MlioLight: Multi-Layered Image Overlay Using Multiple Flashlights

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ABSTRACT
We propose a technique that overlays natural images on the real world using the information from multiple flashlight devices. We focus on finding areas of overlapping lights in a multiple light-source scenario and overlaying multi-layered information on a real world object in these areas. In order to mix multiple images, we developed a light identification and overlapping area detection technique using rapid synchronization between high-speed cameras and multiple light devices. In this paper, we describe the concept of our system and a prototype implementation. We also describe two different applications.

Author Keywords
Multiple Flashlights; Projection Mapping; Magic Lens

ACM Classification Keywords
H.5.1. Information Interfaces and Presentation (e.g. HCI): Multimedia Information Systems

INTRODUCTION
A flashlight is a useful light device that has been used for many decades, and the "flashlight metaphor" has been incorporated into a variety of information presentation techniques as an easy way to find or overlay information.Flashlights have also been used for multi-user interactions [1]. In a multi-user or multi-flashlight scenario, lights pointed in the same direction naturally overlap with each other. Detecting the overlapped illuminated area enables the system to determine the area of interest that is shared by users. In addition, displaying synthesized information on the overlapped area promotes communication between users.

In recent research in the HCI field, especially on interactive surfaces or augmented reality, a small projector has been employed as a flashlight-like device that can project information anywhere in the real world [4]. However, there are some problems with using a projector as a flashlight. In a small projector-based system, the flashlight must obtain its three-dimensional (3D) position and orientation as well as the 3D shape of the projection target. This information is used for the main projection processes, which consist of setting the projector image area, correcting distortion, and detecting the area overlapped by multiple lights. In addition, in multiple mobile projector situations, the image luminance and color of the overlapped projection area should be corrected to improve visibility. These calculations have a direct effect on the sensation of using a flashlight; however, it is not so easy for small devices to calculate these variables in real time. In this research, we focused on a projector-camera system to address these limitations. We propose a novel projector-camera based system that can provide users with a multi-layered image-overlay experience using multiple flashlight devices.

MLIOLIGHT SYSTEM
We propose a novel projector-camera based multi-flashlight detection system called "MlioLight." The system has three main capabilities: low-latency/accurate image projection that reproduces the complete sensation of using flashlight, identification of multiple lights in multi-user scenarios, and overlapped area detection and information synthesis in multi-light scenarios.

In this system, a flashlight device emits an invisible infrared (IR) light toward the target object. The diffusion of the IR light on the target's surface is captured by the IR camera and is immediately visualized by the visible light projector in the projection on the screen. The light pattern is used as a blend factor for mixing the background and foreground textures and colors of the screen image. This approach enables the system to reduce the computational cost and latency of accurate projection onto real world objects.

In addition to these basic projection processes, the system transmits a few bits of information in a radio signal to the individual flashlight devices at every shutter activation. This signal communication enables the system to control the switching (on and off) of the individual light devices. By turning on and off the lights, the system can easily and precisely separate the overlapping light images and detect or identify the light source and overlapped illuminated area in pixel units. These processes enable the system to synthesize multi-layered images and also project a variety of information on the overlapping light area.

RELATED WORK
Motion capture systems have been used in previous research [1] to detect and identify multiple lights. However, motion capture cameras require multiple markers to be attached to the light devices, which limits the usability of the flashlight. To detect multiple light devices, invisible two-dimensional

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barcode have been used in previous research [2]. However, the hardware configuration may become more complex because a special IR projector and camera-implemented light are needed. In addition, the processing cost and latency of the system also increases. Light can be separated by using multiple bandpass filters and multiple-wavelength lights [3]. In this method, however, multiple cameras or a bandpass filter switching mechanism are required; thus, the maximum number of lights is greatly restricted.

IMPLEMENTATION

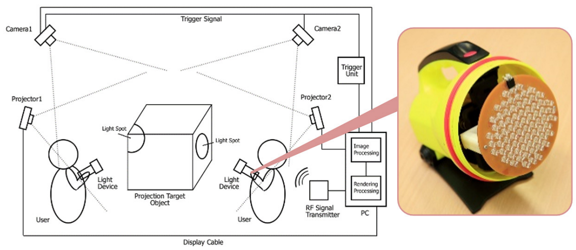

Figure 1. System hardware (left) and light device (right)

The left side of Figure 1 shows the hardware configuration of our prototype system. The system is composed of four components: a signal transmitter, an image processing system for capturing and identifying the light image, a projection unit for projection mapping, and multiple light devices with signal receivers. Each light device (Figure 2, right) has an IR light source composed of 72 IR LEDs (850 nm) and a 2.4 GHz radio signal receiver with a micro-controller (nRF51). The on/off state of individual light devices can be controlled by the radio signal sent from the signal transmitter at every shutter activation (over 150 fps). The image processing unit is composed of an IR camera, external trigger controller, and image processing system (on a PC) with an RF signal transmitter. The image processing system sends a light control signal via a transmitter before firing the shutter of the cameras. If three overlapped lights are captured by the camera, the system sequentially captures two different images with different IR signal transmissions that have bits 101 and 010, respectively (Figure 2, left). This process enables the system to separate overlapping lights into different frames (Figure 2, right). The IR image captured by the cameras is sent to the image processing PC and used to calculate its position, size, and shape information. Simultaneously, all camera images are transferred to the GPU as multiple layers of texture data. The final projection image is flexibly synthesized by a fragment shader program and rapidly projected onto the target by the projector. Note that our system can not only project onto a planar target (i.e., a wall-size or tabletop screen) but can also project onto a 3D projection target using multiple projectors and cameras.

APPLICATIONS

Our system can provide variety of visual content that is multi-layered and customizable using the GPU programming. One application we developed is a 2D visual content browsing application using a wall-sized display. The user can browse for hidden information by pointing a light device at a specific location on the wall, as if it were a magic lens. When

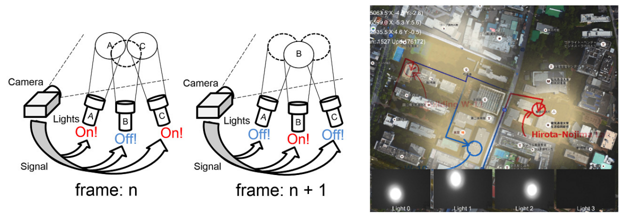

Figure 2. Three-light overlapping separation example (left) and projection result (right)

browsing content based on an anatomical chart, different internal organs are assigned to different light devices. If multiple lights are mixed at a specific location, a different image is displayed (in this example, naturally synthesized images of multiple organs). In this application, the light images captured by the cameras are binarized to increase a visibility of overlay image. In another browsing application with multi-language translation content, a web page is displayed on the large screen. The user can browse the translation result by pointing at a specific location with one of several lights that are each assigned to a different language. In this application, a light image that is smaller in size is displayed on the higher-level layer to avoid interference between the different languages.
We also developed a game application using a 3D projection target. This application provides the players with the experience of exploring a 3D projected target in the real world with the lights. In this application, the players try to capture a variety of characters that are hidden on the 3D object in cooperation with other players. In addition, the system counts the number of light layers. To find unique characters, the players must shine two or more lights at the same location. This rule promotes communication between users and increases their enjoyment of the game.

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