Lightfields and Lumigraphs

Vision for Graphics
CSE 590SS, Winter 2001
Richard Szeliski
(with lots of slides from Michael Cohen)
Modeling light

How do we generate new scenes and animations from existing ones?

Classic “3D Vision + Graphics”:

- take (lots of) pictures
- recover camera pose
- build 3D model
- extract texture maps / BRDFs
- synthesize new views
Computer Graphics
Computer Vision

Output

Model

Real Cameras

Real Scene
Combined

Output
Image

Synthetic Camera

Model

Real Scene

Real Cameras
But, vision technology falls short
... and so does graphics.
Image Based Rendering

- Real Scene
- Real Cameras
- Expensive Image Synthesis

Output

Image

Synthetic Camera

Images + Model

Real Scene

Real Cameras
Ray

Constant radiance
  • time is fixed

5D
  • 3D position
  • 2D direction
All Rays

Plenoptic Function:

- all possible images
- too much stuff!
Line

Infinite line

4D
- 2D direction
- 2D position
- non-dispersive medium
Ray

Discretize, then interpolate

Distance between 2 rays
- Which is closer together?
Image

What is an image?

All rays through a point
• Panorama?
Image

Image plane

2D

• position
Object

Light leaving towards “eye”

2D
  • just dual of image
Object

All light leaving object
Object

4D
- 2D position
- 2D direction
Object

All images
Lumigraph / Lightfield

Outside convex space

Empty

4D

Stuff

3/7/2001

Vision for Graphics
Lumigraph

Inside convex space

Stuff

4D

Empty

3/7/2001

Vision for Graphics
Lumigraph

How to

• organize
• capture
• render
Lumigraph - Organization

2D position
2D direction
Lumigraph - Organization

2D position
2D position

2 plane parameterization
Lumigraph - Organization

2D position
2D position

2 plane parameterization
Hold $s,t$ constant
Let $u,v$ vary
An image
Lumigraph - Organization

Discretization

- higher res near object
  - if diffuse
  - captures texture
- lower res away
  - captures directions
Lumigraph - Capture

Idea 1

• Move camera carefully over s,t plane
• Gantry
  – see Lightfield paper
Lumigraph - Capture

Idea 2

• Move camera anywhere
• Rebinning
  – see Lumigraph paper
Lumigraph - Rendering

For each output pixel
- determine $s,t,u,v$
- either
  - find closest discrete RGB
  - interpolate near values
Lumigraph - Rendering

- For each output pixel
  - determine s,t,u,v

- either
  - use closest discrete RGB
  - interpolate near values
Lumigraph - Rendering

Nearest
- closest s
- closest u
- draw it

Blend 16 nearest
- quadrilinear interpolation
Lumigraph - Rendering

Depth Correction

• closest s
• intersection with “object”
• best u
• closest u
Lumigraph - Rendering

Depth Correction

- quadrilinear interpolation
- new “closest”
- like focus
Lumigraph - Rendering

Fast s,t,u,v finding
- scanline interpolate
- texture mapping
- shear warp
Lumigraph - Ray Space
Lumigraph - Ray Space

Image effects:
• parallax
• occlusion
• transparency
• highlights
Lumigraph - Demo

Lumigraph

- Lion, Fruit Bowl, Visible Woman, Path Tracing
Lightfield - Demo

Digital Michelangelo Project

– Marc Levoy, Stanford University
– Lightfield ("night") assembled by Jon Shade
Surface Lightfields

Turn 4D parameterization around
Leverage coherence
Surface Lightfields

Wood et al, SIGGRAPH 2000
3D Representations

Image is 2D
Lumigraph is 4D
What happened to 3D?

- 3D Lumigraph subset
- Concentric mosaics
3D Lumigraph

One row of s,t plane
• i.e., hold t constant
3D Lumigraph

One row of s,t plane
- i.e., hold t constant
- thus s,u,v
- a “row of images”
Concentric Mosaics

Replace “row” with “circle” of images
Concentric Mosaics
Concentric Mosaics

From above
Concentric Mosaics

Depth correction
Concentric Mosaics

- Panorama
2.5D Representations

Image is 2D
Lumigraph is 4D
3D
  • 3D Lumigraph subset
  • Concentric mosaics

2.5D
  • Layered Depth Images
  • View Dependent Surfaces
Layered Depth Image

2.5 D ?
Layered Depth Image

- Rendering from LDI

- Incremental in LDI X and Y
- Guaranteed to be in back-to-front order
Layered Depth Image

- Rendering from LDI

- Incremental in LDI X and Y
- Guaranteed to be in back-to-front order
Layered Depth Image (LDI)
Tiled LDIs
Tiled LDIs

Multiresolution
Directionally dependent
Image Based Models

Modeling and Rendering Architecture from Photographs
Debevec, Taylor, and Malik 1996

Original photograph with marked edges
Recovered model
Model edges projected onto photograph
Synthetic rendering
Image Based Faces

Estimate shape from images
Match metrics to shape
Project video onto shape
  • Texture map
Animate
Summary

5D: Plenoptic Function (Ray)
4D: Lumigraph / Lightfield
3D: Lumigraph Subset
3D: Concentric Mosaics
2.5D: Layered Depth Image
2.5D: Image Based Models
2D: Image