Lightfields and Lumigraphs

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Image-Based Rendering (IBR)

• Built on the desire to bypass the (manual) modeling phase and directly produce the final visual results
  – Does *not* just place images on geometry
  – Does *not* try to reconstruct the geometry of the environment

(some slides courtesy of Voicu Popescu, Anselmo Lastra, and Marc Levoy)
Photographs

• We have tools that acquire and tools that display photographs at a convincing quality level
Image-Based Rendering (IBR)

- Built on the desire to bypass the (manual) modeling phase and directly produce the final visual results
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- How can we use images (of some kind) to “model” 3D objects and 3D environments?
Plenoptic Function

• $P(x, y, z, \phi, \varphi, \lambda, t)$

  – 7D function to describe light intensity passing through every viewpoint, for every direction, for every wavelength, and for every time instant
Plenoptic Function

- “Holodeck” (Star Trek)
- Layered Depth Images [Shade98]
- 3D Image Warping [Max95, McMillan95, ...]
- View Interpolation [Chen93]
- Sea of Images [Aliaga01]
- Lightfield/Lumigraph [Levoy96, Gortler96]
- Plenoptic Stitching [Aliaga99]
- Concentric Mosaics [Shum99]
- Panoramic Images [Szeliski97, ...]
What is a “light ray through space”?

Lines, rays, bundles of them, line is 2D+2D, ray is 3D+2D
Light Ray Organization

- Surface-centric
- Viewpoint-centric

or

- Inside-looking-out
- Outside-looking-in
Reducing Dimensions of the Plenoptic Function

• Use constant frequencies
• Use static environments
• Use open spaces
Light Ray Parameterization

• Random collection of rays
• Two slab representation \((s,t,u,v)\)
• Box representation
4D Lightfield / Lumigraph

• Demo
4D Lightfield / Lumigraph
Discreete 4D Lightfield
Lightfield

- Set of images with COPs on regular grid
Lightfield

- Set of images of a point seen at various angles
Depth Correction of Rays
Depth Correction of Rays
Capture a dense set of photographs
Capturing a sparse set of photographs

acquisition stage

camera positions

blue screening
Filling in gaps using pull-push algorithm

- **Pull phase**
  - low res levels are created
  - gaps are shrunk

- **Push phase**
  - gaps at high res levels are filled using low res levels
Compression

• Large size uncompressed: 1.125GB
  – 32x32 (s, t) x 256x256 (u, v) x 6 faces x 3 B

• Compression
  – JPEG + MPEG (200:1 to 6MB)
  – or vector quantization + entropy encoding
Vector Quantization (VQ)

• Principle
  – codebook made of codewords
  – replace actual word with closest codeword

• Implementation
  – training on representative set of words to derive best codebook
  – compression: replacing word with index to closest codeword
  – decompression: retrieve indexed codeword from codebook
Lightfield compression using VQ

- Light field $\rightarrow$ VQ (402 MB)
- Indices $\rightarrow$ LZ (16.7 MB)
- Codebook $\rightarrow$ LZ (0.8 MB)
- Bitstream $\rightarrow$ (3.4 MB)
Acquiring a 4D Lightfield/Lumigraph

- Capture (many images)
- Organize into a \((s,t,u,v)\) parameterization
  - Do not "need" to resample the pixels
  - Use (linear) interpolation to extract an arbitrary ray/line
  - Optionally compress/decompress data
  - Interactively extract rays/lines to create a visual representation
Limitations of a Lightfield/Lumigraph

• What are they?
Limitations of a Lightfield/Lumigraph

- Resolution
- High storage requirement
- Difficult capture (?)
- No geometry
  - Cannot add new geometry and (easily) do occlusion and re-illumination