HALO: Wearable Lighting

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Nan Zhao
MIT Media Lab
75 Amherst Street
E14-548
Cambridge, MA 02139 USA
nanzhao@media.mit.edu

Joseph A. Paradiso
MIT Media Lab
E14-548
75 Amherst Street
Cambridge, MA 02139 USA
joep@media.mit.edu

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Abstract
What if lighting were not fixed to our architecture but becomes part of our body? Light would be only where it is needed. Buildings would light up brightly when busy, and dim down when people leave. Lighting would become more energy efficient, more personal, and colorful, tailored to individual needs. What applications beyond illumination would be possible in such a scenario? Halo is a wearable lighting device that aims to investigate this question. More specifically Halo explores the potential of body-centered lighting technology to alter appearance and create a personal space for its wearer. A ring of colored LEDs frames the wearer's face, putting her into the light she desires. Borrowing from both theatrical and photographic lighting design, Halo has several different lighting compositions that make the wearer appear happy, sad, energetic, mysterious, etc. Using a smart phone application, the wearer can switch between these modes. She can also let the application adjust automatically depending on her activities. Halo is an experimental technology that combines function and fashion—a platform to probe the future of wearable lighting.

Author Keywords
Wearable Technology; Lighting; Perception; Augmentation

ACM Classification Keywords

H.5.2. User Interfaces: User-centered design

Introduction

Recent developments in solid state lighting (SSL) technologies have enabled a range of user-centered lighting applications, for example systems that are aware of the user's location, context, or preference. A growing body of research in adaptive lighting has been leveraging intelligence, sensors, and seamless connectivity, but these efforts have made one limiting factor more and more evident: our light sources remains fixed in space, hanging from the ceiling or tethered to the wall. In this regime, adaptivity can only be achieved with a dense network of lights. The idea of wearable lighting is motivated by the potential to overcome this limitation with small, energy efficient, high brightness SSL devices. We imagine a future where power consumption is reduced significantly by switching from architectural to wearable lighting. To put this in perspective, lighting accounts for 11% of the total electricity consumption in the U.S. today [1].

The transition from static to moving, body-centered sources can be compared to a highway with and without street lighting. In the first scenario, lights along the road turn on in the evening and off every morning. A highway without street lighting, on the other hand, is bright when it is busy and dark when it is unused. In this example, headlights are used to light the driver's way, pointing ahead but still leaving the driver unseen. Mobile lighting can be much more than illumination; what might we achieve if we turn the source around, to face us?

Light gives us the opportunity to manipulate reality. Masters of this discipline can be found in theater, cinematography, and photography [4]. Artificial lighting is a tool to present context, enhance emotions, or direct viewers' attention. In a simplified form, the art of light composition has been replicated in computer graphics with what we often refer to as filters. While it is easy to change the appearance of a photo with filters, to achieve a lasting effect in real life requires more effort. In our daily routine we use pigments, such as make-up, to create artificial shadows and contours on our faces, and we wear black color or vertical stripes to alter the appearance of our body. Halo aims to bring the flexibility and ease of use of filters into the physical world. It focuses on the presentation of the head and the shoulders of its wearer.

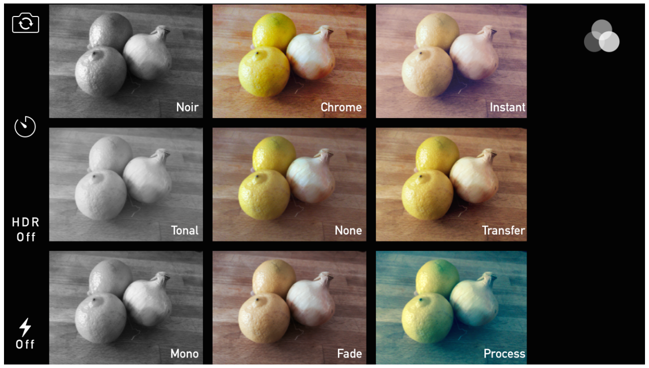

Figure 1. Screen capture of the iOS photo application interface for selecting filters.

Besides this extroverted quality of Halo, it also has effect on the wearer's internal state. In numerous studies it has been shown that specific light spectra and brightness has effect on alertness, emotions, and

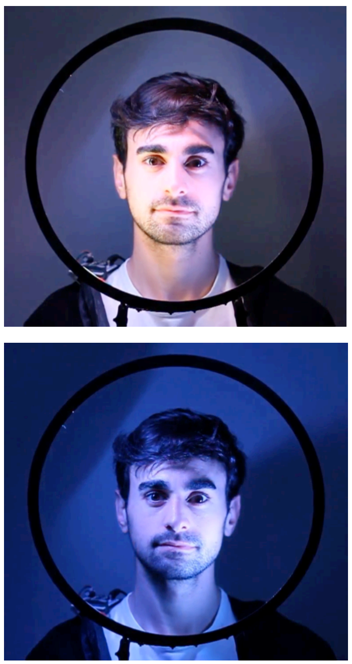

Figure 2. User in two different lighting compositions. The wearer's facial expression remains completely identical in both images, yet he appears differently to the observer.

circadian rhythm [2], [3]. Halo leverages both the extroverted, outside facing and introverted, self-regulating qualities of personal lighting. It therefore establishes a window between the wearer and her surroundings that connects but also separates her through a mask of photons, just like a filter.

Prototype

Halo consists of 170 individually addressable RGB LEDs attached to an aluminum ring, pointing towards the center. The LED ring sits around the wearer's head. It is stabilized with a flexible, lightweight aluminum harness on the wearer's shoulders, see figure 3. The ring can be adjusted at different angles. The LED driver unit communicates over Bluetooth Low Energy (BLE) to a smart phone application.

Figure 2 shows a user in two different lighting compositions. The user's expression is the same in both images, yet he appears differently to the observer. The color, intensity and angle of illumination enhance different cues of expression. They also trigger association of different contexts. We composed a list of semantic categories and designed lighting compositions that subjectively represent those categories. These include happy, sad, fear, fire, alien, etc. Using the smart phone application the user can switch between these settings. She can also configure the software to change settings automatically based on her activity and interaction.

The preset lighting compositions are defined through the position, angle, distance, brightness, size, and color of a set of virtual light sources. A transfer-function converts these parameters to a vector of RGB values, which contains the corresponding lighting patter on the Halo, see figure 4.

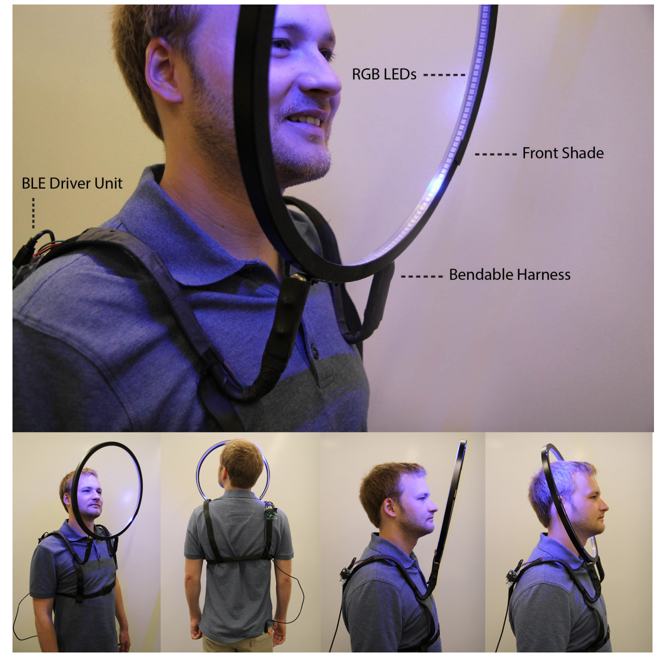

Figure 3. Halo in close up, from different angles, and two different ways of adjustment.

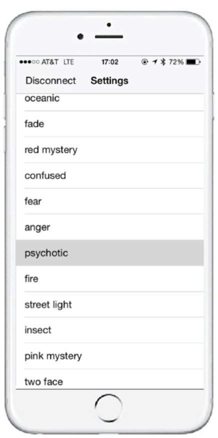

Figure 6. Halo application interface showing a list of preset lighting compositions.

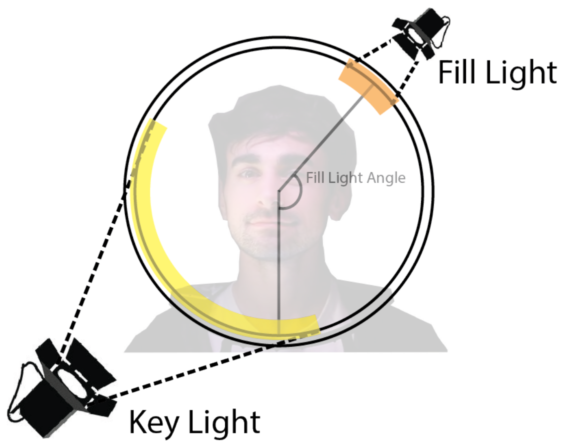

Figure 4. This image illustrates how we used virtual light sources for the design of the preset lighting compositions. This particular setting is named “passion”.

Applications

Current applications include manual control, activity driven control, single user, and multi-user scenarios.

In manual mode the user can select preset lighting compositions from a list. In autonomous mode the software selects and pushes suitable settings to the LED driver depending on the user’s current activity level. Activity level is measured using the embedded accelerometer and a leaky integrator. A set of lighting scenes are chosen to match high, medium and low activities. For example, a low activity setting is a dark mysterious scene, while a high activity setting might be a spiralling lighting pattern.

In a multi-user scenario the application detects other Halos in close proximity. In automated mode the software will try to synchronize all detected Halos to the same lighting composition. People within range are probably interacting with each other or most likely to engage in a conversation. The synchronization enhances their closeness by creating a social lighting bubble. This social space can be enjoyed with the spirit of sharing, but can also result in a game where one user trys to gain control over the other user’s Halo.

Figure 5. This image shows the moment where two Halos slowly switch to the same lighting composition. In this particular case they transform to a red colored setting named “fire”.

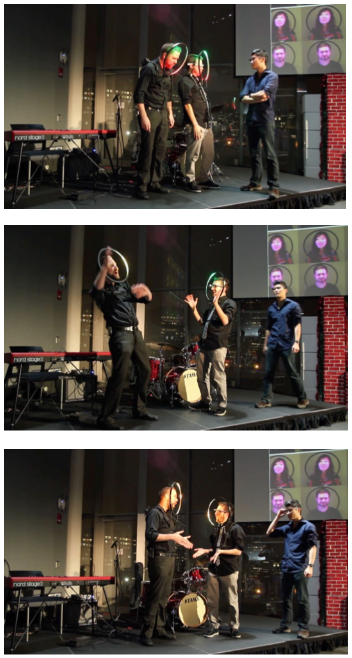

Figure 7. Improv performance featuring Halo. The actors play different characters depending on the lighting.

Deployments

Halo has been tested in the wild in a range of different contexts. We observed users enjoying their appearances and acting out their associations to the lighting. This experience motivated us to create an improv comedy show with Halo. In collaboration with a local improv group we performed a live show featuring 2 Halos and 5 different lighting compositions. At the beginning of the show, actors with Halos entered the stage and asked the audience for their associations for each lighting scene. The audience was encouraged to shout out their suggestions. The actors picked "happy",

Figure 8. Usage scenario in an outdoor environment. The wearer is trying different lighting compositions and taking selfies.

"have the flu", "greedy", and "possessed by a demon" to be the descriptors. A 5th setting remained a surprise to the audience. During the performance one actor behind the stage remotely controlled the Halos. When the lighting switched, the two actors with Halos had to change their character to match the descriptors.

In other, informal testing, we found that while some users are more intrigued by the ability to manipulate their appearance, others derived comfort from letting their environment appear warmer and sunnier.

Future Directions

Halo is a tool designed to explore a future in which personal, wearable lighting complements traditional, static architectural light sources. In the next iteration, we are planning to experiment with different form factors and materials. The LED ring can be reduced to only a few light sources. These could be placed close to the skin to create high-resolution patterns and further away to create diffused effects.

We are also planning to expand the modes of interaction to allow Halo to respond to people and objects in close proximity. This involves incorporating additional sensors. For example, could we direct or enhance emotional feedback by measuring affect?

Lastly, we are experimenting with computer vision algorithms to detect memorability of faces and facial expression. The goal is to create an automated calibration routine that derives lighting settings customized for individual faces and contexts. Possible optimization objectives are to enhance or hide the user's current feelings, to make the user appear younger or older, or to make them look more or less memorable.

We believe mobile, wearable lighting will play an increasingly important role in future lighting design, especially as solid state lighting technologies develop further and energy constraints become more stringent. Through devices like Halo, we are investigating the design space of these kinds of wearables.

Acknowledgement

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