Sensor accuracy: standard deviation

FizziQ activity · High school · 25 min

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With the smartphone at rest, students record 20 seconds of accelerometer data and use FizziQ statistics to compute standard deviation and assess sensor precision.

Learning objectives

- Record a time series of accelerometer measurements with the smartphone at rest
- Analyze the distribution of measured values using histograms and statistical tools
- Calculate the mean, standard deviation, and relative uncertainty of the accelerometer
- Understand the difference between accuracy (systematic error) and precision (random error)
- Evaluate whether the measurement noise follows a normal (Gaussian) distribution

Instruments and sensors

Absolute acceleration · Accelerometer

Materials

- Smartphone with the FizziQ application
- Stable surface to place the smartphone
- Possibly several smartphones of different models for comparison
- FizziQ experiment notebook
- Optional: spreadsheet software for additional analysis
- Note: the protocol remains adaptable to any comparable data acquisition tool.

Protocol

1. Open FizziQ and select the Accelerometer sensor. Choose absolute acceleration for a single-value measurement.
2. Place the smartphone on a flat, stable surface (a solid table, not a flexible desk or soft surface). Ensure nothing touches or vibrates near the phone.
3. Start recording and collect data for at least 20 seconds at the highest available sampling rate.
4. Stop recording and note the total number of data points collected.
5. Examine the raw acceleration-versus-time graph. The values should fluctuate slightly around a mean close to 9.81 m/s².
6. Use FizziQ's statistical tools to calculate the mean (average) and standard deviation of the recorded data.
7. Record these values. The standard deviation represents the precision of the sensor (random uncertainty).
8. If available, view the histogram of the data. It should approximate a bell curve (Gaussian distribution).
9. Calculate the relative uncertainty: (standard deviation / mean) × 100%. A good smartphone accelerometer should show relative uncertainty below 0.5%.
10. Compare the measured mean with the accepted value of g at your location. The difference between them represents the accuracy (systematic error) of the sensor.
11. If you have access to another smartphone, repeat the same measurement and compare the means and standard deviations of the two devices.
12. Discuss: if you average N measurements, the uncertainty of the mean decreases by a factor of √N. Calculate how many measurements would be needed to achieve a relative uncertainty of 0.01%.

Expected results

Typical smartphone accelerometers show a standard deviation of 0.02-0.10 m/s² when stationary, corresponding to a relative precision of 0.2-1.0%. The mean value typically falls within 0.1-0.3 m/s² of the accepted value of g, reflecting the sensor's accuracy. The histogram should approximate a Gaussian distribution, though some sensors may show slight asymmetry or discrete quantization steps. Higher sampling rates may reveal high-frequency noise that is averaged out at lower rates. Different smartphone models can show significantly different precision levels. Environmental vibrations (nearby machinery, traffic, people walking) will increase the apparent standard deviation and may distort the Gaussian shape.

Questions

- What is the difference between the precision and accuracy of a measuring instrument?
- Why does the standard deviation decrease when you average more measurements?
- What factors contribute to the random fluctuations observed in the accelerometer readings?
- How could you improve the accuracy of the accelerometer (reduce systematic error)?
- Why is the Gaussian (normal) distribution so common in measurement science?
- How would you determine whether a sensor is suitable for a particular experiment?

Going further

- Compare the statistical properties of different sensors on the same smartphone (accelerometer, gyroscope, magnetometer, barometer)
- Investigate how placing the smartphone on different surfaces (wood, metal, foam) affects the measurement noise
- Study the effect of sampling rate on the apparent standard deviation
- Perform the same analysis during a controlled vibration (e.g., phone on a washing machine) and compare the histogram shape
- Use the analysis to determine the minimum detectable signal: what is the smallest acceleration change the sensor can reliably detect?