Image-Based Rendering

October 30, 2006

What Does 3D Mean? (1/3)

- Computer games like these are 2D:

What Does 3D Mean? (2/3)

- Computer games like this are 3D:

Screenshot from Age of Mythology, © Microsoft and Ensemble Studio
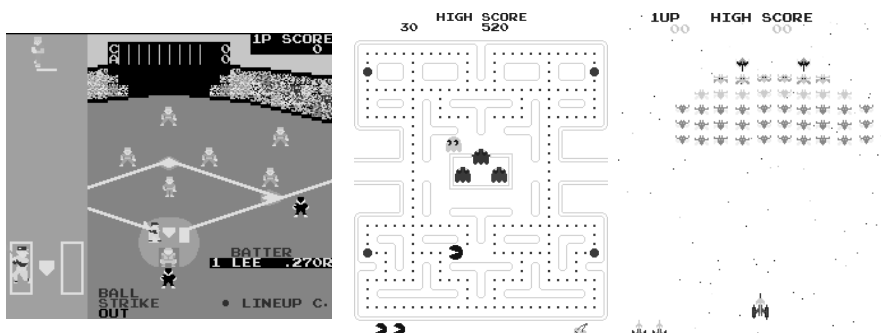
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What Does 3D Mean? (3/3)

- Movies are 2D, but why do we call these 3D animations:
  - Luxo Jr.
  - Toy Story, A Bug's Life, Finding Nemo…etc. from Pixar
  - Ants, Shrek, Ice Age…etc.

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Answer Anyone?

- What are the limitations of 2D?

How to Create 3D Contents

- AutoCAD: used for architectures (buildings)
- 3D Studio Max, Softimage…etc.
- Maya is a major production tool used in art schools.
- Problems? It takes an artist, and it's still hard to make it look real!

3D Photography

- Can building 3D models be as easy as taking 2D photos?
- How do we digitize the massive assets in various museums?
  - QuickTime VR object movies
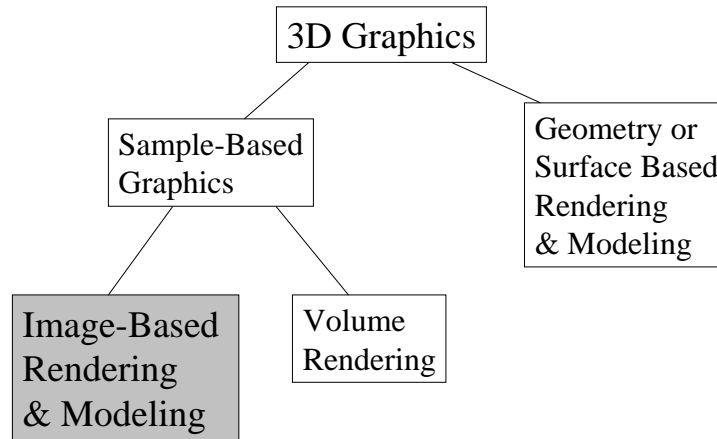 - 3D Scans: Cyberware scanner, Digital Michelangeo

Source: www.cyberware.com

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Image-Based Rendering

- Can we build 3D contents from photographs directly?
  - Difference from computer vision?
- Can we make the objects look more real?
  - Difference from texture mapping?

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Top Level Survey

```
                    3D Graphics
                   /          \
          Sample-Based      Geometry or
          Graphics          Surface Based
          /        \        Rendering
    Image-Based   Volume    & Modeling
    Rendering     Rendering
    & Modeling
```

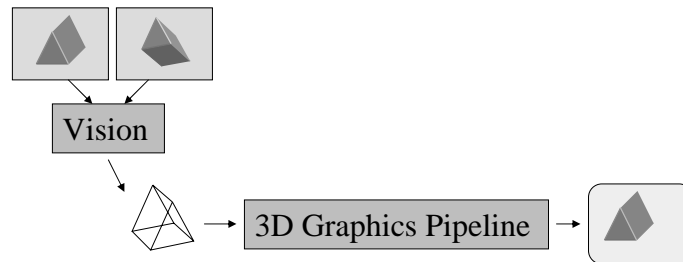CS5502 Digital Image Synthesis
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Traditional Computer Graphics

- Input: Geometry, Material Properties (Color, Reflectance,…etc.), Lighting.
- Transformation and Rasterization.

Transf... 3D Graphics Pipeline ...zation
(& Lighting)

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Role of Images

- Used as textures.
- Or, as input to computer vision methods in order to recover the 3D models.

Vision

→ 3D Graphics Pipeline →

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Image-Based Rendering

- To bypass the 3D models altogether.

Vision

Image-Based Rendering

→ 3D Graphics Pipeline →
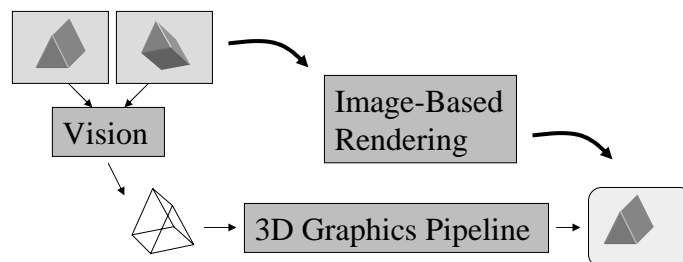
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Image-Based Rendering

- Input: Regular Images or "Depth Images."
- No 3D model is constructed.
- Example: 3D Warping.

3D Warping: Another Example

- Reading room of UNC CS department
  - Source images contain depths in each pixel.
  - The depths are obtained from a laser range finder.

Why IBR?

	Geometry	IBR
Modeling	Difficult	Easy
Complexity	#triangles	#pixels
Fidelity	Synthetic	Acquired

- Problems of triangle-based graphics:
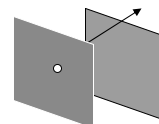 - Always starts from scratch.
  - Millions of sub-pixel triangles.

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Why is It Possible?

Picture source: Leonard McMillan

- 5D Plenoptic Function.
  - Color = $f(x, y, z, \theta, \phi)$
  - (x, y, z) defines the viewpoint.
  - (θ, ϕ) defines the view direction.
- 4D Light Field/Lumigraph
  - Color = $f(u, v, s, t)$
  - (u, v) defines the viewpoint.
  - (s, t) defines the pixel coord.

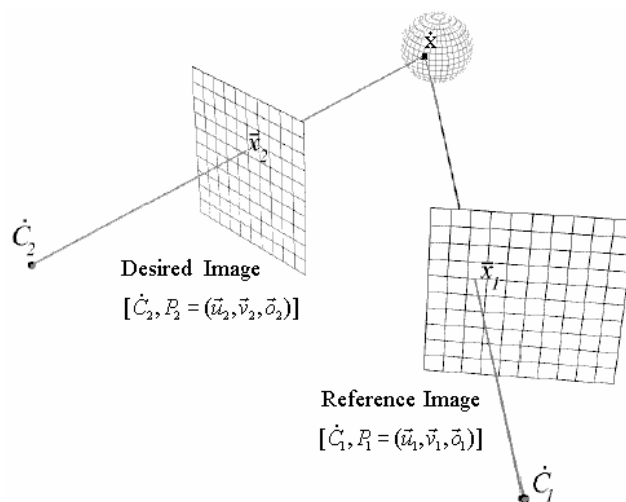CS5502 Digital Image Synthesis
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3D Image Warping

– Each pixel in the source images has coordinates (u_1, v_1), depth info δ_1, and color.

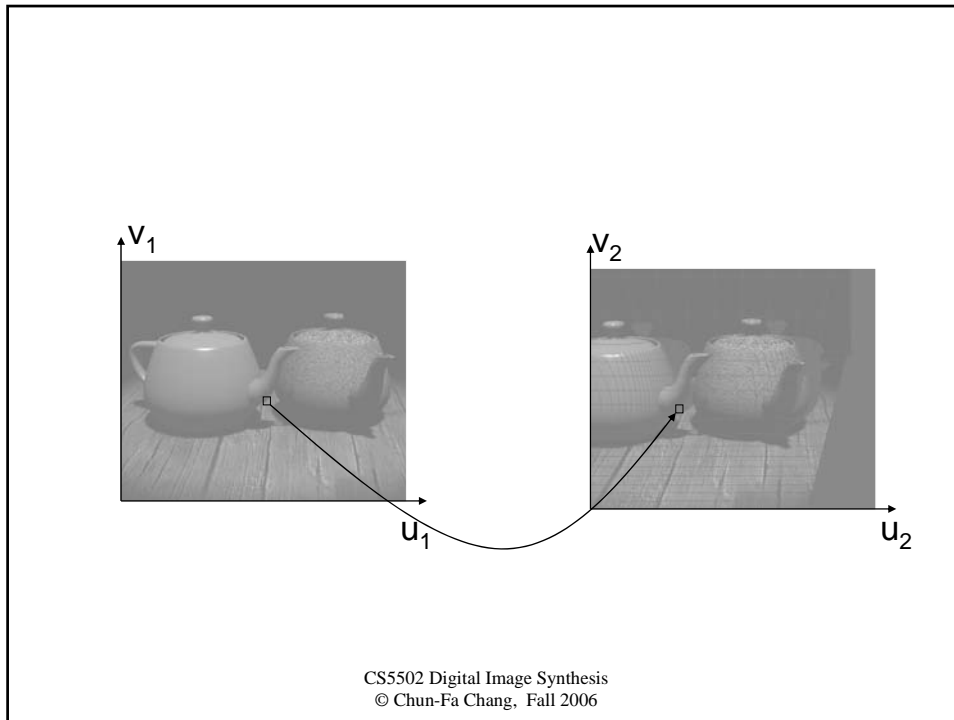– Warping Equation is applied to each pixel

$$(u_2, v_2) = f(u_1, v_1, \delta_1)$$

$$= \left(\frac{a \times u_1 + b \times v_1 + c + d \times \delta_1}{i \times u_1 + j \times v_1 + k + l \times \delta_1} \ , \ \frac{e \times u_1 + f \times v_1 + g + h \times \delta_1}{i \times u_1 + j \times v_1 + k + l \times \delta_1} \right)$$

where variables a to l are fixed for the same view.

– Rendering Time = O(#pixels)

Desired Image
$[\dot{C}_2, P_2 = (\vec{u}_2, \vec{v}_2, \vec{o}_2)]$

Reference Image
$[\dot{C}_1, P_1 = (\vec{u}_1, \vec{v}_1, \vec{o}_1)]$

v_1

v_2

u_1

u_2

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Artifacts of 3D Image Warping

- Surfaces that were occluded in source images.
- Non-uniform sampling (an example in the next slide).

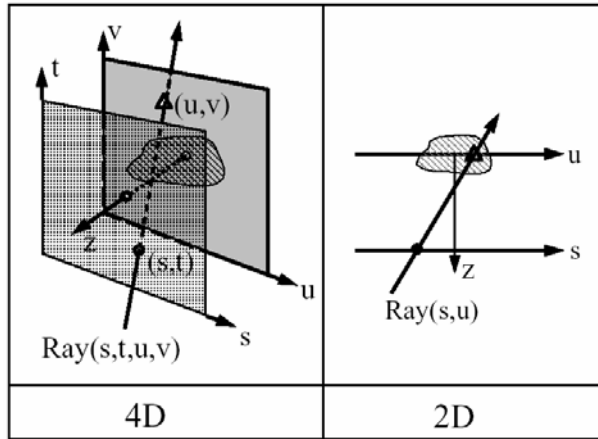CS5502 Digital Image Synthesis
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Reconstruction

Using Multiple Source Images

Light Field & Lumigraph

4D   2D

Images as 4D Samples

- Consider each image pixel a sample of 4D Light Field.
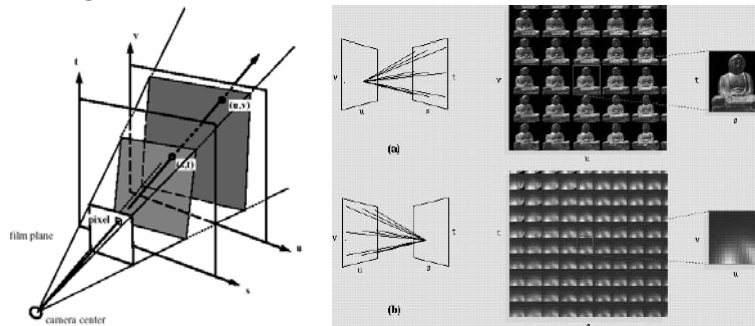
Does it Matter Where We Place the Planes?

- Yes!
- Depth correction in Lumigraphs:
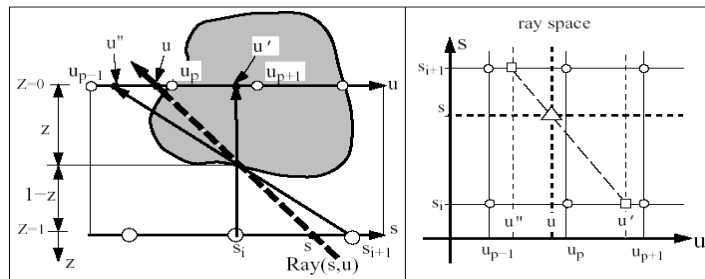
Concentric Mosaic

- Hold a camera on a stick, then sweep a circle.
- Viewpoint is constrained on a 2D plane.
- Reducing the 4D light field to a 3D subspace.

Surface Light Field

- May be considered a compression scheme for light field data.
- 3D geometry required.

For More detail

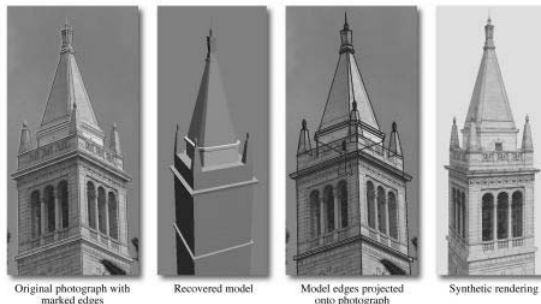- See Chapter 16 of Watt's book.

Hybrid Methods

- Combination of geometry-based and image-based approaches.
- Examples:
  - Façade by Debevec et al. [SIGGRAPH 96]
  - Inverse global illumination by Yu et al. [SIGGRAPH 99]
  - IBR from a single image by Boivin and Gagalowicz [SIGGRAPH 2001]

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Using Simple Shapes

- A classical example:
  - Façade by Paul Debevec et al.

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

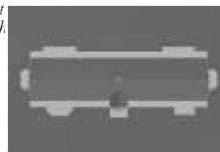CS5502 Digital Image Synthesis
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A Hybrid Geometry/Image Method

- Flat polygons are recovered from photographs.
  - Users identify the edges.
- Textures from photographs.
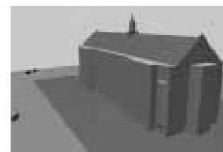- Questions: Is the texture static? If yes, is it OK? If no, what can we do about it?

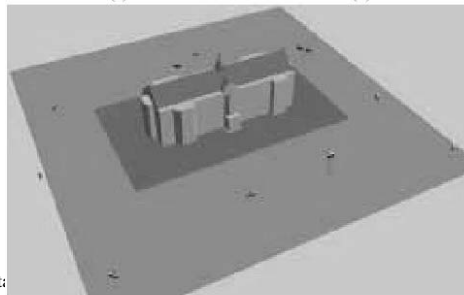CS5502 Digital Image Synthesis
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Figure 7: *Three of twelve photographs used to reconstruct t exterior of University High School in Urbana, Illinois. Th imposed lines indicate the edges the user has marked.*

(a)

(b)

(c)

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