The Art and Science of Depiction

Photorealism vs. Non-Photorealism in Computer Graphics

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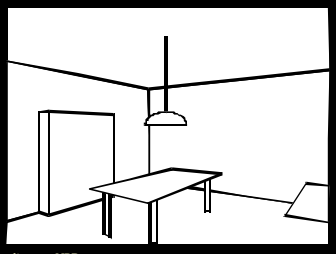
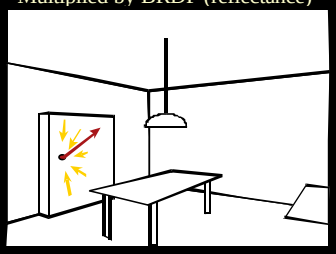
Global illumination

- How to take into account all light inter-reflections



The Rendering equation

- Light leaving one point in one direction
  - Integral of incoming light from every direction
  - Multiplied by BRDF (reflectance)

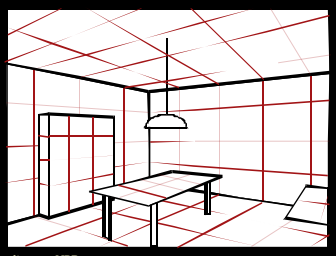


Radiosity

- E.g. Lightscape
- Assume surfaces diffuse (independent of direction)

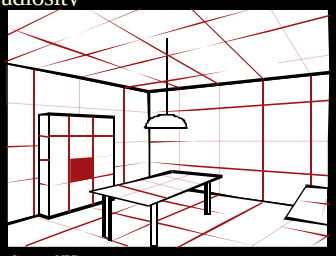
Radiosity

- Subdivide the scene into discrete elements



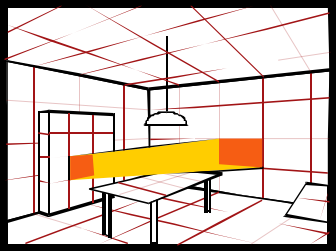
Radiosity

- Subdivide the scene into discrete elements
- Each element is assumed to have constant radiosity



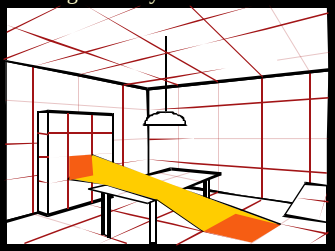
Radiosity

- Form-factor between 2 elements: ratio of light leaving one element that reaches the other



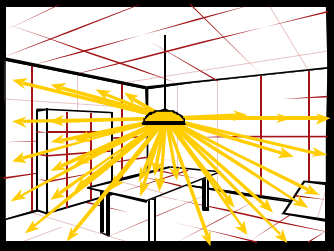
Radiosity

- Form-factor between 2 elements: ratio of light leaving one element that reaches the other
  - Taking visibility into account



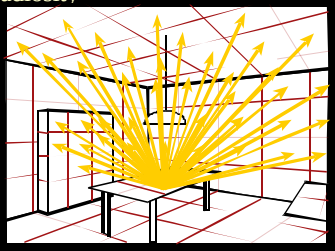
Radiosity

- Iterative solution
- Shoot light from the most luminous source



Radiosity

- Iterative solution
- Shoot from element with the most unshot radiosity



Radiosity

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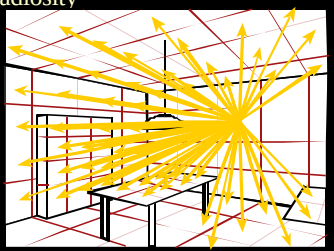


Radiosity

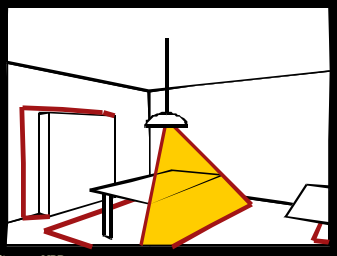
- Smoothing and other gimmicks

Radiosity

- Pros
  - View independent
- Cons
  - Meshing is costly
    - Memory
    - Mostly limited to polyhedra
  - Aliasing (jagged shadow boundary)
  - Diffuse assumption (can be sort of alleviated)

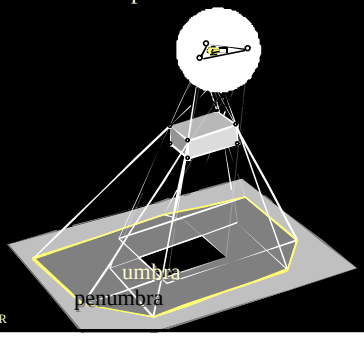
Discontinuity meshing

- Subdivide along shadow boundary
- But costly and complex (not in commercial soft)

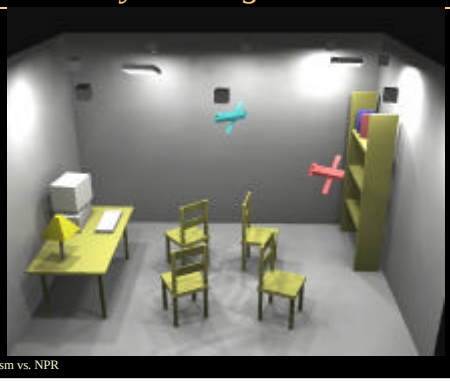


Discontinuity meshing

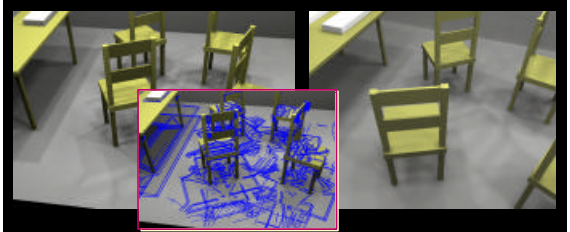
- Limits of umbra and penumbra



Discontinuity meshing



Comparison

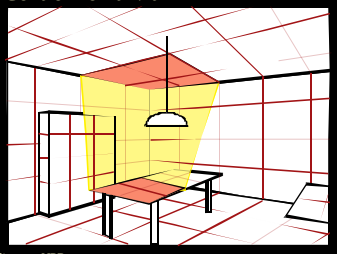


With skeleton
10 minutes 23 seconds

[Gibson 96]
1 hour 57 minutes

Hierarchical approach

- Group elements when the light exchange is not important
  - Control non trivial

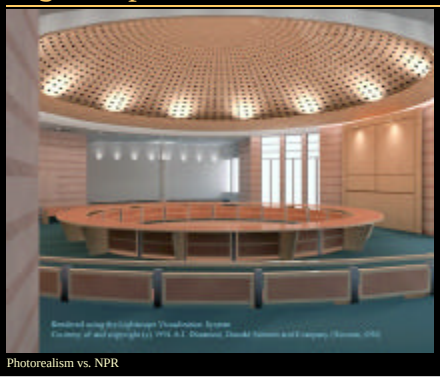


Lightscape

Lightscape

Lightscape

Lightscape



Lightscape

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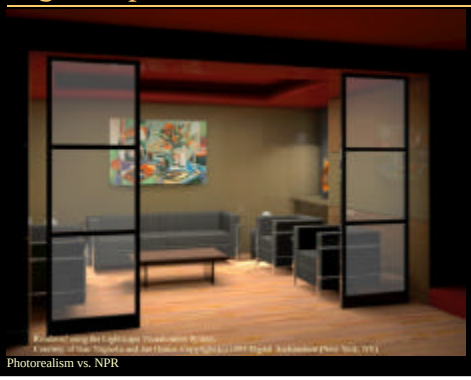
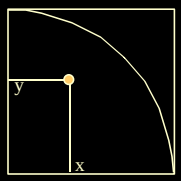


Monte-Carlo ray-tracing

- E.g. Radiance (by Greg Ward-Larson), Mental Ray
- Probabilistic sampling approach

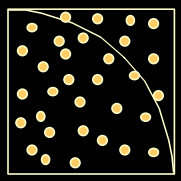
Monte-Carlo computation of p

- Take a square
- Take a random point (x,y) in the square
- Test if it is inside the ¼ disc ($x^2+y^2 < 1$)
- The probability is π /4



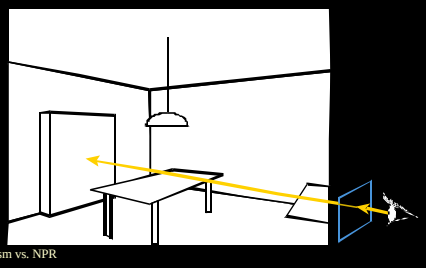
Monte-Carlo computation of p

- The probability is π /4
- Count the inside ratio n = # inside / total # trials
- $\pi \approx n * 4$
- The error depends on the number or trials



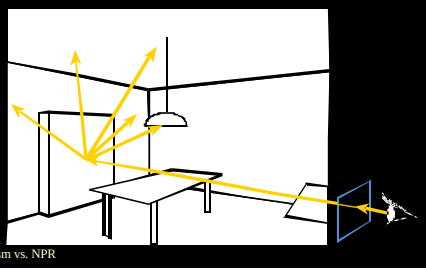
Monte-Carlo

- Cast a ray from the eye through each pixel



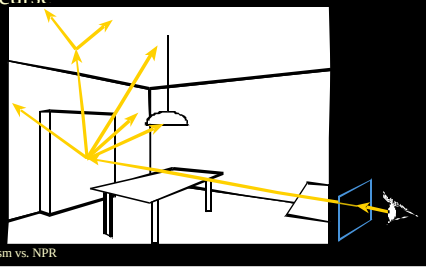
Monte-Carlo

- Cast a ray from the eye through each pixel
- Cast random rays from the visible point



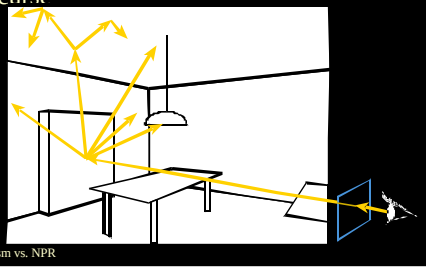
Monte-Carlo

- Cast a ray from the eye through each pixel
- Cast random rays from the visible point
- Recurse



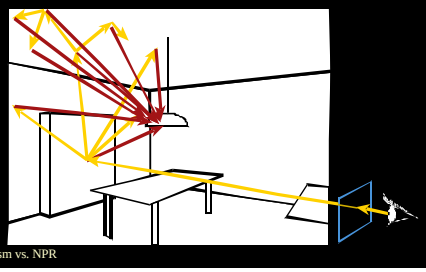
Monte-Carlo

- Cast a ray from the eye through each pixel
- Cast random rays from the visible point
- Recurse



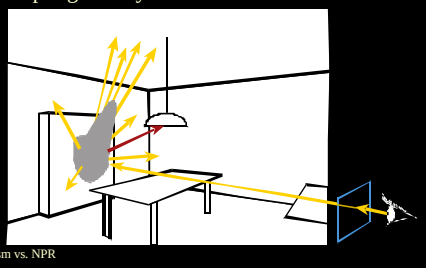
Monte-Carlo

- Systematically sample primary light



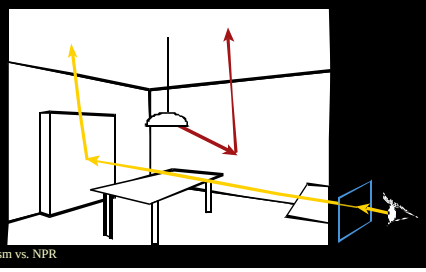
Monte-Carlo

- Take BRD into account
  - Multiply incoming light
  - Sampling density



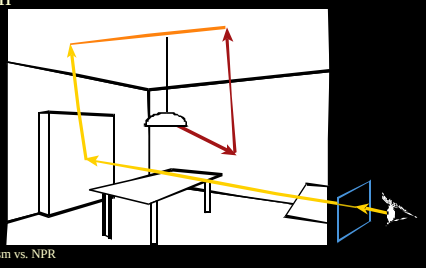
Monte-Carlo

- Bi-directional
- Cast rays from the eye and from light



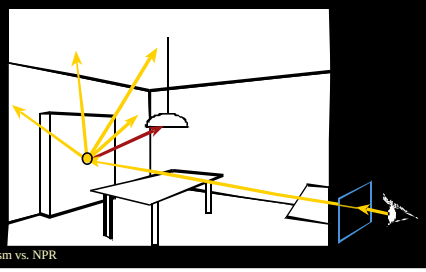
Monte-Carlo

- Bi-directional
- Cast rays from the eye and from light
- Join



Radiance cache

- Store the indirect illumination



Radiance cache

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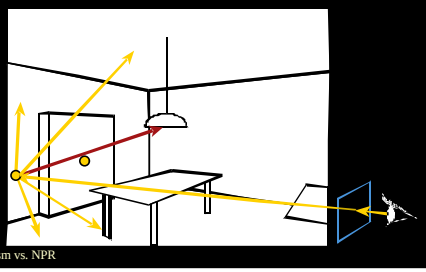
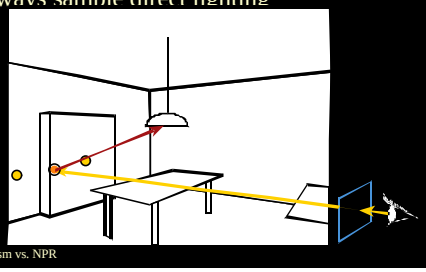


Radiance cache

- Store the indirect illumination
- Interpolate existing cached values
- Always sample direct lighting

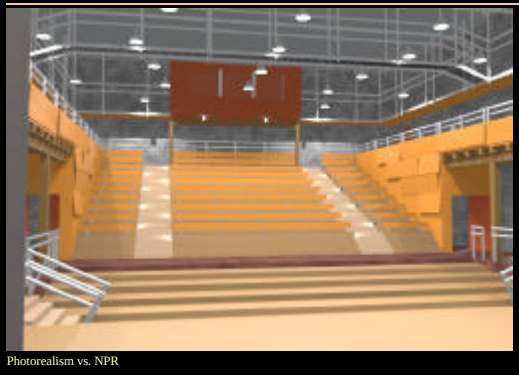


Monte-Carlo & Radiance

- Pros
  - Can treat any scene and any BRDF
  - The Radiance system is free!
- Cons
  - View-dependent
  - Costly
  - Can be noisy (because of sampling)

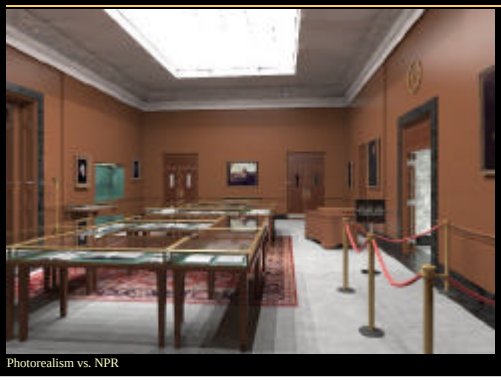
Radiance

Radiance



Radiance

Radiance



Radiance

Radiance

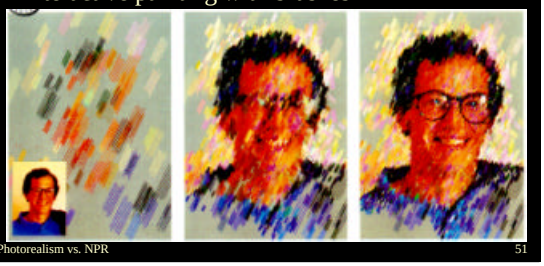
Monte-Carlo ray-tracing

Non Photorealistic Rendering

- Stanislaw Ulam
  - The study of non-linear physics is like the study of non-elephant biology
  - (quoted by Craig Reynolds)

Painting with numbers

- [Haeberli 1990]
- Reference photo for color
- Interactive painting with brushes



Painting with numbers

- [Haeberli 1990]
- Reference photo for color
- Interactive painting with brushes

Painting with numbers

- Direction control

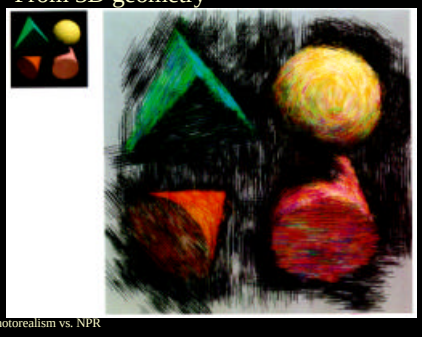
Figure 6. Using a second image to control brush stroke direction.

Painting with numbers

- Direction control using gradient

Painting with numbers

- From 3D geometry

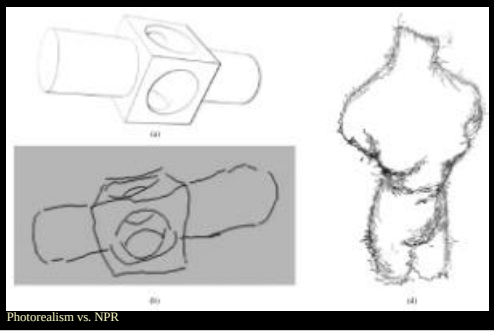


Painting with number

- Automatic optimization of brush placement

Line drawing

- [Markosian et al. 97]

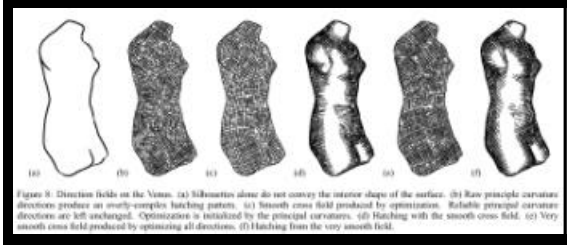


Line drawing

- [Hertzman and Zorin 2000]

Line drawing

- [Hertzman and Zorin 2000]



Watercolor

- [Curtis et al. 1997]
- Physical simulation of watercolor-paper interaction

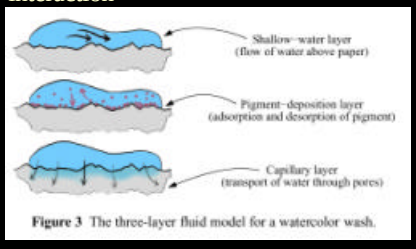
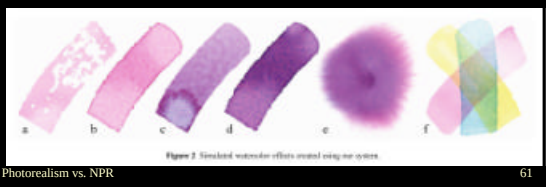


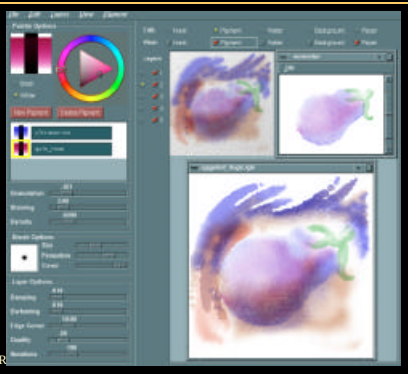
Figure 3 The three-layer fluid model for a watercolor wash.

Watercolor

- [Curtis et al. 1997]
- Physical simulation of watercolor-paper interaction
- Very costly (not interactive)



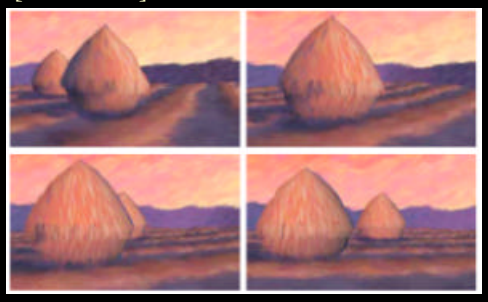
Watercolor



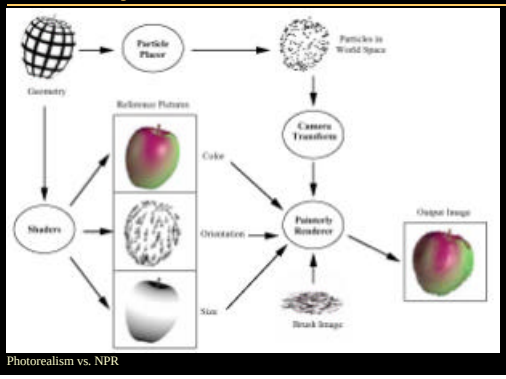
Watercolor

Painterly animation

- [Meier 1996]



Painterly animation



Painterly animation

- Different styles

Painterly animation

- Use of different layers

Brushes of multiple sizes

- [Hertzman 1998]

Brushes of multiple sizes

- Different styles depending on parameters

"Impressionist"

"Expressionist"

Brushes of multiple sizes

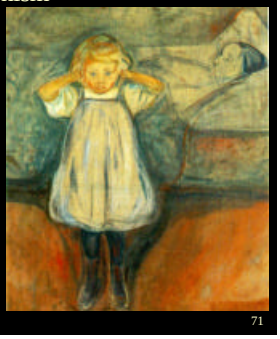
- Different styles depending on parameters

"Impressionist"

"Expressionist"

Style and soul

- Icon painting, Expressionism

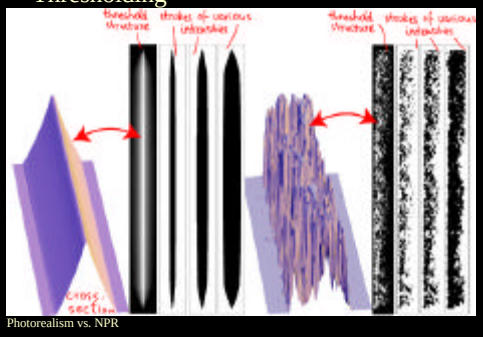


Interactive assisted drawing

- [Durand, Ostromoukhov et al.]

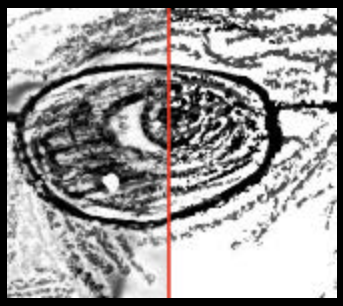
Interactive assisted drawing

- Thresholding

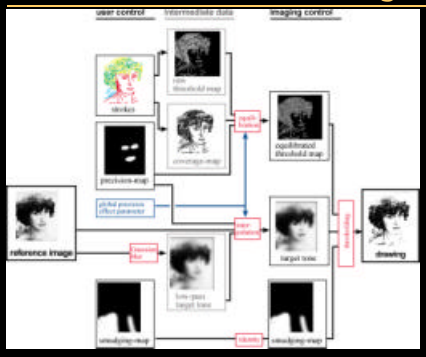


Interactive assisted drawing

- Smudging



Interactive assisted drawing



Interactive assisted drawing

Interactive assisted drawing

NPR: fuzzy issues

- No systematic classification of techniques
  - Mainly by medium and interactive/full 3D
- No clear issues
  - What are we trying to solve?
- No inter-operability of techniques
  - No clear input and output
- Mainly out-of-the-blue full systems with overlap

Some issues in NPR

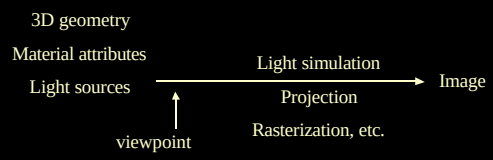
- Medium simulation
- Animation and coherence
- Line drawing, hatcing
- Shading
- Style
- Perspective
- User interface

Can visual art and psychology help?

- Understand underlying and "universal" pictorial issues
  - Limitations and compensation
  - Different modes
    - Texture, color, shape
  - Composition, color harmony
- Coarse-grain classification of issues in picture-making
  - Drawing
  - Denotation
  - Tone and Color
  - Physical realization through marks

A one-way pipeline

- Mechanical and deterministic projection from 3D to 2D
- Input is purely 3D (world space)



A one-way pipeline

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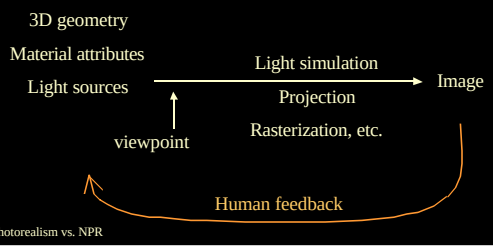

Mixed 2D/3D specification

- We should be able to specify "properties" and constraints directly in 2D
  - E.g. color harmony, composition, style
- Still edit the image after rendering
  - E.g. shadows, lighting, colors, compensations

Pictures for dummy

- Help non-artists produce nice images
- The "gorgeous image" button in your CAD software
- The "digital photo beautifier"
- Realistic or Non-Photorealistic
- Digital assistant that finds problems

Style

- Coarse-grain style
  - Different categories of drawing, denotation, tone
- Finer-grain
- Local style

- Parameterization
- Capture
  - Automatically deduce style from 3D renderings
  - (semi)-Automatically capture style from image(s)

Convergence of games and movies

- Game industry is now as big as movie industry
- Graphics accelerator permit stunning 3D graphics
- Cinema quality is not far
- However, games are interactive, “unpredictable”
- How can we transform the art and craft of cinema into algorithmic games
- E.g. Lighting, camera control, editing