

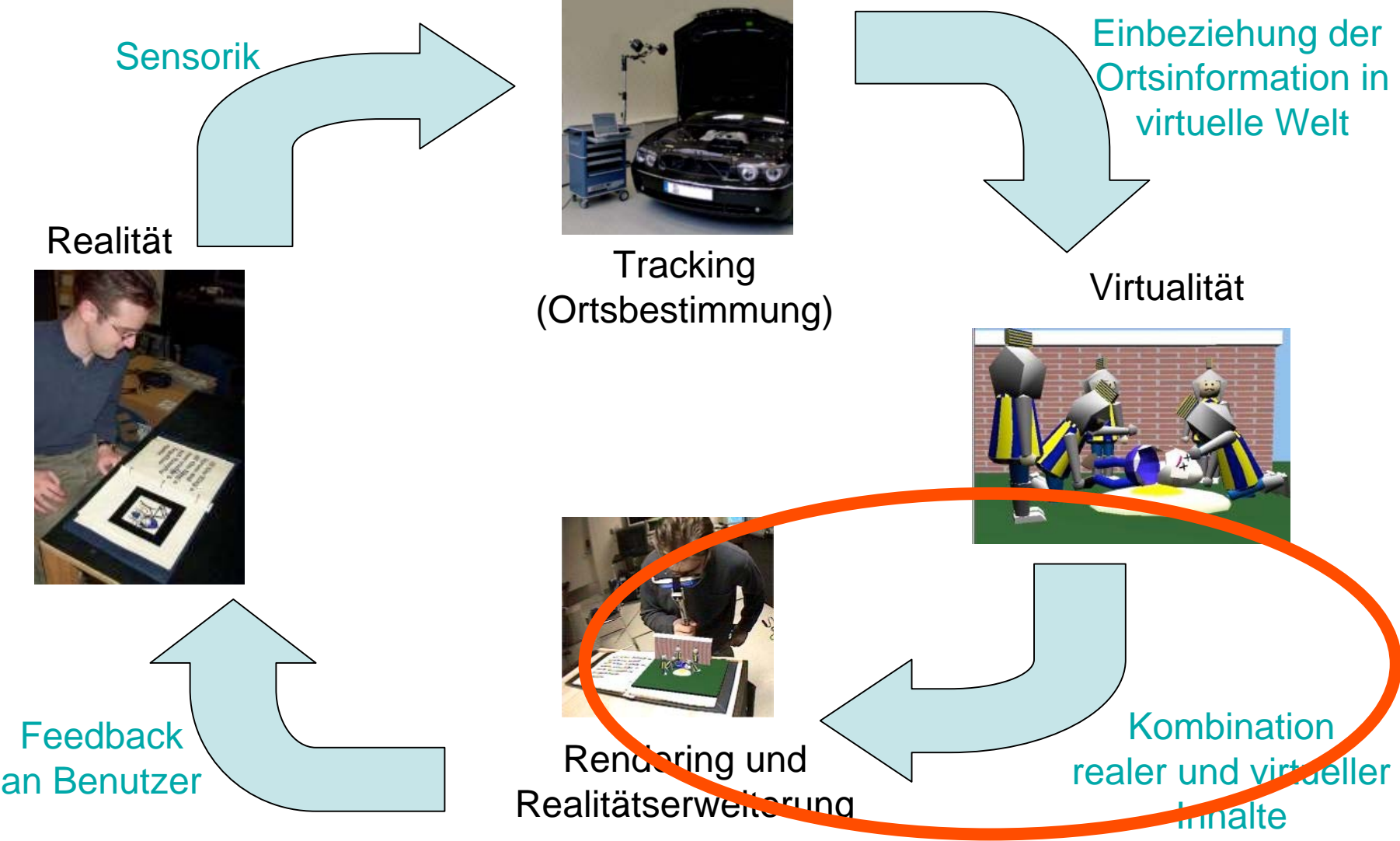
Augmentation using projectors

Vorlesung „Augmented Reality“

Prof. Dr. Andreas Butz

WS 2006/07

Ein Generisches AR-System



Augmentation using projectors

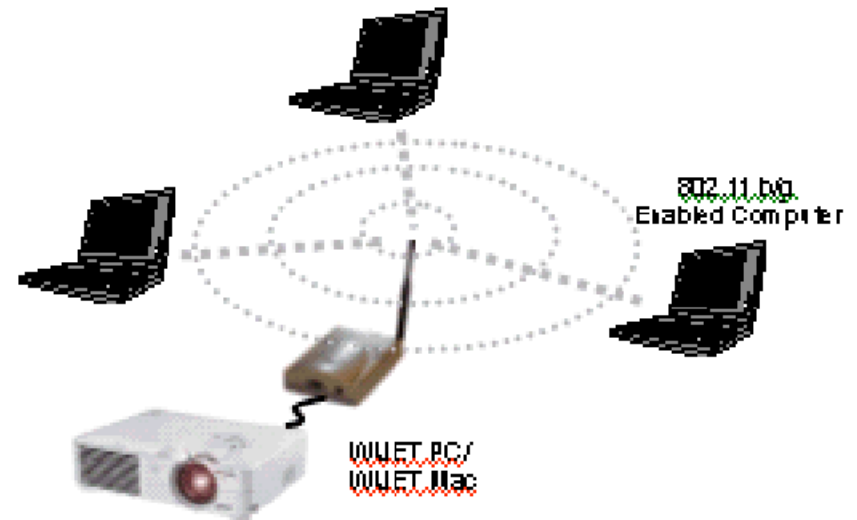
- Projectors and their working principles
- Using projectors as shader lamps
- Combining two projectors
- Steerable projectors
- Projection on structured surfaces
- Combining many projectors

Projectors

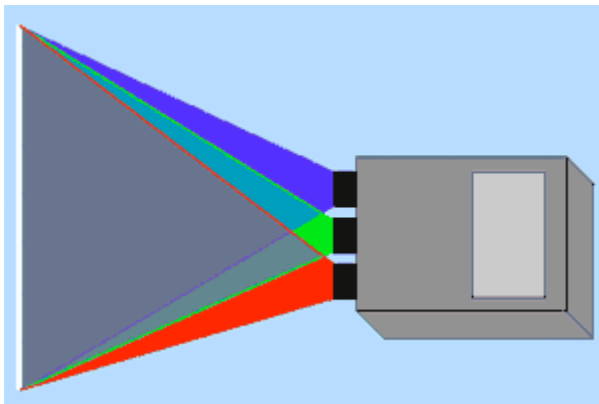
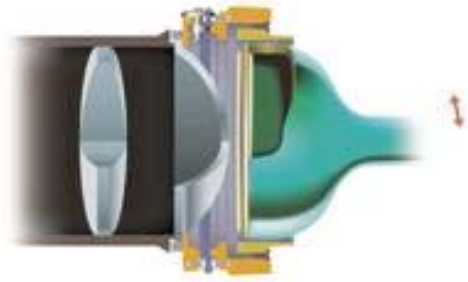
- Key Criteria
 - Resolution
 - Brightness
 - Weight
 - Noise
 - Lens
 - Image correction
 - Projection distance
 - Connections
 - Lamp life time



- E.g. Toshiba TLP-T720U
 - Wireless 802.11B
- E.g. WiJET
 - <http://www.otcwireless.com/802/wijet.htm>



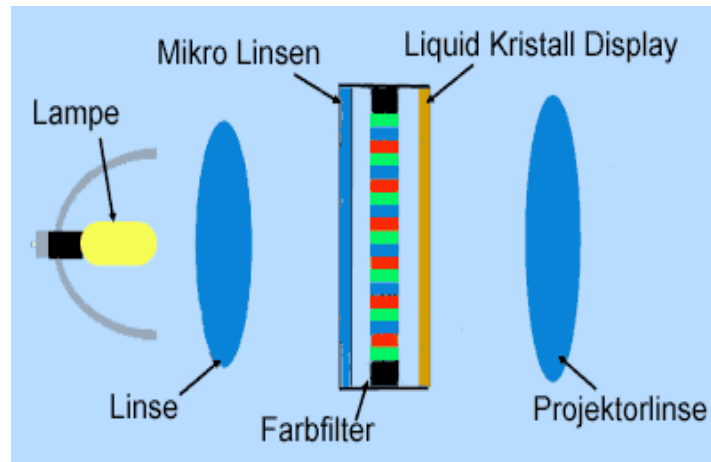
CRT projector



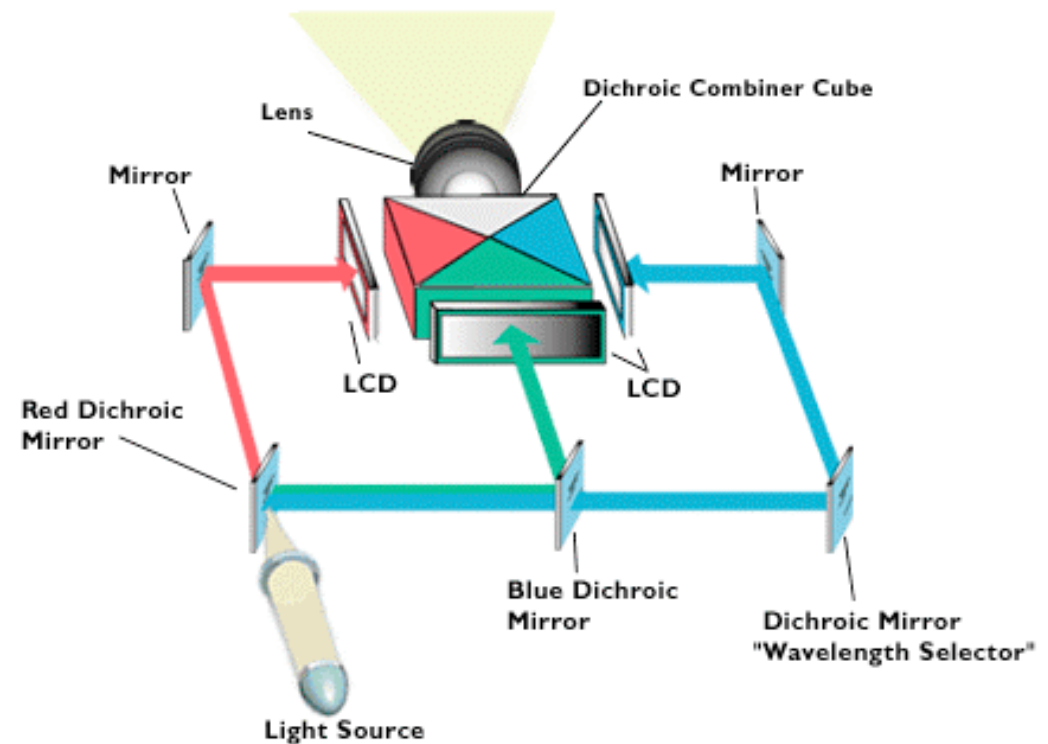
- Use R,G+B CRTs as light sources
- Good black areas
- Low brightness
- Fast
- Need to calibrate convergence!

www.projektoren-datenbank.com/rohre.htm

LCD projector

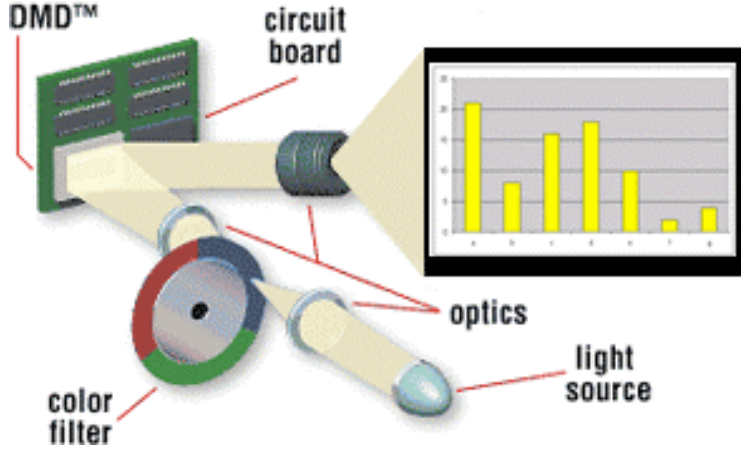
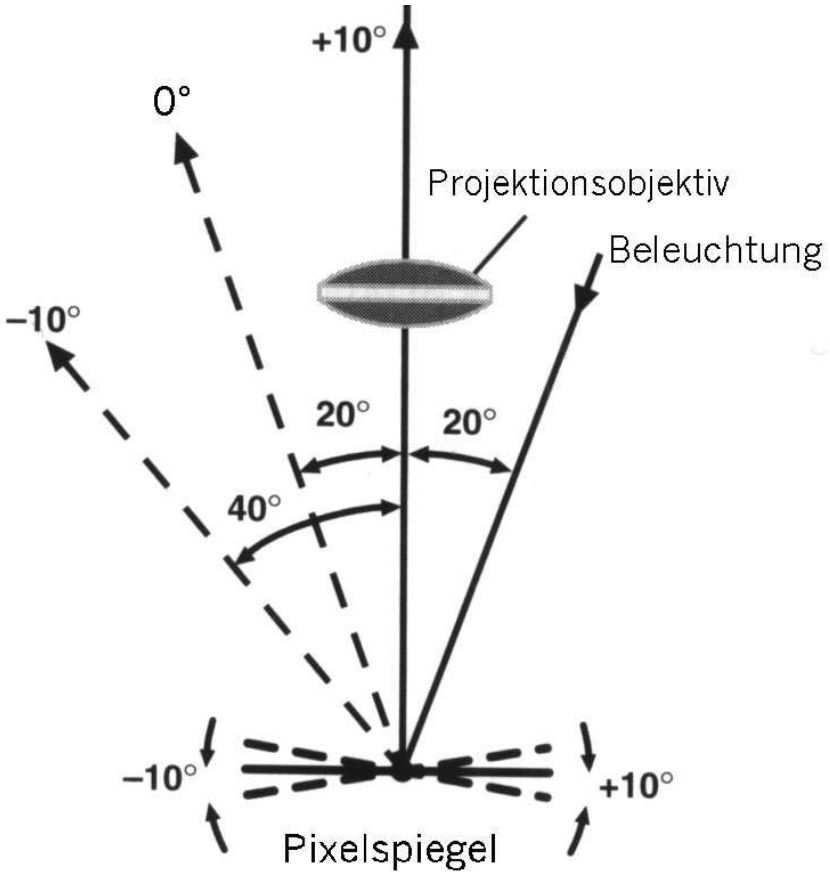
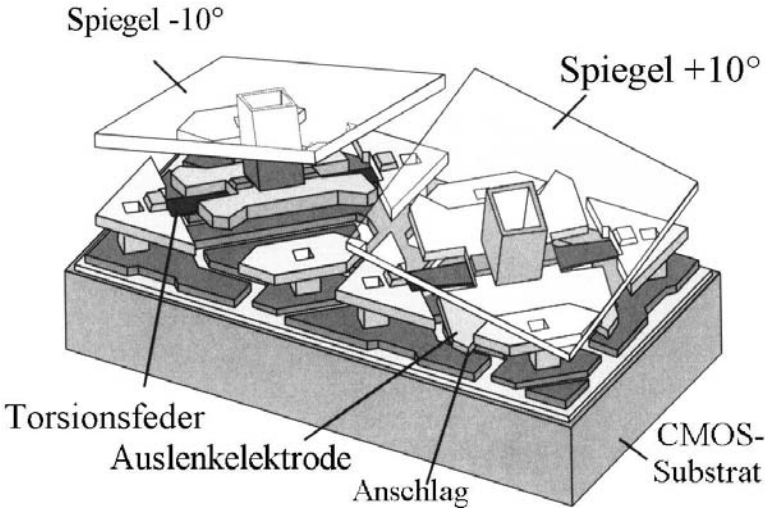


www.projektoren-datenbank.com/lcd.htm

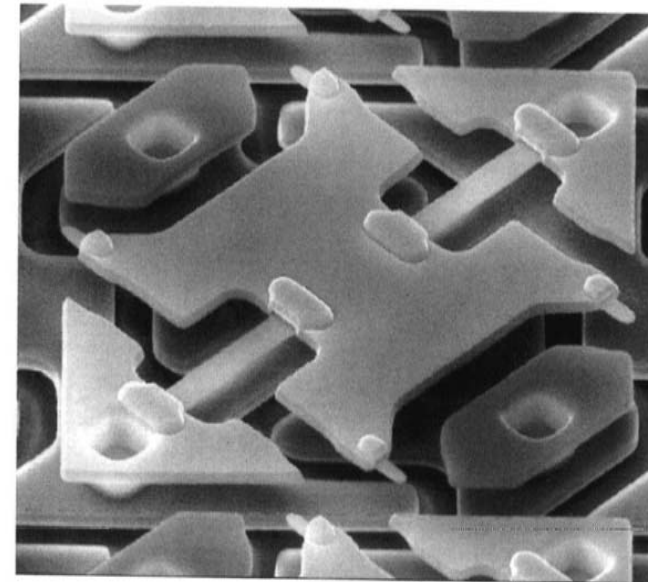
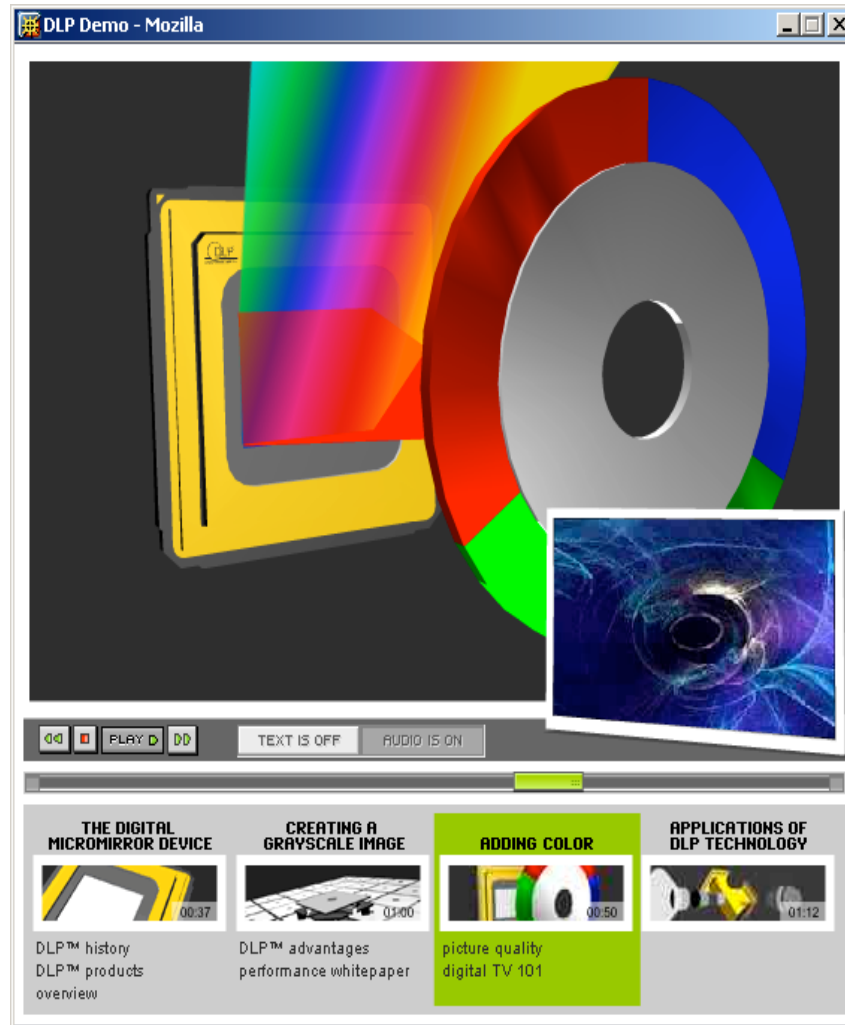


www.projectorpoint.co.uk/projectorLCDvsDLP.htm

DLP projector

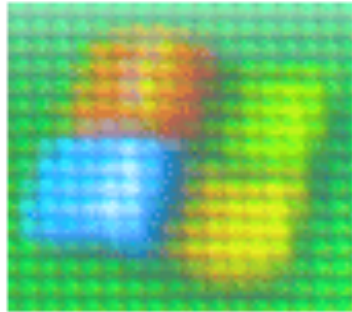


DLD projector (movie)

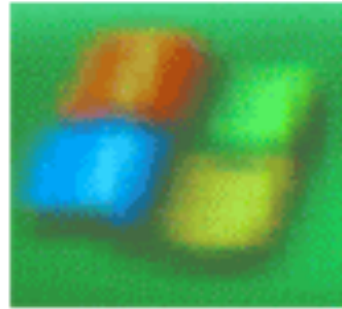


<http://www.dlp.com/>

Technological side effects



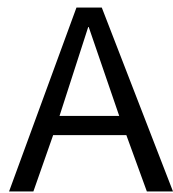
LCD



DLP

(image is a magnified portion of the start up icon)

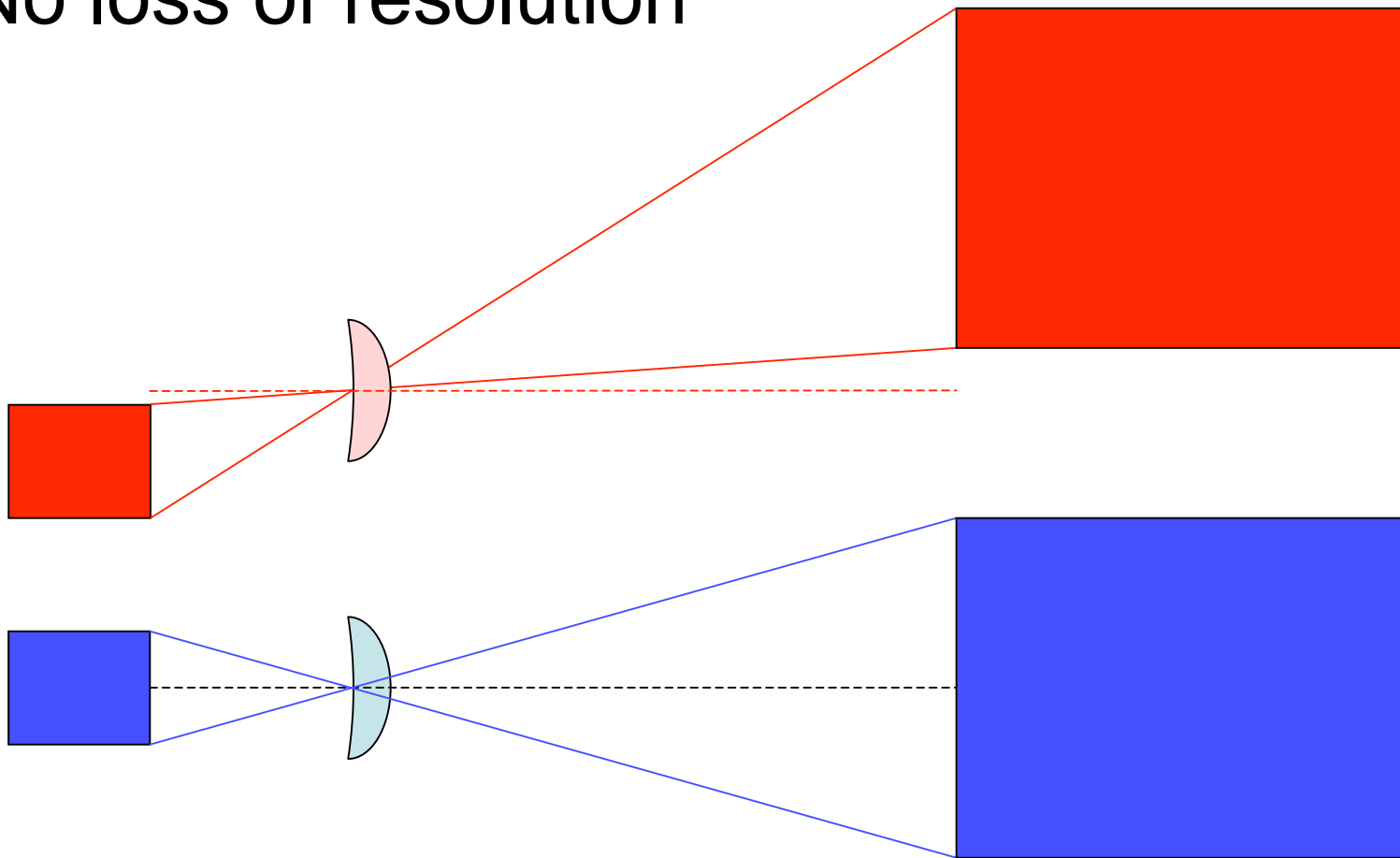
- Screen door effect
 - Caused by LCDs
 - Less prominent in DLP



- If a DLP projector is moved, color seams appear

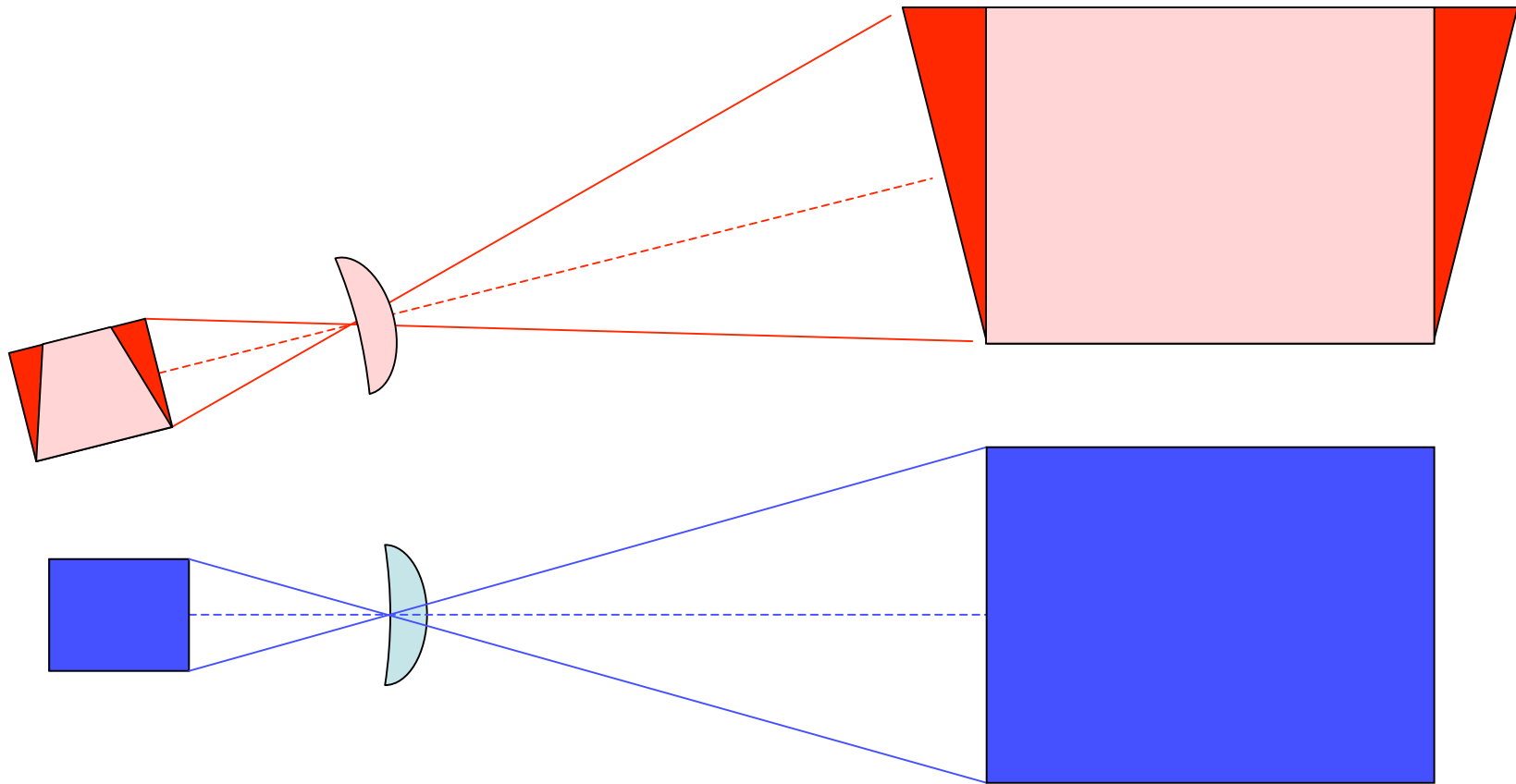
Lens shift

- Optical construction
- No loss of resolution



Keystone correction

- Computed correction
- Loss of resolution!



Shader Lamps: Basic Idea

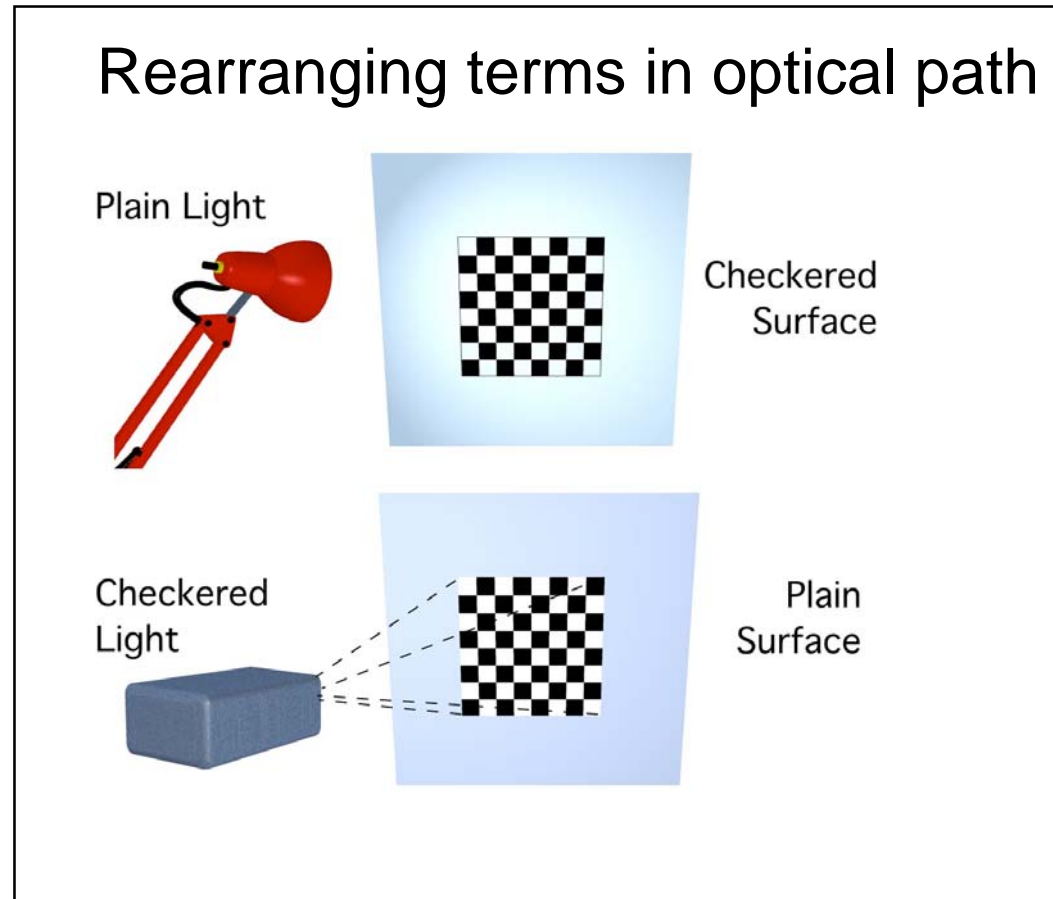
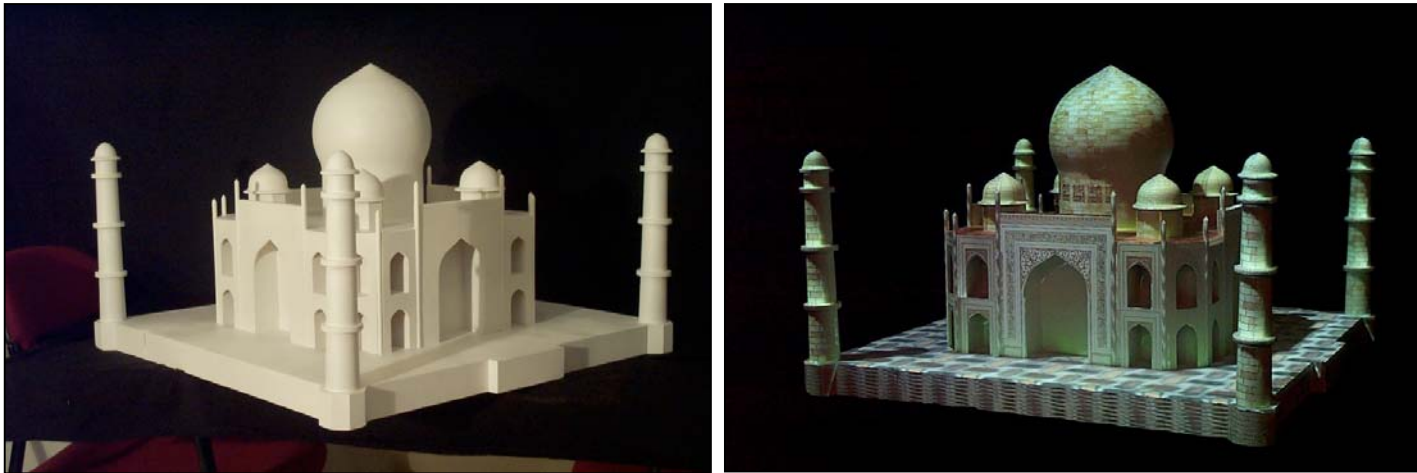
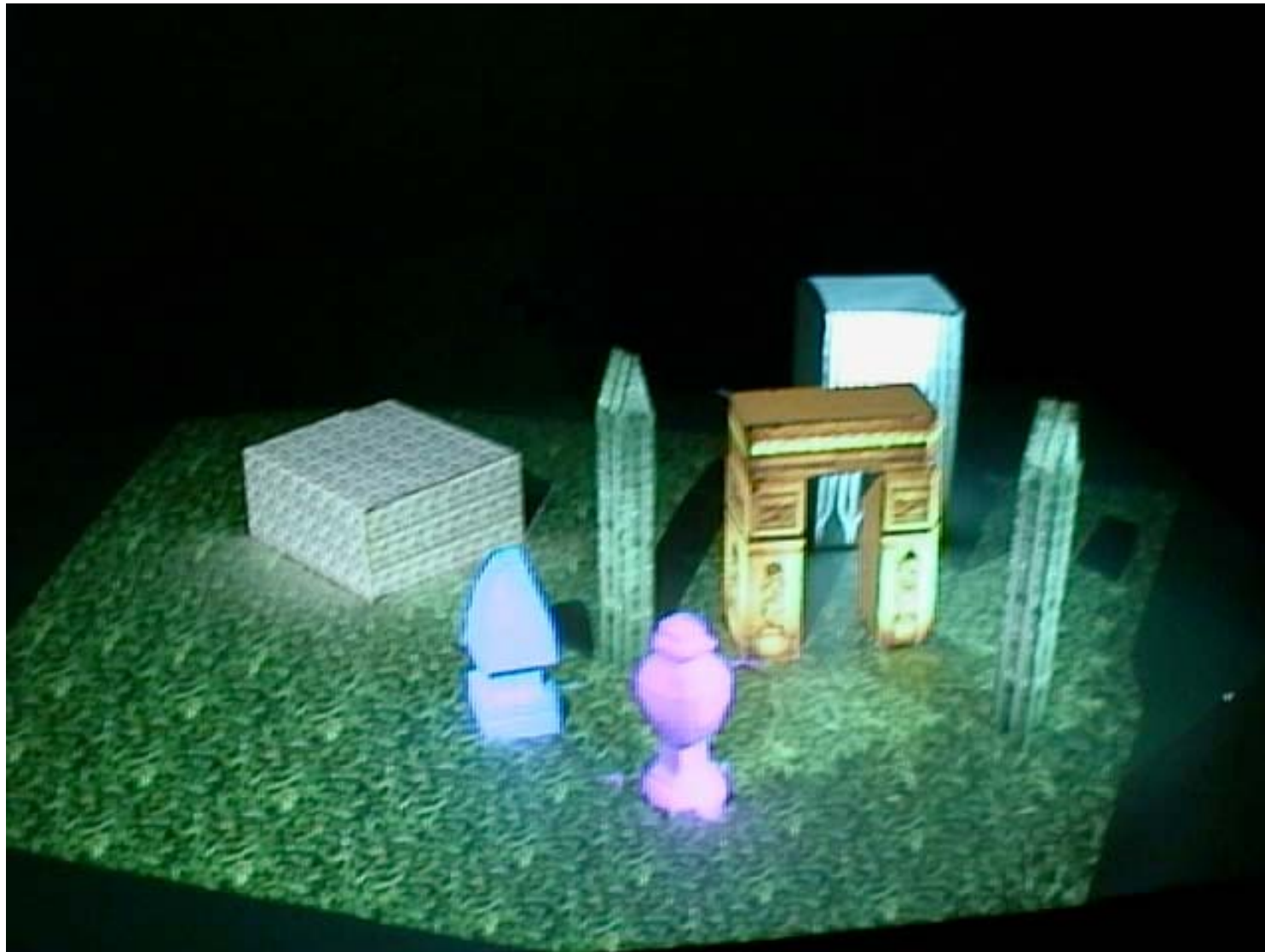


Image based Illumination

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

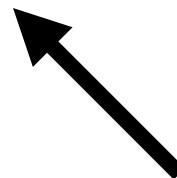
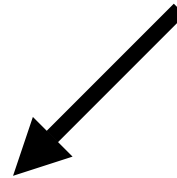


Shaderlamps: Example



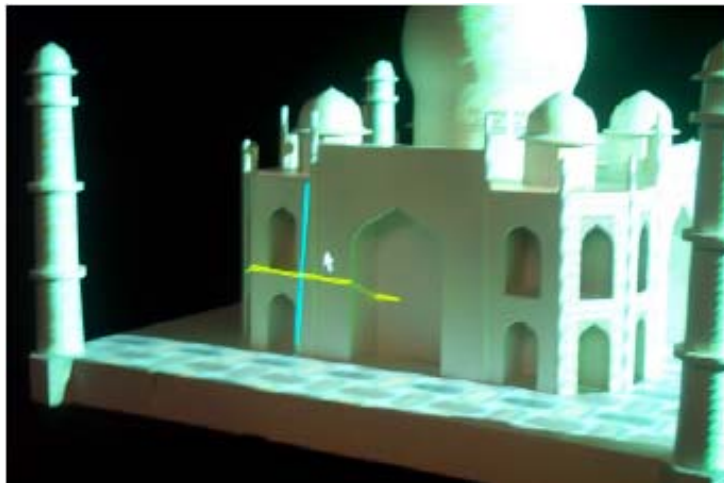
Problem: shadow areas

Solution: two projectors



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

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

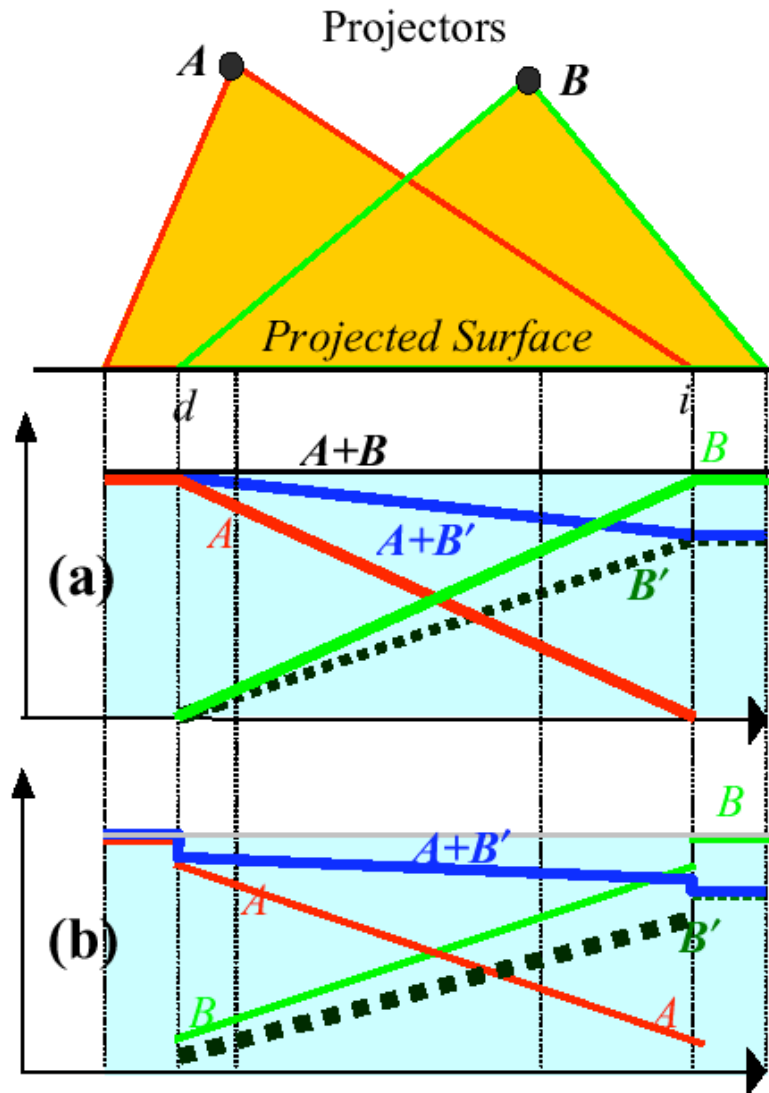
Occlusion and Overlaps

- 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

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

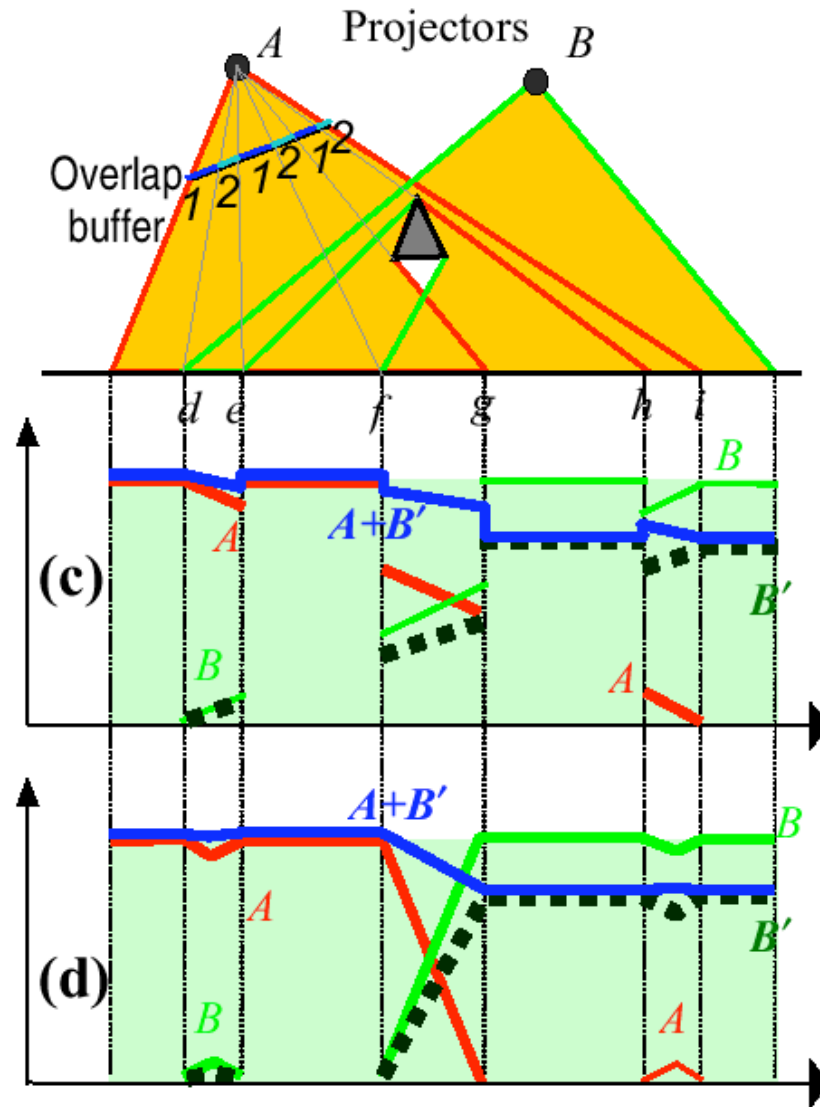


- If both projectors produce same color, $A+B$ at maximum and constant over surface
- If not $A+B'$ produces smooth transition

Feathering

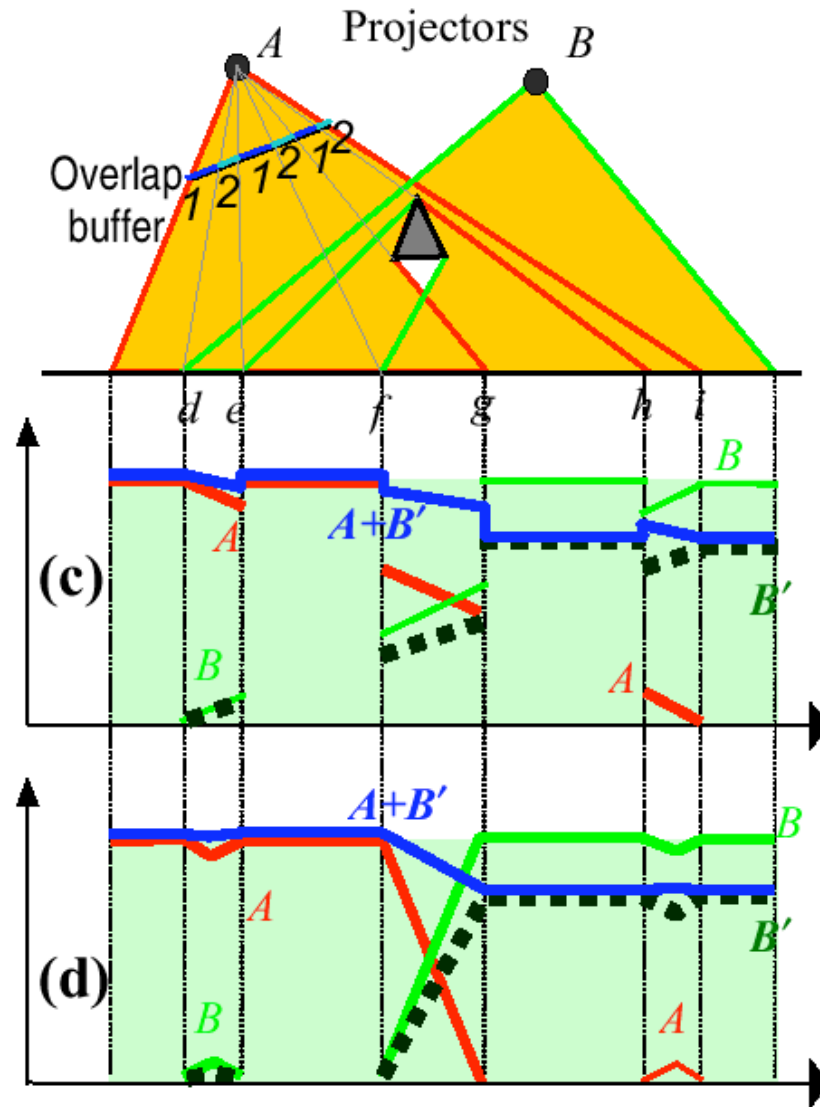
1. Sum of intensity weights of projector pixels is 1 → Intensities normalized
2. Weights along physical surface change smoothly in and near overlaps → suppress discontinuity due to color differences
3. Smooth distribution of intensities per projector → suppress sharp edges due to small errors in calibration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

Feathering



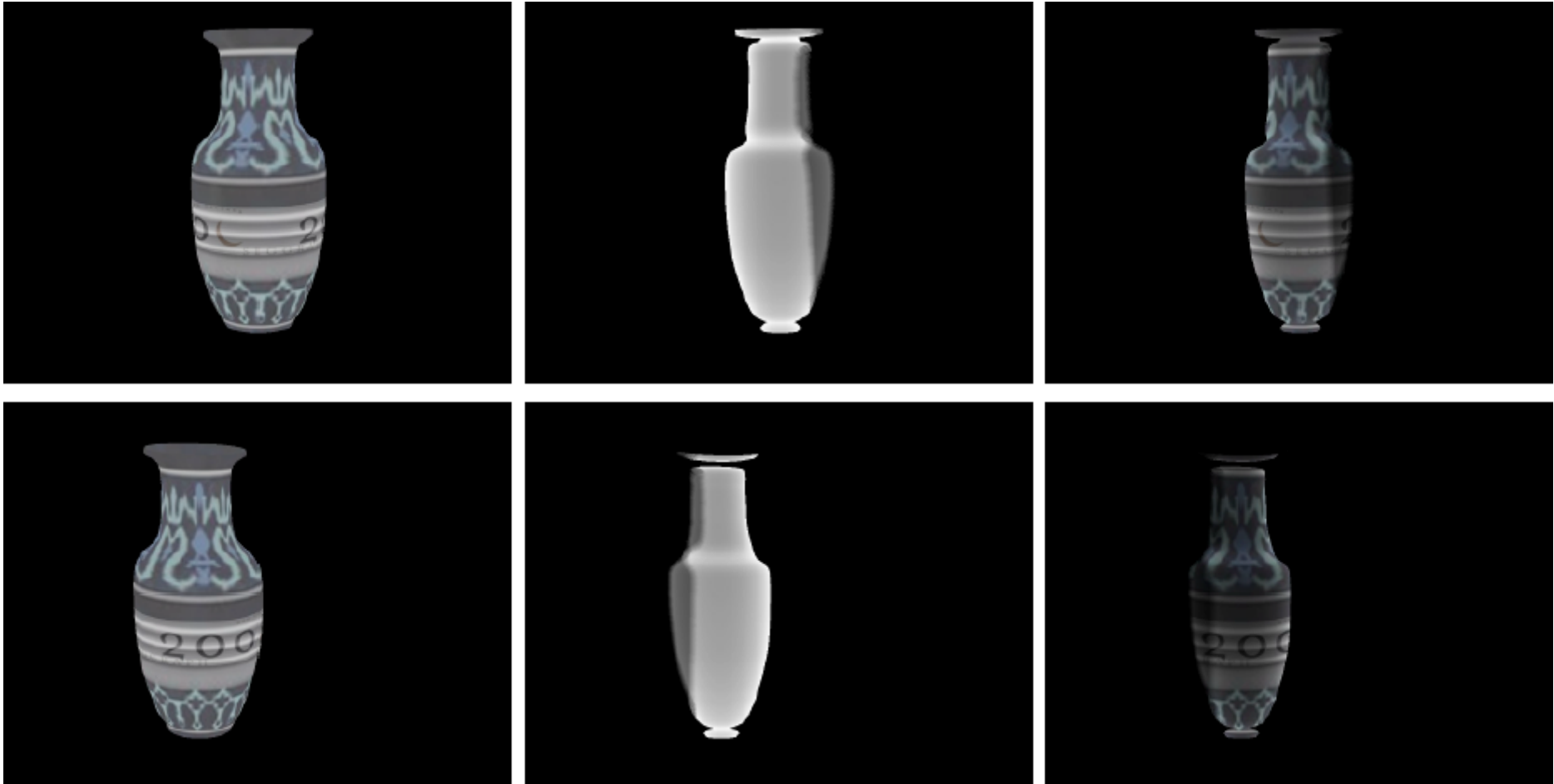
- Non-convex objects
- Collection of disjoint objects
- Shadows
- Fragmented overlaps
- Depth discontinuities

Feathering

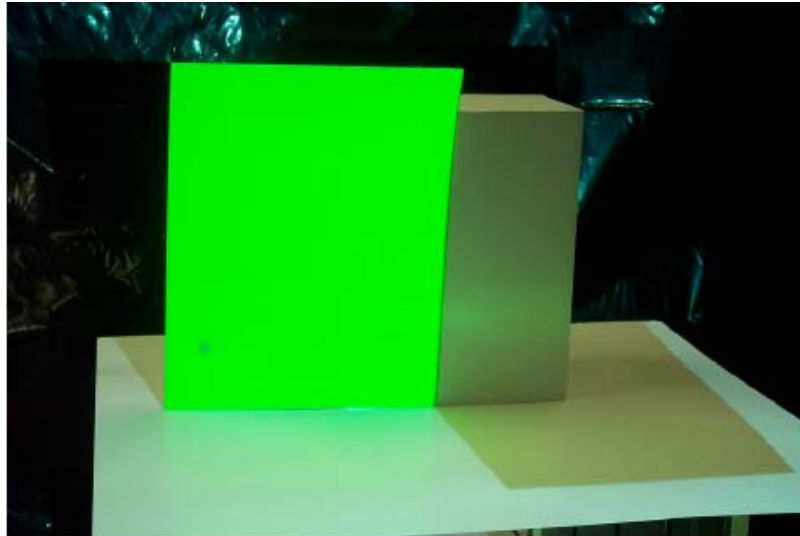


- Find regions illuminated by one projector and assign weight=1
- Use shortest euclidian distance to a pixel with weight=1 to compute weight

Examples



Radiosity

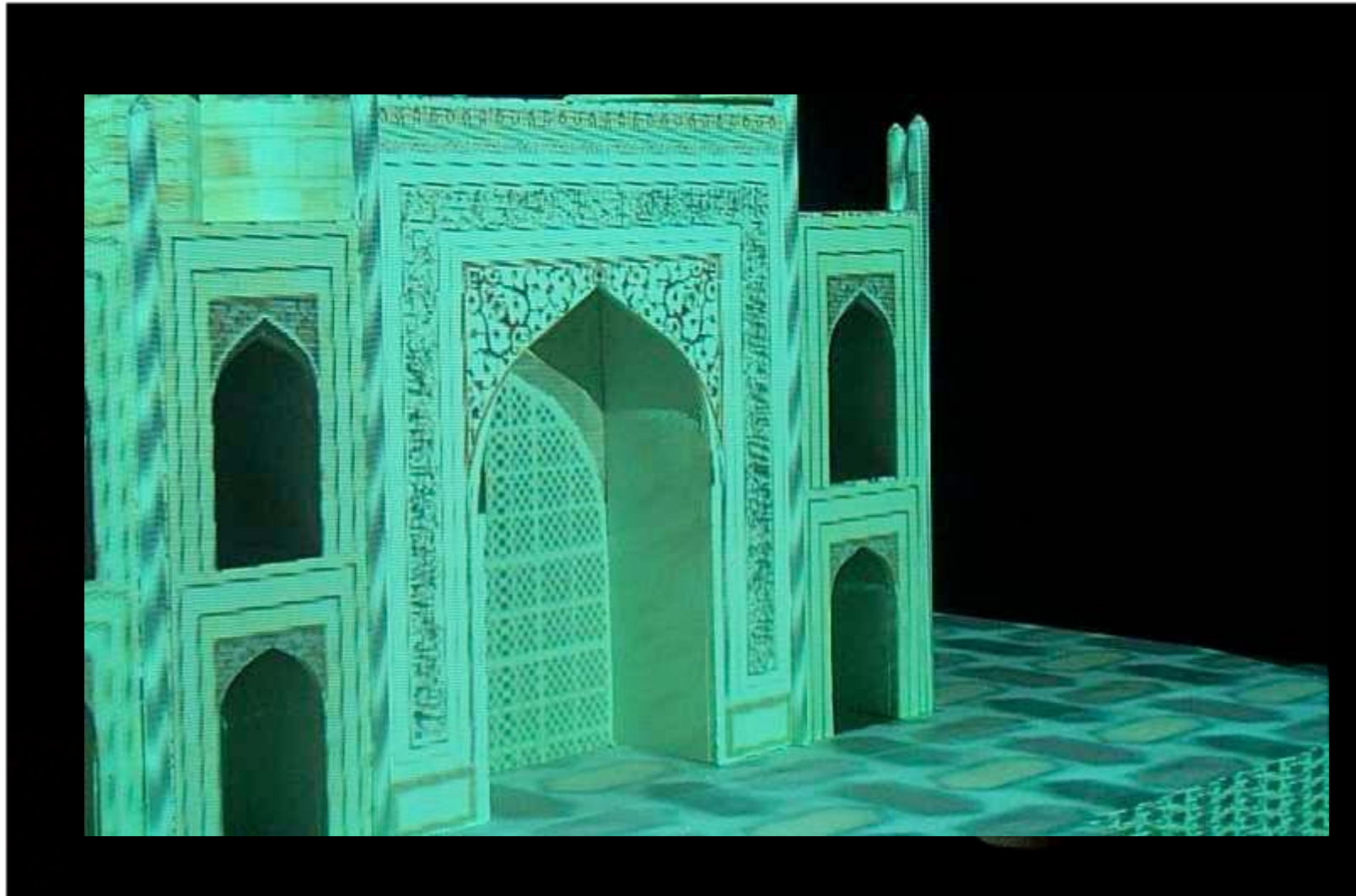


- Objects illuminated by direct and indirect light
- Parts of an object can scatter light onto other parts of object and other objects
- High computational effort to calculate correctly
- Often approximated by „ambient light“
- Comes for free with shaderlamps!

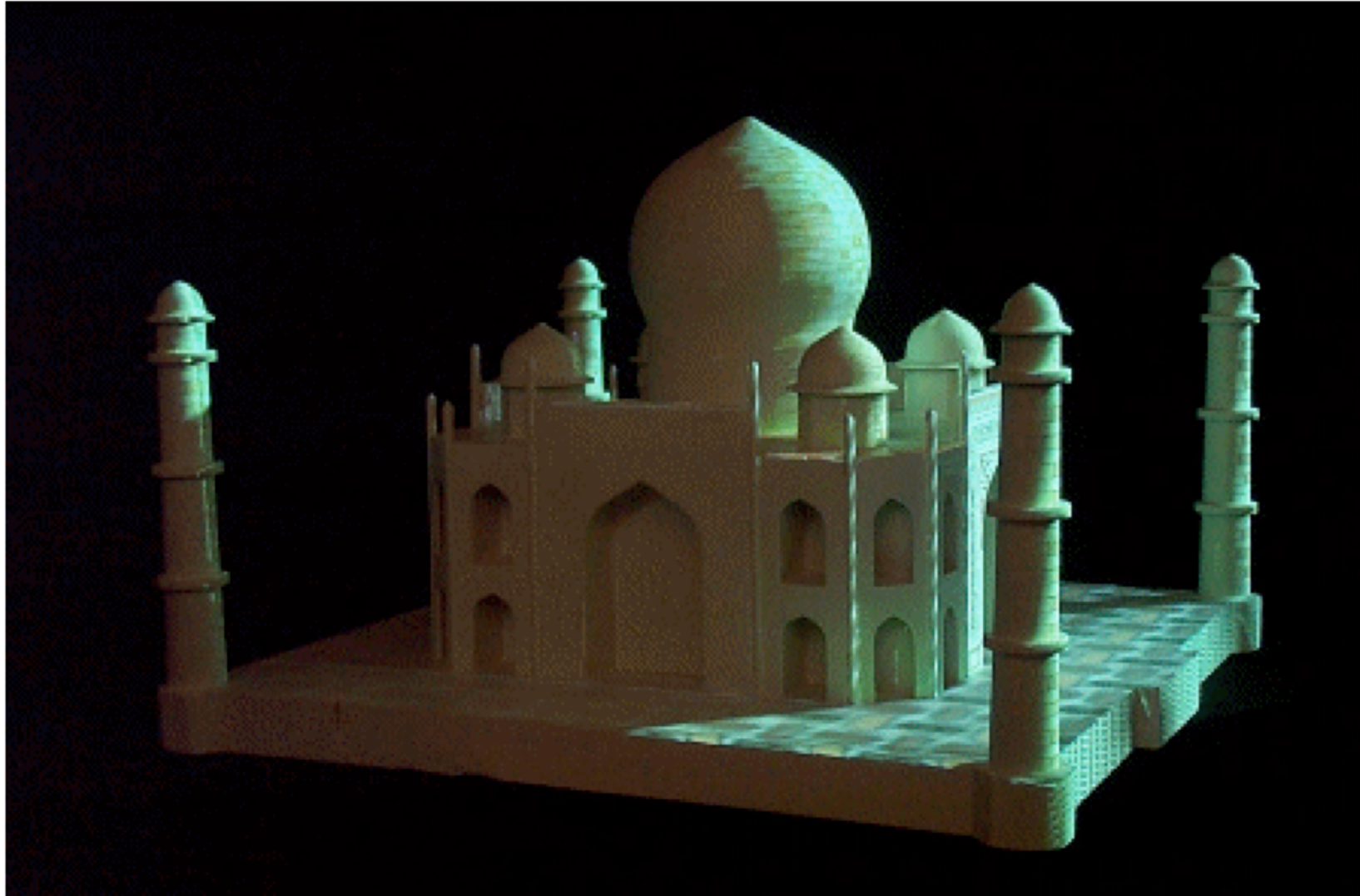
Limitations

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

Example



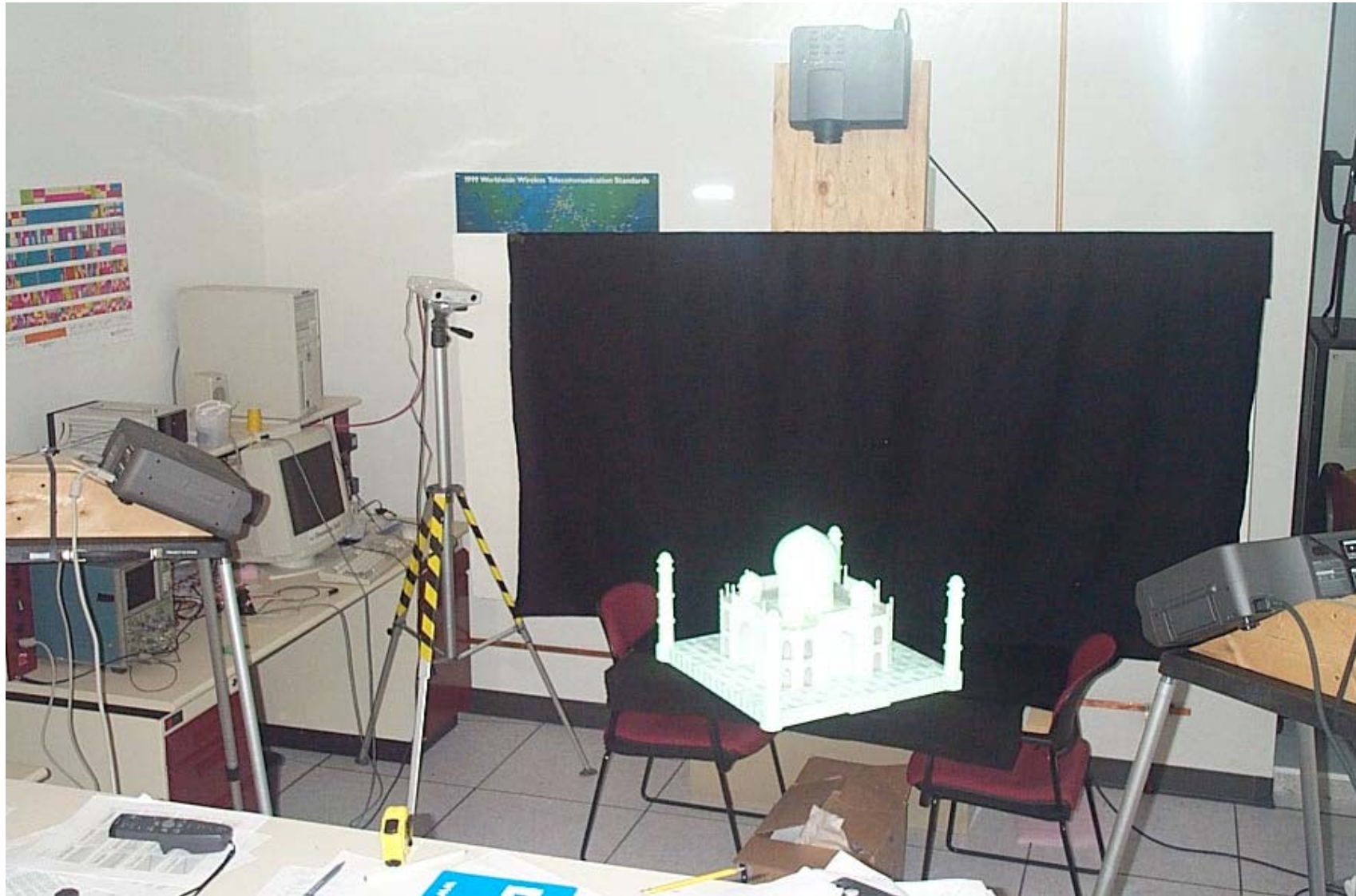
Example



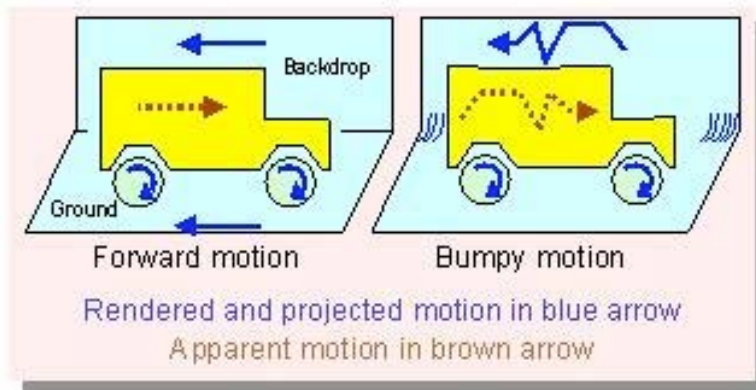
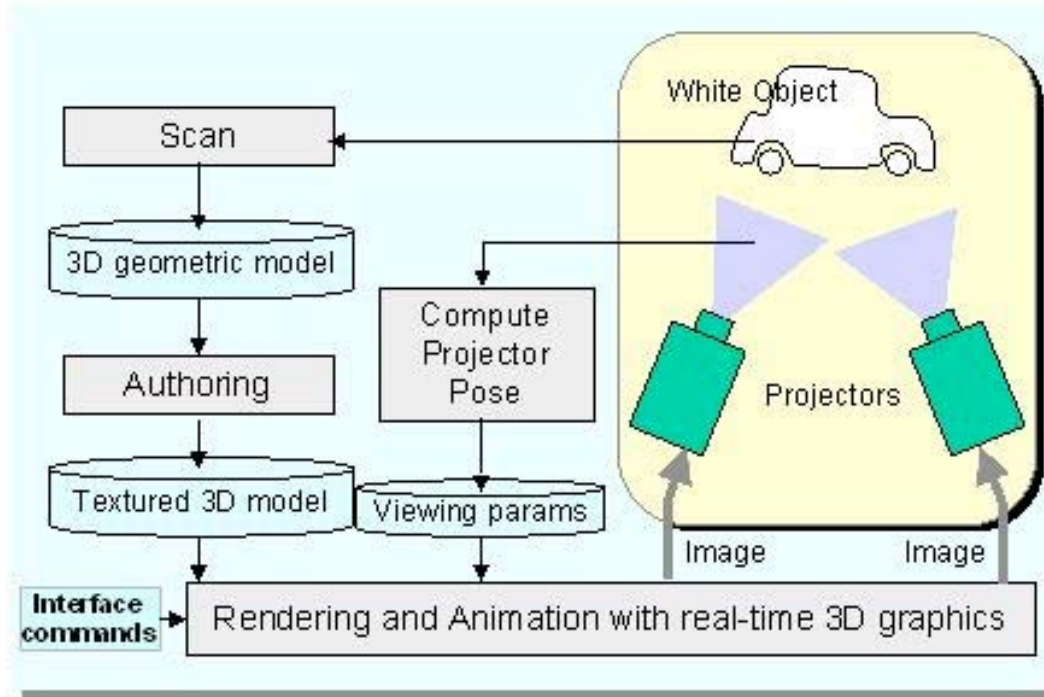
Implementation

- 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

Setup



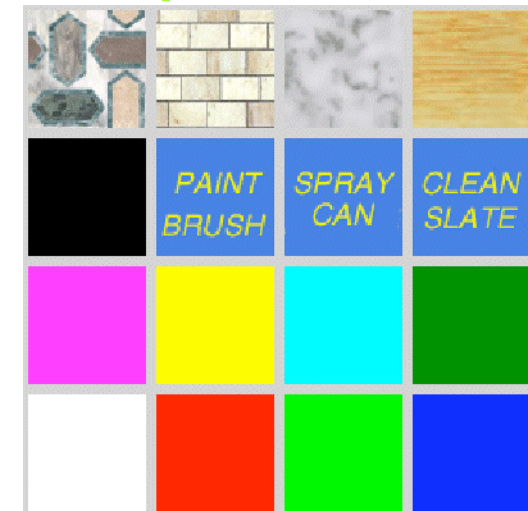
Cartoon Dioramas in Motion



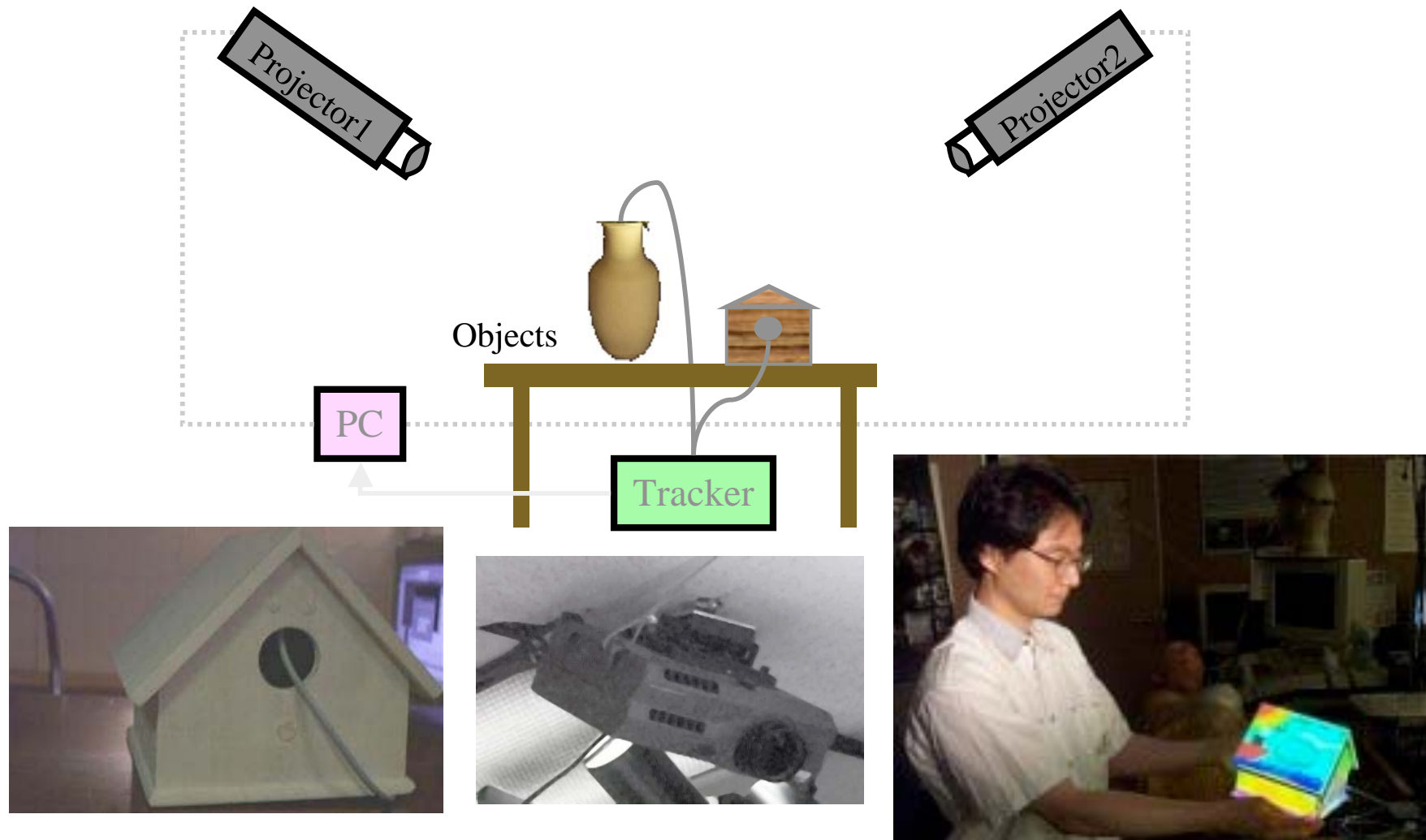
Painting on Movable Objects

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

- 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



Dynamic Shaderlamps: Setup

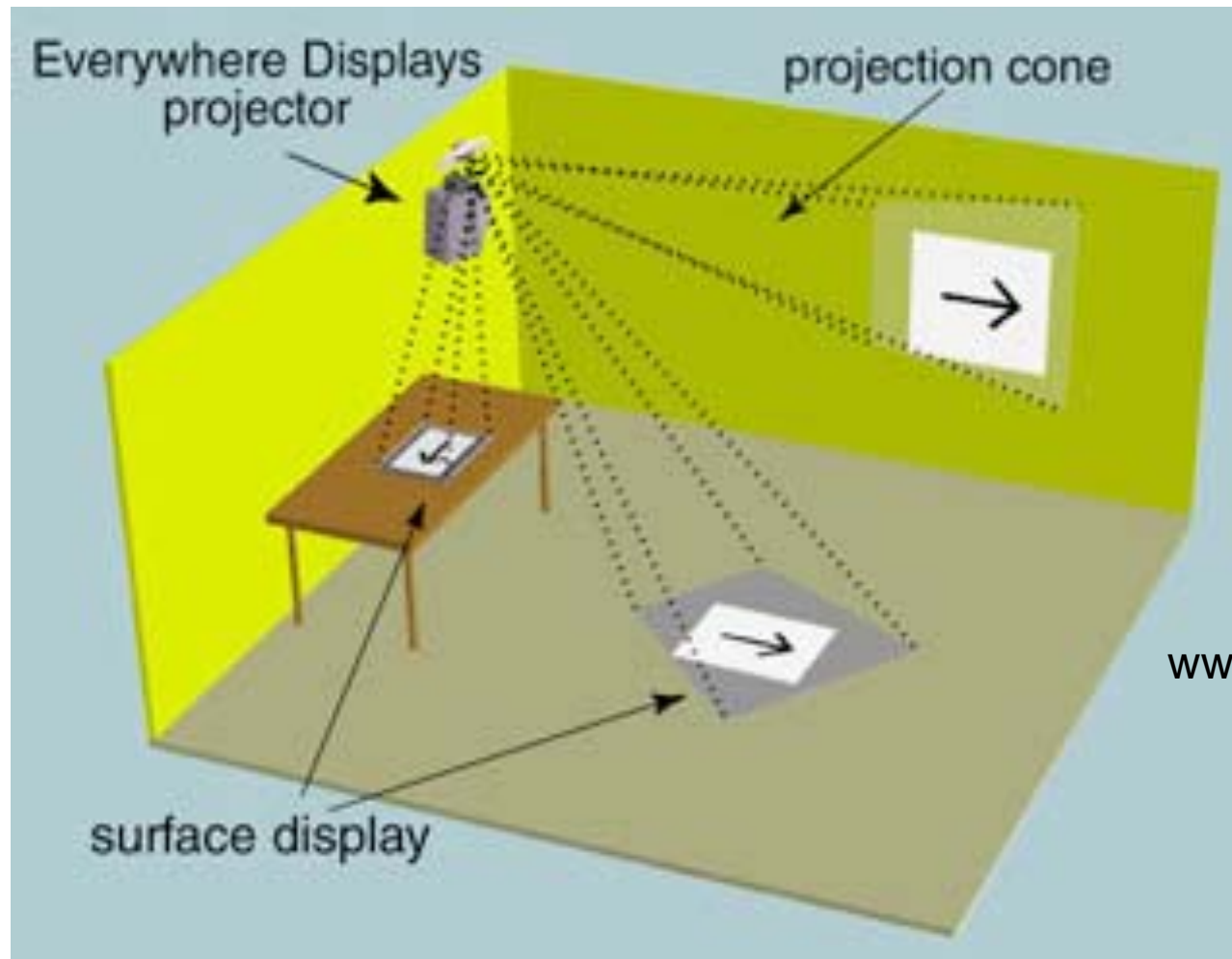


Dynamic Shaderlamps: Video



Everywhere Display Projector (IBM)

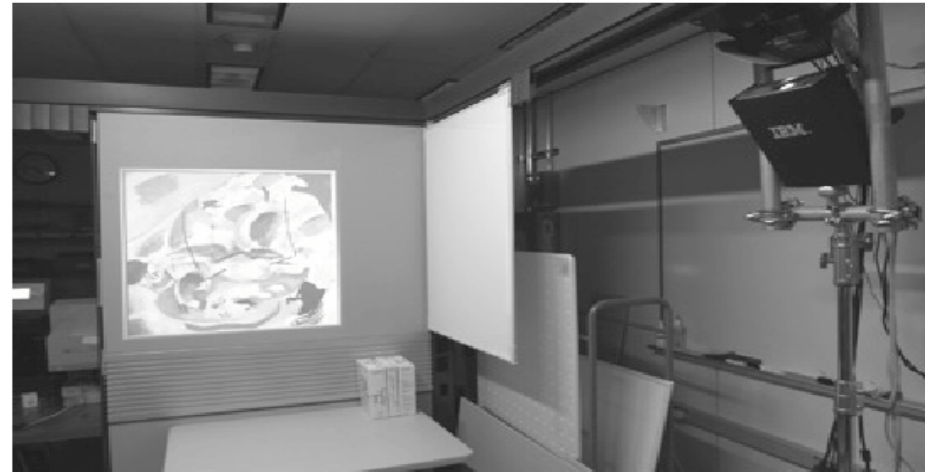
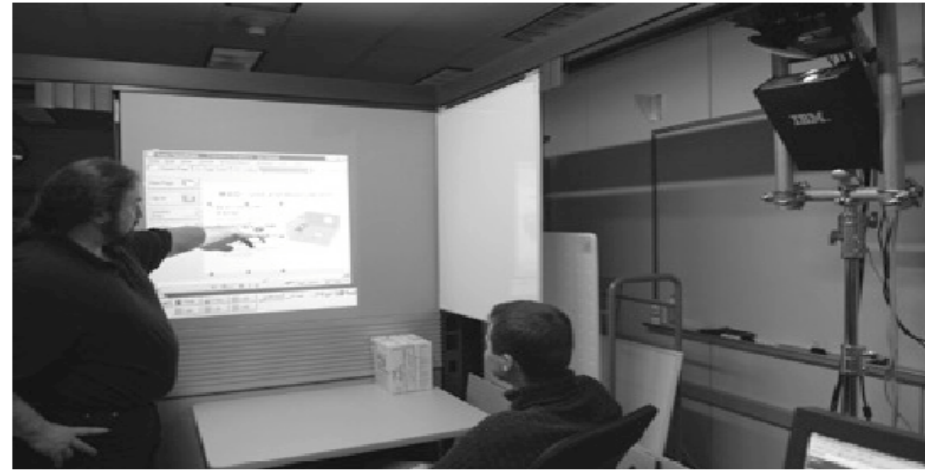
<http://www.research.ibm.com/ed/>



Claudio Pinhanez

www.research.ibm.com/ed/

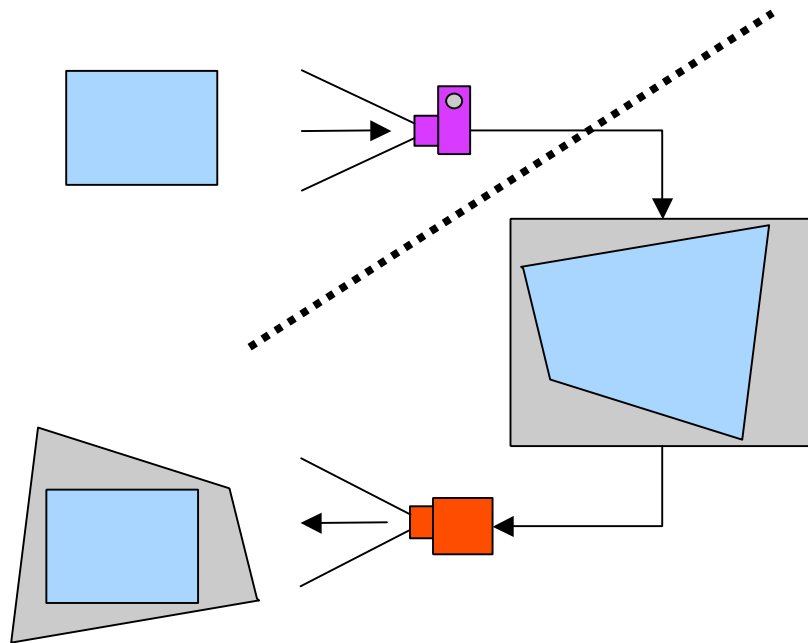
Everywhere display (cont.)



Output: a projector and a rotating mirror

Input: a camera for interaction, NOT for image rectification!

Undistorting the projected image

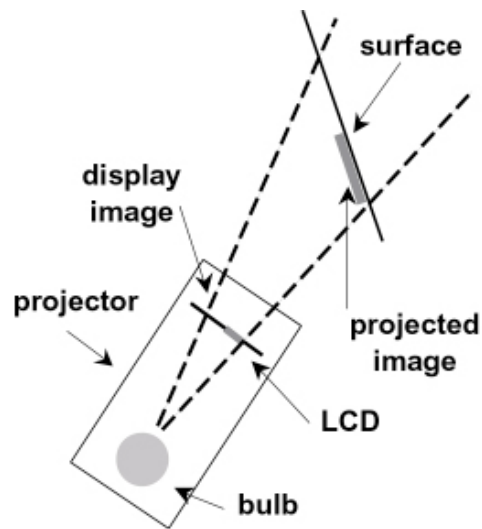


- Place original image in the **3D model**
- **Virtual** camera image shows it distorted
- Project the distorted image from 3D model with the **Real** projector into the **real world**

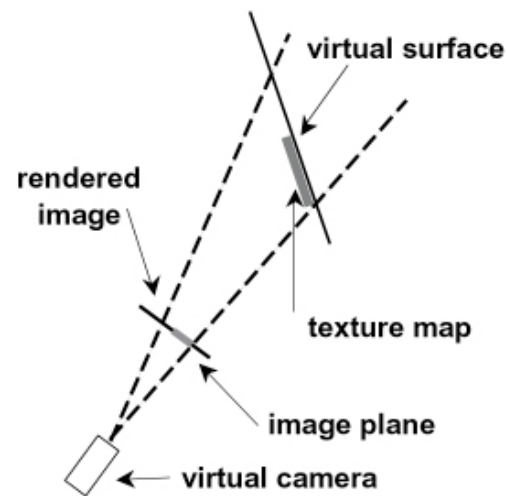
– Distortions cancel each other out IF **virtual** camera and **real** projector are in the same location

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



REAL WORLD



VIRTUAL 3D WORLD

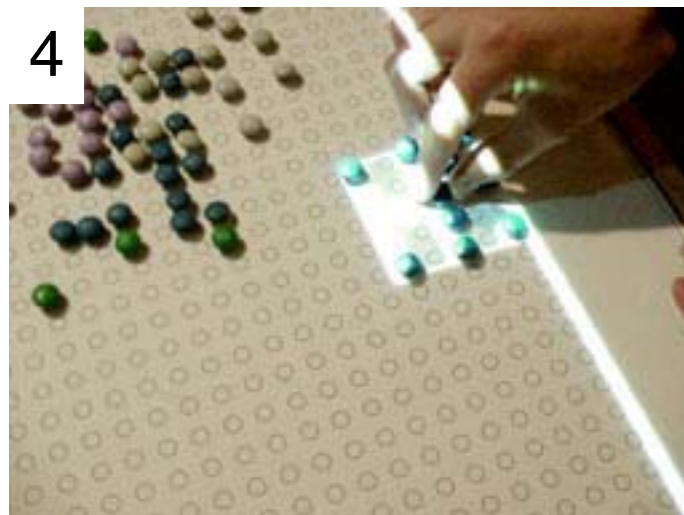
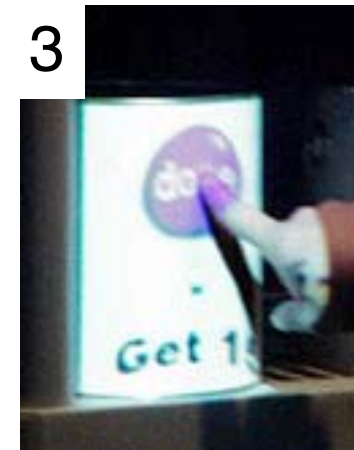
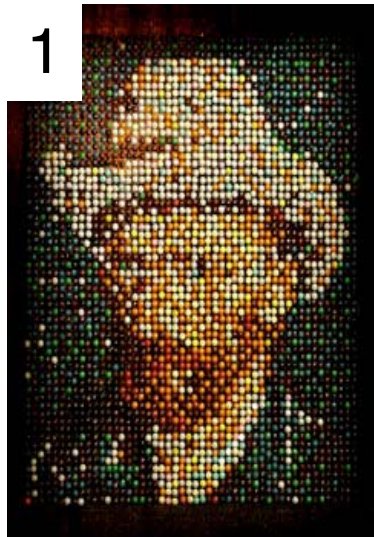
Everywhere display (cont.)



BLUESPACE office scenario

Everywhere display (cont.)

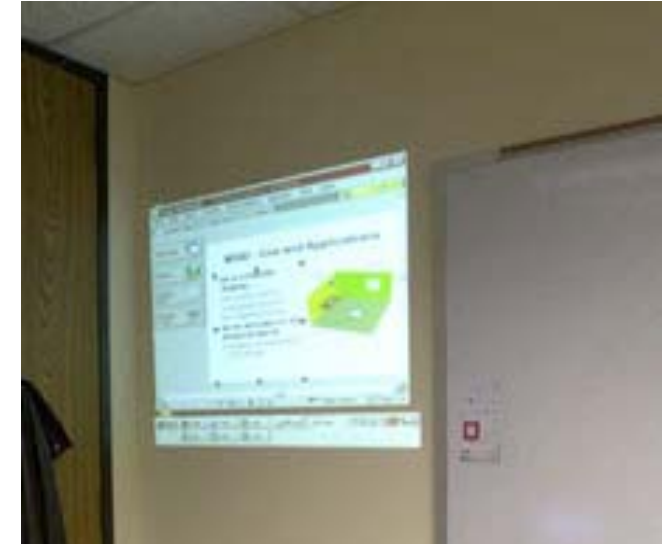
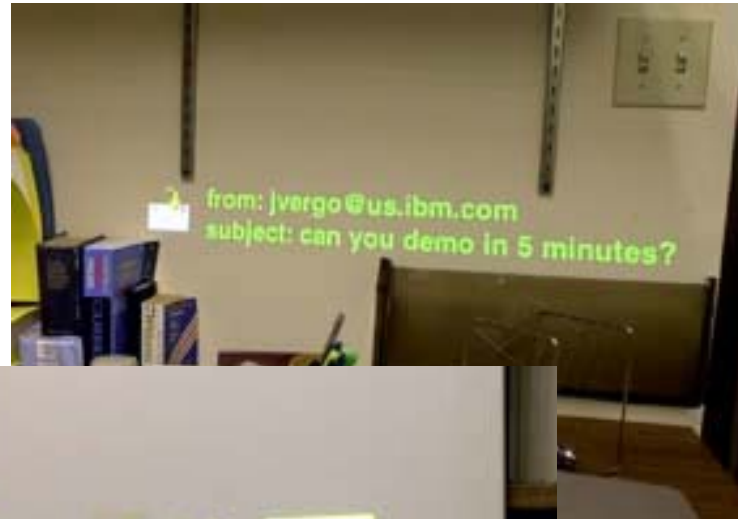
Collaborative experience at SIGGRAPH 2001



[Video](#)

Everywhere display (cont.)

Other Applications



<http://www.research.ibm.com/ed/>

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

Step 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

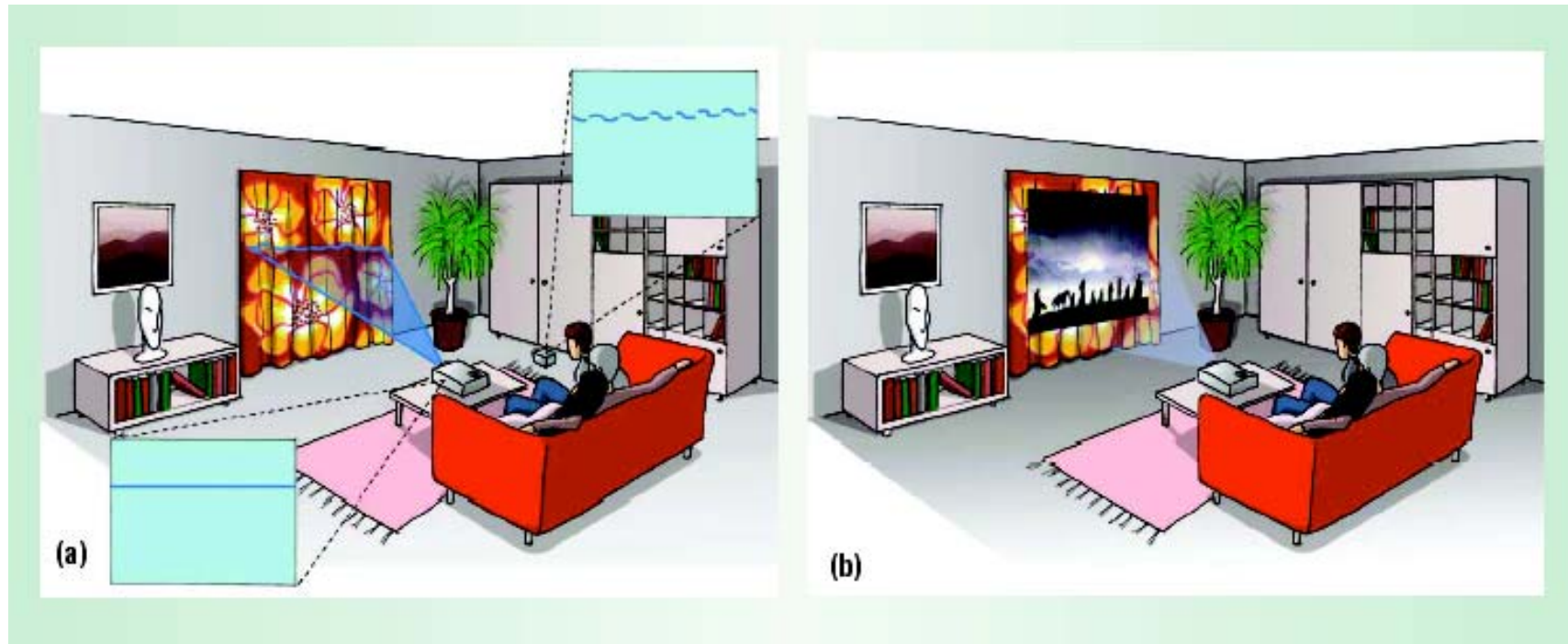
Step 2: Showing objects

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



Smart Projectors

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

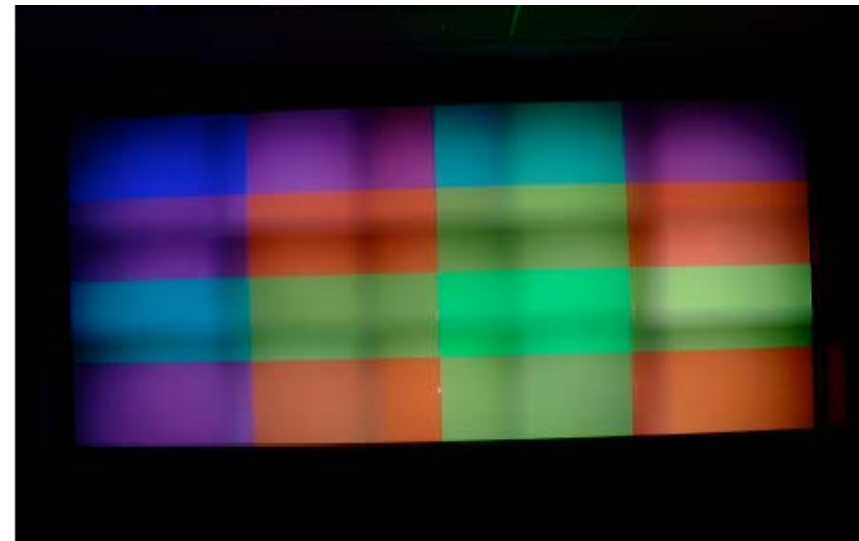
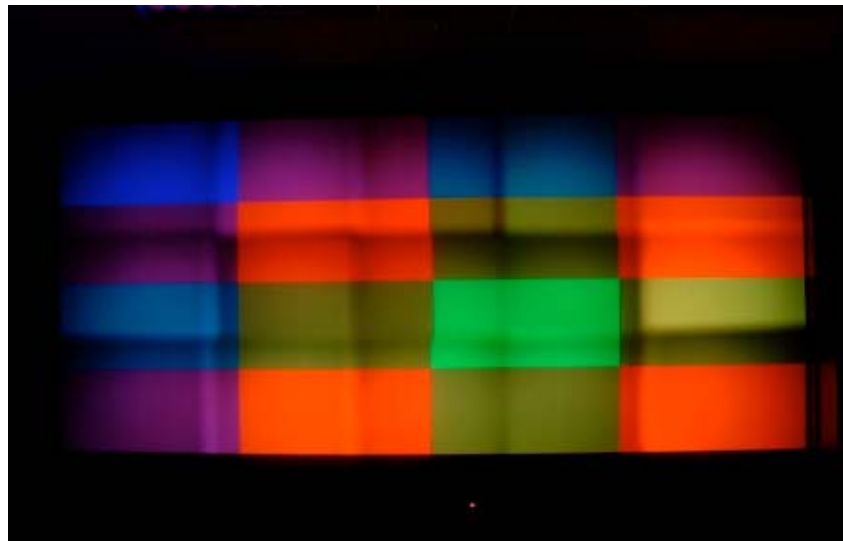


- Projection onto curved surfaces can be solved by 3D rectification, ...but:
- What if the projection surface is not uniformly colored?
- See [Video \(scientific\)](#) or [Video \(TV\)](#)

Luminance Attenuation Map

[Majumder & Stevens, VRST 2002]

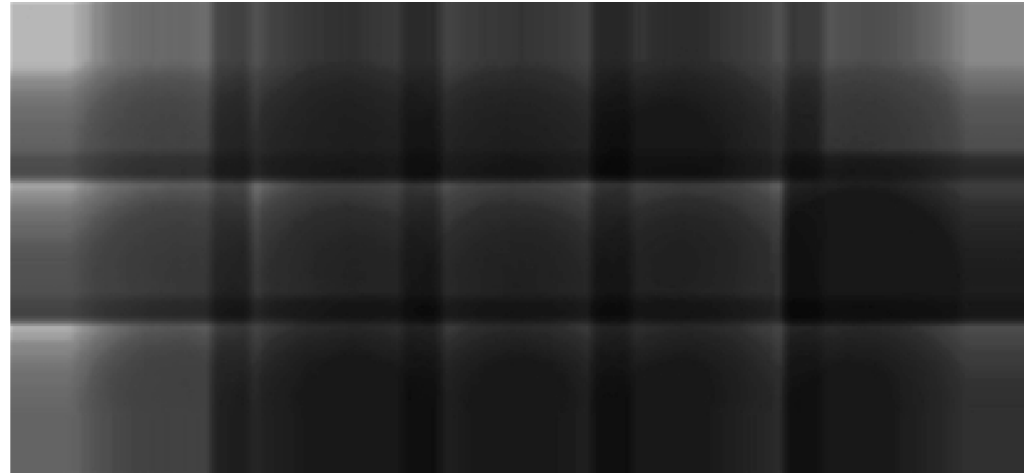
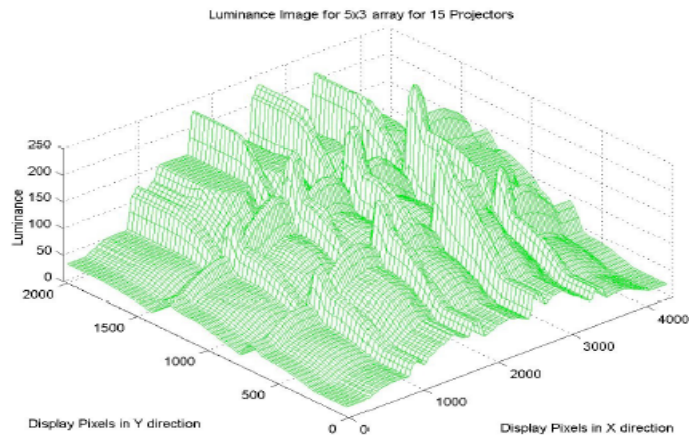
- Large display wall with 5x3 projectors
- Linear ramps (feathering) don't work perfectly
- Goal: get rid of the remaining unevenness
- Strategy: don't assume, but measure!



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 to 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.

Measured luminance response



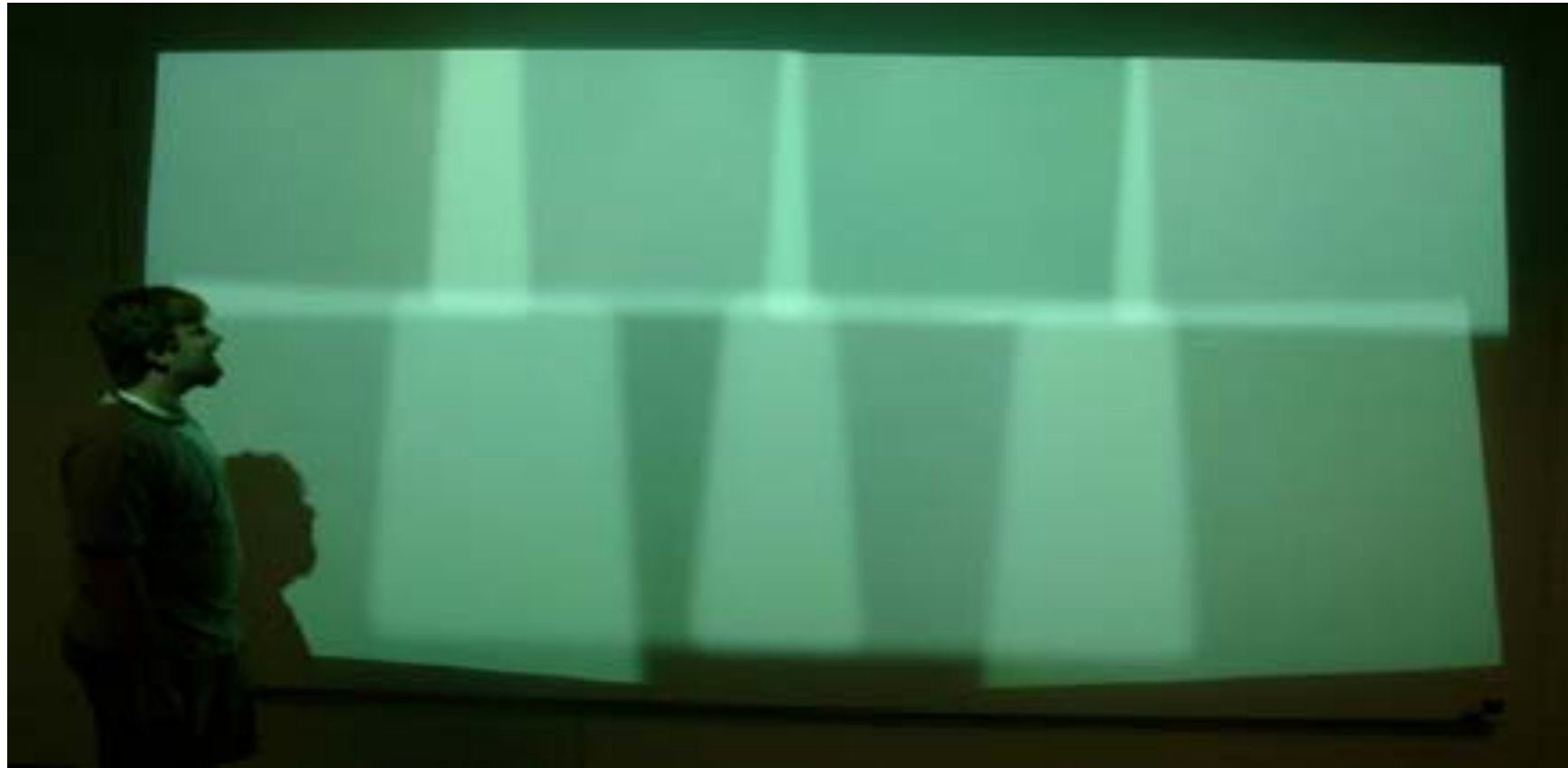
- Gives a factor for multiplication of the final images (just as in feathering)
- Can be done in graphics hardware via alpha channels

LAM: results



PixelFlex2

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



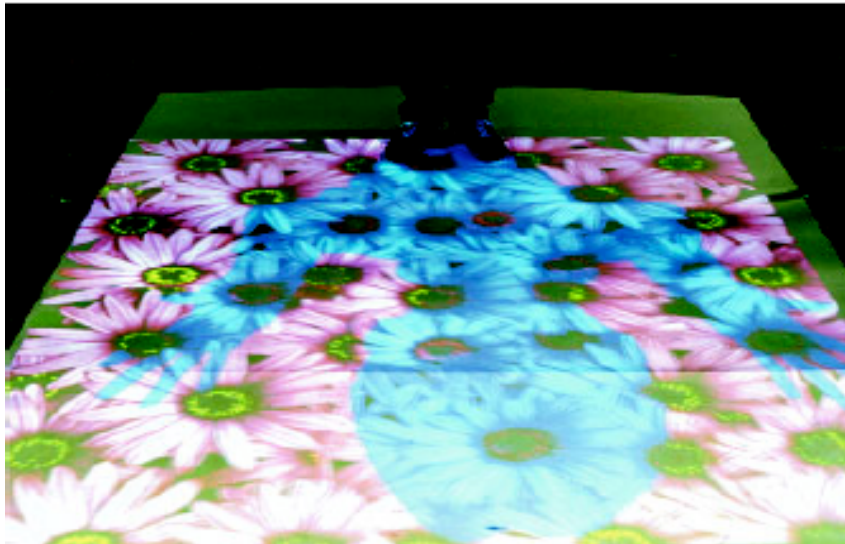
- Uneven brightness and arbitrary geometry:
 - Rectify each projector by calibrating 4 points
 - Used LAMs for brightness

PixelFlex2



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](#)

What we saw today

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

Info-Veranstaltung Hauptstudium

- Informationsveranstaltung zum Hauptstudium für Studierende der Medieninformatik ab 5. Semester und für andere Studierende der Informatik mit Interesse an der LFE Medieninformatik
- Themen f. Proj.- & Diplomarbeiten
- Termin: **Di, 5.12., 16 Uhr c.t.** (ca. 1h)
- Raum: **C 112, Theresienstr.**