Augmentation using projectors

Vorlesung „Augmented Reality“
Andreas Butz, Martin Wagner
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Augmentation using projectors

- Projectors and their working principles
- Using projectors as shader lamps
- Combining two projectors
- Steerable projectors
- Projection on structured surfaces
- Combining many projectors

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Ein Generisches AR-System

- Sensorik
- Tracking (Ortsbestimmung)
- Feedback an Benutzer
- Kombination realer und virtueller Inhalte
- Einbeziehung der Ortsinformation in virtuelle Welt

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Projectors

- Key Criteria
  - Resolution
  - Brightness
  - Weight
  - Noise
  - Lens
  - Image correction
  - Projection distance
  - Connections
  - Lamp life time

- E.g. Toshiba TLP-T720U
  - Wireless 802.11B

- E.g. WiJET
  - http://www.otcwireless.com/802/wijet.htm

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CRT projector

- Use R,G+B CRTs as light sources
- Good black areas
- Low brightness
- Fast
- Need to calibrate convergence!

www.projektoren-datenbank.com/rohre.htm

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LCD projector

www.projektoren-datenbank.com/lcd.htm

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Butz/Wagner - Vorlesung Augmented Reality - SS 2005
### DLP projector

- **Screen door effect**
  - Caused by LCDs
  - Less prominent in DLP

- If a DLP projector is moved, color seams appear

### Lens shift

- Optical construction
- No loss of resolution

### DLD projector (movie)

- **Lens shift**
  
  - Optical construction
  
  - No loss of resolution

- **Screen door effect**
  
  - Caused by LCDs
  
  - Less prominent in DLP

- If a DLP projector is moved, color seams appear

### Technological side effects

- **Screen door effect**
  
  - Caused by LCDs
  
  - Less prominent in DLP

- If a DLP projector is moved, color seams appear

### Keystone correction

- Computed correction
- Loss of resolution!

### Shader Lamps: Basic Idea

- Rearranging terms in optical path

- Checkerboard Light

- Plane Light

- Checkerboard Surface

- Plane Surface
**Image based Illumination**

- Basic Idea
  - Render images and project on objects
  - Multiple projectors
  - View and object dependent color

**Projector alignment**

- Position projector roughly
- Adapt to geometric relationships between physical objects
- Take fiducials on physical object and find corr. projector pixels
- Compute 3x4 projection matrix
- Decompose into intrinsic & extrinsic projector params

**Shaderlamps: Example**

**Occlusion and Overlaps**

- Several problems:
  - No color equivalence between two projectors (manufacturing & temperature color drift)
  - Minimize sensitivity to small errors in calibration parameters or mechanical variations
- Relatively good solution: Feathering

**Problem: shadow areas**

**Solution: two projectors**

Every visible surface must be illuminated by at least one lamp (projector)

**Feathering**

- Normally the overlap region is a well-defined contiguous region
- Intensity of every pixel weighted proportional to Euclidian distance to nearest boundary pixel of image
- Weights in range [0,1] multiplied with intensities in the final image
**Feathering**

- If both projectors produce the same color, \( A+B \) at maximum and constant over the surface.
- If not, \( A+B' \) produces a smooth transition.

**Feathering**

1. Sum of intensity weights of projector pixels is 1 \( \Rightarrow \) Intensities normalized.
2. Weights along the physical surface change smoothly in and near overlaps \( \Rightarrow \) suppress discontinuity due to color differences.
3. Smooth distribution of intensities per projector \( \Rightarrow \) suppress sharp edges due to small errors in calibration or mechanical variations.

**Feathering**

- Find regions illuminated by one projector and assign weight=1.
- Use shortest euclidian distance to a pixel with weight=1 to compute weight.

**Examples**

**Radiosity**

- Objects illuminated by direct and indirect light.
- Parts of an object can scatter light onto other parts of the object and other objects.
- High computational effort to calculate correctly.
- Often approximated by “ambient light”.
- Comes for free with shaderlamps.

**Feathering**

- Non-convex objects.
- Collection of disjoint objects:
  - Shadows.
  - Fragmented overlaps.
  - Depth discontinuities.
**Limitations**

- Must have neutral physical surface (white, pure diffuse color)
- Dark ambient lighting
- Secondary scattering makes it difficult to mimic low reflectance surfaces
- Projectors have limited depth of field, reduced dynamic range and non-uniformity
- Shadows can disturb the view

**Implementation**

- 2 Projectors with 1024x768 resolution
- Rendering with OpenGL
- Vase 12 cm x 12 cm x 35 cm
  - 7000 Triangles
- Taj Mahal 70 cm x 70 cm x 35 cm
  - 21 000 Triangles
  - 15 Texture Maps
- Calibration about 5 min per projector
- Re-projection error less than 2 Pixels
- Intensity weights computation in preprocessing (10 sec per projector)
- Application of weights with alpha-blending

**Example**

![Example Image](image1)

**Setup**

![Setup Image](image2)

**Cartoon Dioramas in Motion**
Painting on Movable Objects

- Objects hand-held or set on table.
- Tracked stylus with spherical tip
  - facilitates contact painting
- Projected touch palette, modeled as a static object with behavior:
  - choose contact, spray or texture paint
  - choose brush color

http://www.cs.unc.edu/~debug/papers/DSLpaint/

Everywhere Display Projector (IBM)

Everywhere Displays projector

Claudio Pinhanez

www.research.ibm.com/ed/

Dynamic Shaderlamps: Setup

Dynamic Shaderlamps: Video

Everywhere display (cont.)

Output: a projector and a rotating mirror
Input: a camera for interaction, NOT for image rectification!

Undistorting the projected image

- Place original image in the 3D model
- Virtual camera image shows it distorted
- Project the distorted image from 3D model with the Real projector into the real world

- Distortions cancel each other out IF virtual camera and real projector are in the same location
Everywhere display (cont.)

- Correct distortions
  - Use the fact that camera and projectors are geometrically the same (optically inverse)
- Use standard HW components
  - 3D-Graphics board and VRML-world

Everywhere display (cont.)

BLUESPACE office scenario

Everywhere display (cont.)

Steps 1: Room Scanning

- Projector/camera unit moving and taking pictures
  - Until the whole room is covered
  - Neighbouring pictures slightly overlap
- Recognized marker IDs are stored with:
  - pan/tilt values when taking the picture
  - position of the marker in the picture

SearchLight: Basic Idea

- Build a search function for physical objects
- A tool for directing the user's attention
- No 3D model of the environment

Ideas for realization:
- Optical markers for object recognition
- Highlighting by a projected spot

Other Applications

Step 2: Showing objects

• Retrieve object's marker ID
• Move unit to stored pan/tilt position
• Project a spot around the marker's position

Calibration step

• **Measuring the Luminance Response:** The *luminance response* of any pixel is defined as the variation of luminance with input at that pixel. We measure the luminance response of every pixel of the display with a camera.
• **Finding the Common Achievable Response:** We find the common response that every pixel of the display is capable of achieving. The goal is to achieve this common achievable response at every pixel.
• **Generating the Luminance Attenuation Map:** We find a luminance attenuation function that transforms the measured luminance response at every pixel to the common achievable response.

Smart Projectors

[Oliver Bimber et al., IEEE Computer, January 2005]

• Projection onto curved surfaces can be solved by 3D rectification, but:
• What if the projection surface is not uniformly colored?
• See Video (scientific) or Video (TV)

Measured luminance response

• Gives a factor for multiplication of the final images (just as in feathering)
• Can be done in graphics hardware via alpha channels

Luminance Attenuation Map

[Majumder & Stevens, VRST 2002]

• Large display wall with 5x3 projectors
• Linear ramps (feathering) don’t work perfectly
• Goal: get rid of the remaining unevenness
• Strategy: don’t assume, but measure!

LAM: results
**PixelFlex2**

[Raij, Gill, Majumder, Towles, Fuchs, ProCams 2003]

- Uneven brightness and arbitrary geometry:
  - Rectify each projector by calibrating 4 points
  - Used LAMs for brightness

**What we saw today**

- Projectors and their working principles
- Using projectors as shader lamps
- Combining two projectors
- Steerable projectors
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- Combining many projectors

**Schönes Wochenende!**

**Graphic Shadow**

[Kato et al. Ismar 2003]

- Creative use of two projectors and a camera:
  - Can remove physical shadows
  - Can add artificial shadows
  - Can animate shadows
  - See [video](#)