Augmenting Interpersonal Communication through Connected Lighting

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 CHI'17 Extended Abstracts, May 06-11, 2017, Denver, CO, USA ACM 978-1-4503-4656-6/17/05.
http://dx.doi.org/10.1145/3027063.3053141

Abstract
This paper describes a system, WeLight, that we developed to facilitate communication. It allows individuals to configure the lights in one another's homes as well as their own. We describe this system and its motivation from exploratory interviews with households using existing connected lighting products. To ease inter-household communication, we integrated connected lights, specifically Phillips Hue and LIFX, with widely adopted messaging services, such as SMS. To support spontaneous communication within and across households, we developed scene creation capabilities involving natural language processing and image search. We also describe features intended to enhance spoken conversation, specifically light adjustment according to speech content and sentiment.

Author Keywords
Connected devices; IoT; lighting; communication; emotion.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous; H.5.3. Group and Organization Interfaces.

Introduction

Today's connected devices are primarily focused on automation and efficiency. They enable users to monitor air conditions, adjust temperature remotely, activate playlists by voice and automate many other aspects of home life. But they aren't designed for communication. It is particularly challenging to use these devices for communicating across households.

We set out to expand options for remote communication using smart lighting. We focused on supporting emotional communication in close relationships, where the familiarity provides a context for signals that could otherwise be confusing or invasive [7]. This expression of feeling, termed phatic communication, lacks instrumental content but provides important structure and support for relationships [13]. Currently, many people use social media features such as image sharing, emoticons, and "likes" to convey positive emotion and validate friends in a lightweight manner. These activities generally require users to look down at a device, which may limit engagement with their immediate surroundings.

To cultivate more embodied communication, researchers and product manufactures have created dedicated devices for sharing of intimate physiological data. The most visible recent example may be the haptic heartbeat sharing feature of the Apple Watch, but there is a long history of related HCI research on sharing biometrics and daily rhythms within close relationships. Intimate Computing research [2] has explored the connectivity of many of our most familiar or habituated personal objects [3, 19], such as tea cups [4], clothing [15, 18] and beds [8]. Lighting has similarly been examined as a means of conveying presence and indicators of wellbeing [9,14, 20]. Recent work on "ghosting" sought to amplify presence by synchronizing the lights and sounds in two homes [5].

The current project advances Intimate Computing but focuses on intentional communication rather than passive sharing of sensor data. It extends past work on minimal, expressive communication including Strong and Gaver's Feather, Scent and Shaker [17], Kaye's Minimal Intimate Objects [11] and CoupleVIBE by Bales, Li and Griswold [1], which explore how rich communication can play out through very thin channels. Our goal was to enhance the communicative potential of existing connected devices rather than to create a new expressive form factor. Below, we discuss use scenarios, barriers to communicating with existing connected lights and the WeLight system that we developed to support communication.

Use scenarios: Communicating with light

To examine how people might use smart lighting for communication, we asked a range of technology consumers and practitioners to incorporate Philips Hue lights into their communication for several weeks and to describe their experiences in open ended interviews. Below we discuss types of communication that were attempted. Identifying information has been changed.

Signaling affection: Alex returned home to find her apartment lit up in violet and blue, a welcoming message from her boyfriend whom she had just visited. The light message extended the emotional connection that they had felt during the visit. To send the lights, he signed into her Hue account and selected colors for specific bulbs. He had linked his phone to her bridge during a previous visit. These light exchanges became an important part of their long distance relationship but did involve some challenges. After sharing lights, they each had to re-link their Hue accounts to their local Hue bridges so that they could control the lights in their own homes.

Availability checking: Chianti and her partner Robin have art studios at opposite ends of their large house. They work alone for long stretches of time, valuing intense focus. They sent lights to one another's studios to feel out availability for breaks without physically intruding. They experimented with the lights as ambient communication—probing for contact without demanding attention or even an explicit response from a partner.

Playful prodding: Chianti and Robin sometimes tossed light messages between their respective studios as moral support to keep working. They competed to "out white" one another, and played with affectionate pinks and aggressive greens.

Location sharing: Karthik lives with his parents, who want to know where he is in the evenings. To meet this request, Karthik linked GPS updates from his phone to his parents' lights at home using an IFTTT protocol that assigns colors to geographical zones. For example, a red light indicates that he is on the east side of the city and a green light indicates that he is walking home from the bus station. This allows him to reassure his parents without divulging his exact location.

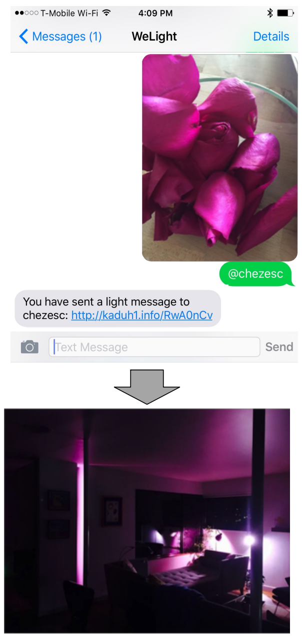
Nudging: To nudge his reclusive sister out of her bedroom for family dinners, Karthik used the lights as an aversive stimulus. He flickered the lights in her room, creating such an unpleasant atmosphere that she came to dinner. He had previously adjusted the app settings so that he could override her light selections. Another participant did something similar, flickering the lights in her husband's study so that he would join her as she fell asleep.

Conflict negotiation: One couple, Sasha and Nick, had a recurring conflict: Nick repeatedly invited dinner guests without checking in with Sasha beforehand. One night, Nick sent Sasha a text at work saying that he was bringing guests home for dinner. To express her irritation, Sasha turned the Hue lights in their house deep red from her office. She knew Nick would see them immediately when he got home. Later, they talked, exploring color ranges for the lights and mutually agreeable ways to host dinners at home.

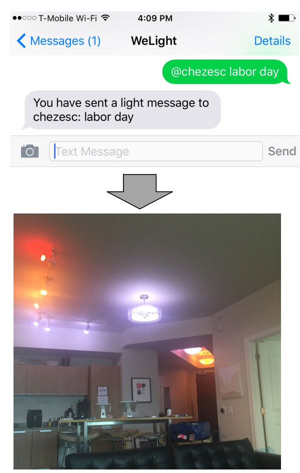
Remote caregiving: Sam's parents live in a small town, prone to isolation since their three children are busy professionals living far away. They set up three lights with the idea that the children would frequently touch base with their parents by changing the color of their designated light. In advance, they had to sign into their parents' Hue account during a visit home. This system worked, but the children often forgot to touch base and struggled with the account settings when they did remember. They were often unsure which account the app was controlling at any given time.

Limitations of existing connected lights

The types of communication described by these users required creativity and in some cases, considerable effort. Their goals were generally achievable as long as the communication was restricted to one household. But when communication crossed households, more difficulties arose. This is because a single Hue account



(a) Scene creation using an image



(b) Scene creation using English text

Figure 1: Examples of WeLight algorithmic scene creation.

cannot support multiple households. It is especially hard to use today's connected lights for communicating location and calendar reminders across households (i.e., adjusting someone else's lights based on a triggering event from a different account) since IFTTT does not allow simultaneous registration of multiple Hue accounts. Users struggled to assign colors to specific lights, whether they were communicating within or across households. While the Hue app contains simple light recipes, users found those lighting schemes too simplistic for conveying feelings and experiences.

We addressed these limitations in three main ways. First, we built the WeLight system on top of widely adopted and understood communication systems, principally text messaging. Second, we created an authentication policy that makes it easy for users to grant others access to their lights. Lastly, WeLight enables intuitive and automatic scene creation to facilitate spontaneous self-expression. Below we describe the WeLight system and its capabilities for scene creation and interhousehold communication.

WeLight system

The WeLight system goals are intuitive scene creation with easy access and secure management of lights across households. The system was built in Python (about 2,000 lines of code) and runs on the Amazon AWS public cloud infrastructure. The scene creation and authorization systems that deliver these goals are detailed in the following sections.

Scene creation

A primary contribution of WeLight is an easy, single step method of scene creation. Users can provide either images or text as input. The scene creation algorithm then identifies and assigns colors to the user's lights.

In the case of image input, an algorithm extracts the distribution of colors in the image(s), as shown in Figure 1. The color extraction starts with recoloring the images to use the most common and distinct colors based on the Floyd-Steinberg dithering algorithm. The distinct colors chosen are proportional to the number of lights the recipient has registered. The algorithm then builds a histogram of color occurrences, which are mapped to lights. Colors with higher occurrence frequency are mapped to more lights. Substitute colors are chosen when a specific color is beyond the spectrum of household lights. We used a simple heuristic that limits excessive white lights resulting from common image characteristics such as logo backgrounds. The brightness of each light is adjusted based on the relative intensity of colors in the images. We implemented this algorithm using the Python Image Library (PIL) package.

In the case of text input, the system extracts terms from natural text to index a dictionary of color mappings. WeLight uses the NLTK natural language processing package for initial text analysis and root word extraction. If there is not a dictionary match, WeLight will search Google Images using the user's text input. Color histograms are generated through the scene extraction process (described previously) on the top five search images returned by the query. A final heuristic is used to combine the histograms and assign colors to lights.

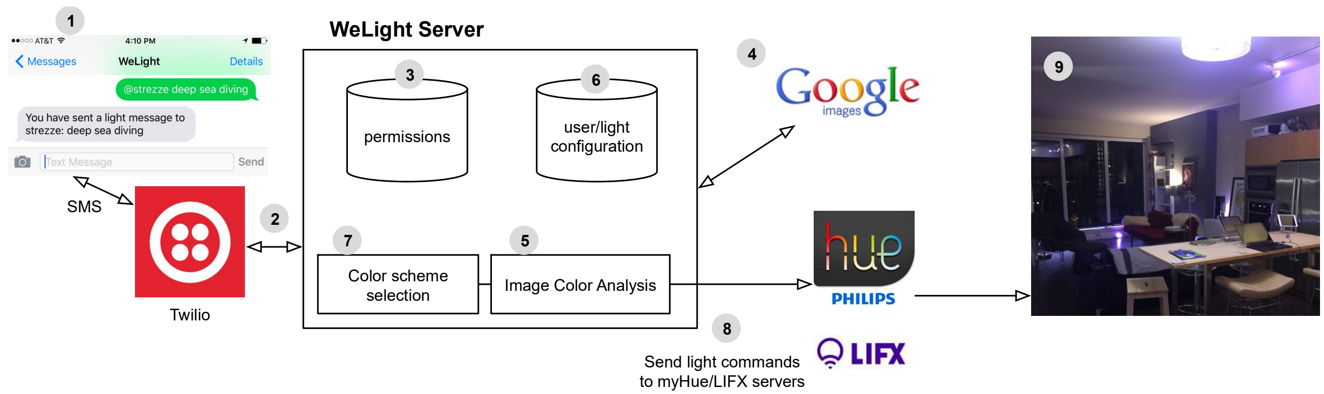


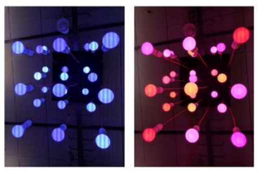
Figure 2: WeLight system overview and operation. The sender texts the WeLight chatbot (1) with a light message "strezze deep sea diving" which is managed by Twilio (2). The WeLight chatbot sends messages to the WeLight server, which (3) checks if the recipient allowed access to the sender. The server extracts colors using a dictionary and images returned from Google Image search (4) that are processed by the color analysis algorithm (5). Once a color list is built, the system looks up the recipient's light configuration (6), and maps colors from the list to the lights, according to the devices' color profile (7). Finally, the WeLight server sends a securely authenticated message to the Hue and LIFX servers (8), setting the lights in the recipient's household (9).

Messaging and authorization system

The primary goal of this system was to enable easy and intuitive light exchanges among end users. We wanted to make it simple for users to indicate and modify permissions for others to change their lights. Rather than learning a new app, users could operate WeLight via text messaging (SMS via Twilio). Users interact with WeLight sending messages to the WeLight chatbot. When a user signs up using WeLight's web service, the system requests a phone number, which is validated with a confirmation text message. From this point on, the session is tracked with a chatbot.

An overview of how the system sends a light message is shown in Figure 2. To enable control, the system asks users to specify who can send them light messages and which physical lights in their home should be affected by these messages. These settings are easily changed. As part of the sign-up process, users have the choice of both sending and receiving light messages or just sending. If the user chooses to receive light messages, WeLight requests access to the user's Hue or LIFX credentials, and then asks the user to select which lights in the house should be affected by light messages. The remote light control uses the Phillips Hue and LIFX cloud-based light control infrastructure API. Users control who can send them messages with specific allow and disallow command messages to the WeLight chatbot; e.g., "!allow Jane", "!disallow Joe". Users can also set a Do-Not-Disturb mode, which blocks any incoming messages, and a Demo mode, which allows messages from any user.

(a) Light scene derived from conversation about “Olympics”.



(b) Light scene derived from negative (left) and positive (right) sentiment.

Figure 3: WeLight scenes based on spoken conversation using a 27-light fixture.

New directions for WeLight: Enhancing spoken conversation

WeLight was initially intended to support remote communication, but experimentation among end users spurred additional development to enhance co-present conversation. For example, a toddler and her friends enjoyed seeing how they could make the room change color by shouting out words to her dad, who transcribed the words into WeLight text messages. This play and similar experimentation by others sparked interest in a more direct transformation of the environment through speech.

We recently developed a voice-based interface to WeLight’s scene creation feature that continuously controls light scenes based on the spoken conversation in a room. The system works through a real time speech transcription service and the WeLight automatic scene creation process. The intention is to augment conversations in a room with light representations of the subjects being discussed. To experiment with biasing lights according to the emotional tenor of the conversation, we drew on previously developed classifications of sentiment and color [10, 16]. The lights in a 3x3x3 cube fixture react to a conversation about the 2106 Olympics (Figure 3a) and to expressions of sadness and excitement (Figure 3b). We envision that such “semantically aware” light pieces could reflect or possibly redirect conversation.

Conclusions

Today’s connected devices are designed to work only within one household and are oriented towards automation rather than communication. We sought to support communication via connected lights by building on widely understood platforms such as text messaging, simplifying authentication processes and offering simple means of creating light scenes. Our development goals expanded as we observed use of connected lights and as we deployed WeLight. We initially set out to support remote signaling of affection and other emotionally based communication, but gained an appreciation for supporting instrumental communication such as conveying proximity or nudging someone towards a particular behavior. Our most recent development has focused on supporting communication within a household, in particular augmenting spoken communication with light that changes based on sentiment and topic of conversation.

Acknowledgements

We thank the individuals who participated in this research and colleagues Karin Strauss, Lydia Monirian, Ankur Agrawal, Becky Chierichetti, and Heather Patterson. This research was funded by NSF under grant #1518703.

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