What Does 3D Mean? (1/3)

- Computer games like these are 2D:
What Does 3D Mean? (2/3)

• Computer games like this are 3D:

[Image]

Screenshot from Age of Mythology, © Microsoft and Ensemble Studio

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.
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

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?
Top Level Survey

3D Graphics

Sample-Based Graphics

Image-Based Rendering & Modeling

Volume Rendering

Geometry or Surface Based Rendering & Modeling

Traditional Computer Graphics

• Input: Geometry, Material Properties (Color, Reflectance, etc.), Lighting.
• Transformation and Rasterization.
Role of Images

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

Image-Based Rendering

- To bypass the 3D models altogether.
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?

<table>
<thead>
<tr>
<th></th>
<th>Geometry</th>
<th>IBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modeling</td>
<td>Difficult</td>
<td>Easy</td>
</tr>
<tr>
<td>Complexity</td>
<td>#triangles</td>
<td>#pixels</td>
</tr>
<tr>
<td>Fidelity</td>
<td>Synthetic</td>
<td>Acquired</td>
</tr>
</tbody>
</table>

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

Why is It Possible?

• 5D Plenoptic Function.
  – Color = f(x, y, z, θ, φ)
  – (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.
3D Image Warping

– Each pixel in the source images has coordinates \((u_1, v_1)\), depth info \(\delta_1\), 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 = \(O(#\text{pixels})\)
Artifacts of 3D Image Warping

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

Using Multiple Source Images
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]

Using Simple Shapes

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

Figure 7: Three of twelve photographs used to reconstruct the exterior of University High School in Urbana, Illinois. Dotted lines indicate the edges the user has marked.