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The Audiator: A Device-Independent Active Marker for Spatially Aware Displays

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1 Introduction

The LightSense system [Olwal 2006] promotes printed public information sources, such as maps, into interactive surfaces enriched with digital information, which is accessed through a spatially aware display [Fitzmaurice 1993]. Using outside-in tracking, LED lights on cell phones are located using an instrumented environment with either a combination of a computer/camera or microcontroller/photosensors. The location is continuously sent to the phone over Bluetooth, such that context-sensitive information can be shown as the device is moved by the user.

We have extended this work with *the Audiator*, a custom-made active marker and an integrated projector-camera setup, achieving the following new features:

1) virtually any device can be used as a spatially aware display (not only specific cell phones with built-in LEDs)
2) support for simultaneous interaction with multiple devices
3) public projected imagery can now complement the printed information and the private handheld display

LightSense requires an instrumented environment but has several advantages over more traditional egocentric tracking techniques that use the phone's camera, such as the system described by Henrysson and Ollila [2004]. Those techniques can not use the device directly on the surface, since the camera will be blocked. They are computationally expensive, which is a problem on small devices with limited computation power and minimal image processing capabilities. Additionally, marker-based approaches are visually distracting and intrusive, whereas our tracking is hidden and performed behind the surface, maintaining the original visual appearance of the surface.

2 The Audiator

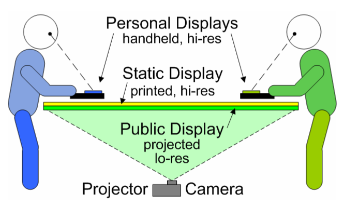
The original LightSense system was designed for camera phones with built-in light LEDs. The inability to control the light through software prevented us from supporting multiple devices on the surface, since light sources from two devices could not be distinguished. Additionally, many devices do not have built-in LEDs and it also seems like the trend is moving away from camera phone lights with ultrabright LEDs, to real flashes.

These issues inspired us to develop the Audiator, an active LED marker that can be plugged into the headphone jack of any audio-capable device. It can be controlled from software on the device through the means of generated sound, which is amplified and converted to light, transmitted using an ultra-bright LED. By encoding data in the stream of generated audio, the device can not only be positioned but also identified, through resulting modulated light in a series of camera frames.

Figure 1. (left) The Audiator consists of a mini stereo connector, resistors, an operational amplifier, batteries and an ultra-bright LED. (right) A cell phone with the Audiator connected to the headphone jack on the handsfree modulates the LED light using software generated audio.

The Audiator inherently allows optical encoding schemes such that multiple devices can be disambiguated on the surface. Devices can be identified by being sent a secret bit pattern over a private Bluetooth connection from the server, which they blink to identify themselves (the use of private/public keys could also be employed). The blinked pattern is acquired by the camera and allows the system to associate an ID with the light source at that position. Once the ID is established for a light source, it is permanently turned on and the system can track it on the surface using frame-to-frame correspondence. The identification process is repeated whenever the system experiences ambiguity (such as two light sources being very close to each other) or when unidentified light sources appear.

3 Public & Private Multi-user Interaction



Adding a projector enabled rear-projected information to be overlaid on the printed material. Public data can thus be easily shared, while private information is kept on the user's personal display. The projected imagery also allows users without a personal device to participate. An example scenario would be to augment a road map with real-time traffic data, while personal destinations and annotations can be kept private.

4 References

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