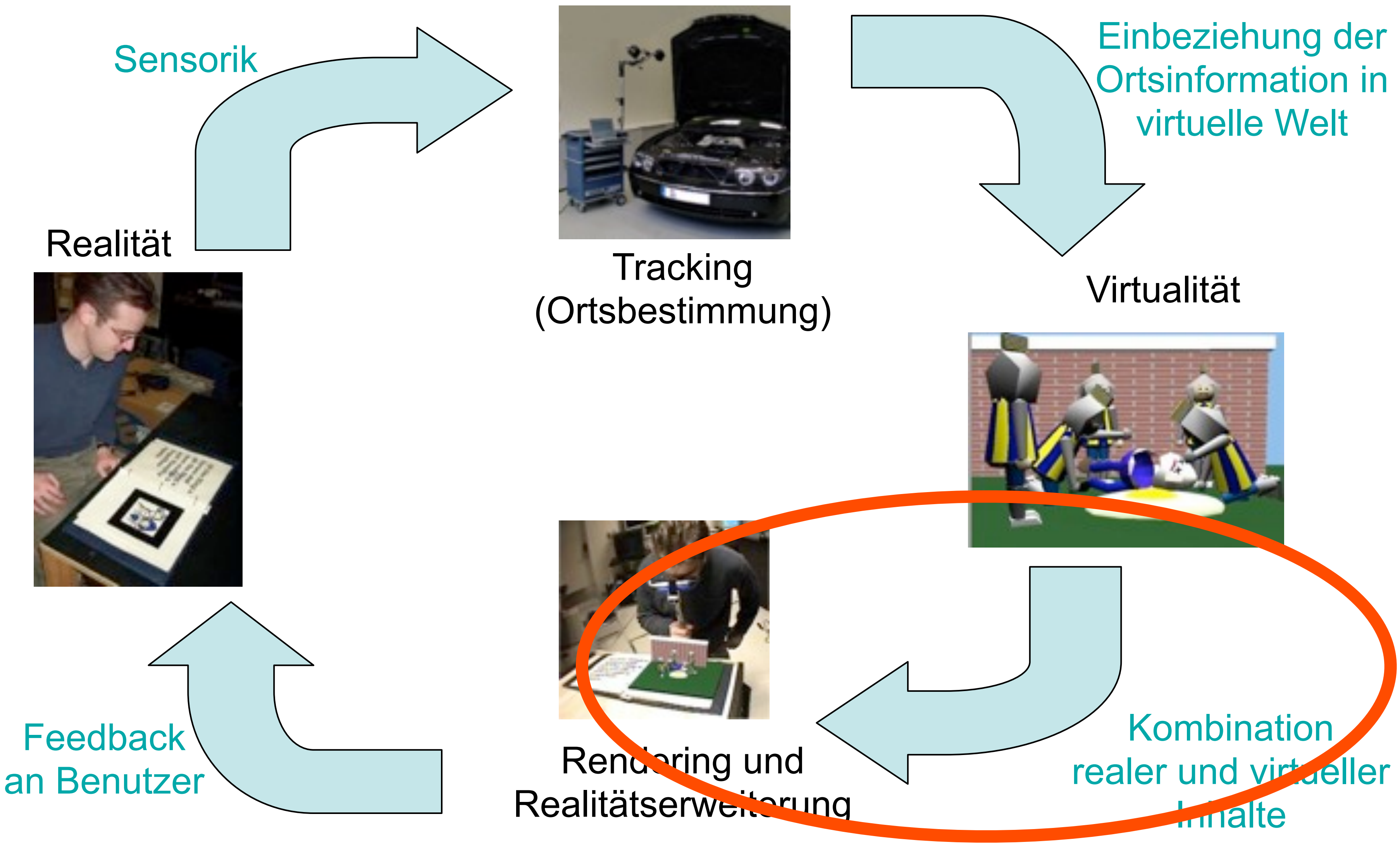
Augmentation using projectors

Vorlesung „Augmented Reality”

Andreas Butz

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

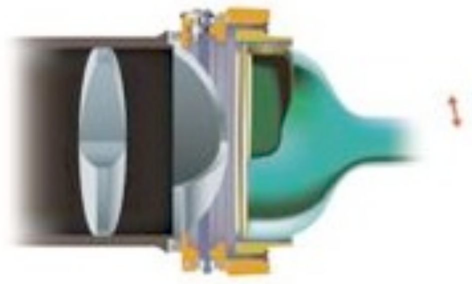
Projectors

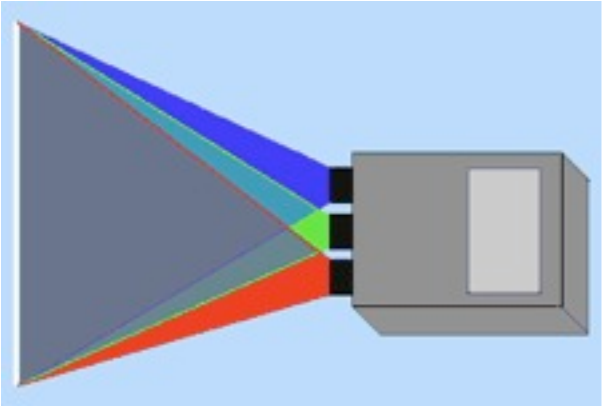
- Key Criteria
  - Resolution
  - Brightness
  - Weight
  - Noise
  - Lens
  - Image correction
  - Projection distance
  - Connections
  - Lamp life time

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

http://www.projectorpoint.co.uk/wirelessprojectors.htm

CRT projector

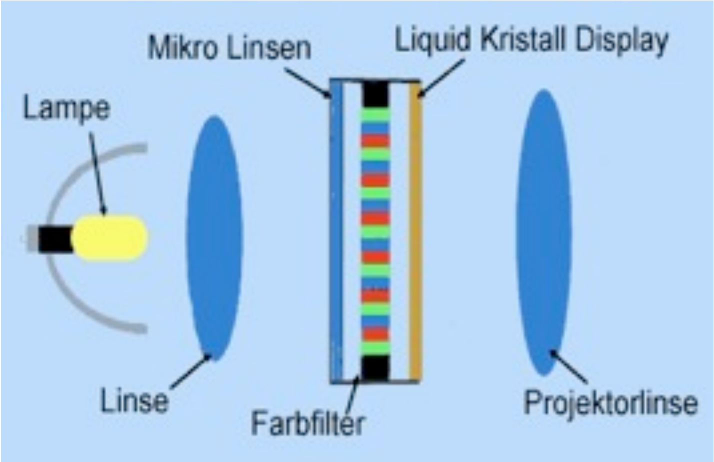




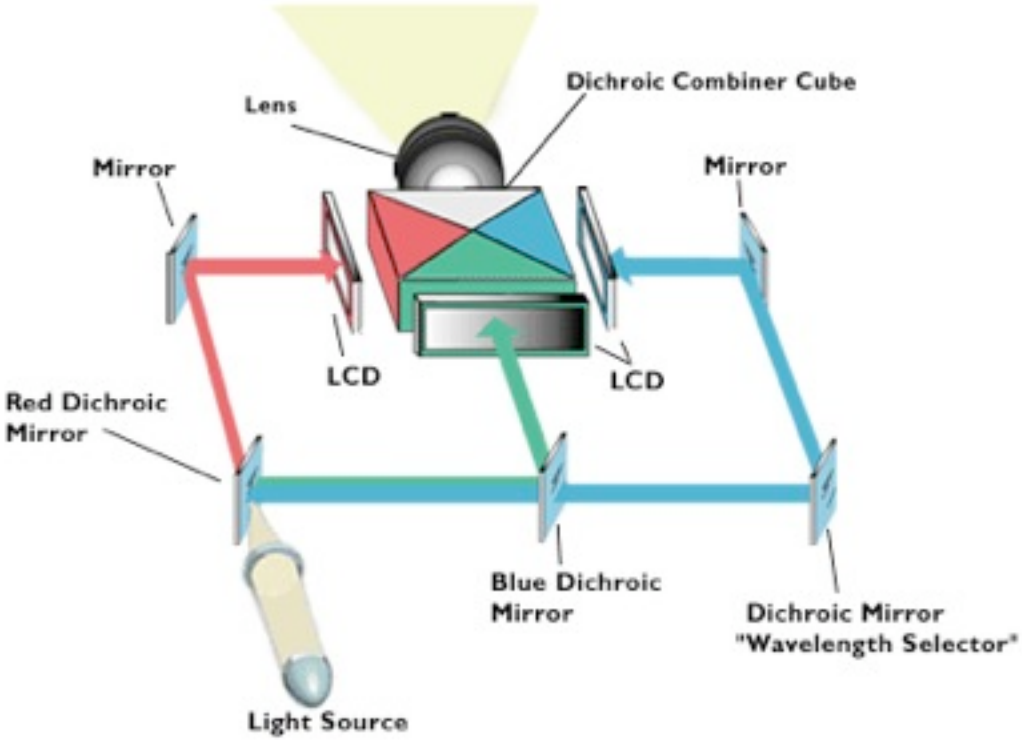
- Use R,G+B CRTs as light sources
- Good black areas
- Low brightness
- Fast
- Need to calibrate convergence!

www.projektoren-datenbank.com/rohre.htm

LCD projector

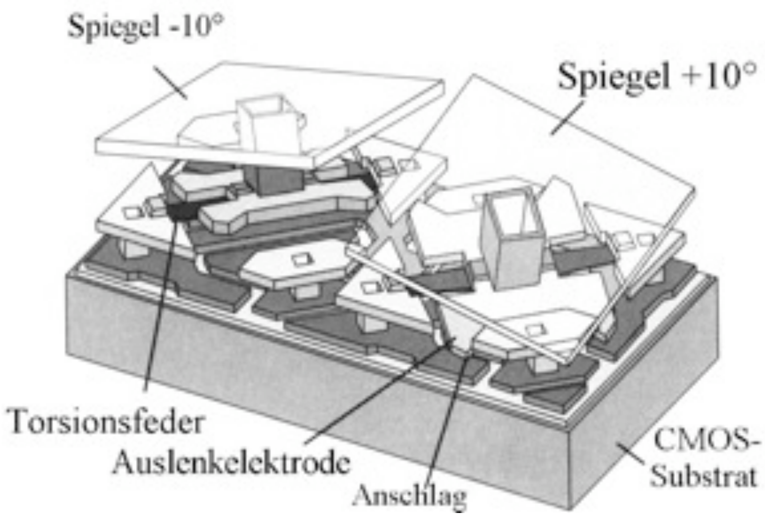


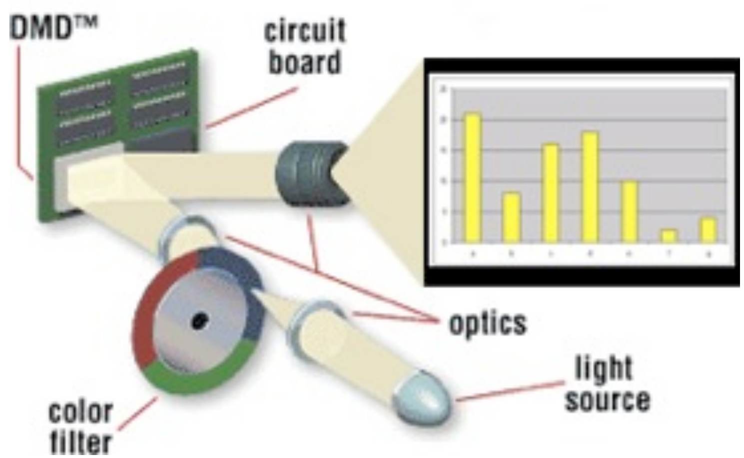
www.projektoren-datenbank.com/lcd.htm

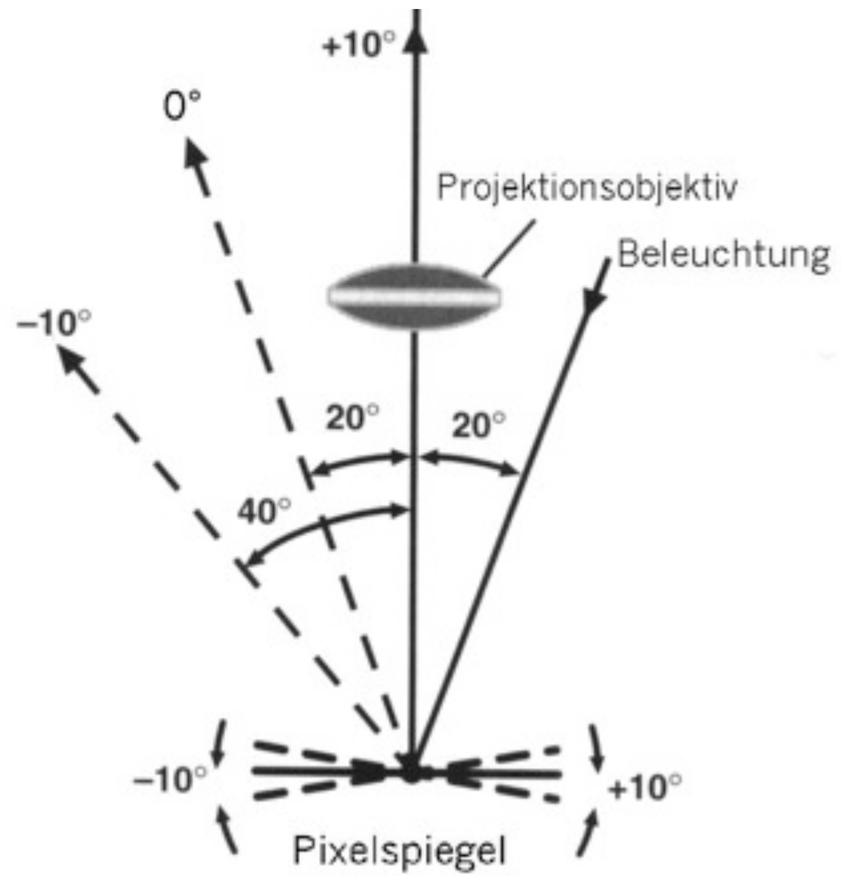


www.projectorpoint.co.uk/projectorLCDvsDLP.htm

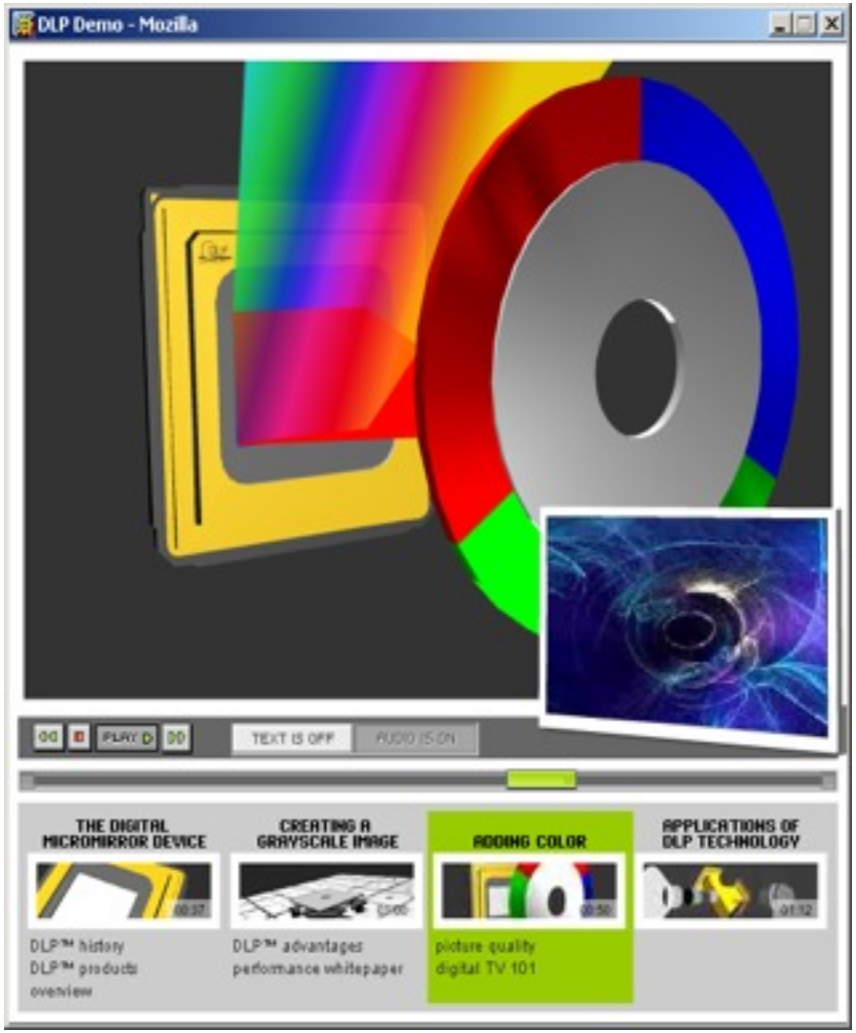
DLP projector

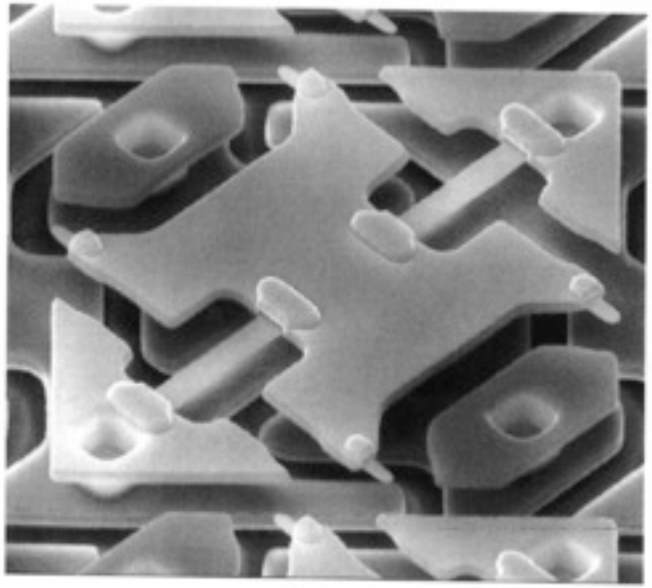






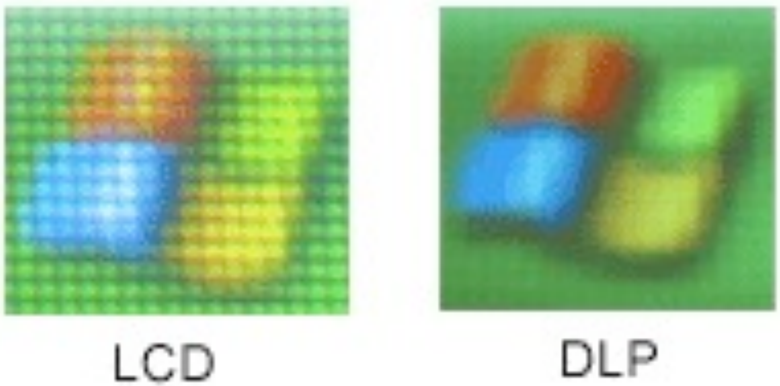
DLD projector (movie)





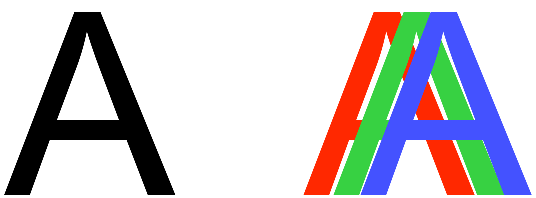
http://www.dlp.com/

Technological side effects



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

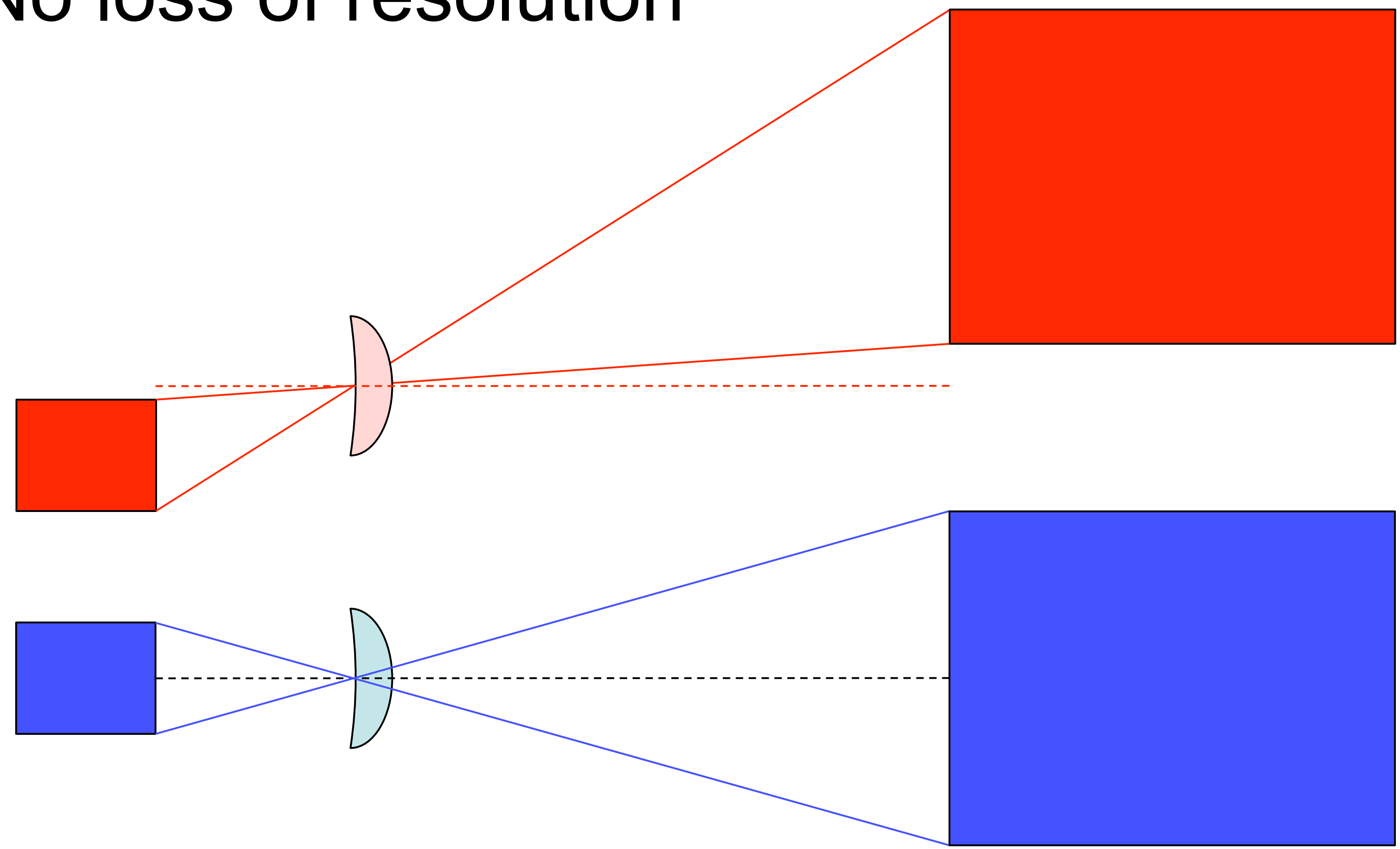
- Screen door effect
  – Caused by LCDs
  – Less prominent in DLP



- If a DLP projector is moved, color seams appear

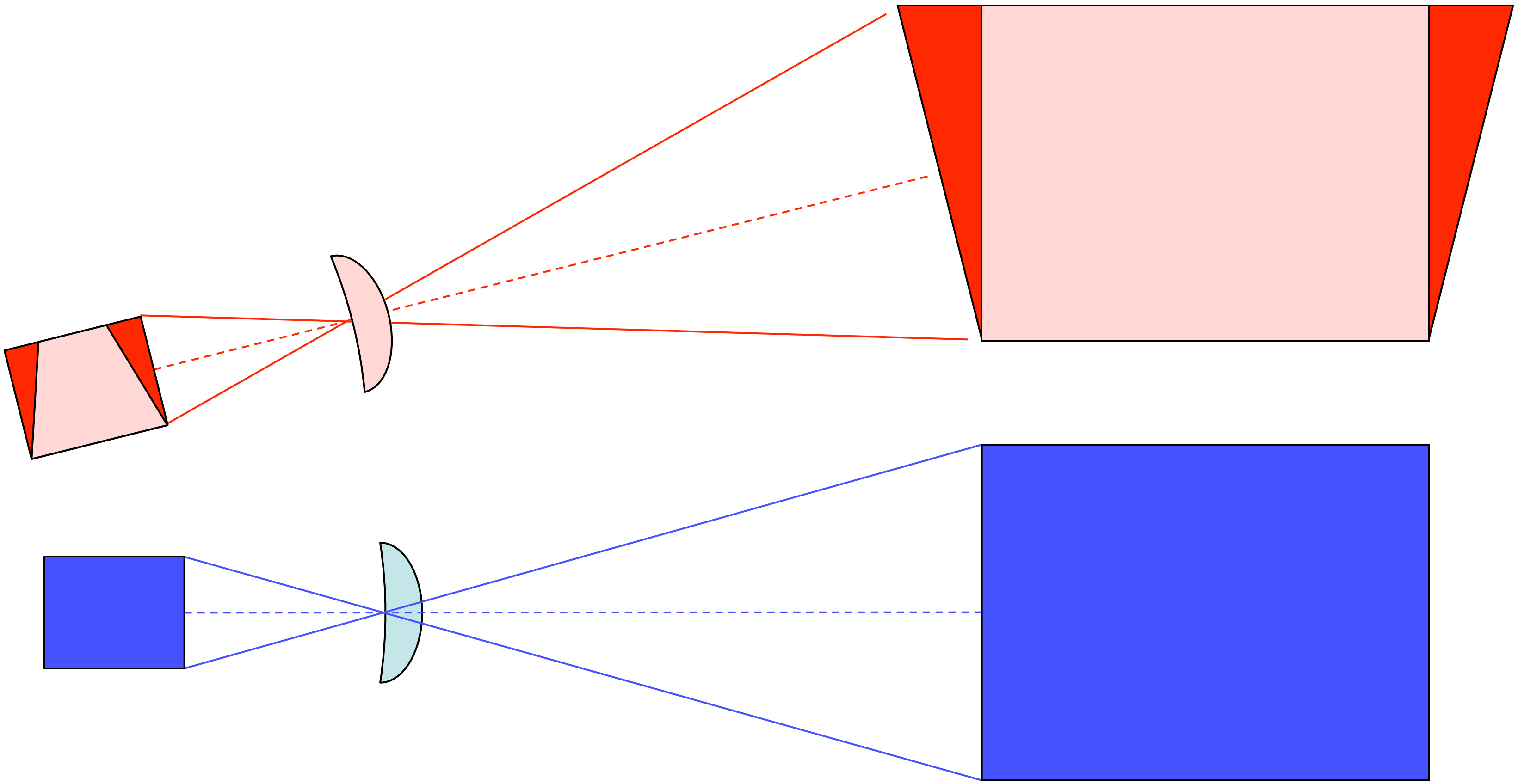
Lens shift

- Optical construction
- No loss of resolution



Keystone correction

- Computed correction
- Loss of resolution!



Shader Lamps: Basic Idea

Rearranging terms in optical path

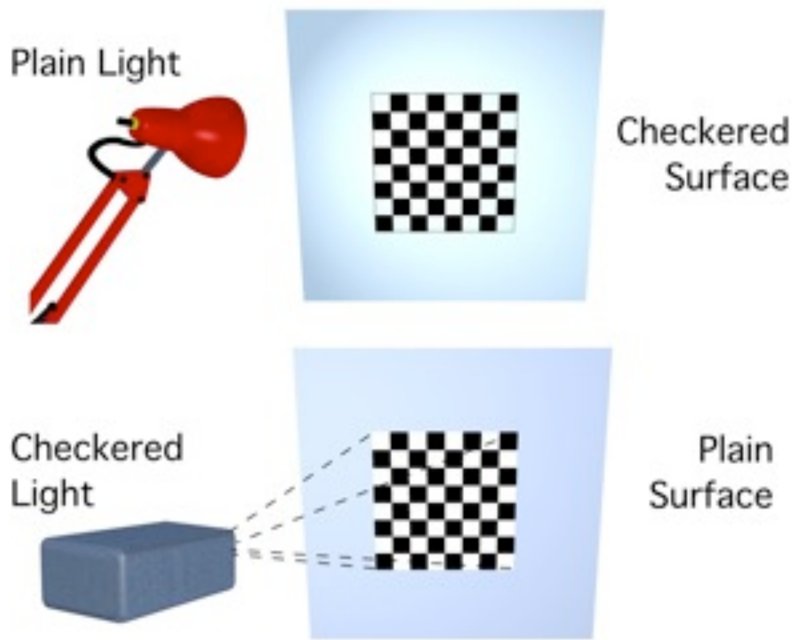
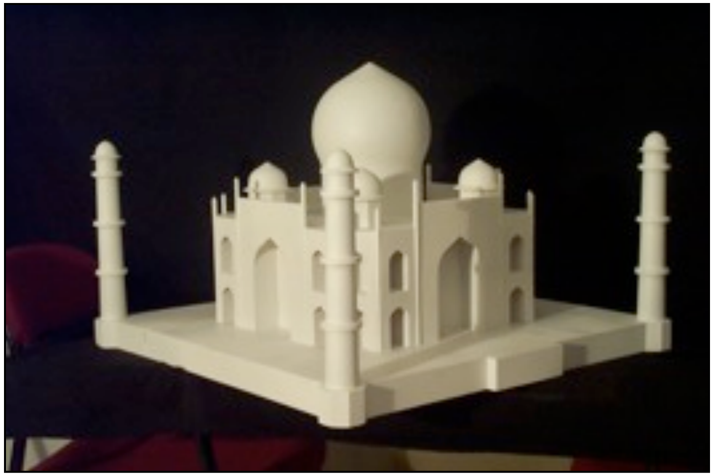
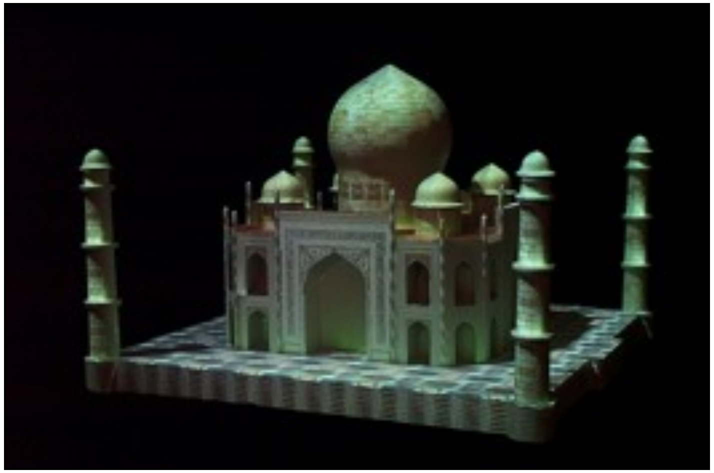


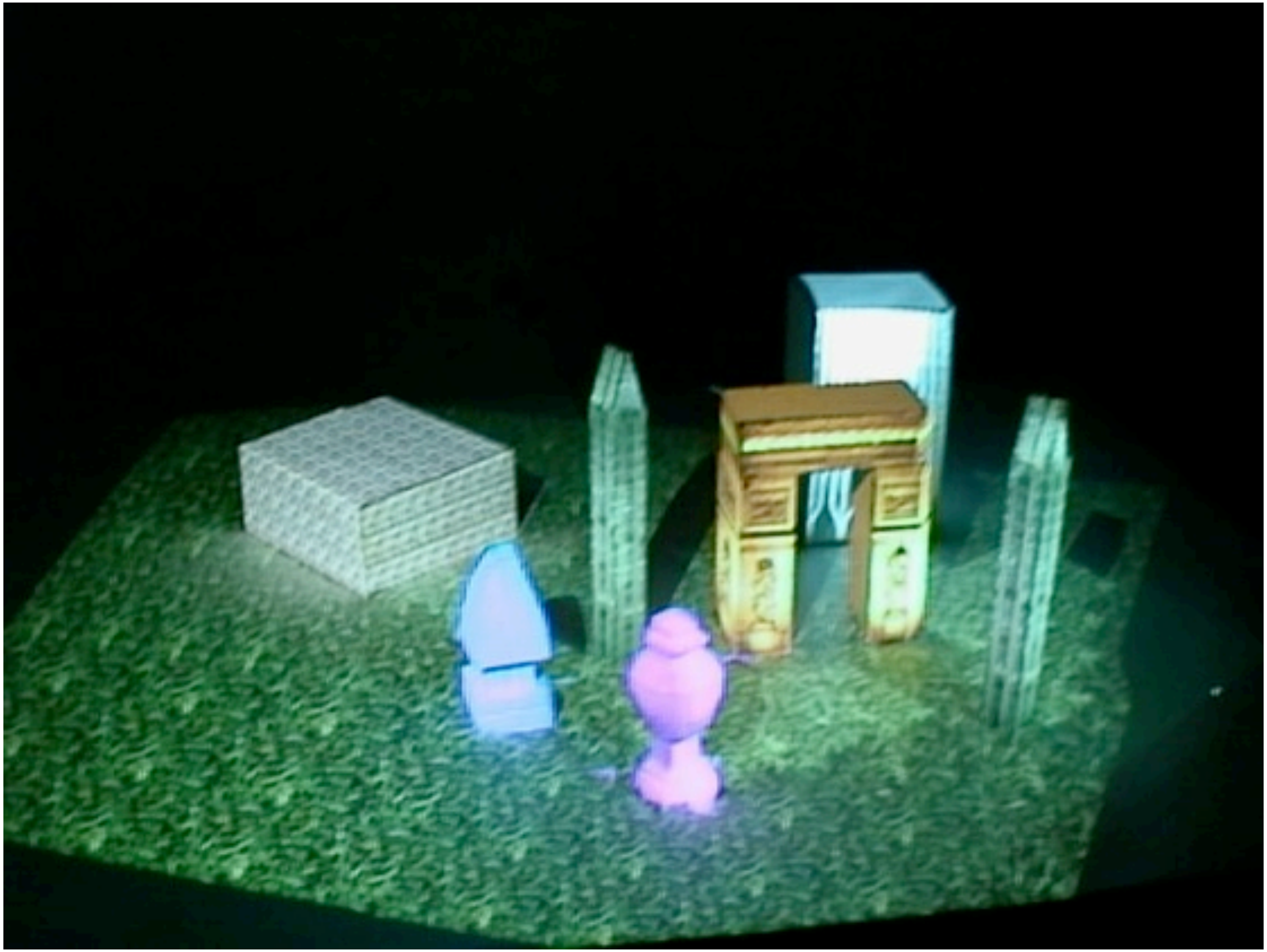
Image based Illumination

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

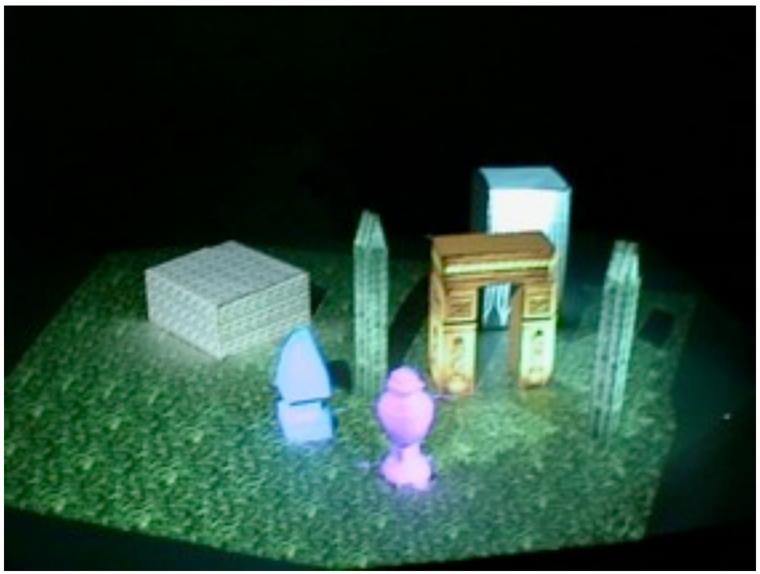




Shaderlamps: Example

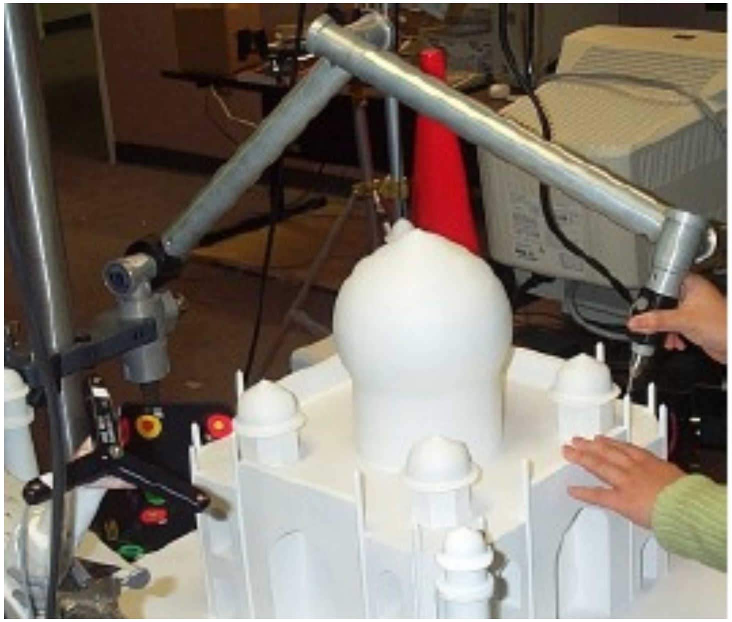


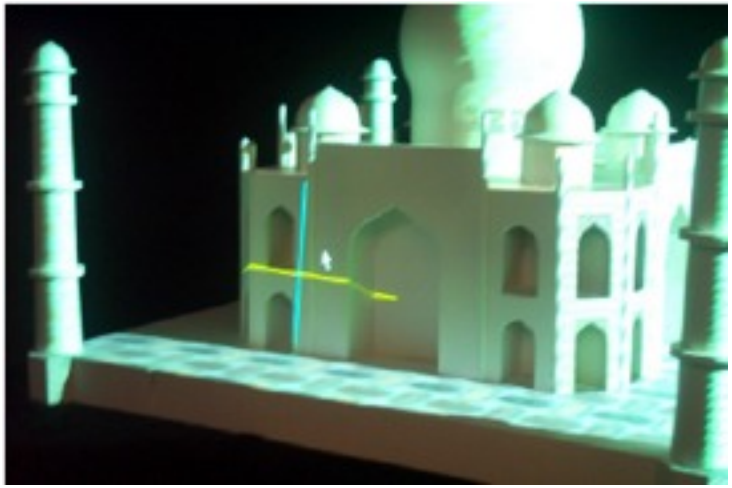
Problem: shadow areas
Solution: two projectors



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

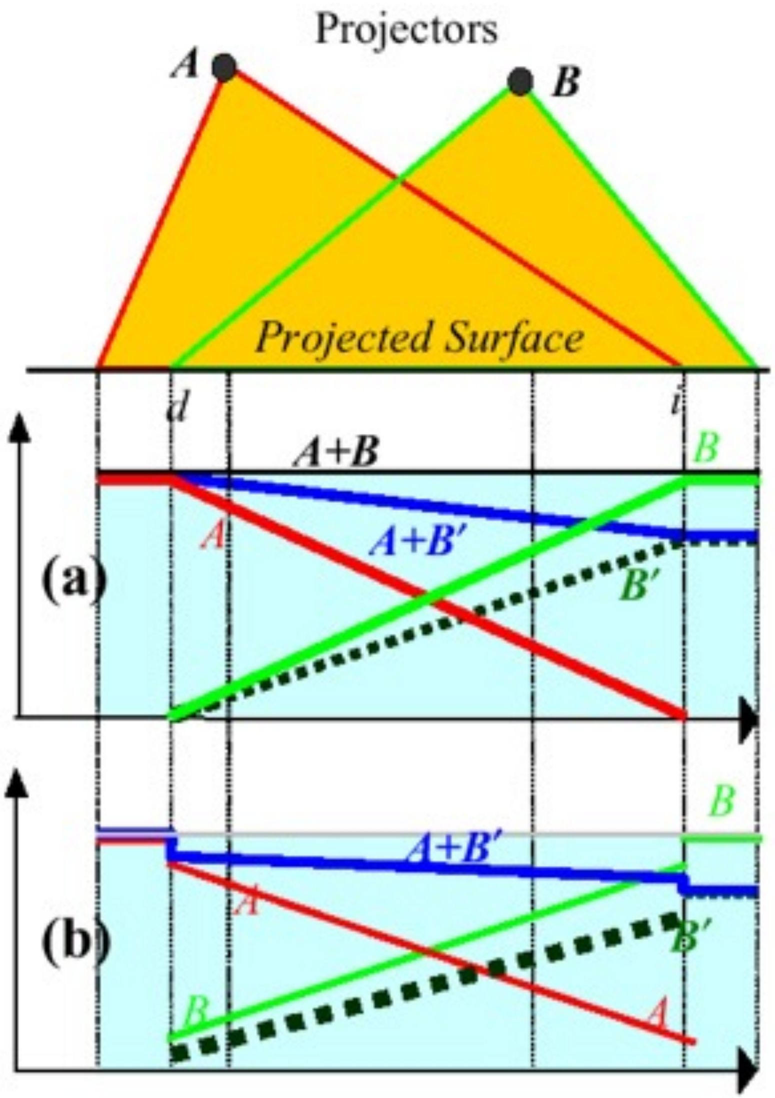
- Several problems:
  - No color equivalence between two projectors (manufacturing & temperature color drift)
  - Minimize sensitivity to small errors in calibration parameters or mechanical variations

- 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

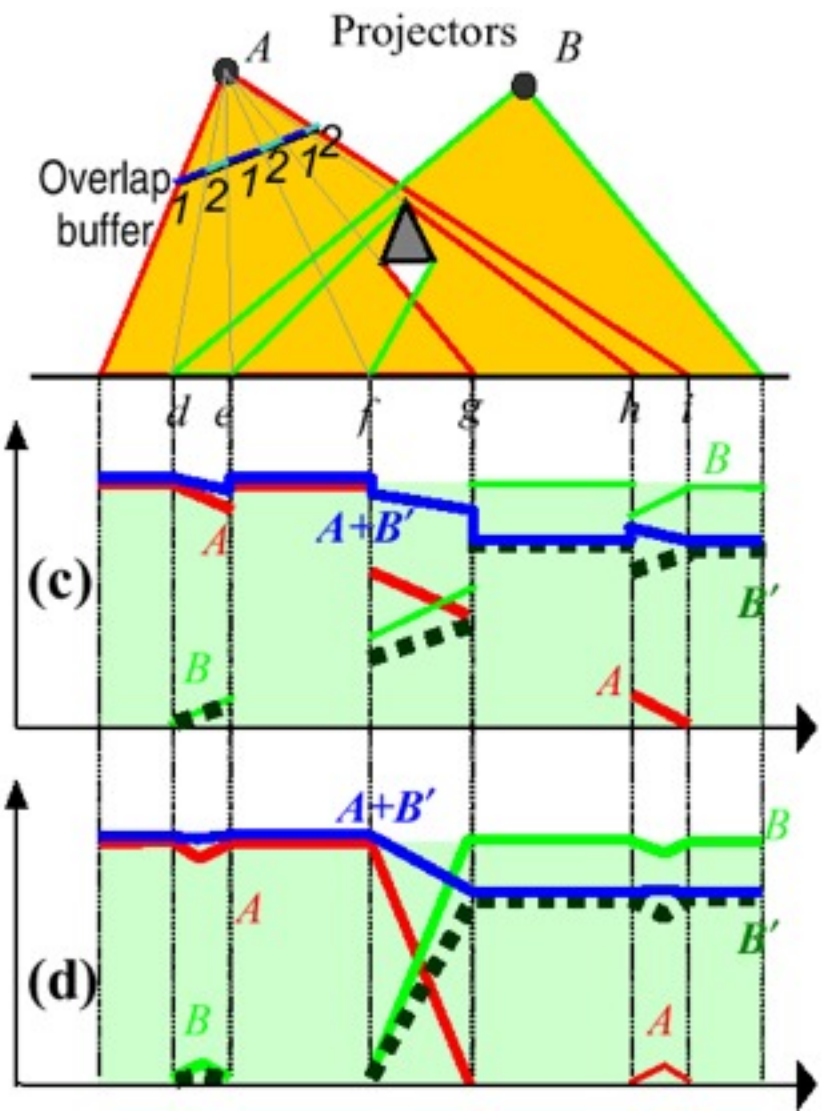


- If both projectors produce same color, A+B at maximum and constant over surface
- If not A+B´ produces smooth transition

Feathering

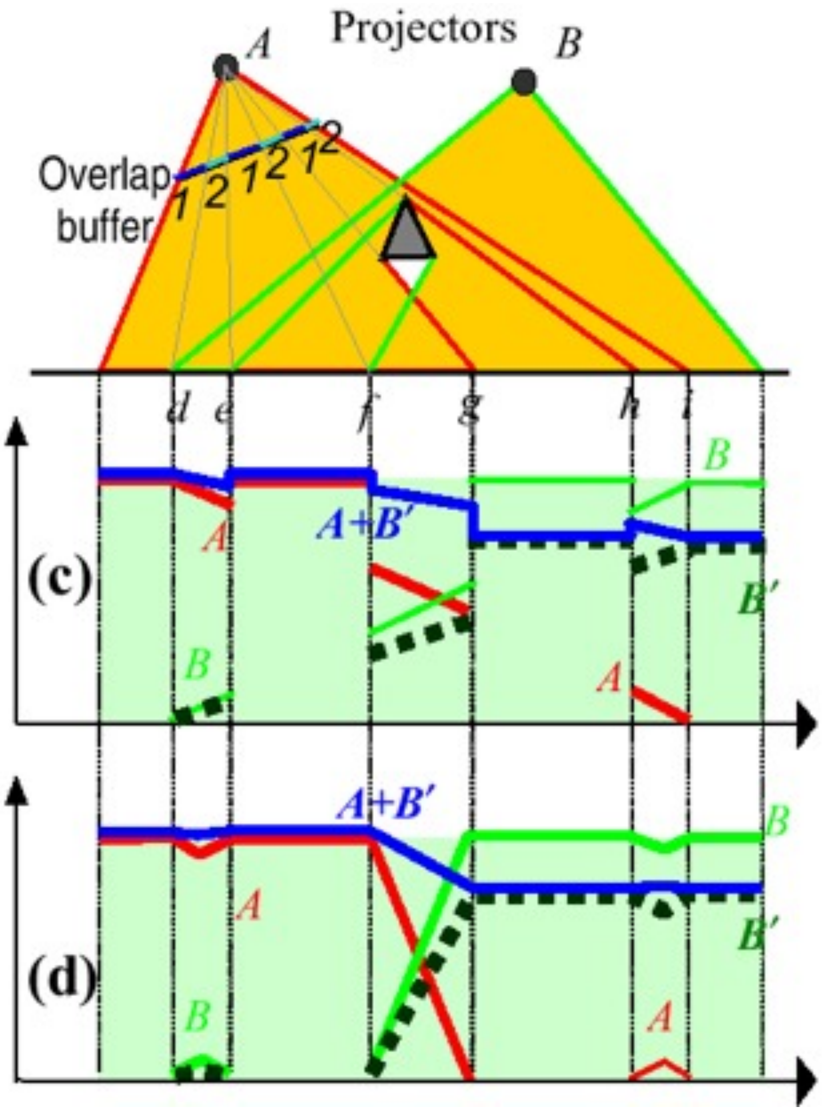
1. Sum of intensity weights of projector pixels is 1 ➔ Intensities normalized
2. Weights along physical surface change smoothly in and near overlaps ➔ suppress discontinuity due to color differences
3. Smooth distribution of intensities per projector ➔ suppress sharp edges due to small errors in calibration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

Feathering



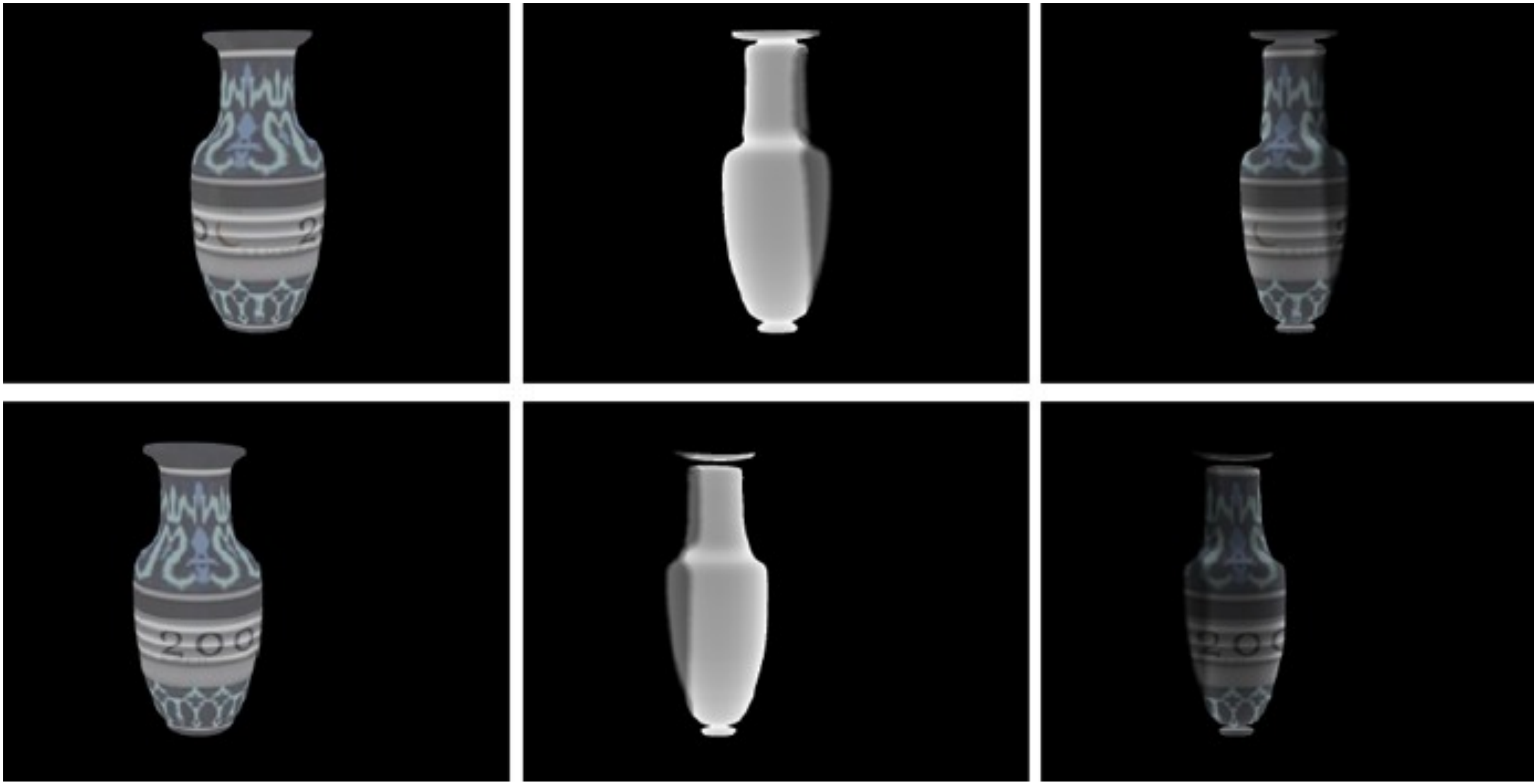
- Non-convex objects
- Collection of disjoint objects
  - ➢ Shadows
  - ➢ Fragmented overlaps
  - ➢ Depth discontinuities

Feathering

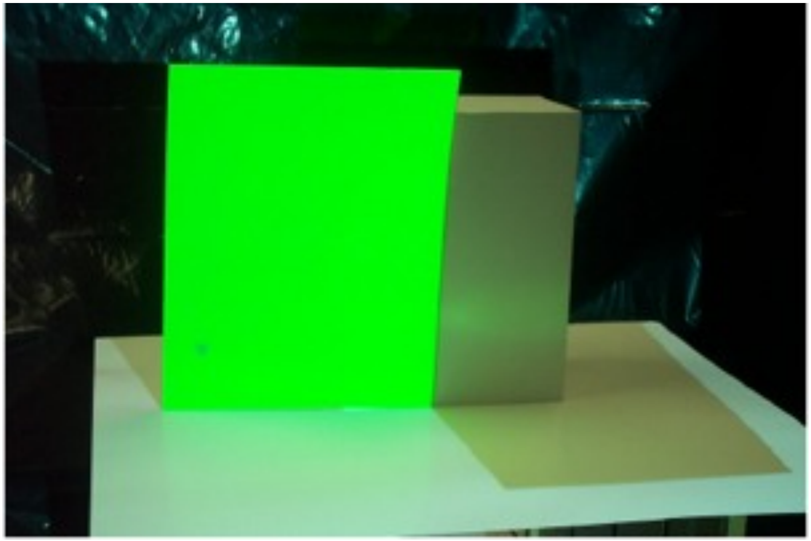


- Find regions illuminated by one projector and assign weight=1
- Use shortest euclidian distance to a pixel with weight=1 to compute weight

Examples



Radiosity

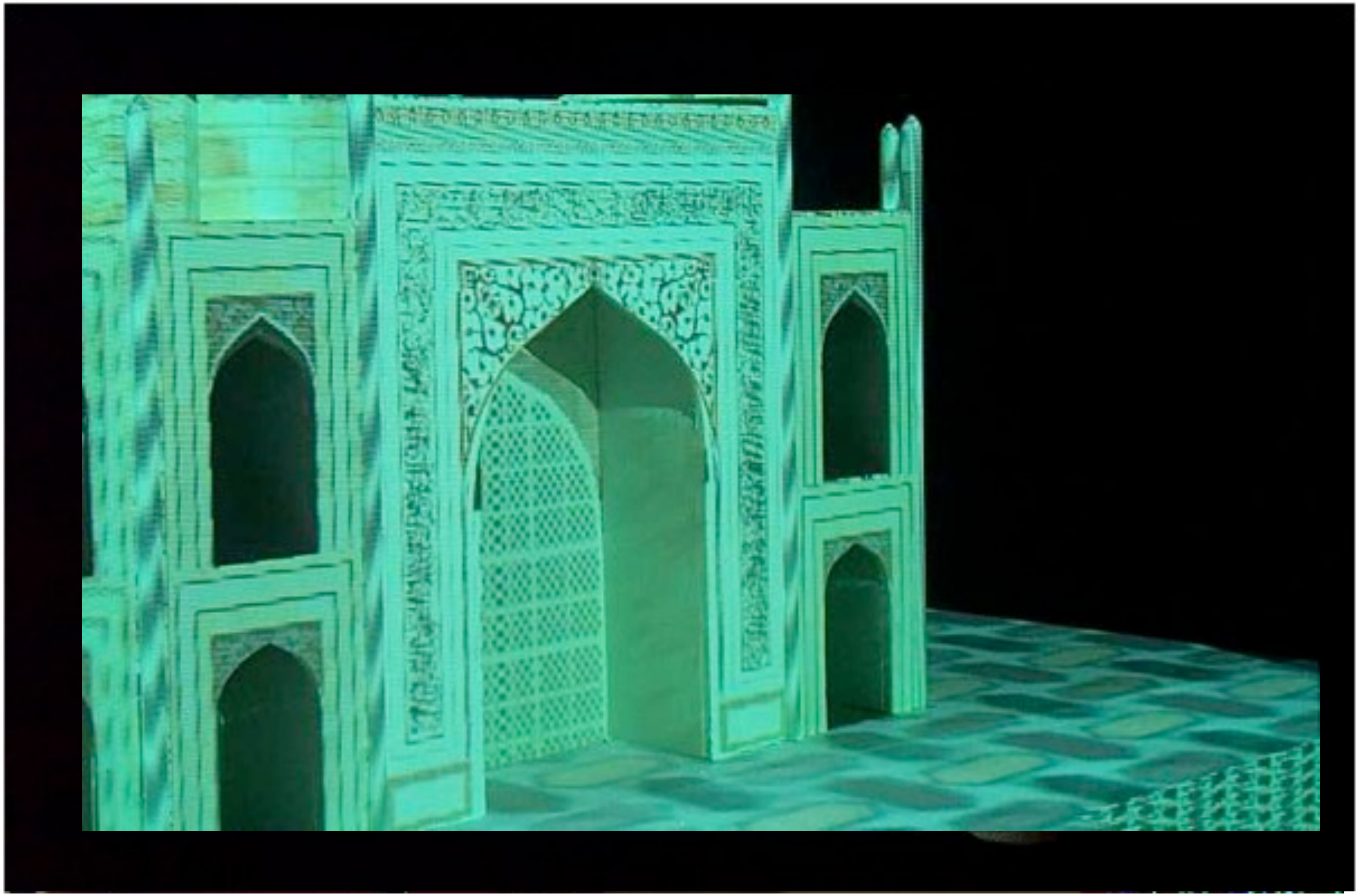


- Objects illuminated by direct and indirect light
- Parts of an object can scatter light onto other parts of object and other objects
- High computational effort to calculate correctly
- Often approximated by „ambient light“
- Comes for free with shaderlamps!

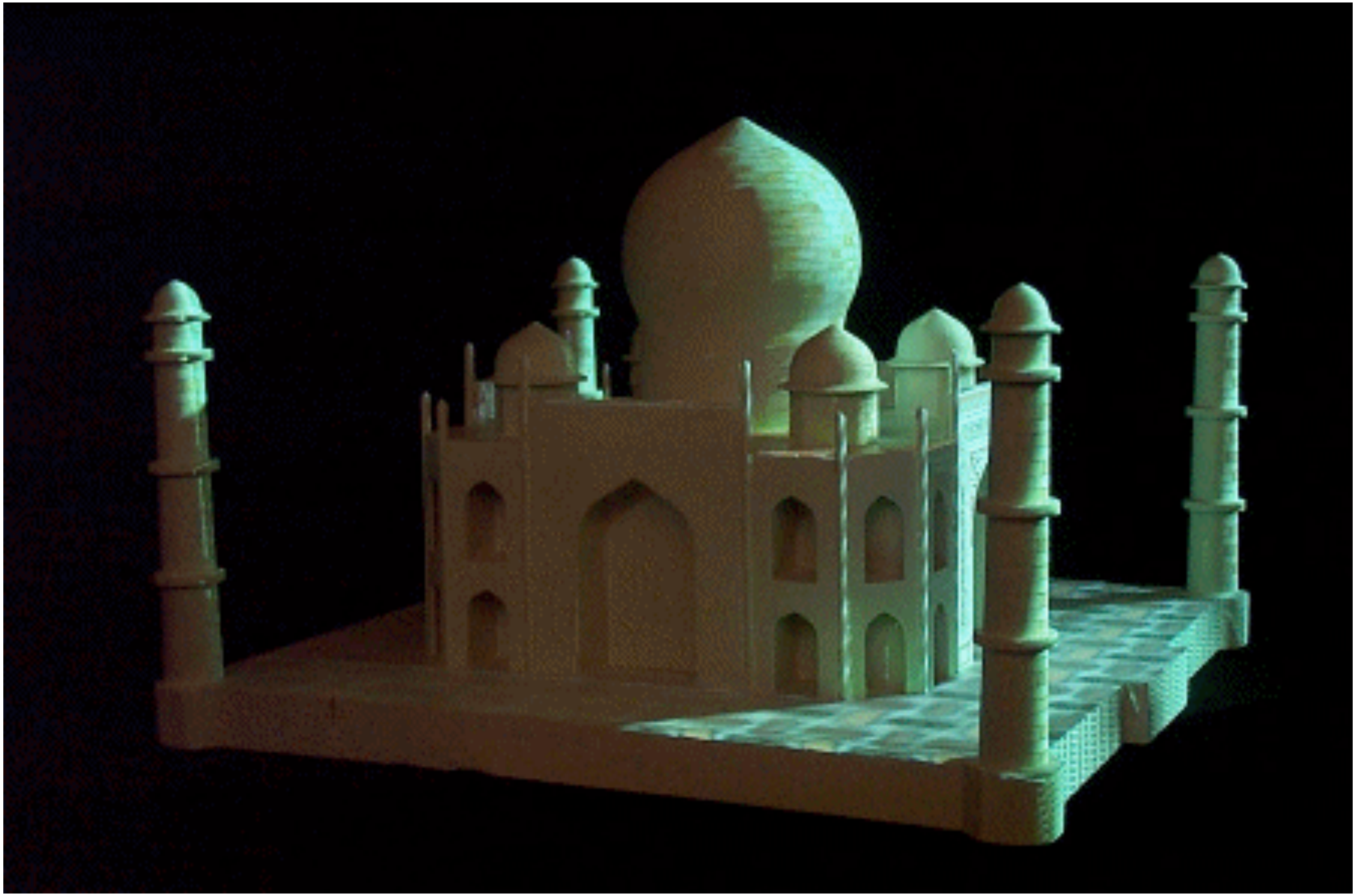
Limitations

- 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



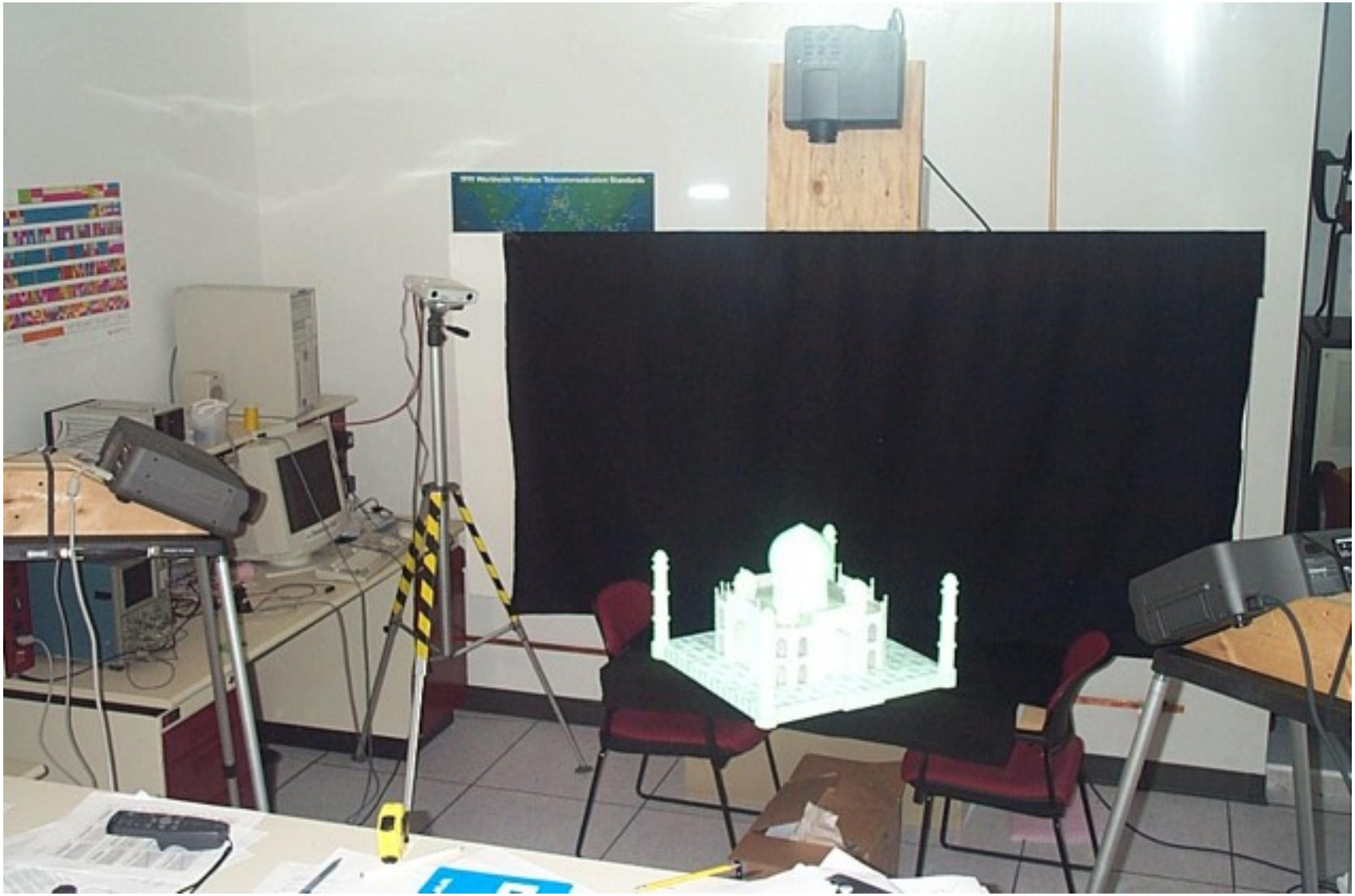
Example



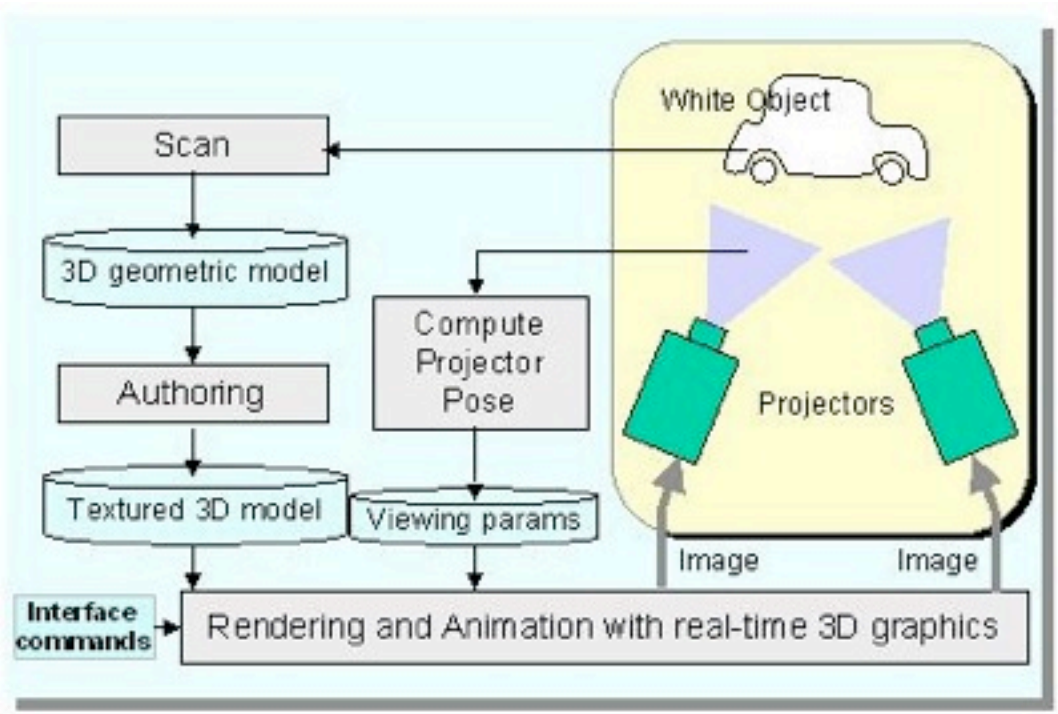
Implementation

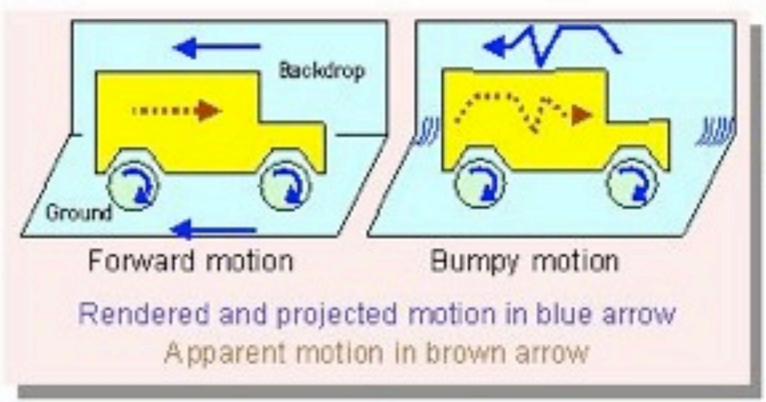
- 2 Projectors with 1024x768 resolution
- Rendering with OpenGL
- Vase 12 cm x 12 cm x 35 cm
  - 7000 Triangles
- Taj Mahal 70 cm x 70 cm x 35 cm
  - 21 000 Triangles
  - 15 Texture Maps
- Calibration about 5 min per projector
- Re-projection error less than 2 Pixels
- Intensity weigths computation in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

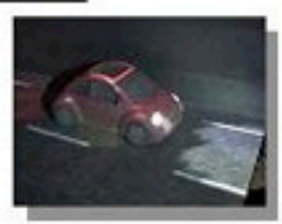
Setup

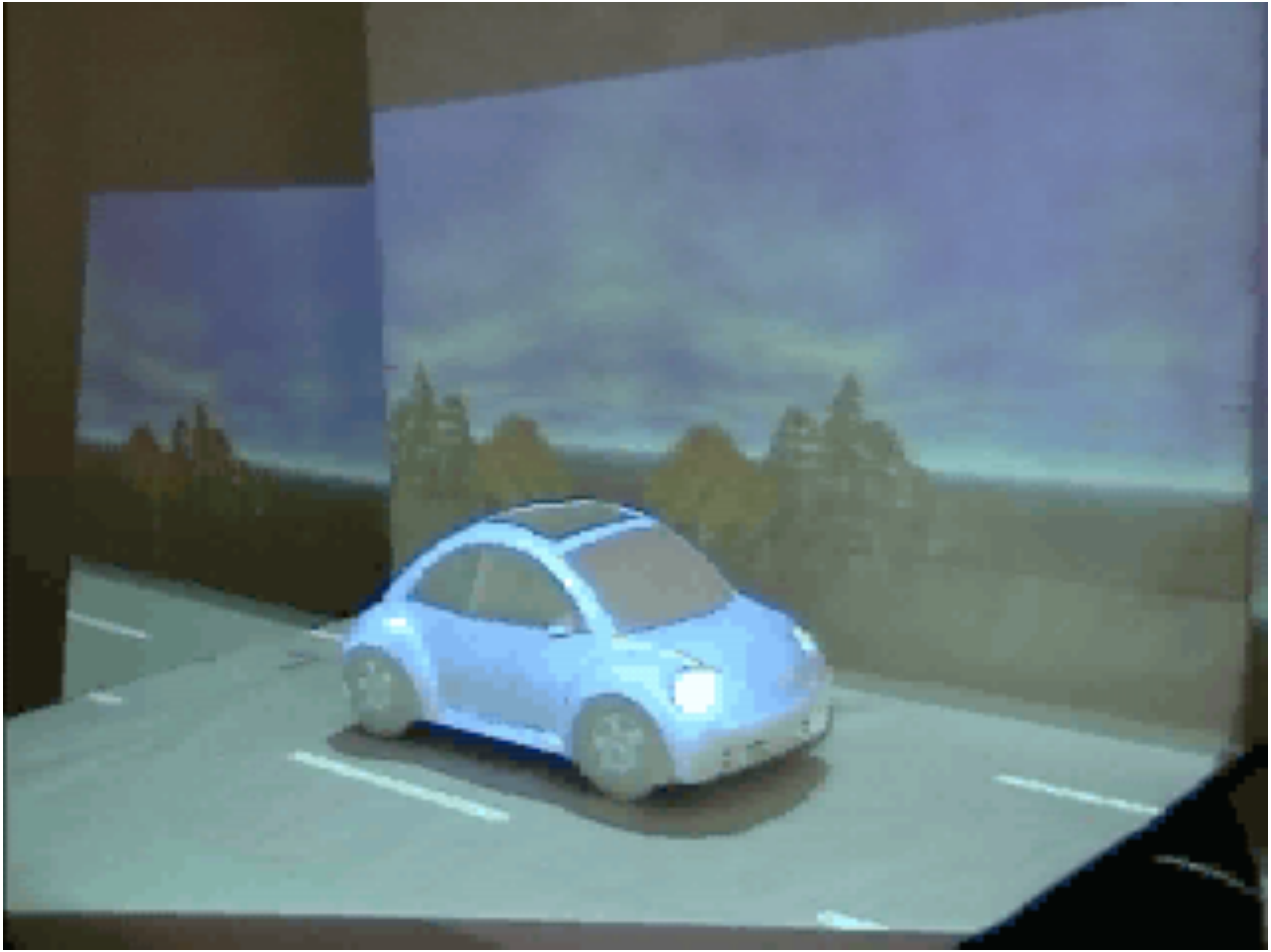


Cartoon Dioramas in Motion





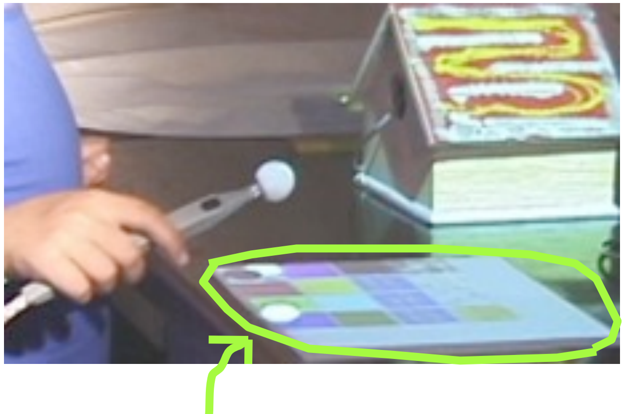




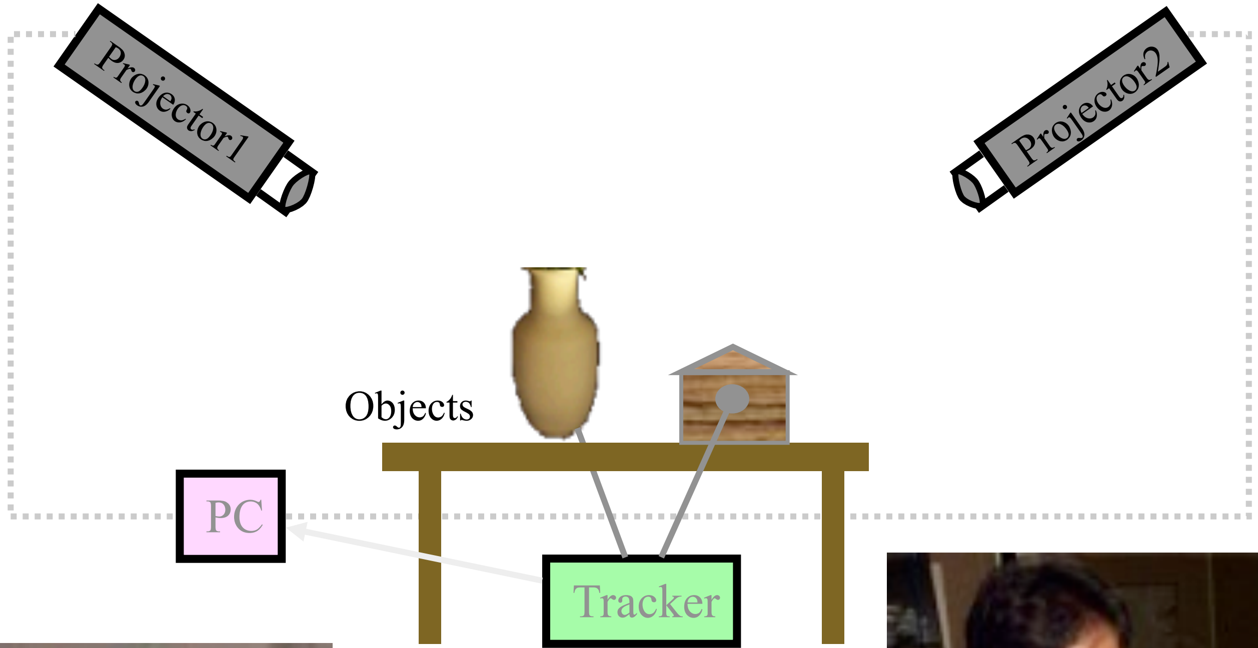
Painting on Movable Objects

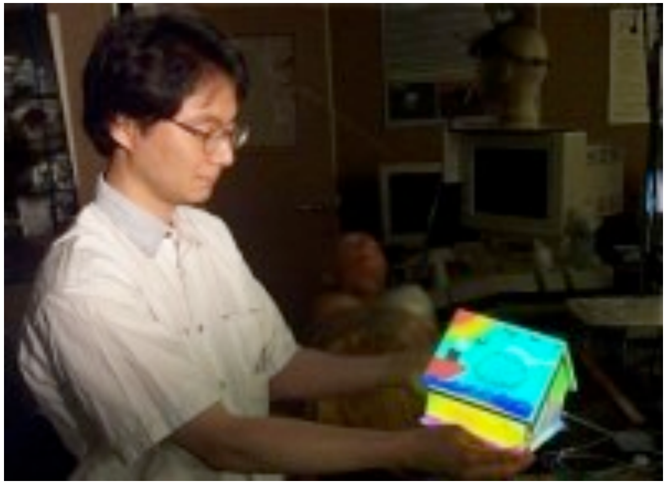
http://www.cs.unc.edu/~debug/papers/DSLpaint/

- 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

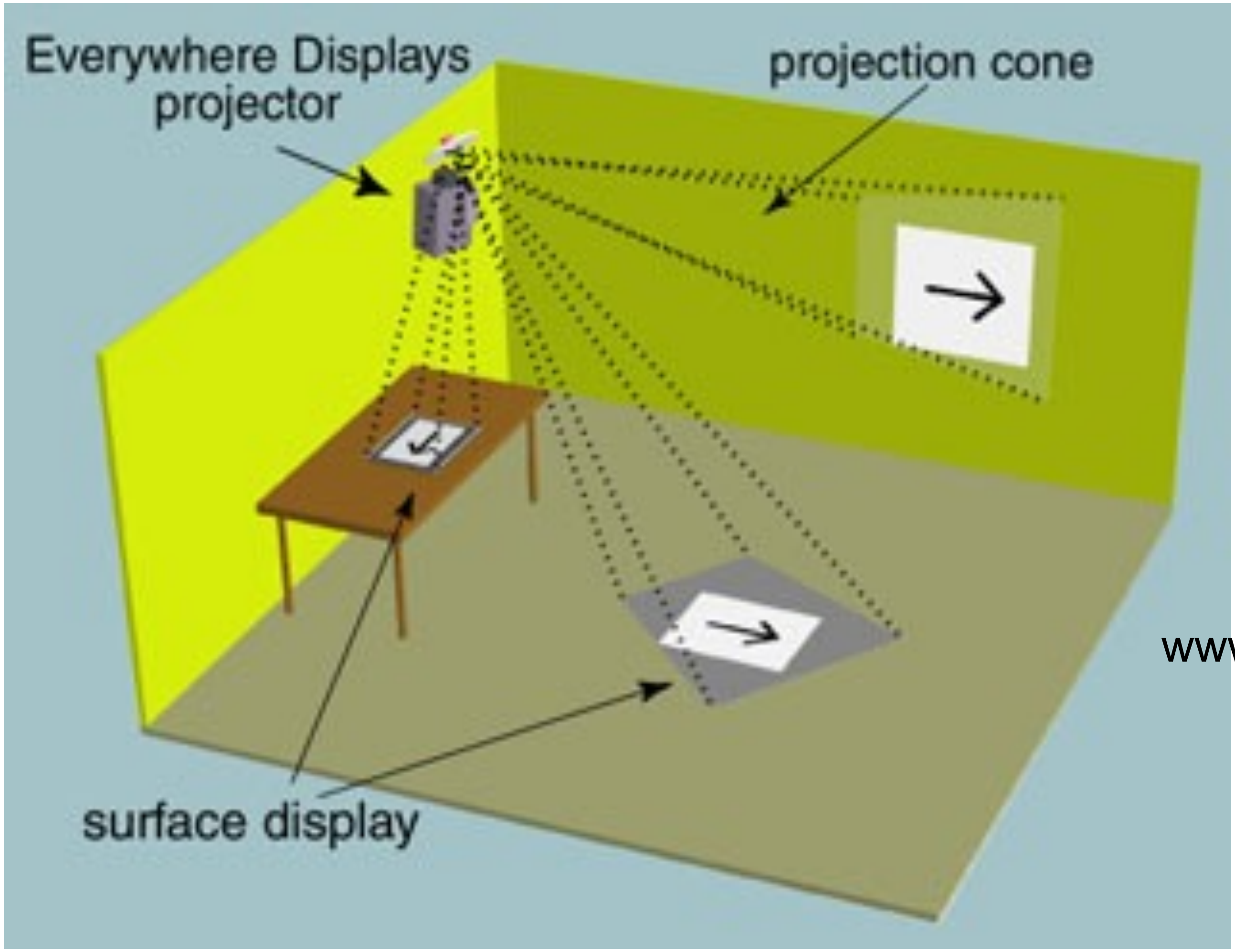




Dynamic Shaderlamps: Video

Everywhere Display Projector (IBM)

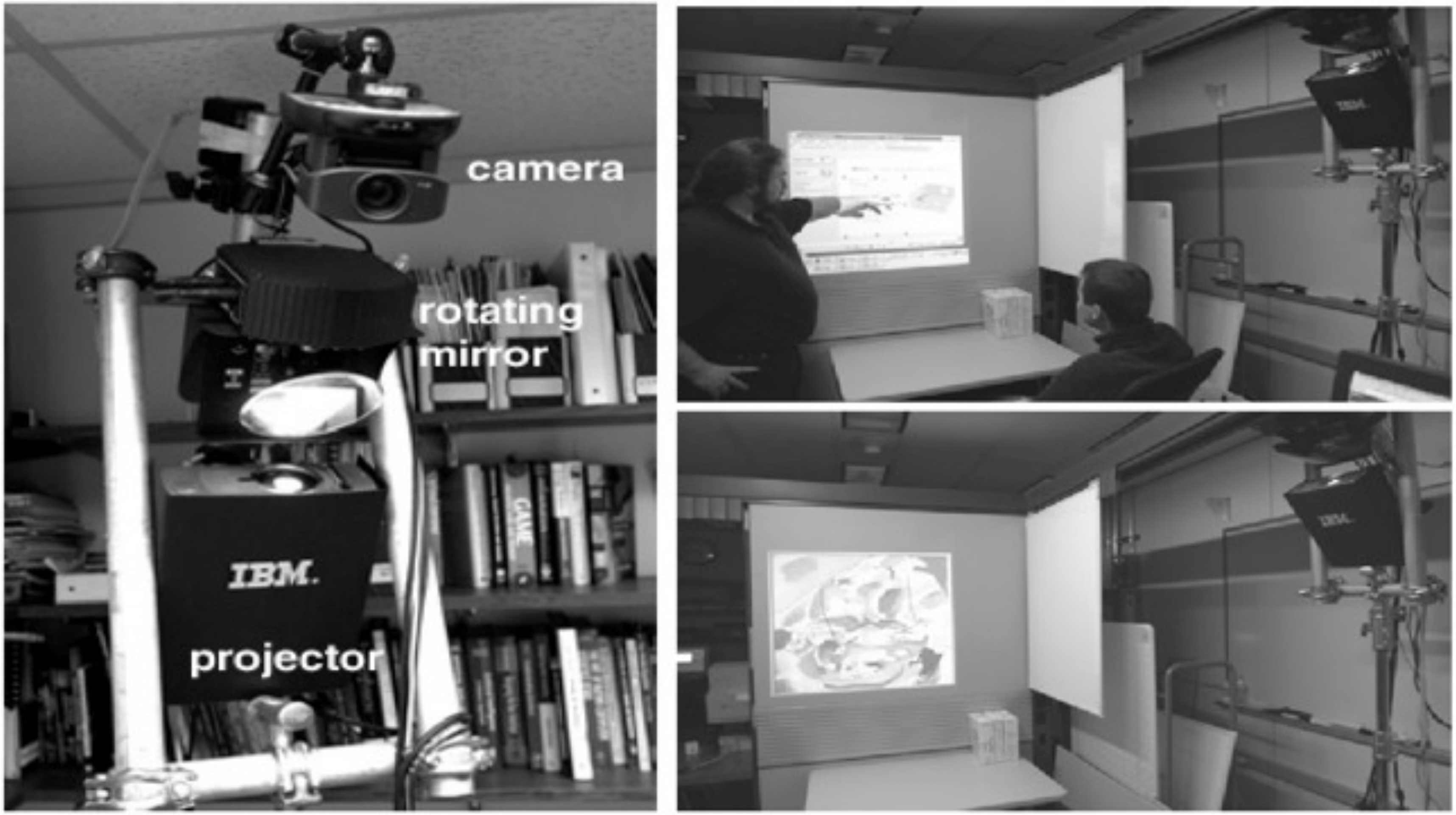
http://www.research.ibm.com/ed/



Claudio Pinhanez

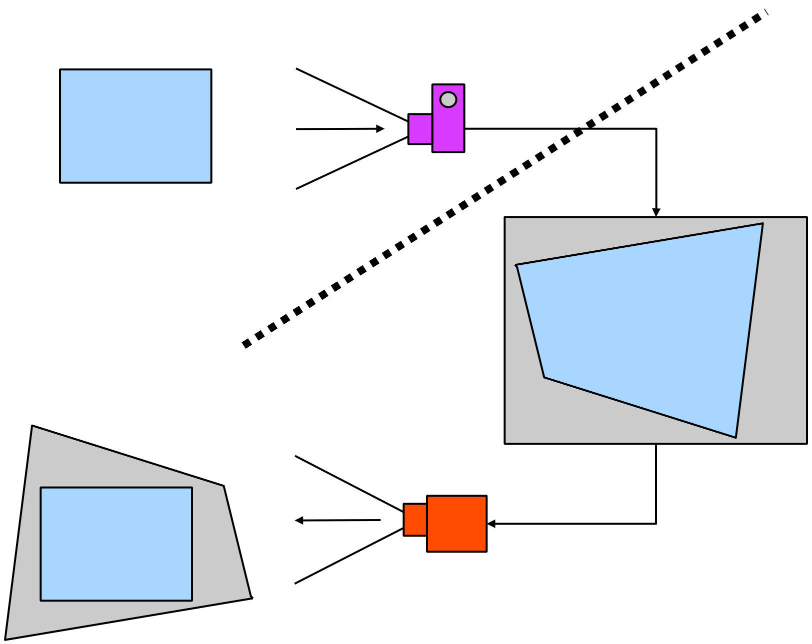
www.research.ibm.com/ed/

Everywhere display (cont.)



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

Undistorting the projected image

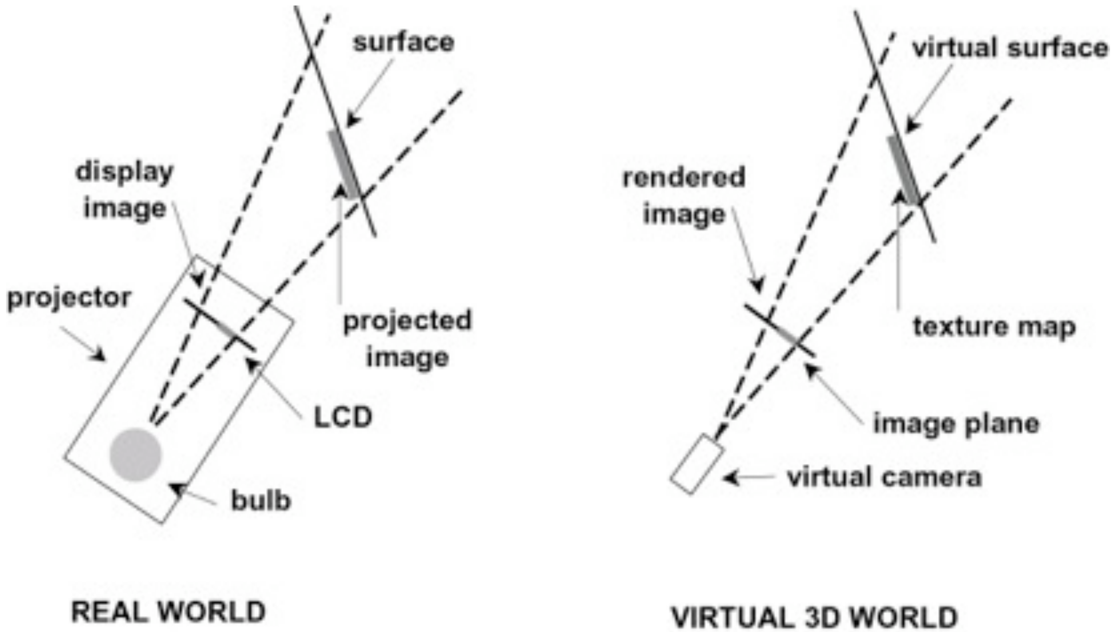


- Place original image in the 3D model
- Virtual camera image shows it distorted
- Project the distorterd image from 3D model with the Real projector into the real world

– 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



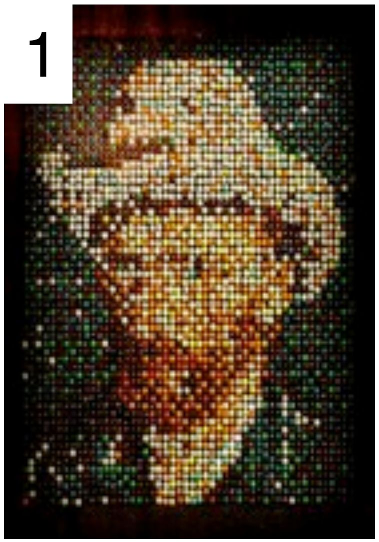
Everywhere display (cont.)

BLUESPACE office scenario

Everywhere display (cont.)

Collaborative experience at SIGGRAPH 2001

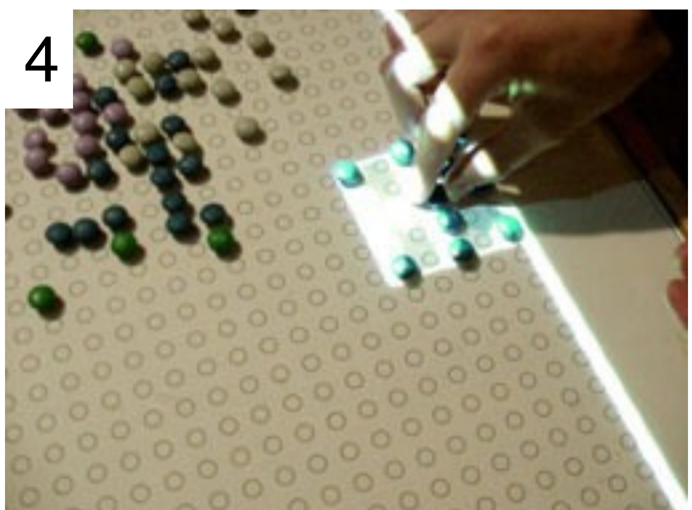
1



2

3

4



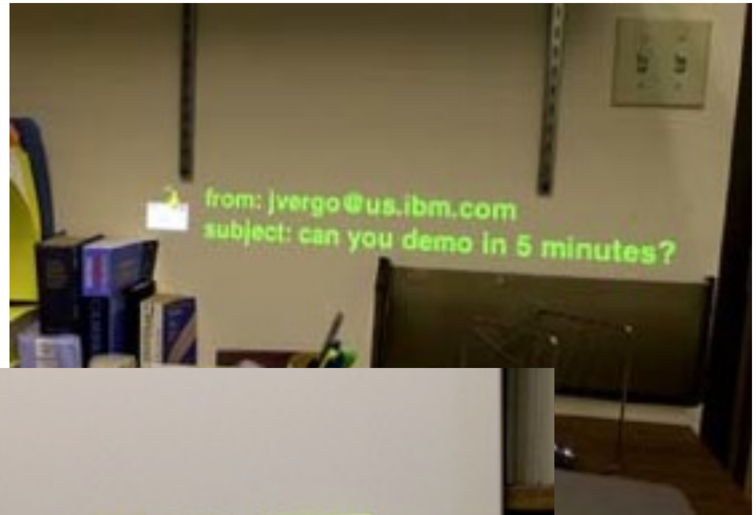
5

Video


visitor 240
Touch to begin.

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

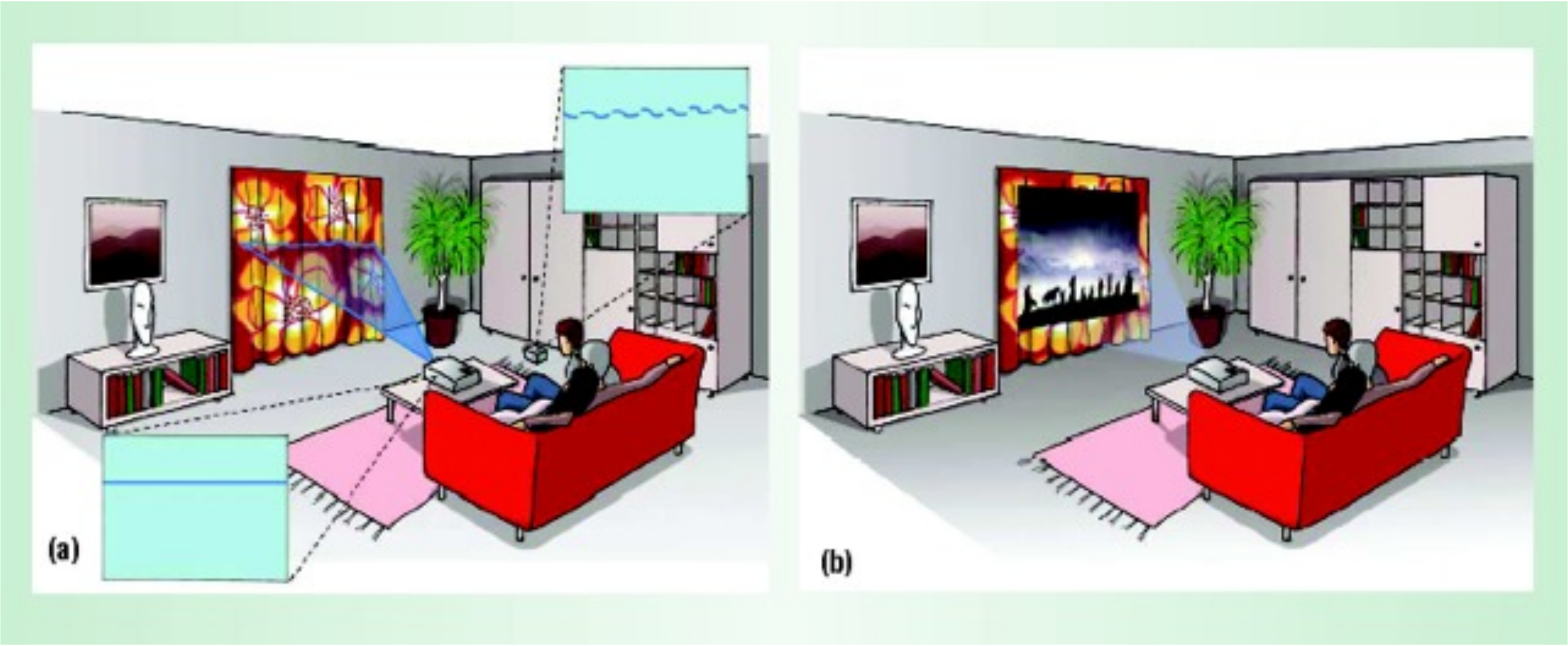
Step 1: Room Scanning

- 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

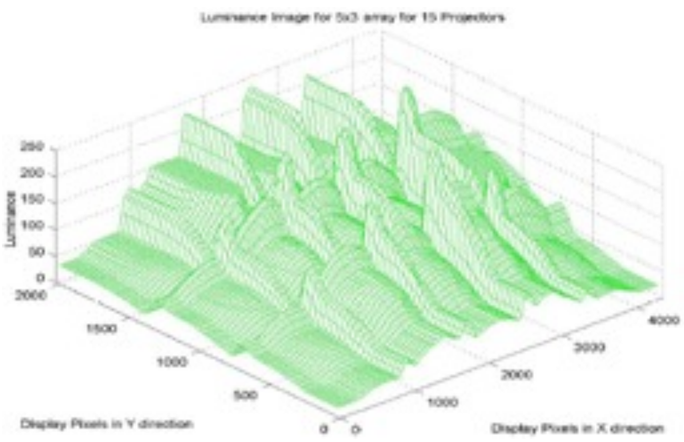
[Majumder & Stevens, VRST 2002]

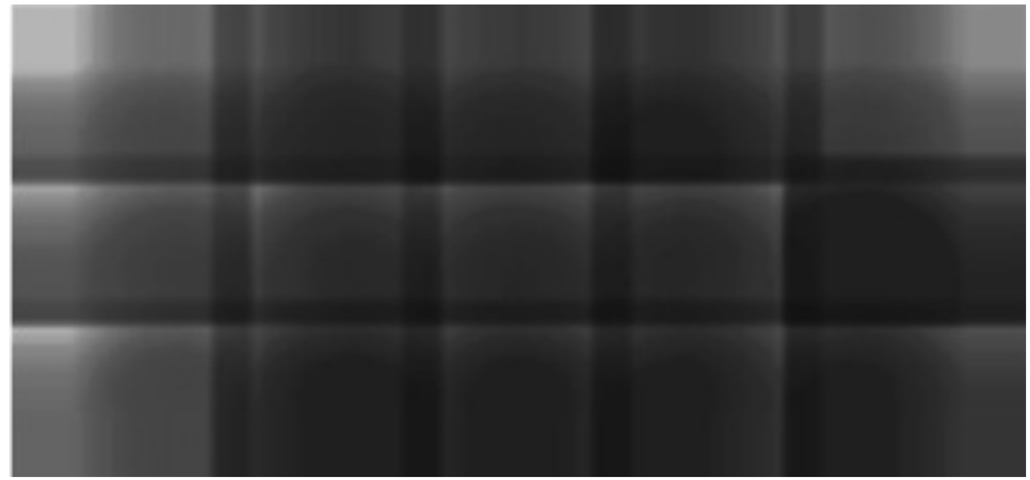
- Large display wall with 5x3 projectors
- Linear ramps (feathering) don‘t work perfectly
- Goal: get rid of the remaining unevenness
- Strategy: don‘t <u>assume</u>, but <u>measure</u>!

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



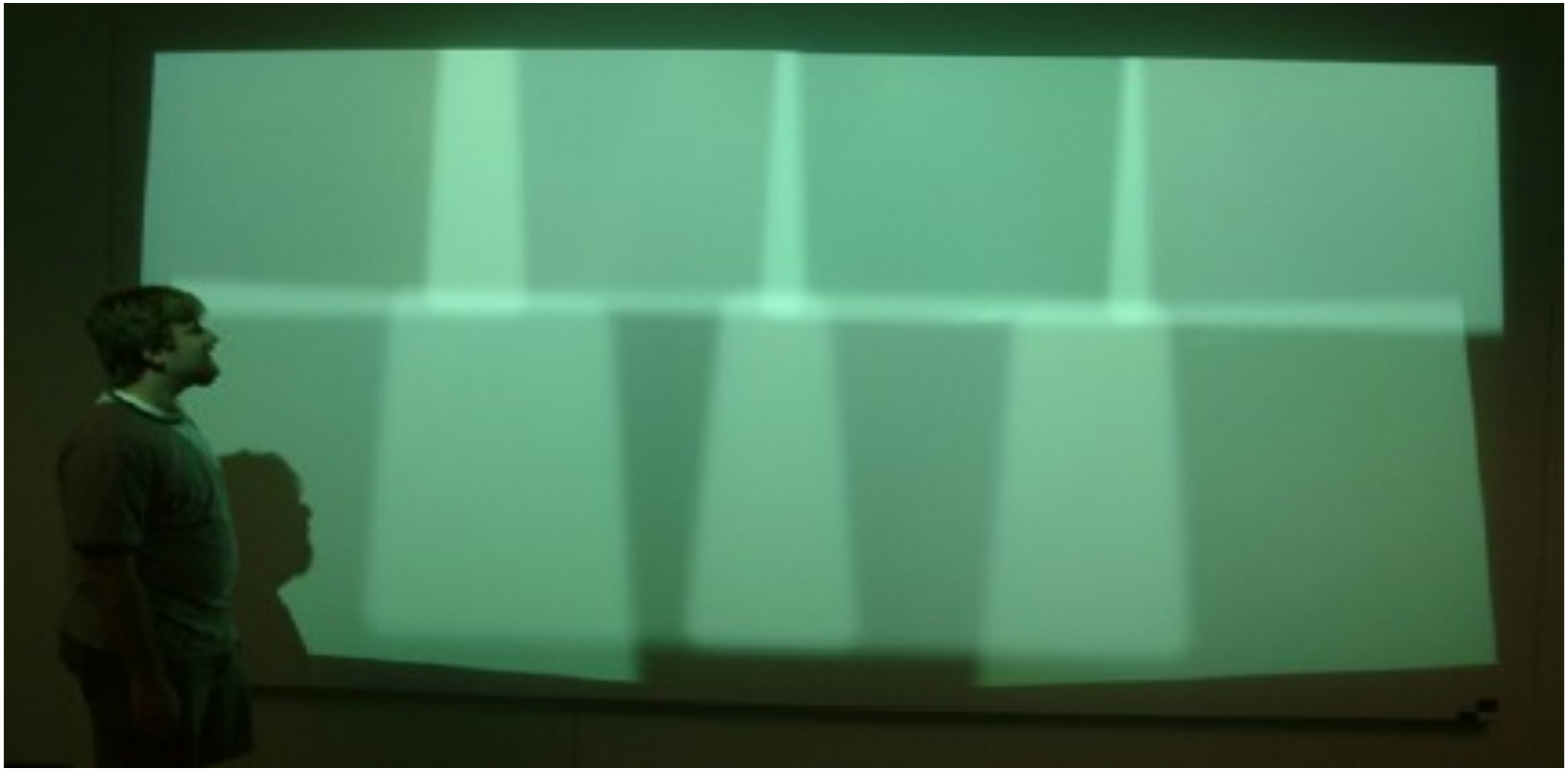


- Gives a factor for multiplication of the final images (just as in feathering)
- Can be done in graphics hardware via alpha channels

LAM: results

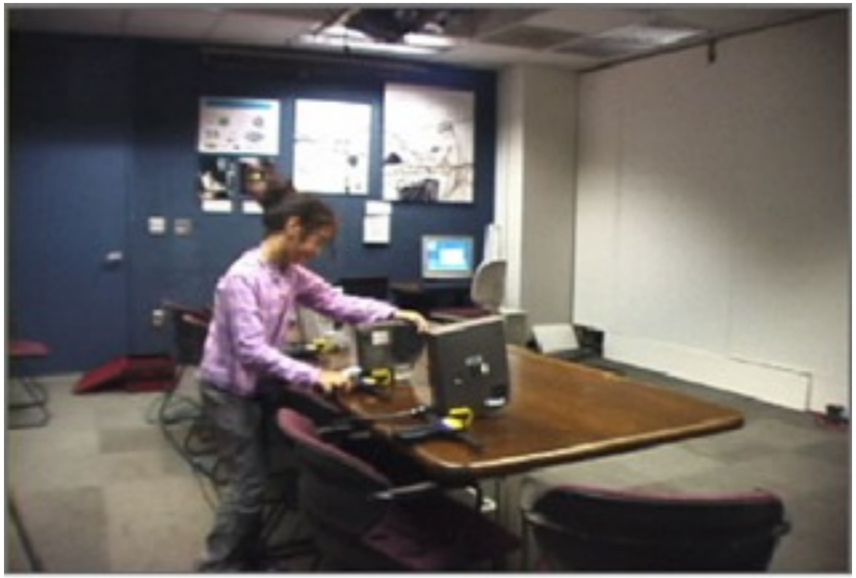
PixelFlex2

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

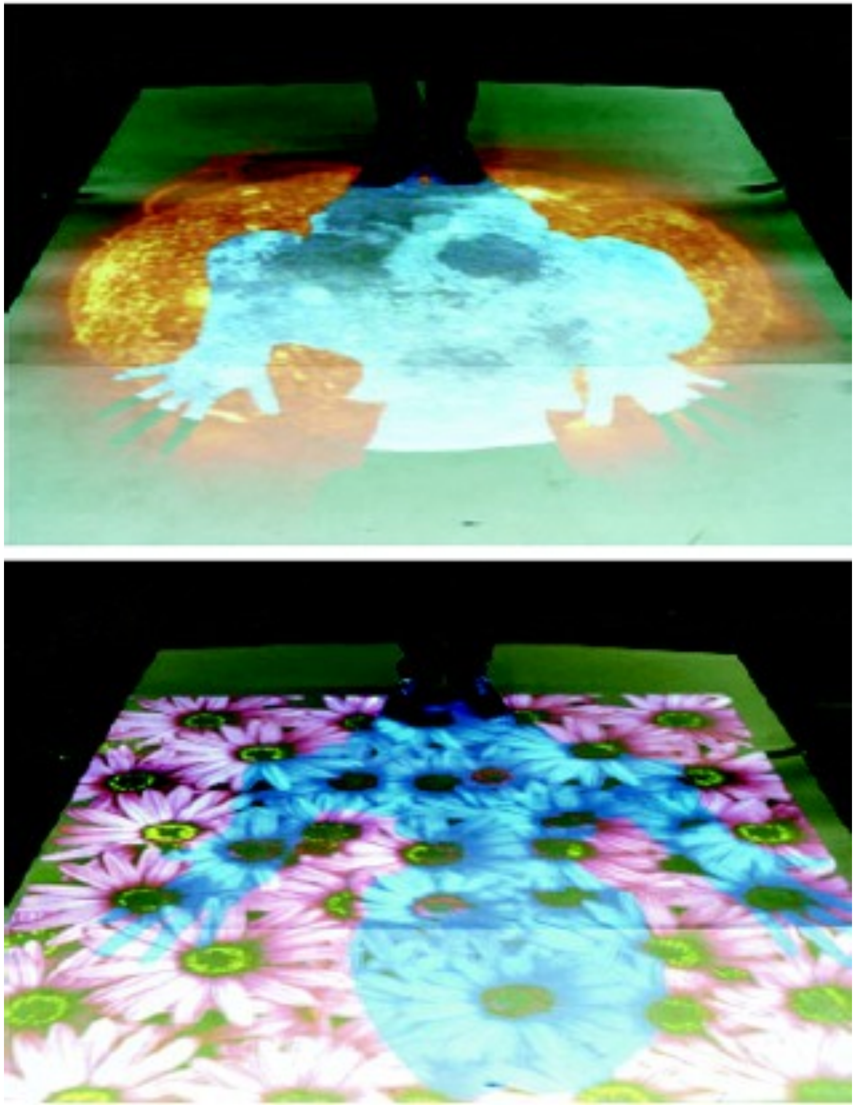


- Uneven brightness and arbitrary geometry:
  - Rectify each projector by calibrating 4 points
  - Used LAMs for brightness

PixelFlex2

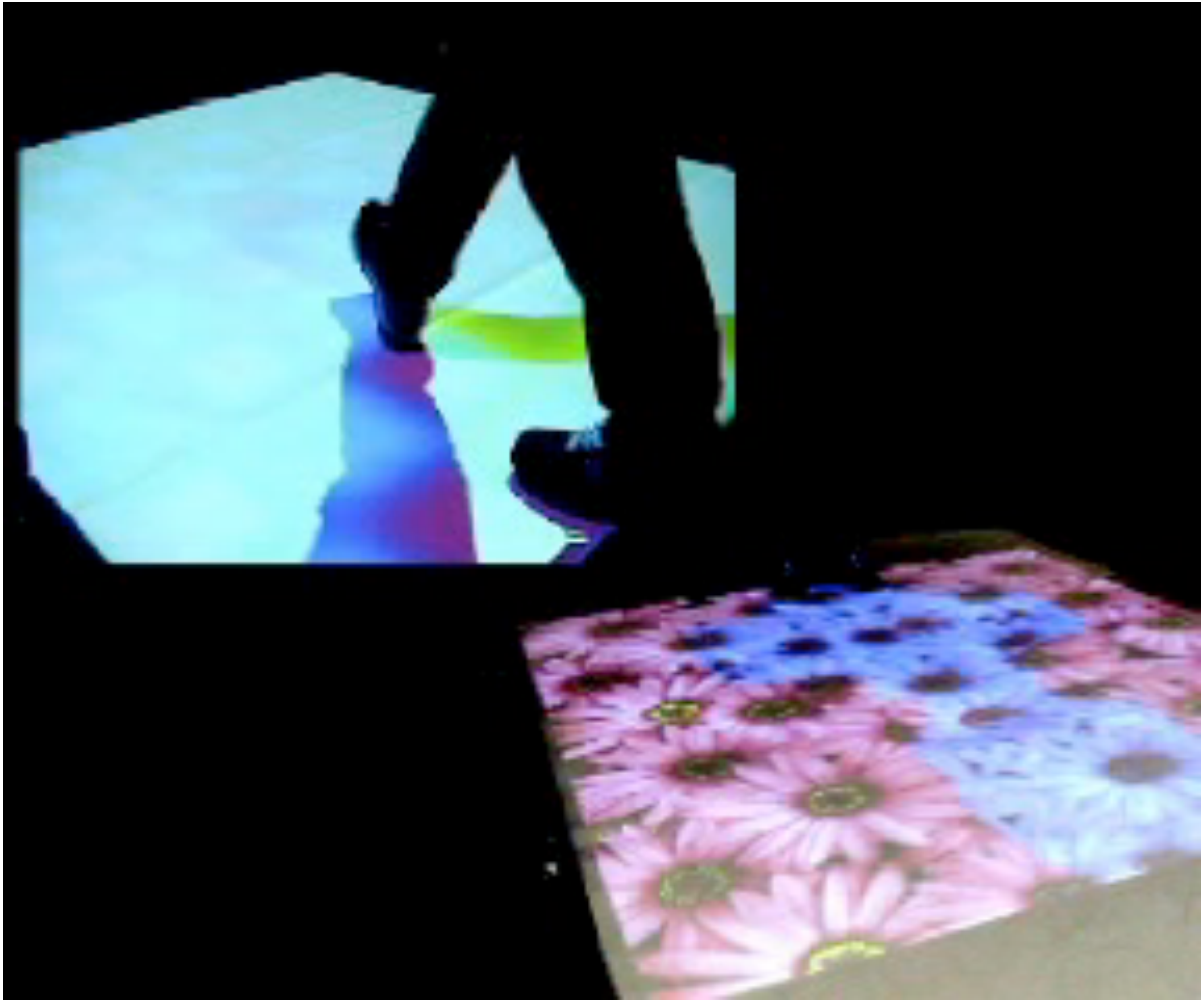


Graphic Shadow
[Kato et al. Ismar 2003]



- 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