Cord UIs: Controlling Devices with Augmented Cables

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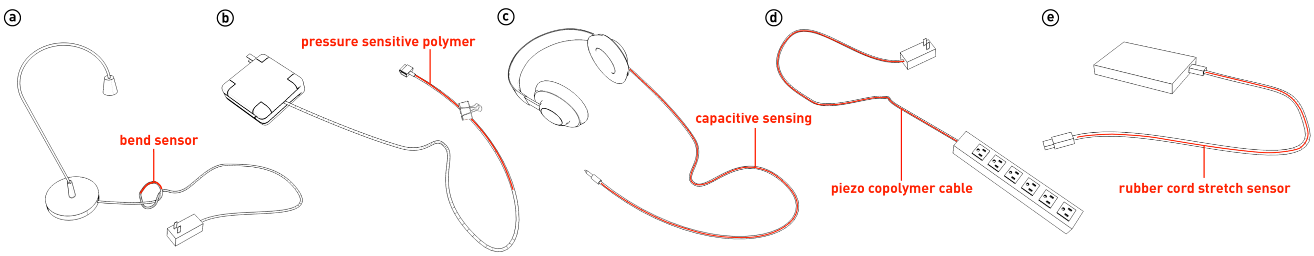

Figure 1: a) tightening the knot dims the lamp. b) attaching a clip on the power cord puts the computer to sleep. c) squeezing the headphone cable temporarily mutes the headphones. d) kinking the power strip's cord toggles it on/off. e) stretching the USB cord safe-ejects the hard drive.

ABSTRACT

Cord UIs are sensorial augmented cords that allow for simple metaphor-rich interactions to interface with their connected devices. Cords offer a large underexplored space for interactions as well as unique properties and a diverse set of metaphors that make them potentially interesting tangible interfaces. We use cords as input devices and explore different interactions like tying knots, stretching, pinching and kinking to control the flow of data and/or power. We also look at ways to use objects in combination with augmented cords to manipulate data or properties of a device. For instance, placing a clamp on a cable can obstruct the audio signal to the headphones. Using special materials such as piezo copolymer cables and stretchable cords we built five working prototypes to showcase the interactions described in this paper.

Author Keywords

Tangible Interface; Ubiquity; Touch Sensors; Seamless Interface; Sensing Technology.

ACM Classification Keywords

H.5.2 User Interface, B.4.2 Input/Output Devices.

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INTRODUCTION

Traditionally, electrical devices are dependent on cords, either for power or data-transmission. Cords are often times considered a nuisance and wireless technologies have advanced to a point where they can be used to charge small devices over short distances. However, technology has not yet reached a point where we can imagine a cord free future for all of our electrical devices. This is mainly due to the exponential power loss over distance. Most recently researchers have accomplished to transmit 209 W of power at 8% efficiency over a distance of 5 m [4]. Wireless data transmission technologies are more advanced, however, they still suffer from inherent vulnerabilities and security threats and it usually takes considerable effort to setup.

Despite the intensive research on wireless technologies, cords are not going to disappear in the near future. Among their vast ubiquity cords hold unique properties, which make them a interesting tangible user interface. They offer diverse material properties and form factors (flexible, rigid, flat, round, spiral); they can be used to offload interactions from the device and can offer quick and eyes-free interactions (e.g. Figure 1c). Moreover, one of the underlying principles of tangible interface design is to augment everyday objects with technology aimed at exploiting real-world metaphors. Most interactions we describe in this paper evolved from the idea to regard the cord as a water hose and data or power as water flowing in this water hose. We propose simple interactions that involve pinching, stretching, kinking, attaching objects, or making knots with our augmented cords.

The goal is to take advantage of the richness of human intuition and handling skills developed over time through interaction with these objects. In our opinion, cords exemplify this principle, since humans have been interacting with strings and ropes for thousands of years.

REALTED WORK

In the field of human-computer interaction, cords have not yet been extensively explored. The most relevant work is by Schwarz et al. [7] who were the first to describe a cord-like multi-DOF input-device to control mobile devices. Wimmer et al. [9] explore Time Domain Reflectometry to sense input and present an application that let's users adjust the volume of music by touching the headphone cord at different locations. Nokia published a patent [2] that describes ideas to use cords as an input device. Minguet [5] augmented a rope with flex sensors to detect knots, which can be used creatively to generate visuals and sounds on an attached iPhone. Sousa and Oakley [8] investigated how cords and a bead in clothing can be used as discrete input control. Yao et al. [10] explored ropes and how its common affordances can be used to design a novel gaming interface. Balakrishnan et al. [1] describe ShapeTape, a cord-like sensor that allows to precisely tracks its current shape and orientation and, among other things, can be used to manually and precisely manipulate Bezier curves in CAD programs.

These projects use the unique properties of a rope or cord to explore different interactions. However, we believe that the affordances and especially metaphors of cords are not adequately investigated. The main contribution of this paper is the exploration of novel metaphor-rich interactions and applications with augmented cords and all kinds of electrical devices. We consider the cord as an alternative input device for simple specialized tasks that comes naturally with the device and not as an additional versatile/sophisticated interface for complex tasks as [7][1].

INTERACTION

Most of the presented interactions lend strongly from the metaphor of regarding the cord as a hose and the power and data as liquid flowing in that hose. Additionally we explore other metaphors and analogies ("breaking a connection", "pulling something out of something") that create a strong conceptual model that can help to make interactions more understandable.

Cords offer endless possibilities of manual manipulation that could be used for interaction but are better performed with other devices that offer easier multi-DOF control. Hence, we decided to focus on interactions that are simple and could potentially be performed eyes-free.

We decided to classify the interactions with cords into three categories (Touch, Knot, Objects). For each category we list several application scenarios of which we chose to exemplify five through physical prototypes described later in this paper.

Figure 2: The five prototypes. a) embedded bend sensor detects knot's tightness. b) we can sense the clamp's pressure using conductive polymer. c) conductive yarn woven into the cord sleeve senses touch and pressure. d) special piezo copolymer cable can detect kinks. e) stretchable cord with rubber resistive cord to sense pulling.

Touch

We touch or apply pressure to the augmented cord to manipulate various parameters of the device to which it is connected. A cord's form factor lends itself for multiple types of touch interaction (sliding, pinching, twisting, swinging, stretching or kinking). Pinching the cable and varying the pressure applied, could alter the volume or speed of the music played. We imagine that people could pinch the cable of their headphones to mute the music temporarily to listen to in-flight announcements or their cab driver. This application is exemplified in our prototype (Figure 2c).

Further touch interactions that explore different metaphors are the kink and stretch. Kinking a cord back and forth in a certain frequency could be used to set a certain parameter (e.g. speed of a fan). Moreover, kinking a cord can be used to "break" a connection to the device. In our prototypes we demonstrate a power strip that switches off as soon as you kink the cable (Figure 2c). "Un-kinking" would switch it on again. The advantage hereby is that the whole cable acts a sensor and the power strip can be easily switched using the feet or hands. Power strips are often at hard to reach locations whereas large parts of its cord are usually accessible.

A stretching interaction on a cord can be an analogy to pulling out of something. In our prototype (Figure 2e) we use a stretchable cord on a portable hard- drive that can be used to indicate that a user would like to disconnect it from the computer, instead of having to use the mouse and click the eject/safe-remove button before one can pull off the hard-drive.

Knots

Tying knots in our augmented cords can manipulate a specific parameter of an appliance. For example, the tightness of a knot determines the level of data or power flow. In one of our prototypes, a simple overhand knot in the cord connected to an LED table lamp controls the intensity of the light; the looser the knot the brighter the LED light while tightening the knot dims the light until it switches off completely (Figure 2a). This is based on the analogy that a knot constricts or cuts-off the flow of something (light, volume, data, etc.) depending on how it is tied.

One key difference of using a knot over one of the touch interactions as control mechanism is that it provides visual feedback about the state it is currently in and is therefore better suited for controlling analog settings than binary ones. A further feature is that a knot can be moved along the whole length of the cord. The device's control could so be moved to most suitable position. We also imagine the possibility for multiple knots to control a number of independent parameters of a device. For instance, three knots could represent the red, green, or blue value of an RGB-LED lamp, respectively. Knot detection could be implemented using the technology described in [1].

Another, more poetic application idea lends from the old tradition of tying a knot in a handkerchief to remember something important. We imagine a cable - connected to a computer - in which the user ties a slipknot. This action automatically creates an event reminder in the user's calendar or a task in the To Do list. Upon completion the knot can be removed and the event or task is automatically checked off. The cord then acts as a tangible representation of the digital data.

Considering the countless types of knots there are more potential applications to be explored in future work.

Objects

Another way of interacting with appliances is using small objects, each having their own set of affordances, on an augmented cord. For example, users can attach and slide clips on the cord to change the volume of music. Different clips could be used to control different parameters. The shape and position of the clip provides immediate visual and tangible feedback about the type and level of control. Objects also have the advantage of maintaining a continuous state. In our prototype, for example, we show how to use a clip to put your computer into sleep mode (Figure 2b). As soon as the clip is removed, the computer starts up again. It is possible to place a multitude of objects (mug, water-bottle, paperweight, etc.) onto the cord to switch off any device. Another application could be an office telephone that cannot be called as soon as you place an object on its cord. Thinking more advanced we can imagine a cord that, e.g. via RFID, can distinguish between objects placed on or near it and switches functionality accordingly. For instance a speaker placed near the cord would eavesdrop into the flow of data and play it back.

TECHNICAL IMPLEMENTATION

To explore some of our proposed interactions we built five prototypes that work by augmenting the whole cord or parts of it. In all prototypes we use commercially available materials, sensors and cables. Sensor reading is done using the Arduino microcontroller.

Lamp (Figure 1a and 2a)

To detect a knot in a cord, and use it to adjust the brightness of a lamp by altering its tightness, we embedded a Flexpoint 2.2" bend sensor into wrap-around isolation together with a four-strand cable. Two of the strands were used to read out the sensor data. The other two strands were used to power the lamp. We used the microcontroller to read out the analog resistance value and to control the brightness of the light accordingly.

Laptop (Figure 1b and 2b)

We augmented a MacBook power cord with conductive polymer sandwiched between two sheets of heavy copper foil. When applying pressure the resistance between the two copper sheets decreases. Since the power cord doesn't offer the possibility to send any signals to the laptop we decided to send a long pulse (1000ms) by switching the power cord on/off using a relay. Using AppleScript we listen for this rising-edge "signal" by checking if the computer AC power is connected or not. We then issue the command to go to sleep or wake up.

Headphone (Figure 1c and 2c)

We use conductive yarn that we wove into the fabric of braided cable sleeving. The micro-controller detects touch via a large resistor (~1 MOhm) placed in series, which responds to any resistance changes following contact with the human body and ground. It can also detect the amount of pressure that is applied to the cord, since the resistance is inversely correlated to the area of human skin touching the cord. By temporarily shorting ground to the microphone input on an audio cable we can toggle the pause/resume functionality in an iPhone. We chose to use capacitive sensing over pressure sensors to detect pinching, to avoid accidental triggering in through cable stress.

Power Strip (Figure 1d and 2d)

Alongside the power cord we placed a Piezo Copolymer Coaxial Cable from Measurement Specialties™ to detect kinks and switch on/off the power strip. The piezo polymer generates a voltage that is proportional to the amount of compression or stretch that is put on it. Piezo cables are often times used in traffic counting. To switch the power on/off we implemented a relay into a power strip that is controlled by a microcontroller.

Hard Drive (Figure 1e and 2e)

For the easy-eject hard drive we augmented a stretchable cord with a stretch sensor (resistive rubber) that decreases its resistance when expanded. We use a a special stretchable cord which is often used in robotics where it can help to reduce a lot of wear and tear caused by the moving robots. This cable can usually only be stretched up to 30% of its original length but by removing the curled strands from their original sleeving and threading it in rubber tubing we increased the stretch to more than 50%. To interpret a stretch and eject the hard drive we used openFrameworks in combination with AppleScript.

CHALLENGE AND FUTURE WORK

As future work, we plan to explore more sophisticated technologies for linear shape and input sensing like Optical Domain Frequency Reflectometry or Swept Frequency Capacitive Sensing [6] to obtain more exact touch location readings and reliably detect different gestures. However, we believe that the gestures and interactions themselves should stay simple.

Another potentially interesting area for further exploration is the actuation of cords. Cord UIs could be used as output rather than only input. Similar to [3] this could allow for ambient, audio, visual or haptic feedback about events or interactions. For example, a cord could indicate suffering by wiggling and cringing when a data connection gets weaker. Or, similar to a fire hose when water pressure changes, a cord's stiffness could change when the connected device draws a lot of power.

Moreover, there needs to be more investigation into the diverse form factors cords come in (spiral, thick, thin, flat, etc.) and what different interactions these afford. To then better evaluate the findings a user study needs to be conducted.

CONCLUSION

This paper presents the idea of interacting with cords to manipulate parameters of connected devices through touching or making shapes. As a proof of concept, we developed five prototypes to demonstrate how cords could be used to control 1) the intensity of light in a lamp, 2) temporarily mute a media player 3) put a computer to sleep 4) switch on/off a power strip, or 5) eject a portable hard drive.

There are challenges that need to be addressed before we will see Cord UIs used in everyday devices. However, we believe the possibility of Cord UIs can inspire product designers to outfit everyday cords with sensors, giving their products new interaction and design possibilities. These cords will not be seen as a nuisance anymore, but will offer an interesting alternative interface for the appliances they are connected to.

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