Image-Based Rendering

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What is it?

- Still a difficult question to answer
- Uses images (photometric info) as key component of model representation

What's Good about IBR

Model acquisition

- Detailed 3D geometry difficult to construct
- Images relatively easy to acquire

Model quality

- If you want photo-realistic output, start with photo-realistic input

Rendering complexity

- dependent on resolution of images and screen, not 3D geometry

Defining the Problem

Plenoptic function

$$p = P(\theta,\phi,\lambda,V_x, V_y, V_z, t)$$

"Given a set of samples (complete or incomplete) from the plenoptic function, the goal of image-based rendering is to generate a continuous representation of that function"

Accomplishing IBR

Sampling

Reconstruction

Re-sampling

3D Images (Depth Images)

Image has x and y resolution

Each sample has *depth* as well as color

Acquiring 3D Images (Sampling)

Range camera

Overlapping images

Camera rotation about tripod

Conventional 3D rendering

Rendering 3D Images

Think of each sample as a 3D point

- Transform each point according to viewing parameters
- Kind of slow

3D image warping

- Don't transform each point independently
- Take advantage of the x and y coherence of the image representation

3D Image Warping as Forward Mapping

Depth image is the *source*

Generated image is the *destination*

Very regular source image is warped to destination image

- No longer regular in destination image
  - Similar to problem in texture mapping
- Ultimately need to get regularly sampled destination

Difficulties of Forward Mappings

- Mappings are "many to one"
- Some destination pixels may be multiply-covered
- Some destination pixels may not be covered at all

Dealing with Difficulties

Multiple coverage

- Z-buffering
- back-to-front traversal

Holes

- alleviated by warping multiple images
- hole-filling interpolation possible

Some 3D Image Warping Based IBR Algorithms

- **View Interpolation**
  - **Chen/Williams, *SIGGRAPH 93***
- **Post-Rendering Warping**
  - **Mark et al., *I3DG 97***
- **QuickTime VR**
  - **Chen, *SIGGRAPH 95***
- **Plenoptic Modeling**
  - **McMillan/Bishop, *SIGGRAPH 95***
- **Layered Depth Images**
  - **Shade et al., *SIGGRAPH 98***

View Interpolation

Sample a number of depth images

Build adjacency graph of images

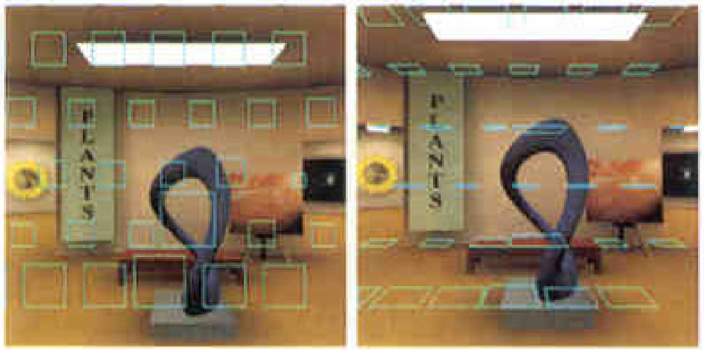
- nodes are images
- edges are mappings between them

Interpolate pixels to construct in-between images (i.e. - 3D image warping)

Correspondence Mappings

- Apply 4x4 transformation to source pixels to determine location in destination frame
- Approximate transformation by per-pixel linear interpolation
- For each graph edge, construct two mappings, one for each direction

View Interpolation Examples



(a) (b)

Fig. 2 Extents of pixel movement for 2D viewpoint motions: a) viewpoints parallel to the viewing plane, b) viewpoints parallel to the ground. (Source pixels are in the lower right corner of each extent.)

(a) (b) (c) (d)

Fig. 5 (a) Holes from one source image, (b) holes from two source images, (c) holes from two closely spaced source images, (d) filling the holes with interpolation.

from Chen and Williams, "View Interpolation for Image Synthesis," *Proceedings of SIGGRAPH 93*, pages 286-287.

Post-Rendering Warping

- Render conventional 3D graphics images slowly, on-the-fly
- Apply 3D image warping to generate in-between images quickly
- Use view prediction to guess future view to start rendering conventionally

Post-Rendering Warping Example

Plate 1: A typical derived frame produced by our test-bed. The reference frames were generated at 5 frames/sec, and the average per-axis position prediction error was 5.0 cm.

Plate 3: A particularly bad reference frame produced by our test-bed. Some areas of the image near the door were occluded in both reference frames, mostly because of prediction error.

from Mark, McMillan, and Bishop, "Post-Rendering 3D Warping", *Proceedings of 1997 Symposium on Interactive 3D Graphics*, page 180.

Video

Mark, McMillan, and Bishop, "Post-Rendering 3D Warping", ***Proceedings of 1997 Symposium on Interactive 3D Graphics***

Quick-Time VR

Choose key eye positions to sample

Capture/create cylindrical panoramic image for each eye position

Allow users to "hop" among eye positions and rotate/zoom at each position

- Fairly simple computation to map panorama to screen

Actually, doesn't use depth images

Quick-Time VR Examples

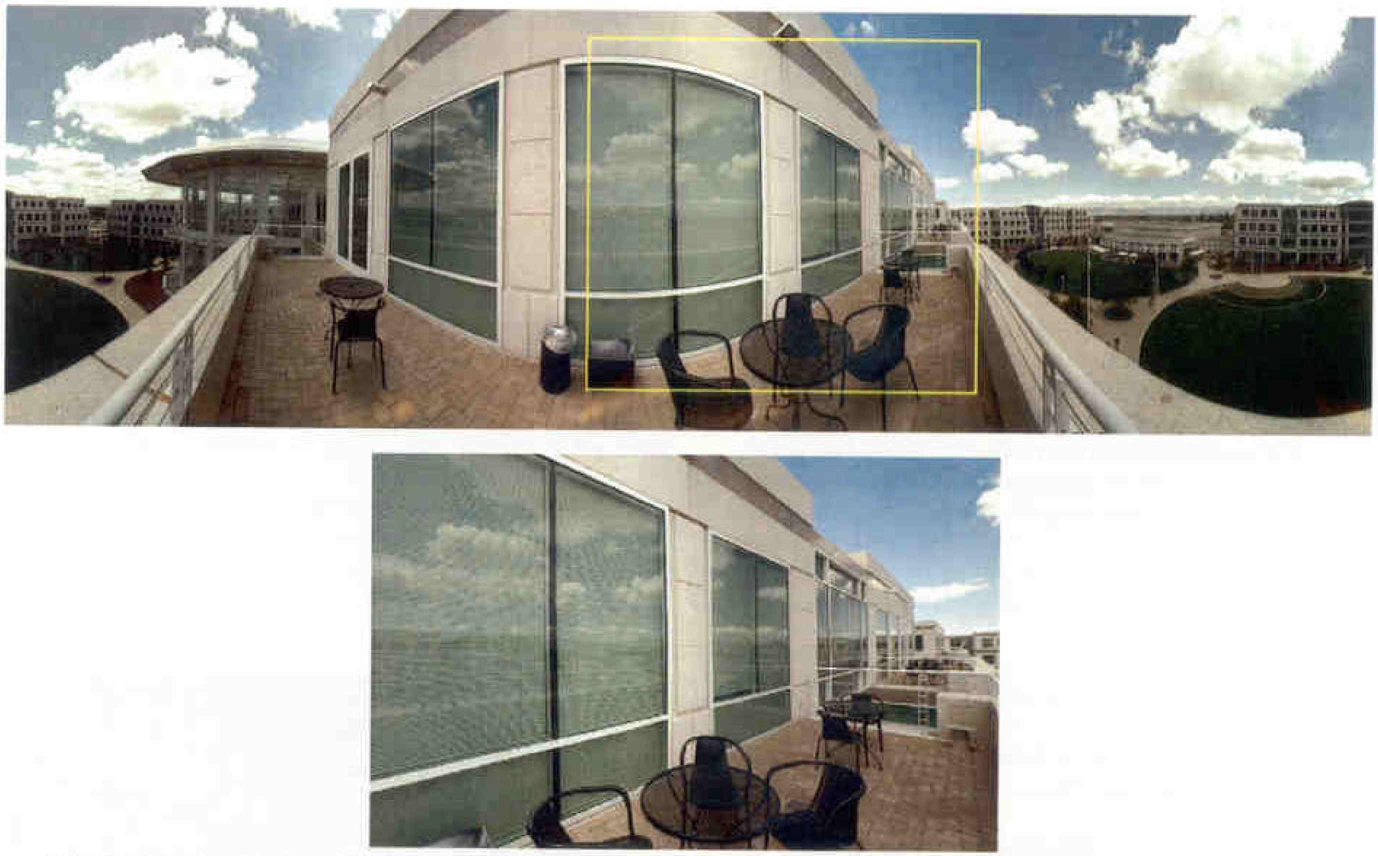


Figure 5. A perspective view created from warping a region enclosed by the yellow box in the panoramic image.

from Chen, "Quick-Time VR: An Image-Based Approach to Virtual Environment Navigation," *Proceedings of SIGGRAPH 95*, page 38

Plenoptic Modeling

- Provides mathematical framework for analyzing IBR algorithms with respect to plenoptic function
- Presents algorithm for visibility-preserving (back-to-front) traversal in 3D image warping
- Develop system for full 3D image warping of cylindrical panoramas

Plenoptic Modeling Examples

from McMillan and Bishop, “Plenoptic Modeling: An Image-Based Rendering System”, page 45.

Layered Depth Images

Allow multiple samples per pixel in depth image

- Each sample at different depth
- All the front-most samples are first “layer”, etc.

Alleviates *exposure* artifacts

Often small average number of samples per pixel can remove most of the artifacts

Videos

Shade, Gortler, He, and Szeliski, "Layered Depth Images," *Proceedings of SIGGRAPH 98.*

Oliviera and Bishop, "Image-based Objects," *Proceedings of 1999 Symposium on Interactive 3D Graphics.*

Chang, Bishop, and Lastra, "LDI Tree," *Proceedings of SIGGRAPH 99.*