SelfSustainableCHI

Self-Powered Sustainable Interfaces and Interactions

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SelfSustainableCHI: Sustainable Self-Powered Interfaces and Interactions

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Abstract
Current computing devices require increasing amounts of energy which makes their production and use problematic as awareness increases of the climate emergency facing the planet. Self-powered interfaces are crucial for sustainable use of future computing devices. Therefore, we aim to bring together researchers and practitioners from design, computer science, materials science, engineering and manufacturing industries working on self-powered interfaces and interactions, to begin a new area of endeavour. This workshop will provide a platform where we will review and discuss challenges and opportunities associated with sustainable self-powered interfaces and interactions, develop a design space and identify opportunities for future research.

Author Keywords
Interfaces and Interactions; Internet-of-Things (IoT); Internet-of-Materials (IoM); Photovoltaics (PV); Electrochromic (EC) display; e-ink displays.

Background
Sustainable computational devices are key to human progress. The threat of climate change means we cannot rely on the same sources of energy or technologies which we are using at present. With more people moving towards better quality of life across the world and a rise in overall consumption levels, the devices, technologies and energy sources must

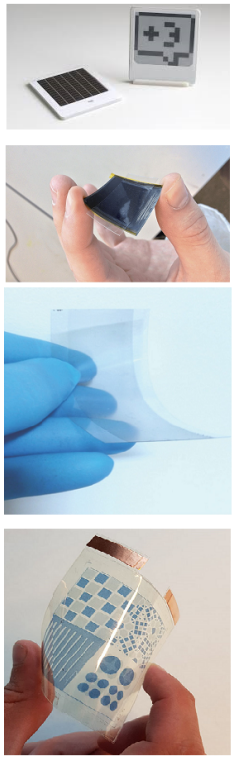

Figure 1: Top:Ultra-low power displays combine an e-paper display with photovoltaic energy harvesting [7], Middle two: flexible and transparent PV materials [6], [12], Bottom: transparent and flexible displays based on electrochromics [8].

be more sustainable and carbon neutral. Hence, we need to work on a two-pronged strategy – powering our technologies from renewable sources and making more intelligent devices that are more energy efficient.

Computational devices such as Internet-of-Things (IoT) connected sensors, actuators and displays have made tremendous progress over the last 10 years, for example, smartwatches, voice controllers, smart and interactive displays, digital signboards, etc. However, all such systems either require being plugged to a constant source of energy or battery backup, thereby limiting either the lifetime or performance of these devices.

Energy harvesting is a promising solution. Many researchers and industries are investigating novel solutions to harvest and store energy to achieve self-sustainable IoT devices. Research into ambient energy harvesting and ultralow power electronics has produced some interesting devices which are capable of harvesting energy from a variety of sources, including ambient indoor lighting [2], thermal sources [11], mechanical vibrations [5], and ambient RF [9].

In terms of photovoltaic (PV) materials, for instance, [7] demonstrates the combination of PV with digital displays to present a prototype of ultra-low power displays (see Fig 1 (top)). Further advances can also mean integration of flexible, transparent, coloured, and patterned PV materials in such devices [6], [12] (see the example of flexible and transparent conducting adhesive of PV materials in Fig 1 (middle)).

Apart from providing sources of energy, many of these sources may also provide a means to detect gestures through interaction with these energy sources. For example, watches and eye-glasses have been prototyped using light to both detect hand gestures with a high degree of accuracy and provide self-sustained operation [10]. Others have used RF fields that allows interacting with devices with 3D gestures [1].

Energy harvesters have also been rethought as self-sustainable sensors e.i. they produce power when the phenomenon to be sensed occurs. This can be powerful while building self-sustainable sensing and communication systems (i.e., Internet of Materials (IoM)). Fig 2 (Top), for instance, shows SATURN [4] a self-sustainable thin acoustic sensor which is used to build ZEUSSS [3], a Zero Energy Ubiquitous Sound Sensing Surface (Bottom) which senses information using SATURN and communicates the information by back-scatter technology. The ubiquitous presence of such zero-energy, or very low energy, requiring surfaces can provide enormous contextual understanding, interactive and surveillance capabilities.

As well as developements in energy harvesting materials, advances in display materials further open up possibilities. For instance, customisable electrochromic (EC) displays [8] (see example of display in Fig 1 (bottom)) enable unique devices can be incorporated into practically any domestic object.

Workshop Topics of Interest: The topics of interest for the workshop include, but are not limited to the following:

- Methods and materials for self-powered interfaces and interactions
- Novel interfaces and interaction styles afforded by energy harvesting and low-power materials
- Scenarios and contexts of use for sustainable interfaces and interactions

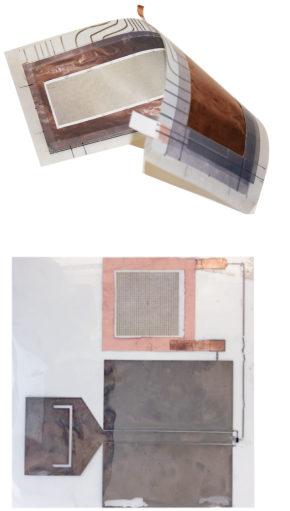

Figure 2: Top: SATURN - thin and flexible self-powered microphone [4] , Bottom: ZEUSSS : Zero-energy Ubiquitous Sound Sensing Surface [3].

Goal of the workshop: In this workshop, we will discuss the challenges and opportunities associated with self-powered interfaces and interactions. This workshop will bring together an international and cross-disciplinary group of researchers from academia and industry to collaborate and explore the the topic.

Organisers

The organising team brings together expertise and interests from material science, HCI, ubiquitous computing and system engineering.

Yogesh Kumar Meena is a Research Officer in the Future Interaction Technology Lab at Swansea University. His research focuses on self-sustainable Internet-of-Things (IoT) devices, machine learning, adaptive multimodal interactions, and brain-computer interfaces.

Nivedita Arora is PhD student in Ubiquitous Computing Lab at Georgia Institute of Technology. She combines learning from HCI, material science, chemical, electrical and mechanical engineering to develop computational material that can self-sustainably sense, compute, actuate and communicate.

Xing-Dong Yang is an Assistant Professor of Computer Science at Dartmouth College. His research contributes new concepts and working prototypes that advance the technology of interactive smart “things” through (1) better input devices and techniques; (2) more expressive non-visual output mechanisms; and (3) interactive systems that consume less power.

Markus Löchtefeld is an Associate Professor in the Department of Architecture, Design and Media Technology at Aalborg University, Denmark. His research focuses on wearable and tangible computing as well as novel prototyping and fabrication techniques.

Matt Carnie is Associate Professor in Materials Engineering, at the College of Engineering, Swansea University. He works on a number of photovoltaic technologies, not least perovskites which have shown exceptional ambient light harvesting.

Matt Jones is a research professor at the Computational Foundry, Swansea University. His work considers both emerging technologies and "emergent" users in rural and urban settings notably in India and sub-Saharan Africa.

Niels Henze is professor for Media Informatics at the University of Regensburg. His research interests are mobile human-computer interaction and pervasive computing. His recent work focuses on what makes mobile devices social acceptability and how we will interact with them in the future.

Gregory Abowd is Regents’ Professor and J.Z. Liang Chair in School of Interactive Computing at Georgia Institute of Technology. His research interests concern how the advanced information technologies of ubiquitous computing (or ubicomp) impact our everyday lives when they are seamlessly integrated into our living spaces.

Website

The workshop web pages can be found at (http://cs.swansea.ac.uk/~SelfSustainableCHI/. This will promote the workshop theme, engage a broader audience in discussions, and facilitate submissions of position papers.

Pre-Workshop Plans

We will distribute a call for position papers in design, computer science, materials science, engineering and manu-

facturing communities. We will announce the Call for Participation in mailing lists and calendars (e.g., ACM, CHI-announcements, Interaction-Design.org, WikiCFP) and social media (e.g., Twitter, Facebook). The calls will also be posted on the workshop website, along with other details about the workshop. Furthermore, we will directly contact researchers and practitioners who are likely to be interested in the workshop and write to relevant institutions, projects and companies. We will continue our efforts of promoting the workshop and getting in touch with potential participants during the period leading up to the position paper deadline. We have already made a list of 40 potential collaborators and attendees from industry, startups, design/HCI, material science, computer science and engineering.

Workshop Structure

The one-day workshop will be organized in three phases. The workshop will start with an introductory round and an overview of the grand challenges and opportunities in sustainable self-powered interfaces and interactions research. Then three phases will be used to drive an agenda for future research and innovation. These phases will be seeded by the participants' position papers and prototypes.

Phase 1: Technological possibilities

- This phase will concentrate on deepening understanding of the materials and methods available for self-powered interfaces and interactions.

Phase 2: Interface and Interaction Paradigm Shift

- Given the emerging materials and methods, this phase will explore the the features of the new interaction paradigm that they afford. We will consider for example, granularity of input/ output and interface dynamices (e.g. speed of response) and the application possibilities.

Phase 3: Setting an agenda for transformation

- The outcome of this phase will be a coherent set of research directions that will enable other researchers to pursue the goal of creating technological futures that will enable rich digital interactions through responsible and sustainability-orientated innovation.

Post-Workshop Plans

The results of the workshop will be communicated to the larger HCI community via a magazine article (e.g., ACM Interactions). In this article, we will define future design spaces and opportunities for future research.

We will also invite all workshop participants to submit an extended article of their submission for a special journal issue on Sustainable Self-Powered Interfaces and Interactions (e.g in Personal Ubiquitous Computing). This information and call for papers will also be shared on the website and will be open to other interested researchers in the community.

Call for Participation

We invite position papers for the CHI 2020 Workshop on Sustainable Self-powered Interfaces and Interactions. This one-day workshop will offer a cross-disciplinary forum of discussion and knowledge exchange for both academics and practitioners.

This workshop focuses on three grand challenges in sustainable self-powered interfaces and interactions research:

- Methods and materials for self-powered interfaces and interactions
- Novel interfaces and interaction styles afforded by energy harvesting and low-power materials
- Effective and delightful scenarios and contexts of use for sustainable interfaces and interactions

Researchers from both academia and industry with an interest in sustainable self-powered liferfaces and interactions research are invited to submit a position paper. The paper should be at most four pages in the CHI Extended Abstracts format. This position paper should address one or more of the workshop's three grand challenges or suggest another (we encourage diversity and provocation). All submissions will be reviewed by the workshop organizers. Accompanying demos are encouraged, and will be allocated time in the workshop agenda.

Participants will be selected on the basis of the quality of their position paper and on the basis of background and perspective; we are seeking to bring together a cross-disciplinary mix of perspectives. At least one author of each accepted paper must register for the workshop and for one day of the conference itself. Participants will be invited to present a position statement at the workshop and will actively engage in a discourse on the meaningful design space for sustainability of self-powered interfaces and interactions in HCI.

For further details or to submit a position paper, please see the workshop website: http://cs.swansea.ac.uk/~SelfSustainableCHI/

References

[1] Alejandro Alanis, Trang Thai, Gerald Dejean, Ran Gilad-Bachrach, and Dimitrios Lymberopoulos. 2014. 3D gesture recognition through RF sensing. *Tech. Rep. MSR-TR-2014-81* (2014).

[2] Ryota Arai, Seiichi Furukawa, Narumi Sato, and Takuma Yasuda. 2019. Organic energy-harvesting devices achieving power conversion efficiencies over 20% under ambient indoor lighting. *Journal of Materials Chemistry A* 7, 35 (2019), 20187–20192.

[3] Nivedita Arora and Gregory D. Abowd. 2018. ZEUSSS: Zero Energy Ubiquitous Sound Sensing Surface Leveraging Triboelectric Nanogenerator and Analog Backscatter Communication. In *The 31st Annual ACM Symposium on User Interface Software and Technology Adjunct Proceedings (UIST '18 Adjunct)*. ACM, New York, NY, USA, 81–83. DOI: http://dx.doi.org/10.1145/3266037.3266108

[4] Nivedita Arora, Steven L. Zhang, Fereshteh Shahmiri, Diego Osorio, Yi-Cheng Wang, Mohit Gupta, Zhengjun Wang, Thad Starner, Zhong Lin Wang, and Gregory D. Abowd. 2018. SATURN: A Thin and Flexible Self-powered Microphone Leveraging Triboelectric Nanogenerator. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 2, 2, Article 60 (July 2018), 28 pages. DOI:http://dx.doi.org/10.1145/3214263

[5] S P Beeby, M J Tudor, and NM White. 2006. Energy harvesting vibration sources for microsystems applications. *Measurement science and technology* 17, 12 (2006), R175.

[6] Daniel Bryant, Peter Greenwood, Joel Troughton, Maarten Wijdekop, Mathew Carnie, Matthew Davies, Konrad Wojciechowski, Henry J Snaith, Trystan Watson, and David Worsley. 2014. A transparent conductive adhesive laminate electrode for high-efficiency organic-inorganic lead halide perovskite solar cells. *Advanced Materials* 26, 44 (2014), 7499–7504.

[7] 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. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology (UIST '16)*. ACM, New York, NY, USA, 41–48. DOI: http://dx.doi.org/10.1145/2984511.2984513

[8] Walther Jensen, Ashley Colley, Jonna Häkkilä, Carlos Pinheiro, and Markus Löchtefeld. 2019. TransPrint: A Method for Fabricating Flexible Transparent Free-Form Displays. *Advances in Human-Computer Interaction* 2019 (2019).

[9] Miao Li, George Daniel, Bruce E Kahn, Liam H Ohara, Bernard DF Casse, Nathan Pretorius, Brent Krusor, Ping Mei, Gregory L Whiting, Chip Tonkin, and others. 2018a. All Printed Large Area E-field Antenna Utilizing Printed Organic Rectifying Diodes for RF Energy Harvesting. In *2018 IEEE 18th International Conference on Nanotechnology (IEEE-NANO)*. IEEE, 1–5.

[10] Yichen Li, Tianxing Li, Ruchir A. Patel, Xing-Dong Yang, and Xia Zhou. 2018b. Self-Powered Gesture Recognition with Ambient Light. In *Proceedings of the 31st Annual ACM Symposium on User Interface Software and Technology (UIST '18)*. ACM, New York, NY, USA, 595–608. DOI: http://dx.doi.org/10.1145/3242587.3242635

[11] Ayesha Sultana, Md Mehebub Alam, Tapas Ranjan Middya, and Dipankar Mandal. 2018. A pyroelectric generator as a self-powered temperature sensor for sustainable thermal energy harvesting from waste heat and human body heat. *Applied Energy* 221 (2018), 299–307.

[12] Joel Troughton, Daniel Bryant, Konrad Wojciechowski, Matthew J Carnie, Henry Snaith, David A Worsley, and Trystan M Watson. 2015. Highly efficient, flexible, indium-free perovskite solar cells employing metallic substrates. *Journal of Materials Chemistry A* 3, 17 (2015), 9141–9145.