Self-powered Users, “Free” Energy Harvesting and Interaction-powered Devices: a Hybrid Vision for Improved Sustainability

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Abstract
In a world facing climate change emergency, energy harvesting must be improved. Future interactive devices (with new materials) and a move of energy harvesting from devices to users can trigger this improvement. This paper presents a vision on how (many) future interactive devices should be powered. Beyond the benefits of a self-powered and ultra-low power interactive devices vision, a complementary one with self-powered users and “free” energy harvesting is essential. For example, harvesting user’s energy (e.g. heart rate pulsations) and/or enabling him/her to produce (e.g. kinetic/inertial energy harvesting) and store (e.g. wearables) energy for future interactions. Self-powered users can then perform interactions with devices (that require only power during interaction or extra power during interaction) powering them through direct contact interaction. This will allow the removal of built-in batteries on these devices and a global reduction of batteries. The proposed hybrid vision combines self-powered devices/users and “free” energy harvesting.

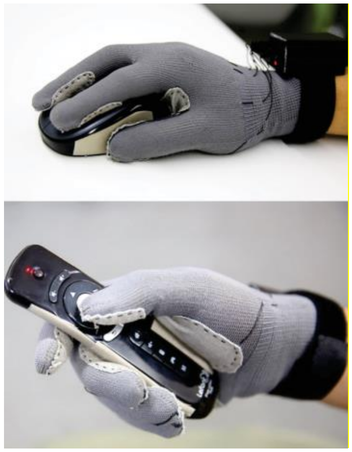

Figure 1. A user wears the user-end of TouchPower and uses a mouse and TV remote controller without batteries [1].

Author Keywords

Interface and Interactions; Self-powered Users; “Free” Energy Harvesting; Interaction-powered Devices.

CSS Concepts

• **Human-centered computing~Human computer interaction (HCI)**; HCI theory, concepts and models; Interaction techniques; Interaction devices.

Introduction

The world desperately needs an energy paradigm shift for an improved sustainability. The energy used by interactive devices is electricity, considered clean energy if obtained exclusively from renewable sources. However, electricity is still highly reliant on burning fossil fuels [2] and/or nuclear activity. There is a pressing need to increase energy harvesting from renewable sources to improve sustainability.

In chemistry, the well-known law of conservation of mass[1] discovered by Lavoisier state that “nothing is lost, nothing is created, everything is transformed”. Similarly, the conservation of energy[2] law state that energy can neither be created nor destroyed; rather, it can only be transformed or transferred from one form to another. Therefore, we still have nowadays an immense waste of energy because most of them is not transferred where needed.

For instance, focusing on interactive devices, when users interact with them (e.g. pressing a button or swiping) there is “free” energy (from pressure and/or friction) that could be transferred back to the device.

The trend to an increasing number of electronic devices demands novel directions such as ultra-low power devices, interaction and ambient energy harvesting but also novel low maintenance power schemes to decrease the burden of maintaining this huge number of devices.

The Vision

To achieve a successful paradigm shift, a hybrid approach should be followed. This means that efforts should be made in different directions. First, the number of batteries should be reduced to diminish the burden of maintaining a huge and increasing number of devices. This can be accomplished moving batteries from devices to users [1] (see Figure 1). Users with (wearable) batteries enable additional energy harvesting that can be obtained from users and their activities. Second, ultra-low power devices associated with ambient energy harvesting will tend to make devices self-sustainable. And, devices’ functionalities or states with additional energy requirements could be powered with energy from self-powered users while interacting with the device. Finally, energy from the interaction should also be harvested. For example, when a user is interacting with a touchscreen the frictional energy resulting from the interaction should be transferred back to the device or to the user for future interactions. As billions of users interact daily with touch screens this simple additional energy harvesting could save a gigantic number of Joules. Furthermore, recent advances in hypersurfaces[3] enable

[1] https://en.wikipedia.org/wiki/Conservation_of_mass (last accessed January 29, 2020).

[2] https://en.wikipedia.org/wiki/Conservation_of_energy (last accessed January 29, 2020).

[3] https://www.hypersurfaces.com (last accessed January 29, 2020)

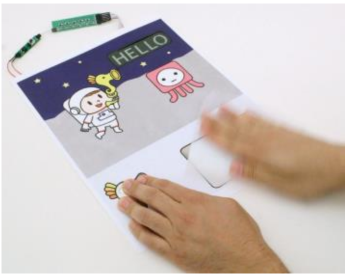

Figure 2. Paper Generator harvests energy from rubbing and activates the e-paper display, revealing the word “hello” [5].

the conversion of any material of any shape into an intelligent surface that will recognize gestures. Each gesture on the surface creates a distinctive vibration pattern that is identified and converted into a command. This leads to believe that touch interactions will not decrease in near future. Therefore, friction/ pressure energy harvesting will have a huge impact.

The move of battery from devices to user (as proposed in the work of Zhang et al. [1]) enables a lower maintenance power scheme and an increasing potential source of energy to harvest available. Reducing to one battery per user and being able to harvest energy from users, their activities, interactions and, environments are advantages that became possible.

Self-powered users will foster power-as-needed devices (i.e., devices that only require power during interaction) and the removal of built-in batteries, but other devices will continue to be required. Therefore, self-powered and sustainable devices must also be fostered. However, some of these devices might require more energy while being interacted that might not be available. This falls in the benefits of this proposed hybrid vision that merges both:

1. Self-powered devices - able to manage power requirements of devices while “idle” (nonbeing interacted);
2. Self-powered users - provide power to power-as-needed devices and extra power to other devices to deal with additional power requirements associated with interactions;
3. “Free” energy harvesting - provides a source of energy to self-powered users.

Some authors [3, 4] have started to harvest “free” energy from common human activities. This energy together with a move to lower-power devices pave the way to self-powered and sustainable users fueled with “free” energy from their common activities (e.g. walking, opening a door, breathing). Furthermore, interaction-powered interactive devices can complement the stated vision. For instance, a touchscreen built with energy harvesting materials (e.g. Paper Generator [5]) and being able to harvest energy from interaction (e.g. scrolling) can increase the usage efficiency of “free” energy.

Discussion
The proposed vision presents potential benefits in terms of sustainability however, with potential implications in terms of User Experience. For instance, current ultra-low energy devices provide less attractive interfaces [6][7]. Furthermore, some devices might require more pressure to harvest more energy from the interaction and/or might be unable to provide a colorful interface. Another disadvantage of the proposed vision is the required use of a glove by self-powered users to transfer energy to devices. However, as stated by Zhang et al. [1] some techniques such as skin electronics [8][9] and intrabody [10] can help get rid of the glove.

Future research should focus on harvesting “free” energy from user interaction. The effectiveness of the presented vision might imply changes in users’ interactions and behavior. For example, more vigorous interactions might be needed to harvest enough energy or a need for a more active users’ lifestyle. This might be mitigated by designing solutions focusing on users’ needs instead of users’ wants.

Conclusions

This paper presents a hybrid vision aiming to improve energy sustainability. The approach focusses on the intersection of three points: i) powering users; ii) harvesting "free" energy; iii) low powered, self/interaction-powered and sustainable devices. Finally, a discussion of the proposed vision and directions for future work is presented.

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