The Art and Science of Depiction

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HERE, TAKE A PICTURE OF ME, OK?

SURE.

I'LL SIT HOLDING THIS BIG BOOK, LOOKING CONTEMPLATIVE.

WHY DO YOU WANT A PICTURE LIKE THAT?

ON THE OFF-CHANCE I DECIDE TO DO SOMETHING RESPONSIBLE WITH MY LIFE, I'LL NEED TO ESTABLISH A FICTITIOUS CHILDHOOD.

THIS IS WHAT I LIKE ABOUT PHOTOGRAPHY. PEOPLE THINK CAMERAS ALWAYS TELL THE TRUTH.

THEY THINK THE CAMERA IS A DISPASSIONATE MACHINE THAT RECORDS ONLY FACTS, BUT REALLY, CAMERAS LIE ALL THE TIME! SELECT THE FACTS AND YOU MANIPULATE THE TRUTH.

FOR EXAMPLE, I'VE CLEARED OFF THIS CORNER OF MY BED. TAKE A PICTURE OF ME HERE, BUT CROP OUT ALL THE MESS AROUND ME, SO IT LOOKS LIKE I KEEP MY ROOM TIDY.

IS THIS EVEN LEGAL?

WAIT, LET ME COMB MY HAIR AND PUT ON A TIE.
From geometry and rendering

- Visibility
- Realistic rendering
- Real-time rendering
… to make-up and swimming-suits
Motivations: Post-PhD blues…

• Why do our image 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-realism vs. realism

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

- A realistic image is MORE than realistic
- E.g. dodging and burning
  - During the print
  - Locally darken or lighten using a mask
Dodging and Burning

- Ansel Adams
- Clearing Winter Storm
Generic pictorial issues

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

- Contrast is reinforced at the occlusion silhouette
- Tone modification / haze
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
Plan

- Pictures and vision
- Limitations of medium: compensation and accentuation
- Perspective & drawing
- 2D/3D, stuff
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
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
Brightness vs. lightness

• Brightness: subjective amount of light
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Brightness vs. lightness

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The white cells in shadow are as dark as the black illuminated cells.
Shading and highlighting
The paradox of Pictures

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

proximal stimulus (2D)
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
Extrinsic

Object-centered
Intrinsic
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

Child’s view
Relation to pictures

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

View-centered
Extrinsic

Object-centered
Intrinsic
Relation to pictures

- Chinese painting refuse extrinsic, only essential
- No shadow

View-centered  \[\rightarrow\]  Object-centered
Extrinsic        Intrinsic
Retinal image

- Impressionism
- Photography
Retinal image

- Turner
- “My business is to paint not what I know, but what I see”
Retinal image

- Impressionism
- Not so simply classified
Image-based

• Line Drawing
Higher level

- Primitive art
- Cubism
- Schema
- “What I know”
Higher level

- Primitive art
- Cubism
- Schema
- “I do not paint what I see, I paint what I know”
Expressionism

- “What I feel”
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…
Plan

• Pictures and vision

• Limitations of medium: compensation and accentuation

• Perspective & drawing

• 2D/3D, stuff
Limitations of the medium

- Flatness
- Finite size, frame
- Unique viewpoint
- Static
- Contrast and gamut

- Can be eliminated
- Can be compensated
- Can beaccentuated
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
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
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
Red Filter
Lighting

• Painting with light
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
The limit of illusion

- Bruneleschi’s experiment
  - Used a mirror for the sky
Tone mapping [Durand et al.]

photo

Spatially-varying tone mapping
Tone mapping [Durand et al.]

photo

Spatially-varying tone mapping

The Art and Science of Depiction
Representing night scenes

- Pissaro, Montmartre
Representing night scenes

- James Abbott Mc Neil Whistler
  *Nocturne in Blue And Silver The Lagoon Venice*
  1879-1880
Plan

• Pictures and vision

• Limitations of medium: compensation and accentuation

• Perspective & drawing

• 2D/3D, stuff
Primary/secondary geometry

• Primary geometry
  – Description in 3D object-space

• Secondary geometry
  – Description in 2D image-space
Primary/secondary geometry

- Primary geometry
  - Description in 3D object-space

- Secondary geometry
  - Description in 2D image-space
  - 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

Fig. 2.2. Classification scheme for projection systems, based on 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
Orthogonal

• **Direction**
  – Perpendicular to image plane
  – Along one principal direction
• **True shape for objects parallel to image plane**
• **Typically engineering**
**Fold-out oblique**

- Horizontal oblique
- Vertical oblique
- Direction
  - 45°, parallel to one principal face (top or side)
Fold-out oblique

- Horizontal oblique
- Vertical oblique
- Direction
  - 45°, parallel to one principal face (top or side)
- Can be stretched for fold-out
  - True shape for 2 directions
- Mainly interesting for secondary geometry
Horizontal oblique

- Icons
Vertical oblique

- Soriguerola, 13\textsuperscript{th}
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
1-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
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
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
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

The Art and Science of Depiction
Plan

• Pictures and vision

• Limitations of medium: compensation and accentuation

• Perspective & drawing

• 2D/3D, stuff
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)
- The 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

![Diagram with cusp, t-vertex, and fold]
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

The Bull by Picasso
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
Personal agenda

- Pictorial tools
- Pictures for dummies
- User interface
- Notion of style
  - Versatile Non-Photorealistic Rendering system
  - Parameterization
  - Assessment for various picture purposes
  - Capture (vision, machine learning)
  - Back to art history
Personal agenda

- Pictorial tools
- Pictures for dummies
- User interface
- Notion of style

- Visual arts and perception provide
  - Issues
  - Relevant examples, parameter space

- Computer Graphics should provide
  - Solutions!
  - Validation of perception & visual art theories
  - Other issues
Thanks

AHHHH...

UH-OH. SOMETHING IS SERIOUSLY WRONG HERE.

THE LAWS OF PERSPECTIVE HAVE BEEN REPEALED.

OBJECTS NO LONGER DIMINISH IN SIZE WITH DISTANCE?

LINES DO NOT CONVERGE TOWARD ANY POINT ON THE HORIZON.

ALL SPATIAL RELATIONSHIPS ARE LOST! IT’S IMPOSSIBLE TO JUDGE WHERE ANYTHING IS! OH NO!

CALVIN, QUIT RUNNING AROUND AND CRASHING INTO THINGS, OR I’LL SELL YOU TO THE MONKEY HOUSE!

...AND NOW SHE’S LOST PERSPECTIVE.
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