Final projects

- Final report due tomorrow Friday at 5pm
- Next Tuesday: Best project presentation in class

IBMR

- Image-Based Modeling and Rendering
- Reuse images to generate new views
- Use images to create 3D models

- New area of computer graphics (mid nineties)
- Lot of research at MIT

What we have learnt so far

- Graphics is about producing images from a scene description
- Geometry + reflectance property + light
- From continuous description to a discrete image

What IBMR is about

- Focus on discrete descriptions
- Forget (mostly) about geometry

- IBMR is about samples
  - cf. lecture on sampling and antialiasing
Motivations

- Geometry is costly
- Triangles become tiny
- Triangles are not good for complex objects, e.g. plants
- Photos are photorealistic
  - Well, we could argue about that another time
- Modeling is tedious

IBR Principles

- Consider images as a collection of rays,
  … rather than a collection of pixels.

The Plenoptic Function

- Complete view for each point of space
- 3D (for position) * 2D (for view) * 1D for wavelength * 1D for time

Image-based rendering is about

… signal reconstruction rather than physical simulation.

Geometry vs. sample

- Geometry exploits the structure of the scene
  - Compression (information theory point of view)
- IBMR is brute force
  - Closer to final images
  - Simpler to render
  - More costly to store
  - Harder to manipulate, create, edit
- To decrease dimensionality
  - Add geometry for structure
  - Forget some visual phenomena

We already know some IBR…

- Texture mapping!
Overview

• Image-based rendering
  – Various dimensionalities
  – Various structure

• Image-based Modeling

• Image-Based Modeling and Editing

Questions?

QuickTime VR & Panoramas

• 2D reconstruction only:
  1 single complete view

See http://www.panoguide.com/gallery/

Video

• 3D slice

Light field and Lumigraph

• 4D representation

• Plane of cameras

2-plane parameterization

• Lines in space have 4D
2-plane parameterization

• Sample this 4D space of light rays
• What do we miss in the plenoptic function?

Light field reconstruction

• Compute an image similar to ray casting
• Simple lookup
• Can be optimized

Light field

• Collection of rays
• Collection of images

Light-field/Lumigraph slice

• Demo

Structure…

• Which ray is best?

Structure…

• Which ray is best?
• Geometry matters!
**Depth correction: Lumigraph**

Without depth correction  
With depth correction

From [Gortler et al. 96]

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**Light Field Acquisition**

- **Motion Platforms**
  - Precise positioning
  - Calibrated digital camera
  - Expensive (> $10K)
  - Very Slow (~20 mins)
- **Light field cameras**
  - Less precise
  - Calibration per aperture
  - Inexpensive (~ $100)
  - Slow (> 3 mins)

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**LF Rendering**

- **Advantages**
  - Simple/Fast rendering algorithm
  - View-dependent shading
  - High-quality reconstructions

- **Disadvantages**
  - Huge memory footprint (compression)
  - Incompatible with traditional graphics

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**Images with Depth**

- [Chen & Williams 1993, McMillan & Bishop 1995]
- 2D representation (image) + depth per pixel
- View warping to reproject pixels
- Tradeoff between dimensionality and geometric information

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**View warping**

- [Chen & Williams 1993, McMillan & Bishop 1995]
- Reprojects pixels with depth
- 2 Types of problems
  - Disocclusion
  - Undersampling
- Undersampling can be alleviated using splatting
  - Instead of displaying a pixel, display a “splat” (ellipse)
Layered Depth Images (LDI)

- Same as Images with depth, but multiple samples in depth for one (x,y) pixel
- Solves many disocclusion artifacts

- Demo

Acquiring Depth Images

- Economical laser scanners

Images and video courtesy of the University of North Carolina at Chapel Hill, “Office of the Future” Project, Wei-Chao Chen, Henry Fuchs, Lars Nyland, Herman Towles and Greg Welch.

Visual Hulls

- Intersection of all silhouette cones

What is a Visual Hull?

Why Use a Visual Hull?

- Finding silhouettes is simple and robust
  - Blue-screen methods
  - Image differenceing

- Contains actual object
  - Can seed more sophisticated methods

Acquisition

- Several cameras with overlapping views
  - Geometric calibration
  - Photometric calibration
  - Synchronization
Representing a Visual Hull

- Geometric Model
  + Know how to render
    - Calculating intersections isn’t robust
    - High polygonal complexity
- Volumetric Model
  + Easy to compute
  - Expensive storage
  - Result seldom predicts inputs

Image-based Visual Hulls

- Volume-like
- Self-consistent
- Discrete-discrete-continuous

Shading Visual Hulls

- View-dependent illumination
- Visibility

Results

A range of different virtual viewpoints of a visual hull computed from four cameras in real-time. Top images show depth maps and bottom images show shaded visual hulls. The background is a textured polygonal model.

Summary

- Plenoptic function is mostly 5D
- Images and panoramas are 2D
- Video is 3D
- Light fields are 4D
- Structure can help
- Images with depth
- Visual hull

Results Video
Overview

- Image-based rendering
  - Various dimensionalities
  - Various structure

- Image-based Modeling

- Image-Based Modeling and Editing

Image-based Modeling

- From a set of 2D images
- Build a 3D polygonal model
- Using vision techniques & user intervention

Polygonal Representation

- Modeling and Rendering Architecture from Photographs
  [Debevec et al. 1996]

Image-based modeling

- Write down the equations
- Optimize
  - Camera coordinate system
  - Edge location

Video
Questions?

Overview

- Image-based rendering
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- Image-based Modeling

- Image-Based Modeling and Editing

Image-based modeling & editing

- Joint work with Oh, Chen & Dorsey
- Create an Image-Based representation
- Editing of sampled representation
- Our context: Single image as input

Image-Based Representation

- Images with depth per pixel [Chen 93]
- Layers

Workflow

Depth Assignment Tool

- Tool that assigns or modifies the depth of pixels
- Similar to tools of 2D photo editing
  - But on the depth channel
Depth Assignment and Selection

- Arbitrary selection/segmentation restricts the affected pixels

Going Beyond Painting

- Painting absolute depth is hard
- Hybrid geometric tools
  - But still pixel based (flexible, use of selection)
  - Geometry is temporary

Ground Plane Tool

- The ground plane is easy to infer (horizon)
- Will be used as a reference

Vertical Tool

- Uses ground plane as reference
- Draw contact between ground and object in image

Other Geometric Primitives

- Sphere, cylinder, box, pyramid, etc.
- Possible snapping to constrain verticality

Organic Shapes

- Level set method [Wil98,IMT99]
- Distant depth at boundary, closer depth towards center
### Generic Geometry Tool
- 3D template
- User defined point correspondences
- 3D pose optimization
- Refinement through 2D morphing

### Depth Painting & Chiseling
- Paint on depth channel \([\text{Kan}98]\)
- Relative or absolute
- Local smoothing, sharpening

### Refined Example

### Clone brushing
- Copy via brush interface

### 2D Clone Brush
- Copy via brush interface
2D Clone Brush

- Copy via brush interface

Limitations of 2D Clone Brushing

- Distortions due to foreshortening and surface orientation

Coping with Distortions

- We have depth information
- Minimize distortion
- Non-distorted parameterization
- Iterative optimization

Examples
Results – Hotel Lobby

Results – Dali

Tuesday

• Best project presentations

Images vs. geometry

• Photos

Image-Based Models: What do they allow?