Adaptive Color Marker for SAR Environments

Ross T. Smith* Michael R. Marner† Bruce H. Thomas‡

University of South Australia
Wearable Computer Laboratory

Abstract

This paper explores how passive colored markers used for blob-tracking can be advanced to improve their operation in spatial augmented reality environments. We have created an adaptive marker that captures the color of environmental light, and then changes its own appearance in order to optimize tracking performance. We have provided implementation details and proof of concept for an active marker that supports interactive operations and visual feedback. We compared the performance of both the passive and adaptive color marker in varying lighting conditions. Our results show a significant improvement in four scenarios where a passive marker is known to have poor tracking quality.

Index Terms: H.5.2 [Information interfaces and Presentation]: Graphical User interfaces—Input Devices and Strategies; I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction Techniques

1 Introduction and Motivation

This paper explores the idea of using an adaptive Red, Green, Blue light-emitting diode (RGB LED) in place of a passive color marker for a vision based tracking solution specifically for Spatial Augmented Reality (SAR) environments [6]. Our novel active marker allows its own appearance to be altered in real-time to avoid conflicting environmental lighting conditions. By incorporating a color light sensor that can capture the surrounding environmental lighting conditions, an optimal marker color can be chosen and applied to maximize the performance of the tracking system. This approach is particularly useful for SAR environments where the projected light interferes with the perceived color of passive markers. We also leverage the colored light of the marker to present visual feedback on the top of the user's fingertip to provide a combined input/output device for a virtual-physical interface [3].

Our motivation for investigating this problem stems from an ongoing effort to explore interactive SAR technologies for industrial design visualizations, training and product evaluations.

In previous research, a blob-tracking system [9] with a passive orange marker was used to allow the designer to interact with a physical-virtual dashboard prototype [5]. In practice, the performance of the passive marker suffered when the SAR projections contained orange, or when the ambient lighting changed.

In this paper we explore how an active marker can overcome these limitations. We have considered two styles of active marker: Infra-Red (IR) and visible light. IR markers are particularly useful for creating markers that are invisible to the human eye and can not be used to provide visual feedback. An advantage of visible light is the marker can be used for two functions: firstly, to capture a 3D position allowing interactions with the system without specialized cameras. Secondly, the active colored marker can be used to

*e-mail:ross@r-smith.net
†e-mail:michael.marner@unisa.edu.au
‡e-mail:bruce.thomas@unisa.edu.au

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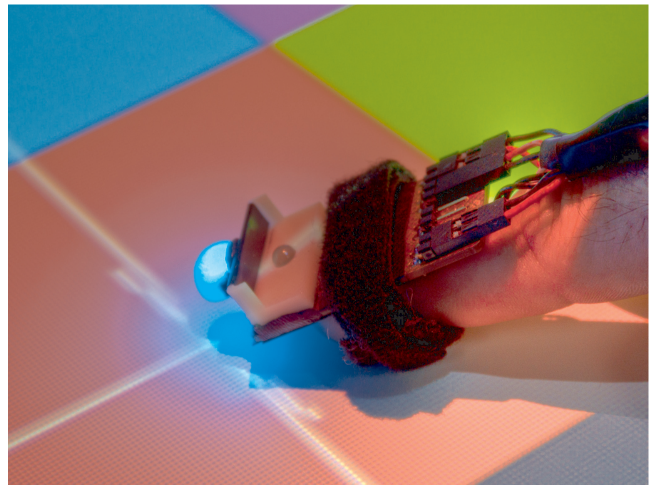

Figure 1: Adaptive marker being tracked. The color of the RGB LED is automatically selected based on the color of the projected light that is detected on the integrated color sensor.

provide visual feedback when operating interactive physical-virtual controls. Figure 1 shows the adaptive marker prototype capturing the color of the red projected light and selecting blue as an optimal tracking color.

2 Related Work

Spatial augmented reality uses projection technologies to present perspectively correct computer generated graphics directly onto physical objects [6]. Our research efforts have been exploring how aspects of industrial design modeling can be advanced using SAR technologies for visualizing concepts [5]. Tracking systems are regularly used to capture position and orientation of physical objects in virtual and augmented environments. Our investigations are focused on the functional aspect of active visible markers, which are closely related to vision based blob-tracking. Rasmussen et al. discussed blob tracking algorithms using color alone in a variety of lighting conditions [7]. Brusey et al. further explored using color, and found that there are certain objects and color combinations that are indistinguishable when combined [1]. Smith et al. employed static coloured markers for finger interactions on a mobile augmented reality system [8]. IR light is also commonly used, using a variety of marker types [4]. Commercial systems such as those from Vicon[1] use IR light with retro-reflective markers. More recently, the commercially available Playstation Move[2] controller uses an active colored marker on the top of its game controller for position tracking. None of these systems combine the concept of capturing the projected light color to set the visible marker color and also use the marker for integrated interactive feedback.

[1] www.vicon.com
[2] http://us.playstation.com/ps3/playstation-move/

3 AN ACTIVE FINGERTIP MARKER

Our fingertips are one of the most sensitive parts of the human body, the distribution of the primary motor cortex is pictorially represented on the Cortical Homunculus diagram [2]. We use our fingers to feel textures, test the temperature and perform fined grained manipulation tasks. The dexterous nature of our fingers make them an obvious choice for interactions in SAR environments. Attaching a passive colored marker to the index finger allows the finger's position to be tracked and used as a gateway between the physical and virtual worlds. This paper advances the marker's functionality further by making it possible to actively change color. This provides more robust tracking and visual feedback directly on top of a user's fingertip. The color light sensor is also positioned above the fingertip to capture the environmental light and is used to adapt the marker to changing conditions in real-time.

We have modified our previously employed tracking software [9] to support an active, adaptive marker. The integrated color sensor is used to sense the color being projected onto the marker. Our goal is to select the *opposite* of this color for the LED. The detected color is converted to the Hue/Saturation/Value (HSV) color space. HSV places hues at specific locations on a virtual color wheel. The *opposite* color will be the hue 180° from the detected color. We set the LED on the marker to this color. The cameras capture the finger tip marker, and color segmentation (thresholding) is performed to separate the marker from the background. Using these images, the tracking software calculates the 3D position of the marker.

3.1 Visual Feedback Technique and Applications

Our primary application for the active visible light marker is to support interactions in a SAR environment. Traditional buttons commonly use an internal light to illuminate the top surface when depressed. This provides an intuitive form of visual feedback to indicate the operation has been successful. When operating the combined physical-virtual buttons in a SAR environment the illuminated button press can be difficult to display when the user's finger is on the projection surface. For this scenario, the visible light of the active marker can be leveraged to provide interactive feedback that is incorporated with the function of virtual buttons. For example, when the system registers a virtual button press the color of the active marker can be altered to notify the user with clear visual feedback. Tabletop systems such as the Microsoft Surface[3] allow complex multi-user interactions on their surface. Using a fingertip active color marker the same feedback technique can be used to provide additional information to the user. A slider could also leverage a similar functionality where the intensity of the LED is used to represent the current value of the slider.

4 PERFORMANCE EVALUATION

We compared the tracking performance of our adaptive marker to a passive color marker in a tabletop SAR environment, and identified a number of scenarios where the static color markers fail in comparison to the adaptive marker. One projector was used to project a crosshair on the marker, and another to project the SAR information onto the table. The tracking software was calibrated to maximize the performance for each marker. The two marker types were subjected to four test projections: a color palette, a color palette with the ambient light changing during the test, a grid of orange and green, and an animated background. Each test ran for two minutes, with the marker moving at a speed ranging from approximately 20 to 400 centimeters per minute. The total number of frames processed and the number of frames where accurate tracking was obtained were recorded, allowing us to measure the performance of each marker type.

[3]http://www.microsoft.com/surface/default.aspx

The adaptive marker achieved much higher performance in all four test conditions. In total, the adaptive marker was tracked 91.71% of the time, where as the passive marker was tracked 42.41% of the time. The passive marker was much more susceptible to changes in both ambient lighting and the projected images. As a passive device, good ambient lighting is needed to segment the image. Tracking failed when the ambient light was off. In contrast, the adaptive marker emits light. This makes it less susceptible to poor or changing ambient lighting conditions. In addition, the marker is able to change its color, making it much easier to segment from the background. In testing, we observed that many of the missed frames for the adaptive marker were during the transition from one color to the next. The reason for this is the latency in the camera system; the tracker would look for the new marker color in camera images before the change occurred.

5 IMPLEMENTATION DETAILS

An RGB LED is used as the tracking marker, with a 12mm dome shaped diffuser to increase the size of the active marker. An Avago color light sensor with a 5mm dome lens is used capture the environmental lighting conditions. A barrier is placed between the LED and sensor to prevent light contamination. A micro-controller board is used to interface between the color sensor, LED and PC over the serial port. The software was built on our framework for spatial augmented reality applications. The software is implemented in C++ using OpenGL, and runs on standard desktop computer hardware running Ubuntu Linux. Two NEC 410W projectors were used at a resolution of 1280x800. Two Pyro FireEye cameras were used for tracking, providing a resolution 640x480 at 15Hz.

6 CONCLUSION

We have presented the concept of using a color light sensor to capture the environmental light used to calculate an opposite color in HSV and set a LED marker to assist the vision tracking algorithm. To compare the performance we tested both a passive and active color marker in four conditions that highlight the benefits of the active marker. We have also identified how the visible spectrum active marker can be leveraged to provide visual feedback with virtual buttons. This is advantageous since the "click" indication can be seen on top of the users finger when operating occluded controls.

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