Foot Tap: Self-Sustainable Socially Appropriate Subtle Interaction

Qiuyue Xue
University of Washington
Seattle, USA
qxue2@cs.washington.edu

Shwetak Patel
University of Washington
Seattle, USA
shwetak@cs.washington.edu

Self-Sustainable CHI Workshop'20, April 25–30, 2020, Honolulu, HI, USA

Abstract

We proposed the design of self-sustainable foot tap sensing surface for socially appropriate subtle interaction using piezoelectric sensors. As piezoelectric materials can harvest more than hundreds of microWatts energy from tapping foot, it is enough to power a simple backscatter communication circuit to send the pressure signal back to a computing device such as a smartphone, which can process and recognize different foot gestures. The foot tap gesture is natural and subtle, which enables users to interact with their smartphone or wearable devices in a more discreet manner.

Author Keywords

Interfaces and Interactions; Piezoelectric; Foot Gestures; Social Acceptability

Introduction

Piezoelectric sensors have been demonstrated for energy harvesting and researchers have integrated them under shoes to harvest energy from human motion such as walking, jumping, etc to power wearable sensors. However, besides harvesting energy for other wearable devices, the piezoelectric sensor under shoes can act as a self-sustainable interaction interface as well. Tapping foot is a common activity that most peoples do when they are sitting or listening to music. The tapping motion can generate enough power to send the sensed pressure signal back to computing devices like smartphones or smartwatches to enable foot input interactions. The different tapping patterns such as the left foot or right foot, the pace of tapping, and the number of taps can be decoded as discrete interaction commands, which can be used for commands invocation. Since foot tapping is natural, easy to perform, and usually unnoticeable, it enables subtle interaction that is socially appropriate and can be used when the users are in a meeting or talking to someone face to face.

Piezoelectric Sensing and Energy Harvesting

Researchers have been actively exploring energy harvesting in decades, and several energy harvesting concepts have been studied. Piezoelectric and triboelectric are one of the energy harvesting methods that can transform mechanical energy into electrical power. The main sources of mechanical energy for piezoelectric harvesting include human motions, vibration of infrastructures, and vehicle motions etc[4]. Human motion is one of the most popular mechanical energy sources that can be harvested by piezoelectric materials. Kymissis et al[2] [6] first demonstrated harvesting energy by integrating piezoelectrics into shoes. [4] shows that the embedded piezoelectric materials under a shoe can generate around $0.4mWcm^{-3}$ from normal gait of a 68kg user.

Foot tapping will generate less power than walking because the tapping force is much less than the walking force. Mohsen Safaei et al 2019[7] did an experiment which shows that the average force for a foot tapping task is about 150N for young people and 75N for elderly people. Compared with human walking, the max force under shoes will be the person's weight, which is around 667N for a 68kg user. Thus we can estimate the power that can be harvested from a natural foot tap is around $0.4mWcm^{-3} * 150/667 \approx 90uWcm^{-3}$ for young people. With a $3cm * 3cm * 0.5cm$ piezoelectric patch, it can potentially generate $90 * 3 * 3 * 0.5 = 405uW$ power per tap gesture. The harvested energy from foot tap motion is enough to power a simple ambient backscatter communication circuit and transmit the piezoelectric sensor signal to the user's smartphones, smartwatches, or other wearable devices, which can then process and recognize the signal for gesture interactions.

Ambient backscatter communication is a low-power communication method that transmits data by reflecting existing signals, and the power consumption of a backscatter system is typically less than $100uW$ [8]. Since the backscatter circuit usually has only a few components, the backscatter circuit can be embedded in the groove of the soles without adding uncomfortableness for users. Overall, the whole system can be embedded into normal shoes without adding a battery.

Interaction with Foot

Foot interaction enables users to interact with their computing devices such as smartphones, smartwatches, or head-mounted display(e.g. Google Glass) in a more discreet manner for social appropriateness or privacy concerns. Since tapping foot is subtle and usually not noticeable, users can tap foot to dismiss a call or notification when in a serious meeting or talking to someone face to face. Foot Interaction can also be used to perform secret tasks like entering passwords or other private information.

Rico et al.[3] evaluated social acceptability for different gestures and their result showed that foot tapping had an acceptance rate of 88% based on audience. Their study showed that the gestures that were familiar in feeling or appearance are more acceptable by users, and users report that "foot tapping looks very similar to what you do normally anyway".

Researchers have proposed different gestures and use cases for foot related interactions in the past few years. Different foot gestures including tapping foot, tapping toe[1], pivoting heel[5] etc have been explored. And researchers have also proposed applications including interacting with a computing device that resists in the user's pocket, a head-mounted display, or a standing desk. However, the previous research focuses on designing and evaluating the foot gestures, none of them aims to develop a self-powered foot interaction interface that can be fully embedded into shoes without additional equipment such as cameras or projectors.

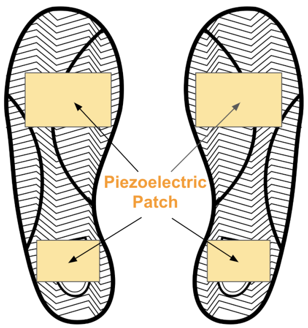

Figure 1: Figure 1. Piezoelectric Patch under shoes design

Piezoelectric Subtle Foot Interaction Design

System Design

Since there are a lot of daily activities related to feet and shoes, the foot tap interface requires careful design to avoid false positives that are not intended for interaction.

Human walking is one of the most common motion but not related to interaction. In order to differentiate tapping foot and walking, we can put two piezoelectric sensing patches under each shoe, one at the sole side and another one at the heel side, as shown in figure 1. As walking will activate both patches under the shoe, tapping foot will only activate the sole side patch and almost doesn't active the heel side patch, thus the system can differentiate the gesture input from walking or other non-tapping motions.

Besides the daily activities related to foot that may activate the interaction interface, users may also accidentally activate it when they start tapping their feet after hearing some music. So a robust trigger gesture that requires some mental attention needs to be designed. Alternating left foot tap and right foot tap three times may be a good trigger gesture since it is not a common pattern in daily life and it requires some attention but still easy to perform.

Gesture Design

The left and right foot tap can be used as a two bits input system such as yes or no, left or right, etc. For scenarios when users need to accept or reject an incoming call, open or dismiss a notification, left and right foot tapping can be decoded as yes or no command for these scenarios. The left and right foot can also be used as left and right navigation in a menu bar.

Another easy to perform gesture is double tap the same foot in a short period of time. The double tap gesture can be used as a confirm button that is similar to a click in touchscreen or touchpad.

Tapping at different frequencies is another set of gestures in which each button can be represented by a unique frequency. It can also be used to type on a keyboard where letters are blinking at a specific frequency, and the user can select each letter by tapping the foot at the corresponding frequency. In this way, foot tap can enable high bandwidth text entry besides just two bits of input.

Conclusion

We have proposed our design of a self-sustainable piezoelectric powered foot gesture interface for socially appropriate interaction. It is feasible to only use the harvested energy from foot tap gesture to communicate the piezoelectric signal back to a computing device by ambient backscatter, and the whole foot interaction system can be embedded into shoes and self-powered without a battery.

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