An Invitation to Discuss Computer Depiction

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“Philosophical” interrogations

- What are the goals/context of NPR?
- What are the goals of computer graphics?
- Are photos photorealistic?
- After the Grail, then what?
- Does Pr=NPr?
- What is picture making?

- Interdisciplinary class *The Art and Science of Depiction*
- SIGGRAPH course *Perceptual and Artistic Principles for Effective Computer Depiction* (Sunday)
How is NPR different?

- **Style**
  - Imitation of traditional media (pencil, oil, etc.)
- **Interaction**
  - Less automatic, more user control

Emphasis on aesthetic, legibility

Subjective assessment
What are the frustrating points?

- Not satisfying name
- What are the issues?
  - Hard to explain what we do
  - Hard to set goals
- Modularity
- Lack of common language
Outline

- NOT photorealism vs. non-photorealism
- General issue of depiction
- Control & interaction are overlooked
- Look for a language
  - So far, we have written complex sentences
  - We need to discuss the basic vocabulary and grammar

- Plan
  - Picture making is more complex than we think
  - Framework
One-way graphics pipeline

- Common framework, paradigm [Kuhn]
- Modularity
- Common and clear goals

Real scene:
- 3D geometry
- Material
- Light

Projection
- Hidden-surface removal
- Local shading
- Lighting simulation

Image
**Problems**

- Requires extension for richer styles
- User feedback loop
  - Reverse-engineers the image

Real scene:
- 3D geometry
- Material
- Light

Projection
- Hidden-surface removal
- Local shading
- Lighting simulation

User feedback loop

Image
**Depiction as an inverse of inverse**

- Picture that conveys same impression as reality

Real scene
  (possibly imaginary)

Picture

Human perception

Message, goal
Realistic image simulation

Real scene

Image

Human perception
Message, goal
From 3D to 2D via interpretation

Real scene

Human perception
Message, goal

Picture
3D and 2D attributes

- Show a die to children (~6-7)
- They usually draw a rectangle
- The rectangle could stand for one face
3D and 2D attributes

- Show coloured or numbered die to children (6-7)
- The still draw a rectangle
- But different colours or many points
- The rectangle stands for the whole die
- The notion of 3D object with corners is translated as a 2D object with corners
Inversing our view of Depiction

- 2D sometimes rules

Real scene (possibly imaginary)

Picture

Human perception
Message, goal
Purely 2D depiction

Real scene
(possibly imaginary)

Picture

Human perception
Message, goal
2D/3D dualism

- 3D-driven picture: architectural visualization

- 2D-driven picture
  - Horizontal organization & magnitude
  - 2D gradients for spheres
Mixed 2D-/3D-driven: group photo

- 3D position are determined by 2D goals
- See also the technique of trenching
Summary

- One-way pipeline is powerful yet limited
- Requires user feedback loop
- Depiction is an inverse of inverse
- Can go from 3D to 2D via interpretation and/or from 2D to 3D
Depiction as optimization

- “Best” picture reaching goals and respecting constraints

Real scene (possibly imaginary)

Picture

Human perception

Message, goal
Realistic image simulation:
There is an analytical direct formulation

Real scene

Image

Human perception
Message, goal
The computer solves the optimization

- Route maps [Agrawala 01]
- Lighting optimization [Schacked 01]
- Composition [Gooch 01]
- Paint with relaxation [Haeberli 91, Hertzman 01]

- Define the energy function
- Exploration of a highly-non-linear parameter space
- Or come up with a set of direct rules [He 96]
When the human solves

- Fast feedback
- Relevant degrees of freedom
- Uniform and meaningful parameter space
- Controls in image space
- High-level controls related to goals & constraints
- Pictorial techniques to alter the picture
General case: computer+human

- The computer solves some issues, the human has control and adds the “magic”
- Decouple relevant dimensions of depiction

- Exciting challenge: Convergence of games and movies
Framework: Representation systems

- Adaptation of Willats [1997]
- With inspiration from cartography

- Decompose depiction into orthogonal issues
- Vocabulary
- Modularity
- Coarse-grain definition of style
Representation systems

- Spatial
  - Eye-balled perspective
- Primitives
  - Lines
- Attributes
  - Color, thickness
- Marks
  - Physical stroke

Toulouse Lautrec, *Femme rousse nu-tête*, 1891
Classification with dimensions

- Inputs and outputs
- 3D: object space
  (3D colors, intrinsic colors, light intensity)
- 2D: picture space (2D coordinates, extrinsic color)
- 2.5D: Intermediate representations
  - Z-buffer, normal maps, G-buffer, etc.
- Perspective matrix: 3D→2D spatial system
- Realistic local shading: 3D→2D attribute system
- Painting with light: 2D→3D attribute system
Imaging vs. interaction

- Direct picture making always decreases dimension
  - Globally, 3D→2D
- Interaction might require to increase to propagate picture-space goals & constraints
Spatial systems

- Map 3D spatial properties and 2D spatial properties

<table>
<thead>
<tr>
<th>perspective</th>
<th>orthographic</th>
<th>topological</th>
<th>symbolic</th>
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<tbody>
<tr>
<td>Criveli</td>
<td>Brooks-Greaves</td>
<td>Klee</td>
<td>De la Francesca</td>
</tr>
</tbody>
</table>
Examples of spatial techniques

- **3D → 2D**
  - 4*4 perspective matrices
  - Non-linear projections
- **2.5D → 2D**
  - View warping [Chen 93]
- **2D → 2D**
  - Correcting perspective distortions [Zorin 95]
- **2D → 3D**
  - Image-based modeling [e.g. Debevec 96]
  - Sketch-based modeling [Zeleznik 96]
  - View-dependent geometry [Rademacher 99]
Primitive systems

- Map 3D primitives (points, lines, surfaces, volumes) to 2D primitives (points, lines, regions)

2D regions 1D lines 0D continuous points

Picasso
**Primitive systems**

- Map 3D primitives (points, lines, surfaces, volumes) to 2D primitives (points, lines, regions)
- Can be complex

Arm:
- Elongated 3D volume
  → 1D line primitive

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**Les devises de Shadok**

En essayant continuellement on finit par réussir, donc:
Plus ça rate, plus on a de chances que ça marche.
Examples of primitive techniques

- Classical graphics: continuous point
- Silhouette rendering:
  - 3D → 2D: e.g. [Markosian 97]
  - 2.5D → 2D z-buffer-based, e.g. [Saito 90, Raskar 99]
  - 2D → 2D edge detection, e.g. [Canny 86, Pearson 90]
Attributes systems

- Assign visual properties to primitives
  - E.g. Color, texture, thickness, wiggleness, orientation

Color: Extrinsic  Color:Extrinsic B/W  Color:Intrinsic hue  Thickness

McCurry  Park  Jawlensky  Polke
Examples of attribute techniques

- **3D → 2D**
  - Realistic shading
  - NPR shading [Gooch 98]
  - Line shading [Gooch 99]

- **2.5D → 2D**
  - Comprehensible rendering [Saito 96]
  - Lumo [Johnston 02]

- **2D → 2D**
  - Painting/drawing systems
  - Brightness/contrast/saturation
Mark systems

- Implementation of the primitives placed at their spatial location with their attributes
- Medium simulation, physical strokes
**Marks vs. primitives**

- Discrete 0D marks, but 1D line primitives
NPR marks

- Most NPR papers have a mark component
- Watercolor [Curtis 97]
- Engraving [Ostromoukhov 99]
- Issue of temporal coherence

[Ostromoukhov 99]  [Curtis 97]
Meier’s painterly animation

3D
mark
attributes

Particle Placer → Particles in World Space

Reference Pictures

Shaders → Color, Orientation, Size

Camera Transform

Painterly Renderer → Brush Image

Output Image
Invitation

- Express PR & NPR techniques in this framework
- Find-out missing categories
- Use it for modularity
- Extension to animation
- Complex coupling between representation systems
- Finer notion of style
- Abstraction
- Different pictures, different users, different contexts
- Back to art history & perception
Further reading
Thanks

- The reviewers
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- The students of the 4.209 course *The Art and Science of Depiction*
Mapping of curvature

- **Convex**: positive curvature
  - 3D example: Egg
  - 2D: Convex contour

- **Concave**: negative curvature
  - 3D example: Interior of cup
  - 2D: Nothing, hidden contour

- **Saddle**: mix of positive and negative curvature
  - 3D example: Saddle (surprising!)
  - 2D: Concave contour
Mapping of curvature

- Small plate under the cup
Mapping of curvature

- But some artists map 3D concave objects to 2D concave outlines.
- This maps the property of concavity.
- The left view of the plate is more “correct” but does not convey the notion of concavity.
Figure 6. Using a second image to control brush stroke direction.
Summary

- Images: direct optical recording/simulation
- Pictures: more general visual representation
- Depiction is more than direct rendering
- Complex interaction/mapping between 3D and 2D
- Depiction is an optimization problem