Figure 1: Example of the two projections one segment of ShadowLamp can produce.

ShadowLamp - An Ambient Display with Controllable Shadow Projection using Electrochromic Materials

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ABSTRACT

In this paper we present ShadowLamp, a lamp concept supporting controllable shadow casting for displaying ambient information. The concept uses electrochromic displays to mask light and thereby allow switching of projected shadows. We implemented a prototype in a hexagon frame with six separately controlled LEDs compartmentalized to casts shadows in 60° angles. Alongside the LEDs, each compartment contains an electrochromic display for shadow control. As a use case we fabricated displays for a children's book and used them to change the shadows as the story progress. The displays and LEDs are controlled by a Bluetooth connected Android application.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; **Interaction techniques**; **Ubiquitous and mobile computing**; **Ubiquitous and mobile computing systems and tools**;

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Figure 2: Example of a shadow casting lamp. The Shadow Chandelier by Forms in Nature. [4]

KEYWORDS

ambient display; ambient media; ambient backdrop; electrochromic material; electrochromism;

INTRODUCTION

Ambient displays have been widely researched in the past decades. From entire rooms with the ability to draw attention to parts of the room, to retro fitted furniture that slowly emit changing light to specifically designed ambient displays that subtly project changes in a localized space [2, 8]. Per definition ambient displays are subtle and do not grab attention making them perfect for calm computing [12]. To our knowledge, only one project has utilized hard shadows with discernible projections as an output modality for displaying ambient information [9]. Hard shadows provide a unique ability in that they can project text, icons and graphics onto surfaces, either subtly by fading in the shadows or directly by swiftly changing them. Although ambient displays have mostly used abstract changes, we believe using shadow projections with clear perceptible shapes can open up the possible uses of ambient displays in human computer interaction.

Inspired by lamps produced by Pranaya Design, Forms in Nature and Moroccan lamps in general, we sought to create an ambient display that projects hard shadows (see Figure 2). These lamp designs work by incorporating light masks that would cast hard shadows and produce artisan patterns on the wall or in the case of Forms in Nature an ambient backdrop. The masks are often the frame of the lamps themselves, and can be produced in a variety of ways, e.g. by laser-cutting holes or shapes into the side panels which allow light through and because of this the projections they provide are static. Opposed to this, our concept will use masks that can change between two or more patterns allowing us to change parts of or the entire ambient backdrop. A type of material that allows this are electrochromic materials which has mostly been used to control light transmittance in windows to control the temperature and shade in a room or building. Recently, however, it has become possible to fabricate and prototype custom electrochromic displays using off-the-shelf tools that are thin, flexible and transparent [6]. Using electrochromic displays as masks we are able to create an interactive ambient display that can produce slow changing (30s - 3m) hard shadows for information display. This is possible because each side of an electrochromic display can have a print, where when powered, one print will be near invisible and the other visible. Changing the polarity alternates which print is visible. And because they can be fabricated in non-uniform shapes with nearly any print on them their shadow casting properties can range from small localized shadows to wall sized shadows. Multiple electrochromic displays oriented in differing directions allow us to control the ambient backdrop of an entire room.

In this paper we present ShadowLamp, a prototype that allows control of the ambient backdrop in a room by changing between two sets of projected shadows. The purpose of the lamp is to enable a wide

Figure 3: ShadowLamp design with electrochromic displays.

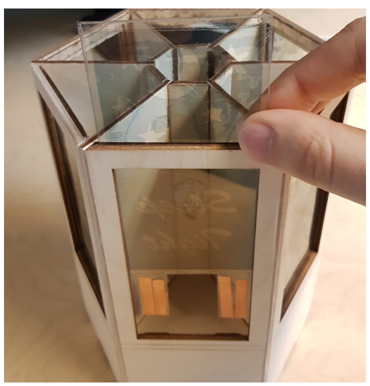

Figure 4: The slide-in mechanism allows easy change of the displays.

range of use cases that are enabled by fabricating electrochromic displays. We hope that this lamp can help immersion when reading to children e.g. by accentuating parts of the story by projecting shadows on the wall.

RELATED WORK

Since the inception of ambient information displays and calm computing research has focused on presenting information in the user's periphery using different types of ambient displays. The information is typically abstractly presented, for example in the form of the brightness of a light or the intensity of a vibration. The research ranges from entire rooms with different types of integrated ambient displays that display information using either light, sound or vibration [8] to very specific use cases such as e.g. an ambient light to help increase physical activity in the workspace [5] or using ambient stimuli to enhance media consumption [10]. In most of the research the ambient display is embedded into everyday objects or aesthetically developed as an everyday object allowing easier integration into homes or workspaces. Gleamy [2], an aesthetically pleasing lamp, subtly change its lighting using transparency controlled panels. The authors present an application case where Gleamy is used as a bedside lamp that visualizes the amount of physical activity by controlling how much of the lamp is shaded. In the Candle Light [7] a candle light is used with rotating cardboard cutouts to provide changeable shadow casting for emotional communication. The candle is connected through Bluetooth to a mobile phone that changes the shadow when receiving messages.

Shadows have been used for centuries in puppet theatre and shadow play for storytelling, however, in human-computer interaction they are a lesser researched subject. Few studies have utilized shadows. In [3], Cowan et al. used juxtaposed hand cast shadows as input in a mobile projector phone system. Häkkilä et al's [7] lamp projected different smileys by rotating the cardboard cutout using a servo motor.

Similar to the candle light lamp we use hard shadows to present our information but without the need for a servo. We do this by changing the state of an electrochromic displays similarly to the panels used in the Gleamy lamp. However, to our knowledge, no ambient display has yet to achieve using a large amount of wall-space as a big information display from a centralized place. Our work differs from previous research in that we can project shadows along all walls in a rectangular room and subtly change them which allows us to ambiently present information on a larger scale.

SHADOWLAMP PROTOTYPE

The aim of ShadowLamp is to create an aesthetic night desk lamp with ambient display properties. However, as opposed to previous ambient displays we aim to use hard shadows to control the ambient scenery in a room. Using hard shadows enables us to create specific moods and backdrops. And because electrochromic displays can be fabricated with any design as long as they are within the confines of the

Figure 5: Example of electrochromic display. *Left)*: Side A visible. *Right:* Side B visible. The bright parts let light through and thereby projects intricate shadows.

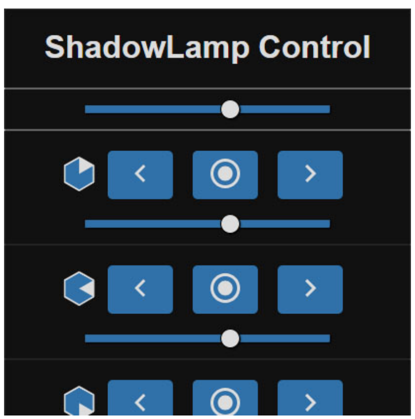

Figure 6: Part of the ShadowLamp Control User Interface. Sliders control brightness of LEDs and buttons control which side is visible with middle button making neither side visible

individual displays there are many possibilities. The prototype consists of six individually controlled LEDs shining through an electrochromic display creating shadows for the full circumference of the lamp. As the lamp is wirelessly controlled it can be integrated with other technologies such as e.g. an ebook reader where parts of the story is projected through the room, or smart lighting to change the scenery of the room in conjunction with lighting changes.

Implementation

As seen in Figure 3, the prototype is glued together in a hexagon shape from 4mm laser-cut plywood. Each section of the hexagon contain a high powered LED and a slide-in holder for the electrochromic displays. The slide-in allow easy change of the displays (see Figure 4). The six LEDs are individually controlled by an ESP32 and an SX1509 GPIO extender board powers the electrochromic displays. The extender board is needed because each electrochromic display require two connections that programmatically can change polarity. The ESP32 serves as a WiFi access point with a webserver for communication and control.

Electrochromic Displays

The electrochromic displays consist of two sheets of Polyethylene Terephthalate (PET) treated with Indium Tin Oxide (ITO). The designs for the display were printed using electrochromic ink on the ITO side of the PET-ITO by either ink-jet or silkscreen printing. To complete the display a thin spacer material (double sided tape) with a width of 3-5mm was used along the circumference of the display. The spacer keeps the two PET-ITO sheets together and allows electrolyte to be deposited in the center of the display. Which in turn keeps the two ITO layers from short circuiting. Applying a low voltage (1.5v-3v) on one side oxidizes it and reduces the other side. Depending on the electrochromic ink used, the oxidized side will become visible whereas the reduced will become near invisible and changing the polarity to the display changes which side is visible (see Figure 5). [6]

User Interface

The interface is programmed in HTML to allow easy control from a wide variety of devices. In the top of the interface a slider controls the overall brightness of the lamp (see Figure 6). The rest of the interface is split up into segments that control each side of the lamp. Each of these segments contain a slider to control the individual LEDs brightness and three buttons to control the state of the electrochromic display in that segment. The left and right buttons make either of the sides visible and the middle button balances the display making neither side visible.

USE CASE: NIGHT TIME READING

As a use case we created six displays for two Smurf [1] stories that projects imagery from the book on the wall as the story progresses. This is to be used for night time bedside reading as one side of the displays projects a starry night sky providing a cozy backdrop for reading. By slowly changing the individual displays to project parts of the story instead of the starry sky (see Figure 7) we hope to increase immersion in the story and foster inter-personal communication and talk about the story. E.g. "See it's the house where Smurfine lives". Encouraging children to become more active in telling the story is promoted by approaches such as co-reading and dialogic reading to boost language acquisition [1, 11]. The reader is presented with icons in the physical book that match the user interface when a change in the projections is required.

DISCUSSION AND CONCLUSION

In this paper, we presented a novel lamp concept that utilizes electrochromic displays to project shadows for ambient communication. Albeit the concept allows easy change of the displays we are aware that fabricating them is not widely understood in the CHI community and is only possible for a limited number of people. We do however believe this paper will help increasing awareness of the opportunities afforded by electrochromic displays. We believe that, in our use case, ShadowLamp provides an interesting and novel approach to increase immersion and engagement through displaying changeable scenes in bedroom settings.

For future work, we wish to run a study with parents reading to their children to verify that ShadowLamp actually increases immersion in bed-time reading and/or engagement in the story telling. In addition to developing other use cases for the lamp.

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