ELECTRICAL & COMPUTER ENGINEERING
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MagBall: Magnetic Rollerball for Multi-Scale Contact Interactions on Diverse Surfaces

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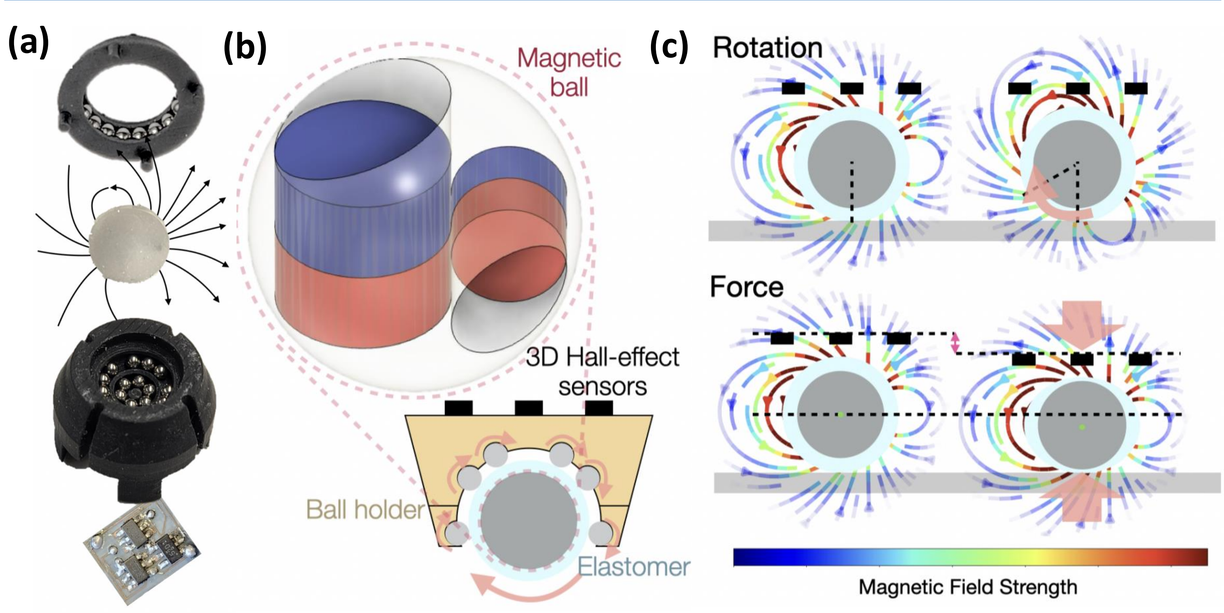
Wearable Intelligence Lab

Abstract

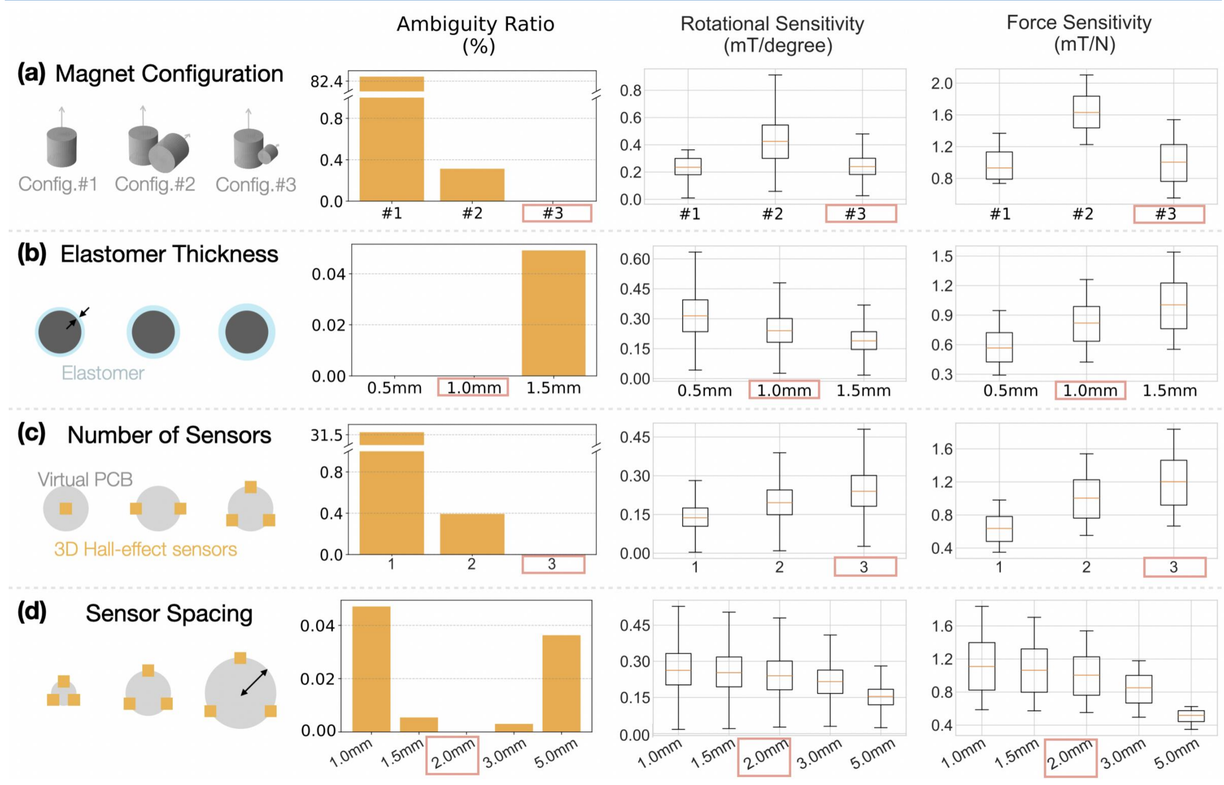
New tangible input techniques are transforming human-computer interaction.[1] Point-contact devices[2] such as buttons are simple and scalable, but they capture limited spatial information. In contrast, surface-based contact interfaces[2] such as touchpads provide richer spatial input but require larger instrumented surfaces. We present MagBall, a magnetic-ball sensor that captures fine-grained interactions, including displacement and force, through the rotation of a magnet-embedded ball over a 3D Hall-effect sensor array. Our design localizes diverse physical interactions to a single point-contact yet operates at multiple scales from millimeters to meters. Our machine learning models can infer the displacement and force accurately. Furthermore, our device supports interactions across diverse surfaces such as glass, metal and human skin, without additional instrumentation. We demonstrate applications in stylus pens, wearable trackballs and smart massage tools, which naturally align with the rolling mechanism.

System Overview

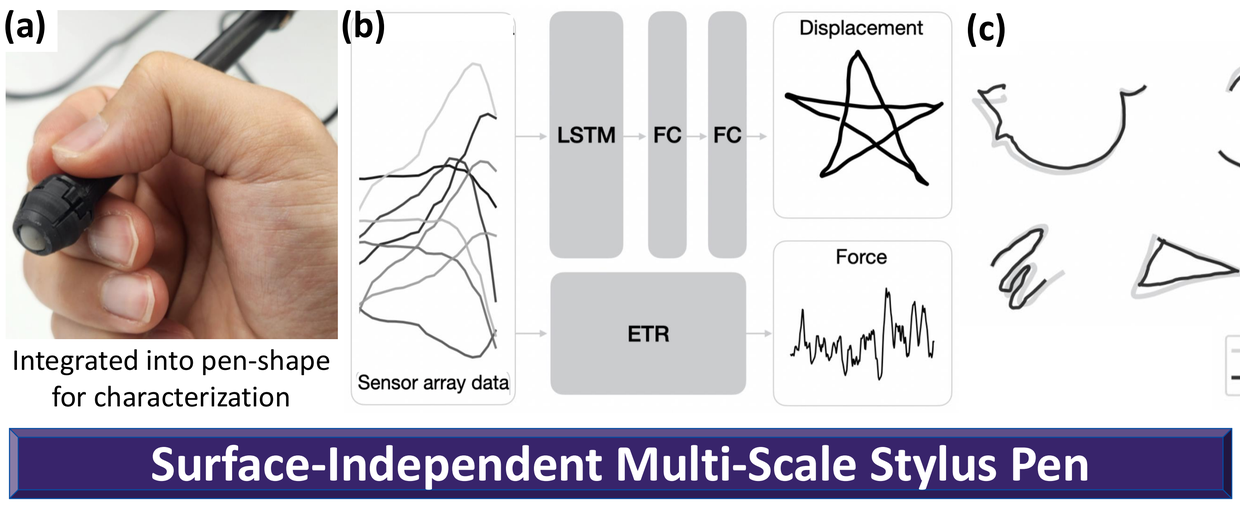


(a) Assembly of MagBall. (b) The sensor consists of a multi-magnet core within an elastomer shell, which rotates freely in a ball holder over a 3D Hall-effect sensor array. (c) User-applied rotation and normal force changes the magnetic field patterns detected by the sensors.

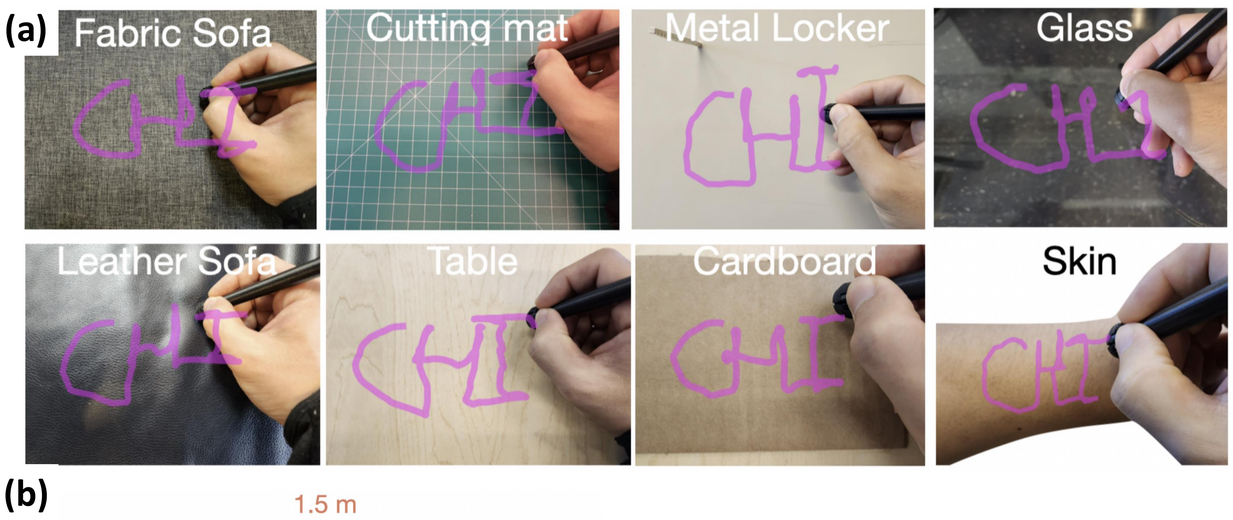
Design Exploration



Rolling Contact Displacement and Force Tracking

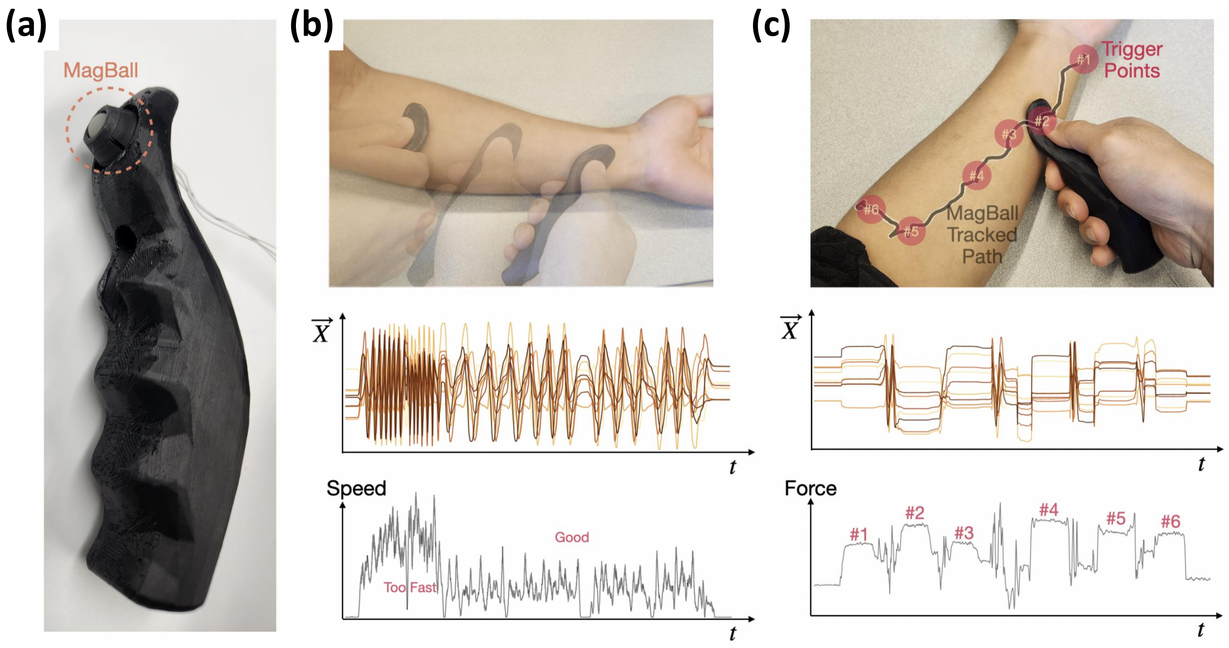


Surface-Independent Multi-Scale Stylus Pen



(a) The MagBall pen works on a variety of surfaces, including magnetic metal, transparent glass, soft sofa material and human skin. (b) It enables drawings of multiple scales from millimeters to meters.

Smart Massage Monitoring Tool



(a) MagBall integrated into a massaging tool. (b) The tool monitors massage speed to ensure a safe warm-up phase. (c) It guides users to target trigger points with appropriate force and duration for effective massage.

Future Work: MagBall Array for Robotic Skin

While MagBall is currently a single point-contact device, extending it to an array could enable multi-point interaction measurements. In robotics, such arrays could provide rich spatial tactile information for sliding contact events, which are ubiquitous in both daily life and manipulation tasks. Moreover, applying customized magnetic fields, we could even use MagBall arrays as controllable frictional interfaces. This would enable integration of both sensing and actuation at the fingertip of robotic hands in a compact design for either smooth rolling contact or precise grasping control.

References

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[2] Zhang, Sen, et al. "MagTex: Machine-Knitted Magnetoactive Textiles for Bidirectional Human-Machine Interface." Proceedings of the 38th Annual ACM Symposium on User Interface Software and Technology. 2025.
[3] Huang, Kunpeng, et al. "MagDesk: Interactive Tabletop Workspace Based on Passive Magnetic Tracking." *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 8.4 (2024): 1-31.