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DEPARTMENT OF PHYSICS

Real-time trajectory prediction of High Altitude Balloon (HAB) using machine learning (ML) algorithms".

PROJECT REPORT

Submitted by,

Akshaya Krishnan p 210011023190

Under the guidance of

Dr Manesh Michael
Assistant Professor,Department of physics,
Bharata Mata College,Thrikkakara
Visiting Associate,IUCAA,Pune

Dr. Binu Kumar
Postdoctoral Research fellow,
Indian Institute of Astrophysics
Bangalore

In partial fulfilment of the requirements for the degree of
Master of Science in Space Science
2021-
2023

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DEPARTMENT OF PHYSICS

CERTIFICATE

Certified that the project titled " Real time prediction of High Altitude Balloon (HAB) using Machine Learning (ML) algorithms" is carried out by Mrs. Akshaya Krishnan p (210011023190) who is a bonafied student of Bharata Mata College, Thrikkakara in partial fulfillment for the award of degree of Master of Science in Space Science of the Mahatma Gandhi University, Kottayan the year 2021-2023.It is certified that all the corrections are indicated for Internal Assessment have been incorporated in the report deposited in the departmental library. The project report has been approved as it satisfies the academic requirement in respect of project work prescribed by the institution for the said Degree.

Signature of Internal Guide　　　　Signature of External Guide

Dr Manesh Michael　　　　Dr Binu kumar

Indian Institute of Astrophysics
Block II, Koramangala
Bangalore - 560034
India

Ref: SPG/PCL/N./04/06/23

CERTIFICATE

To whomsoever it may concern

This is to certify that Ms. Akshaya Krishnan P, 4th semester M Sc Space Science student, Bharata Mata College, Thrikkakkara, Ernakulam (Affiliated to Mahatma Gandhi University, Kottayam) has completed her project work at the Indian Institute of Astrophysics, Bangalore during 14th April 2023 to 16th June 2023.

She has worked on the project titled "**Real-time prediction of High Altitude Balloon (HAB) trajectories using machine learning (ML) algorithms**". Objective of the project was to develop a Graphical User interface for recording and sorting the in situ data received during the HAB flight and processing the data with ML to predict and correct the trajectory. During the course of the project she has demonstrated excellent design and problem solving skills. She had a self-driven attitude to venture into new arena of contemporary research in the field of High altitude ballooning and trajectory predictions. Her performance was par excellence.

We wish her best of luck for all her future endeavors.

30/06/2023
Bangalore

Binukumar Gopalakrishnan
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DECLARATION

I, Mrs. AKSHAYA KRISHNAN P(210011023190), student of fourth Semester MSc Space Science, Department of Physics, Bharata Mata College, Thrikkakara, hereby declare that the project titled entitled"Real-time prediction of High Altitude Balloon(HAB) trajectories using machine learning(ML) algorithms has been carried out by us and submitted in partial fulfilment of fourth semester requirements in Master of Science in Space Science of Mahatma Gandhi University, Kottyam during the year2021-2023.

Further we declare that the content of the dissertation has not been submitted previously by anybody for the award of any degree or diploma to any other university.

I also declare that any Intellectual Property Rights generated out of this project carried out at IIA will be the property of Bharata Mata College, Thrikkakara and I will be one of the author of the same.

Place:Thrikkakara

Date:

Name Signature

Akshaya Krishnan p (210011023190)

ACKNOWLEDGEMENT

Any achievement, be it scholastic or otherwise does not depend solely on the individual efforts but on the guidance, encouragement and cooperation of intellectuals, elders and friends. A number of personalities, in their own capacities have helped us in carrying out this project work. I would like to take this opportunity to thank them all.

I deeply express our sincere gratitude to our internal project guide Dr. Manesh Michael, Assistant Professor, Department of Physics, Bharata Mata College Thrikkakara and external project guide Dr. Binu Kumar, Postdoctoral Research Fellow, Indian Institute of Astrophysics, Bangalore, for their able guidance, regular source of encouragement and assistance throughout this project.

I would like to thank Dr.Shibi Thomas, Head of Department of Physics, Bharata Mata College, Thrikkakara for her valuable suggestions and support provided during the project period.

I would also like to thank Dr. Johnson K M, Principal, Bharata Mata College, Thrikkakara, for his moral support towards completing our project work.

I thank my Parents, and all the Faculty members of Department of Physics, Bharata Mata College Thrikkakara and Indian Institute Astrophysics, Bangalore for their constant support and encouragement. Last, but not the least, I would like to thank our peers and friends who provided me with valuable suggestions during this project.

ABSTRACT

The flight path of high-altitude balloons can be predicted by mathematical modeling based on parameters such as the wind vector, rate of ascent and descent, nature of the gas filled in the balloon (H2 or He), dimensions of the parachute used for descent, etc. We have developed a software package to estimate the trajectory of balloon flight using these parameters along with the physical conditions in troposphere and stratosphere. Various additional inputs such as anomalies in the wind vectors, jet stream, etc. may be used to fine-tune the existing predictor algorithm. In this project, we are planning to measure various parameters such as wind direction, speed, humidity, temperature etc. during a balloon flight and fit this data into the existing model to improve the flight path predictions. A dynamic version of the code will be developed to generate in-situ prediction by incorporating the real-time data downlink from the payload while in flight.

Nature of the project: data-acquisition/modelling.: Most of the work will be carried out in the lab. Student(s) will work with our team to learn about the challenges in high altitude balloon experiments, familiarize themselves with payload development, and work on the software improvements. if time permits and if conditions are appropriate, enthusiastic students may join us for balloon launch from IIA-CREST campus (Hoskote), and subsequent payload recovery.

Requirement: Knowledge of python programming is essential. Familiarity with sensors, IoT,and hobby electronics would be an added benefit.

CHAPTER 1

INTRODUCTION

The atmosphere play a crucial role in regulating the Earth's climate and weather patterns, and is also a key factor in determining the habitability of our planet. Atmospheric scientists use a variety of techniques to study the atmosphere, including remote sensing, ground based measurements and airborne or satellite-based observations. A high altitude balloons is unmanned aerial vehicles that is designed to ascend to the upper reaches of the atmosphere. Typically it's altitude between 60,000 to 120,000 feet above sea level. These balloons are often used in scientific research, for weather monitoring, capturing images of cosmos etc. It is used for lower and upper atmospheric studies which includes experimental studies on troposphere and stratosphere. Advantages of high altitude balloon which includes affordability, high payload capacity, easy to launch, flexibility etc. High altitude balloons are typically made of thin, lightweight materials such as polythene film and are filled with hydrogen or helium gas. They are usually launched from the ground using small rocket or other propulsion system. Once they reached the desired altitude, the gas inside the balloon expands. As we go upwards the pressure goes on decreasing in the atmosphere and the pressure inside the balloon expands. It eventually causes balloon to burst.

1.1ATMOSPHERE

Atmosphere is the layers of gases that covering a planet. It mainly consists of 78.08 % nitrogen and 20.95 % of oxygen as major constituents, as minor components it's observed that the carbon dioxide, ozone and water vapour plays an important role in the atmosphere. Like any other planetary atmosphere, earth's atmosphere mainly gives importance in transfer of energy between the sun and the planet surface. These transfers maintain thermal equilibrium and determine the planet's climate. Solar radiation comes in to the atmosphere and can be scattered in any direction as it passes through the medium. There are three types of scattering involves in atmosphere which includes Rayleigh scattering, Mie scattering and Non selective scattering. Rayleigh scattering consists of scattering from atmospheric gases. This occurs when the size of particles that causes scattering is smaller than the wavelength of radiation. This type of scattering is wavelength dependent. As wavelength decreases amount of scattering decreases. Because of Rayleigh scattering, the sky appears blue in colour. Dust, smokes, water droplets and other particles in lower atmosphere causes Mie scattering. It occurs when the size of particles are larger than the wavelength of radiation. It is the reason for the white appearance of the cloud. It is also wavelength dependent. In Non-Selective scattering, causes fog and clouds to appear white to our eyes and all other colours scattered in almost equal quantities. Atmosphere continually bombarded by solar photons at various wavelengths. Some are scattered back to the space in the form of gases or by clouds or by earth's surfaces and some particles like ozone and water vapour leads to the heating to the parts of atmosphere.

Since the atmosphere is a wide area direct studies are very complex. By using the scientific method we can study about the atmospheric phenomena and thus we can formulate the hypothesis. We can develop a model by shifting them to data. Models are performed by using a set of equations. On solving these equations by applying various conditions and solutions will be interpreted. We can judge the models performance by comparing this model with that of atmosphere. There are two models in the atmosphere, the first one is defective and the latter one is the representation of green house effect. Models are mainly used for weather forecasting .Complex models are also used for data assimilation.

Green house gases are one of the reasons for sustaining life by giving a suitable temperature to planet. It absorbs infrared radiation in the form of heat from the sun. The radiation from the sun is fallen to the earth surface and it is reflected back. The reflected radiation is absorbed by the green house gases such as CO_2, methane etc results in increase in temperature. Higher temperature leads to global warming. It affects the earth surface. By using the law of thermodynamics we can study about the effects of atmospheric processes. The atmospheric thermodynamics describes the effect of buoynacy force that cause the rise of the lighter air and the descent of the denser air and the conversion of water from liquid to vapour and its condensation.

Earth is in hydrostatic balance. On combining the hydrostatic balance equation with the ideal gas equation we can say that atmosphere is an isothermal one. But in the real case it's non isothermal. In the case of isothermal, pressure and density varies in exponential form.Fornon isothermal, as height increases temperature decreases and pressure decreases and e - folding occurs. By using the law of thermodynamics we can study about the effects of atmospheric processes. The atmospheric thermodynamics describes the effect of buoyancy force that causes the rise of the lighter air and the descent of the denser air and the conversion of water from liquid to vapour and its condensation.

1.2ATMOSPHERIC LAYERS

The atmosphere can be divided into layers based on its temperature. These layers are

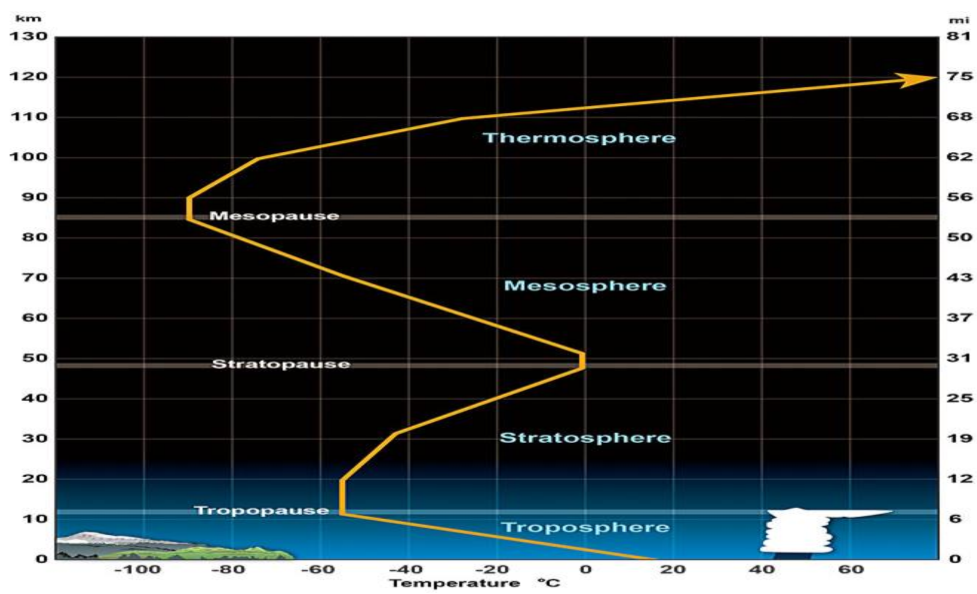
- The Troposphere
- The Stratosphere
- The Mesosphere
- The Thermosphere

The troposphere is the lowest part of atmosphere. The average height of troposphere is about 18 kms. In this part of atmosphere, as height from the earth increases temperature gone decreasing is a result of decreasing pressure. This is the region where we live. Most of weather, cloud, rain and snow contain in this region. Here the emission and absorption of infrared radiation by molecules like water vapour, co_2 is observed thatprovide efficient transferof heat between different levels in this region. Early scientists believed that the temperature continues to decrease upward an atmosphere gets terminated at about 50 km and there merges into cold interplanetary space. The top of the troposphere is called tropopause.

This extends upwards from tropopause to about 50 km is the region called stratosphere.. Most of the ozone particles are seen in this region. Because of the absorption of UV radiation from the sun by the ozone results in the increasing of temperature with the height. By absorbing this harmful UV radiation, ozone protects us from serious health problems like skin cancer. But chemicals like CFC, Freon's which were once used in refrigerators , spray cans have reduced the amount of ozone in the stratosphere results in the creation of ozone hole and so called " Antarctic ozone hole". Nowadays human reduces the making of the most of harmful chemicals.

The region above the stratosphere is called mesosphere, starting at an altitude about 50 kms and extending up to 85 km above the Earth's surface. In this region again temperature decreases with altitude. It is the coldest level in the entire atmosphere. We cannot see the ozone existence in this levels, it is rapidly destroyed by photochemical reaction. It is the coldest layer of earth's atmosphere.

The region which lies above the mesopause is called thermosphere. It is beginning around 85 km and extending up to about 600 km above the surface. We can see that the temperature again increases with height. By absorbing UV radiation and X ray radiation from the sun results in increasing of temperature. The exosphere is the outermost layer of the Earth's atmosphere. It starts around 600 km and extending out into space. It separates the rest of the atmosphere from outer space. This region has gases like hydrogen and helium. There is no air to breathe. The Ionosphere is the ionized part of the upper atmosphere. It is a region that includes the thermosphere and the parts of exosphere and mesosphere.



The layer in which aircrafts usually fly is the troposphere. Although within this layer each type of aircraft uses different altitudes depending on the type of needs. In general, private flights remains in the troposphere. This is because it is necessary to maintain visual reference with terrain and piston engine needs oxygen to operate. Commercial aircraft uses upper reaches of the atmosphere. Advantages of this are lower consumption and low air density helps to achieve higher speeds. This altitude is free from birds and other intense weather phenomena. Military flight usually travels in a region between troposphere and stratosphere known as tropopause. In this layer, density is even lower so their jet engines are at their most efficient. In general most commercial airlines tend to fly at an altitudes between 30,000 and 40,000 feet above sea level. This is known as the “cruising altitude” and safest altitude for commercial aircraft.

1.3 TRAJECTORY PREDICTION

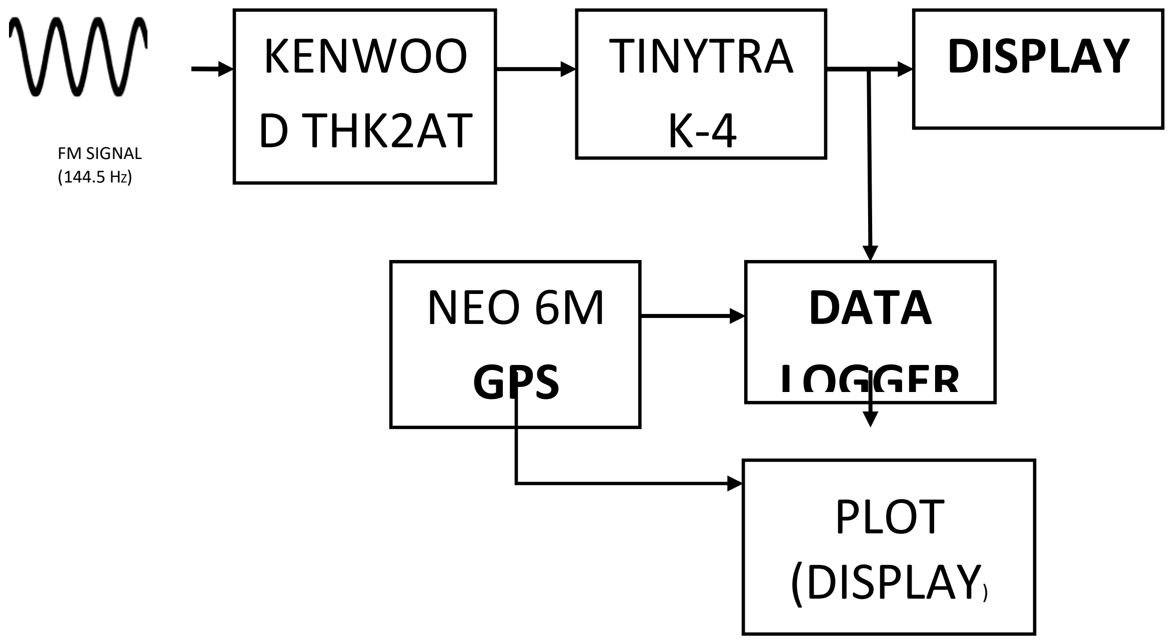
The balloons often occupied with various instruments and payloads such as cameras ,sensors etc which can gather data and perform experiments at high altitudes. Scientific research is the one of the uses of high altitude balloon. It is used to carry scientific instruments and sensors into the upper atmosphere, where they can measure atmospheric conditions. It is also used for weather forecasting. Depending on the usage, they vary in size. For scientific purposes, we use larger HABs weighing up to 3600 kilograms. For meteorological purposes, we use smaller HABs weighing up to few kilograms. Larger HABs can stay a lot in atmosphere while the later ones are of smaller purposes. These both can go to 17-35 km above sea level. The fuel used here is hydrogen and helium. The white latex balloon used which can be filled with 115ft^3 of hydrogen gas to inflate the balloon. The total weight of payload is about 1.4 kg. The payload contains several sensors including UV sensor, temperature sensor, ozone sensor etc. GPS tracker, radar reflector and power system are major components of balloon. Every 5

minutes they updates the location of payload and it helps to locate the payload for its track and recovery.

High altitude balloons have become increasing popular due to their low cost and advantages in terms of learning and correcting errors. To ensure safety, it is necessary to predict the trajectory that the balloon will follow. The results obtained by the simulation of the trajectory of high altitude balloon for a chosen day, it is important to highlight that the developed software will only evaluate the ascent part of the trajectory. After evaluating for several months, the ideal places to launch the balloon is confirmed and ensure the trajectory prediction fulfils he legal requirements. The trajectory of the balloon is mainly influenced by the direction of wind. However the fluctuations in the speed of wind will not affect the trajectory since to obtain this , it is necessary to integrate and therefore it is an average. The ability to accurately estimate balloon burst altitude is important for modelling balloon flight predictions. To find and retrieve the grounded payloads, researchers need reliable flight path,predictions based on ascent rate ,burst altitude, weather condition. Payloads are attached to the parachute and filled with hydrogen to correct lift. After release, researchers collect the payload and bring them back for analysis. Researchers use a variety of tracking hardware to follow the path of a balloon. Variables that affect the burst altitude of a balloon size, time of a day, launch and final ascent and velocity. UV radiation is harmful for latex and the vertical velocity of the balloon can affect its performance. Data was collected from the balloon to analyze variables affecting burst height. Further research is needed to determine which variables have a greatest effect on balloon burst altitude. Italian aerospace research has developed methodologies and tools to evaluate balloon mission feasibility, predict trajectory and access trajectory prediction errors. Validation of methodology was carried out via Monte carlo analysis.

CHAPTER 4

FUNCTIONAL BLOCK DIAGRAM



FM SIGNAL
(144.5 Hz)
KENWOOD THK2AT
TINYTRAK-4
DISPLAY
NEO 6M GPS
DATA LOGGER
PLOT (DISPLAY)

Kenwood transceivers

For professional and commercial use, Kenwood produces transceivers primarily for amateur radio (also known as ham radio) operators. Their transceivers are known for their reliability, performance, and feature-rich designs. A variety of transceiver models was offered by Kenwood. Each has its own set of features and capabilities. Some of their popular transceiver series include:

Kenwood TS series

This series includes high-performance HF (high-frequency) transceivers that cover a wide range of amateur radio bands.

Kenwood TṀ series

Mobile transceivers offer wide frequency coverage and high power output.

Kenwood TK series

It is designed for commercial and professional use. TK series transceivers are rugged, reliable and advanced.

Kenwood TH series

Handheld transceivers used for communication, outdoor activities, and emergencies. These devices are commonly used in emergency situation,outdoor activities.

Kenwood NXseries

Digital transceivers provide enhanced audio quality, extended coverage, and advanced features

Decoder

It is a device that converts encoded data backs to its original form. It is widely used in various fields including digital media,computer systems and electronics.

The TinyTrak4 (TT4) is a radio interface capable of transmitting and receiving position and other digital information over a two-way FM radio. It can be connected to a computer to display stations and messages received from the APRSTM network, and can be updated by downloading new firmware from the TinyTrak4 website.

Display

The display from a decoder refers to the output or visual representation of the decoded information.

Datalogger

A datalogger is a device used to collect and store data from various sensors and instruments. In high altitude balloon, a datalogger can be employed to record information such as pressure , temperature ,altitude,humidity and other parameters during the flight.

Arduino

Arduino is an open source electronics platform with simple hardware and software functions. It work with processing of Arduino programming language (can be relate to C/C++) and Arduino software (IDE). It is basically a microcontroller that can support microprocessor and controllers. t is an Italian company, Arduino project began in 2005 as a tool for students aiming to provide low cost microcontroller. They have many types of Arduino according to their purpose. Some of famous boards are;.

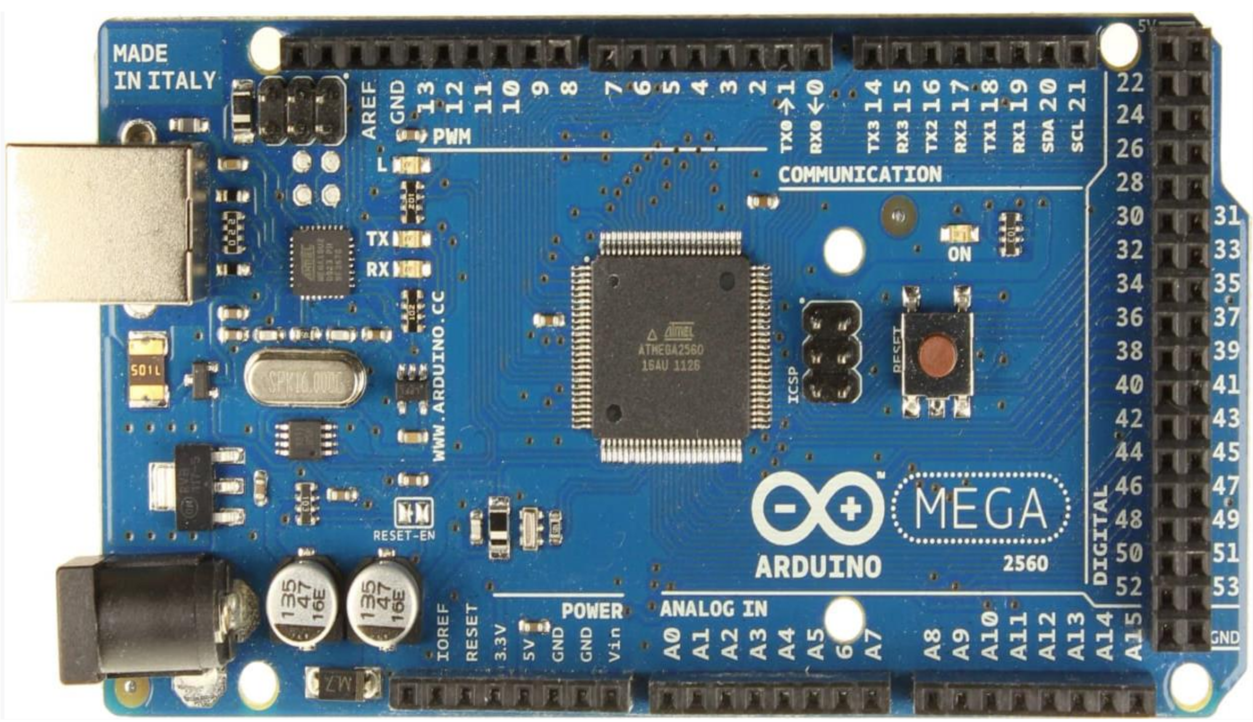
- Arduino Diecimila
- Arduino Mega
- Arduino UNO
- Arduino Leonardo
- Arduino Nano
- Arduino Micro
- Arduino Mega

Arduino MEGA 2560

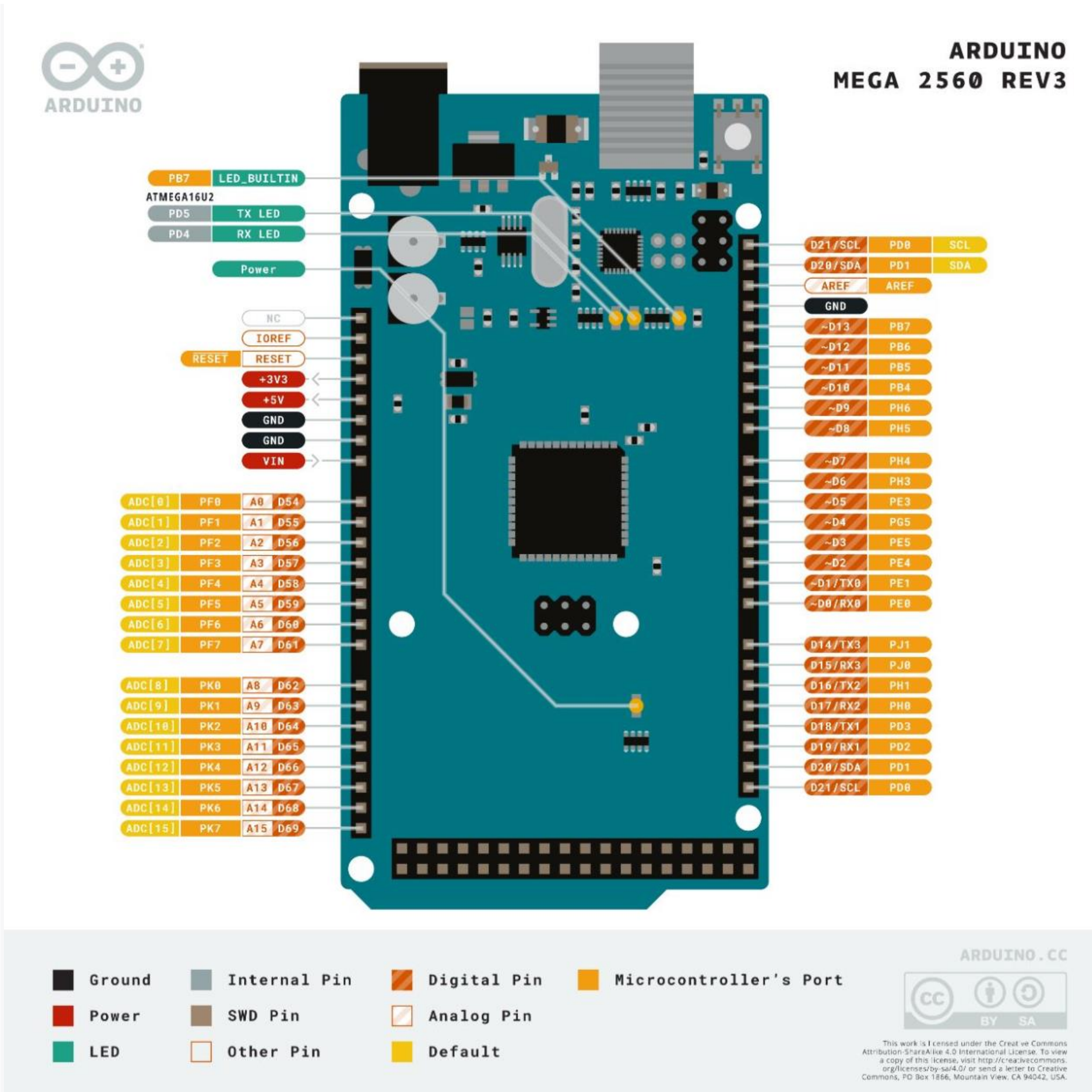
The Arduino Mega is a microcontroller board based on the ATmega2560. It is one of the popular boards in the Arduino family, known for its extensive number of input/output pins and increased memory and processing power compared to other Arduino boards. It has total of 54 digital input and output pins in which 14 can be used as PWM outputs, 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It is advanced than ordinary Arduino UNO in multi-funtions with more pins. This microcontroller can be powered by simply connect it to a computer with either USB cable nor power it with an AC to DC adapter nor battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila board based on the ATmega168.

Features of arduino MEGA 2560

Feature	*Description*
Microcontroller	ATmega2560
Operating voltage	5V
Input voltage	7-12V
Digital I/O pins	54
Analog Input Pins	16
Flash Memory	256KB
SRAM	8KB
Shield Compatibility	Comptabile with Arduino shields.
EEPROM	4KB
Clock Speed	16MHz

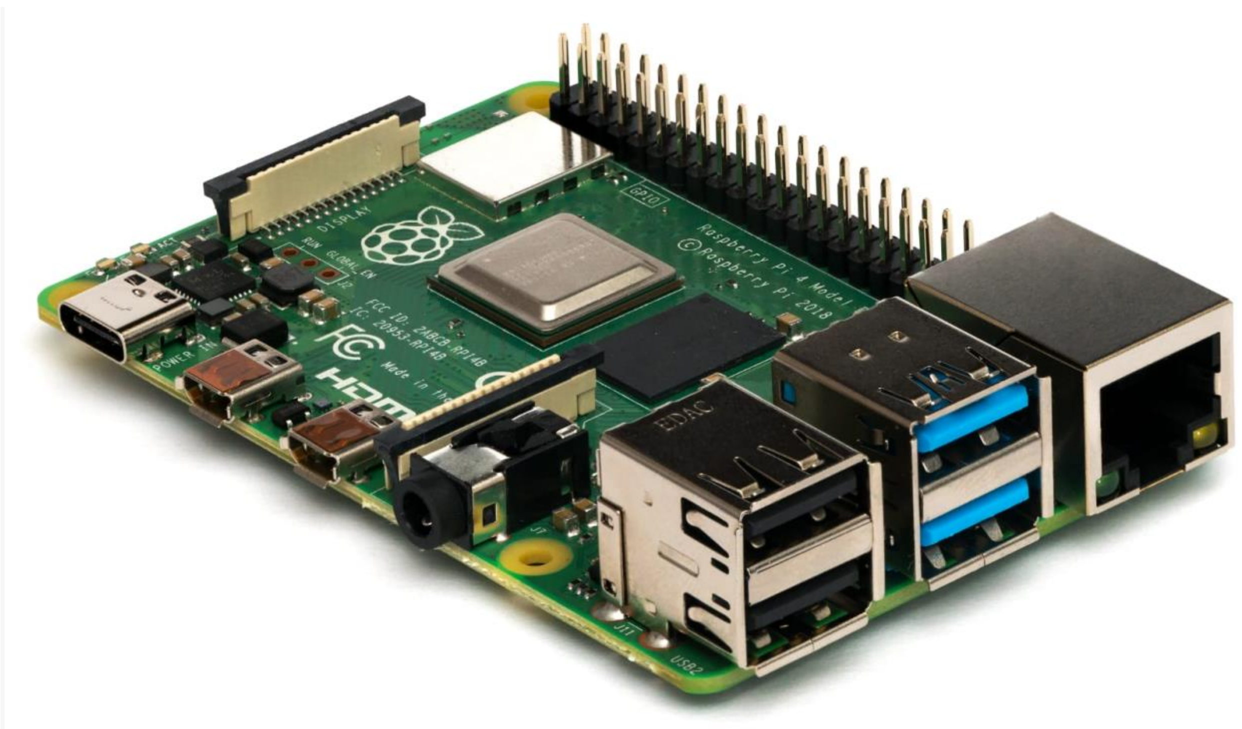


Pin out diagram of arduino MEGA 2560



Raspberry Pi

To promote the teaching of basic computer science in schools and to enable enthusiasts to experiment with computer hardware and software, a small single-board computer, that is designed to promote the teaching of basic the Raspberry Pi used.Raspberry Pi is United Kingdom based company which provides microprocessor which is a series of small board computer. Raspberry Pi foundation started its production since 2012. First generation Pi had single core 700 MHz and 256MB RAM from there they developed the latest version which has quad core CPU clocking in at over 1.5GHz, and 4GB RAM. Raspberry Pi is cost efficient and powerful to develop complex robotics and project. The Raspberry Pi performs in the openSource ecosystem: it runs the Linux and its main supported operating system is Pi OS,and it is an open source operating system.



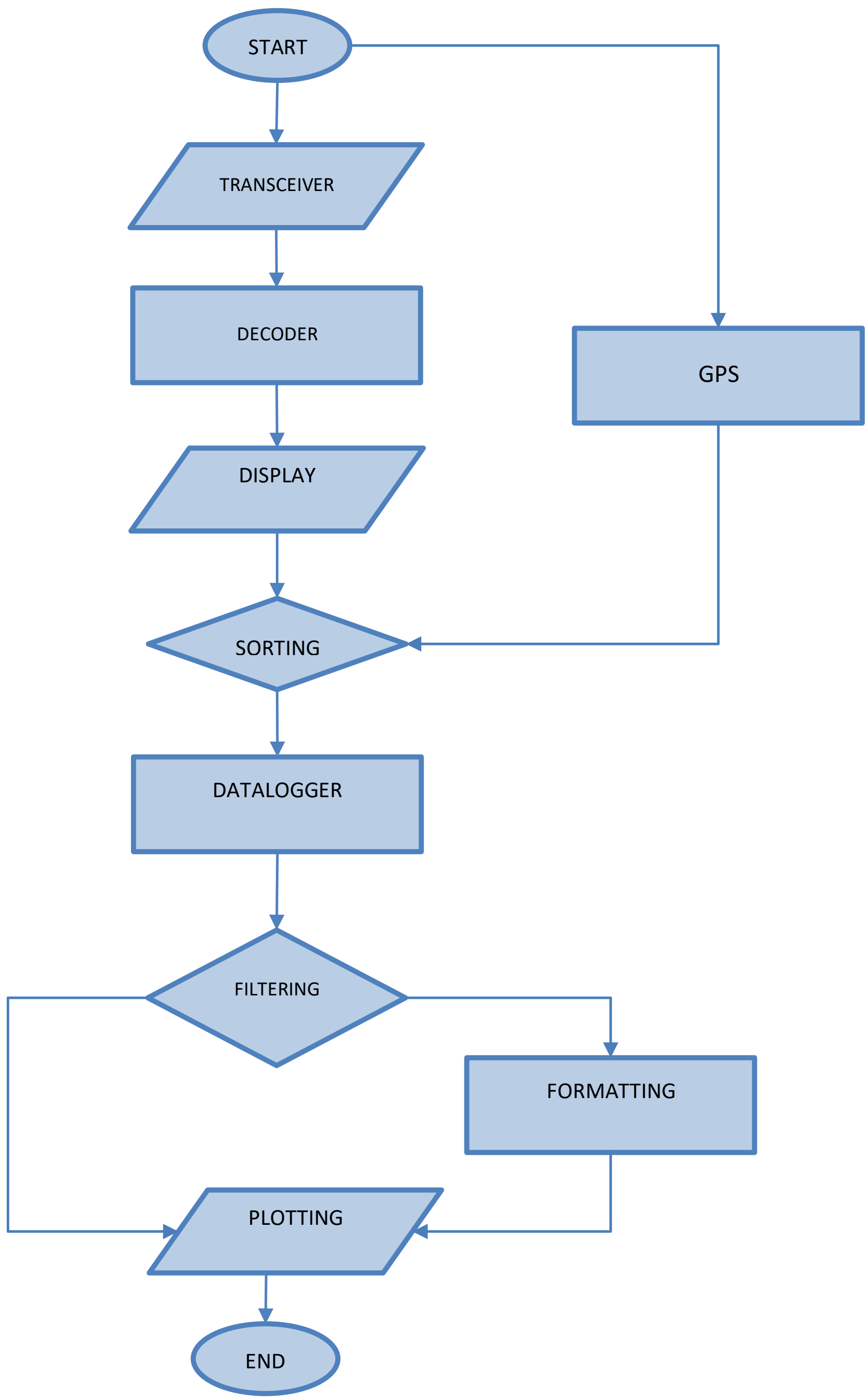
GPS Module

To determine their precise location anywhere on Earth, GPS, which stands for Global Positioning System, is a satellite-based navigation is used. The system consists of a network of satellites in space, ground control stations, and GPS receivers.The Global Navigational Satellite System (GNSS) is the constellation of spatial satellites that contribute highly accurate positioning navigation and timing (PNT) measurements worldwide. GNSS provideglobal(Global Positioning Satellite) is one of the many GNSS that provide PNT measurement which is operated by U.S Armed force. Likewise GLONASS, China – BeiDou, India – NavIC, Japan – QZSS in all weather conditions with line of sight communication with 4 or more GPS satellites for accuracy. The givenfigure is a complete GPS module which is based on NEO -6M. This updated GPS module provides the possible information,allowing for better performance with Ardupilot platform.NEO-6M GPS Module has high precision binary output, sensitivity, battery backup, EEPROM, antenna connection, serial TTL output, four pins, and u-center softwareconfiguring and changing settings. .

Features of GPS module

feature	*Description*
GPS Chipset	U-blox NEO -6M chipset
GPS Receiver	50-channel GPS receiver
Communication Interface	Serial communication via UART
Opening voltage	Typically 3.3 V
Positioning accuracy	Gives accurate position data with typical accuracy of up to 2.5 meters
Update rate	Support configurable update rates,typically up to 10 Hz

FLOWCHART


START
TRANSCEIVER
DECODER
GPS
DISPLAY
SORTING
DATALOGGER
FILTERING
FORMATTING
PLOTTING
END

ALGORITHM

Step 1: start

Step 2: Frequency modulated signal of 144.5 MHz is received via Transciever.

Step 3: The data we received is decoded by using the Tinytrack4 decoder.

Step 4: The decoded data will be displayed through the monitor.

Step 5: The required data will be sorted out.

Step 6:The sorted data will be saved as .csv or .txt file format.

Step 7: From the sorted data , the two required data for plotting is filtered out.

Step 8: If filtered data is in correct format, step 10 happens, else step 9.

Step 9:if filtered data is not in a correct format, formatting takes place.

Step 10: plotting the map using latitude and longitude.

Step 11: end

CHAPTER 4

FLIGHT REQUIREMENTS

BALLOON DETAILS

1. Dimensions of Balloons:

Balloon type (kg)	Balloon condition	Volume(m^3)	Diameter(m)	Weight (kg)
2	Inflated	2.45	2.05	2.45
2	Deflated	nil	1.65	2

2. Payload Weight: 2.2 kg + 1.9 kg + 2.45 kg (balloon weight)
3. Maximum Altitude: 35-40 km
4. Duration of flight: 2-6 hours
5. Trajectory and rate of ascent: Expected to rise straight up in the sky at rate of 3.53-8.08 m/s
6. Maximum lateral extent of balloon: 60-80 km (due to wind drift)
7. Color of the balloon: White latex
8. Gas used for filling: Hydrogen
9. Launch window: 2:00 AM - 4:00AM On Sundays
10. Launch location: Hoskote

    Latitude: 13° 06’ 46.8” North

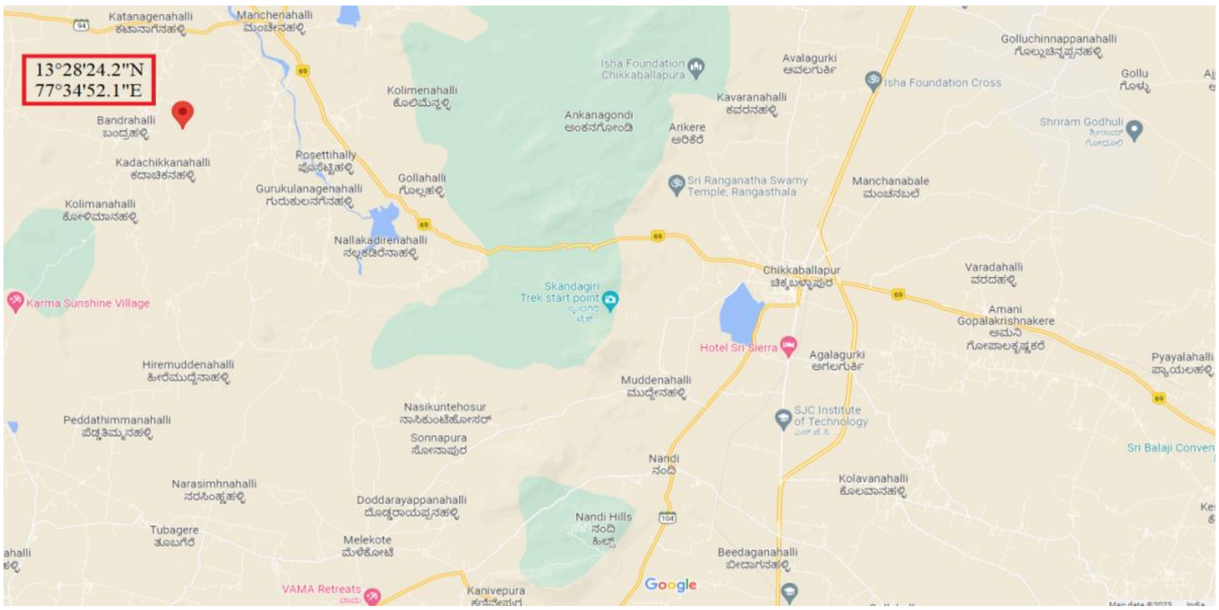
    Longitude: 77°47’24” East

LAUNCH REQUIREMENTS

- The team arrived at Hosakote on 21/01/2023 at 18:00 IST and started the preparation at 18:30.
- Base station equipments were tested and assembled.
- Radio amplifier and transceivers of the base station was switched ON

- Payloads and radio integration within payload box was completed and radio and LORA was tested. (22:00)
- Final preparations were started at 22:30; at 00:15 we started filling the balloon. Two 2 Kg balloons were used for the launch. Two H_2 cylinders were used for inflating the balloons.
- After informing the ATC and HAL, the balloons were launched at 02:31. The coordinates were shared with the team at ATC Devanahalli.
- Initially balloon started drifting towards NE direction, later on changed the course around an altitude of 3.5 km. Thereafter it started travelling in NW direction until the cut off at 04:42.
- The payload was recovered from Sadenahalli, (13.473392 N, 77.581142 E) 07:10.

High altitude balloon launches is a type of experimental technology used for research and educational purposes. The main objective of these launches is to send scientific payloads, such as cameras, sensors, and other equipment, to the upper reaches of the atmosphere for data collection and analysis. The balloon itself is typically filled with helium or hydrogen, which allows it to reach altitudes of 100,000 feet or more. The payload is attached to the balloon and is carried to the upper atmosphere where it can collect data on a variety of subjects, including weather patterns, atmospheric composition, and cosmic radiation. High altitude balloon launches are often used to test new technologies and equipment before they are used in space missions. They are also used to train students and researchers in the field of atmospheric science and space technology.



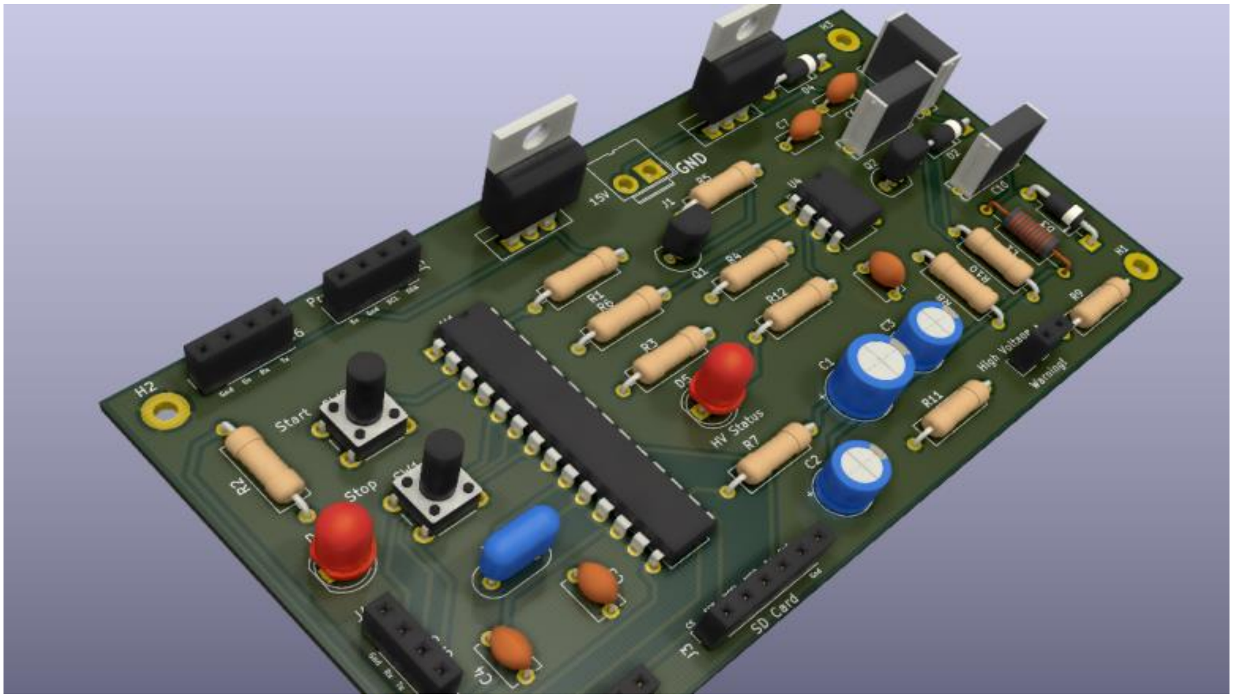
By filling the balloon with an appropriate gas and attaching with payload. The balloon will then ascend to its target altitude and the payload will collect data for a specified period of time before the balloon bursts and the payload returns to earth via parachute. OverallHigh Altitude Balloon launches are a cost-effective and relatively safe way to conduct research and test new technologies in the upper atmosphere, where conditions can be challenging for manned or unmanned aircraft.

Payloads

Geiger-Muller counter

A Geiger-Muller counter, also known as a Geiger counter, is a type of particle detector that can be used as a payload on high altitude balloon launches. The Geiger-Muller counter is designed to detect ionizing radiation, such as alpha particles, beta particles, and gamma rays.

When included as a payload in a high altitude balloon launch, a Geiger-Muller counter can be used to measure the levels of cosmic radiation at different altitudes in the upper atmosphere. This information can be used to study the effects of radiation on the Earth's atmosphere, as well as to monitor for potential hazards from solar flares or other space weather events. In addition to measuring radiation, a Geiger-Muller counter can also be used to detect other types of particles such as cosmic rays, which can be used to study the properties of the upper atmosphere and to study the origins of cosmic rays.



APPENDIX

Code for saving the data in csv file format:

```
#Develop Python Code to Read Serial Data from Arduino

import serial
import csv

arduino_port = "/dev/cu.usbmodem14201" #serial port of Arduino
baud = 9600 #arduino uno runs at 9600 baud
fileName="analog-data.csv" #name of the CSV file generated


ser = serial.Serial(arduino_port, baud)
print("Connected to Arduino port:" + arduino_port)
file = open(fileName, "a")
print("Created file")


#Create an Arduino Data Logger: Send Serial Data into a CSV File

#display the data to the terminal
getData=ser.readline()
dataString = getData.decode('utf-8')
data=dataString[0:][:-2]
```

```
print(data)

readings = data.split(",")
print(readings)

sensor_data.append(readings)
print(sensor_data)

samples = 3 #how many samples to collect
print_labels = False
line = 0 #start at 0 because our header is 0 (not real data)
sensor_data = [] #store data

# collect the samples
while line <= samples:
    getData=ser.readline()
    dataString = getData.decode('utf-8')
    data=dataString[0:][:-2]
    print(data)

    readings = data.split(",")
    print(readings)

    sensor_data.append(readings)
    print(sensor_data)

    line = line+1


#Add the Arduino Serial Data to a CSV File
#
# create the CSV
with open(fileName, 'w', encoding='UTF8', newline='') as f:
    writer = csv.writer(f)
    writer.writerows(sensor_data)

print("Data collection complete!")
file.close()
```

Code for plotting temperature and pressure

```
import tkinter as tk
from matplotlib.backends.backend_tkagg import FigureCanvasTkAgg
import matplotlib.pyplot as plt
```

```
# Define the data for the charts
x = [1, 2, 3, 4, 5]
y1 = [1, 4, 9, 16, 25]
y2 = [1, 3, 5, 7, 9]
y3 = [2, 4, 6, 8, 10]

# Create the main tkinter window
root = tk.Tk()
root.geometry("800x500")

# Create the figure and subplots
fig, (ax1, ax2, ax3) = plt.subplots(1, 3, figsize=(8, 4), dpi=100)

# Plot the data on the subplots
ax1.plot(x, y1)
ax1.set_title("Chart 1")
ax2.plot(x, y2)
ax2.set_title("Chart 2")
ax3.plot(x, y3)
ax3.set_title("Chart 3")

# Create a canvas for the figure and add it to the main window
canvas = FigureCanvasTkAgg(fig, master=root)
canvas.draw()
canvas.get_tk_widget().pack(side=tk.TOP, fill=tk.BOTH, expand=1)

# Start the tkinter event loop
root.mainloop()
```

code for plotting the map with latitude and longtitude.

```
import folium

with open('data.txt', 'r') as file:
    coordinates = [line.strip().split(',') for line in file]

# Create the map object
mymap = folium.Map(location=[float(coordinates[0][0]), float(coordinates[0][1])],
zoom_start=13)

# Mark the launching site (first data set) in red
launching_site = [float(coordinates[0][0]), float(coordinates[0][1])]
html_launching_site = f"""
    <div style="white-space: nowrap; font-weight: bold; text-align: center; font-size: 10px; color:
red;">
```

```
        Launching Site<br>Latitude: {launching_site[0]}, Longitude: {launching_site[1]}
    </div>
"""
folium.Marker(location=launching_site, popup=html_launching_site,
icon=folium.Icon(color='red')).add_to(mymap)

# Iterate over the coordinates to add markers for each location (except launching and landing
sites)
for coordinate in coordinates[1:-1]:
    latitude, longitude = map(float, coordinate)
    html = f"""
        <div style="white-space: nowrap; font-weight: bold; text-align: center; font-size: 10px;
color: blue;">
            Latitude: {latitude}, Longitude: {longitude}
        </div>
    """
    folium.Marker(location=[latitude, longitude], popup=html).add_to(mymap)

# Mark the landing site (final data set) in red
landing_site = [float(coordinates[-1][0]), float(coordinates[-1][1])]
html_landing_site = f"""
    <div style="white-space: nowrap; font-weight: bold; text-align: center; font-size: 10px; color:
red;">
        Landing Site<br>Latitude: {landing_site[0]}, Longitude: {landing_site[1]}
    </div>
"""
folium.Marker(location=landing_site, popup=html_landing_site,
icon=folium.Icon(color='red')).add_to(mymap)

# Convert the coordinates to a list of float values for the polyline
locations = [[float(lat), float(lon)] for lat, lon in coordinates]

# Add the polyline to the map
folium.PolyLine(locations=locations, color='blue').add_to(mymap)

# Save the map to an HTML file
mymap.save("mymap.html”)
```

CHAPTER 5

RESULTS

The data from the sensors is saved in csv format. plotting the graph with time versus temperature,pressure and relative humidity. The map is plotted with latitude and longtitude.

CASE 1 :

Using the data of January 2023, the actual flight and preflight have been predicted and there corresponding plots are made. Hence we got two plots whose error values are obtained . From these error values ,error plot is made.

CASE 2:

Using the data of March 2023,the actual flight and preflight have been predicted and there corresponding plots are made.Hence we got two plots whose error values are obtained, From these error values,error plot is made.

COMPARISON:

`On comparing error plots of both case 1 and case2, mean deviaton is taken. Improvement has been observed .

CHAPTER 6

CONCLUSION AND FUTURE WORKS

Conclusions

In this project , by using the existing data we are comparing the actual flight and preflight of the balloon. The deviation between the both of them is noted. The experiment is repeated with another launch. Both of the error plots were compared by using machine learning. Improvement in trajectory prediction has been noticed with the code which had been developed with the help of machine learning.

Future reference :

- Currently observations are made in already existing data. Real time data are going to be taken in the future.
- We are planning to make a standalone system
- Real-time operating system is going to be used in the future.
- Real time corrector will be used for testing using tethered launch.
- Extend this predictor’s capability to predict the trajectories of other aerial vehicles

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Create an Arduino Data Logger: Send Serial Data into a CSV
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File#display the data to the terminalgetData=ser.readline()dataString = getData.de...
www.learnrobotics.org

samples = 3 #how many samples to collectprint_labels = Falseline = 0 #start at 0 b...
www.learnrobotics.org

create the CSVwith open(fileName, 'w', encoding='UTF8', newline='') as f:writer = cs...
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import tkinter as tkfrom matplotlib.backends.backend_tkagg import FigureCanvas...
University of Northampton on 2023-01-16

x = [1, 2, 3, 4, 5]y1 = [1, 4, 9, 16, 25]y2 = [1

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