | Great Britain | 1984 | 65         | 0.5                       | 1,300,000.00                  |
| Falcon Gold | United States | 1997 | 179        | 0.7                       | 550,000.00                    |
| SUNSAT      | South Africa  | 1998 | 624        | 4.5                       | 1,950,000.00                  |
| TUBSAT A    | Germany      | 1991 | 35         | 5                         | 2,000,000.00                  |
| BREMSAT     | Germany      | 1994 | 63         | 3                         | 3,500,000.00                  |

Another cheap alternative to satellites is to build a Balloon Satellite. A BalloonSat is constructed using cheap, easily available off-the-shelf electronic components. The main reason behind making a BalloonSat is that students of developing countries can get initial idea and experience about space research with a very low budget [4]. The practical implementation of a BalloonSat, among others, might be to collect weather data periodically to figure out the changes in weather patterns. It can also be used to detect the rate of riverbank erosion [5]. Other uses might be by biologists to keep track of endangered animal species in a forest.
2. System Overview

2.1. Electronic Components

The main computational brain behind this BalloonSat is the Raspberry Pi 2 Model B+. It has been chosen for its high processing power with a clock speed of 900MHz and 1GB RAM. The Adafruit Ultimate GPS Module is used to keep track of the BalloonSat explores the skies with error less than 3m. A 10-degree Inertial Measurement Unit (IMU) is used in the setup. It senses 3 axes of acceleration, 3 axes of gyroscopic data, 3 axes of magnetic fields, pressure, temperature and altitude. In addition to these, a SI1145 sensor chip enables UV index sensing along with, IR and the visible light spectrum. The 5-megapixel Pi-Cam is programmed manually to take high definition photographs at 30s intervals, the circuit setup is as shown in figure 1 and the actual circuit on PCB in figure 2 both of which is our own design. The data collected by these sensors (except images) are then transmitted wirelessly using an XBee radio module. A 9V DC battery is regulated to 5V to power up the whole circuitry.

![Figure 1: Circuit diagram of BalloonSat.](image1)

![Figure 2: Actual circuit integration](image2)

2.2. The Ground Station (GS)

A Ground Station (GS) is developed to receive and store sensory data. The Graphical User Interface (GUI) of the GS has been coded using LabVIEW, which is a system-design platform and development environment for a visual programming language from National Instruments. As LabVIEW uses visual language, it is very easy to implement and build the GUI. The interface is grouped into several tabs where data from the sensors are viewed separately. The GS also has a data logging option enabled. Every time the program is run, it will save the data in an Excel spreadsheet for further analysis.

In the GUI, the tabs are labelled as Connection, GPS, Gyro, IMU Data, Light Sensor and Weather. The connection tab deals with the serial connection and shows the input in the com port. There is also a drop down list to select the correct com port to begin the connection. It also has a slider to adjust the delay of the receiving data. GPS tab shows the satellite time and date and also the longitude and latitude of the current position. There is also a button which will call up an executable file (.exe) which can plot the positions in a map. The Gyro tab shows the X, Y and Z components of the gyroscope in a live graph. The IMU Data (inertial measurement unit data) tab displays the pitch, roll, heading and altitudes in radial dials and a bar. The following tab is the Light Sensor tab which displays information from the SI1145 UV sensor. This tab has three dials to visualize Visible Light, Infrared and UV Index.

Finally, the Weather tab shows atmospheric temperature and pressure as well as the CPU temperature of the Raspberry Pi. Figure 3 shows some of the tabs of the GUI.
Figure 3(a-d): Different tabs of the Graphical user interface (GUI)

Figure 4 below summarizes the LabVIEW program used for the Ground Station. The serial connection opens with a predefined Baud Rate of 9600. The data that is being pulled from the XBee module connected to the computer is stored in a string where each data is separated using a comma delimiter. Then pattern match functions are used to parse each data before the commas. When the program stop button is clicked, the program is halted and the serial connection with the XBee module is closed.

Figure 4: Flow-chart of the LabVIEW program
2.3. Applications

A cheap BalloonSat such as the one discussed in this paper can be used for several purposes. As it is easy to build and implement, multiple copies can be mass manufactured and flown in different areas of the country. Then collected data can be stored in a dedicated server for further weather pattern analysis. Students and researchers can benefit from these data to study the arrival of storms or other natural calamities. Figure 5 below shows a plot of temperature against time, which was taken using the BalloonSat for ten hours.

![Figure 5: A plot of ten-hour time period temperature data](image)

3. Image Analysis

3.1. Image Thresholding and Boundary Detection

Image thresholding is the simplest method of image segmentation. From a RGB image, thresholding can be used to create binary images [6] [7]. The simplest thresholding methods replace each pixel in an image with a black pixel (0) if the image intensity $I_{x,z}$ is less than some fixed constant $T$ (that is, $I_{x,z} < T$), or a white pixel (1) if the image intensity is greater than the constant. Color images can also be thresholded. The approach is to designate a separate threshold for each of the RGB components of the image and combine them with an AND operation.
Figure 6: Color thresholding of an image of a park

Figure 6 above shows the original image as input and the green filtered image after thresholding. The image was originally taken by our BalloonSat. The pixels of the original image which have values within the defined range of RGB values are represented as white (1) and the rest as black (0). Later we used boundary detection to identify patches of greenery, which was inspired by the work of Maloof et al [8].

3.2. Vegetation Health Analysis

Image processing is very useful for agriculture; we can take an image of a vegetation field and match the leaf color with the leaf color charts to understand the Nitrogen fertilizer dosage of the field. C. Witt (2005) says that, the leaf color chart (LCC) as shown in figure 7 helps the farmers to evaluate plant nitrogen (N) demand [9]. The LCC was made by calculating the leaf spectral reflectance measurement, this reflectance varies with the color of the leaf. The leaf color chart has four different green shades as shown in figure 7, so we took each shade and found its corresponding RGB composition in MATLAB. Table 2 shows the RGB values obtained using MATLAB. An image taken from the BalloonSat can be processed using these values to find the nitrogen composition and identify plant types of a region saving farmers from manual inspection [10].

Figure 7: LEAF Color Chart (LLC), courtesy of Irrigated Rice Research Consortium
Table 2: RGB Spectrum of IRRI Leaf Color Chart (LCC)

| Strip Number | Red     | Green    | Blue    | Nitrogen Level       |
|--------------|---------|----------|---------|----------------------|
| 2            | 103-255 | 145-255  | 0-12    | Critically low       |
| 3            | 83-98   | 145-165  | 0-30    | Below average        |
| 4            | 0-106   | 111-113  | 0-30    | Above average        |
| 5            | 0-104   | 0-105    | 0-62    | Surplus amount       |

4. Conclusion

Space research is still a new field for a developing country. Before jumping to large-scale satellites for research purposes, Students can approach BalloonSat such as ours to collect data for analysis and implementation. This paper focuses on the acquisition of data imitating a real world satellite and implementing those data in our activities such as agriculture and weather. The acquired information could help farmers improve their yield of crop production; weather can also be predicted using a BalloonSat warning farmers and villagers of incoming natural disasters before it is late. BalloonSat could provide a developing country with the opportunity to approach space research, improve agriculture and weather prediction.

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