# Electromagnetic Tracking of Capsule Endoscopes Using On-Chip TMR Sensors

Seán Coombes[1], Pádraig Cantillon-Murphy[1,2]

[1] School of Engineering, University College Cork, College Road, Cork, Ireland

[2] Tyndall National Institute, Lee Maltings, Dyke Parade, Cork, Ireland

**Aims**

Capsule endoscopy is a maturing technology with the potential to significantly reduce the need for traditional colonoscopy procedures. However, current systems lack a reliable method for accurately locating capsule position within the body and mapping images to patient anatomy. This is crucial for identifying the location of polyps, tumours, and bleeding, thereby informing clinical decision-making and surgical planning. This work proposes the use of wireless electromagnetic tracking (EMT) for capsule localisation. EMT is a non-ionising approach unlike fluoroscopy or CT. While capsule localisation has been demonstrated using EMT with inductive sensors in the past, this work uses an on-chip tunnelling magneto-resistive (TMR) magnetic sensor. TMR sensors offer the advantages of low cost ($7), scalability and manufacturability which is essential in a single use device such as an endoscopic capsule.

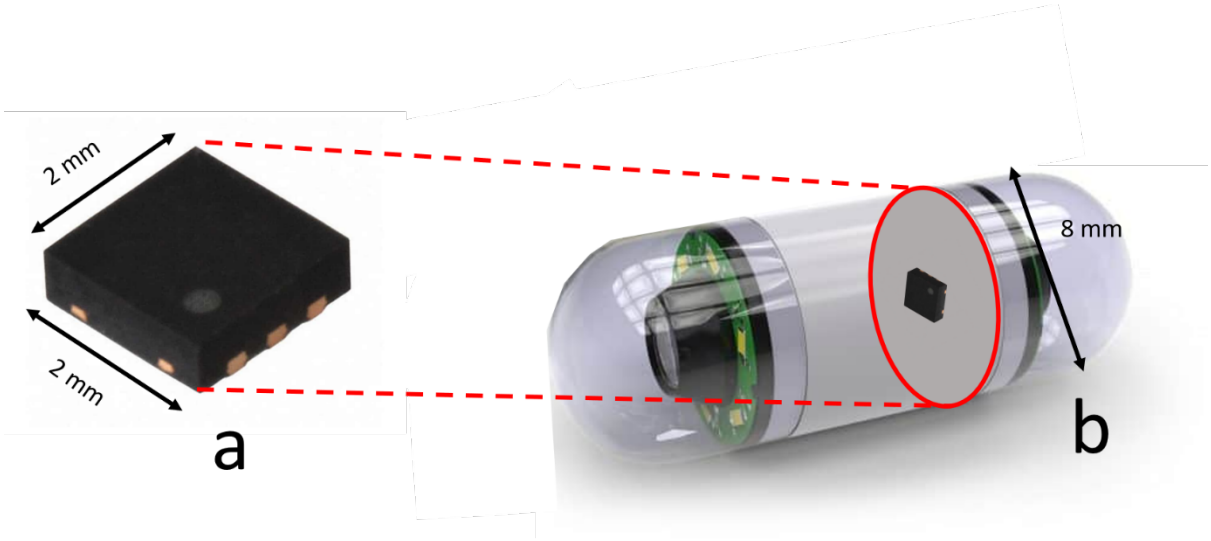


Figure 1: a. On-chip TMR magnetic sensor (2 mm x 2 mm). b. This work will use the on-chip TMR sensor for magnetic field measurements to determine the position of an endoscopic capsule within the patient.

**Materials and methods**

A wired TMR sensor was integrated with the open-source Anser EMT system developed at University College Cork [1] to demonstrate five-degree-of-freedom tracking. The TMR sensor output is amplified, filtered, and sampled, and the resulting measurements are used to estimate the position and orientation of the sensor.

**Results**

A 4-axis linear robot was used to evaluate the accuracy of the wired TMR sensor within a 25 cm × 25 cm × 15 cm volume under low-frequency magnetic field (2–4 kHz) excitation. The robot arm position (±0.1 mm) served as ground truth, confirming mean positional error for EM tracking of 1.5 mm and a mean orientation error of 0.97°.

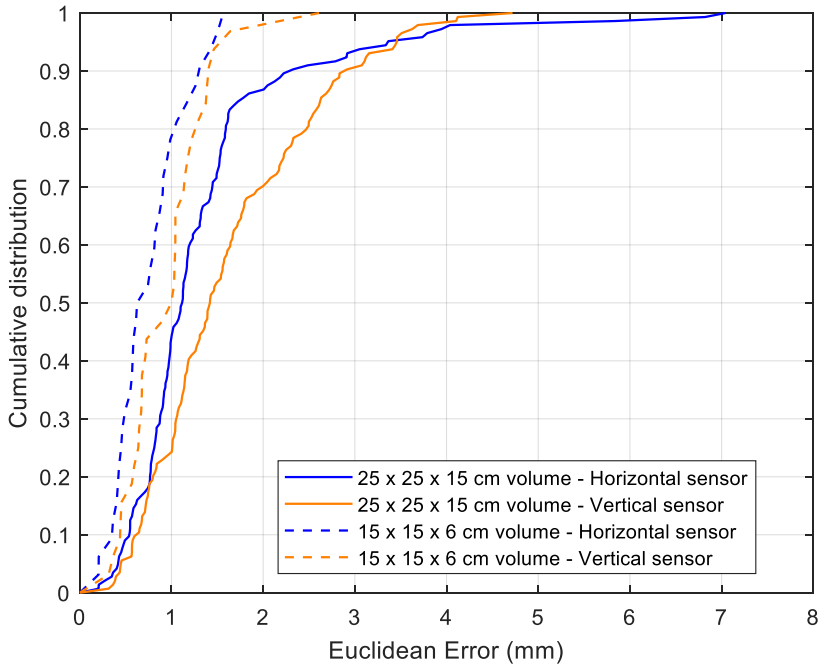


Figure 2: Cumulative distribution of the positional errors using a wired TMR sensor for EMT, including the full volume (25 x 25 x 15 cm) and a reduced volume (15 x 15 x 6 cm).

## Conclusions

This work presents an accurate and low-cost method for capsule tracking using an on-chip TMR sensor suitable for large-scale manufacturing. The tracking of a wired TMR sensor was demonstrated with five-degrees-of-freedom and a mean error of 1.5mm. Future work will develop a wireless sensor node, integrating the TMR sensor on a battery-powered module and transmitting the measured information via Bluetooth to a receiver. This advancement represents a significant step toward reliable capsule localisation and the broader adoption of capsule endoscopy in clinical practice.

## References

[1] Jaeger, H.A.; Franz, A.M.; O'Donoghue, K.; Seitel, A.; Trauzettel, F.; Maier-Hein, L.; Cantillon-Murphy, P. Anser EMT: The first open-source electromagnetic tracking platform for image-guided interventions. Int. J. Comput. Assist. Radiol. Surg. 2017, 12, 1059–1067