PROJECT REPORT
(IIT MANDI WINTER INTERNSHIP)
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Introduction

ROS

It is a flexible framework for writing robotic software. It provides services for hardware abstraction, device drivers, communication between processes, package management, and more. ROS is widely used in academia and industry for developing and prototyping robotic systems.

ROS Tools

roscore:

- The ROS Master is a crucial component that manages the naming and registration of nodes within the ROS system. Running roscore launches the ROS Master and other core components.

rqt:

- rqt is a Qt-based framework for developing ROS graphical user interfaces (GUIs). It includes various plugins for visualization, logging, and debugging.

rviz:

- RViz is a 3D visualization tool for ROS. It allows you to visualize sensor data, robot models, and other information in a 3D space. This is particularly useful for debugging and understanding the behavior of a robotic system.

rosbag:

- rosbag is a command-line tool for recording and playing back ROS message data. It enables the capture and replay of data, which is useful for testing and analysis.

catkin:

- Catkin is the build system used in ROS. It organizes packages and manages their dependencies, making it easier to build and distribute ROS code.

Gazebo:

- Gazebo is a powerful simulation tool often used in conjunction with ROS. It allows developers to simulate robots and environments, enabling testing and development without requiring access to physical hardware.

rosrun and roslaunch:

- rosrun is a tool to locate and run ROS nodes. roslaunch is used to launch multiple nodes with specific parameters and configurations.

Acoustic levitation

Acoustic levitation is a technique that uses sound waves to suspend and manipulate small objects in mid-air without any physical contact. The basic principle relies on the pressure exerted by sound waves to counteract the force of gravity, allowing objects to levitate. This phenomenon is made possible by the acoustic radiation force, which is the result of the pressure variations caused by the interaction of sound waves with an object.

Sensor fusion

Sensor fusion is the process of combining data from multiple sensors to provide a more comprehensive and accurate understanding of a system or environment. This integration of data helps overcome the limitations and weaknesses of individual sensors. Navigation and Localization:

- In autonomous vehicles, sensor fusion is crucial for accurate navigation. Combining data from GPS, inertial measurement units (IMUs), wheel encoders, and cameras helps improve location accuracy, especially in urban environments with obstacles that can obstruct GPS signals.

Augmented Reality (AR) and Virtual Reality (VR):

- Sensor fusion enhances the user experience in AR and VR applications. Combining data from accelerometers, gyroscopes, and cameras allows for more precise tracking of head and body movements, providing a more immersive and realistic virtual experience.

Robotics:

- Robots often rely on sensor fusion to navigate and interact with their environment. Combining information from various sensors such as lidar, radar, cameras, and tactile sensors allows robots to perceive and adapt to dynamic surroundings, avoiding obstacles and completing tasks more effectively.

Health and Fitness Monitoring:

- Wearable devices use sensor fusion to gather and interpret data from accelerometers, gyroscopes, and heart rate monitors. This helps provide more accurate measurements of physical activity, sleep patterns, and overall health status.

Smartphones and Tablets:

- Mobile devices employ sensor fusion to enhance user experience and enable features such as automatic screen rotation, gesture recognition, and step counting. Combining data from accelerometers, gyroscopes, magnetometers, and GPS allows for more robust and accurate functionality.

Acoustic levitation

Ultrasonic acoustic levitation is a specific type of acoustic levitation that utilizes ultrasonic sound waves to suspend and manipulate objects. Ultrasonic waves have frequencies higher than the upper limit of human hearing, typically above 20,000 hertz. This high frequency allows for more precise control and manipulation of small objects in comparison to lower-frequency acoustic levitation techniques

Working Principle:

Standing Waves:

- The emitted ultrasonic waves interfere with their reflections, creating a stable pattern of standing waves. This pattern consists of regions of high pressure (antinodes) and low pressure (nodes).

Pressure Differences:

- The pressure differences between antinodes and nodes exert forces on the object placed within the standing wave. These forces create a net upward force that can counteract the force of gravity, allowing the object to levitate.

Stability and Control:

- The stability and control of the levitated object depend on factors such as the frequency and intensity of the ultrasonic waves, the size and shape of the object, and the characteristics of the surrounding medium.

Applications:

Material Handling and Manipulation:

- Ultrasonic acoustic levitation is used for precise and contactless handling of small objects in manufacturing and microelectronics.

Levitation Displays:

- Ultrasonic levitation has been explored for creating visually captivating displays, where objects appear to float in mid-air.

Hardware and sensors

1. **MPU 6050 (Accelerometer and Gyroscope):** The MPU-6050 is a popular integrated circuit that combines both accelerometer and gyroscope sensors into a single chip. It is commonly used in various applications, including robotics, motion sensing, and orientation tracking.
    - Accelerometers typically measure acceleration along three perpendicular axes: X, Y, and Z. In a 3-axis accelerometer, each axis corresponds to a direction in three-dimensional space.
    - Accelerometers are commonly used to detect the orientation of devices such as smartphones and tablets. For example, they enable screen rotation based on the device's tilt.
    - Gyroscopes also measure rotation along three axes (X, Y, and Z). In a 3-axis gyroscope, each axis corresponds to a rotational direction.

2. **U-blox NEO M8N GPS SENSORS:** The u-blox NEO-M8N is a GPS (Global Positioning System) module manufactured by u-blox, a Swiss company that specializes in positioning and wireless communication technologies. The NEO-M8N is widely used for various applications, including navigation, tracking, and timing.The applications are:

Navigation and Tracking:

- The NEO-M8N is commonly used in navigation systems for vehicles, ships, and aircraft. It is also employed in tracking devices for asset monitoring and personal tracking.

Surveying and Mapping:

- Surveying and mapping applications benefit from the high accuracy and multi-constellation support provided by the NEO-M8N.

3.**Ultrasonic Sensor HC - SR04 :** The HC-SR04 is a popular ultrasonic distance sensor that is widely used in robotics and electronics projects. It's an inexpensive and straightforward sensor for measuring distances using ultrasonic waves. The HC-SR04 is widely used in robotics, obstacle avoidance systems, automated measuring applications, and more. It offers an affordable and reliable solution for distance sensing in various projects.

4. **Arduino:** Arduino is an open-source electronics platform that consists of both hardware and software components. It is designed to make it easy for individuals, hobbyists, and professionals to create interactive and programmable electronic projects. The core of the Arduino platform is the Arduino board, which can be programmed using the Arduino Integrated Development Environment (IDE).

Data Acquisition

LDR

LDR, or Light Dependent Resistor, is a type of resistor whose resistance changes with the intensity of light falling on it. LDRs are commonly used in applications where the amount of light needs to be measured, such as in light-sensitive circuits, streetlights, and photography exposure meters. When acquiring data from an LDR, you typically measure its resistance or voltage output based on the light conditions

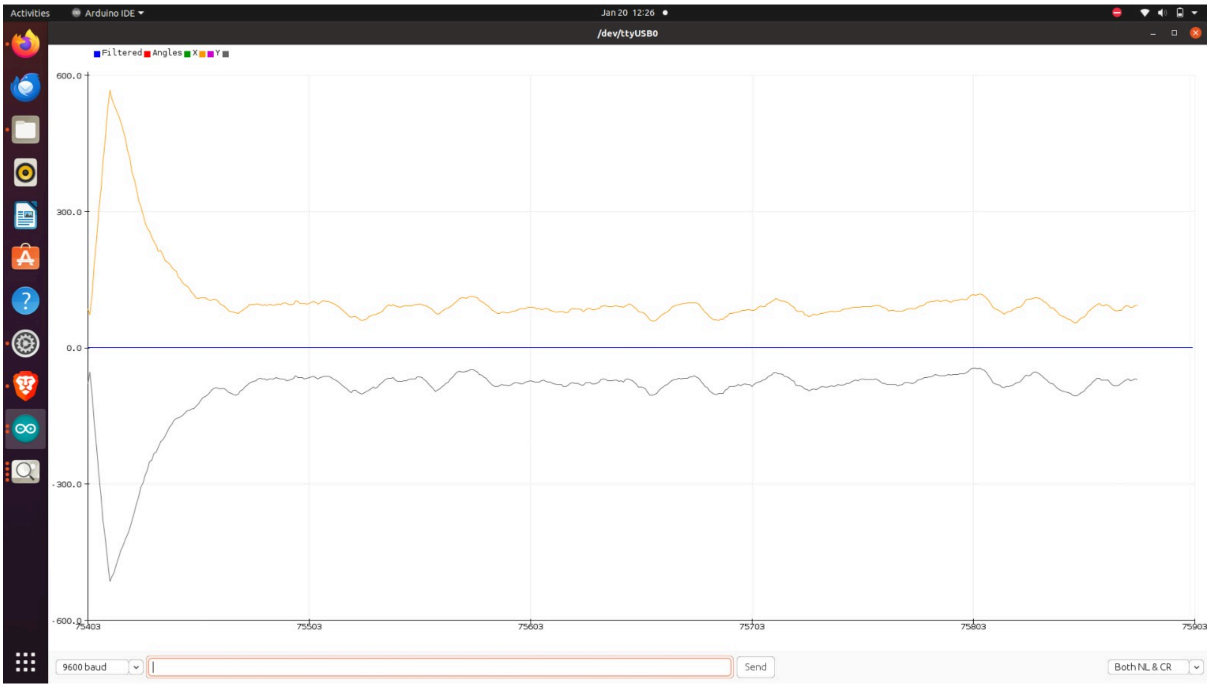
Filters

Kalman Filter : A Kalman filter is a recursive algorithm that provides an optimal estimate of the state of a linear dynamic system from a series of noisy measurements over time. It is widely used in various fields, including control systems, signal processing, robotics, and navigation. The Kalman filter is particularly useful when dealing with systems subject to uncertainty and measurement.

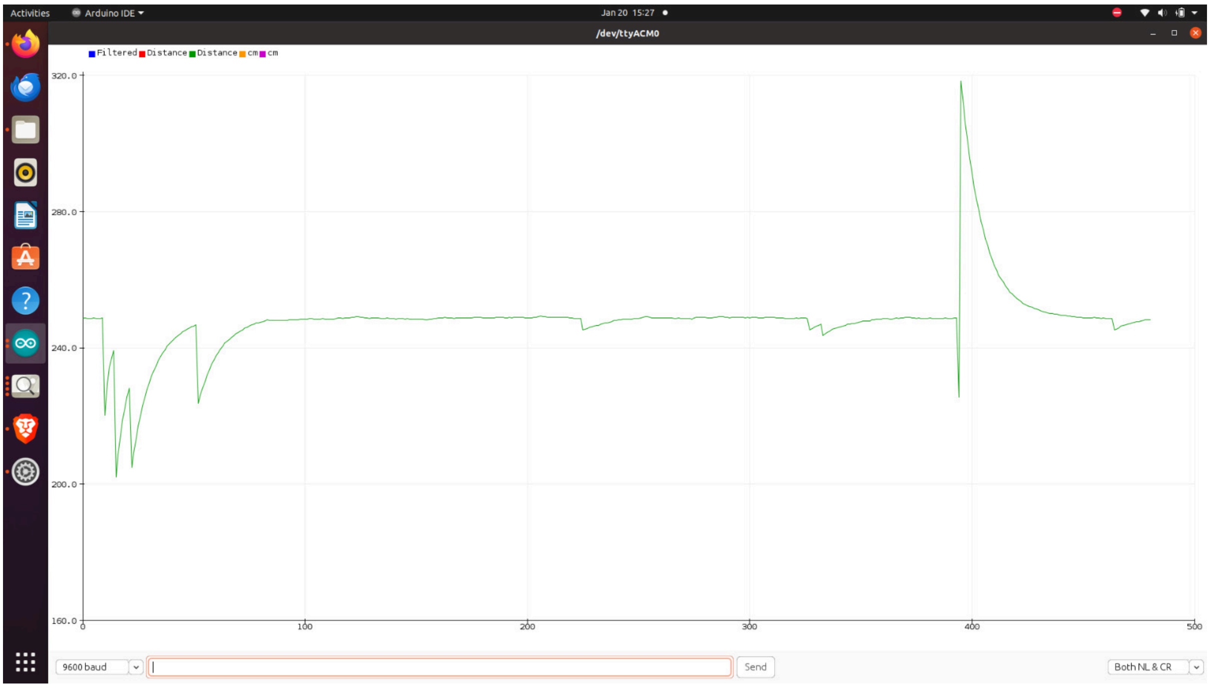
Predicted state estimate	$\hat{x}^{-}_{k}=F\hat{x}^{+}_{k-1}+Bu_{k-1}$
Predicted error covariance	$P^{-}_{k}=P^{+}_{k-1}F^{T}+Q$

Implementation:

IMU SENSOR



ULTRASONIC SENSOR



COMPLEMENTARY FILTER:

A complementary filter is a sensor fusion algorithm used to combine the information from multiple sensors, typically an accelerometer and a gyroscope, to obtain a more accurate and stable estimate of an orientation (pitch and roll) or other dynamic variables. Complementary filters are commonly employed in robotics, drones, and other motion-sensing applications where accurate and real-time orientation estimation is crucial.

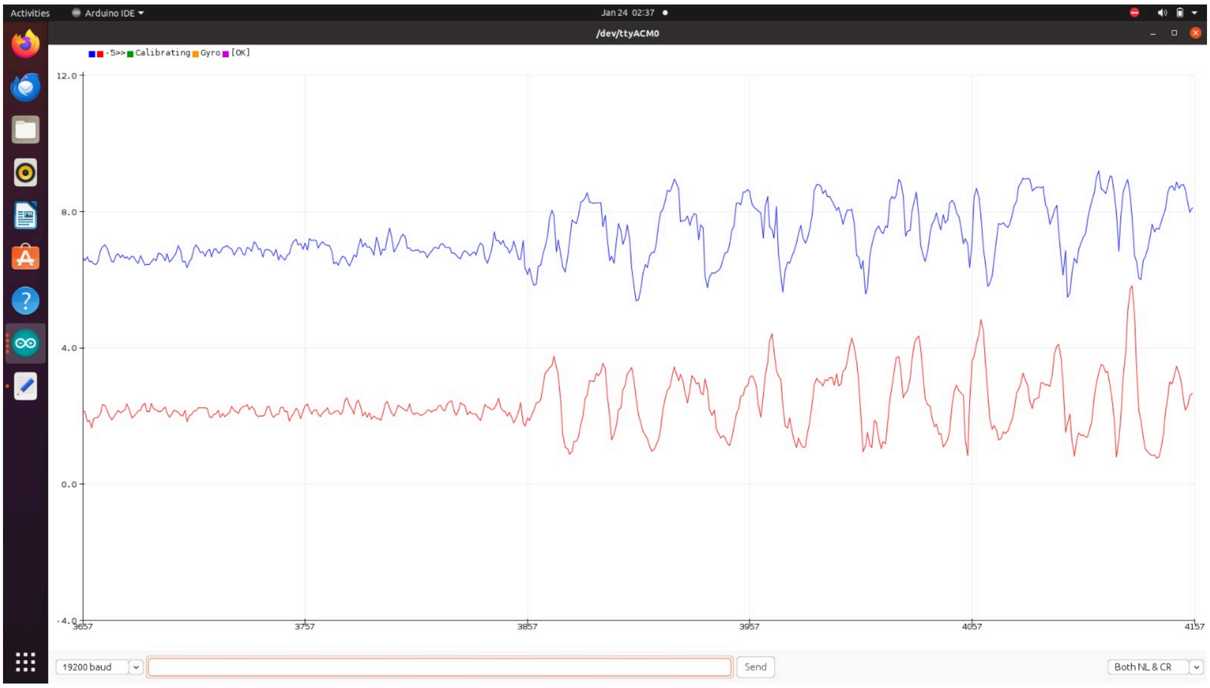
The basic idea behind a complementary filter is to use the accelerometer's data to estimate the tilt angle accurately in static conditions (e.g., when the sensor is not accelerating) and use the gyroscope's data to maintain accuracy during dynamic conditions (e.g., when there is angular velocity). By blending these two sources of information, the filter can effectively compensate for the limitations of each sensor.

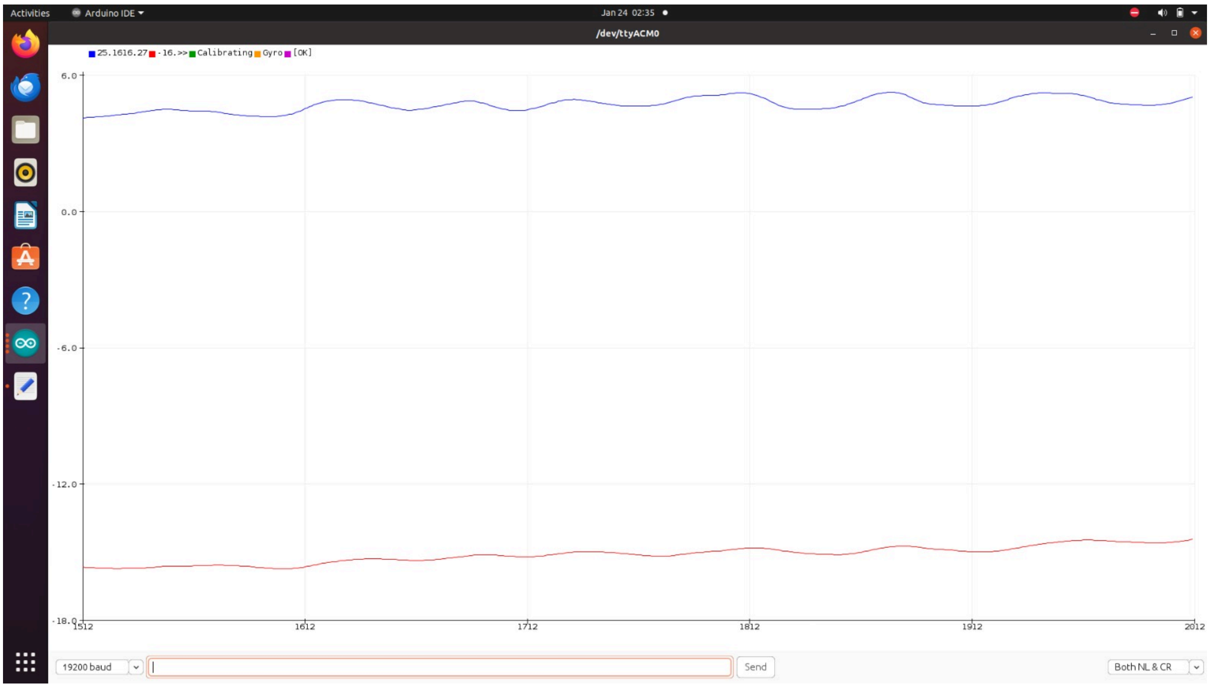
Complementary Filter Algorithm:

- The complementary filter combines the accelerometer and gyroscope data using a weighted average. The basic formula for updating the orientation estimates is:
- $angle=\alpha\times(angle+gyroRate\times dt)+(1-\alpha)\times accelAngle$
- $angle=\alpha\times(angle+gyroRate\times dt)+(1-\alpha)\times accelAngle$

Implementation

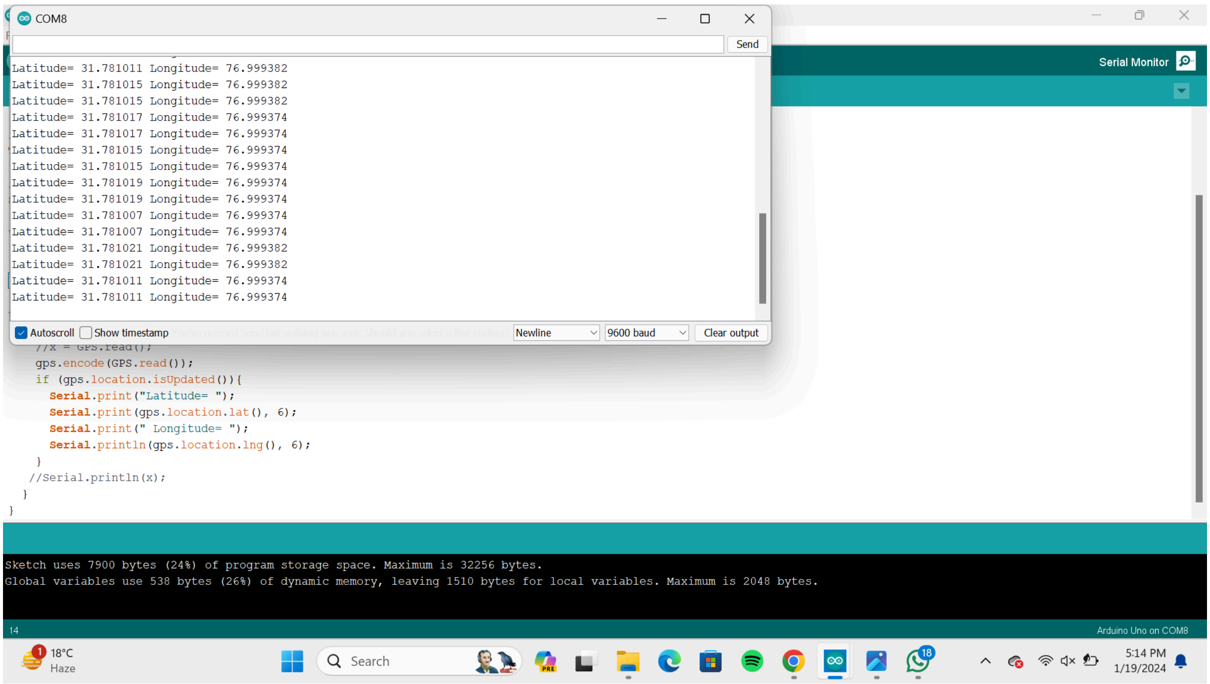
ROLL AND PITCH:





IMU GPS FUSION

GPS GRAPH


COM8
Send
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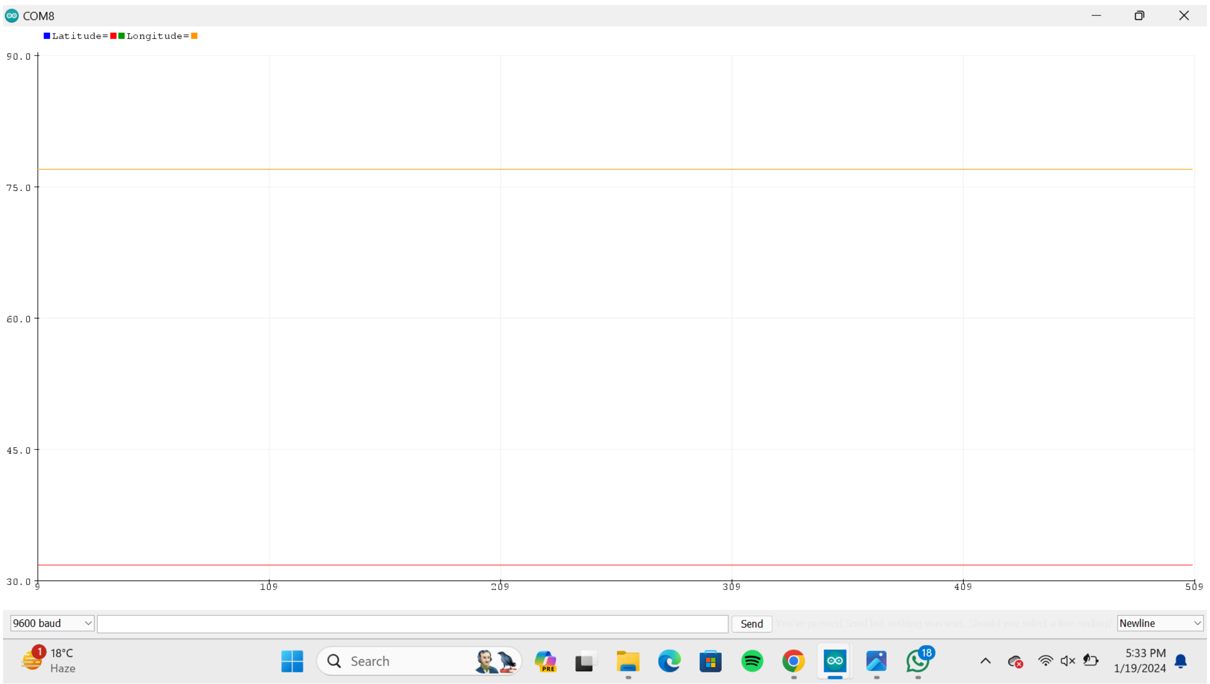
Latitude= 31.781021 Longitude= 76.999382
Latitude= 31.781021 Longitude= 76.999382
Latitude= 31.781011 Longitude= 76.999374
Latitude= 31.781011 Longitude= 76.999374
Autoscroll
Show timestamp
Newline
9600 baud
Clear output
Serial Monitor
gps.encode(GPS.read());
if (gps.location.isUpdated()){
Serial.print("Latitude= ");
Serial.print(gps.location.lat(), 6);
Serial.print(" Longitude= ");
Serial.println(gps.location.lng(), 6);
}
//Serial.println(x);
}
}
Sketch uses 7900 bytes (24%) of program storage space. Maximum is 32256 bytes.
Global variables use 538 bytes (26%) of dynamic memory, leaving 1510 bytes for local variables. Maximum is 2048 bytes.
14
Arduino Uno on COM8
18°C
Haze
Search
5:14 PM
1/19/2024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30.0
9
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209
309
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Search
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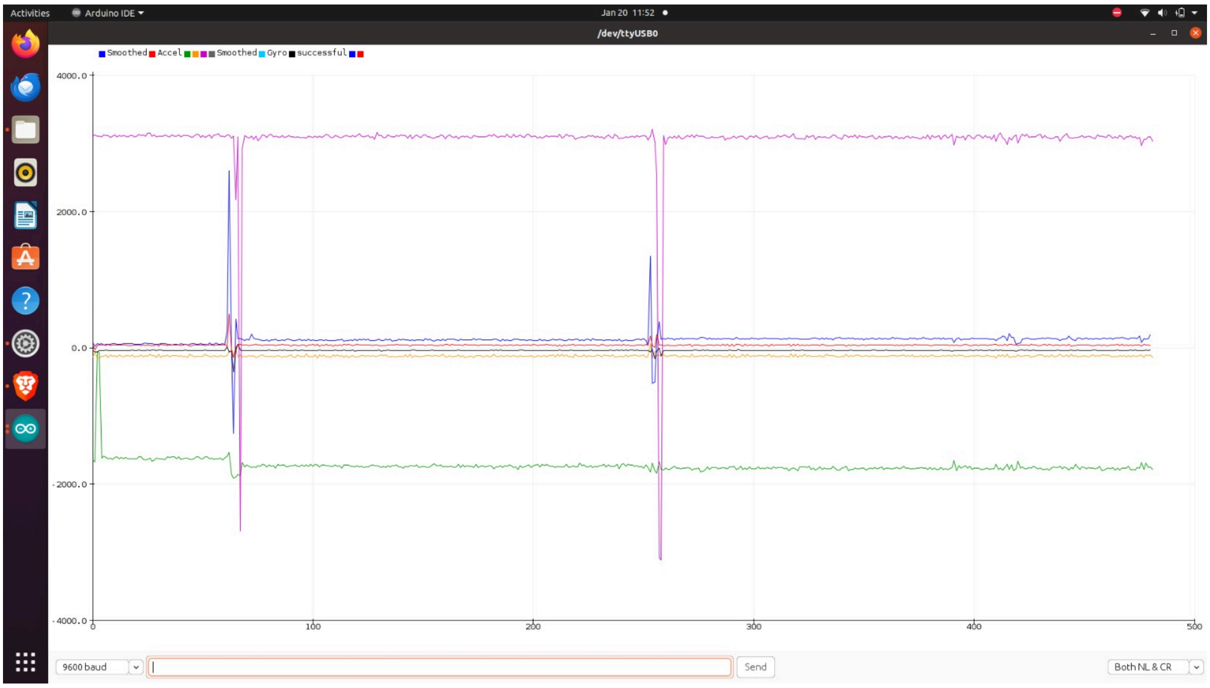
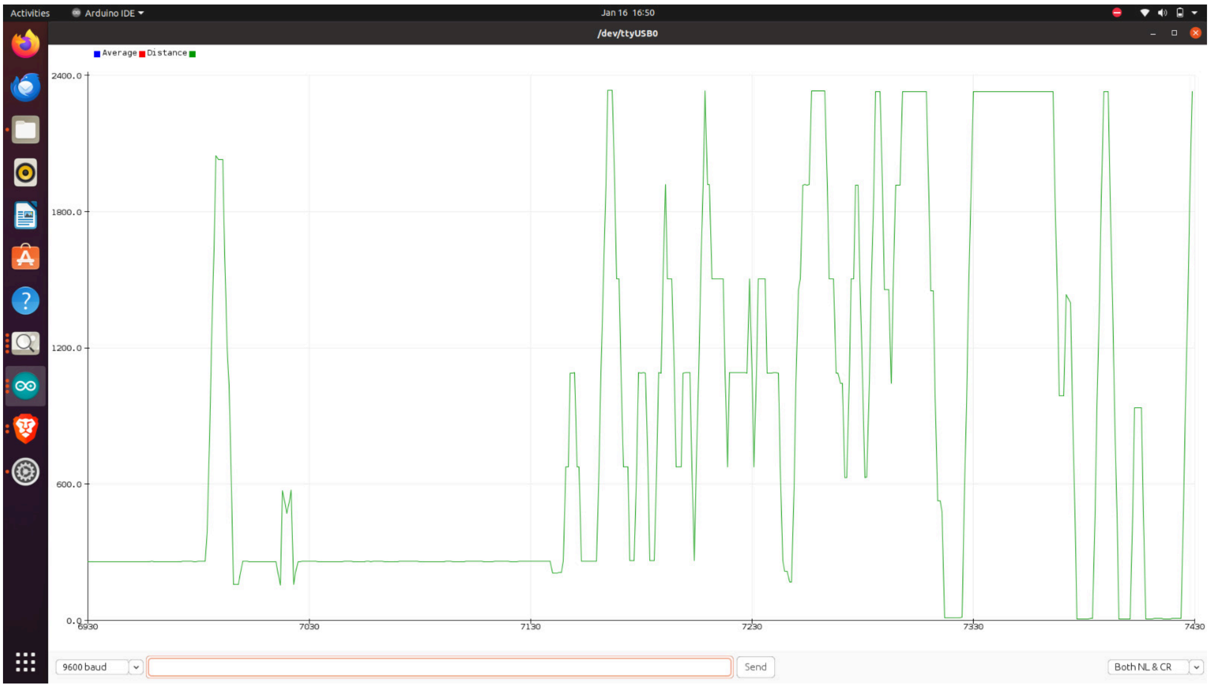
1/19/2024

IMU GRAPH USING MOVING AVERAGE



ULTRASONIC GRAPH USING MOVING AVERAGE



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- https://www.electronicwings.com/arduino/gps-module-interfacing-with-arduino-uno