Non-Photorealistic Rendering (NPR)

Christian Richardt, Rainbow Group
Structure in six parts

1. Definition of “non-photorealistic rendering” (NPR)
2. History of computer graphics: from 1970s to 1995
3. Overview of NPR techniques
4. Example 1: toon shading
5. Example 2: painterly rendering
6. Example 3: video abstraction
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Rendering  |ˈrɛnd(ə)rɪŋ|

- The conversion of a high-level object-based description into a graphical image for display. (FOLDOC)
- The process of generating an image from a model, by means of computer programs. (Wikipedia)
Photorealism

Telephone Booths (Richard Estes, 1968)
Non-Photorealism (1886)

A Sunday Afternoon on the Island of La Grande Jatte (Georges Seurat, 1884–1886)
Photorealism (2006)

http://www.flickr.com/photos/oldonliner/182839989/
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History of computer graphics

- term “computer graphics” coined in 1960
- synonymous with graphics hardware
- tremendous increase in computation power
- stand-alone GPUs from mid-1990s
- driven by 3D computer games
- primary aim is to achieve photorealism
Texture mapping

Catmull 1974
Phong shading

Phong 1975
Ray tracing

Whitted 1980
Radiosity

Goral et al. 1984
Tone mapping

Tumblin & Rushmeier 1993
Also 1995: Toy Story
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WYSIWYG NPR:
Drawing Strokes Directly on 3D Models

Kalnins et al. 2002
Processing Images and Video for an Impressionist Effect

Litwinowicz 1997
Video Watercolorization using Bidirectional Texture Advection

Bousseau et al. 2007
Suggestive Contours for Conveying Shape

DeCarlo et al. 2003
Flow-Based Image Abstraction

Kang et al. 2009
Image and Video Abstraction by Anisotropic Kuwahara Filtering

Kyprianidis et al. 2009
# Recap of NPR techniques

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X-Toon: An Extended Toon Shader

Barla, Thollot & Markosian 2006
Toon shading

- cartoon style a.k.a. cel shading (from cel = celluloid)
- dominated by large areas of flat colour
- often stylised highlights and shadows

Snow White and the Seven Dwarfs (Walt Disney 1937)
Basic toon shading
Basic toon shading

http://www.eliphas-arts.co.uk/tutorials/intro%20to%203d/rendering.html
Basic toon shading

- diffuse shading: $d = n \cdot l$
  - unit surface normal $n$
  - direction to the light $l$

- basic toon shading:
  - compute diffuse shading
  - quantise into discrete steps

Basic toon shading

- typically use a 1D texture
- more flexible than hard-coded thresholds
- artists can modify shading for each object
Tone detail

- extend 1D toon texture by a second dimension (D for level of detail), e.g.
  - depth
  - highlights
  - near-silhouette
Depth-based tone detail
Near-silhouette tone detail
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Image and Video Based Painterly Animation

Hays & Essa 2004
Brush stroke properties

- colour
- opacity
- anchor
- lengths
- width
- angle
Brush stroke textures

impressionism

pointillism

“flower” style

van Gogh style
Brush stroke layers
Brush stroke layers
Brush stroke layers
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Brush stroke layers
Brush stroke layers
Brush stroke orientation
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Brush stroke orientation
Brush stroke orientation
Brush stroke motion
Brush stroke motion
Brush stroke motion
Brush stroke regeneration
Brush stroke regeneration
Extra result: pointillism
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Real-Time Video Abstraction

Winnemöller, Olsen & Gooch 2006
Real-Time Video Abstraction

Winnemöller, Olsen & Gooch 2006
Bilateral filter

- edge preserving filter [Tomasi & Manduchi 1998]
- weight pixel contributions by
  - spatial distance between pixels
  - colour difference between pixels
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\[
l'(x) = \frac{1}{k} \cdot \sum_{y \in N_x} G_{\sigma_r}(\Delta E(x, y)) \cdot G_{\sigma_s}(|x - y|) \cdot l(y)
\]
Bilateral filter

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filtered pixel colour at \( x \)
all pixels near \( x \)
Bilateral filter

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all pixels near \(x\)

colour of pixel \(y\)
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filtered pixel colour at \(x\)  
all pixels near \(x\)  
spatial distance  
colour of pixel \(y\)
Bilateral filter

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\[ I'(x) = \frac{1}{k} \cdot \sum_{y \in N_x} G_{\sigma_r}(\Delta E(x, y)) \cdot G_{\sigma_s}(\|x - y\|) \cdot I(y) \]
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\]

filtered pixel colour at \(x\)  
all pixels near \(x\)  
normalisation constant  
k = \sum_{y \in N_x} G_{\sigma_r}(\Delta E(x, y)) \cdot G_{\sigma_s}(\|x - y\|)
Bilateral filter
Bilateral filter

input image
Bilateral filter

input image

spatial filter
Bilateral filter

central pixel

input image

spatial filter
Bilateral filter

- **Input Image**
  - Central pixel

  - Spatial filter
  - Range weights (for central pixel)
  - Bilateral weights (for central pixel)

The bilateral filter processes images by considering both spatial and range information, effectively smoothing images while preserving edges.
Bilateral filter

- Input image
- Filtered image
- Central pixel
- Spatial filter
- Range weights (for central pixel)
- Bilateral weights (for central pixel)
Luminance quantisation

- colour quantisation for a cartoon-like effect
- but small changes in input can cause large changes in output: causes flickering, particularly in noisy videos
- solution: use soft quantisation
- can adapt sharpness according to luminance gradient in image
- hard boundaries only near strong gradients
Results so far
Results so far

input image
Results so far

input image  abstracted
Results so far

input image  abstracted  quantised
DoG edges

- DoG: difference of Gaussians
- approximation to human edge detection
[ Marr & Hildreth 1980]
DoG edges

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  [Marr & Hildreth 1980]
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Final result

abstracted

abstracted + quantised
Final result

abstracted

DoG edges

abstracted + quantised
Final result

abstracted + quantised

abstracted

×

=  

DoG edges

abstracted + quantised
Final result

abstracted + quantised

abstracted

DoG edges

result (without quantisation)

abstracted + quantised

*=*

Final result
Final result

abstracted + quantised

abstracted + quantised

abstracted

DoG edges

result (without quantisation)

result (with quantisation)

Final result \(=\) abstracted + quantised \(\times\) DoG edges \(\times\) result (without quantisation) = result (with quantisation)
Real-Time Video Abstraction

Winnemöller, Olsen & Gooch 2006
Summary

- Non-photorealistic rendering is an alternative to conventional, photorealistic computer graphics.
- Aims to make visual communication more effective.
- Also strives to (semi-)automatically create aesthetic results resembling a variety of existing art styles.
- Main venue: Annual Symposium on Non-Photorealistic Animation and Rendering (NPAR).
Questions?