The situated laptop: a tangible interface for computer-based studies of surface appearance

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In recent years, the study of surface appearance has been greatly facilitated by computer graphics and electronic display technologies that enable experiments in which images of surfaces with complex geometric, reflectance and illumination properties can be rendered and displayed with great fidelity. However, a significant limitation of current methods is that these images are typically presented statically or in pre-calculated motion sequences that are passively viewed by experiment observers. Under real-world conditions, to understand surface properties, observers often engage in complex behaviors that involve active manipulation and dynamic viewpoint changes. To support these kinds of interactions, we have developed a novel display system that supports both active manipulation and dynamic viewing of computer graphics simulations. The system is based on an off-the-shelf laptop computer that contains an accelerometer and a webcam as standard components. Through custom software that integrates these devices, we are able to actively sense the 3d orientation of the laptop's display and dynamically track the observer's viewpoint. We use this information to drive a physically-based illumination-map rendering algorithm that generates an accurately oriented and realistically shaded view of a surface to the laptop's display. 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 environmental surface reflections. The system provides a powerful research tool that allows anyone with a compatible laptop computer to use more natural modes of interaction in their surface appearance studies.

The Situated Laptop: A Tangible Interface for Computer-based Studies of Surface Appearance

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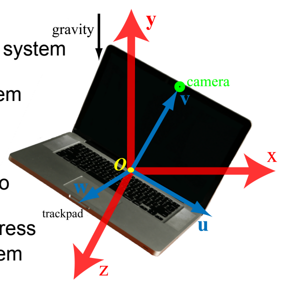
Abstract

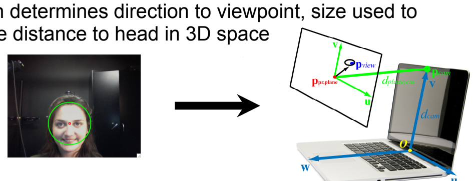
The study of surface appearance has been facilitated by computer graphics and display technologies that allow images of complex materials to be rendered and displayed with great fidelity. A limitation of current methods is that these images are often presented statically or in pre-specified sequences, and observers are not able to engage in complex behaviors involving active manipulation and dynamic viewpoint changes that may be used to help assess the surface properties of a real object. To allow for these types of interactions with virtual surfaces, we have developed a novel display system using a laptop computer that contains an accelerometer and a webcam as standard equipment. Custom software tracks the orientation of the laptop screen and the observer's position in real-time and renders images to the screen so that rotating the laptop or moving in front of the screen produces realistic changes in surface appearance.

System Design

- **Off-the-shelf MacBook Pro with custom software**
- **Coordinate systems**
  - **xyz** axes define world coordinate system with respect to gravity
  - **uvw** axes define object space system with respect to laptop landmarks



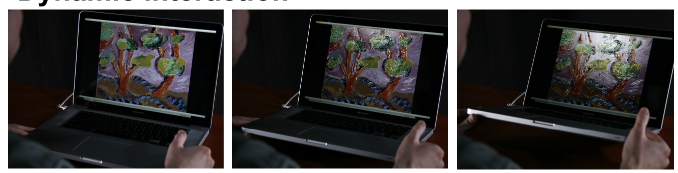
- **Orientation tracking**
  - Uses triaxial accelerometer built into Sudden Motion Sensor (SMSLib)
  - Rotation matrix **R** calculated to express orientation of **uvw** axes in **xyz** system
- **Viewpoint tracking**
  - Computer vision-based head-tracking using built-in webcam
  - Head center position and radius found in each image using Lienhart's Haar cascade algorithm from OpenCV
  - Position determines direction to viewpoint, size used to estimate distance to head in 3D space



- **Modeling and rendering**
  - Object geometry modeled as a rectangle in plane of the screen
  - Surface texture specified with an object-space normal map
  - Material properties specified by Ward (1992) model parameters: diffuse reflectance (ρ_d), specular reflectance (ρ_s), roughness (α)
  - Custom OpenGL shader uses tracking info for shading, renders from different viewpoint to place virtual surface at screen location
  - Two lighting techniques available:
    - Set of discrete lights (for speed & accuracy)
    - Cubic illumination maps (for realistic glossy reflections)

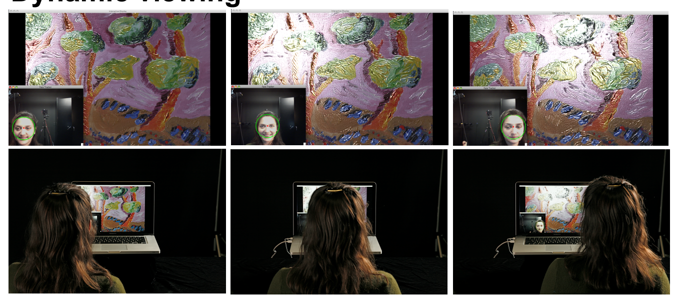
Capabilities

- **Dynamic interaction**



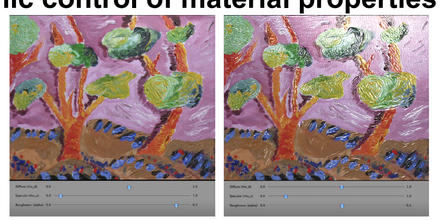
Tilting the laptop causes changes in virtual surface reflections, based on the new orientation relative to virtual lighting.

- **Dynamic viewing**



As the user moves in front of the display, the head location is detected (shown in the insets), and surface reflections are updated for the new relationship between the viewing position, surface, and virtual lighting.

- **Dynamic control of material properties**



By adjusting the sliders for the ρ_s and α Ward parameters, a surface can be changed dynamically from matte (left) to glossy (right).

- **High resolution surface texture**

  Spatially-varying normal maps can be applied to the virtual object to reproduce the appearance of mesoscale texture.

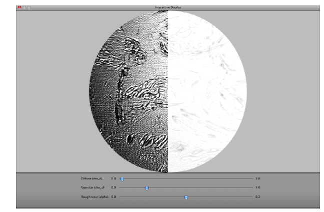
- **Lighting with real-world environment maps**

  Illumination maps captured from real environments (Debevec 1998) can be used to light the virtual surface

http://gl.ict.usc.edu/Data/HighResProbes

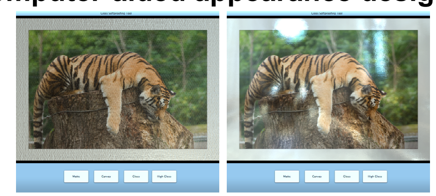
Applications

- **Psychophysics of material appearance**



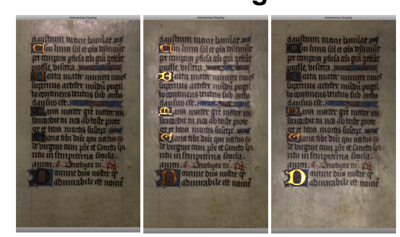
Sample experiment to study the influence of diffuse color on the perception of surface gloss. The user can adjust the ρ_s and α parameters interactively until a match in apparent gloss for the dark patch and light patch is reached.

- **Computer-aided appearance design**



Sample soft-proofing application for evaluating preferred surface properties for digital printing. The interface allows an image to be proofed on simulated photo papers with different textures and gloss levels.

- **Enhanced access to digital collections**



Sequence of images showing a model of an illuminated manuscript (digitized by Gardner et al.) displayed on the tangiBook. Tilting the display allows the user to observe changing highlights in the gold leaf and vellum.

References

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