Crafting Crank-Powered Interactions

Anders Lundström, Ylva Fernaeus, Charles Windlin, Cristian Bogdan
Media Technology and Interaction Design
KTH Royal Institute of Technology
Stockholm
{andelund, fernaeus, windlin, cristi}@kth.se

Abstract
We report on three ongoing human-powered interaction explorations with a focus on batteryless interactions using hand cranking movements. Importantly, our explorations concerned not only the matter of powering but also using human physical engagement for controlling interactive systems, and how to support designers in testing, exploring, and making such interactions. The three demonstrators consist of a) a hand cranked quote reader, b) an email sending device, and 3) a new bit for exploring this mode of interaction within the LittleBits ecosystem.

Author Keywords
Human-Powered Interactions;

CHI 2020 Extended Abstracts, April 25–30, 2020, Honolulu, HI, USA.

ACM ISBN 978-1-4503-6819-3/20/04.
DOI: https://doi.org/10.1145/3334480.XXXXXXX
*update the above block & DOI per your rightsreview confirmation (provided after acceptance)

CSS Concepts
• **Human-centered computing~Human computer interaction (HCI)**; *Interaction techniques*;

Introduction
Throughout history, people have for the most part relied on their own bodily capacity, in essence leading a human-powered or self-powered lifestyle. In contrast, today's energy abundance have led to a replacement of human-power by invisible centralized electricity production, enabling people to easily use magnitudes of more energy than the bodily limits of the individual, what is sometimes referred to as the homo colossus [3]. Our work focuses on the design and prototyping of interactive technology that is limited in energy usage to our bodily capabilities – tech driven by human power. The work aligns strongly with energy-sensitive design [8] as power is only generated and used when needed.

A bit more than a decade ago, Nicolas Villar and Steve Hodge [15] and others [1] explored the notion of human-powered interaction (HPI) through a series of intriguing designs in which the interaction itself generated sufficient power to send wireless control messages to remotely control a video player. However, little has been done in the past decade to follow up on this work despite the emerging relevance of power grid (in)dependence, natural disasters, climate change and increased worldwide geopolitical tension. In the work presented here, we have revisited and continued this work through a series of design explorations focusing on the design and implementation – crafting – of HPI technology. We find this important as the design and implementation of HPI is still poorly understood from a perspective of interaction design.

Examples of modalities for HPI include self-powered push buttons [11], paper generators [6] power through touching, sliding and rubbing, interactive photovoltaic tiles [10], and shoes [5,7]. The currently most used commercial product is probably EnOceans[1] interactive energy harvesting switches that has enabled batteryless devices such as Philips Hue Tap[2]. Within the domain of IoT sensors [9], there is also much work concerned with energy harvesting without need for active human interaction, such as harvesting energy from ambient light, heat, wind and radio signals. Some notable works are radio frequency harvesting devices such as the battery-free cell phone [13], and situated displays (e.g. [4] and LoRaPaper[3]).

Beyond these more sophisticated examples there are also more mundane devices that enable harvesting of electricity from human physical activity. The most common are devices based on *hand-cranking*, with multiple commercial examples such as FM radios, flashlights, and phone chargers, designed for providing an alternative energy source when off the grid. These are based on the same principles as general purpose pedaling generators, such as bike light dynamos, which have been available since the late 18oo's. However, to date, hand cranking devices are typically used only for providing electricity, and do not provide much in terms of computational or interaction design perspectives.

[1] https://www.enocean.com/
[2] https://www2.meethue.com/en-us/p/hue-tap-switch/046677473365
[3] https://github.com/RobPo/lorapaper

This is even though explorative work has reported that people experience that such engagements provide values such as being more involved, self-sufficient, and having ownership of power [12]. However, one challenge concerns reducing tediousness of generation and making pleasurable and aesthetically engaging interactions using our bodies. One promising example of commercial products is the human-powered Playnetic[4] ecosystem, including steering wheels, swings, see-saws and other playground equipment used for powering of simplistic interactive behaviors.

Our current focus is to develop tools that enable interaction designers to explore this design space. On a higher level we hope to contribute to alternative computing paradigms that may increase resilience within collapse informatics [14] scenarios, that may lead to more sustainable digital technology, and decrease power grid dependence.

Method

We will present our explorations in the area of hand cranked HPI, used not just for powering but also for controlling interactive systems. Our approach is to practically engage with designing and building a series of design exemplars and treat the process as our empirical data. For each exemplar we document, discuss and report our learnings. In this paper we describe three demonstrators developed on the theme of hand-cranked batteryless interactions, and their basic functionality. We end by outlining some high-level topics we wish to bring to discussion at the workshop.

[4] https://playnetic.nl/

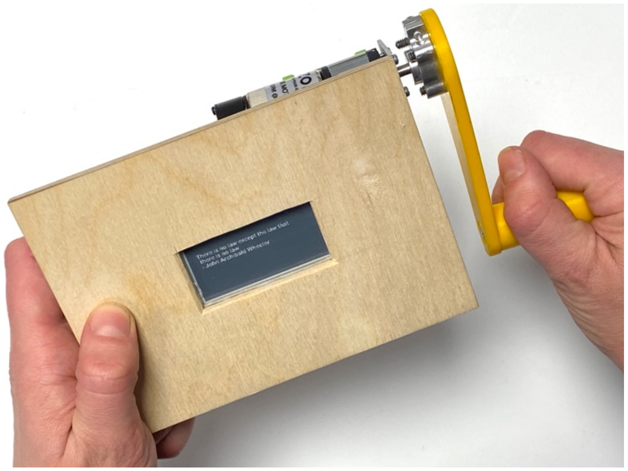

Figure 1: The hand cranked quote reader made to explore the design of HPIs. The machine allows scrolling back and forth through 20 famous science quotes. The quotes stay on screen after cranking since we used an e-paper display. The machine also preserves its state between cranks.

Exploring crank-powered interaction

In this section we will briefly present three ongoing explorations focusing on cranking:

1. The hand cranked quote reader
2. A human powered email sender
3. Human powered LittleBit

The hand cranked quote reader

In our first exploration we made a standalone box (Figure 1) that enables users to read and scroll different famous science quotes. The purpose was to put the Peppermill circuit and human-power to the test for a different yet simple design case, with the aim of extracting practical general learnings relevant for the design of human-powered interactions. The Peppermill circuit is simple circuit that, in addition to having a full-bridge rectifier and regulator connected to a generator, also provides interaction outputs for direction of generator spin (DC motors only) and the speed of spinning. The design took the shape of a wood box with an e-ink display powered by and interacted with using a crank. When cranking clock- or counterclockwise the user can scroll between 20 quotes store in the microcontroller's memory. The design only uses small capacitors around the regulator for stable operation.

The human-powered emailing machine

This project again focused on a hand cranked machine in which users could learn more about the human efforts needed to send various emails (See Figure 2). As the users cranked the device booted up and

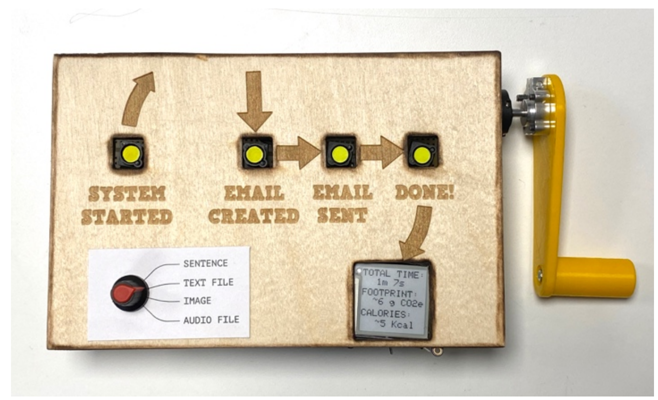

Figure 2: The human-powered email machine exploring hand cranked communication. The user boots the system by cranking until the magnetic indicator shows that the system has started and then can choose to send 4 different sized emails. After selection users have to crank through the progress bar until done and the e-paper display shows total time and estimations for saved carbon footprint and burned calories.

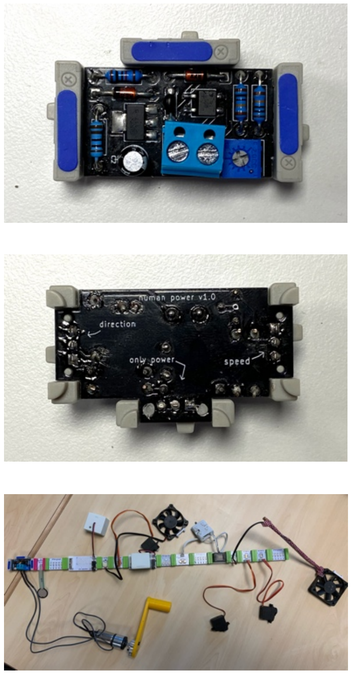

Figure 3: The human-powered LittleBits based on the Peppermill circuit. The top 2 images showing front- and backside of the LittleBit. The LittleBit has three output snaps. The middle output provides only power. The left snap both power and the direction of cranking on the signal line. The right snap provides an adjustable speed of the cranking. The bottom image showing a typical exploration made by a student group with various sensors and actuators.

connected to the WIFI. When connected an electromagnetic indicated flipped and the design demanded the user to select one of four different sized emails; a simple sentence, a text file (0.4kb), a small image (1.56kb) and an audio clip (32.82kb). After selection the user had to crank until the final magnetic indicator flipped and an e-ink display updated showing the total time, an estimated carbon footprint (only for the energy used by the device itself), and an estimated number of calories needed for the interaction. The cranking only supplies power and the interaction is mainly thought the selection buttons. A smoothing capacitor was used to avoid blocking the microcontroller caused by smaller changes in power generation. Everyone has been somewhat surprised that it takes about 1 minute and 10 seconds and a lot of tedious cranking to send an email with a small (32kb) audio clip attachment. The prototype was developed in collaboration with five master students. During the design and implementation process the first author facilitated with the electrical and software challenges that emerged in order to learn more about their needs for making HPI devices.

HPI LittleBit

Our third exploration focused on making a human-powered LittleBit (Figure 3 and 4) based on a modified version of the Peppermill circuit [15] as we think that this could be a quick and easy way to explore HPI using different sensors and actuators provided by the LittleBits [2] ecosystem. During an informal 30 minutes test with 20 students they were able to try out a vast array of sensors and actuators. Our impression was that they better understood the relationship between load and cranking as some discovered that it became harder to crank when more sensors and actuators where added. A typical exploration made by one student group can be seen in Figure 3. Furthermore, some noticed that certain actuators were more demanding than others, indicating that the LittleBit provided a first learning experience on the power requirements of different actuators.

Workshop contributions and discussions

Through the design and development of the above three demonstrators we have encountered several interesting challenges and details relevant for the design of HPI. Several of the more important insights have concerned rather detailed aspects of the interaction, that become obvious and central when designing batteryless interaction in the above technological contexts.

The most obvious insight from our experiences of

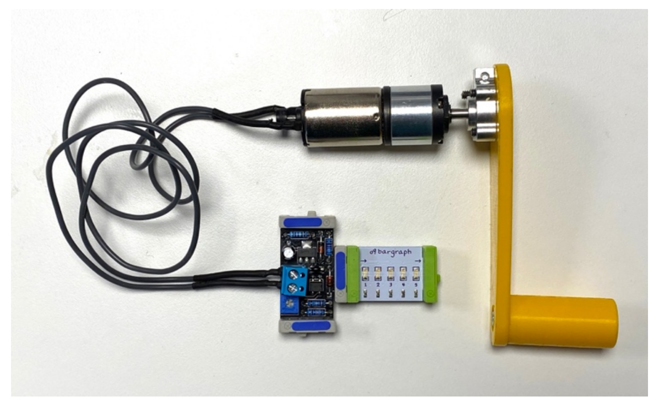

Figure 4: The Human-powered LittleBit connected to a DC motor with a 1:104 gear ratio. The power only snap connected to a bargraph which serves as an easy way to explore the difference between the three output snaps.

working with interaction design students concern the current lack of available resources, both in terms of guidelines and instructions, as well as in terms of readily available technology to use when prototyping and testing out these types of interactions. This led us to develop the HPI littleBit, but also a series of other resources needed to get the students going, in the forms of software, circuit instructions, and recommendations in terms of materials, sensors and actuators to use as parts of their designs. Thus, we see much potential in developing more structured resources along these lines to better support future students, makers, inventors and designers to develop new systems in this domain.

One basic aspect concerns the importance of timing and allowing for meaningful feedback on interactions, while engaging in a physical activity. For instance, in a batteryless setup, the cranking movement, along with limitations of the prototyping platform may not allow more than one small output modality at once, requiring the system to wait for actuators to proceed in a manner that would never have to be considered in a wired setting. Another example concerned details concerning felt interaction with the cranking movement itself, as a device for scrolling, sending, or for getting a haptic sense of other actuators. Obviously, different types of generators and mechanisms allow for different affordances in terms of interaction, and what may be a meaningful use case, which must be tested out.

In the workshop we like to discuss design principles for making HPI devices, current technical challenges, and how to support designers in prototyping processes aiming to progressing HPI technology. We also plan to bring the demonstrators described above, allowing other participants to experience and discuss their use qualities in a hands-on manner.

Future Work

We are currently planning on making the HPI LittleBit publicly available for early learning experiences of electromagnetic HPI as well as for prototyping purposes. Moreover, we have several more general PCBs on the way to support prototyping using other platforms. From a research perspective, we will continue to investigate how to best support students and makers making HPI devices. Currently we are supporting several student projects designing HPI interfaces using mechanical electromagnetic induction and body heat for power. We will follow their work closely and conduct interview about experiences, difficulties and learnings. Another interesting research direction is to combine multiple energy sources in these designs. For instance, a photovoltaic cell could provide power for the microcontroller meanwhile interactive cranking powers sensors and actuators as needed.

Acknowledgements

Thanks to all the students who have contributed to testing our prototypes and especially to Elena Gonzales Rabal for the construction of the emailing machine. This project has been funded by StandUp for Energy.

References

[1] Akash Badshah, Sidhant Gupta, Gabe Cohn, Nicolas Villar, Steve Hodges, and Shwetak N Patel. 2011. Interactive generator: a self-powered haptic feedback device. In *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11)*, 2051–2054. https://doi.org/10.1145/1978942.1979240

[2] Ayah Bdeir and Paul Rothman. 2012. Electronics as material: Littlebits. *Proceedings of the 6th International Conference on Tangible, Embedded and Embodied Interaction, TEI 2012*: 371–374. https://doi.org/10.1145/2148131.2148220

[3] William R. Catton. 1986. Homo colossus and the technological turn-around. *Sociological Spectrum* 6, 2: 121–147. https://doi.org/10.1080/02732173.1986.9981780

[4] Tobias Grosse-Puppendahl, Steve Hodges, Nicholas Chen, John Helmes, Stuart Taylor, James Scott, Josh Fromm, and David Sweeney. 2016. Exploring the design space for energy-harvesting situated displays. *UIST 2016 - Proceedings of the 29th Annual Symposium on User Interface Software and Technology*: 41–48. https://doi.org/10.1145/2984511.2984513

[5] Tsung Hsing Hsu, Supone Manakasettharn, J. Ashley Taylor, and Tom Krupenkin. 2015. Bubbler: A Novel Ultra-High Power Density Energy Harvesting Method Based on Reverse Electrowetting. *Scientific Reports* 5: 1–13. https://doi.org/10.1038/srep16537

[6] Mustafa Emre Karagozler, Ivan Poupyrev, Gary K. Fedder, and Yuri Suzuki. 2013. Paper generators: Harvesting energy from touching, rubbing and sliding. In *UIST 2013 - Proceedings of the 26th Annual ACM Symposium on User Interface Software and Technology*, 23–30. https://doi.org/10.1145/2501988.2502054

[7] Tom Krupenkin and J. Ashley Taylor. 2011. Reverse electrowetting as a new approach to high-power energy harvesting. *Nature Communications* 2, 1: 1–8. https://doi.org/10.1038/ncomms1454

[8] Anders Lundström. 2016. Designing Energy-Sensitive Interactions: Conceptualising Energy from the Perspective of Electric Cars.

[9] Dong Ma, Guohao Lan, Mahbub Hassan, Wen Hu, and Sajal K. Das. 2019. Sensing, Computing, and Communications for Energy Harvesting IoTs: A Survey. *IEEE Communications Surveys & Tutorials*: 1–1. https://doi.org/10.1109/comst.2019.2962526

[10] Yogesh Kumar Meena, Krishna Seunarine, Deepak Ranjan Sahoo, Simon Robinson, Jennifer Pearson, Chi Zhang, Matt Carnie, Adam Pockett, Andrew Prescott, Suzanne Thomas, Harrison Ka, Hin Lee, and Matt Jones. PV-Tiles : Towards Closely-Coupled Photovoltaic and Digital Materials for Useful , Beautiful and Sustainable Interactive Surfaces.

[11] Joseph A Paradiso and Mark Feldmeier. 2001. A Compact, Wireless, Self-Powered Pushbutton Controller BT - UbiComp 2002: Ubiquitous Computing. *UbiComp 2002: Ubiquitous Computing* 2201, Chapter 25: 299–304. Retrieved from http://link.springer.com/10.1007/3-540-45427-6_25%0Apapers3://publication/doi/10.1007/3-540-45427-6_25

[12] James Pierce and Eric Paulos. 2012. Designing

everyday technologies with human-power and interactive microgeneration. *Proceedings of the Designing Interactive Systems Conference on DIS 12*: 602. https://doi.org/10.1145/2317956.2318047

[13] Vamsi Talla, Bryce Kellogg, Shyamnath Gollakota, and Joshua R Smith. 2017. Battery-Free Cellphone. 1, 2.

[14] Bill Tomlinson, Eli Blevis, Bonnie Nardi, Donald J. Patterson, M. Six Silberman, and Yue Pan. 2013. Collapse informatics and practice: Theory, method, and design. *ACM Transactions on Computer-Human Interaction* 20, 4: 1–26. https://doi.org/10.1145/2493431

[15] Nicolas Villar and Steve Hodges. 2010. The Peppermill : A Human-Powered User Interface Device. 29–32.