Lab 9 Milestone 2: Sensor Data Processing

Part 1: Understanding Sensor Data Errors

Objective

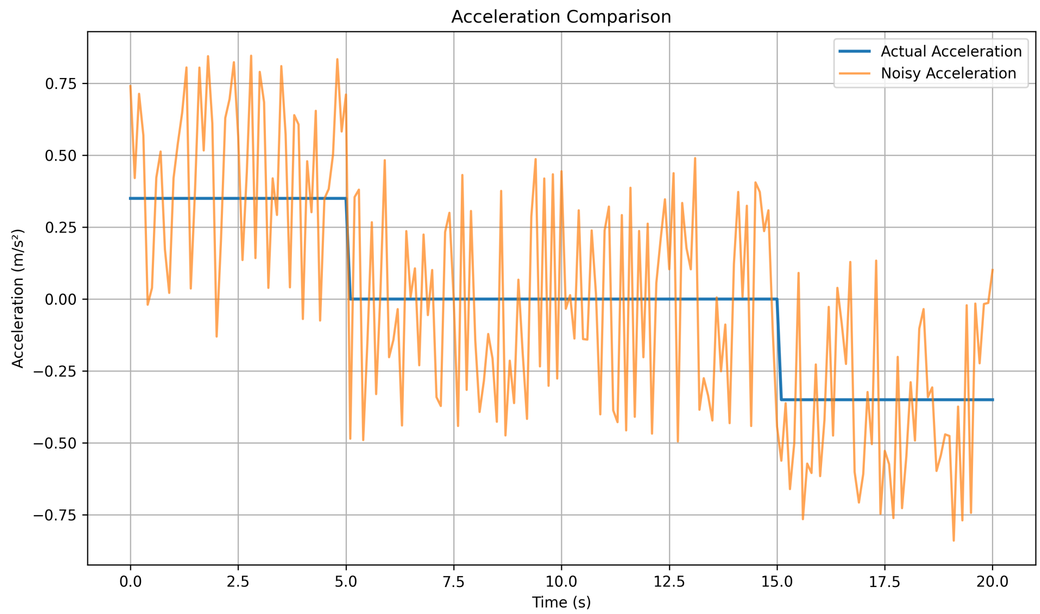
This analysis examines how sensor noise in accelerometer data affects distance estimation. Using synthetic acceleration data, we integrated acceleration values to compute velocity and distance, comparing results from clean data versus noisy sensor readings.

Methodology

The ACCELERATION.csv dataset contains timestamped measurements with both actual and noisy acceleration values. The analysis used numerical integration with a timestep of 0.1 seconds. Velocity was computed as $v(t) = v(t-1) + a(t-1) * dt$, and distance as $d(t) = d(t-1) + v(t-1) * dt$, where dt is the time step between measurements.

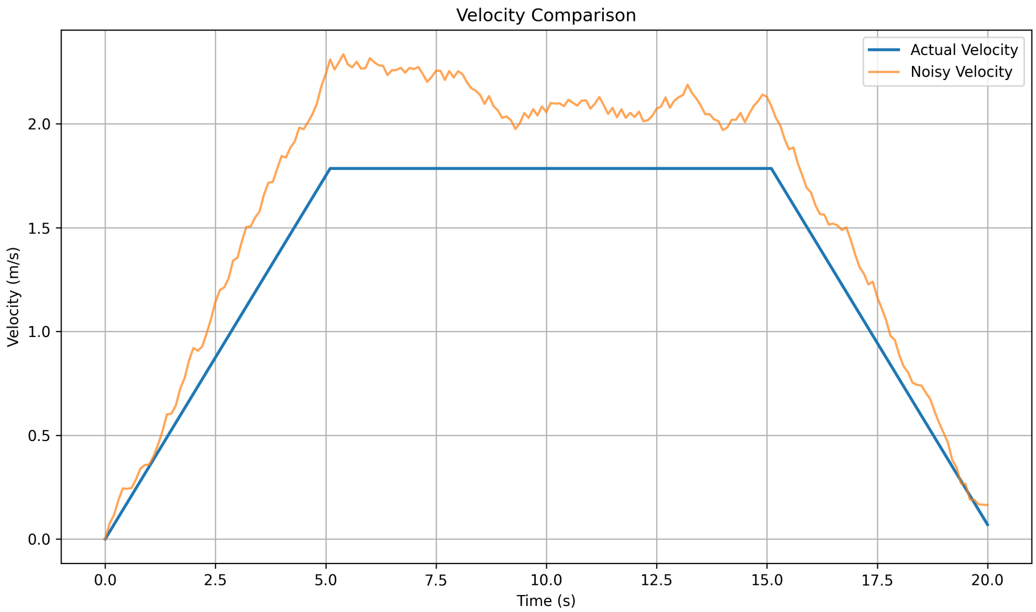
Results

Figure 1: Acceleration Comparison



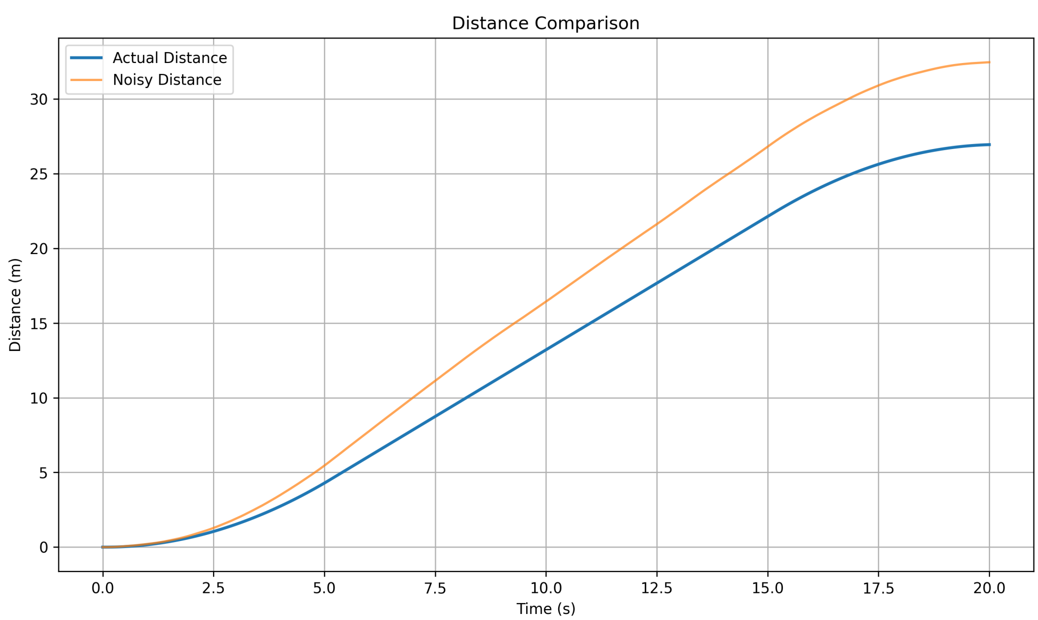
The acceleration plot shows the actual acceleration pattern (a step function with values 0.35, 0, and -0.35 m/s²) compared to noisy sensor measurements. The noise introduces random variations around the true values.

Figure 2: Velocity Comparison



Integrating acceleration produces velocity. The actual velocity follows a clear triangular pattern, while the noisy velocity shows cumulative error that grows over time due to noise integration.

Figure 3: Distance Comparison



Distance traveled shows the most significant error accumulation. The actual distance follows a smooth curve reaching the final value, while the noisy estimate diverges substantially due to double integration of noise.

Quantitative Analysis

Final distance using actual acceleration: 26.9430 m
Final distance using noisy acceleration: 32.4594 m
Difference between estimates: 5.5164 m
Percentage error: 20.47%

Discussion

The analysis demonstrates that sensor noise has a compounding effect when integration is performed. While the noise in acceleration appears relatively small, integrating once to get velocity and again to get distance causes errors to accumulate significantly. The 20.47% error in final distance estimation highlights the critical importance of sensor accuracy in pedestrian dead-reckoning applications.

This error accumulation explains why practical PDR systems require additional techniques such as zero-velocity updates, step detection algorithms, and sensor fusion to maintain accuracy over time. Without these corrections, raw integration of noisy accelerometer data quickly becomes unreliable for navigation.

Conclusion

Noisy accelerometer measurements introduce significant errors in distance estimation through double integration. The 5.5 meter difference over a short movement demonstrates why real-world PDR systems must implement sophisticated filtering and error correction strategies to achieve useful positioning accuracy.