Peripheral Nervous System-aware wearable cuff: a manufacturable prototype for peripheral neural and stress sensing

Dr Shama Rahman
Design Informatics, School of Informatics
University of Edinburgh
Edinburgh, UK
srahman@ed.ac.uk

Abstract: This paper proposes a wearable cuff for sensing peripheral nervous system-related signals using standard electronics and rapid fabrication methods, with the longer-term aim of supporting personalised health monitoring and lightweight closed-loop feedback [Tang et al., 2023]. The prototype is intentionally scoped for manufacturability: a compact printed circuit board, off-the-shelf electromyography and electrodermal activity electrodes, inertial sensing, rechargeable battery power, and a simple 3D-printed housing compatible with iterative assembly and testing [Biswas et al., 2024]. The concept draws on recent advances in peripheral-signal-based intention prediction, soft bioelectronics and flexible energy harvesters, while translating those ideas into a realistic prototype that can be assembled and tested using standard electronics workflows rather than specialised biofabrication [Hua et al., 2023; Biswas et al., 2024].

I. Introduction / Background (Sytle: Heading 1)

Wearable neurotechnology often struggles to balance signal quality, comfort and practicality outside the lab, particularly when central nervous system measures such as EEG are used in everyday settings [Tang et al., 2023]. Peripheral signals such as muscle activity, skin conductance and motion can instead be measured with relatively accessible hardware and still reveal meaningful information about effort, arousal and motor intent [Tang et al., 2023]. At the same time, soft bioelectronic interfaces and hydrogel-based devices show how skin-conformal systems can support longer-term monitoring while maintaining comfort and good signal contact [Hua et al., 2023]. Soft bioelectronic systems designed for precision therapy illustrate how wearable and implantable devices can move beyond passive monitoring into tailored intervention, providing a longer-term direction for the kind of peripheral-sensing platform we envision [Wu et al., 2017].In parallel, emerging flexible energy harvesters demonstrate how movement and mechanical interaction can power wearable devices without large external batteries [Biswas et al., 2024]. This prototype focuses on a narrower but practical goal within that broader landscape: a PNS-aware cuff that demonstrates manufacturable electronics and basic sensing, while leaving room for future upgrades in soft materials and energy harvesting.

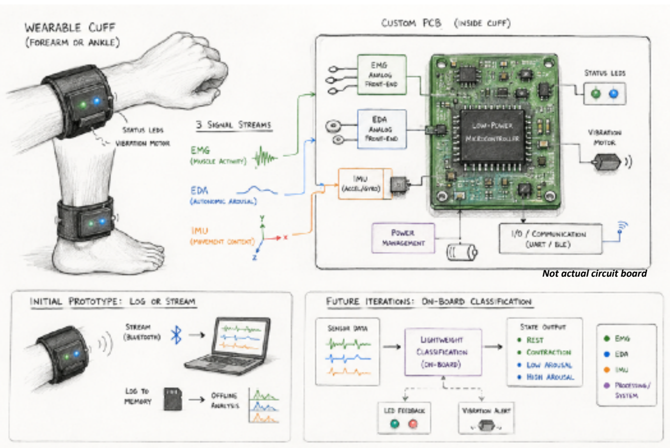
II. Related work

Tang and colleagues discuss how motion intention can be predicted from neural and physiological signals distributed across the human nervous system, emphasising the role of wearables in capturing peripheral activity for real-time interaction and assistance [Tang et al., 2023]. They highlight that combining EMG with inertial sensing in wearable form factors can bridge between brain activity and overt movement in a way that is more practical for everyday use than many traditional CNS-centric approaches [Tang et al., 2023].Hua et al. review hydrogel-based bioelectronics and show how these soft, hydrated materials can form intimate, low-impedance interfaces with skin and tissue while integrating sensing and electronic functionality [Hua et al., 2023]. Their work illustrates a long-term direction for truly skin-like neural wearables, but also underlines that such systems generally require specialised materials, cleanroom-grade equipment or bioprinting facilities that are not always available in rapid prototyping environments [Hua et al., 2023].Biswas et al. survey emerging energy harvesters in flexible bioelectronics, including triboelectric and piezoelectric devices, and discuss their potential to power wearable and implantable systems by harvesting energy from natural body motion and environmental interactions [Biswas et al., 2024]. Their review makes clear that while self-powered systems are an attractive goal, integrating advanced energy harvesters is often an additional layer of complexity on top of already demanding device-integration challenges [Biswas et al., 2024]. Taken together, this literature motivates an intermediate device class: standard-electronics-first wearables that use conventional PCB design, standard sensors and simple housings, but are architected so that future work can migrate towards softer, more integrated and potentially self-powered systems.

III. Imagined prototype sketches/drawings/photos

A. Device Concept

The proposed device is a forearm- or ankle-mounted cuff that combines three signal streams: electromyography for muscle activity, electrodermal activity for autonomic arousal, and inertial sensing for movement context. These signals are acquired through a small custom PCB containing a low-power microcontroller, analogue front-end circuitry for EMG and EDA, power management and simple output channels such as LEDs or a vibration motor. In the initial prototype, data can be logged or streamed for offline analysis; later iterations could support lightweight on-board classification of simple states such as rest versus contraction or low versus high arousal.



B. Build Strategy

The enclosure can be produced using fused-filament 3D printing, with a rigid shell (for example PLA or PETG) and a replaceable strap or inner lining for comfort. The electronics architecture includes a low-power microcontroller, a biosignal front-end for EMG, a conductance-measurement path for EDA, a small inertial measurement unit, battery charging circuitry and exposed test pads to support probing and simple test rigs. This layout makes it straightforward to explore design-for-test and design-for-manufacture considerations once a first version is working.

C. *What is viable now*

Within a prototyping-summer-school setting, the most viable sensing modalities are robust, electrical and physiological measurements that can be implemented with standard electronics and off-the-shelf components. EMG, EDA and motion sensing therefore form the core of the present concept, because they can be set up and bench-tested within days while still providing informative signals about peripheral activity. More advanced ideas drawn from the literature—including hydrogel-based interfaces, biochemical sensing and integrated energy harvesting—are treated as future extensions rather than immediate build targets. Framing them in this way maintains a clear line of sight to more ambitious, soft-material-based devices, while keeping the current scope realistic and well matched to the available tools.

D. *3D Printing and assembly*

The enclosure is designed to prioritise ease of assembly, repeatability and comfort during wear. A two-part printed housing with screw-fit or snap-fit closure allows easy access to the PCB for assembly and repair, while a printed or off-the-shelf strap enables fitting the cuff to different users. Openings for charging, optional buttons and replaceable electrode connectors are incorporated from the outset to simplify testing and iterative redesign. This mechanical strategy also supports future development. If the electronics layout and connector locations are defined cleanly, later versions can incorporate softer skin-contact layers, alternative electrode geometries or additional sensing patches without requiring a complete redesign of the electronics. This includes the possibility of substituting hydrogel-based contact surfaces or attaching additional modules that explore flexible energy harvesting, when suitable fabrication facilities and time are available. Designing the cuff as a comfortable interface between body and electronics aligns with work on bioinspired prosthetic interfaces, which emphasises the mechanical and perceptual qualities of the human–device contact surface [Li et al., 2020].

IV. Responsible innovation

A wearable that interprets peripheral nervous system and stress-related signals has clear potential value for preventive health, self-regulation and performance support, but it also raises questions about data privacy, consent and over-interpretation. To address this, the cuff is framed as a user-controlled research device rather than a diagnostic tool, with explicit control over when data are recorded and clear communication about what the measurements can and cannot infer. Responsible innovation also extends to materials and manufacturing choices. Designing the cuff as a modular device with replaceable electrodes, rechargeable power and repairable housing components can reduce waste and extend the lifespan of the hardware compared with fully sealed, disposable wearables. This approach aligns the drive for manufacturability with a concern for sustainability, rather than treating them as separate objectives.

V. Author bio(s) / experiences

Dr Shama Rahman is a neuroscientist, physicist and AI systems designer with experience in wearable systems, neural interfaces and computational modelling. Her recent work includes 3D-printed prototyping auxetic wrist-strap prototypes as wearables that would support edge computing and processing, exploring how geometry and material choice affect comfort, mechanical response and integration with embedded electronics. She has experience leading interdisciplinary projects spanning neuroscience, AI (including AI-driven signal processing) and design, and has been actively involved in translating research concepts into product-oriented prototypes. This background supports a prototype approach that is both exploratory and grounded in realistic pathways to fabrication and scaling for development of manufacturable neural-sensing devices.

VI. Acknowledgements

This prototype concept is informed by recent work in peripheral-signal-based intention prediction, hydrogel-based bioelectronics and flexible energy harvesters for wearable devices [Tang et al., 2023; Hua et al., 2023; Biswas et al., 2024]. The cuff design represents a practical step towards integrating these ideas into a manufacturable platform that can be iterated within typical electronics and rapid-prototyping environments.

VII. References

1. Tang, C., Xu, Z., Occhipinti, E., Yi, W., Xu, M., Kumar, S., Virk, G. S., Gao, S., & Occhipinti, L. G. (2023). From brain to movement: Wearables-based motion intention prediction across the human nervous system. *Nano Energy*, 115, 108712.
2. Hua, J., Su, M., Sun, X., Li, J., Sun, Y., Qiu, H., Shi, Y., & Pan, L. (2023). Hydrogel-based bioelectronics and their applications in health monitoring. *Biosensors*, 13(7), 696.
3. Biswas, S., Lee, S. W., Lee, Y., Choi, H.-J., Chen, J., Yang, X., Du, Y., Falcone, N., de Barros, N. R., Lee, S.-M., Kim, H., Khademhosseini, A., & Zhu, Y. (2024). Emerging energy harvesters in flexible bioelectronics: From wearable devices to biomedical innovations. *Small Science*, 4(5), 2300148
4. Wu, H., Gao, W., & Yin, Z. (2017). Materials, devices and systems of soft bioelectronics for precision therapy. Advanced Healthcare Materials, 6(10), 1700017.
5. Li, P., Anwar Ali, H. P., Cheng, W., Yang, J., & Tee, B. C. K. (2020). Bioinspired prosthetic interfaces. Advanced Materials Technologies, 5(5), 1900856.