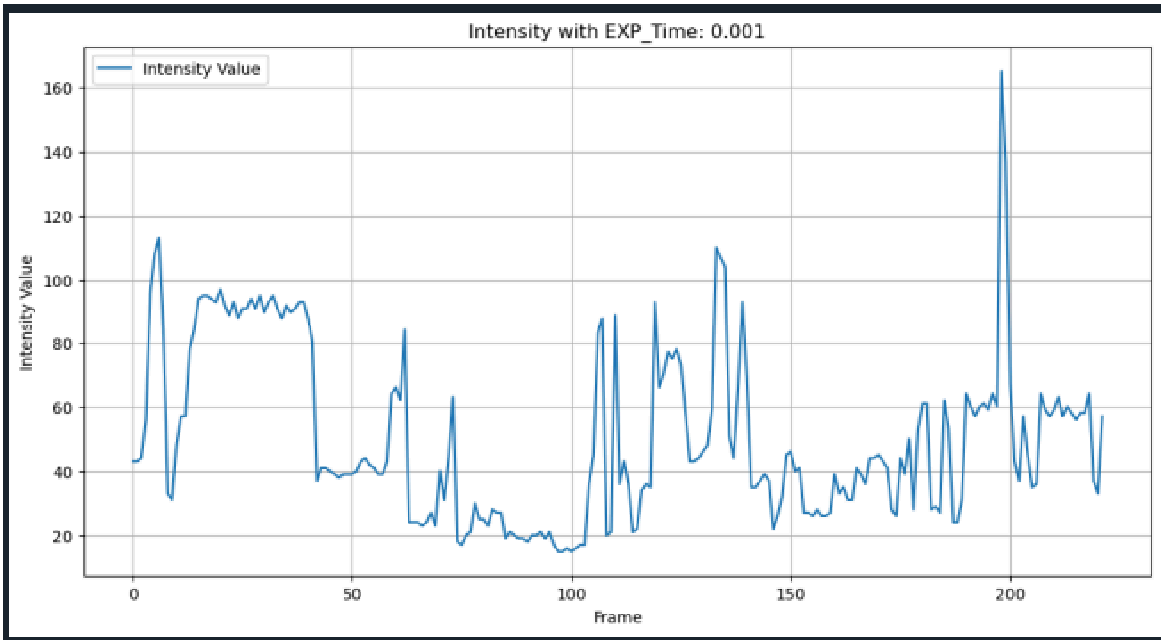
Final Project: Real-Time Object Tracking



Spatial and Temporal Noise of the Image Sensor

To begin, we set the CMV300 image sensor's exposure time to approximately **1 ms**. The intensity graph reflects this, where values typically range between **40 and 100**. Several notable peaks are observed, which can be explained by:

- **The tracked object**: A flashlight introduces sudden increases in brightness for specific pixels.
- **Ambient lighting**: Ceiling lights in the background, despite the lowered exposure time, may contribute to noise.

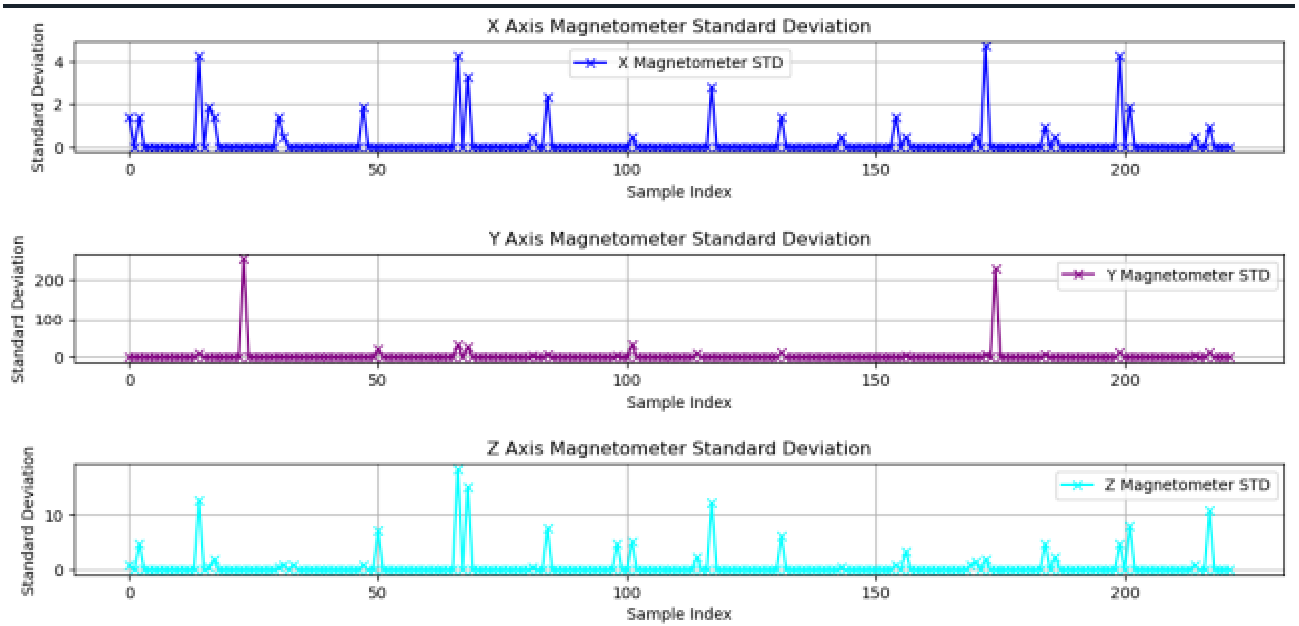
While the peaks indicate sporadic noise, the overall stability in intensity values suggests minimal temporal noise. The graph highlights a balance of stability with occasional outliers, consistent with the image sensor's sensitivity.

Signal-to-Noise Ratio of the Heading Sensor

The magnetometer standard deviation values, shown for the **x, y, and z axes**, represent the noise behavior of the heading sensor. Key observations include:

- **Minimal noise overall**: The standard deviation values hover close to **0** for most samples, as expected.
- **Outliers on the y-axis**: A few values around **200** occurred in **2 out of 222 samples**. While these can be considered outliers, they do not significantly impact overall performance.

Potential noise sources include interference from the flashlight (sourced from a phone) that may cause subtle changes in the magnetometer readings. Despite this, the signal-to-noise ratio remains favorable, demonstrating the sensor's reliability.



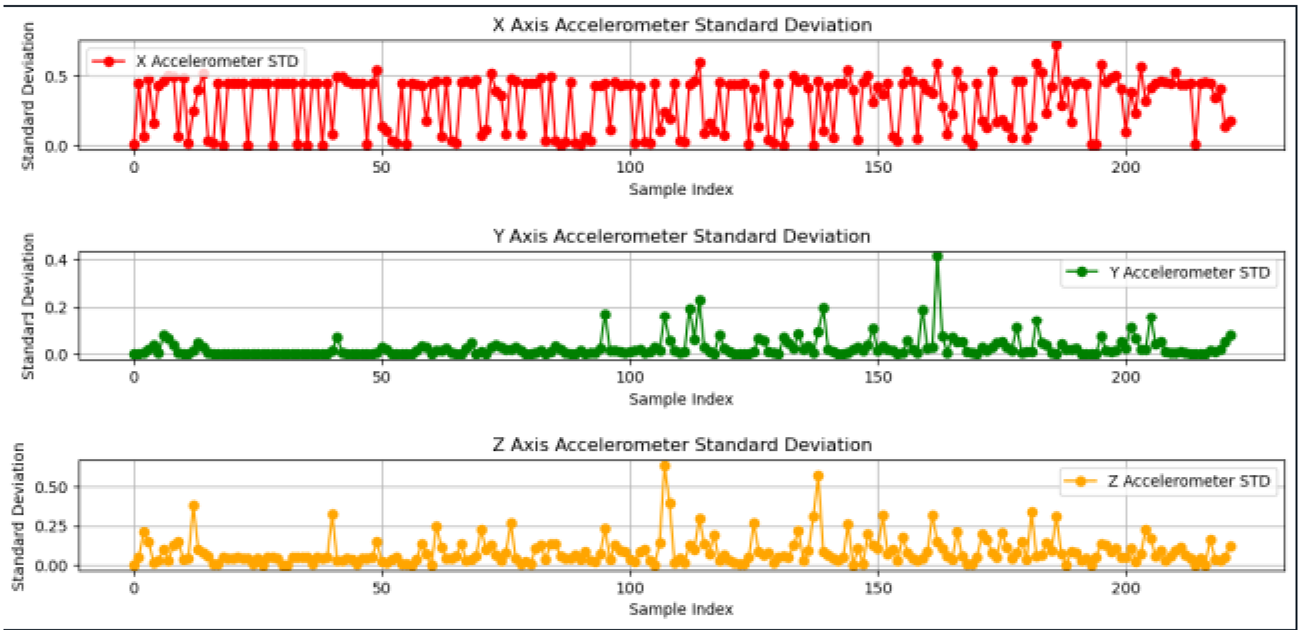
Noise in the Acceleration Sensor

We evaluated the standard deviation of acceleration readings across the **x, y, and z axes**. Results show that the values max out at approximately **0.5**, suggesting low noise levels.

Factors to Consider:

- **Polling method**: The LSM303 sensor registers are polled indiscriminately, without checking if values are fresh. This could lead to minor inaccuracies in the readings.
- **Consistency**: Despite the polling method, the standard deviation remains stable with few peaks, reinforcing the observation of minimal noise.

Overall, the acceleration sensor demonstrates reliable and consistent performance.

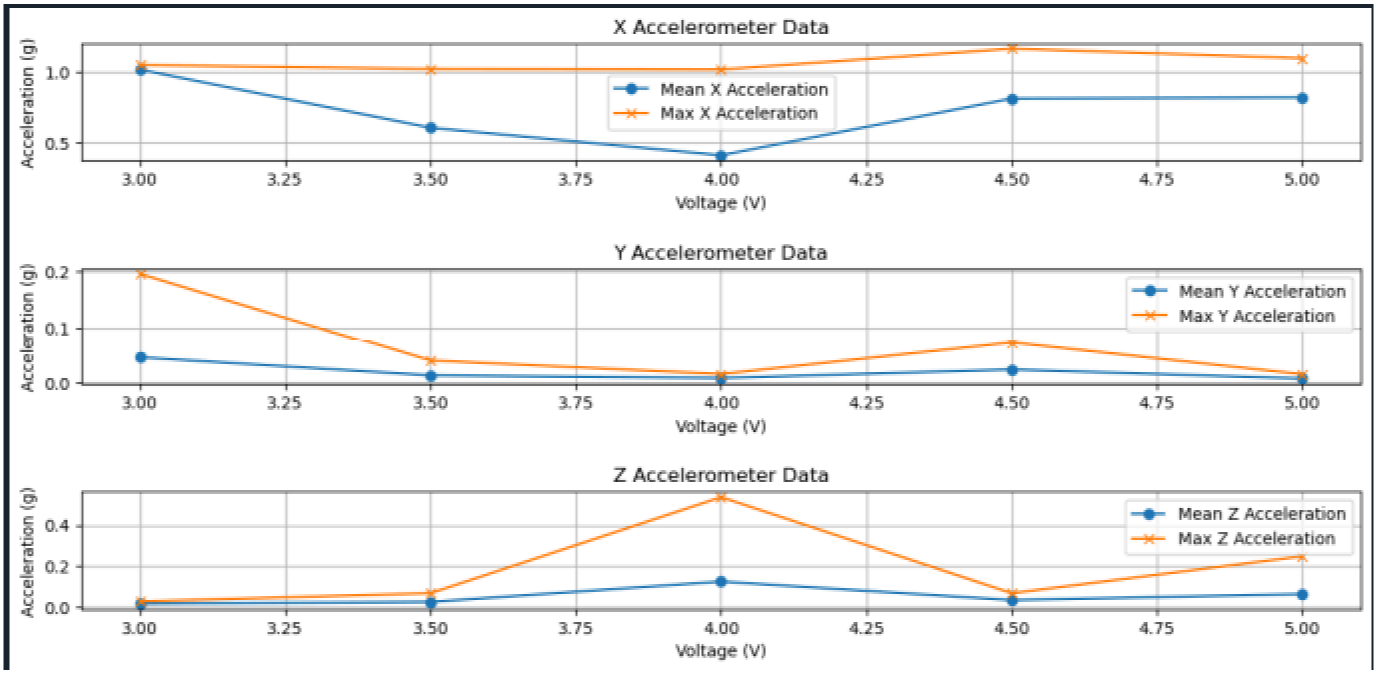


Acceleration of the Sensor Board vs. Applied Voltage on the Motor

For this experiment, we applied a voltage range of **3.5 V to 5 V** to drive the PMOD DHB1 board connected to a DC motor. Key observations include:

- **Exponential relationship**: The acceleration increases exponentially with the applied voltage.
- **Axis interpretation**:
  - **X-axis**: Can be ignored, as it primarily measures gravity due to the sensor's position on the board.
  - **Y and Z axes**: These axes are interpreted together since the board rotates around a single axis, creating circular motion.

The results confirm the expected correlation between motor voltage and sensor acceleration.



5. Accuracy and Limitations of the Tracking Algorithm

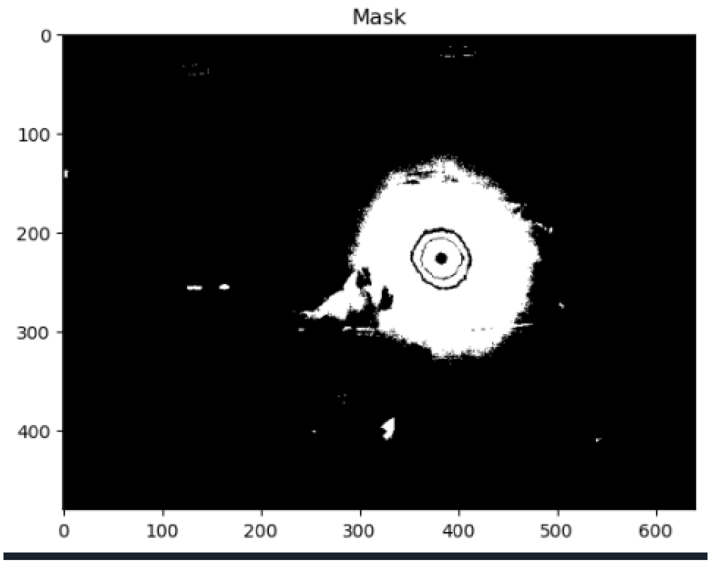
Implementation Overview

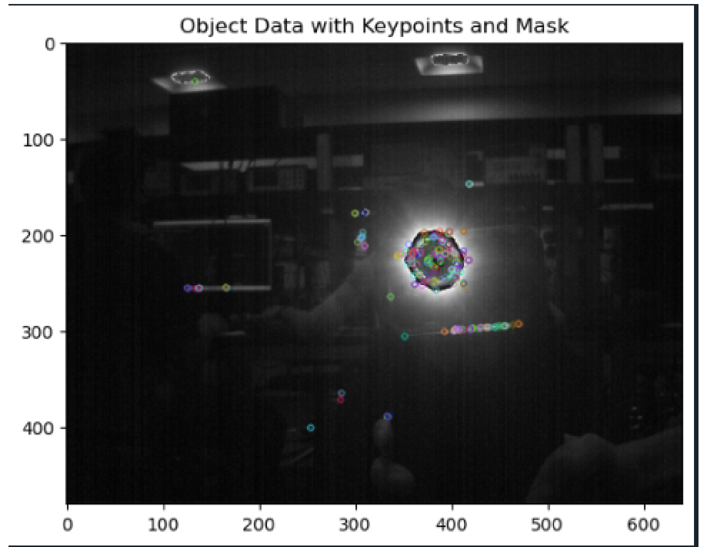
The object detection algorithm integrates the following OpenCV libraries:

- **cv2.ORB**: Generates keypoints and descriptors.
- **cv2.BFMatcher**: Matches keypoints between consecutive frames.
- **cv2.createBackgroundSubtractorMOG2()**: Subtracts the background to isolate the moving object.

Tracking Workflow:

1. **Background Initialization**: Capture initial frames of the static background and the object.
2. **Mask Calculation**: Use the background to generate a mask and identify accurate keypoints/descriptors.
3. **Real-Time Detection**: Subtract the background in future frames, detect keypoints, and match descriptors using **BFMatcher**.
4. **Movement Calculation**: Compute the horizontal movement of the object, which triggers a corresponding motor command.





Limitations

While the algorithm operates effectively in many scenarios, it has the following limitations:

- **Background Interference**: Dynamic backgrounds, such as a lab environment, introduce noise that confuses object detection.
- **Frame Motion**: The **BackgroundSubtractorMOG2** struggles to distinguish between the moving object and the background in continuously shifting frames.
- **Exposure Adjustment**: To mitigate interference, we reduced the exposure time and relied on a flashlight to enhance object visibility.

These factors result in occasional miscalculation of keypoints/descriptors, reducing accuracy. However, the algorithm performs well under controlled lighting and minimal background motion.