"Tangible Lights"

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“Tangible Lights”: In-Air Gestural Control of Home Lighting

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Abstract
While there has been much focus on tangible lighting interfaces embedded in physical objects and smartphones as remote control, there has not been sufficient attention on how the expressivity of bodily movement can be used when designing interactions with light. Therefore, we investigate interaction with lighting technology beyond the smartphone and physical controllers. We examine the usefulness of the in-air gestural interaction style for lighting control. We bring forward “Tangible Lights”, which serves as a novel interface for in-air interaction with lighting, drawing on existing knowledge from the tangible world. Tangible Lights has been subject to initial evaluations.

Author Keywords
Interactive lighting; lighting control; in-air gestures; user interfaces; home customization

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces.

Introduction
Lighting is a key aspect of the design of interior spaces, which serves functional purposes of illuminating tasks, accentuating the objects and materials in the room, and setting the atmosphere experienced by the occupants. More recently, the commercially available, mul-

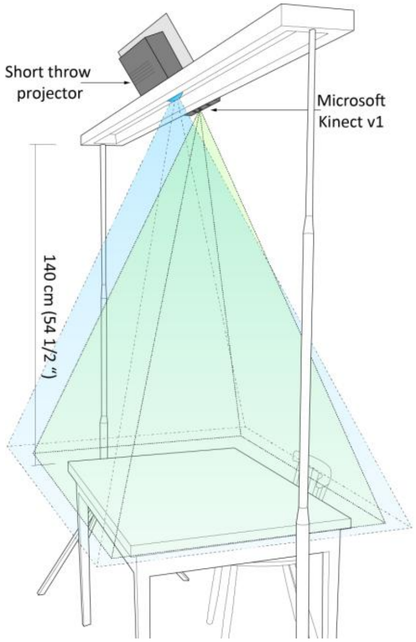

Figure 1. Technical setup

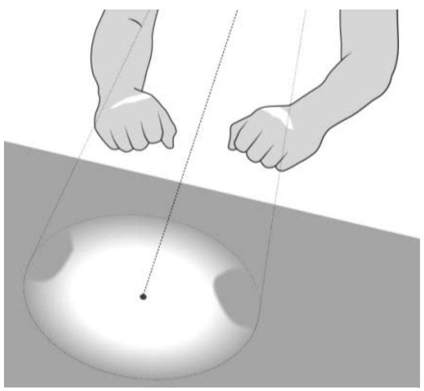

Figure 2. Mapping two hands to a cast light. Light strikes on top of hands and causes shadows

ticolored light emitting diodes (LEDs) have been introduced in the home domain providing new possibilities when using and controlling light. How can technology and interactive lighting enable new customization possibilities of the home and support desirable experiences in daily life? We take a step towards this vision by combining interactive lighting with in-air gestures. As a result we present the "Tangible Lights" platform for in-air gestural lighting control at the dining table. As our work is currently in progress, this paper focuses on the initial aspects of interaction and mapping.

Commercially, we have started to see interconnected smart bulbs for the home, which can be controlled from smartphone apps, e.g. Philips Hue, Samsung Smart Bulb, Stack Alba, and LIFX. We see several practical benefits in utilizing the smartphone as a central platform for interaction, e.g. dynamic interface; 'always' with you; remote access and control without dedicated remote controllers. However, this direction comes with a list of shortcomings: smartphones can be displaced from the user, other residents and guests cannot interact without connecting to the wireless infrastructure, and interacting users are not necessarily situated in the lighting environment they are controlling [7]. Socially, the action of physically switching the lights on/off or adjusting the brightness provides immediate, visible clues to other people in the context.

With the new possibilities of the emerging LED technology come new challenges. In research, this has been recognized by Aliakseyeu et al. [1] who set up a workshop on "Designing Interactive Lighting" at DIS 2012, and by Offermans et al. [8] who explored the initial design space of interactive lighting interfaces, and present important aspects regarding the interaction in a relational model. Researchers have also developed various physical interfaces for lighting control [2, 6, 7, 8].

Focusing on In-Air Gestures

Research has found that interactions relying on bodily movement possess unique interaction qualities in terms of expressivity and supporting the capabilities of the body [4, 5]. In-air gestures as an input style effectively allows for communication of your intentions to other participants through interaction and allows for the possibility of engaging multiple users simultaneously. However, working with in-air gestures also poses challenges, such as the lack of tactile and haptic feedback due to the inherently invisible interface. As with the "live mic" problem in audio, when is the control system listening? Moreover, we find the "segmentation issue", which deals with the temporal length of interactions. When does a gesture start and end? Our work combines the area of interactive light control with the interaction style of in-air gestures. This style of interaction can be seen as radically different from typical smartphone and tangible controllers.

Use Scenario: Dinner with Friends at Home

We created a scenario to illustrate some of the existing practices in the home, which Tangible Lights is envisioned to support. The scenario illustrate the current practice of decorating and setting a table, where considerable effort and thoughts are put into creating the right atmosphere both in terms of ordinary decorations and attention to lighting.

Julia awaits three guests for dinner and starts cooking dinner two hours before. She wants to set the table, and she finds four identical, nice looking plates and cups. She figures she wants to do something extraordinary and brings in colored linen napkins and arranges

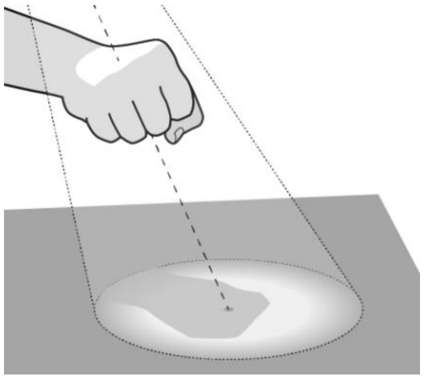

Figure 3. Mapping one hand to a cast light. Light strikes on top of the hand and causes a shadow

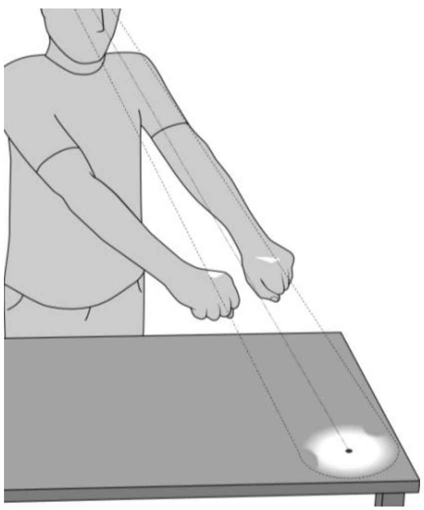

Figure 4. The mapping scheme allows reaching far corners

them evenly on top of the plates. Julia also wants to do something to the lighting to create a sense of coziness. She decides to dim the main light via the dimmer in the wall where it has been set to full brightness due to the darkness outside. Further, she decides to switch on two small lamps near the dark corners of her living room, and brings in two candlelights for the table. As her guests are welcomed they immediately comment on the lovely atmosphere and the detailed table decorations. After the dinner, Julia puts the brightness back up while her guests help her move the dishes to the kitchen. The friends suddenly decide on playing a board game while chit-chatting and having evening coffee. One of the friends notices the now bright lights from above the table, and locates the wall dimmer in order to again fit the relaxed atmosphere.

Tangible Lights

We now present our system called "Tangible Lights" which serves as an interactive lighting platform around the dining table. Tangible Lights enables the user to customize the light setting at the table with precise control through several, individual illuminated regions, which can be manipulated freely in the space above the tabletop. As a result, the position and size of each individual illuminated region can be manipulated through in-air gestures as desired. The name Tangible Lights stems from our intentions of creating an interface where the user feels as if she is holding onto the lights and controlling it at her fingertips. To accommodate this, we seek to draw on her existing knowledge from daily life when grabbing and moving physical objects around. The challenge here is that lights are generally perceived as non-tangible, although they do have an insignificant small physical mass, and the warmth of intense light can be felt on the skin.

Technically, the platform consists of a short-throw projector and a Microsoft Kinect sensor (see Fig. 1). The short-throw projector serves as the light source as it provides an easy and dynamic way to position an arbitrary amount of illuminated regions on the tabletop. The Kinect sensor continuously streams depth maps to the gesture recognition software at 30 frames per second. Our software is an extension of the C# wrapper for the KinectArms project developed for quick mock-ups by Genest et al. [3].

Direct Mapping between Hands and Light

To interact with the lighting in Tangible Lights, we needed a way to map the hands to the cast light. As it is our intention to design for the experience of tangibility of manipulating cast lights, we have sought inspiration in the domain of tangible user interfaces (TUI). We have applied a direct mapping scheme, which refers to the design of interfaces, particularly in the TUI domain, where input and output is tightly coupled in space.

For our design of the direct mapping, a cast light is enabled for interaction when hands interfere the projected light beam. This looks different in the case of one or two hands as seen in Fig. 2-3. As a natural consequence of using one global light source (i.e. the projector), the center of the cast light is occluded by the hand creating a shadow on the tabletop (also seen in Fig. 2-3). This provides two concurrent means of visual feedback for the person interacting to visually make contact with and maneuver a lit region around the table.

As a result of our designed mapping, it is possible to reach far corners of larger tables, since the light cast on the tabletop is positioned with an offset to the interacting hand(s) as seen in Fig. 4.

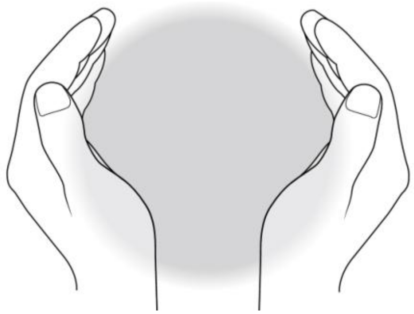

Figure 5. Spawning a new light by holding hands in a vertical position

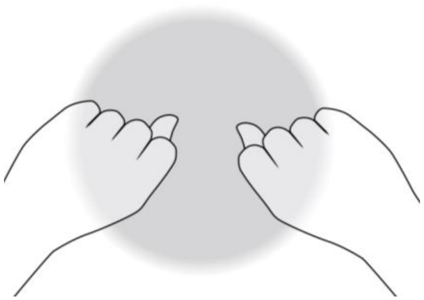

Figure 6. Grabbing a cast light by closing the hands near its perimeter

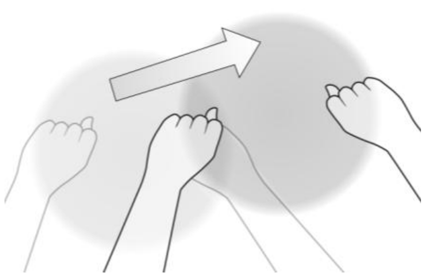

Figure 7. Moving a cast light by moving the hands

Designing the Interactions

The interactions designed provide a set of interconnected actions for manipulating the light setting. Actions include spawning, selecting, deselecting, moving, scaling, and removing lights. To simplify the interactions, we draw inspiration from known daily life actions such as grabbing, holding onto a plate or cup. We have explored different interaction alternatives requiring both one and two hands, as the number of hands is found to possess different qualities, which will be explained in the following. On-going evaluations have helped shape the interactions to their current form as presented here.

Spawn gesture

It is possible to create a new illuminated region by holding two hands in a vertical position as if holding onto a physical bowl (Fig. 5). This hints that the lights can be physically contained within the circle enclosed by the hands.

Grab and move gestures

A cast light is selected with two hands by "grabbing the light" near its perimeter as if it was a physical steering wheel (Fig. 6). This interaction, of course, yields no physical feedback as when grabbing an actual steering wheel. The grab gesture can also be performed with one hand, as two hands could yield a problem when carrying objects such as dishes, plates and cup. In use, the one-handed grab often allows for quicker positioning than the two-handed grab. The one-handed grab is initiated near the center of the cast light on the table and can be viewed in Fig. 3. Once grabbed, the newly spawned and existing cast lights can be moved according to the position of the hands in a 2D plane above the tabletop (Fig. 7).

Scale gesture

When selected, cast lights can be scaled up and down in size. The user can resize the lights to highlight physical objects on the table, e.g. dishes, cups, plates, plants etc. When interacting with two hands it might seem natural to just move the hands away from each other (Fig. 8), building on experience from the real world. Here, flexible objects such as bags, rubber bands, fabric, etc. can be expanded by grabbing and pulling hands in opposite directions. For scaling with one hand we seek inspiration in the behavior of a flashlight. Moving it closer or further from a surface results in a smaller or larger cast light, respectively (Fig. 11).

Release gesture

In Tangible Lights, releasing (i.e. unselecting) an already grabbed light is implemented as the reverse grab gesture. In other words, when not intending to manipulate a cast light anymore, the person extends her fingers. The final hand posture for two-handed interaction can be seen in Fig. 9.

Remove gesture

Lastly, to remove a cast light completely from the table, the light is pressed (squeezed) together with two hands or reduced in size with one hand moved very close to the table. Essentially, this is the scale gestures being used to make the light continuously smaller until it disappears (Fig. 10).

Initial Evaluation Results

Based on our current lab and contextual evaluations with 21 people, we have categorized our initial findings.

Tangibility of Cast Lights

As our set of gestures is conceptualized based on tangible phenomena, we want to understand how people

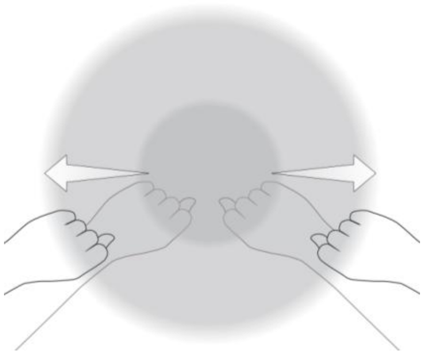

Figure 8. Scaling of a cast light by pulling in both directions

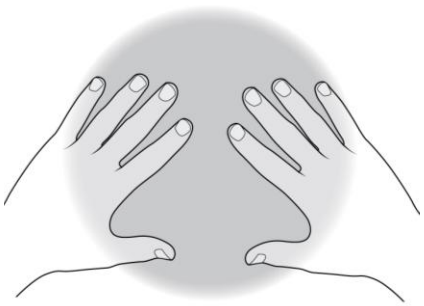

Figure 9. Releasing a grab by extending the fingers (reverse grab gesture)

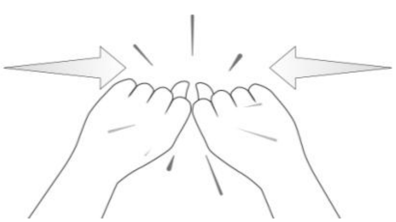

Figure 10. Removing a cast light from the table by squeezing it together

feel when using them, and how they learned and understood the suggested tangible qualities. Thus far, we have mainly had people trying different gesture variations when selecting and have asked them to reflect upon the differences. Our current evaluations suggest that the grab and release gestures are generally an accepted and straightforward way of selecting and deselecting a cast light. As one person explained *"it [grabbing the lights] just came natural to me… I had totally forgotten about last time"*. For him, grabbing was an unconscious action.

Contextual Implications

An important part of our evaluation is to reflect upon the context for which our design is intended. A first impression is that users are able to start highlighting objects on the table as soon as the grabbing concept is explained. During contextual evaluations, one of the house residents stated, "*I can see this being used in practice, now when we do all this other stuff [setting the table with napkins and candles]*". This category is subject to further contextual evaluations.

Direct Mapping and Alignment

The alignment of hand and cast light was, for many people, an intuitive way of selecting light, and was expressed by one participant, "*it is easy to just move my hand in [above the table] and, like, interfere with the light beam*". However, when not instructed or demonstrated, we also observed a tendency to reach out directly above the cast light trying to select a light (exemplified with one hand in Fig. 12). Following a quick how-to demonstration, people were able to adapt to our intended mapping. It would be interesting to collect more detailed information on how the two mapping alternatives are understood.

Although we intended to provide a smooth interaction experience, we encountered some technical challenges, which affected the perceived mapping. When observing interaction sessions, the largest technical breakdown occurred when people continuously reached out for a specific cast light, but did not get in contact with it. This was caused by system instabilities of either not recognizing the hand, the gesture, or by the mapping being misaligned in the software. Beyond technical improvements, the question is, how can we help the user to understand the mapping?

Gestures and Functionality

Once shown or told how to select and move lights, people were able to independently explore the scaling functionality by moving the hands apart (or up and down if one hand). Scaling actions were almost always performed during the very first interaction and can arguably be contributed to the system behavior of being reactive to changing distances between hands (or height if one hand).

When interacting, the light is visible on the hands. Once selected, the instantaneous visual feedback of the cast light moving according to hand movement provided an easy way for people to control the light around the table. However, approaching the table, new users do not know that it is possible to reach out for lights with the hands unless the functionality is explained. In the near future we will explore how the use of different feedforward techniques [9] can help to communicate the functionalities and provide suggestions for use. We intend to explore a number of iterations focused on how subtle behavior such as movement and pulsation of cast lights can invite interaction.

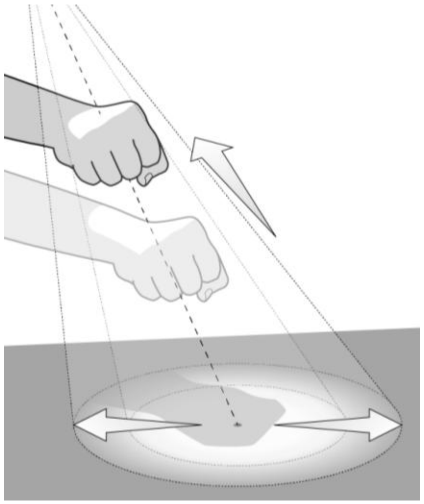

Figure 11. One hand scaling of a cast light by varying the height of the hand

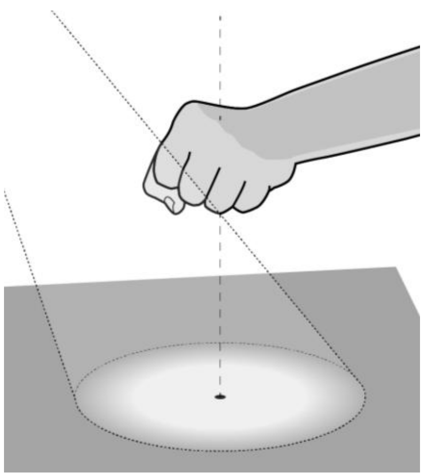

Figure 12. We observed a tendency to grab lights directly above the cast light instead of interfering the light beam

Discussion and Future Work

Tangible Lights requires a relatively high amount of interaction effort. By integrating gestures for color and brightness control, the interaction effort is intensified. In contrast, it is interesting to explore use cases where the user is not likely to put in much effort beyond a focus on satisfying the functional needs, e.g. study or office work, where the lighting need is task-oriented rather than customization.

Tangible Lights is designed as individual, manipulatable spotlights inspired by the tangible interaction paradigm. To keep this effect, it is necessary to perceive the edges of a cast light. As the living environment often uses diffused lighting, we have sought to make each light appear more natural by adjusting the projector by softening the focus adjustment and applying a gradient to the edges of the cast light. As a result, we found a balance between blurring the edges and yet still support the recognition of individual spots.

Through evaluations we have observed several users adding elements of playfulness, such as sliding or "throwing" cast lights around the table or by other means adding some "life" to the lights. We agree that this might allow for delightful experiences. Thus, in the near future we wish to explore how implementing subtle behaviors might add to the interaction experience. Further, we will explore the social dimension of the interface, as current evaluations have already hinted at various opportunities to support interesting and playful experiences.

Lastly, we see a potential in exploring how controlling the lights via gestures at the table can be integrated with the existing home lighting. This includes outlining how gestures performed above the tabletop can affect other areas of the home, which arguably accounts for a large part of setting an atmosphere. Moving the in-air control away from the table and into other areas of the home provides yet another path for further exploration.

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