From Wearable Electronics To In-Fiber Circuits?

CEDRIC HONNET, Massachusetts Institute of Technology, honnet@mit.edu
JOSEPH A. PARADISO, Massachusetts Institute of Technology, paradiso@mit.edu
STEFANIE MUELLER, Massachusetts Institute of Technology, stefanie.mueller@mit.edu

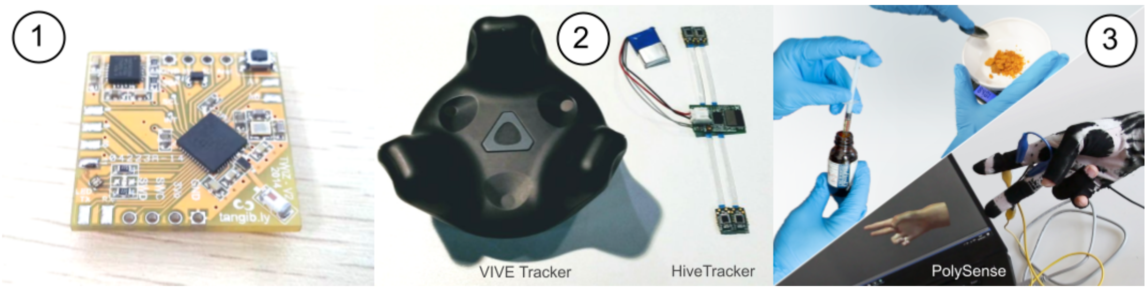

Fig. 1. Wearable explorations with [1] the Twiz: a wireless motion sensor, [2] the HiveTracker: a 3d position tracker, and [3] PolySense: an eTextile system for wearable sensor fabrication.

We present a set of wearable toolkits for applications ranging from artistic performance to neuroscience. The development of these projects allowed discovering engineering and strategic mistakes over the years. From embedded electronics to eTextiles and materials science, our research leans towards accessible and reproducible smart fibers to democratize conformable wearable devices.

CCS Concepts: • **Human-centered computing → Human computer interaction (HCI)**.

Additional Key Words and Phrases: Digital Fabrication, Motion Capture, eTextiles, Materials Sciences, Wearable Electronics.

ACM Reference Format:

Cedric Honnet, Joseph A. Paradiso, and Stefanie Mueller. 2023. From Wearable Electronics To In-Fiber Circuits?. In *ACM CHI Conference on Human Factors in Computing Systems '23: Apr 23-28, 2023, Hamburg, Germany*. ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/1122445.1122456

0 INTRODUCTION

Wearables have been the subject of extensive research for decades both in HCI [5,6] and other research communities. For example, in-fiber electronics systems were recently proposed by Loke et al. [7] and textile displays were achieved by Choi et al. [8] with record-breaking definitions. With these in mind, we discuss in the following how we contributed to the field. Fig. 1 illustrate some of these contributions: Twiz [1, 4] is a wireless motion sensor, and it is not Arduino compatible which made it difficult for some users to incorporate into their prototypes. The HiveTracker [2] is a low-cost, scalable device for 3D positioning that is Arduino compatible, but still requires a high level of technical expertise to use.

Manuscript submitted to ACM

PolySense [3] augments textiles with electrical functionality using in-situ polymerization, making it easy to create wearable motion sensors through eTextiles. For our next steps, we propose to integrate electronics directly into fibers to create a more flexible and lightweight solution for electronic prototyping, using a traditional flex PCB manufacturing technique. In the following, we illustrate why these toolkits are important.

1 TWIZ: WEARABLE MOTION CAPTURE

In the research project entitled "The Movement of Things" [4] we explored the properties of movement, using a custom tool called Twiz[1]. Through a range of exercises these movements were captured and translated by custom-built software and the use of an autonomous, tiny and wireless motion sensor (Fig. 1.1). A series of 3d printed extensions suggested different approaches of how to use a motion sensor within various physical environments to capture movement and better understand the materialization of movement or new forms of interactions through movement.

Using the same toolkit, we later explored augmenting ordinary objects to act as motion controlled interfaces [1]. The motivation was to develop a toolkit that enables end users to quickly prototype for artistic expressions through movement. We explored a range of experiments related to visual arts, dance, and music by attaching the Twiz to different objects to allow users to carry out impromptu interactions. This tool was not Arduino compatible, thereby imposing significant usability limitations on its users, but a fix for this mistake was attempted in the subsequent project:

2 HIVETRACKER: MINIATURE 3D POSITION TRACKING

The pursuit of capturing 3D motion has been the subject of inquiry for over a century. Notably, in the early 1900s, the analysis of the hand gestures of factory workers was undertaken with the aim of optimizing productivity, utilizing long exposure photography. Nevertheless, a comprehensive resolution to the task of 3D movement capture remains elusive, and continues to be a topic of exploration across diverse disciplines, ranging from neuroscience to robotics and entertainment. With dance motion capture in mind, we built another open source [2] tool for accurate indoor positioning, the HiveTracker [1]. Using lasers, this miniaturized system (Fig. 1.2) allows 3D position tracking with sub-millimeter precision. The incorporation of a 9 degrees of freedom (9DoF) inertial measurement unit (IMU) serves to enable 3-dimensional orientation, while concurrently providing a degree of resilience against optical occlusion. However, the integration of sensors in fabric itself may afford potential benefits in this regard, but also in wearability.

3 POLYSENSE: AUGMENTING MATERIALS WITH ELECTRICAL CAPABILITIES

PolySense [2] is another open system[3] to enhance materials with electrical characteristics, in order to build wearable sensors, inter alios. The glove depicted in Fig. 1.3 is linked to a microcontroller, while a virtual reality model renders the movements. Subsequently, on-skin strategies were investigated, comprising resistive and capacitive sensing. These wearables possess the capacity to be affixed onto diverse body parts to document movements, or to amplify dance through sonification or visualization for example. This unique wearable sensing approach presents all the advantages of textiles, and allows sensing pressure, stretch, heat, humidity or capacitive touch. But being molecularly integrated inside the fibers, the computing has to be performed outside of the textile, unless we think of fibers differently:

[1] Twiz open source documentation: https://hackaday.io/project/7121-twiz
[2] HiveTracker open source documentation: https://hackaday.io/project/160182-hivetracker
[3] PolySense open source documentation: https://hackaday.io/project/168380-polysense

4 WORK IN PROGRESS

Our work aims to take electronic prototyping to the next level by integrating electronics directly into fibers. The current prototyping platforms (such as Lilypad [9]) can be sewn into textiles to create eTextiles. However, the circuit board is still rigid and can be cumbersome to work with. Thinking about the SensorTape [10] as a thick (and flat) fiber, we can miniaturize the idea and integrate electronics into fibers, to create a more flexible, lightweight, and durable solution for prototyping. This idea was explored from the materials science perspective [7], but the fabrication technique is far from accessible. Our approach uses traditional flex PCB manufacturing, it gives the potential to revolutionize the way we think about electronic textile prototyping. It will make it easy for a broader range of creators to incorporate computing into the fabric of the world around us, and will open up new opportunities for research, and commercialization. A further step for this exploration will eventually lead us to push the boundaries of wearable through human computer integrations with implantables [11]. Meanwhile, we are excited to share our vision for this new eTextile paradigm and to explore with this community the future of electronics toolkits.

5 CONCLUSION

Our wearable research spans from eTextiles to embedded electronics. We speculate that in the near future, in-fiber electronic will be as common as smartphones replaced landline phones. Generic eTextile ecosystems that integrate sensing and actuation capabilities inside fibers are starting to get accessible, so we can ask: what could be the Arduino of fiber electronics? We hope to participate in writing the next volume of this evolution with the HCI community.

REFERENCES

[1] Andreas Schlegel, Cedrid Honnet. 2017. Digital Oxymorons, From Ordinary to Expressive Objects Using Tiny Wireless IMUs. In Proceedings of the International Conference on Movement Computing (MOCO '17). Association for Computing Machinery, New York, NY, USA, Article 4, 1–8. https://doi.org/10.1145/3077981.3078040

[2] Cedric Honnet and Gonçalo Lopes. 2019. HiveTracker: 3D positioning for ubiquitous embedded systems. In Proceedings of the 2019 ACM International Conference Ubiquitous Computing (UbiComp '19). Association for Computing Machinery, New York, NY, USA, 288–291. DOI:https://doi.org/10.1145/3341162.3349295

[3] Cedric Honnet, Hannah Perner-Wilson, Marc Teyssier, Bruno Fruchard, Jürgen Steimle, Ana C. Baptista, and Paul Strohmeier. 2020. PolySense: Augmenting Textiles with Electrical Functionality using In-Situ Polymerization. Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems. Association for Computing Machinery, New York, NY, USA, 1–13. DOI:https://doi.org/10.1145/3313831.3376841

[4] Andreas Schlegel and Cedric Honnet. 2016. Movement of Things Exploring Inertial Motion Sensing When Autonomous, Tiny and Wireless. In Proceedings of the International Symposium on Movement and Computing (MOCO '16). Association for Computing Machinery, New York, NY, USA, Article 47, 1–2. https://doi.org/10.1145/2948910.2948916

[5] Maggie Orth, Rehmi Post, and Emily Cooper. 1998. Fabric computing interfaces. In the ACM Conference on Human Factors in Computing Systems (CHI '98). https://doi.org/10.1145/286498.286800

[6] E. R. Post and M. Orth, "Smart fabric, or "wearable clothing"," Digest of Papers. First International Symposium on Wearable Computers, 1997, pp. 167-168, doi: 10.1109/ISWC.1997.629937.

[7] Loke, G., Khudiyev, T., Wang, B. et al. Digital electronics in fibres enable fabric-based machine-learning inference. Nat Commun 12, 3317 (2021). https://doi.org/10.1038/s41467-021-23628-5

[8] Choi, H.W., Shin, DW., Yang, J. et al. Smart textile lighting/display system with multifunctional fibre devices for large scale smart home and IoT applications. Nat Commun 13, 814 (2022). https://doi.org/10.1038/s41467-022-28459-6

[9] Leah Buechley, Mike Eisenberg, Jaime Catchen, and Ali Crockett. 2008. The LilyPad Arduino: using computational textiles to investigate engagement, aesthetics, and diversity in computer science education. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '08). Association for Computing Machinery, New York, NY, USA, 423–432. https://doi.org/10.1145/1357054.1357123

[10] Artem Dementyev, Hsin-Liu (Cindy) Kao, and Joseph A. Paradiso. 2015. SensorTape: Modular and Programmable 3D-Aware Dense Sensor Network on a Tape. In Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology (UIST '15). Association for Computing Machinery, New York, NY, USA, 649–658. https://doi.org/10.1145/2807442.2807507

[11] Strohmeier, P., Honnet, C. and Von Cyborg, S., 2016. Developing an ecosystem for interactive electronic implants. In Biomimetic and Biohybrid Systems: 5th International Conference, Living Machines 2016, Edinburgh, UK, July 19-22, 2016. Proceedings 5 (pp. 518-525). Springer International Publishing. https://doi.org/10.1007/978-3-319-42417-0_56