SITUATED DISPLAY SYSTEMS: BRINGING VIRTUAL OBJECTS INTO THE REAL WORLD

Innovative Student Research Proposal

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Abstract:

With recent advances in computer graphics technologies, accurate physically-based rendering can now be performed at interactive rates, allowing users to manipulate realistic virtual objects in complex 3D environments. However, even with state-of-the-art interactive graphics, the display only provides a window into a virtual world and viewers are still one step removed from the virtual objects they are manipulating. Our objective is to remove this barrier between the real and virtual worlds by developing an interactive display system that brings synthetic objects into the real world and gives viewers the same visual experience they would have if the virtual object were situated in the real environment. The situated display presents the virtual object at the physical location of the display and supports natural interaction with it, including direct manipulation of the object’s orientation by rotating the display and dynamic viewpoint changes through observer tracking. We are requesting support to develop a component-based system that integrates a lightweight LCD display, a camera system for tracking the observer, a triaxial accelerometer for sensing the display’s orientation, and a state-of-the-art graphics card. This situated display will be used to support research in three areas: psychophysics of material appearance, soft proofing of digital print media, and high fidelity digital archiving of artwork.

Dollar Request: $5,475

Desired Funding Dates: February 2009 – January 2010
Scientific Justification

Fig. 1. Left, a realistically-rendered model of an oil painting is displayed on the situated display prototype. Right, the rendering is interactively updated for changes in the display’s orientation and the observer’s viewpoint using the built-in accelerometer and webcam. Note the changes in surface highlights and texture. The image changes in the same way that the real object would. The situated display allows virtual objects like this one to be brought into the real world.

Advances in computer graphics technologies have provided the capabilities for realistic image synthesis, allowing images of synthetic objects to be rendered that are nearly indistinguishable from photographs of real-world objects (Greenberg et al., 1997). The ability to create realistic visual depictions of an object, without that object having to be physically constructed, has proven to be a valuable tool in a variety of application domains. For example, it has revolutionized special effects in the entertainment industry, facilitated research on material and surface perception, and enabled enhanced soft proofing tools for simulating hardcopy prints.

Due to the high computational cost of physically-based rendering techniques, realistic image synthesis was initially limited to producing only static images. As the technology progressed, pre-calculated motion sequences could be generated from sets of rendered images, allowing the synthetic objects to be viewed in motion. With recent advances in graphics hardware, accurate physically-based renderings can now be generated at interactive rates, allowing users to manipulate realistic virtual objects in complex 3D environments.

However even with state-of-the-art interactive graphics, the viewer is still one step removed from the virtual objects they are manipulating. The display screen acts as a window into the virtual world, and the viewer does not interact with the objects directly, but instead uses indirect means, such as the mouse and keyboard, to rotate objects or shift the point of view.

Our objective is to remove this barrier between the real and virtual worlds by developing an interactive display system that brings synthetic objects into the real world and gives viewers the same visual experience they would have if the virtual object were situated in the real environment. Instead of providing a view into a virtual world, this novel display system presents virtual objects, situated in the real world, at the physical location of the display. It supports natural interaction with the virtual object, including direct manipulation of the object’s orientation by rotating the display and dynamic viewpoint changes through observer tracking.

An initial prototype of the system has been developed using an off-the-shelf laptop computer that contains a triaxial accelerometer and a webcam as standard components. Through custom software that integrates these devices, we have been able to actively sense the 3D orientation of the laptop’s...
display and dynamically track the observer’s viewpoint with camera-based head-tracking. We use this information to drive a physically-based rendering algorithm that generates an accurately oriented and realistically shaded view of a surface to the laptop’s display (shown in Fig.1). The user experience is akin to holding a physical surface in one’s hands and being able to actively tilt it and observe it from different directions to see the changing patterns and properties of surface reflections. While sufficient for demonstration purposes, the use of an off-the-shelf laptop in the prototype imposes limitations that impact its utility as a research tool. Due to the limited processing power of the laptop’s graphics processing unit (GPU), it is not possible to render at interactive rates using realistic, image-based environmental illumination or to incorporate object inter-reflections. Without these capabilities, the prototype produces convincing results for low gloss surfaces, but cannot produce the sharp environmental reflections that can be observed in high gloss surfaces.

To address these limitations and enable our research, we are requesting support to develop a component-based situated display system. The system will be synthesized from commodity hardware, including a desktop computer with a state-of-the-art graphics card, a lightweight LCD display, an accelerometer module for orientation tracking, and an external camera system for head-tracking. Within this more powerful hardware platform, we will integrate physically-based rendering methods that accurately reproduce the appearance of complex objects in realistic illumination environments at interactive rates.

This situated display system, with its enhanced capabilities, will be used to support research in three areas: psychophysics of material appearance, soft proofing of digital print media, and high fidelity digital archiving of artwork.

**Material appearance research:** The study of material perception has been facilitated by the ability to simulate the appearance of materials and control various properties using 3D computer graphics simulations. The ability to manipulate an object and observe the resulting changes is important when studying material perception, because it is one of the principal ways to differentiate between the visual effects resulting from material properties and those due to lighting (Kingdom, 2008). Under real-world conditions, to understand surface properties, observers often engage in complex behaviors that involve active manipulation and dynamic viewpoint changes. The use of a situated display allows researchers to use natural modes of interaction when using 3D graphics simulations to study material perception.

**Soft proofing:** In photographic printing and desktop publishing, it is useful to be able to simulate the appearance of a hardcopy print during the editing process by soft proofing on a computer display. Traditional soft proofing makes use of color appearance models to account for differences between viewing a hardcopy print and self-luminous display. More recently, soft proofing systems have started to model the glossiness of prints in addition to their color (Patil et al., 2004; Gatt et al., 2006) and display them in 3D graphics simulations. A soft proofing system using a situated display will provide the user with an interactive experience comparable to viewing a real hardcopy print, where object orientation and viewpoint changes result in dynamically varying environmental reflections off the surface of the print.

**Situated Art Reproductions:** A static image of a painting, taken from a single vantage point, cannot fully convey the appearance of the work of art. As the viewer walks around a real painting, the appearance changes due to the interplay of the environmental lighting with the spatially varying materials and media used by the artist. With an illumination map of the painting’s environment, and spatially varying bidirectional reflection distribution function (BRDF) data for the painting, the situated, viewpoint-aware display system can be used to recreate the experience of walking around a real painting to examine it from every direction.
References


Budget

Equipment:

- 20” Apple Digital Cinema Display: $600
- Digital video camera with Firewire interface (Pt.Grey GRAS 14 or equiv) $995
- USB Streaming Triaxial Accelerometer (Sensr model GP2 or equiv) $600
- GPU graphics card for Mac Pro (Nvidia GeForce 8800 GT or equiv) $280

Equipment subtotal $2,475

Summer Stipend Support: $1500

Travel (conference registration, airfare, hotel, per diem) $1500

Total request: $5,475

Project plan

Timeline and milestones:
Feb – April 2009: Acquisition and integration of hardware components
April – June 2009: Development, integration, & evaluation of rendering methods
July – Sept 2009: Application development (soft-proofing, artwork reproduction, perception research tools)
Oct 2009 –Jan 2010: Application testing and psychophysical study of material perception

Outcome:
The final outcome of this project will be the creation of a novel situated display system that allows for natural modes of interaction with virtual objects. This system will have the capability to realistically render the appearance of complex surfaces with different textures and reflectance properties. In addition to demonstrating the capabilities of advanced interactive computer graphics techniques, it will enable fundamental research in three areas: psychophysics of material appearance, soft proofing of digital print media, and high fidelity digital archiving of paintings.