Body IO: Exploring Human-Machine Syntonicity With Self-Adapting Sensor-Actuator Interfaces

Statement of Objectives

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ABSTRACT

This is the story of my metamorphosis, from a failing dyslexic student more interested in making music than school, to an international consulting engineer with honors for two masters and a full paper to appear at CHI 2020[1].

A chronic disease tried hard to get rid of me when I was a student. Since my recovery, I became a new person, with an inexhaustible determination and perseverance in life.

This statement starts biographically, explaining why I pursue grad school again, why I can succeed, and how I will contribute. It then overviews some of my publications and my research proposal.

KEYWORDS

HCI, Wearables, (Machine) Learning, Human Augmentation, Music Interfaces, Syntonicity, Neuro-psychology, Neuromotor / Bio-Sensing. Haptuators, Electro-polymers.

1 BIOGRAPHY

Oxymorons pave my path.
I have been a vagabond and a builder,
systematically dissecting and endlessly dreaming,
an old soul filled with childish wonder,
once cursed, now miraculously fortunate.

Raised by a single mother on a disability pension, and mistaking an exhausting chronic disease for laziness, I gave school a pass at 17 and went to work. I found life in making music, waking up with simple obsessions, practicing my vinyl scratching techniques, composing for my groups, and working on my radio show.

At 22, amidst odd jobs including sound engineering and cinema set construction, came my chronic disease discovery, and a new treatment gave me hope to go back to school. Coincidentally, I finally found my father and he happened to be a mathematics researcher, computer scientist, and musician. He took his new role seriously and among many things, I had the chance to learn the most important skill from him: he taught me how to learn, and I am still addicted.

Silicon Valley

I ended up completing two masters with honors (Electronics, and then Computer Science), despite the treatment that also tried to kill me. Once cured, the startup bug bit me.

Figure 1: The Sifteo modular and tangible interface.

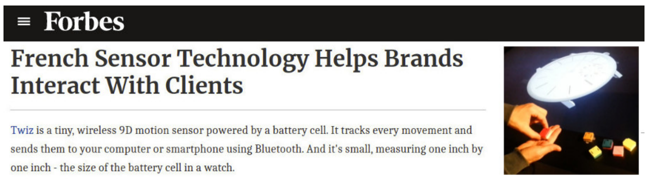
Working at Sifteo (see fig. 1), a Media Lab spin off, gave me the opportunity to work on many technologies. It included machine learning for gesture recognition, audio-haptic communication, and custom OS for embedded game engines. I got involved in my local hackerspace (Noisebridge), teaching interactive electronics or music tech, and collaborating on diverse projects (including an urban art installation for Boston - see fig. 2).

Figure 2: Boston mayor testing our device, playing music at the speed of his heartbeat (Pulse Of The City, 2013).

[1]To appear at CHI 2020 - Preview: https://youtu.be/QGMpUNgQt00

Building A Startup

I also co-founded "Tangible Display" with the hackerspace passion and the experimental mindset discovered at Sifteo. We raised hundreds of thousands in grants and investments, and we built interactive devices and installations for various industries, from luxury to museums. Some projects were covered in Forbes (see fig. 3), others in Hack-A-Day, and we proudly sponsored TEI for several years.


Forbes

French Sensor Technology Helps Brands Interact With Clients

Twiz is a tiny, wireless 9D motion sensor powered by a battery cell. It tracks every movement and sends them to your computer or smartphone using Bluetooth. And it's small, measuring one inch by one inch - the size of the battery cell in a watch.

Figure 3: Forbes article covering my Twiz project (2015).

Independent research and consulting

Through my travels, I worked remotely from hackerspaces all over the world. I helped companies to manufacture their products in China, and to explore interactive technologies, such as Google-Soli (see fig. 4). I then co-founded a hackerspace and some of our work was published at TEI, NIME, MOCO, ISWC, and UbiComp. This included interactive implants, performance visualizations and sonifications, 3d positioning for neuroscience, and material science for sensors.

Figure 4: Google Soli visualization of its radar operation.

2 MY RESEARCH

Wearables and eTextiles

For CHI 2020[2], I worked with material scientists to understand piezo-resistive sensing, and developed a process to augment materials at a molecular level (see fig. 5). While exploring different use cases, we discovered that "In-Situ Polymerization" works with anything porous or fibrous, and demonstrated hybrid results with sensitive or conductive zones. This project has just been conditionally accepted and while it was a combined effort with extraordinary collaborators, being first author makes me start to trust my intuitions and possible contributions to academia.

[2]To appear at CHI 2020 - Preview: https://youtu.be/QGMpUNgQt00

Figure 5: (a) polymerization chemistry (b) a glove before functionalization (c) the glove used in a 3d application.

This project extended our effort to improve matrix pressure sensors. Our previous work relied on interdigitation to increase measurement accuracy with parametric patterns and optimal reconstruction algorithms (TEI 2019 [1]).

Before the Google Jacquard publications, my first university-hackerspace collaboration gave birth to a "Multi-Touch eTextile for Music Performances" [2]. We also investigated 3D and Stretchable Textiles [3, 4] for the TEI Art track and the ACM Interaction Magazine [5].

Embedded Systems

In collaboration with a neuroscience lab at UCL, we recently developed the "HIVE Tracker: a tiny, low-cost and scalable device for sub-millimetric 3D positioning" (see fig 6). It was published at Augmented Human 2018 [6] and demonstrated at UbiComp 2019 [7].

Figure 6: The HTC Vive Trackera and the HiveTracker, my open source reverse-engineered version.

This work follows a CHI workshop in which we proposed that "to improve haptic experiences we must first improve tracking." [8]. The collaboration was built on "Developing an Ecosystem for Interactive Electronic Implants" [9] which explored ultra low power, secure, and reliable electronics, but also cyborgs and their body modification art.

Finally, "Exploring Inertial Motion Sensing" [10] for artistic visualizations (see fig. 7) used my wireless motion sensor (Twiz - see fig. 3). This collaboration with a core member of the Processing.org community was later extended in "Digital Oxymorons" [11].

My exploration of body interaction revealed to me the importance of 3D positioning in order to jettison the metaphorical "underwater GUI iceberg" [12]. It imbues a deep excitement for this proposed research.

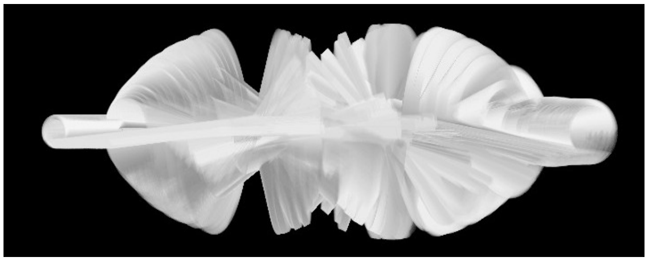


Figure 7: An abstract graffiti, artistic visualization of a dancer movement measured with Twiz sensors.

3 RELATED WORK

HCI research seems to be particularly concerned about at least the two following critical problem: translating between the physical and the digital, and interfacing between divergent types of cognition.

- How can intuition be presented to an algorithm?
- How can complex data be presented to a human?

Among other things, Mark Weiser described the ultimate purpose of a computer (1) "as a quiet, invisible servant" and (2) "to extend our intuition and unconscious" [13, 14]. Twenty years on, the former almost sounds banal, but the latter has yet to be materialized.

If devices are attuned to our intentions and speak with us syntonically, then the boundaries between physical and digital can be lifted. My conviction is that physical and digital realms can be bridged through *integration between humans and devices with an adaptive haptic-sensory system.*

Body inputs

Across millenia, living creatures had to adapt to environmental input for survival. For instance, some of our ancestors developed jaws that could feel vibrations of running herds through the ground [15]. In recent times however, humans have been able to assimilate new forms of input without physiological evolution. For example, Braille was developed and effectively used within a couple of decades.

While reading Braille did not require any genetic mutation or selection, it did require a non-trivial level of training. But more recently, Stanford neuroscientists found that they could teach deaf students to understand voice through a vest (see fig. 8 right) vibrating at different frequency bands [16]. Cerebral plasticity allowed these students to learn a dozen words in a dozen hours of training. More can be done to expand on the use of neuro-plasticity involving haptic input to allow passive learning (as in PianoTouch[17] for example), but machines have to learn to *talk* to us in an adaptive way. If this is achieved, then we can forsee a syntonic human-machine integration.

New interfaces should participate in a mutual process of adaptation, dynamically learning human needs and being aligned to them. Such a technology could use a haptic interface, building on the most basic language we have for understanding the world - touch. Unlike visual or audio interfaces, a haptic modality has the benefit of being an almost universally accessible, yet minimally distracting mode of interaction occurring at the edge of our consciousness.

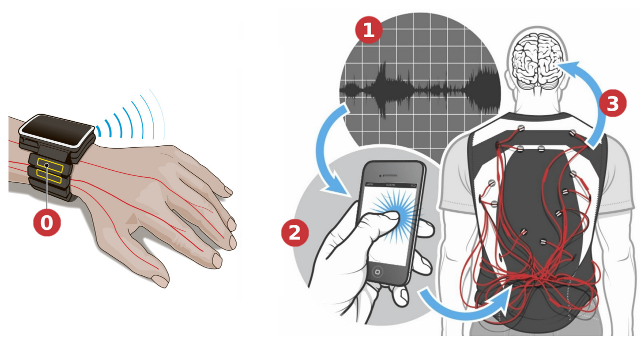


**Figure 8: (Left) Ctrl Kit: a wearable sensor measuring neuromotor signals allowing intention inference (0).
(Right) Neosensory: sound is captured (1) and converted to frequencies (2) mapped to control vibrations (3) interpretable by the brain.**

Body outputs

Reflecting on my vinyl scratching obsession, I developed motor skills that allow me to create synchronous sounds with finesse, a natural ability to adopt specialized neuro-motor output for self expression. Since the highest information bandwidth accessible from the brain is neuromotor activity in the hands [18, 19], we can monitor neuromotor signals before they get amplified by the muscle fibers of motor units, and translate mental intent into output. This output can for example be measured with devices such as the Ctrl Kit (see fig. 8 left), but other implementations are possible.

4 VISION

Framework

Weiser's legacy sparked a plethora of projections. From tangible interaction, to music performance systems or emotion communication, achieving human-machine syntonicity has an endless potential, and the challenge is proportional. Such a *Body IO* system (see fig. 9) could be described with:

- **Input:** micro mechanichal haptics, electro-active polymers, or electro-stimulation actuators
- **Learning:** reinforcement learning to adapt actuation and to improve sensing interpretation
- **Output:** neuromotor or other biophysical signals

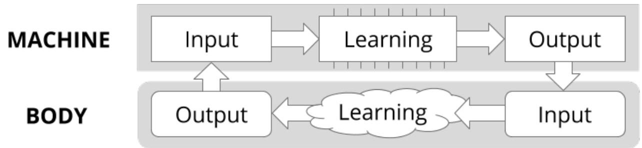


Figure 9: The Body IO and its human-machine syntonicity.

Why now?

In 1926, research on haptic feedback had already begun to enable deaf people to "feel" speech with audio speakers [20]. A century later, haptics potential is still huge [21], partially because the industry has shunned it for its costs and life expectancy. However, new material science and solid-state technologies are changing the game.

On the body output side, measuring neuro-motor intention is not very visual, and can appear taboo. This is actually advantageous from an innovation standpoint[3], nevertheless, it is important to consider the ethical and social implications.

Why me?

As this is a highly interdisciplinary research project, I will build on my existing network of academic, hackerspace and industry scientists, as well as the resources at MIT. I have been here since September, organizing a visiting research at the Media Lab, and working with neuroscientists at the Picower institute. I have also connected with friends at CBA to begin micro actuator experimentation, and at the material science department to prepare my next electro-active polymerization challenge. My experiences at MIT over the past months affirms my conviction that the Media Lab will allow me to accelerate this work.

5 CONCLUSION

I had the chance to attend graduate school in centenarian institutions where radioactivity was discovered, and also where "telecommunication" was coined. Throughout and beyond my formal education, I have come to understand that technology is short-lived and transient. A strong, long-term vision can only be accomplished with both a rigorous foundation in theory as well as a keen ability to adapt and invent. To this end, MIT is a perfect catalyst.

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I am an oxymoron, an impossible geometry that should not exist, let alone fit in. But with my paradoxical lenses I see an unlimited world, and my undeserving existence is simply fuel for my resilience, growth, and creation. The Media Lab is the ideal place where my curiosity can soar to greater heights. I am enthusiastic and ready to be among this hive of like-minded visionaries, to be where science meets art to create magic.

[3]The Rise of *Taboo Entrepreneurship*: https://huffpost.com/entry/b_4658493

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