The Interaction Engine: Tools for Prototyping Connected Devices

Nikolas Martelaro
Stanford University
424 Panama Mall, Bldg. 560
Stanford, CA 94305 USA
nikmart@stanford.edu

Michael Shiloh
California College of the Arts
San Francisco, CA USA
mshiloh@cca.edu

Wendy Ju
Stanford University
424 Panama Mall, Bldg. 560
Stanford, CA 94305 USA
wendyju@stanford.edu

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Abstract
In this workshop, we will familiarize participants with the Interaction Engine, a system for prototyping connected, interactive devices using low cost, single-board Linux computers and Arduino microcontrollers. Our main objective is to introduce participants to the basic architecture of connected devices and provide hands-on experience creating networked, physical hardware. The Interaction Engine is a generic framework, not a specialized toolkit. We employ widely available, community-supported tools that can enable web-connected hardware capable of merging tangible interfaces with audio/visual web interfaces. We view low-cost single-board computers as an enabling technology, representing the next step for tangible, embedded, and embodied designs enabling deep interaction between physical and digital worlds. This workshop will be a starting point for participants to begin exploring connected device development and will provide a basic set of tools and skills that participants can use in their own applications.

Keywords
Instructions, connected devices, single board Linux computer, interactive devices, physical computing

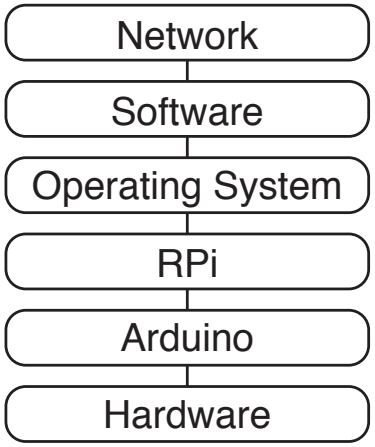

Figure 1 - Connected devices architecture.

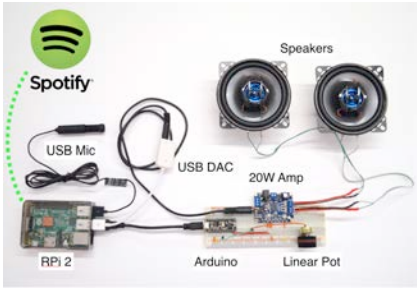

Figure 2 - Example physical Spotify radio built using Interaction Engine.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction

Next generation tangible, embedded, and embodied devices will be networked, audio/visual, tangible objects capable of collecting, processing, and transmitting data between physical and digital worlds. Hardware designs in the TEI community are heavily based on microcontroller systems, capable of a wide range of tangible interactions, and mobile phone/tablet systems supporting networked, audio/visual, data intensive applications. The next generation of devices will merge the capabilities of these systems, enabling highly interactive, connected, embedded experiences. Examples include a physical radio allowing tangible interaction with the Spotify web music service, or a web interface enabling access to an interactive art installation providing live video of user engagement. Many of these interactions require a full computer and operating system. Although there are a variety of tools and systems to enable these designs, within the TEI community a well-established prototyping system for connected, high compute devices does not exist. New, low-cost, operating system-based computing platforms like the Raspberry Pi are becoming more readily available and, when paired with microcontrollers, enabling faster and more extensible prototyping of connected devices.

This workshop will serve as an introduction to extending microcontroller hardware with a single-board Linux computer based on tested models for interactive device prototyping systems [2]. We call this framework the *Interaction Engine*. Our goal is to provide an introduction to using single-board computers to add networking and audio/visual interactions to physical hardware. The workshop will introduce the basics of using an embedded Linux computer, setting up communication between the computer and microcontroller, and connecting hardware to a web interface. We will do this by building a "Hello, You!" device that uses physical and web interfaces to say hello to someone at a distance. Participants will modify example code to learn a toolset for enabling web-connected hardware. We will also provide sample code for more advanced features such as audio/visual recording and playback. Participants will then explore using the systems during a free build activity.

Although previous TEI workshops have explored prototyping connected devices with specialized kits [1], we will work with a set of widely available, community-supported tools. We hope this provides designers with a starting point for enabling their own designs when they leave the workshop. In addition, we aim to inspire discussion regarding the types of interactions these tools can enable and how future prototyping tools for tangible, embedded, and embodied systems can support researchers in the community.

Duration

1-day workshop (6 hours).

Proposal

This workshop will introduce participants to the Interaction Engine prototyping framework. We combine a microcontroller with a single-board Linux computer to quickly add networking and data intensive computing to tangible hardware designs. We will introduce various generally available tools through the creation of a

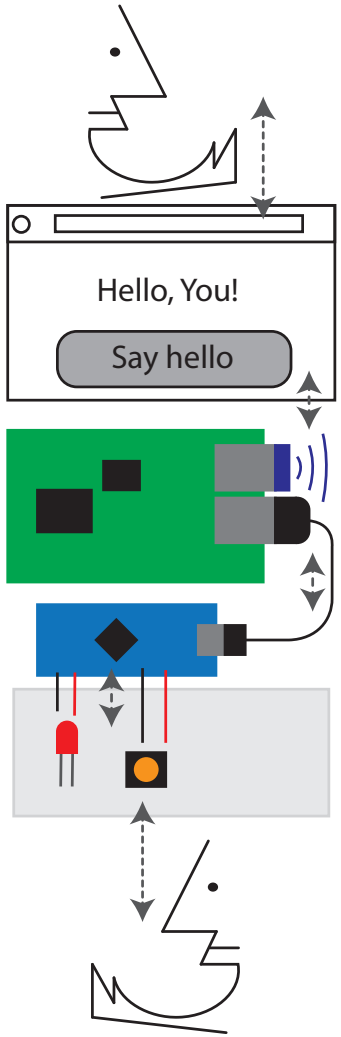

Figure 3 - "Hello, You!" remote greeting device, showing full connecting between physical hardware and web interface.

"Hello, You!" remote greeting device. The device will show physical control of a web interface running on a single-board Linux computer and web control of a physical interface connected to an Arduino microcontroller. When a user presses a button on the web page from his or her own laptop, it will light an LED on the Arduino. When another user presses a button on the Arduino, it will display "Hello!" on the remote webpage. This will give participants an introductory set of tools to start enabling their own interactive designs. Through exploring interactions between hardware and networked software, we intend to foster discussion around new interactive devices that can take advantage of higher computing capabilities and network connections. We also want participants to begin thinking about how we can extend and adopt new prototyping tools into the TEI community.

The studio will be broken into four phases. In the first phase, we will introduce connected devices and provide motivations for extending microcontroller-based designs with single-board Linux computers. We will cover possible interactions that can be enabled with an operating system and embedded computer systems. We will also cover the basic set of tools required to prototype connected devices. This toolset includes running a Linux-based operating system on a single-board computer, setting up a web server, building a simple web page, and connecting the web interface to microcontroller hardware via a USB serial connection.

In the second phase, we will introduce and build a basic interaction application through a "Hello, You!" remote greeting device. We will use this example hardware and software to further explain the various layers of connected devices including embedded hardware, single-board computer hardware, operating systems, web servers, and network architecture.

The third phase will involve an open prototyping activity that allows participants to explore these prototyping tools. Using sample code, participants will learn by doing, creating various web-enabled, tangible designs. At the beginning of this phase, we will also briefly introduce advanced topics such as audio/video capture and playback using webcams and microphones and advanced data processing using high-level code libraries.

We will conclude the workshop with a discussion of how these tools can enable new interactions in the participants' own work. We will also discuss how these new tools can be introduced to and improved on for the TEI community. Finally, we will demonstrate and/or discuss other options such as Bluetooth, BLE, Arduino YUN, Beagle Board, etc.

This workshop is intended for 12 participants with an intermediate level of experience with interactive systems. As we are providing a general introduction to the various tools to enable connected devices, we cannot dive into the specifics of Arduino or web-app development. One ideal participant has familiarity with Arduino hardware and firmware development and desires to further their designs by connecting them to the web. We also invite participants who are experienced with interactive web or audio/visual software development and wish to add a hardware component to their designs. Our goal is to attract a mix of hardware- and software-oriented participants to foster collaboration and accelerate learning.

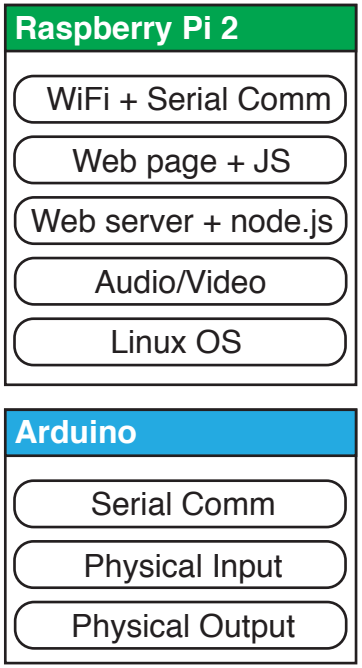

Figure 4 - Device topics

Topics to be covered

This workshop will cover the basic architecture of networked and embedded computing systems for use in tangible and embodied interaction design. This will include the hardware layer, operating system layer, software layer, and networked architecture. Specifically, participants will learn how to connect an Arduino microcontroller to a Raspberry Pi 2 single-board Linux computer with a Wi-Fi adapter. Participants will learn how to connect the Raspberry Pi to the network and interact with a command line Linux operating system via secure shell (ssh) from their own computer. We will then cover how to create a simple web server using JavaScript and node.js, a server side JavaScript platform. This web server will then be used to host a simple web page that can serve as an interface for physical hardware. We will connect this web page to physical hardware using the JavaScript serial library and the Arduino serial library. Participants will learn how to edit and run code on the embedded computer as well as how to edit and upload code to the Arduino using command line tools.

Learning Goals

We have the following learning goals for participants:

1) Understand the basic architecture and enabling technologies for prototyping connected devices.
2) Gain a basic understanding of how single-board computers can enable new interactive designs.
3) Become familiar with how to use a command line Linux system to connect to the Internet and run high-level code.
4) Become familiar with how to set up a simple web server and web interface using node.js using examples.
5) Become familiar with how to connect Arduino hardware to software on the single board computer using serial communication.

These goals will provide a set of actionable skills that participants can use to enable their own tangible, embedded, and embodied interfaces with web connection and blended tangible, visual, and audio interfaces.

Positioning

The workshop is a practical introduction to the skills and tools needed for prototyping connected devices. We primarily will focus on providing hands-on experience with connecting physical and digital interfaces to enable new interactive designs. However, we hope to inspire participants to consider how these new capabilities will change tangible, embedded, embodied design paradigms. We also aim to foster discussion around the nature of prototyping tools and how they shape our design concepts.

Supporting Web Documents

For this workshop, we will provide a full set of code and an illustrated guide to building a "Hello, You!" device on GitHub. The guide will document how to set up required hardware and software systems. All material will be open source with attribution.

References and Citations

[1] Andrea Bellucci, Díaz, P., Aedo, I., & Malizia, A. (2014, February). Prototyping device ecologies: physical to digital and viceversa. In *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction* (pp. 373-376). ACM.

[2] Edgar Berdahl & Ju, W. (2011, May). Satellite CCRMA: A musical interaction and sound synthesis platform. In *Proceedings of the International Conference on New Interfaces for Musical Expression* (pp. 173-178).