Image-Based Modeling, Rendering and Lighting

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UFRGS

Image-Based Modeling

- Construction of geometric models from images
- Exploiting object features (parallelism, symmetry)
- Better results for architectural models
- Main approaches
  - Projective geometry
  - Non-linear optimization
- Computer vision

Image-Based Rendering

- Rendering from samples (no explicit geometric model)
- Reduces the amount of work required to model a scene
- Decouples rendering time from scene complexity
- Uses shading from the original images
- Produces realistic renderings

Image-Based Lighting

- Illuminating scenes and objects (real or synthetic) with images of light from the real world
- Can produce very realistic renderings
- Basic Steps
  - Capture real-world illumination as omnidirectional, high-dynamic range images
  - Map the illumination onto a representation of the environment
  - Place the 3D objects in the environment

Modeling and Rendering Spectrum

images ⟵ hybrid ⟶ geometry

IBR

Pure IBR
- Panoramas
- Concentric Mosaics
- Light Field Rendering
- Plenoptic Stitching
- Polynomial Texture Maps*

- Images with Depth
- LDIs
- Image-Based Objects
- Relief Textures
- Lumigraph
- IB Visual Hulls
- Surface Light Field
- Light Field Mapping

IBM

Pure IBM
- Projective Methods

- Tour into the Picture
- Façade
- Voxel Coloring

Rendering from Panoramas

- Panoramas are usually acquired using special cameras or created by stitching several pictures together
- Most common: cylindrical panoramas (360° horizontal)
- Distortions are compensated for during the rendering

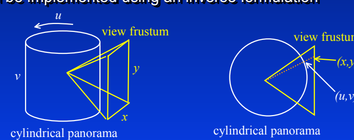
QuickTime® VR - An Image-Based Approach to Virtual Environment Navigation. SIGGRAPH 95.
Copy by permission of ACM, Inc.

Examples of Panoramas

Images by Hans Nyberg - Denmark

Cylindrical Panoramas

- Planar images reprojected from the cylindrical ones
- Scene can be explored by panning and tilting
- Results are correct only from the original viewpoint
- Warping function
  - scaling the columns of the cylindrical image
  - can be implemented using an inverse formulation



Cylindrical Panoramas

Images by Hans Nyberg (top) Philip Morgan (middle) and Armchair Travel Co Ltd, London (bottom)

Spherical Panoramas (cont.)

- Created stitching images acquired using
  - ultra-wide angle fisheye lens to capture at least 180° vertically
  - a parabolic mirror
  - more than one row of pictures

Images by Helmut Dersh: http://www.panoguide.com/technique/spherical.html

Spherical Panoramas

- Covers the entire field of view (360° x 180°)

Image by Helmut Dersch

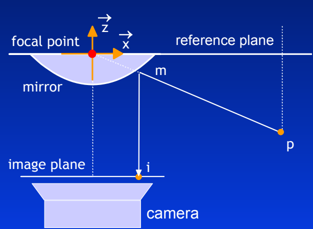
Plenoptic Stitching [Aliaga01]

- Supports exploration of unobstructed environments of arbitrary sizes and shapes
- Captures omnidirectional (360°) images over a grid
- Intersects the paths and creates image loops

Images courtesy of Daniel Aliaga, Bell Labs.

Plenoptic Stitching - capture

- Omnidirectional video camera
  - Paraboloidal Catadioptric System [Nayar97]



~1000x1000 pixels

Courtesy of Daniel Aliaga, Bell Labs.

Plenoptic Results

Courtesy of Daniel Aliaga, Bell Labs.

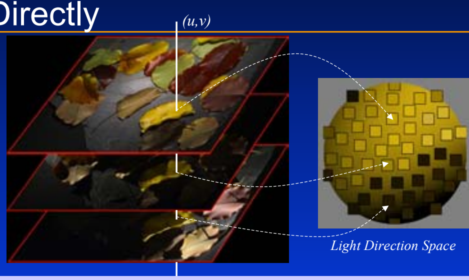
Polynomial Texture Maps

Images and demo by Thomas Malzbender, HP Labs.

Acquiring PTM's Photographically

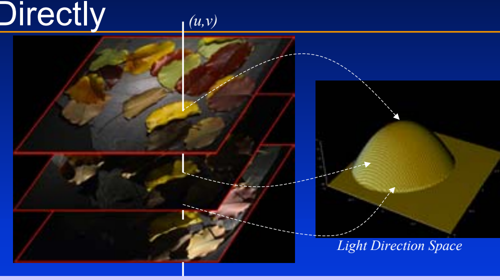
- Fixed object, fixed camera.
- Limited to Diffuse Objects.

Modeling Pixel Color Changes Directly



$$L(u,v;l_u,l_v) = a_0 l_u^2 + a_1 l_v^2 + a_2 l_u l_v + a_3 l_u + a_4 l_v + a_5$$

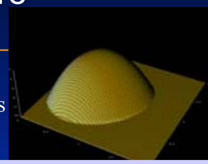
Modeling Pixel Color Changes Directly



$$L(u,v;l_u,l_v) = a_0 l_u^2 + a_1 l_v^2 + a_2 l_u l_v + a_3 l_u + a_4 l_v + a_5$$

Polynomial Texture Mapping

PTM: Store RGB per pixel and Store polynomial coefficients (*a0-a5*) per textel:



$$L(u,v;l_u,l_v) = a_0 l_u^{2} + a_1 l_v^{2} + a_2 l_u l_v + a_3 l_u + a_4 l_v + a_5$$

$R = L\,R'$
$G = L\,G'$
$B = L\,B'$

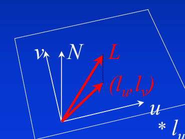
Why Polynomials?

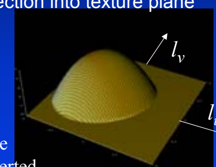
- Compact Representation
- Consist solely of multiplies and adds.
- Cheap to evaluate on both modern CPUs and VLSI

Light Direction Parameterization

$$L(u,v;l_u,l_v) = a_0 l_u^{2} + a_1 l_v^{2} + a_2 l_u l_v + a_3 l_u + a_4 l_v + a_5$$

u,v - texture coordinates
a_0-a_5 - fitted coefficients stored in texture map
l_u,l_v - projection of light direction into texture plane





* l_u,l_v can be scan-converted without normalization

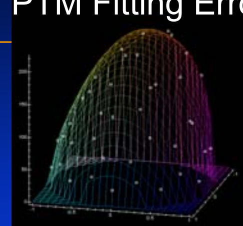
Fitting PTMs to Image Data

- Given *N* light sources we compute the best fit for (a_0-a_6) in the L_2 norm using S.V.D.

- SVD computed once for a given lighting arrangement

$$\begin{bmatrix} l_{u0}^2 & l_{v0}^2 & l_{u0}l_{v0} & l_{u0} & l_{v0} & 1 \\ l_{u1}^2 & l_{v1}^2 & l_{u1}l_{v1} & l_{u1} & l_{v1} & 1 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ l_{uN-1}^2 & l_{vN-1}^2 & l_{uN-1}l_{vN-1} & l_{uN-1} & l_{vN-1} & 1 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ \vdots \\ a_5 \end{bmatrix} = \begin{bmatrix} L_0 \\ L_1 \\ \vdots \\ L_{N-1} \end{bmatrix}$$

PTM Fitting Errors

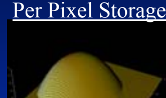


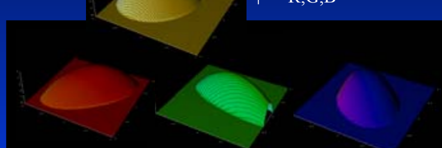
Photograph PTM

- Smoothing is not spatial, it occurs in light space.
- High spatial frequencies are well preserved.
- Hard shadows become softer.
- Point lights become area lights.

PTM Formats

Format Per Pixel Storage

- LRGB -  + R,G,B

- RGB 

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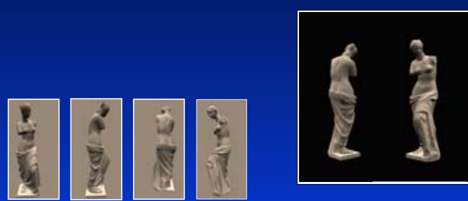
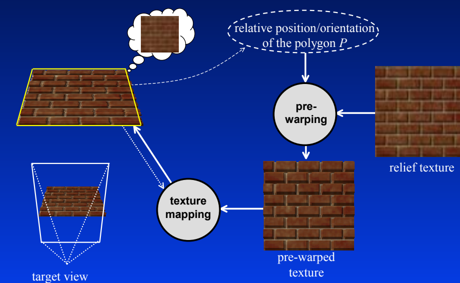
3-D Image Warping

- Reprojects images with depth

Image-Based Objects [Oliveira 99]



Relief Texture Mapping [Oliveira 00]



Light Field Mapping

- Approximate geometric model
- Samples from different viewing directions

Image by Wei-Chao Chen, R. Grzeszczuk, J. Bouguet

Single-View Reconstruction [Criminisi99]

- Recovers incomplete models from single images

Tour Into the Picture

Image-Based Lighting