The Art and Science of Depiction

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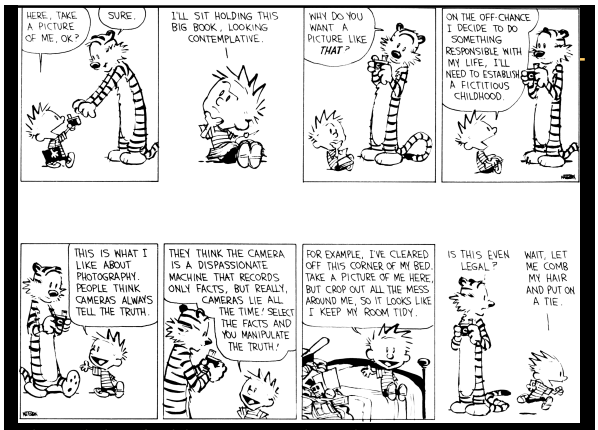
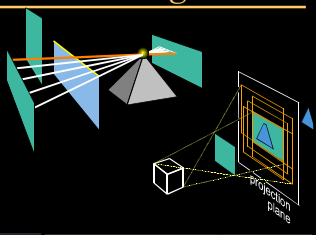
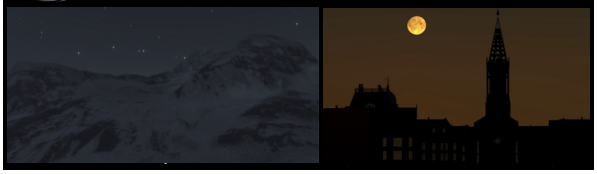


From geometry and rendering

- Visibility
- Realistic rendering
- Real-time rendering

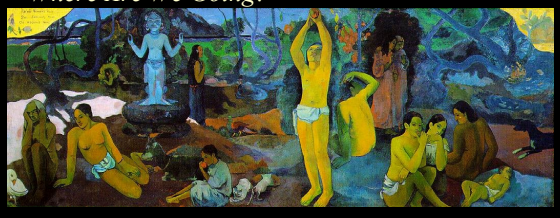




... to make-up and swimming-suits

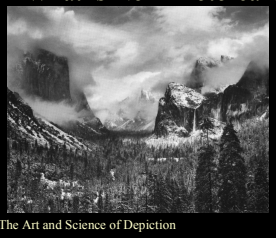
Motivations: Post-PhD blues…

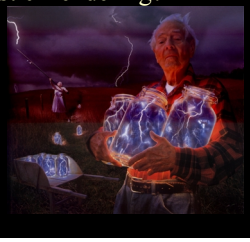
- Why do our image lack aesthetic?
- What's our goal?
- *Where Do We Come From? What Are We? Where Are We Going?*



Motivations

- What is "Realism"? "Photorealism"?
- Are photographs realistic?
- Are photographs photorealistic?
- What is Non-Photorealistic Rendering?



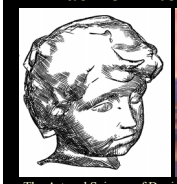
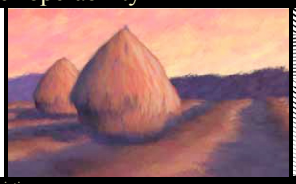
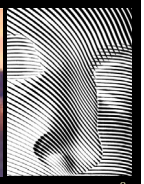


Computer Graphics Imagery

- Rendering is efficient
- Hardware is fast
- 3D content creation becomes the bottleneck
- Most CG images are still not very compelling


Non-Photorealistic Rendering

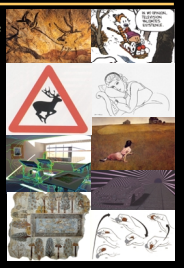
- A variety of awesome techniques and solutions
- But what are the issues?
- Difficulty of classification
- Each paper deals with several problems
- Lack of inter-operability

Why make images?

- Educational
- Tell story
- Simulation
- Design
- Sign
- Guide task
- Visualization
- Search
- Analysis

- Create shape
- Expression
- Beauty
- Shock
- Humor
- Faith
- Prevention
- Etc.

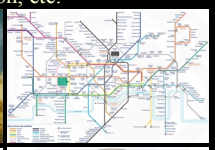
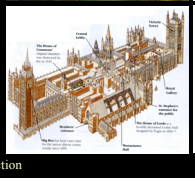


- Not one single class of images
- Thus, there may be many ways to make images
- CG focuses too much on one of them

Non-realism vs. realism

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



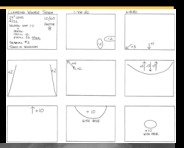

Realism vs. realism

- 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

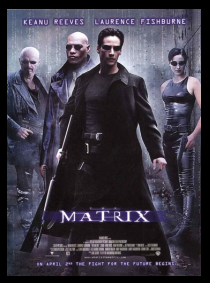
- Ansel Adams
- *Clearing Winter Storm*



Generic pictorial issues

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

Titian



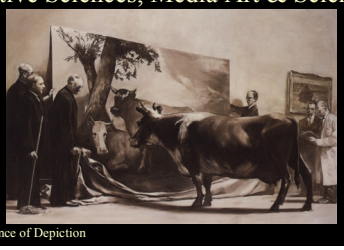
Generic pictorial issues

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

Titian

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

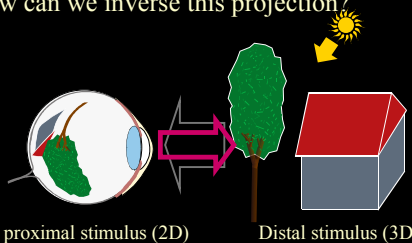


Plan

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

Vision as an inverse problem

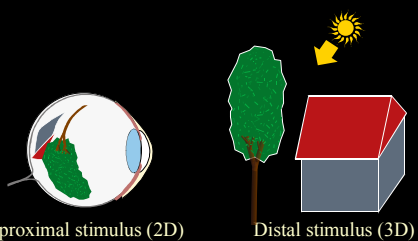
- The distal stimulus is projected into a proximal stimulus
- How can we inverse this projection?



proximal stimulus (2D) Distal stimulus (3D)

The paradox of vision

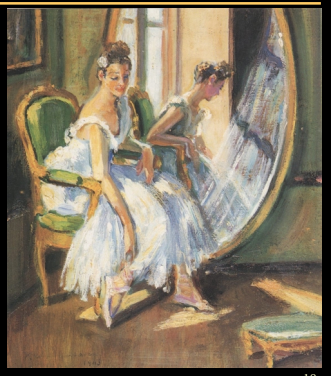
- Available information: proximal stimulus
- Conscious information: distal stimulus



proximal stimulus (2D) Distal stimulus (3D)

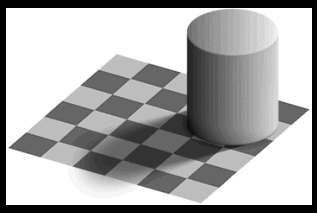
Face in mirror

- 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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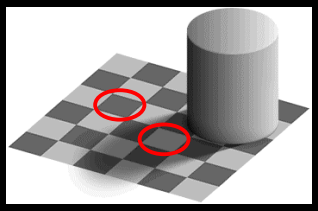

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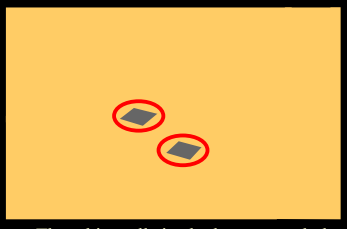
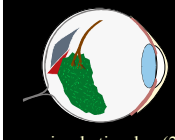


The white cells in shadow are as dark as the black illuminated cells

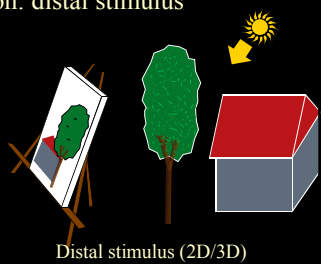
Shading and highlighting

The paradox of Pictures

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



proximal stimulus (2D)



Distal stimulus (2D/3D)

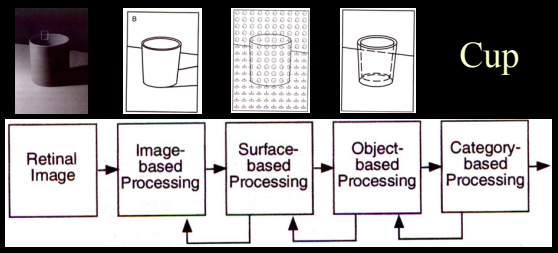
Computational theory of vision

- 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

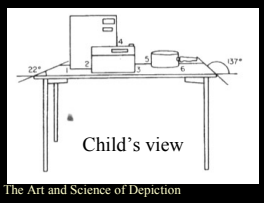
View-centered to object-centered

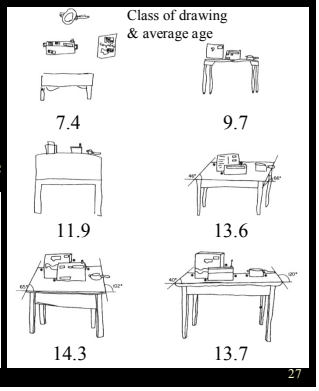
- Bottom-up and top-bottom



Evolution of children's drawings

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





Relation to pictures

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

View-centered Extrinsic ⇒ Object-centered Intrinsic

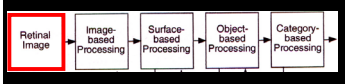
Relation to pictures

- Chinese painting refuse extrinsic, only essential
- No shadow

View-centered Extrinsic ⇒ Object-centered Intrinsic

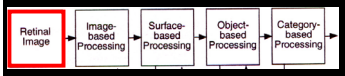
Retinal image

- 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

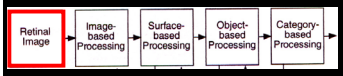
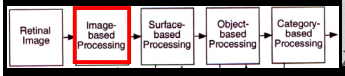


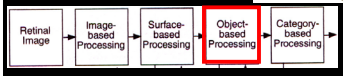
Image-based

- Line Drawing



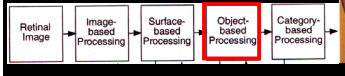
Higher level

- Primitive art
- Cubism
- Schema
- "What I know"



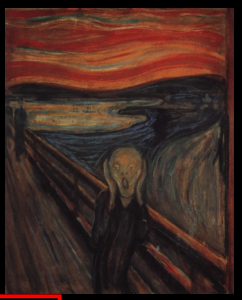
Higher level

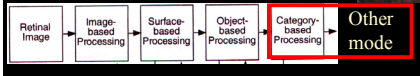
- Primitive art
- Cubism
- Schema
- "I do not paint what I see, I paint what I know"



Expressionism

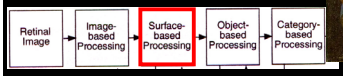
- "What I feel"





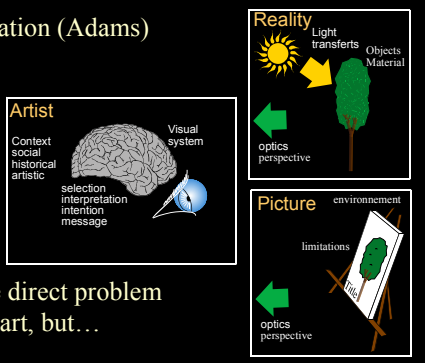
Intermediate

- 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

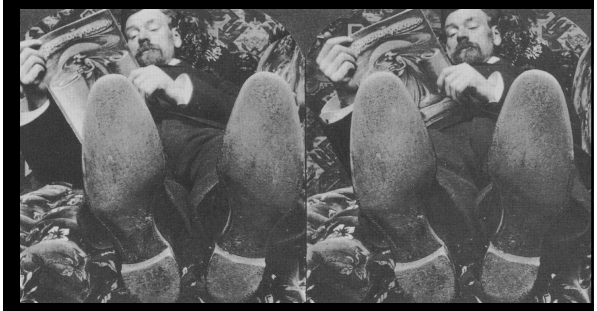
- Pictures and vision
- Limitations of medium: compensation and accentuation
- Perspective & drawing
- 2D/3D, stuff

Limitations of the medium

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

- Can be eliminated
- Can be compensated
- Can be accentuated

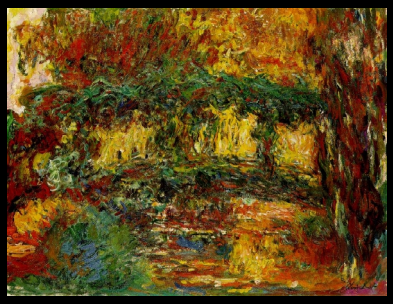
Elimination: stereo



Enhancing depth through contrast

Accentuating flatness

- Monet
- Occlusion boundaries are barely visible
- Retinal stage rather than surface



Accentuating – dissonance

- Magritte
- Occlusions are reversed

Occlusion

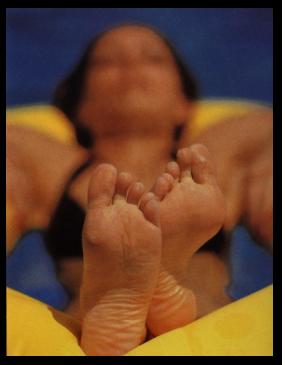
No filter Blue filter Red filter

Aerial perspective

- Constable

Accommodation

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



Planes of light

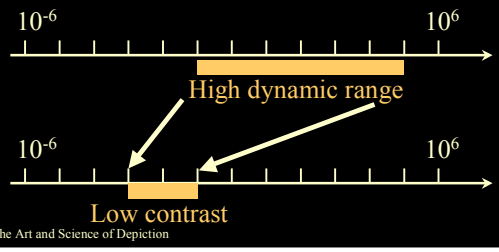
- Goya
- Darker colors usually recede
- Makes picture dynamic

Planes of light

- Lighting


The contrast is limited

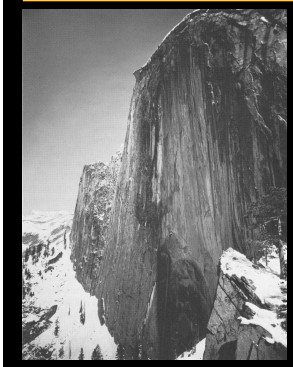
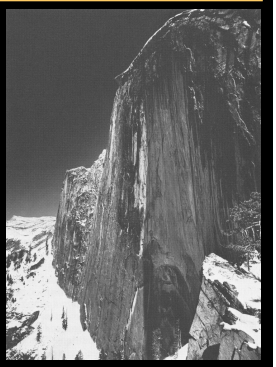
- Real world: 10^{-6} to 10^{6}
- Picture: 1 to 50, 1 to 300 at best



Low contrast is also an advantage

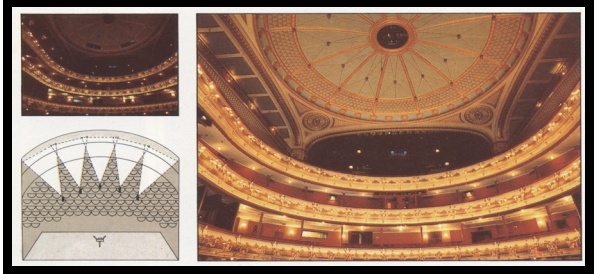
- W. Eugene Smith photo of Albert Schweitzer
- 5 days to print!
- Things can be related because the intensity is more similar
- Balance, composition

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

Representing night scenes

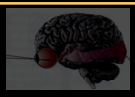
- Pissaro, Montmartre

Representing night scenes

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

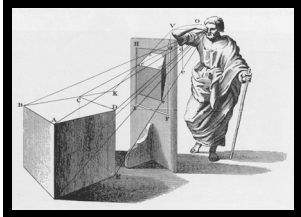
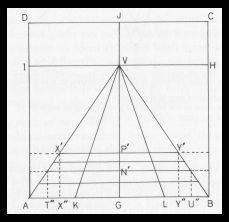
Plan

- 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

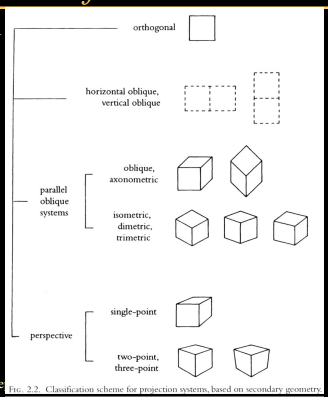


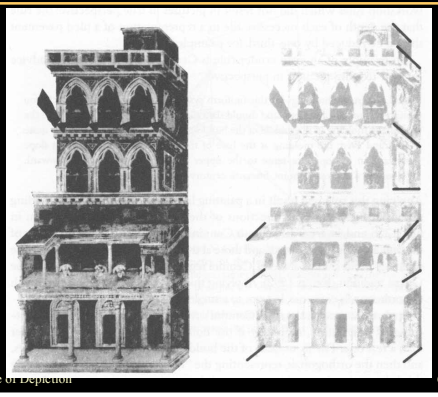
FIG. 2.2. Classification scheme for projection systems, based on secondary geometry.

Naïve perspective

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

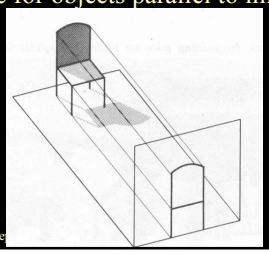
Naïve perspective

- Giotto



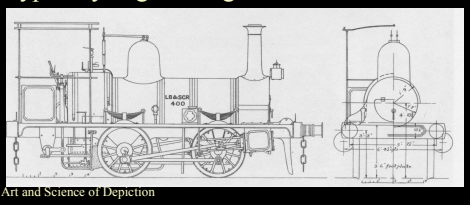
Orthogonal

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



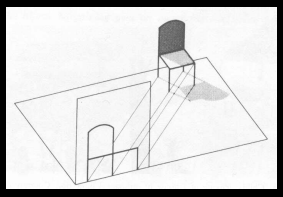
Orthogonal

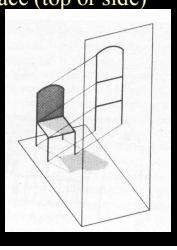
- Direction
  - Perpendicular to image plane
  - Along one principal direction
- True shape for objects parallel to image plane
- Typically engineering



Fold-out oblique

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





Fold-out oblique

- Horizontal oblique
- Vertical oblique
- Direction
  - 45º, 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

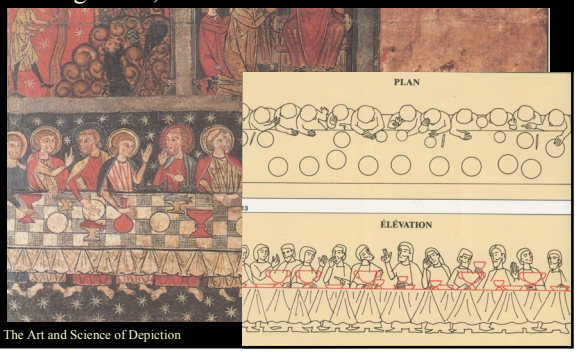
- Icons

Vertical oblique

- Soriguerola, 13th

Vertical oblique

- Soriguerola, 13th



Linear perspective

- Foreshortening
- The spectator is "immersed"
- Potential distortions

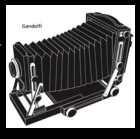
- One point
- Two points
- Three points

1-point perspective

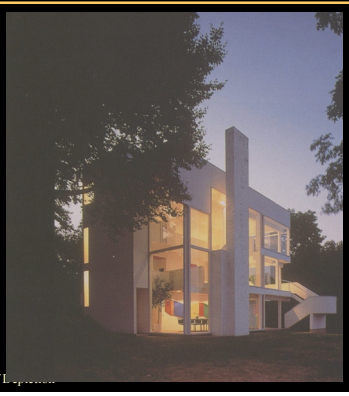
- Central focus
- Preserves horizontals and verticals

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

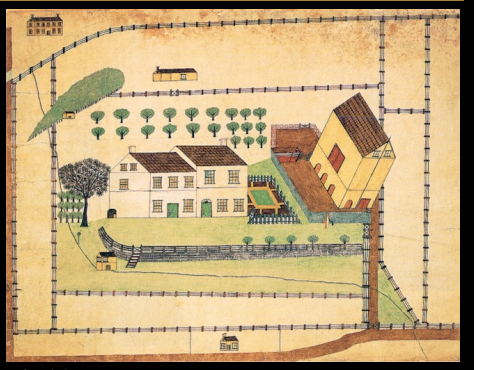
Locally linear

- 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



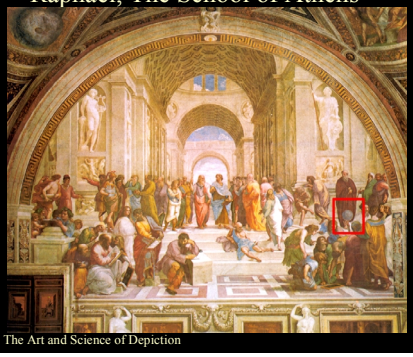
Locally linear

Locally linear

- Egyptian
- Best view for each object

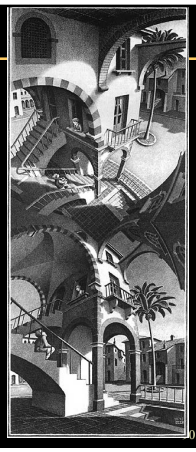
Locally linear

- Raphael, The School of Athens



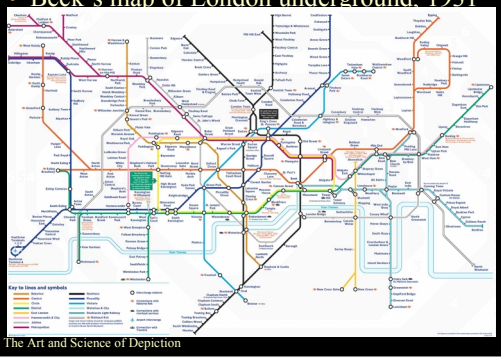
Perspective in secondary space

Secondary space



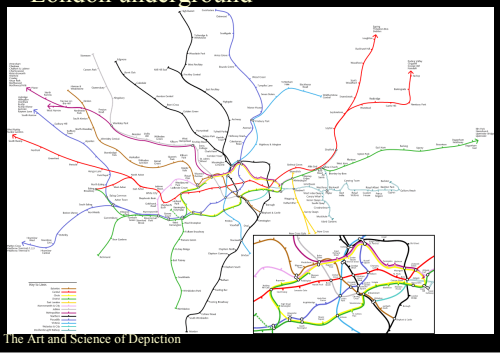
Projection: Topological

- Beck's map of London underground, 1931



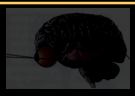
Projection: Topographical

- London underground



Plan

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

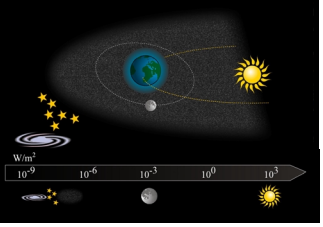


2D/3D dualism

- 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

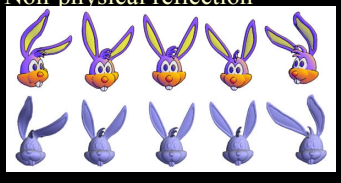
2D/3D dualism

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



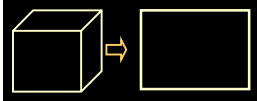
2D

- E.g. trenching
- Placing people for photographs
- Pose
- View-dependent models
- Non-physical reflection



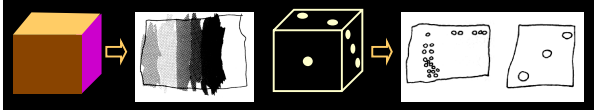
3D and 2D attributes

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



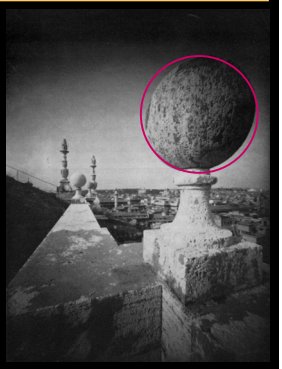
3D and 2D attributes

- 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

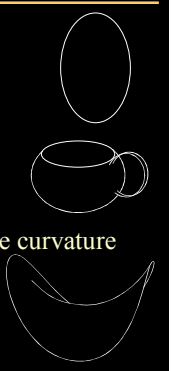


Perspective distortion

- The sphere is projected as an ellipse

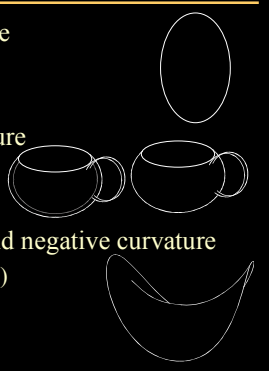
Convex/concave/saddle

- 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

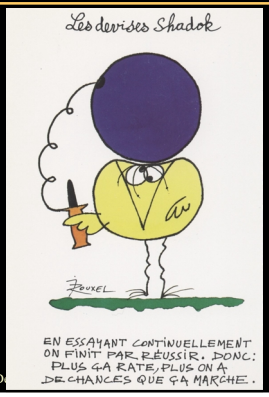
- Convex: positive curvature
  - Egg
  - Convex contour
- Concave: negative curvature
  - Interior of cup
  - Hidden contour
- Saddle: mix of positive and negative curvature
  - Saddle (surprising, isn't it?)
  - Concave contour



A second look

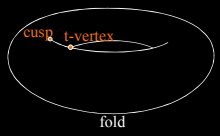
- Cup
- Table

Denotation: volume



Primary/secondary space

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



Primary/secondary space

- Shading
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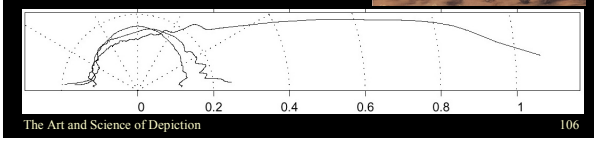
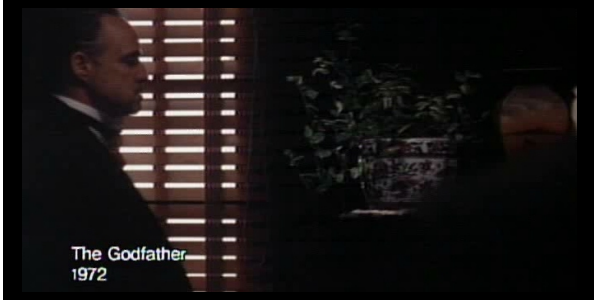
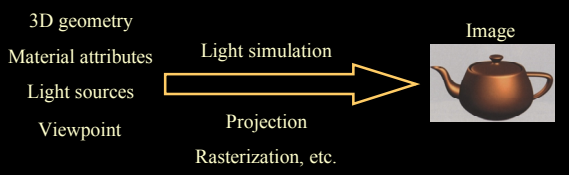


Lighting with image goals



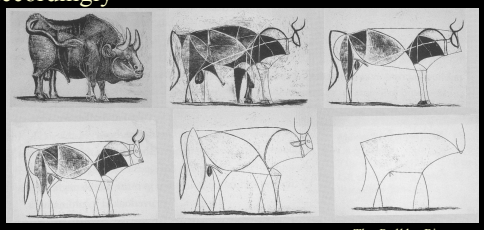
The one-way pipeline

- 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



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

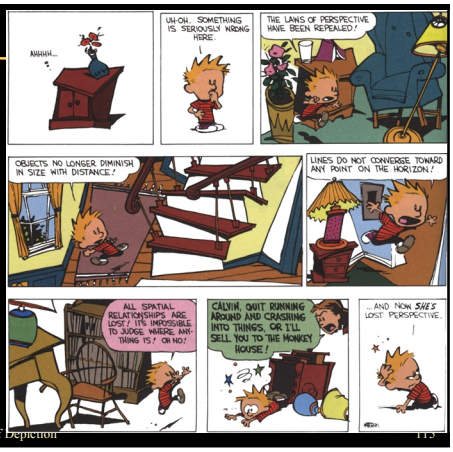
- Pictorial tools
- Pictures for dummies
- User interface
- Notion of style
  - Versatile Non-Photorealistic Rendering system
  - Parameterization
  - Assessment for various picture purposes
  - Capture (vision, machine learning)
  - Back to art history

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



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