Wireless, Magnet-Based Eye Tracking in Lab Animals

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Lightweight Eye Tracking

Eye movements reveal how animals perceive the world, but tracking them during natural movement remains difficult.

Video-based systems are often bulky, computationally heavy, and uncomfortable for freely moving lab animals.

We test whether a small eye-mounted magnet and magnetic-field sensors can track eye motion with useful accuracy and low noise.

Eye-Tracking Prototype

Two Complementary Magnetic Sensors

- TMAG5170 (Hall sensor): measures 3-axis magnetic field (Bx, By, Bz)
- TMAG6180 (AMR sensor): outputs angle-related signals

A Microcontroller Captures and Streams Data

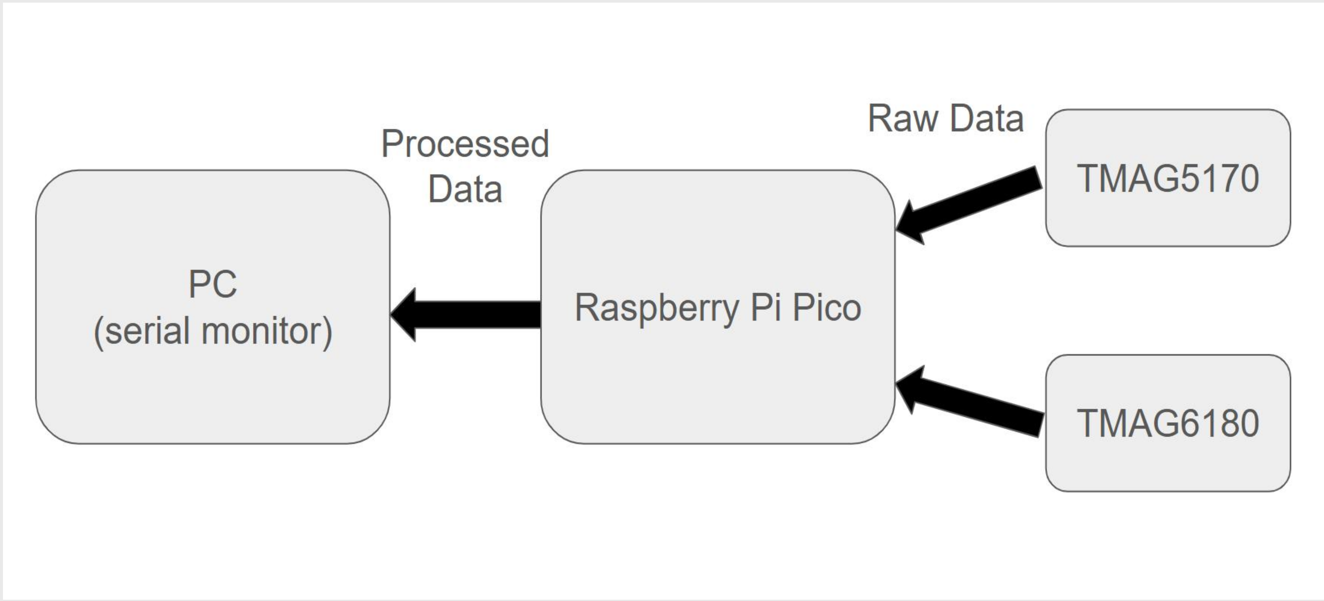
Raspberry Pi Pico collects sensor data in real time

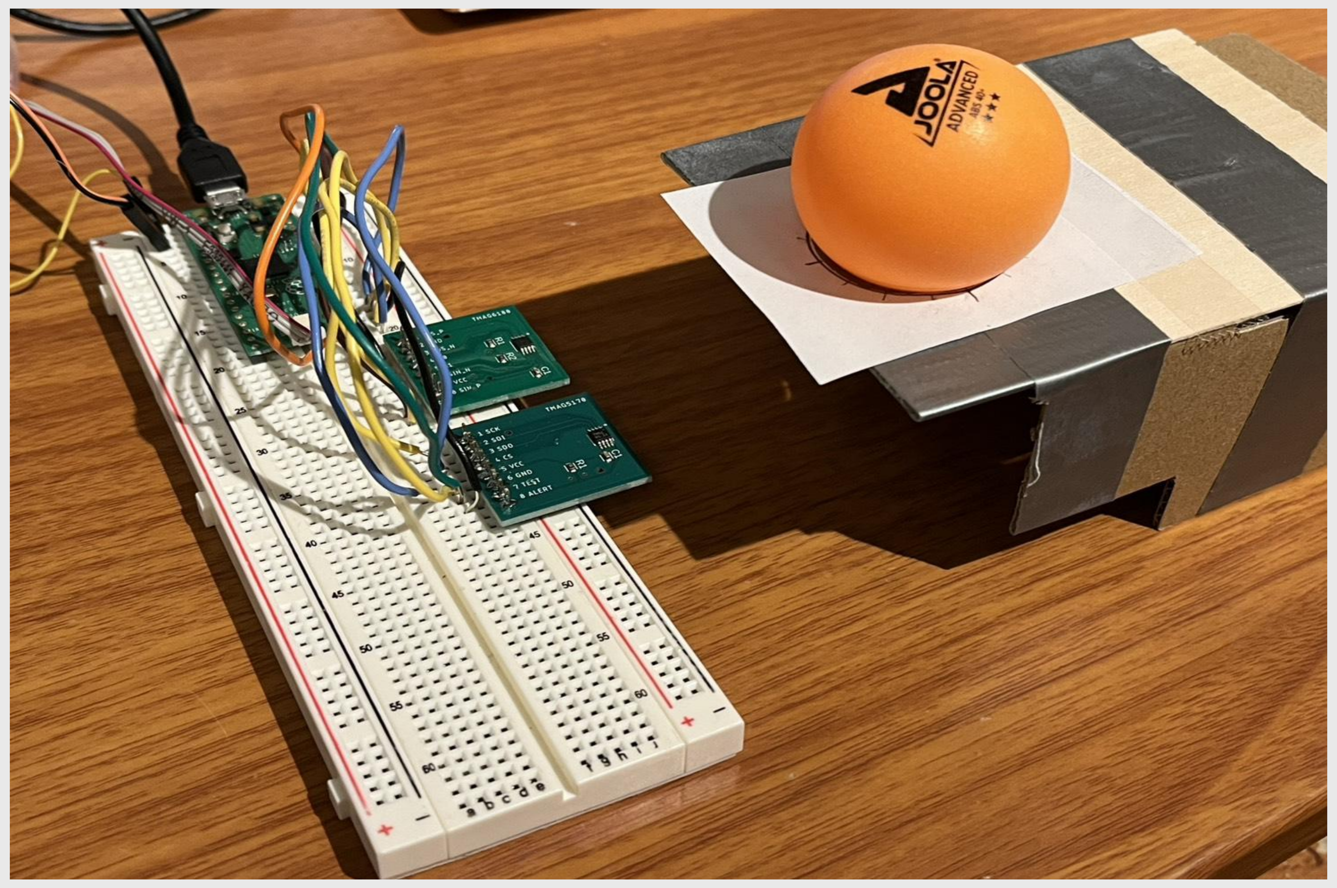
Data is streamed via USB to a PC for analysis

A Physical Model Simulates Eye Movement

A rotating ball with a small magnet mimics eye motion

A calibrated mount provides ground-truth angles





Accurate but Noisy Magnetic Tracking

Our experimental setup successfully tracked angular motion using both magnetic sensors. Across all tested positions, the system produced consistent and repeatable angle measurements that closely followed the ground-truth values.

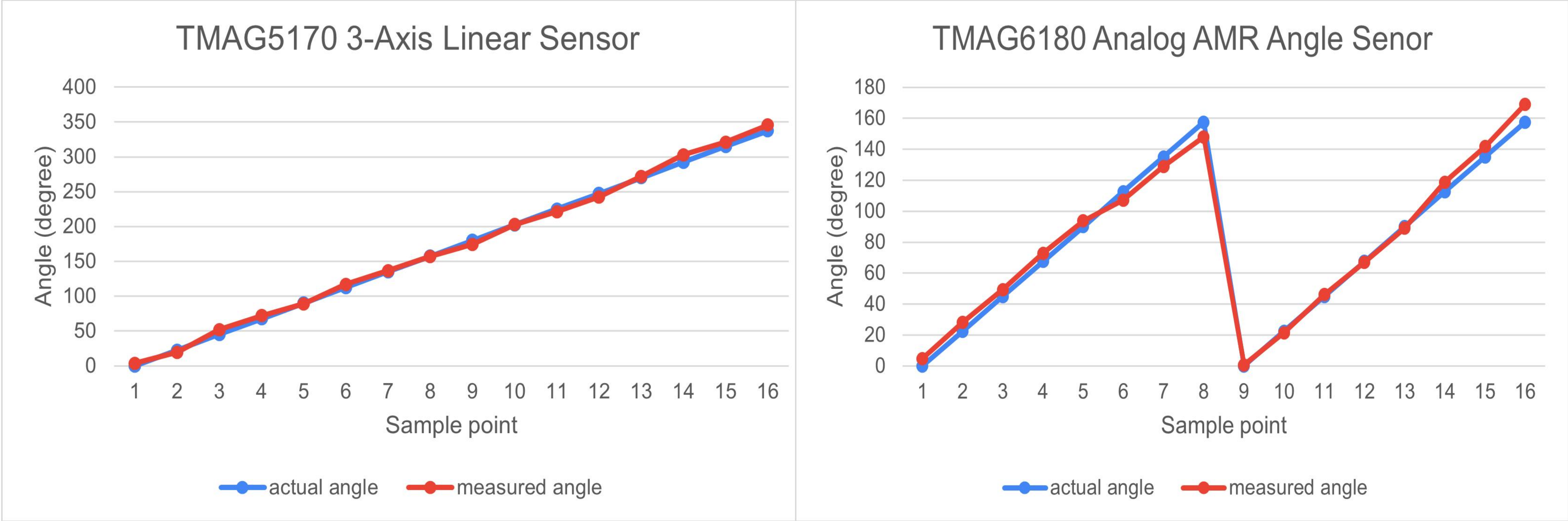
Both sensors exhibited similar baseline accuracy (error generally < 10°).

We recorded measured angles against the ground-truth bracket in 22.5° increments.

Calculation Methods

- TMAG5170: Angle=$\text{atan2}(-B_y, -B_x) \times \frac{180}{\pi}$
- TMAG6180: Angle=$\frac{\text{atan2}(V_{sin}, V_{cos})}{2} \times \frac{180}{\pi}$

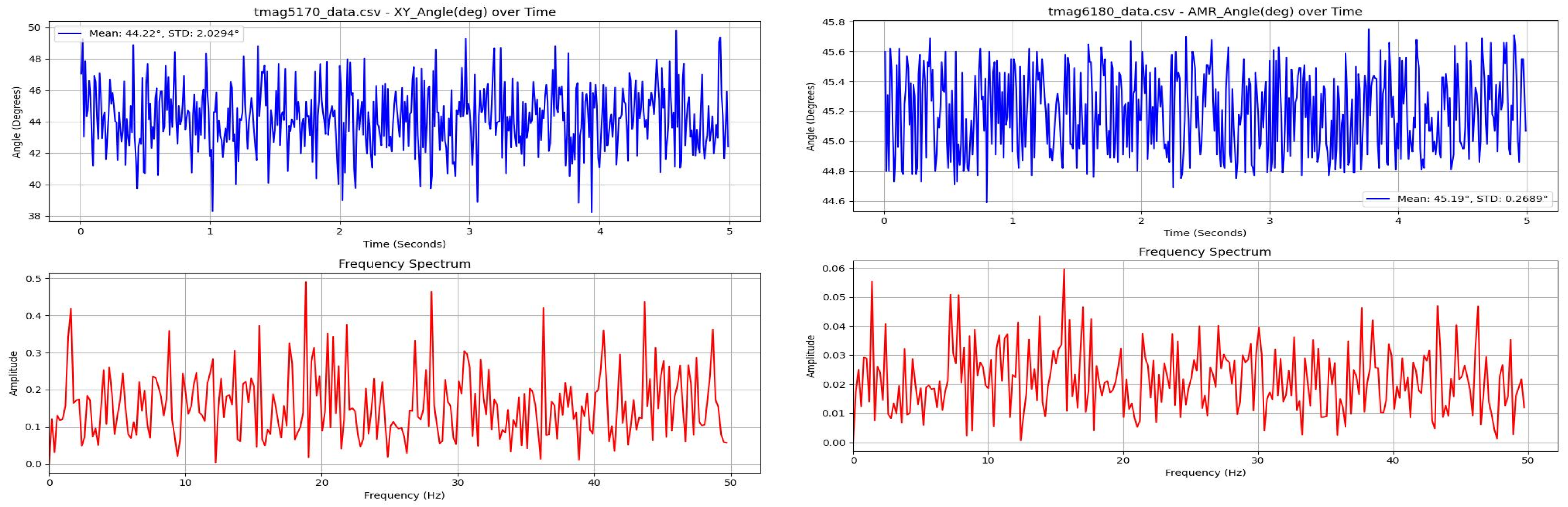
(Note:AMR sensors have a 180°measurement range , causing wrap-around)



Noise characterization at higher sampling rates (100 Hz) revealed significant differences between sensors. The Hall sensor showed larger fluctuations (≈10° peak-to-peak), whereas the AMR sensor demonstrated lower noise levels (≈1° peak-to-peak) and a more stable frequency spectrum.

we removed the low-pass filter, increased the hardware sampling rate to a deterministic 100 Hz, and captured a 5-second burst (500 samples) at a fixed 45° angle.

- TMAG5170 (Digital 3-Axis Linear Sensor): Displayed high inherent noise. The signal exhibited up to 10° of peak-to-peak jitter, with an RMS Noise (Standard Deviation) of ~2.03°.
- TMAG6180 (Analog AMR Angle Sensor): Displayed excellent stability. The peak-to-peak jitter was only ~1°, with an RMS Noise of just ~0.27°.
- Spectrum Analysis: Fast Fourier Transform (FFT) calculations showed a relatively uniform noise floor across the 0–50 Hz spectrum for both devices.



These results confirm that magnetic tracking is feasible and accurate, but its performance is limited by noise characteristics and sensor-specific constraints.

Accuracy Trade-Offs

Both magnetic sensors successfully track magnet orientation within an acceptable margin of accuracy.The TMAG5170 (digital 3-axis) suffers from a poor signal-to-noise ratio, making it unsuitable for tracking rapid eye movements without aggressive filtering that would destroy temporal data. The TMAG6180 (analog AMR) provides a significantly cleaner signal (~8x less RMS noise) and is the vastly superior choice for future miniaturized, wireless tracking in live animal subjects.

Acknowledgements

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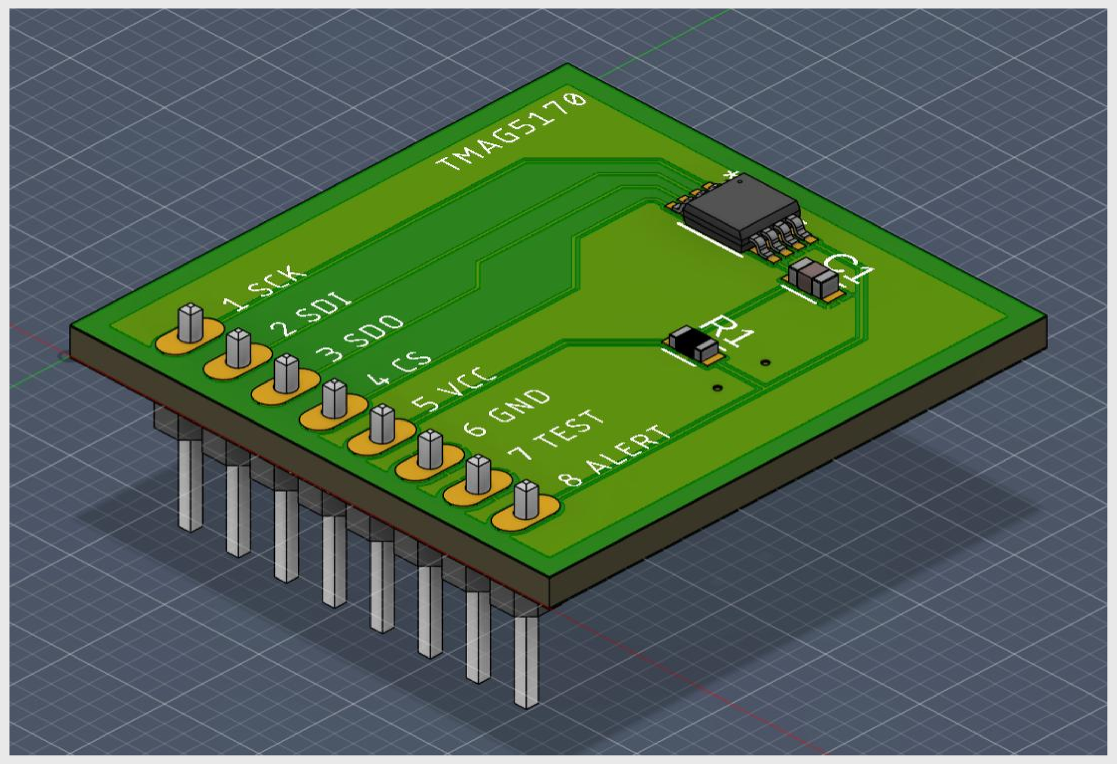

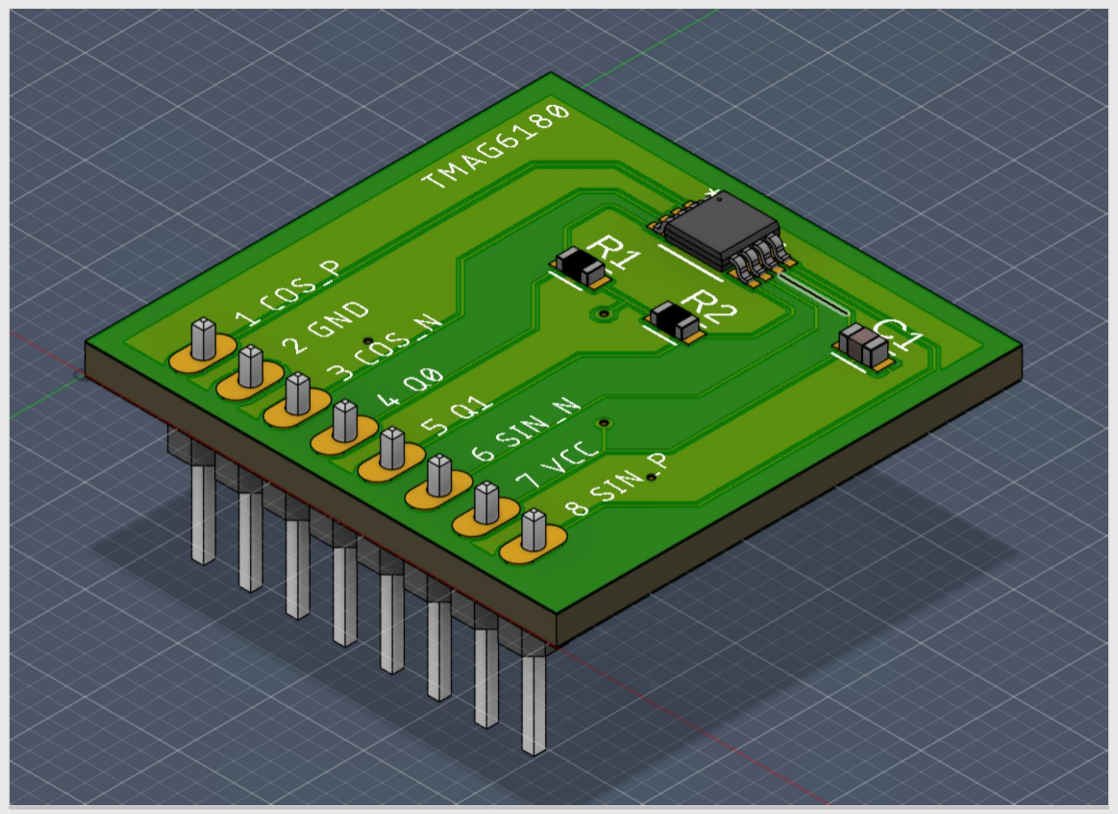

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