Lecture 7
Visualization and NPR

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Outline

• Visualization
• Non-photorealistic rendering
  • Overview
  • Cel Shading
  • Feature edges rendering
• NPR for images
Visualization

- Goal: to use computer graphics to understand data
Numerical data
Graphs
Geographic data
Flow visualization
3D volume data

Figure 2.4: An example of a visualization of a single respiratory phase of a 4DCT visualization showing lung, bone, and skin.
Volume rendering

• Visualize large datasets for scientific/medical applications
  • CT or MRI, usually $512 \times 512 \times 200 \approx 50\text{MB}$
  • Visible human: $512 \times 512 \times 1734 \approx 433\text{MB}$
• Generally, do not start with a 3D model
Volume rendering

- Visualize large datasets for scientific/medical applications
- Generally, do not start with a 3D model

INPUT

CT Scan - White means higher radiodensity.

OUTPUT
Volume rendering techniques

• Direct volume rendering
  • A direct volume renderer requires every sample value to be mapped to opacity and a color. This is done with a "transfer function"
  • A volume may be viewed by extracting isosurfaces (surfaces of equal values) from the volume and rendering them as polygonal meshes
  • The marching cubes algorithm is a common technique for extracting an isosurface from volume data
Volume rendering techniques

- Direct volume rendering
  - Transfer functions
    - Transform scalar data values to RGBA values
    - Apply to every voxel in volume
    - Highly application dependent
    - Usually designed based on the data histogram

Red

Green

Blue

X-ray density

X-ray density

X-ray density
Volume rendering techniques

- Direct volume rendering
Volume rendering techniques

• Direct volume rendering

A volume rendered cadaver head using view-aligned texture mapping and diffuse reflection
Volume rendering techniques

- Direct volume rendering

Crocodile mummy provided by the Phoebe A. Hearst Museum of Anthropology, UC Berkeley. CT data was acquired by Dr. Rebecca Fahrig, Department of Radiology, Stanford University, using a Siemens SOMATOM Definition, Siemens Healthcare. The image was rendered by Fovia's High Definition Volume Rendering® engine.
Volume rendering techniques

- Maximum intensity projection
  - MIP picks out and projects only the voxels with maximum intensity that fall in the way of parallel rays traced from the viewpoint to the plane of projection
  - Computationally fast, but the 2D results do not provide a good sense of depth of the original data
  - To improve the sense of 3D, animations are usually rendered of several MIP frames in which the viewpoint is slightly changed from one to the other, thus creating the illusion of rotation. This helps the viewer's perception to find the relative 3D positions of the object components.
Volume rendering techniques

- Maximum intensity projection

CT visualized by a maximum intensity projection of a mouse
Outline

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  • Feature edges rendering

• NPR for images
Overview

• In contrast to traditional computer graphics, which has focused on photorealism, NPR is inspired by artistic styles such as painting, drawing, technical illustration, and animated cartoons.
Overview

• What is NPR?
  • NPR is an area of computer graphics that focuses on enabling a wide variety of expressive styles for digital art
  • In contrast to traditional computer graphics, which has focused on photorealism, NPR is inspired by artistic styles such as painting, drawing, technical illustration, and animated cartoons
Overview

• Why NPR?
  • Artistic styles:
    • cartoon, watercolor,
    • impressionism, or
    • pen and ink drawing.
  • Technical Illustration:
    • Emphasize important features
    • such as outlines, internal parts, etc.
Overview

• NPR research often follows this pipeline

(1) Study Existing Rendering or Illustration Technique

(2) Extract General Aesthetic Rules

(3) “Algorithmicize” These Rules

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Outline

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  • Cel Shading
  • Texture mapping
• NPR for images
Cel shading

- Cel-shaded animation (also known as Cel shading or Toon shading) is a type of non-photorealistic rendering designed to make computer graphics appear to be hand-drawn.
- Cel-shading is often used to mimic the style of a comic book or cartoon.
- It is a somewhat recent addition to computer graphics, most commonly turning up in video games. However, the result of cel-shading has a very simplistic feel like that of hand-drawn animation.
Cel shading

• For technical illustration [1]

Traditional Lambert shading model

\[ I = k_d k_a + k_d \ \max \left( 0, 1 \cdot n \right) \]

\( k_d = 1 \) and \( k_a = 0 \).

Black shaded regions hide details; Edge lines could not be seen if added. Highlights and fine details are lost in the white shaded regions.

Cel shading

• For technical illustration [1]

Tone-based shading model

\[ I = \left( \frac{1 + \mathbf{l} \cdot \mathbf{n}}{2} \right) k_{cool} + \left( 1 - \frac{1 + \mathbf{l} \cdot \mathbf{n}}{2} \right) k_{warm} \]

where,

\[ k_{cool} = k_{blue} + \alpha k_d, \quad k_{warm} = k_{yellow} + \beta k_d \]

\[ k_{blue} = (0, 0, b), \quad k_{yellow} = (y, y, 0) \]

Edge lines, highlights, fine details in the dark shaded regions, as well as details in the high luminance regions are all visible.

Cel shading

• For technical illustration [1]

Figure 10: Left to Right: a) Phong shaded object. b) New metal-shaded object without edge lines. c) New metal-shaded object with edge lines. d) New metal-shaded object with a cool-to-warm shift.

Texture mapping technique

- Use one-dimensional texture as a Lookup Table instead of color!
- Each material is corresponding to one texture.
- Use $\mathbf{L} \cdot \mathbf{n}$ to decide which texel to use on each vertex.
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Feature edges rendering

• What?
  • Feature edges are the minimum set of lines needed to represent the contour and shape of the object. Feature edges represent not only the outer edges of the object but also points of surface discontinuity

• Why?
  • Feature edges rendered in a black color can amplifies the cartoon look
Feature edges rendering

- Boundaries
  - A boundary or border edge is one not shared by two polygons, e.g., the edge of a sheet of paper. A solid object typically has no boundary edges
Feature edges rendering

• Creases
  • A crease or hard edge is one that is shared by two polygons, and the angle between the two polygons (called the dihedral angle) is greater than some predefined value.
Feature edges rendering

• Material edge
  • A material edge appears when the two triangles sharing it differ in material or otherwise cause a change in shading.
  • It also can be an edge that the artist wishes to always have displayed, e.g., forehead lines or a line to separate the same colored pants and shirt.
Feature edges rendering

• Silhouettes
  • A silhouette edge is one in which the two neighboring triangles face in different directions compared to some direction vector, typically one from the eye.
Feature edges rendering

- Silhouettes
  - For surfaces

Figure 7.2. Definition of a silhouette: At a point on a surface $\sigma(u, v)$, and given $V(u, v)$ as the eye vector and $n(u, v)$, as the surface normal, a silhouette point is defined as the point on the surface where $V(u, v) \cdot n(u, v) = 0$ or the angle between $V(u, v)$ and $n(u, v)$ is 90 degrees.

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Feature edges rendering

- Silhouettes
  - For polygons

if $N \cdot V < 0$ then the polygon is front-facing;
if $N \cdot V > 0$ then the polygon is back-facing;
if $N \cdot V = 0$ then the polygon is perpendicular to the view direction.
Feature edges rendering

- Silhouettes
  - Silhouette edge are view-dependent
  - The silhouettes have to be re-detected and rendered with each change in the movement of the camera or model
Feature edges rendering

• Silhouetting by image processing
  • This class of algorithm operates entirely on data stored in buffers and does not modify (or even know about) the geometry in the scene
Feature edges rendering

• Silhouetting by image processing

depth and world-space surface normal information are rendered to screen-sized textures

Texels on detected edges are black, while all other texels are white
Feature edges rendering

• Silhouetting by image processing
  • How to get the depth map
    • Use Z-Buffer and grey scale!
  • How to get the normal map
    • Use RGB to represent the three elements of normal
Feature edges rendering

- Silhouetting by image processing

(a) Depth map. (b) Edges of the depth map. (c) Normal map. (d) Edges of the normal map. (e) The combined edge images.
Feature edges rendering

• Lines or strokes
  • Lines are important in fields such as CAD for seeing the underlying model facets and discerning the object’s shape
  • They are also useful in highlighting a selected object and in areas such as technical illustration
Feature edges rendering

• Different line styles
  • Jitter: offset of start and end-point by some random value
  • Line extensions: extend the original line by some value. The value can be pre-defined or randomly generated
Feature edges rendering

• Different line styles
  • Construction lines: bounding boxes, or other lines derived from the scene geometry with overshoot
  • End points: strokes are thicker at the beginning and end
Feature edges rendering

• Different line styles
  • Variable thickness: to simulate real media strokes like pencil, ink, marker, watercolor
  • Depth cue: edges closer to the viewer are thicker than background edges; edges fade with distance to the eye
Feature edges rendering

- Different line styles
  - X-Ray draw: give a transparent view for internal structures
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- NPR for images
  - Image NPR based on extended DoG
  - Image NPR based on image parsing
Image NPR based on extended DoG

• Proposed in [1]

• Motivations
  • Edge information conveys the most important structure information of an image
  • DoG (difference of Gaussian) is an effective edge detection method
  • By extending DoG, NPR could be realized

Image NPR based on extended DoG

• Background for DoG

  • Rodieck was the first to quantitatively examine the neurophysiology of vision, including detection of features, such as edges
  • Marr investigated the problem from a computational point of view; proposed the DoG based edge detection
  • Biological relevance: Young found that certain retinal cells behave analogous to the center-surround (CS) activation mechanism, which can be modeled by DoG

  • CS is the underlying principle for many visual saliency modeling approaches

Image NPR based on extended DoG

- Background for DoG

\[
g(x, y; \sigma) = \frac{1}{2\pi \sigma^2} \exp \left( -\frac{x^2 + y^2}{2\sigma^2} \right)
\]

\[
G(x, y; \sigma) = g(x, y; \sigma) \ast I(x, y)
\]

\[
DoG(x, y) = G(x, y; \sigma) - G(x, y; k\sigma)
\]
Image NPR based on extended DoG

- Extended DoG

\[ D_X(\sigma, k, \tau) = G(\sigma) - \tau \cdot G(k\sigma) \]

\[ E_X(\sigma, k, \tau, \varepsilon, \phi) = \begin{cases} 
1, & \text{if } D_X(\sigma, k, \tau) < \varepsilon \\
1 + \tanh\left(\phi \cdot (D_X(\sigma, k, \tau))\right), & \text{else}
\end{cases} \]

- \( \varepsilon \) shifts the detection threshold, thereby controlling sensitivity

- \( \tau \) changes the relative weighting between the larger and smaller Gaussians

- The tanh function creates an adjustable soft ramp between the edge and non-edge values, with parameter \( \phi \) controlling the steepness of this transition
Image NPR based on extended DoG

- Extended DoG
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Image NPR based on image parsing

- Proposed in [1]
- Motivations
  - Problem: computer does NOT know what it is painting
  - Observation: painters DO know what they are painting
  - Solution: interactive image parsing for semantic descriptions; a semantics driven approach

[1] K. Zeng et al., From image parsing to painterly rendering, ACM Trans. Graph., 2009
Image NPR based on image parsing

• Flowchart

[1] K. Zeng et al., From image parsing to painterly rendering, ACM Trans. Graph., 2009
Image NPR based on image parsing

• Image parsing
  • Hierarchical decomposition
    • Interactive segmentation [1]
    • Object Classification [2]; they use 18 common object categories in their article

[1] Y. Boykov et al., Interactive graph cuts for optimal boundary and region segmentation of objects in n-d images, ICCV’ 01
Image NPR based on image parsing

Parse Tree [1]

[1] Z. Tu, Image parsing: Unifying segmentation, detection, and recognition, IJCV’ 05

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Image NPR based on image parsing

- Image parsing
  - Hierarchical decomposition
  - Layering
Image NPR based on image parsing

- Image parsing
  - Sketch map
    - Segmentation boundary
    - Primal sketch [1]

Image NPR based on image parsing

- Image parsing
  - Sketch map
    - Segmentation boundary
    - Primal sketch [1]
  - Orientation Field
    - MRF Optimization
Image NPR based on image parsing

• Brush dictionary
  • An example-based model for brushes with a brush dictionary collected from professional artists
  • Brushes in the dictionary are of four different shape/appearance categories: point, curve, block, and texture
Image NPR based on image parsing

• Brush dictionary
Image NPR based on image parsing

- Brush selection
  - They have hard-coded the mapping relations between brushes and object categories of regions
Image NPR based on image parsing

- Brush color transfer
  - Objective colors for color transfer are obtained by averaging over a few random samples from corresponding areas in the source image (original brushes are all green)
Image NPR based on image parsing

- Results
Image NPR based on image parsing

• Results
Image NPR based on image parsing

• Results
Thanks for your attention