Lighty: A Painting Interface for Room Illumination by Robotic Light Array

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Abstract

We propose an AR-based painting interface that enables users to design an illumination distribution for a real room using an array of computer-controlled lights. Users specify an illumination distribution of the room by painting on the image obtained by a camera mounted in the room. The painting result is overlaid on the camera image as contour lines of the target illumination intensity. The system runs an optimization interactively to calculate light parameters to deliver the requested illumination condition. In this implementation, we used actuated lights that can change the lighting direction to generate the requested illumination condition more accurately and efficiently than static lights. We built a miniature-scale experimental environment and ran a user study to compare our method with a standard direct manipulation method using widgets. The results showed that the users preferred our method for informal light control.

Index Terms: I.3.6 [Computer Graphics]: Methodology and Technieques—Interaction Techniques; I.6.3 [Computing Methodologies]: Simulation and Modeling—Applications; G.1.6 [Numerical Analysis]: Optimization—Constrained Optimization; H.5.2 [Information Interfaces and Presentation]: User Interfaces—User-centered Design.

1 Introduction

We propose an augmented reality (AR) user interface called Lighty that enables users to easily design an illumination distribution for a real room using an array of computer-controlled lights. Users specify which area of the room is to be well-lit and which is to be dark by painting an illumination distribution on a tablet device displaying an image obtained by a camera mounted in the room. The system runs an optimization to calculate the light parameters and then illuminates the room. Our method is inspired by the goal-based lighting optimization approach in computer graphics [1]. We have adapted this approach for lighting control in a living space and address the problems observed in the previous methods [2]. We built a miniature-scale environment featuring twelve lighting units with intensity and orientation that are controlled independently. We ran a user study comparing our method with a standard direct manipulation method using widgets.

2 System Overview

Our overall system is shown in Figure 1. Each light is equipped with two rotational actuators and has a micro-computer that controls the brightness and angle. Lights can be controlled individually by an input signal given by the computer. The image obtained from the camera is used to measure the radiance of the scene, after which the user can design the illumination distribution of the room with the user interface provided by the computer. The control system consists of the painting interface, an optimization module, and a light control module. The painting interface allows the user to design the illumination distribution of the room by painting the desired illumination result directly onto the image. The optimization module interactively calculates the parameters of the lights that will satisfy the desired illumination distribution request [3]. The light control module then sends the calculated parameters to the lights.

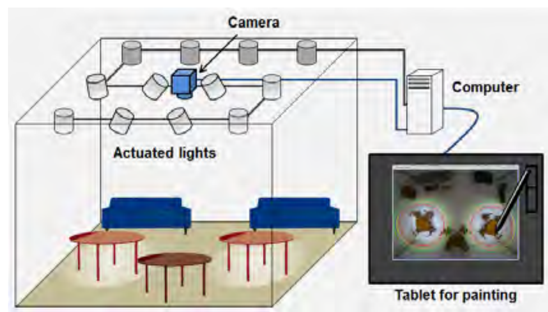

Figure 1: System overview.

3 User Interface

The user interface is shown in Figure 2. The left window shows the live view from the ceiling mounted camera, and the right window shows the basic painting tools. The user specifies the desired intensity on the live view by painting. Previous painting interfaces for lighting design [1, 2, 3] showed the painting canvas (target image) and illumination result separately. This consumes a lot of screen space, which is inconvenient if users have a device with a small screen such as a smartphone. In our system, both views are merged into one screen and the painting result is visualized as contour lines of the target illumination intensity overlaid on the live view. The relative intensity is indicated by color: a warm color indicates a brighter area, and a cold color indicates a darker area. To avoid bothering the user examination, we also added toggle function in the tool panel.

Figure 2: User interface.

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4 EVALUATION

We built a miniature room at 1/12 scale and ran a user study to compare our method with a conventional direct manipulation method which consists of multiple control widgets. We asked the participants to control the lights using these two methods following instructions given in natural language and then measured task completion time and user satisfaction.

4.1 Direct Manipulation Method

As a baseline method, we implemented a standard direct manipulation user interface to control the light units. A screenshot is shown in Figure 3. The left window shows the live view obtained by the ceiling mounted camera, and the right window is the light control widgets. There are 1-DOF sliders to control brightness and 2-DOF direction controllers for the twelve lights. Each slider can be adjusted the brightness level. Users change the direction a light is facing by dragging the corresponding circular handle in 2 dimensions. When the circle is dragged to the left, the light is pointing left in the live view. The arrangement of the controllers corresponds to the arrangement of the lights in the top down view.

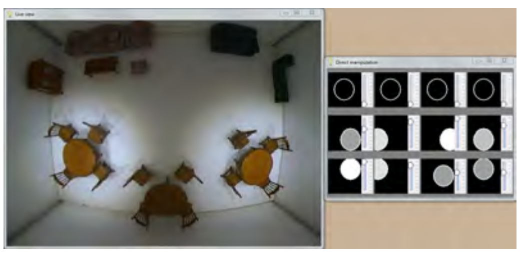

Figure 3: Interface of direct manipulation method.

4.2 Procedure

We recruited 10 participants aged 20–35 years old to participate in our study. Participants were paid $21 for their time and the sessions lasted from 1 to 1.5 hours.

The comparison was performed under a within-subjects condition, where each participant tested both methods. For each method, we instructed participants how to use the interface and had them practice it using two training tasks. We then asked them to complete five tasks. We used the same seven tasks in a fixed order for all participants and both methods. Each task was to specify an illumination distribution for the target scene in the miniature room. The target illumination condition was given via the natural language instructions shown in Table 1. We allowed a maximum of three minutes for each trial. All lights were initialized to 50% intensity and zero degrees in xy-tilting (looking downwards) at the beginning of each trial. For each trial, we recorded the task completion time and asked participants to rate their satisfaction on a seven-point Likert scale with high scores positive. The two methods were used in a balanced order: five participants tested our proposed method first and the other five tested the direct manipulation method first. We interviewed them after all the trials were completed.

Previous studies on painting interfaces for illumination control [2] showed images to the participants to specify the target results. We instead gave instruction in natural language because our target application is illumination control in a living space, and so quick, informal control is more appropriate than precise control.

4.3 Results and Discussions

The task completion time and user satisfaction are showin in Figure 4. Interestingly, the same trials (2, 3, and 5) showed significant difference in both the task completion time and user satisfaction. Trial 1 and 4 did not show significant difference.

Table 1: Task instruction

Trial 1	Make the left and right circular tables brighter while keeping the remaining area the same brightness.
Trial 2	Make the center and right circular tables illuminated well. The upper left area where the sofas and cupboard exist should be darker.
Trial 3	Make the entire room brighter. However, the areas around the left circular table and upper right sofa should be dark.
Trial 4	Make the left side of the room bright and the right side dark, gradually changing the brightness in the middle.
Trial 5	Make the upper right sofa bright and radially decrease the brightness around the sofa.

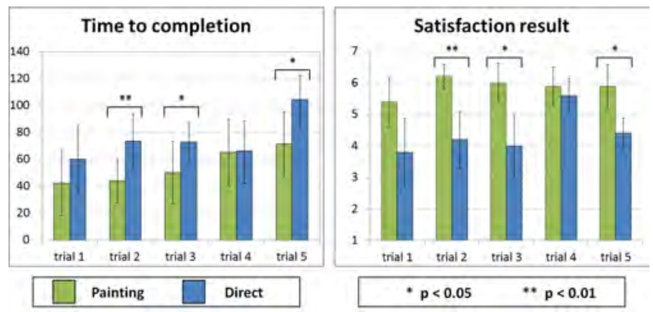

Figure 4: Time to completion and satisfaction results.

Nine participants answered in the post-test interview that they would use the painting method in the future for this task rather than the direct manipulation method. Their main reason was that the painting method required less control, which made it possible to complete a task faster without much fatigue. In contrast, one participant preferred the direct manipulation method because it allowed them more precise control.

It is interesting to see that some tasks showed statistically significant differences while others did not. In our observation, users suffered hardship on a *darkening* operation in the direct manipulation method. This is why the painting method showed better results in the trial 2 and 3. We also found that the most participants did not change the light directions in trial 4 in the direct manipulation method. This is why trial 4 and 5 had quite different results while they were similar in that both requested gradual brightness changes.

5 FUTURE WORK

It remains our future work to perform tests with a real-sized room. Our current implementation uses a fixed top-down view from the ceiling, but we hope to support views from other unfixed cameras, such as cameras embedded in hand-held devices. We need three dimensional geometry information to do this correctly, but we think this is possible by using recently developed 3D scanning methods.

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