StickEar: Augmenting Objects and Places Wherever Whenever

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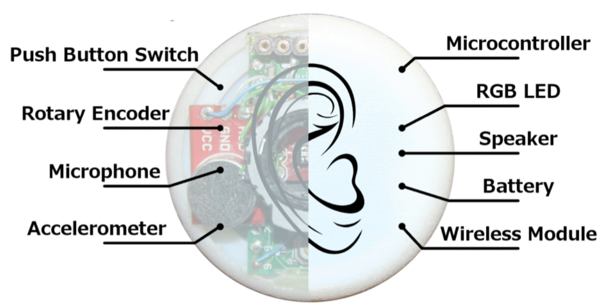

Figure 1. Stick Ear Sensor Node

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Abstract
Sticky notes provide a means of anchoring visual information on physical objects while having the versatility of being redeployable and reusable. StickEar encapsulate sensor network technology in the form factor of a sticky note that has a tangible user interface, offering the affordances of redeployablilty and reusability. It features a distributed set of network-enabled sound-based sensor nodes. StickEar is a multi-function input/output device that enables sound-based interactions for applications such as remote sound monitoring, remote triggering of sound, autonomous response to sound events, and controlling of digital devices using sound. In addition, multiple StickEars can interact with each other to perform novel input and output tasks. We believe this work would provide non-expert users with an intuitive and seamless method of interacting with the environment and its artifacts though sound.

Author Keywords
Distributed tangible user interfaces (dTUI), wireless sensor networks, sound based interactions

ACM Classification Keywords
H.5.2. User Interfaces; H.5.1 Multimedia Information Systems; K.4.2 Social Issues: Assistive technologies for persons with disabilities

Introduction

Spatial anchoring of visual information on physical objects through the use of paperbound materials is a common method for leaving tangible bits of information to facilitate non-verbal communication. Tagging objects and places with visual information using product labels, price tags, and signboards etc., has become a part of our lives. Often these visual tags are static and always visible. Sticky notes are special purpose visual tags used for temporal anchoring of visual information, with the flexibility of being redeployed to another object and space [8].

With StickEar (Figure 1), we want to empower people with the ability to deploy acoustic tags on any objects or space, and be well informed of acoustic cues that may be produced by any object at any location. We also want to emphasize on a device, which has the affordances of a sticky note. In this paper, we outline some of the related work, describe implementation details of the StickEar prototype and discuss some of the StickEar-enabled interactions.

Related Work

Distributed Sensors

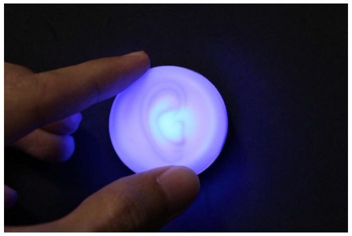
We live in a world surrounded by sensors. They can either be embedded in a device that we carry around with us, or be a permanent installation at a location [10]. While having a portable feature-packed device (such as a mobile phone) with multiple sensors embedded inside may seem to be an 'all-round' solution for many applications, it might not be a cost effective solution when having to deploy multiple devices at various locations. Hence, dedicated low cost sensor devices are often deployed in large sensor networks [1]. Distributed sensor networks pose a different problem, as they are often seen as an expert device that can be complicated to setup and deploy. They are often semi-permanent installations that are not meant to be redeployed on a frequent basis. With StickEar, we want to bring together the advantages of portability, accessibility and re-configurability into a single system.

Tangibility

Ishii and Ullmer proposed the concept of tangible bits as a means to bridge the gaps between the digital and physical world, and also the foreground and background of human activities [5]. The use of dTUIs is demonstrated in *Siftables*, a research project which became a successful commercial product [7]. *Siftables* applies the technology and methodology from wireless sensor networks to a touch and gesture based TUI with graphical displays, allowing the physical interaction of digital information. In StickEar, we harness on the idea of having wireless tangible bits but instead apply it on the interaction with sound.

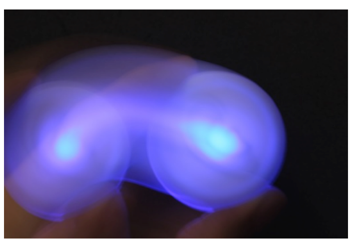
Connectivity

The Internet of Things (IoT) is a concept of extending Internet to real-world objects [9]. It envisions the future of real-world objects being interconnected in the digital domain. *Ninja Bloc*ks [11] and *Twine* [12] are two commercial products that integrate wireless sensor monitoring into a cloud-based service over the Internet. They both feature an intuitive 'rule-based' configuration method to replace traditional programming for setting up the device. In addition, apart from the inbuilt sensors that come along with the device, they both allow external sensors to be connected through connectors. We recognize the potential of IoT enabled devices and the notion of these devices providing 'just in time information'. With StickEars, we want to provide



(a) Turning

(b) Pressing



(c) Shaking

Figure2. StickEar input interactions

users with the ability to stay connected and aware of their surroundings, and at the same time, make the experience intuitive through an inbuilt TUI on the device.

Sound as a user interface

The five traditional human senses are hearing, sight, touch, smell and taste. Sound is perhaps the most natural 'active' form of two-way communication since human hear and produce sound naturally [3]. The use of sound as a user interface has been explored in various research areas. They encompass sensing technologies from acoustic classification to microphone array signal processing for sound localization. *Scratch Input* [4] for example, transforms the unique sound produced when dragging a fingernail on a textured surface into various gesture inputs to the surface. *PingPongPlus* [6] is a novel interface for digital augmented cooperative play. It uses the sound from a ball hitting the table in a game of table tennis as an input to create a digital augmentation layer on the physical table. StickEar implements this concept of using sound as an input to transform objects into one that is interactive.

StickEar

StickEar combines the properties of a sticky note and an ear. Based on the affordances of a sticky note, StickEar provides a means of being easily attached or detached. This is achieved by the use of a reusable adhesive material on the surface of the device. A microphone sensor provides the sound detection and acquisition capability like an ear. StickEar consists of three sub systems – sensor nodes, a wireless networking base station and a computing device with the associated software applications.

StickEar Sensor Node

Each StickEar sensor node functions as a tangible bit, allowing a user to interact with it through various input methods. In the current prototype, we implemented the turning, pushing, and shaking input interactions. By turning the face of the sensor node, a user cycles through the various operating modes, i.e. setting it as an input or output device. Another secondary function of the turning gesture is to set the sensitivity of the microphone sensor. Pressing on the exterior face of the StickEar sensor node is used to trigger various functions such as initiating a pairing sequence, entering a selected mode, or cancelling an output event on the sensor node. In order to redeploy the StickEar sensor node, one would have to 'unstick' it from the object and shake it. We associate the shaking gesture with resetting and un-pairing the StickEar sensor node. The various input interactions are illustrated in Figure 2.

When humans localize a sound source, the natural gesture is to tilt their heads and have the ears point toward the direction of the sound [2]. In some cases, they place their ears directly on the surface of the object (i.e. listening to a heartbeat). StickEar sensor nodes are designed to mimic the directional hearing function of a human ear. To listen to object specific sound events, the user attaches the front facing side of the StickEar sensor node to the surface of the object, setting its sensitivity to a lower range for localized sound detection. Otherwise, to listen to a space specific sound event, the rear side of the StickEar sensor node is attached to a wall or structure such that the front side has the microphone pointing toward the space in front of it. The sensitivity of the sensor node can be tuned to the maximum, so as to maximize its detection range.

The current StickEar sensor node prototype is based on an 8-bit microcontroller. Inputs to the sensor node include a microphone, rotary encoder, push button switch and an accelerometer. A tri-color light emitting diode (LED) and speaker is used for visual and audio feedback respectively. Wireless connectivity is enabled by a 2.4 GHz radio frequency (RF) transceiver. The outer casing is designed such that it has a flat front and rear surface for easy mounting. The microphone is located on the front facing side such that it enables directionality in sound detection, depending on how it is mounted.

StickEar Base Station

The base station is based on an 8-bit microcontroller, a high power long-range 2.4 GHz RF transceiver for communicating with StickEar sensor nodes, and a Bluetooth module for communication with mobile devices. The function of the base station is to route messages between sensor nodes and mobile devices.

A 2.4 GHz RF transceiver is used as the main communication method in all StickEars sensor nodes because we wanted the interactions between StickEar sensor nodes to be independent of an Internet connection, which might not be available all the time. However, the trade off for using RF is that StickEar sensor nodes would not be able to communicate with other devices that only supports Bluetooth or WIFI connectivity (e.g. Smart-phones, Computers). In the current prototype, a separate base station with Bluetooth connectivity is used to route messages from StickEar sensor nodes to other external devices. We recognize the limitations with range in Bluetooth connectivity, but this current implementation is sufficient to demonstrate the interactions we are proposing. In the next design iteration, we would extend the connectivity of StickEars to be Internet enabled through a ‘Master’ StickEar (with the same form factor as a StickEar sensor node) that has an embedded WIFI module. All StickEar sensor nodes could then have access to external devices through the ‘Master’ StickEar.

StickEar enabled interactions

Through the design of a sound-based wireless TUI with the affordances of sticky note, we seek to explore possible interaction techniques and gain insights on novel applications enabled by this device.

The interaction space of StickEar is broad, covering both input and output domains. We identified four possible interactions that support the redeployability nature and collaborative structure of one or more StickEars:

- Remote monitoring of sound events
- Remote triggering of sound output
- Autonomous response to sound events
- Control input for personal digital devices

Remote monitoring of sound events

A single StickEar can be attached to an object or to a specific space to ‘listen’ for sound events. We developed a mobile phone application, which would notify the user whenever a StickEar detects a sound. Setting up StickEar with the mobile phone application is intuitive – a user only needs to attach StickEar to the object, initiate a one-time pairing request to the mobile phone by manually triggering a sound event on the object for the first time. The user then assigns a text entry on the application in response to the pairing request. Subsequent sound events occurring on the object will trigger a notification on the mobile device with the corresponding text assigned to it during the setup. To reuse and redeploy StickEar, a user simply detaches it from the object and gives it a shake to remove its association with the object.

As an input sound-monitoring device, we see a potential of deploying multiple StickEars for a collaborative application such as sound source localization.

Remote triggering of sound output
Misplacing objects can sometimes be a frustrating experience, and one would often hope that the object could somehow respond to your calls and tell you where it is. StickEar as an output device could act as a 'voice' for inanimate objects. We developed a mobile phone application to enable StickEar as an object finder. Adding a 'voice' to an object is as simple as attaching a StickEar to it, and pressing on the exterior face of the StickEar to initiate a pairing request on the mobile phone application. The user then assigns a voice tag, which is stored in the phone's database. To locate a misplaced object, a user simply launches the application and issues a voice command (in the form of the associated voice tag). This then triggers an alarm sound output on the corresponding StickEar. Similarly, reusing and redeploying StickEar only involves detaching and shaking it to remove its association with the object.

One potential application for the deployment of multiple StickEars as output devices is to use them for multichannel audio output.

Autonomous response to sound events
In this interaction space, a StickEar is used as an input and output device at the same time. A sound input event triggers an immediate sound output on the same StickEar. We demonstrate this with an example of using StickEar as a baby monitor. StickEar is placed near a baby's crib and configured to detect the sound of a crying baby. Upon detection, it responds immediately by playing a lullaby.

As an controller for personal digital devices
This interaction is currently conceptual, but its implementation is viable. We are working towards a functional version of StickEar having the ability to perform classification of sound. With this feature enabled, StickEar could function as controllers using different sound inputs. This essentially allows us to also turn any surface into an interactive surface when a StickEar is attached to it. Additionally, users could control personal digital devices by snapping their fingers, tapping on StickEar or possibly 'talk' to it.

Composite Interactions of Multiple StickEars
Apart from the above four basic interactions, composite interactions between them opens up new possibilities. One example scenario is where one StickEar is configured as an output device for locating objects, and another StickEar configured as an input device for sound event monitoring. A user remotely triggers the alarm on one of the StickEar from his or her mobile device. At the same instant, another StickEar within the vicinity can pick up this alarm sound and send a notification to the user informing him or her about the location of this sound event. This then allows a user to find an object from a remote location.

Conclusion and Future work

In this paper, we presented StickEar as a tangible input/output sound-enabled device with the affordances of being redeployable and reusable. It enables accessibility by everyday users to the 'complicated' sensor network application that is available only to expert users.

Future work on StickEar will include the ability to perform recognition of different sound events. StickEar will also be Internet enabled for off-site remote access. A method for a more intuitive pairing between multiple StickEars and other external devices will be implemented. We plan to conduct a user study to understand how users would interact with some of the suggested applications, and possibly see if they would come up with any other novel interactions. We envision StickEar to be an empowering personal device that anyone would carry and use everyday to augment objects and spaces.

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