Controlling Light Environments Using Segmented Light Sources and Mobile Devices

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Abstract. In this paper, we describe a software interface for controlling light environments using segmented light sources based on OLED arrays. We propose requirements for a tool that can be used to author specific light scenarios. Both the technical view and the user view on the system are addressed. We describe the concept of creating such an interface and demonstrate an example for a specific light source. The light source consists of 72 OLED segments that can be individually programmed using a mobile device. Different use cases illustrate the concepts. The description of future work regarding the control of OLED lighting situations concludes the paper.

Keywords: Light, Interaction, OLED, Mobile, Prototyping.

1 Introduction

Intelligent lighting is an interesting research topic for human-computer interaction. Recently, this topic has attracted a lot of attention by both researchers and industry. With the emergence of OLED technology, novel ways of attaching light sources to arbitrary surfaces are conceivable. Moreover, light sources based on OLED technology allow new ways of control over light settings [1, 2]. Modern lighting arrays have a wide range of variable attributes that can influence the lighting situation. For instance, brightness, light color, or spectral attributes can be configured to match personal preferences and moods. These attributes apply to every single segment of the lighting array, which leads to a high variability of light settings. Besides animating and adapting these attributes over time, context-aware adaptations increase the possible scenarios for different lighting situations.

2 Controlling Lighting Environments

To achieve the desired settings for different situations, a means of control is needed that allows an efficient and effective setup. The overall lighting situation depends on three factors: (1) the light source that creates the lighting situation, (2) the person that

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receives, interprets, and finally controls the lighting, and (3) the software interface that enables the control by the person (see Fig. 1). Hence, the situation must be analyzed both from a user-centered view and a technology-centered view. From a user-centered view, the person has either a rather vague or specific idea of how the lighting should look like. This view needs to be addressed by the technical view, which describes each lighting segment with its attributes. Since the amount of segments can be very high, a suitable way of control needs to be established.

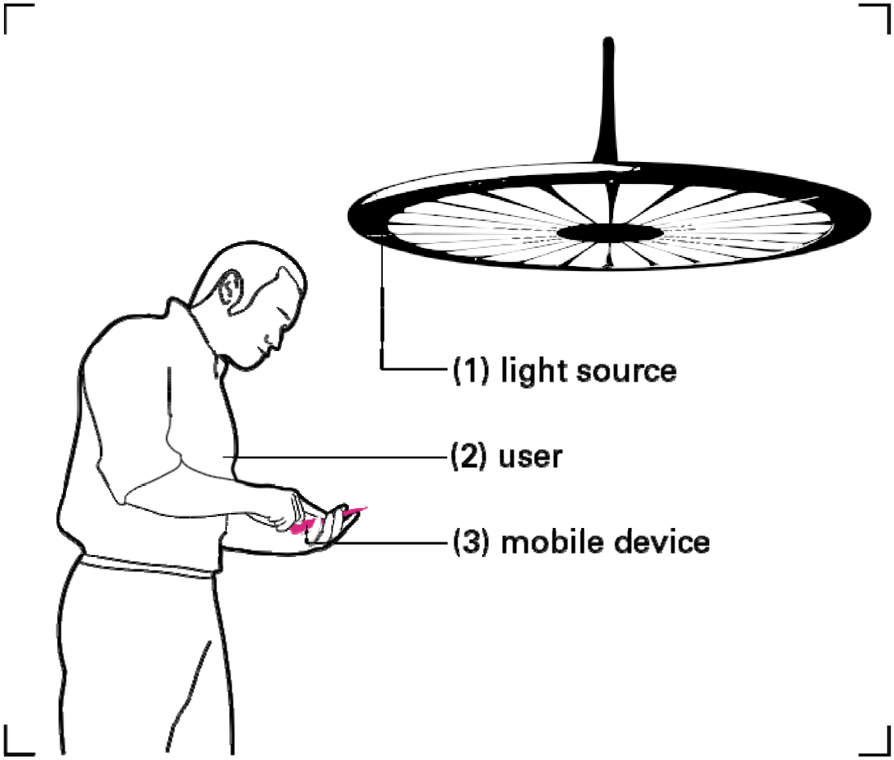

Fig. 1. Schematic view of the interaction situation showing user, light source, and mobile device to control the light source

Additionally, the device that is running the control application needs to be mobile in order to configure light setups in different locations. Therefore, the physical size of the display is limited. Displaying a large amount of segments on a small device is an issue that can be addressed by using Zoomable User Interfaces (ZUI) [4].

Moreover, the graphical user interface (GUI) requires a suitable representation of the light source that supports the user's mental model. The representation should convey the current lighting situation and the possible changes in a suitable way. Finally, the interface should bridge the gap between technical setup and the user's perception of the light source.

2.1 Technical View

The entire setup is influenced by the technical view. First, the individual attributes of each light source or segment, such as color and spectral attributes need to be modeled. The technical aspects also determine the position, shape, and size of each element. The connection of the elements, like groups or hierarchies (e.g. elements of a room) are part of the view as well. Apart from the static parameters, dynamic attributes make the view even more complex. Dynamic attributes can be events that are triggered based on context conditions, which allow more complex and responsive light setups. For instance, light attributes can be changed if a specific event occurs. This may be a person entering the room, sitting down on a chair, or even detecting a specific mood of a person via face recognition.

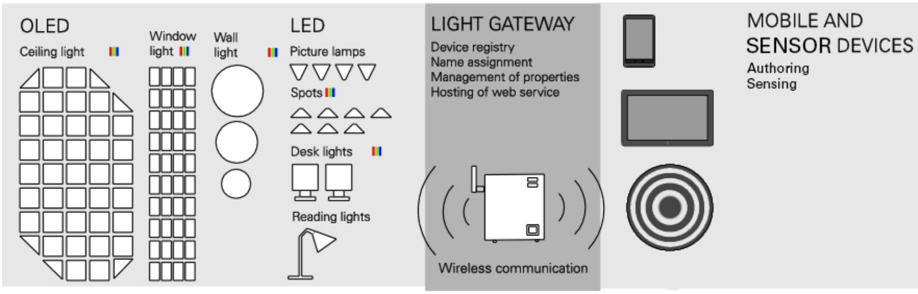

Fig. 2. General architecture for communication between mobile devices and OLED light sources

The technical view lays the foundation of the hardware architecture (see Fig. 2). All lights need to have a control interface. Technically, this interface can either be hard-wired or wireless. The elements are connected to a Light Gateway that processes different types of interface standards and routes the data to different clients. The gateway manages the technical view of the light setup. The model can be created manually using the smartphone application or automatically, by using sensors like depth cameras that reconstruct the room. New light sources are registered with the Light Gateway using an appropriate protocol.

When the user changes light attributes on the smartphone application, these attributes are transmitted to the Light Gateway using the technical view. The Light Gateway then routes the commands to the specific lights, which change their attributes. The Gateway does not only route commands, but also stores frames, animations, and events. Therefore, it is connected to the sensors in the room as well. The smartphone application becomes an authoring tool, while the Light Gateway controls the light in specific situations.

2.2 User View

The complete technical view of the light environment exhibits a very large variety of options. These options need to be accessed on the mobile device using an appropriate graphical interface. When creating a lighting situation, the user needs to select the segments he or she wants to activate and define their attributes. To this end, groups and hierarchies in the technical view make the selection easier. Semantic units of light segments can be selected in the interface (see Fig. 3). The smartphone automatically detects the current position and direction, so that the interface shows the current view as graphical representation. A paintbrush metaphor is used to interact with the light segments. The brush attributes are defined and then "painted" on the segments. On matrix based lighting groups or patterns the brush can be used as well. The resulting lighting situation is saved as a frame. To create animations, several frames can be used as key frames by interpolating the changes in lighting during a defined time period. This method is well-known from many different animation programs and is thus a simple way to create complex animations from basic parts.

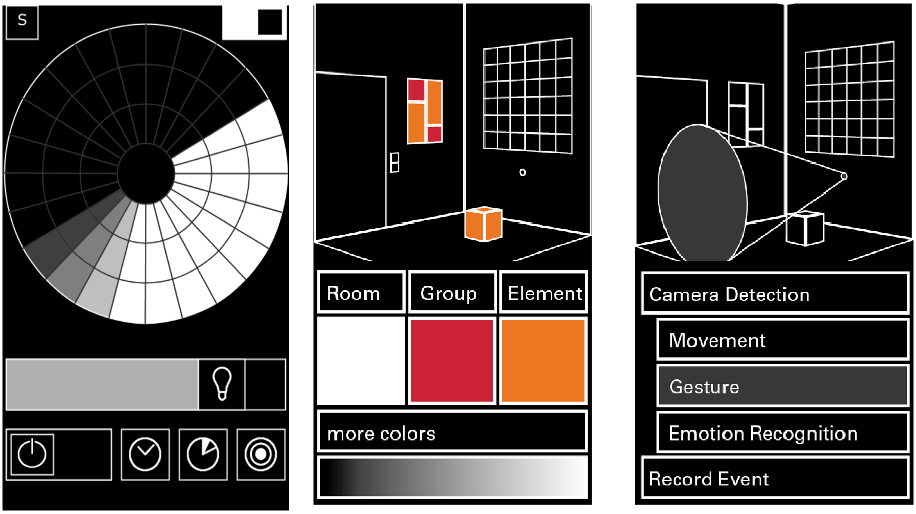

Fig. 3. The interface prototype, each segment can be controlled individually by "painting", the brightness can be selected by a slider and three animations are selectable (left), interface sketch showing the color selection (Middle) and the sensor recording (right)

Frames or animations are triggered by events. The variety of events is defined by the technical view with a wide range of sensor techniques from simple mechanical triggers to motion tracking or even face tracking. The sensor output is used to model events in the technical view. The graphical interface shows positions and ranges of the sensors on a schematical map (see Fig. 3). The user can record an event by activating the record mode and trigger the specific sensor directly. For instance, recording a specific gesture can be done by performing that gesture in front of the motion sensor with the activated record button. The specific event can then be connected to a frame or an animation. By using an identifier for the person, such as an RFID-tag, user specific events are defined. Moreover, general configurations for different times of the day, week, or year are possible.

3 Implemented Prototype

We implemented a prototype system called "Discotheque", which is a segmented OLED lamp that can be controlled by a smartphone application. We modeled the use case with the design method of scenarios [3]. Since the OLED lamp can be described as a disk with segmented stripes, the corresponding interface provides an abstract graphical representation of the lamp (see Fig. 4). Since the lamp consists of 72 segments, it is a possible user goal to control the brightness of each segment individually. Furthermore, the control of segment groups and animations for a dynamical lighting situation are possible goals (see Fig. 5). The most suitable way to control each segment or group is to select the brightness and "paint" the single segments on the representation with a single finger. When used on small displays, segments close to the user's finger work as zoomable elements and increase their size. Technically, the communication between lamp and mobile device works via Wi-Fi using the UDP protocol.

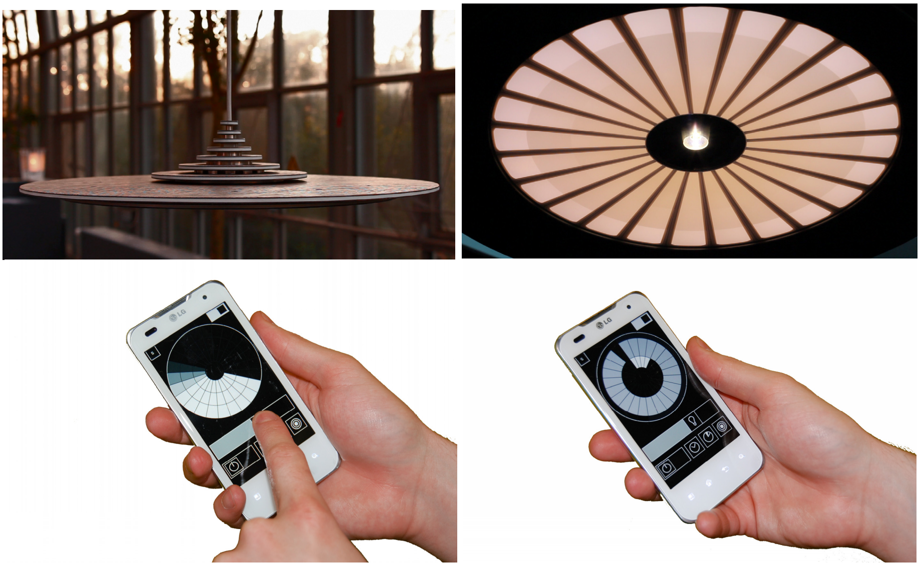

Fig. 4. Segmented OLED lamp side and bottom view and interface of the smartphone app

Fig. 6 shows the complete pre-defined set of animations that can later be substituted by custom programs authored by the user. The program numbers are transmitted using a custom protocol for communication between lamp and smartphone:

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/p <brightness level> <program number> <parameter>
/s <brightness level> <ring number> <segment number>
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The first line executes a light program according to the configuration in Fig. 5. Additionally, a brightness level can be used to adjust the brightness of programs 0-7, which are used to either activate all segments of the lamp or specific groups such as

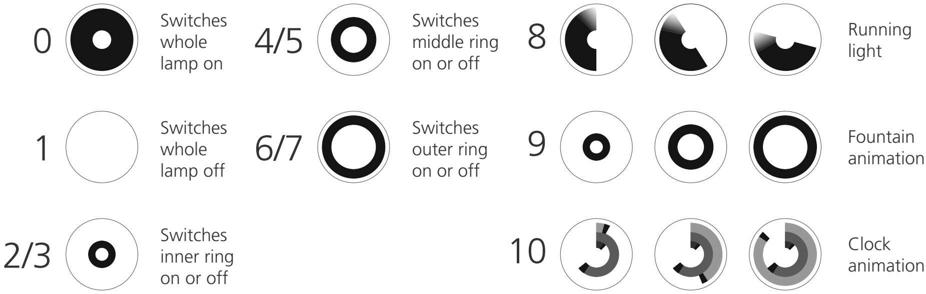

Fig. 5. Complete list of available programs to control the segmented OLED lamp

outer or inner rings. Programs 8-10 are animations of the lamp segments, which are stored in the onboard chip of the lamp.

The proposed protocol needs to be extended in the future. For instance, spectral properties and light colors could also be manipulated when using different light sources.

4 Use Cases

The presented concept offers benefits over common lighting in various contexts. We describe three use cases: commercial spaces, medical use in skin therapy, and people with disordered circadian rhythmicity.

4.1 Commercial Spaces

In commercial spaces such as malls or theatres, a high amount of energy is needed to power all lighting systems. During the day, some spots are more frequented than others, hence, not every light needs to be active at all times. A high energy saving potential is therefore present. Adaptive decision making systems allow to detect the number of persons and evaluate the current need of lighting in single areas [8]. Developed technical solutions already allow detection and lighting control [11], but lack means of customization and an appropriate graphical interface. Integrating such systems in the technical view allows to control them via smartphone. Constrains, events, and behavior patterns can be defined. As a result, environmental lighting can be made adaptive to the users and still be energy efficient.

4.2 Skin Therapy

A possible use for control of light sources is skin therapy, where small OLED panels are integrated into plaster [9]. When using many of such small panels, the light can be emitted as a pattern across skin cancer lesions. Our developed prototype promises future applications, such as the interactive visualization for multiple sclerosis patients. The number of multiple sclerosis (MS) information websites, online communities, and web-based health education programs has been increasing. Therefore, these platforms could be enriched with automatically created data describing technical setups of light environments combined with the healing success of these configurations. New forms of electronic communication appear to have high levels of acceptance for exchanging information about MS between patients and health care providers. Such methods should be integrated into eHealth services, such as electronic health records, neuroimaging, and patient relationship management systems.

Fig. 6. Different lighting in private and public settings can be controlled via mobile devices

4.3 Disordered Circadian Rhythmicity

Elderly people with dementia often suffer from a disordered circadian rhythmicity. They cannot sleep at night and their activity during the day is very low. Specific light setups can improve the circadian rhythmicity of these persons [6,7]. Individuals with melatonine suppression have similar issues. Their winter depressions can be improved with artificial lighting [9]. The special light elements can be integrated in the room light setup and customized as well (see Fig. 6). Hence, they become part of the room and do not appear as medical devices. Therefore, the living quality at home is increased. Since the systems are scheduled and their values can be logged, they deliver data which can be used to improve the therapy of these persons. In comparison, different light setups of patients lead to different therapy results. Hence, field studies can be conducted at home with the consent of the patients.

5 Conclusion and Future Work

We presented a concept for connecting various lighting systems with sensors and introduced means of authoring their attributes and behavior via smartphone. A technical view framing all elements lays the foundation for control. Three example use cases concerning different benefits of this model have been presented. In a prototype we implemented the basic control functions of such a system as proof of concept.

For future applications, the color input and the general authoring can be more object-specific. The concept includes the recording of emotions as trigger directly in front of the camera. Touch responsive light could be activated in the same way. When it comes to highly responsive systems, privacy should be an issue. Since personal data is recorded in the examples for medical research, every person should have the option to decide which data he or she wants to share and which not [5].

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