IAC-22-B4.IP.30

Environmental Satellite to Monitor Real-Time Environmental Parameter Changes in Response to Increased Climate Action

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Abstract

Environmental Satellite is a simulation of a real satellite with a mass of less than a thousand grams and integrated with subsystems such as on-board computers, microcontrollers, sensors, and communication systems. Climate change presents the single biggest threat to sustainable development. So, a prototype of an Environmental Satellite was created as a research project to monitor the different aspects of the environment. The main objectives include measurement of environmental parameters such as temperature, pressure, altitude, dust, humidity, and pollution. The data collected by the sensors were transmitted in real-time through wireless channels, retrieved, and processed on-ground stations. This data was stored in our database and represented graphically in the Graphical User Interface. The data from the device was analysed and compared with standard data to check its accuracy. This device transmitted data directly on the cloud which can be accessed from any part of the globe. The system was capable of transmitting data through Radio Frequency which could be helpful for research in remote areas. The data provided by the sensor was analysed and compared with standard data from open weather maps and the system was found to be accurate with a 95% confidence level.

Keywords: Environmental Satellite, Climate change, Environmental parameters, Ground station, Sensors, API.

Abbreviations

API Application Programming Interface
DC Direct Current
DB Database
GHZ Gigahertz
GUI Graphical User Interface
I/O Input/Output
ISM Industrial, Scientific and Medical
JSON JavaScript Object Notation
ML Machine Learning
PCB Printed Circuit Board
SDG Sustainable Development Goals
SQL Structured Query Language
USB Universal Serial Bus

1. Introduction

An environmental satellite is a simulation of a real satellite with a mass of less than a thousand grams and integrated with subsystems such as on-board computers, microcontrollers, sensors, and communication systems [1]. The system consists of a ground station for receiving real- time data from the Satellite; the data received on-ground station gets analysed and displayed in the GUI. This research project helps to understand the meteorological behaviour of the low troposphere.

Climate change presents the single biggest threat to sustainable development. This problem has inspired many scientists to study weather impacts in living as well as non-living beings. Previously, there were simple and inaccurate instruments, which were inadequate for easy reading and storing data. Nowadays, many advanced observatories and labs are collecting the environmental parameters continuously for different applications. However, these come at the high cost of money, time, and human resources. In this scenario, miniaturised satellites can play an important role not only in academics but also in scientific projects for observing, monitoring, and analysing the environmental data. Even though the cost for constructing small satellites is very low compared with those of the standard sizes designed for science and communication missions, the data provided by these satellites are found to be highly reliable [1].

In the context of our country Nepal, the government has set up pollution measuring stations at 19 different places in the country as shown on the website www.pollution.gov.np [2]. On one hand, while this number is too low, on the other hand, the reliability of the data can be questioned because the 'Research & Data Analysis' page of the website had a blank page [2].

Environmental data analysis is an utmost necessity in our country.

This is a research-based project where a prototype for measuring environmental parameters using relatively inexpensive components was developed. The environmental data from our university location was collected and a system for visually monitoring the data from the ground station was created. By collecting the data from different sensors and analysing various data the current climatic conditions of our location was studied.

Pollution can also be monitored, and alerts can be generated. By comparing our data with the data from pre-existing sources, the usefulness and accuracy of our system was verified. The primary objective of this project is to measure the environmental parameters and develop a system for monitoring the changes in those parameters.

This system retrieves the real-time metrological information i.e., atmospheric pressure, temperature, elevation, and atmospheric humidity. Besides these, the system is embedded with a dust level monitoring system to track the dust density on the lower troposphere. Measuring the pollution level around brick industries, factories, the lab is also one of the important objectives. This system provides free access to data to researchers who would like to study metrological behaviours of specific areas.

2. Material and methods

Different kinds of devices and methodologies were used for the design and development of the satellite:

2.1 Design

Initially, the system architecture of the Environmental Satellite was proposed and finalised. Detailed study of available hardware resources and their cost was analysed to stay within budgetary constraints.

2.1.1 System Architecture

The system block diagram represents the system architecture where there are 2 different modular systems.

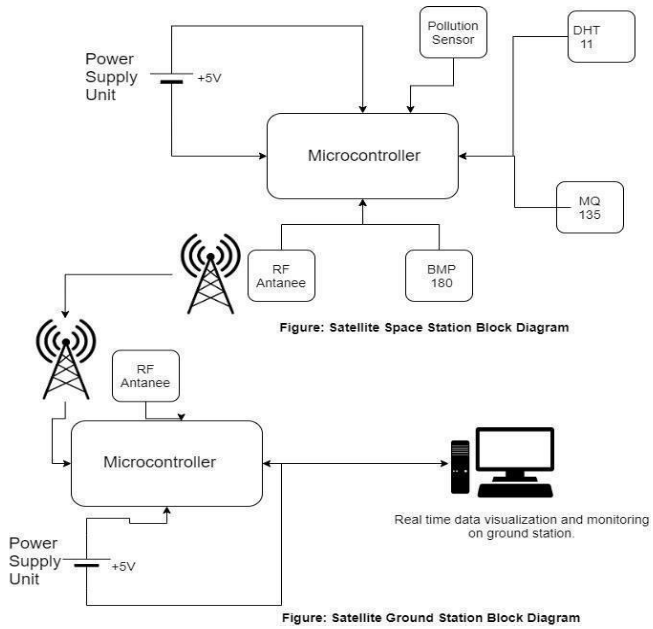

Fig. 1. System Architecture

The first one consists of a satellite that remains in space for a short time. The satellite would be launched on a helium balloon or a drone. It consists of a Microcontroller as its main processing unit. It has its self-sustaining power system which gets charged with a solar panel. Different sensors are embedded on it to sense environmental variables and the information is transmitted to the ground station, where the information gets decoded and loaded on a computer for easy visualisation.

2.1.2 Data Flow

Fig. 2. Data Flow Diagram

2.1.3 Mechanical Design and Construction

The system was designed to be hard hand-wired. Mechanical design includes designing the shape of the system so it can be constructed with minimal payload and proper utilisation of space. The 3D printed case for protecting the internal sensors and subsystems was printed.

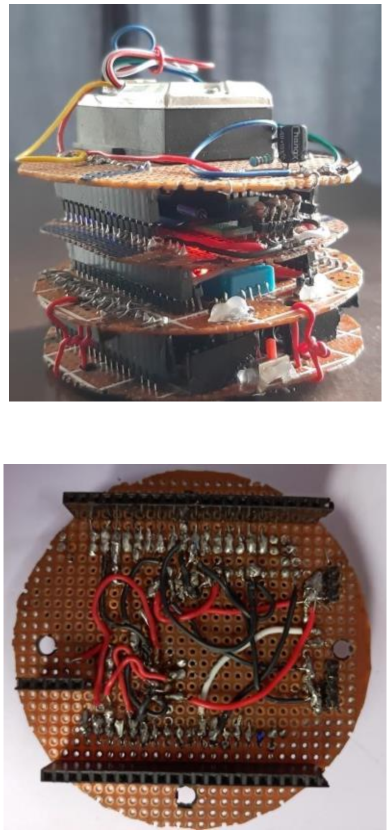

Fig. 3. Mechanical or Physical Design

2.1.4 Data Communication

Initially, successful communication through a 2.4GHZ radio frequency of 2.4GHZ was developed [3]. The simplex mode of communication was successfully established and tested its successful range.

Fig. 4. Communication System with Transceiver.

2.1.5 Creating User Interface

There are two different versions of the GUI. The first one is a Desktop application where data was visualised and got analysed. This was developed for remote areas where internet connectivity is a problem. Similarly, the next interface was a Web application that helps data to reach the global audience.

Fig. 5. Web Based Graphical User Interface.

Fig. 6. Graphical User Interface for Desktop Application.

The collected data were compared and tested with existing standard data provided by open-source platform, open weather map [4] for verification. Our system has its native interface for quick data visualisation. Data that was collected, and found to be accurate with a 95% confidence level. Data was sent to the cloud server [5] directly through the internet. Besides this, the data also gets stored on a micro-SD card as a text file and can be further processed with powerful programming platforms like Python for analysis and visualisation [6].

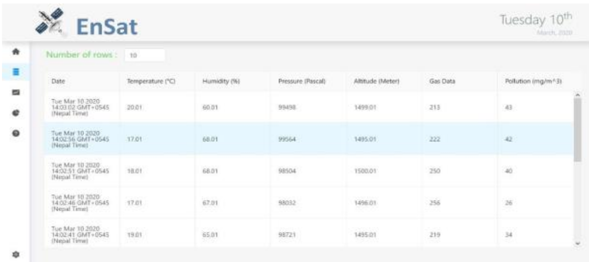

Fig. 7. Real-Time Data Visualisation.

Fig. 8.Data stored on Local Database.

2.1.6 Software Requirements

2.1.6.1 Front End Tools

Microsoft Visual Studio: Microsoft Visual Studio is an integrated development environment from Microsoft. It is used to develop computer programs, as well as websites, web apps, web services, and mobile apps.

C#: C# is a general-purpose, multi-paradigm programming language encompassing strong typing, lexically scoped, imperative, declarative, functional, generic, object-oriented, and component-oriented programming disciplines.

HTML: HTML stands for HyperText Markup Language. HTML describes the structure of Web pages using markup. HTML is the building block of web pages.

CSS: Cascading Style Sheets (CSS) is a stylesheet language used to describe the presentation of a document written in HTML. CSS describes how elements should be rendered on screen or other media

JavaScript: JavaScript is a lightweight, interpreted programming language. It is designed for creating network-centric applications. It is complementary to and integrated with Java. JavaScript is very easy to implement because it is integrated with HTML.

KiCad: KiCad is a free software suite for electronic design automation. It facilitates the design of schematics for electronic circuits and their conversion to PCB designs.

2.1.6.1 Back End Tools

NodeJS: Node.js is a very powerful JavaScript-based framework/platform based on Google Chrome's JavaScript V8 engine. It is used for developing I/O intensive web applications such as video streaming sites, single page applications, and other web applications.

MongoDB: MongoDB is a cross-platform document-oriented database program. Classified as a NoSQL database program, MongoDB uses JSON-like documents with schema. MongoDB is developed by MongoDB Inc

2.1.6 Hardware Requirements

Arduino nano: The Arduino Nano is a small, complete, and breadboard- friendly board based on the ATmega328P. It has more or less the same functionality of the Arduino Uno. It lacks only a DC power jack and works with a Mini-B USB cable instead of a standard one.

MQ- 135: The MQ- 135 Gas sensor is mostly used for detecting NH3, NOx, alcohol, Benzene, smoke, and other harmful gas in the environment. It can be used at home, industries as a domestic gas leakage detector, portable gas detector, and many more.

DHT 11: DHT 11 module is a digital humidity and temperature sensor mostly used for detecting humidity and temperature of the surrounding environment and outputs a digital signal on the data pin. It is durable and has anti-interference ability.

BMP 180 Pressure Sensor: It measures the atmospheric pressure. It helps to measure environment temperature and pressure and barometric pressure.by which assists to calculate altitude which can be used in various applications like weather monitoring, navigation with the I2C interface.

Dust Sensor: Dust Sensor Sharp’s GP2Y1010AU0F is designed to sense fine dust particles. It allows us to detect the reflected light of dust in the air.

MPU6050: The Intenseness MPU-6050 sensor contains a MEMS accelerometer and a MEMS gyro in a single chip. It is very accurate, as it contains 16-bits analog to digital conversion hardware for each channel. Therefore, it captures the x, y, and z channel at the same time.

3. Theory and calculation

The formulas and systems used to calculate different environmental variables have been discussed in this section.

3.1 Altitude Value

The value of altitude is calculated mathematically from the pressure. The altitude above the sea level is calculated using pressure at current level and pressure at sea level. Calculating the altitude, all we need is the non-linear equation that converts pressure to altitude.

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

Where,
p = measured pressure (Pa) from the sensor
$p_0 = p_0$ is the average pressure at sea level 101325pa

3.2 Relative Humidity

The relative humidity is calculated by using DHT 11 sensor using the density of water vapour and density of the water vapour at saturation.

$$\text{RH} = (\frac{\rho_\omega}{\rho_\varsigma}) \text{ x } 100\%$$

RH : Relative Humidity
ρ_ω *: Density of water vapour*
ρ_ς *: Density of water vapour at saturation*

3.3 Gas Sensing Response

The gas sensor works by using the resistance of sensor material at different concentrations of gas levels. It is calculated using the given formula:

$S = R_0/R_{gas} - 1$

Where,
R_0 : sensor resistance in clean air
R_{gas}: sensor resistance under the influence of a reducing gas.

3.4 Orientation and Angular Velocity

MPU 6050 is used to calculate the orientation and angular velocity of the satellite.

In order to calculate the angle of inclination the following formula is used:

$$\textbf{AngleY} = \textbf{atan}(\frac{X}{\sqrt{Y^2+Z^2}})$$

$$\textbf{AngleX} = \textbf{atan}(\frac{Y}{\sqrt{X^2+Z^2}})$$

The angle X and Y are calculated using the previous angles and gyro data coming up with each elapsing time.

$$\textbf{AngleY} = \textbf{PreviousAngleY} + \textbf{GyroDataY . elapsedTime}$$
$$\textbf{AngleX} = \textbf{PreviousAngleX} + \textbf{GyroDataX . elapsedTime}$$

4. Results

4.1 Significant Features

4.1.1 Portability

Here is the specification of our product:

- Weight: 100 grams
- Diameter: 8 cm
- Height: 10 cm

The device is portable, can be installed anywhere easily, be it any terrain or a house room.

4.1.2 Wireless Transmission

The Environmental Satellite transmits the data wirelessly to the ground station through radio frequency using ISM band 2.4 GHz. The transmission range is around 1100 metres.

4.1.3 Economical

The cost to build this project is approximately Rs. 4000 for the hardware and Rs. 1000 for the software. The device is so economical that most of the people living throughout the country can easily afford it.

4.1.4 Self-Sustainable

Environmental Satellite comes with a solar panel making it self-sustainable. So, this can be used in remote areas or difficult terrain where the supply of electricity would be a challenge

4.1.5 Graphical Representation

The environmental data collected is represented graphically in real-time as well as graphs are available for history data. We can see the current real time data of environmental parameters like altitude, temperature, humidity, pressure, gas level and pollution level as well as the past history data of last 24 hours. The data is visualized in charts and graphs. The application has been built using Don Norman's Design Principles for better Human Computer Interaction.

4.1.6 API

The API used in the system, if hosted somewhere on the internet, can be used by developers for developing their products. It promotes the use of locally generated data.

4.2 Field Test

The environmental satellite was tested in different conditions. First and foremost, it was dropped from an elevation of 100 metres with the help of a drone to get on space data. The system was attached to the parachute. The satellite was wrapped with an air bubble wrapper and kept inside a 3D printed case for safe landing. It successfully passed the crash test by continuously transmitting the data throughout the flight time and also after crashing on the ground. The real-time continuous information of environmental variables was taken for 12 hours to test its battery backup and power issue successfully. Range test was also done to test its radio frequency transmission range where we had successful transmission [7]. This technology enables us to monitor the real environmental parameter changes and take action upon it to address the issue. For example, in urban areas, this system can monitor dust density to analyse peak times of pollution thereby taking necessary measures.

After 12 hours of measuring. It was found that the pollution level was low which indicates a green and healthy environment. The temperature reading was found to be similar to that of data from an open weather map which proves the accuracy of our system. Also, the data values were also compared with an WMO verified weather station at Kathmandu University. We compared the elevation provided by the system (1392m) with the standard elevation of Kathmandu University provided by elevation.maplogs.com. (1380) [8]. Similarly, the atmospheric pressure measured by the system was found to be 85.5KPa while it was 85.8KPa on standard site [8].

Time	Temperature	Humidity	atm Pressure(pascal)	Altitude	ax	ay	az	pm 2.5
17:52.6	18.5	65	85829	1392.49	0.22	-0.04	0.9	12
19:10.3	18.5	65	85830	1392.49	0.22	-0.04	0.9	12
19:09.0	18.5	65	85830	1392.49	0.22	-0.04	0.9	12.5
20:52.1	18.4	64	85830.66667	1392.49	0.22	-0.04	0.9	12.5
22:32.8	18.3	64	85831.16667	1392.49	0.22	-0.04	0.9	12.5
23:23.8	18.2	65	85831.66667	1392.49	0.22	-0.04	0.9	12.5
24:40.3	18.1	65	85832.16667	1392.49	0.22	-0.04	0.9	12.5
26:07.0	18	65	85832.66667	1392.49	0.22	-0.04	0.9	12.5
35:27.8	17.5	66	85833.16667	1392.49	0.22	-0.04	0.9	12.5
59:41.6	17	68	85833.66667	1392.49	0.22	-0.04	0.9	12.5
39:04.1	16.5	65	85834.16667	1392.49	0.22	-0.04	0.9	12.5
26:38.4	16.1	66	85834.66667	1392.49	0.22	-0.04	0.9	12.5
26:39.4	13.3	75	85835.16667	1392.49	0.22	-0.04	0.9	12.5
31:37.9	13.2	76	85835.66667	1392.49	0.22	-0.04	0.9	12.5
41:31.0	13	73	85836.16667	1392.49	0.22	-0.04	0.9	12.5
17:36.6	12.5	67	85836.66667	1392.49	0.22	-0.04	0.9	11.2
27:31.0	11	69	85837.16667	1392.49	0.22	-0.04	0.9	11.2
32:29.5	10.5	71	85837.66667	1392.49	0.22	-0.04	0.9	11.2
39:29.2	10	70	85838.16667	1392.49	0.22	-0.04	0.9	13.5
44:31.3	9.5	73	85838.66667	1392.49	0.22	-0.04	0.9	13.5
54:12.5	9	75	85839.16667	1392.49	0.22	-0.04	0.9	13.5
06:31.6	8.7	80	85839.66667	1392.49	0.22	-0.04	0.9	13.5
11:33.4	8.9	80	85840.16667	1392.49	0.22	-0.04	0.9	13.5
14:10.0	9.1	80	85840.66667	1392.49	0.22	-0.04	0.9	14
25:12.9	9.5	79	85841.16667	1392.49	0.22	-0.04	0.9	14
57:54.5	10	79	85841.66667	1392.49	0.22	-0.04	0.9	14
53:20.8	12.9	73	85842.16667	1392.49	0.22	-0.04	0.9	14
14:24.4	13.3	73	85842.66667	1392.49	0.22	-0.04	0.9	14

Fig. 9. Performance Analysis Result.

5. Discussion

5.1 Challenges Faced.

The challenges faced by are:

5.1.1 Technical Challenges:

- There were some hardware failures. The microcontroller was re-programmed a large number of times, and there was wear and tear on its ports.
- Different sensors are required to power on their own. So, power management for every sensor was a huge challenge for us.
- Since our project was on a Matrix board with hand wiring, the soldered connections were not that robust, and dealing with connectivity issues was challenging.
- There was not much support on the internet for the serial port [9] library which was used for reading our data from the ground station.

5.2 Limitations

Although we tried our best to create a robust and perfect system, there are still a few gaping inconsistencies in it.

- The connections made by hand soldering are not as robust as desired.
- The system is not waterproof, so might be a problem after system installation.
- As double-sided printed PCBs were not available in Nepal, we had to use a matrix board which made our system a bit weaker.
- Due to a lack of sufficient data, data analysis could not be that effective and our system cannot be used for a prediction system.

5.3 Future Enhancements

Based on the limitations of the project, we intended to make some enhancements to the project to make it more deployable in the market.

- Use of a double-sided printed PCB instead of the matrix board to make our system robust and much durable.
- Use of outer covering to make the system waterproof.
- Use of data logger in the Environmental Satellite itself to save the data in the satellite itself in case of any data transfer failure.
- Development of weather prediction systems using ML.

6. Conclusions

Environmental satellite is an environmental monitoring system consisting of hardware equipment, web application, and desktop application focused on the SDG number 3 (Good Health and Well Being), 11 (Sustainable Cities and Communities), 13 (Climate Action), and 15 (Life on Land). The project has been built using small, low cost [10] and efficient sensors to make it compact and affordable. The data provided by the sensor has been analysed and compared with standard data from open weather maps and found our system to be accurate with a 95% confidence level. The project helps to give the environmental parameter of a specific area and the results achieved can be used for taking actions and making policies.

Acknowledgements

The authors would like to thank Prof. Dr. Manish Pokharel, Dean, School of Engineering, Kathmandu University, Assoc. Prof. Dr. Bal Krishna Bal, HoD, School of Engineering, Kathmandu University, and Assoc. Prof. Dr. Gajendra Sharma for their guidance in the research. This research was carried out at Kathmandu University.

Appendix A

Fig. Test Flight.

Fig. Presentation to Nepalese Army.

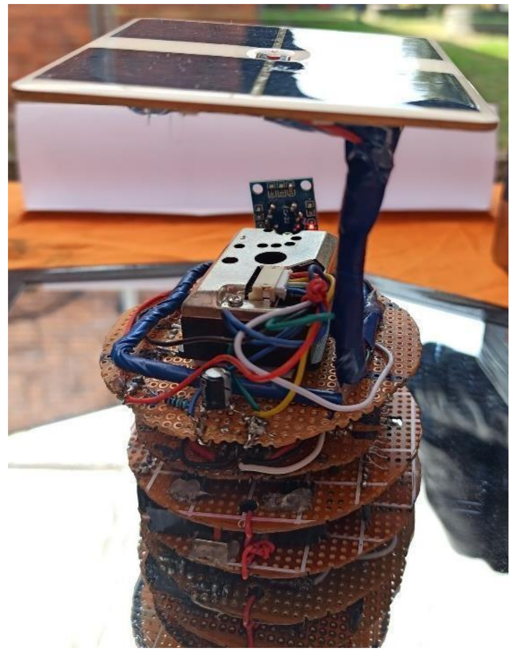

Fig. ensat

List of references

[1] A. Colin, "The cansat technology for climate monitoring in small regions at altitudes below 1km," in *IAA Climate Change and Disaster Management Conference*, Mexico, 2015.

[2] "Air Quality Monitoring | Nepal," Government of Nepal., 3. [Online]. Available: http://pollution.gov.np. [Accessed 2022].

[3] "LastMinuteEngineers," 2022. [Online]. Available: https://lastminuteengineers.com/nrf24l01-arduino-wireless-communication/.

[4] "Current weather data," [Online]. Available: https://openweathermap.org/current. [Accessed 2020].

[5] P. Y. D. Ranjana Sikarwar, "A Survey on IoT enabled cloud platforms," 2020.

[6] F. Q. P. C. S. B. S. F. K. Patricia Morreale, "Real-Time Environmental Monitoring and Notification for Public Safety," *IEEE,* vol. 17, no. 2, p. 11, 2010.

[7] J. W. Longyu Sun, "Application of 4G IOT Card in Automatic Weather Station," *Journal of Physics: Conference Series,* vol. 1601, no. 2, p. 5, 2020.

[8] "Elevation of Dhulikhel, Nepal," [Online]. Available:

https://elevation.maplogs.com/poi/dhulikhel_nepal.141464.html. [Accessed 2022].

[9] “Serialport,” 2020. [Online]. Available: https://serialport.io/docs/api-serialport. [Accessed 26 dec 2018].

[10] R. P. H. J. Dushyant Kumar Singh, “2020 International Conference on Computation, Automation and Knowledge Management (ICCAKM),” 2020.