The Art and Science of Depiction

Frédé Durand
MIT
Lab for Computer Science

From geometry and rendering
- Visibility
- Realistic rendering
- Real-time rendering

... to make-up and swimming-suits

Motivations: Post-PhD blues...
- Why do our images lack aesthetic?
- What’s our goal?
- Where Do We Come From? What Are We? Where Are We Going?

Motivations
- What is “Realism”? “Photorealism”?
- Are photographs realistic?
- Are photographs photorealistic?
- What is Non-Photorealistic Rendering?
Computer Graphics Imagery
- Rendering is efficient
- Hardware is fast
- 3D content creation becomes the bottleneck
- Most CG images are still not very compelling

Non-Photorealistic Rendering
- A variety of awesome techniques and solutions
- But what are the issues?
- Difficulty of classification
- Each paper deals with several problems
- Lack of inter-operability

Why make images?
- Educational
- Tell story
- Simulation
- Design
- Sign
- Guide task
- Visualization
- Search
- Analysis
- Create shape
- Expression
- Beauty
- Shock
- Humor
- Faith
- Prevention
- Etc.
- Not one single class of images
- Thus, there may be many ways to make images
- CG focuses too much on one of them

Non-reality vs. realism
- Non-reality is MORE than degraded realism
  - E.g. clarity, selection, abstraction, etc.

Dodging and Burning
- Ansel Adams
- *Clearing Winter Storm*
**Generic pictorial issues**

- A lot of issues are universal
- E.g. oil painting / photograph

**The Art and Science of Depiction**

- Graduate class at MIT (but 2 undergrads as well)
- Multidisciplinary
- Students from Architecture, Computer Science, Cognitive Sciences, Media Art & Science

**Vision as an inverse problem**

- The distal stimulus is projected into a proximal stimulus
- How can we inverse this projection?

**The paradox of vision**

- Available information: proximal stimulus
- Conscious information: distal stimulus

**Plan**

- Pictures and vision
- Limitations of medium: compensation and accentuation
- Perspective & drawing
- 2D/3D, stuff
**Face in mirror**

- When you look at yourself in a mirror, the size of your image is half your real size.

**Brightness vs. lightness**

- Brightness: subjective amount of light
- Lightness: how “white”

The white cells in shadow are as dark as the black illuminated cells.

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**Shading and highlighting**

**The paradox of Pictures**

- Distal vs. proximal
- Available information: proximal stimulus
- Conscious information: distal stimulus

Proximal stimulus (2D) vs. Distal stimulus (2D/3D)
Computational theory of vision

- Marr’s stages (extended by Palmer et al.)
- Human and Computer Vision
- Classification of different kinds of processes
- Has proved fruitful in art studies

View-centered to object-centered

- Bottom-up and top-bottom

Evolution of children’s drawings

- First draw what they know (object-based)
- Then what they see (towards retinal)
- Asked to draw a table

Relation to pictures

- Different classes of pictures for different stages
- Not a strict classification, not a cultural judgment

Relation to pictures

- Chinese painting refuse extrinsic, only essential
- No shadow

Retinal image

- Impressionism
- Photography
Turner: “My business is to paint not what I know, but what I see.”

Impressionism: Not so simply classified

Line Drawing

Primitive art
Cubism
Schema
“What I know”

“I do not paint what I see, I paint what I know”

Expressionism: “What I feel”

Other mode
**Intermediate**

- View-based
- Cues for surface-based feature extraction are enhanced
  - Depth cues
  - Orientation cues
- No accidental lighting

**Making pictures: inverse of inverse**

- Previsualization (Adams)
  - Solving the direct problem is a good start, but…

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**Limitations of the medium**

- Flatness
- Finite size, frame
- Unique viewpoint
- Static
- Contrast and gamut
  - Can be eliminated
  - Can be compensated
  - Can be accentuated

**Elimination: stereo**

**Enhancing depth through contrast**
**Accentuating flatness**
- Monet
- Occlusion boundaries are barely visible
- Retinal stage rather than surface

**Accentuating – dissonance**
- Magritte
- Occlusions are reversed

**Occlusion**
- No filter
- Blue filter
- Red filter

**Aerial perspective**
- Constable

**Accommodation**
- Blurriness
- But no proprioceptive information
- Related to aerial perspective
- Related to occlusion enhancement
- Fun gaze attraction

**Planes of light**
- Goya
- Darker colors usually recede
- Makes picture dynamic
**Planes of light**

- Lighting

**The contrast is limited**

- Real world: $10^{-6}$ to $10^{6}$
- Picture: 1 to 50, 1 to 300 at best

![Graph showing high dynamic range and low contrast]

**Low contrast is also an advantage**

- W. Eugene Smith photo of Albert Schweitzer
- 5 days to print!
- Things can be related because the intensity is more similar
- Balance, composition

**Lighting**

- Painting with light

**Red Filter**

- The sky is too bright
  - Gradient filter for the top of the photo
- The house is too dark
  - Gradient filter for the bottom of the photo

**Gradient Filter**

- The sky is too bright
  - Gradient filter for the top of the photo
- The house is too dark
  - Gradient filter for the bottom of the photo
**Flare, halo**

- Image of a building with a flare effect.

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**The limit of illusion**

- Bruneleschi’s experiment
  - Used a mirror for the sky

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**Tone mapping [Durand et al.]**

- Photo of a scene with variations in tone mapping.

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**Representing night scenes**

- Pissaro, Montmartre

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**Representing night scenes**

- James Abbott McNeil Whistler
  - *Nocturne in Blue And Silver The Lagoon Venice*
  - 1879-1880
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Primary/secondary geometry

- Primary geometry
  - Description in 3D object-space
- Secondary geometry
  - Description in 2D image-space

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  - Permits the description of more drawing systems
  - Often better corresponds to the drawing approach

Computer Graphics

- Primary geometry
  - Orthographic
  - Perspective

Willats's classification

- Secondary geometry

Naïve perspective

- Attempt to depict scene 3 dimensionally
- Often lack of skill
- More or less formal secondary geometry rules
**Naïve perspective**

- Giotto

**Orthogonal**

- **Direction**
  - Perpendicular to image plane
  - Along one principal direction
- True shape for objects parallel to image plane

**Fold-out oblique**

- Horizontal oblique
- Vertical oblique
- **Direction**
  - $45^\circ$, parallel to one principal face (top or side)
- Can be stretched for fold-out
- True shape for 2 directions
- Mainly interesting for secondary geometry
**Vertical oblique**
- Soriguerola, 13th

**Linear perspective**
- Foreshortening
- The spectator is “immersed”
- Potential distortions
  - One point
  - Two points
  - Three points

**1-point perspective**
- Central focus
- Preserves horizontals and verticals

**2-point perspective**
- Central focus
- Preserves horizontals and verticals
  - Can mean that the optical center is not the center of the image
    - View-camera
2-point perspective

- Objects stand out of the picture
- Preserves verticals
- Can mean that the optical center is not the center of the image
  - Architecture lens

Correction of perspective

- Before: 3-point perspective

Correction of perspective

- After: 2-point perspective

3-point perspective

- Dramatic 3D effect
- The generic case, nothing preserved
- seldom used through art history

Locally linear

- Linear for objects or parts of the scene
- Choose the best system for each part
- Allows different scales, provide context
- In practice, this is the most common system!
Locally linear

- Folk

Locally linear

- Egyptian
- Best view for each object

Locally linear

- Raphael, The School of Athens

Perspective in secondary space

Secondary space
**Projection: Topological**

- Beck’s map of London underground, 1931

**Projection: Topographical**

- London underground

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**2D/3D dualism**

- Image as projection of a 3D world
- Pictures compatible with an hypothetical 3D world
- Primary space
  - World space
- Secondary space
  - Picture space
- Crucial for understanding mental processes

**2D/3D dualism**

- 3D: architectural visualization
- 2D: scientific figure

**2D**

- E.g. trenching
- Placing people for photographs
- Pose
- View-dependent models
- Non-physical reflection
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)
- They still draw a rectangle
- But different colours or many points
- The rectangle stands for the whole dice
- The notion of 3D object with corners is translated as a 2D object with corners

Perspective distortion

- The sphere is projected as an ellipse

Perspective distortion

- The sphere is projected as an ellipse

Convex/concave/saddle

- Convex: positive curvature
  - Egg
- Concave: negative curvature
  - Interior of cup
- Saddle: mix of positive and negative curvature
  - Saddle (surprising, isn’t it?)

Convex/concave/saddle

- Convex: positive curvature
  - Egg
- Convex contour
- Concave: negative curvature
  - Interior of cup
  - Hidden contour
- Saddle: mix of positive and negative curvature
  - Saddle (surprising, isn’t it?)
  - Concave contour
A second look

- Cup
- Table

Denotation: volume

Primary/secondary space

- Shading
  - BRDF
  - Image-space shading and chiaroscuro
- Line drawing
  - Silhouette, singularities
  - Formal rules for junctions

Primary/secondary space

- Shading
  - BRDF
  - Image-space shading and chiaroscuro

Lighting with image goals

The one-way pipeline

- Rendering pipeline, rendering equation
- From 3D model to image
- No feedback

3D geometry
Material attributes
Light sources
Viewpoint
Light simulation
Projection
Rasterization, etc.
Image
Feedback and Darwinian selection

- Picture production is a trial and error process
- The artist tries pictorial techniques, constantly judges the current state of the picture and reacts accordingly

What can we do?

- Optimization approaches
  - Perception/artistic-based “metric”?
- Bypass the feedback
  - What are the pictorial issues/techniques?
  - Hopefully inverse the problem
- Simplify user’s life
  - Better controls (in pictorial space)
  - Relevant degrees of freedom
  - Tools to explore parameter space

What and whom for?

- Trained image makers
  - Understand what they need
  - Provide more relevant tool
- Image-dummies
  - Automatic and semi-automatic
  - E.g. “gorgeous image” for CAD
  - E.g. “digital photo beautifier”
- Computers (100% automatic)
  - E.g. can we transfer the art and craft of cinema into games?

Personal agenda

- Pictorial tools
  - Contrast management (tone mapping, dodging & burning)
  - Gaze control
  - Flatness compensation
  - Image editing in alternative domains
- Pictures for dummies
  - Digital photography beautification
  - Cinematographic lighting, shading
- User interface
  - Pictorial space interface
  - Linearization of parameter space
- Notion of style
  - Versatile Non-Photorealistic Rendering system
  - Parameterization
  - Assessment for various picture purposes
  - Capture (vision, machine learning)
  - Back to art history
Thanks

Conclusions

- Different purposes, different pictures
- Picture generation is the inverse of the inverse
- Ambiguity 2D/3D, extrinsic/intrinsic, viewer-centered/object-centered
- Limitations of the medium
  - Elimination, compensation, accentuation