The Art and Science of Depiction

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The Art and Science of Depiction

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#### 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



- 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?



Distal stimulus (3D)

## 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

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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)

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#### 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



View-centered Extrinsic Object-centered 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



Image-

based

Processing

Retinal

Image

Surface-

based

## 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

Surface-

based

Processing

Object-

based



Image-

based

Processing

Retinal

Image

### 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
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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







#### 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<sup>-6</sup> to 10<sup>6</sup>
- 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











# 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 The Art and Science of Depiction Spatially-varying tone mapping

### Representing night scenes

• Pissaro, Montmartre



#### Representing night scenes

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



#### Plan

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#### 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



#### 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



69

### 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



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# Vertical oblique

### • Soriguerola, 13<sup>th</sup>



# Vertical oblique

### • Soriguerola, 13<sup>th</sup>



### Linear perspective

- Foreshortening
- The spectator is "immersed"
- Potential distortions
- One point
- Two points
- Three points

- Central focus
- Preserves horizontals and verticals



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









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- 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





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



- 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!

• Folk

TOTAL BBBB el 1 目 



- Egyptian
- Best view for each object



#### • Raphael, The School of Athens



### Perspective in secondary space



# Secondary space

# Projection: Topological

#### • Beck's map of London underground, 1931



# Projection: Topographical

#### • London underground



92

### Plan

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- Perspective & drawing
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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)
- 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 (surprising, isn't it?)
- Concave contour

# A second look

• Cup

• Table



### Denotation: volume

Les devises Shadok



EN ESSAYANT CONTINUELLEMENT ON FINIT PAR REUSSIR. DONC: PLUS GA RATE, PLUS ON A DE CHANCES QUE GA MARCHE.

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# 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


## 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



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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





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## Conclusions

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