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ABSTRACT

In this paper we introduce LuminAR: a prototype for a new portable and compact projector-camera system designed to use the traditional incandescent bulb interface as a power source, and a robotic desk lamp that carries it, enabling it with dynamic motion capabilities. We are exploring how the LuminAR system embodied in a familiar form factor of a classic Angle Poise lamp may evolve into a new class of robotic, digital information devices.

Author Keywords: Augmented Reality, Gestural Interfaces, Multi-touch Interfaces, Robotic Lamp, Human Robot Interaction, Actuated UI

ACM Classification Keywords: H5.1 [Information interfaces and presentation]: Multimedia Information Systems. - Artificial, augmented, and virtual realities.

General terms: Design, Human Factors,

INTRODUCTION

In recent years, Pico-projection, embedded mobile computing as well as wireless networking have taken huge leaps forward, empowering several novel Augmented Reality use cases. At the same time, robotic technology has reached a stage where it is ready to propagate into user interfaces. However, little research has been done to explore where robotics and AR meets, specifically for the design of novel user interfaces.

The LuminAR Bulb combines a Pico-projector, camera, and wireless computer. This self-contained system enables users with just-in-time projected information and a gestural user interface. Moreover, it can be screwed into standard light fixtures everywhere. The LuminAR Lamp is an articulated robotic arm, designed to interface with the LuminAR Bulb. Both LuminAR form factors (Bulb and Lamp) dynamically augment their environments with media and information, while seamlessly connecting with laptops, mobile phones, and other electronic devices. LuminAR transforms surfaces and objects into interactive spaces that blend digital media and information with the physical space.

The project radically rethinks the design of traditional lighting objects, and explores how we can endow them with novel AR interfaces.

Figure 1: The LuminAR System Prototype

BACKGROUND AND RELATED WORK

Augmented Interactive Spaces typically use a projector-camera system along with computer vision techniques to augment a physical space with digital information. Wellner's DigitalDesk [1] is considered a key work in this domain. The LuminAR system enables similar flat surface, and table-based augmentation and interaction, yet it provides the advantage of portability, as the system is self-contained.

Underkoffler et al. in his seminal work I/O Bulb and Luminous room [2] described a basic two-way optical information device and how it will be used to transform a room into an architectural information space. At the time, technology and cost limitations prevented the full realization of this vision. The system implemented included spatially separated cameras and projectors. Although a 'real' I/O Bulb was described, it has to date, been unavailable in research labs nor as a commercial product.

The LuminAR Bulb introduces advances over this prior work: First, it realizes the I/O Bulb's vision, and efficiently integrates all the required components for the bulb (camera, computer, projector, sensors, etc.) into a single system. It is, thus, a truly portable and scalable solution to implement customized augmented interaction spaces easily. Secondly, it adds actuated degrees of freedom and robotic control elements that enable the LuminAR Bulb to dynamically change projection parameters.

In later work, Pingali et al. introduced the concept of steerable interfaces, and created the Everywhere Display [3] that used a stationary projector using a rotating mirror to expand projection to multiple surfaces. The LuminAR system builds on the

principles introduced in that work, and extends them further by introducing the truly portable and compact form factors of the LuminAR Arm and Bulb.

In addition, steerable interfaces require a general and dynamic geometric projection model that we have yet to address in our work. Previous results of Ashdown et al who proposed a Steerable Projector Calibration model [4] may be generalized and adapted for our work in the future.

More recent work has combined Pico-projectors and cameras in a lamp form factor. A prominent example is the DockLamp by Kaplan, et al [5].

Even though these examples demonstrate substantial, yet incremental, improvements in portable AR interfaces, unfortunately all of the systems described above are completely static once installed in a space. This fact limits the scope of interaction and augmentation experiences these systems can provide. The LuminAR Bulb and Lamp's portability and robotic capabilities address such limitations directly.

ROBOTIC AUGMENTED INTERACTIONS

The robotic capabilities of the LuminAR system enable it with dynamic motion. As an interactive system it enables a user to direct the robotic arm and the bulb to cast information in different locations. Using robotic projector-camera systems can drastically increase the reach of the projection, in both horizontal and vertical axes.
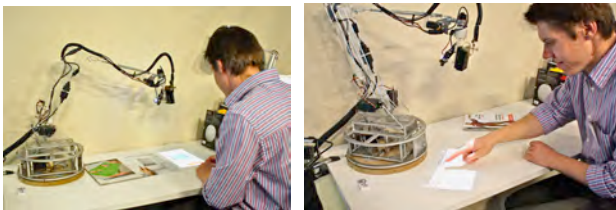

Figure 2: New dynamic and articulated interactions are combined with touch interface

PROTOTYPE IMPLEMENTATION

The LuminAR System is comprised of two separate components that together form the full system:

LuminAR Bulb

The LuminAR Bulb is an evolution of the I/O Bulb into a robotic controlled version of the two-way information device described by Underkoffler[3]. The LuminAR Bulb adds a robotic control element to the classic projector-camera system. The Bulb is designed with its own set of actuated DOFs (Degrees of Freedom). The DOFs are used to support different linear and rotational motion paths that allow the Bulb to extend and dynamically change the projection parameters.

It is clear that the LuminAR Bulb's robotic capabilities have several advantages, as the combinations of sensing and actuated DOFs enable the system to become a complete and controlled (and in the future, geometrically aware) projector-camera system. Since the LuminAR system is primarily an interactive information robot, the ad-

vantages above directly impact the user experience it can provide to augmented reality applications.

The LuminAR Bulb computer module includes wireless networking capabilities that enable it to connect to the web, other information devices and to other LuminAR Bulbs. In addition to the two-way interaction device functionality, the LuminAR Bulb can also function as a simple light fixture and a webcam.

LuminAR Lamp Robotic Arm

The LuminAR Lamp appears as a normal desk lamp, but it is an articulated and animatronic robot. It consists of a human-like robotic arm with 4 DOFs. The arm terminates in a lampshade with a standard Edison socket. Each DOF has a motor, positional and torque sensors, as well as motor control and power circuitry. This design enables the arm with force-controlled compliant motion capability.

The robotic arm design described above enables the LuminAR Lamp with a subtly expressive robotic interface. The combination of the animatronics capabilities of the arm and simple-composed robotic motions can generate an inviting user experience that encourages users to interact and anthropomorphize the LuminAR Lamp.

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