An Invitation to Discuss Computer Depiction

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"Philosophical" interrogations

- What are the goals/context of NPR?
- What are the goals of computer graphics?
- Are photos photorealistic?
- After the Grail, then what?
- Does Pr=NPr?
- What is picture making?

- Interdisciplinary class *The Art and Science of Depiction*
- SIGGRAPH course *Perceptual and Artistic Principles for Effective Computer Depiction* (Sunday)

How is NPR different?

- Style
  - Imitation of traditional media (pencil, oil, etc.)
- Interaction
  - Less automatic, more user control

Emphasis on aesthetic, legibility

Subjective assessment

What are the frustrating points?

- Not satisfying name
- What are the issues?
  - Hard to explain what we do
  - Hard to set goals
- Modularity
- Lack of common language

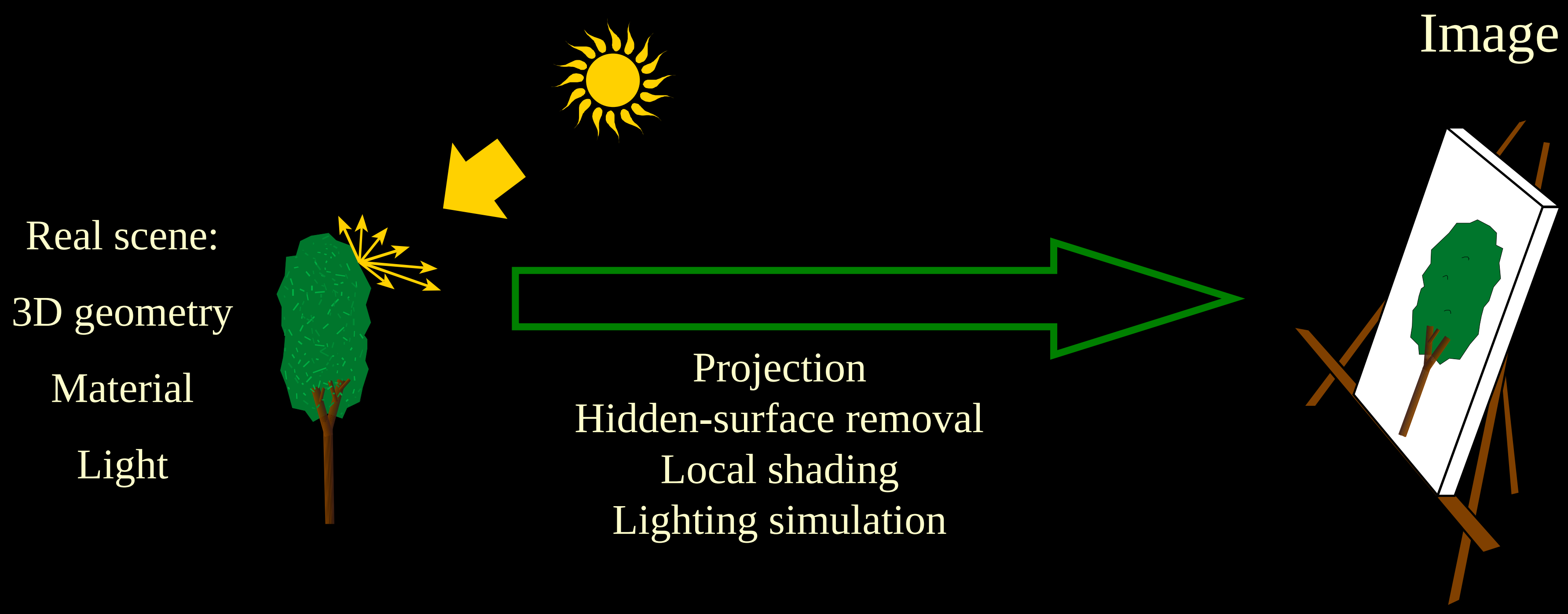
Outline

- NOT photorealism vs. non-photorealism
- General issue of depiction
- Control & interaction are overlooked
- Look for a language
  - So far, we have written complex sentences
  - We need to discuss the basic vocabulary and grammar

- Plan
  - Picture making is more complex than we think
  - Framework

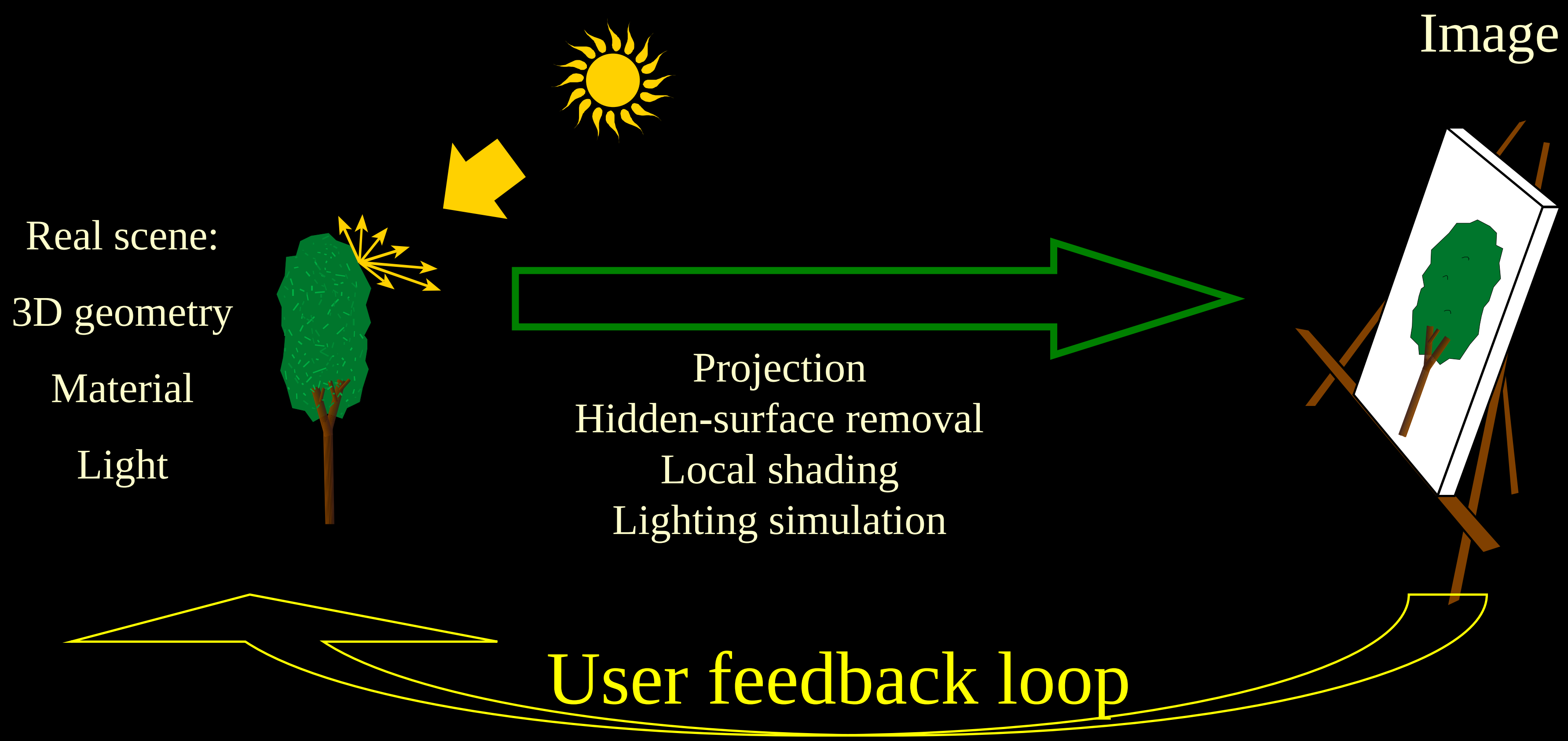
One-way graphics pipeline

- Common framework, paradigm [Kuhn]
- Modularity
- Common and clear goals



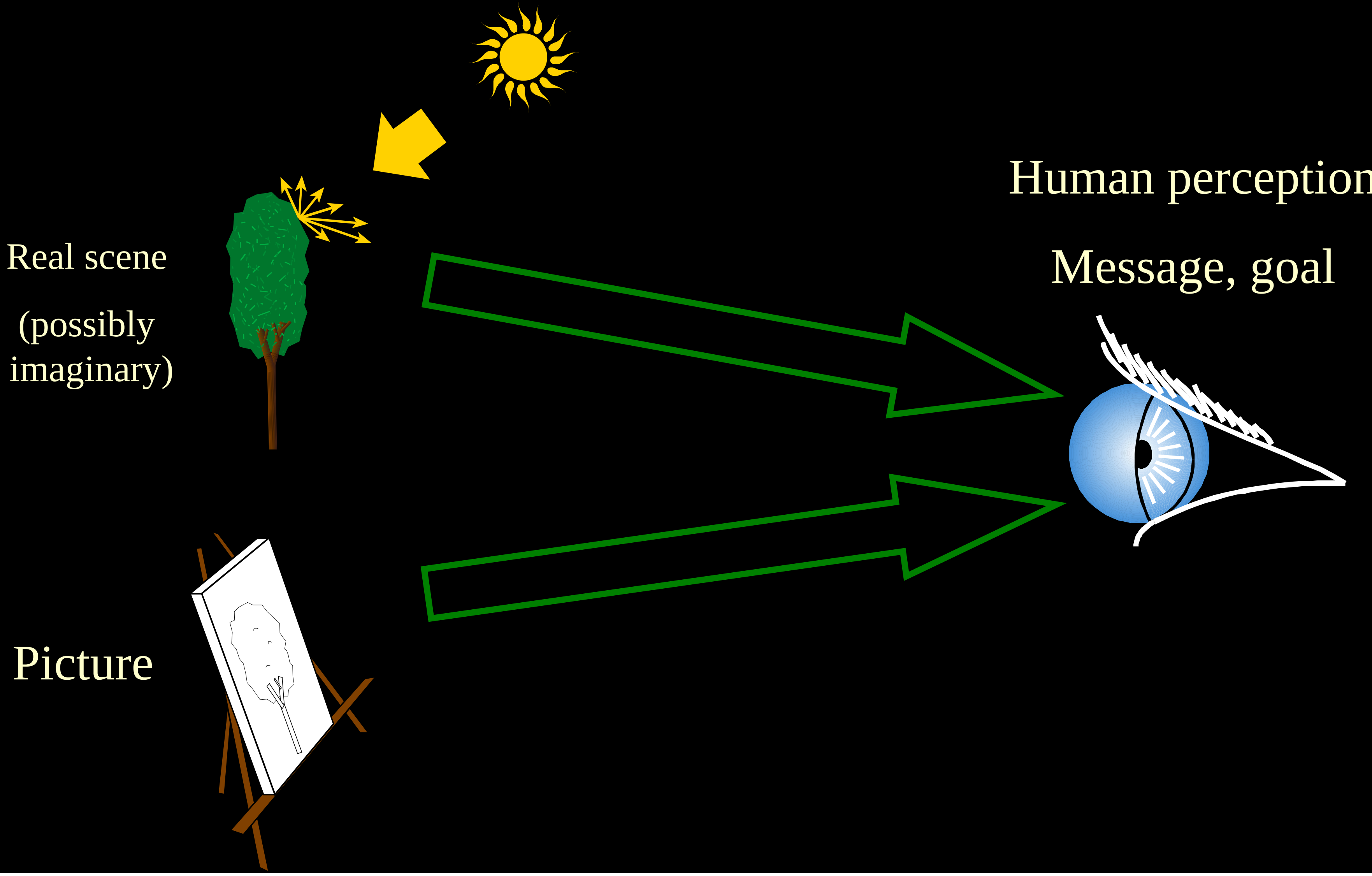
Problems

- Requires extension for richer styles
- User feedback loop
  - Reverse-engineers the image

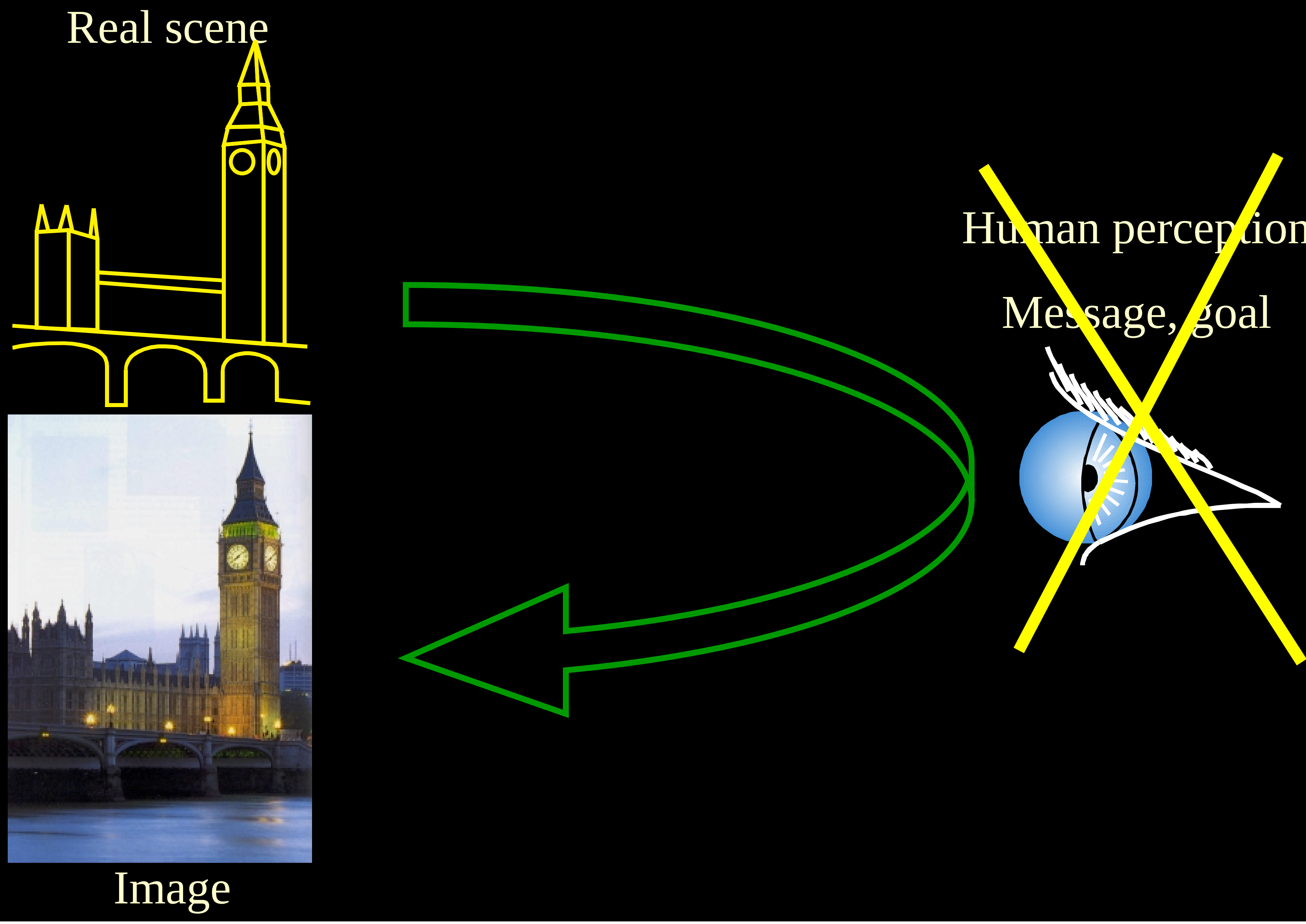


Depiction as an inverse of inverse

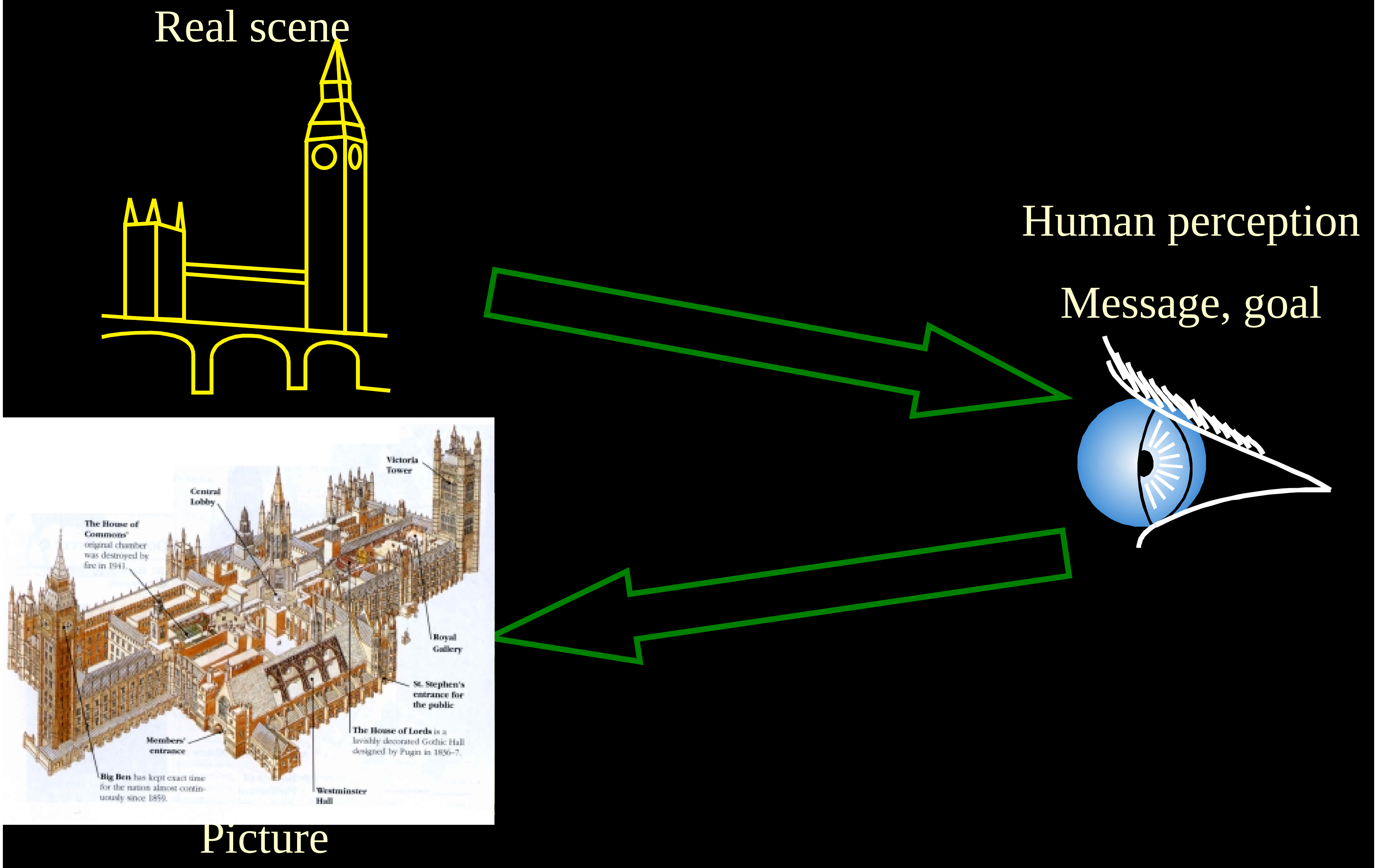
- Picture that conveys same impression as reality



Realistic image simulation

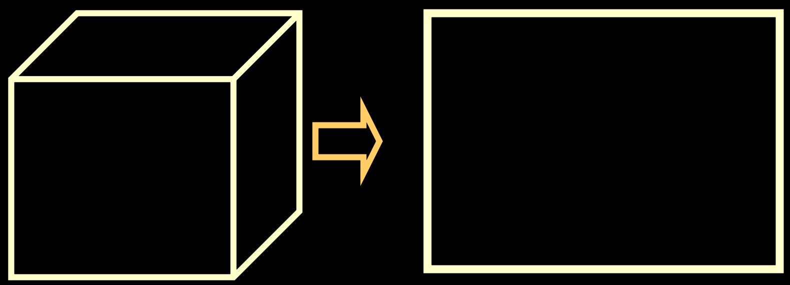


From 3D to 2D via interpretation



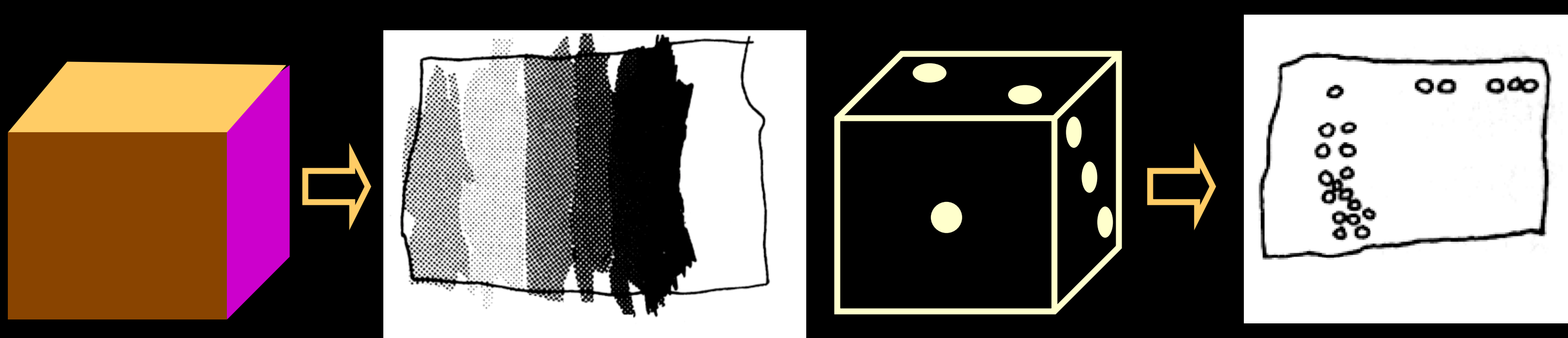
3D and 2D attributes

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



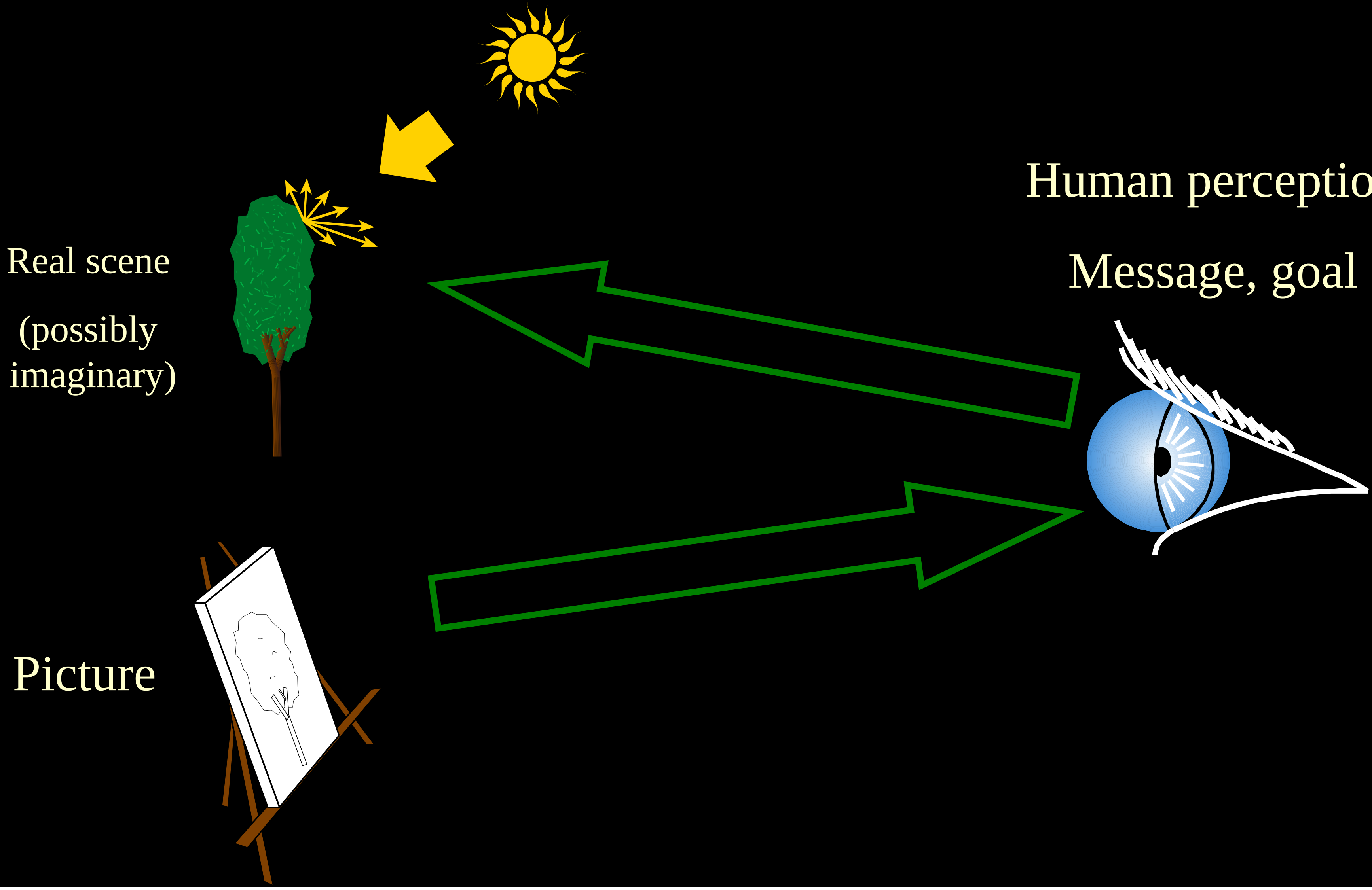
3D and 2D attributes

- 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 die
- The notion of 3D object with corners is translated as a 2D object with corners

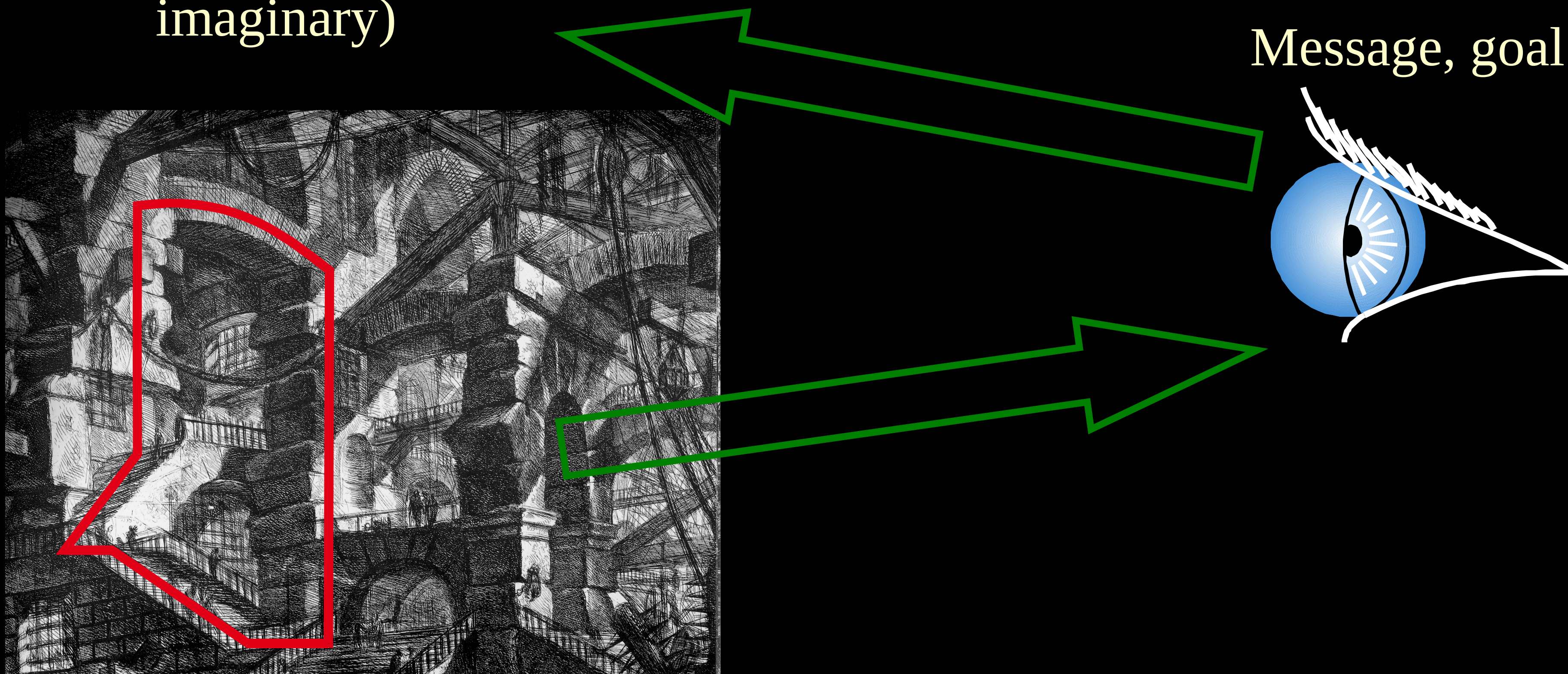


Inversing our view of Depiction

- 2D sometimes rules



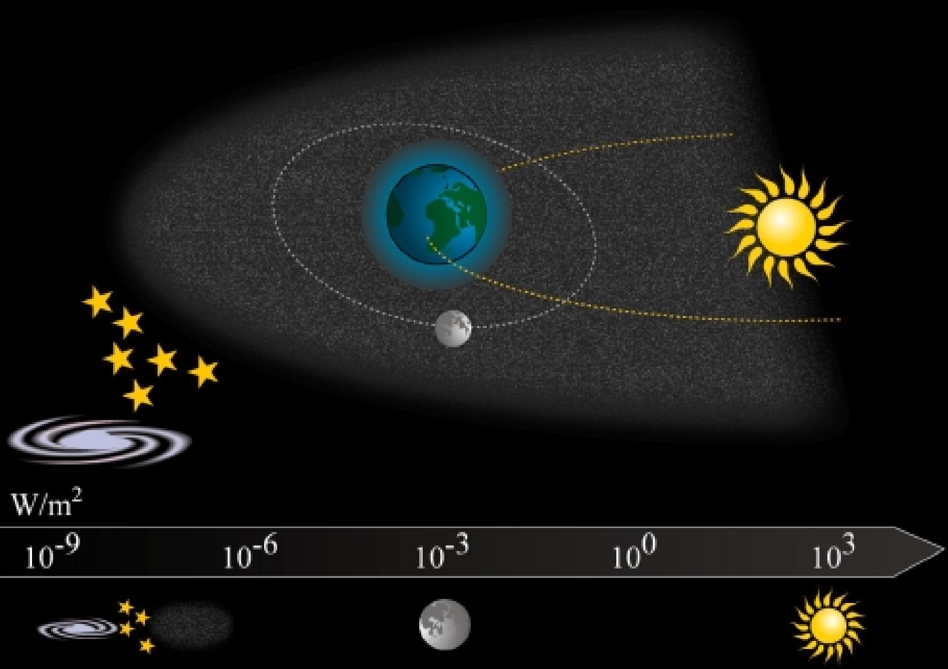
Purely 2D depiction



2D/3D dualism

- 3D-driven picture: architectural visualization

- 2D-driven picture
  - Horizontal organization & magnitude
  - 2D gradients for spheres

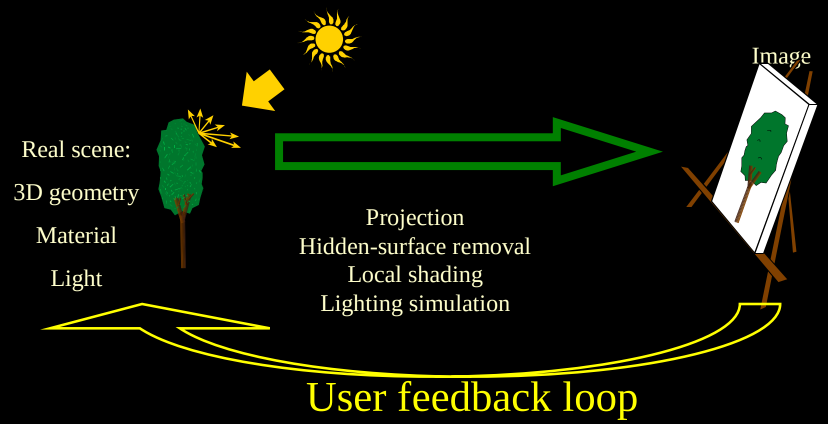


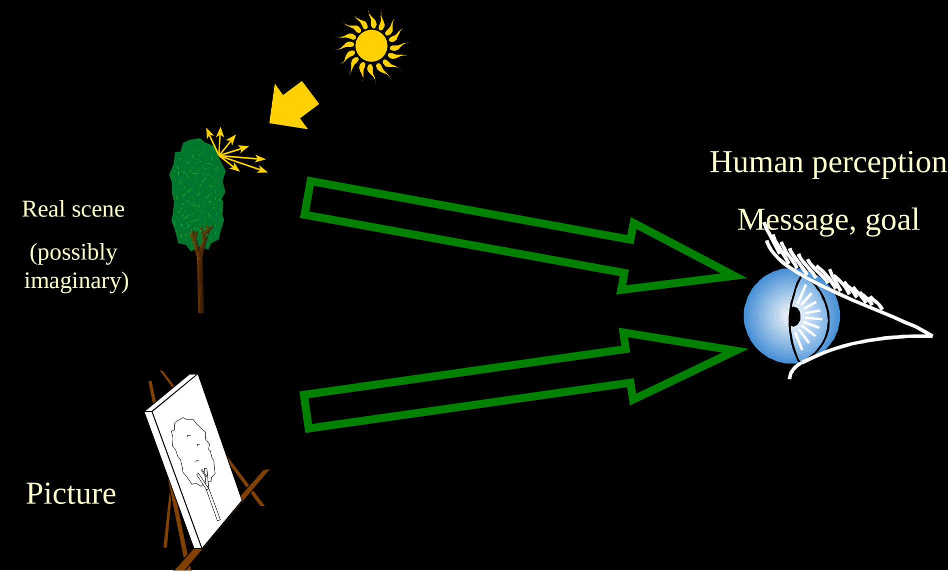
Mixed 2D-/3D-driven: group photo

- 3D position are determined by 2D goals
- See also the technique of trenching

Summary

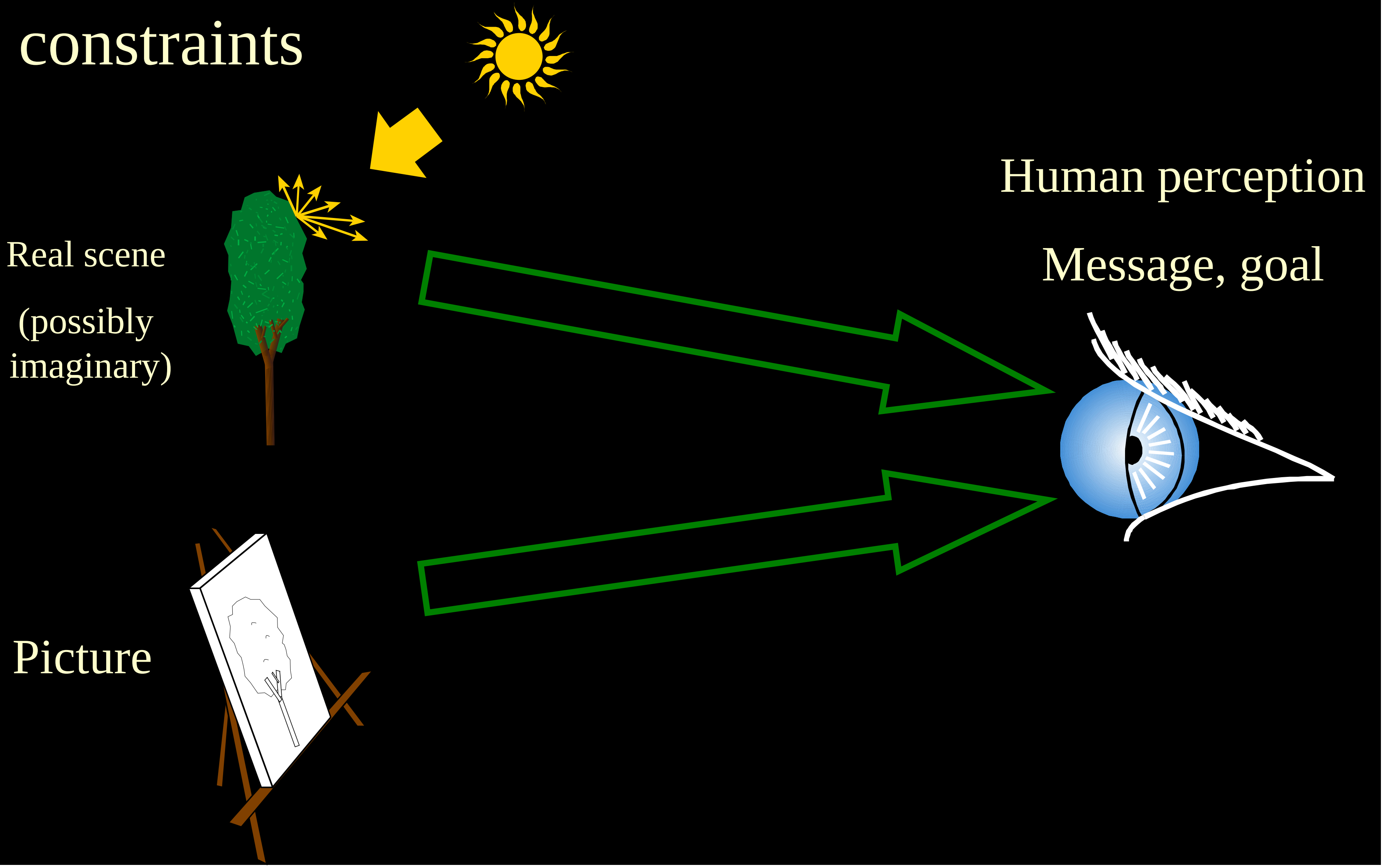
- One-way pipeline is powerful yet limited
- Requires user feedback loop
- Depiction is an inverse of inverse
- Can go from 3D to 2D via interpretation and/or from 2D to 3D





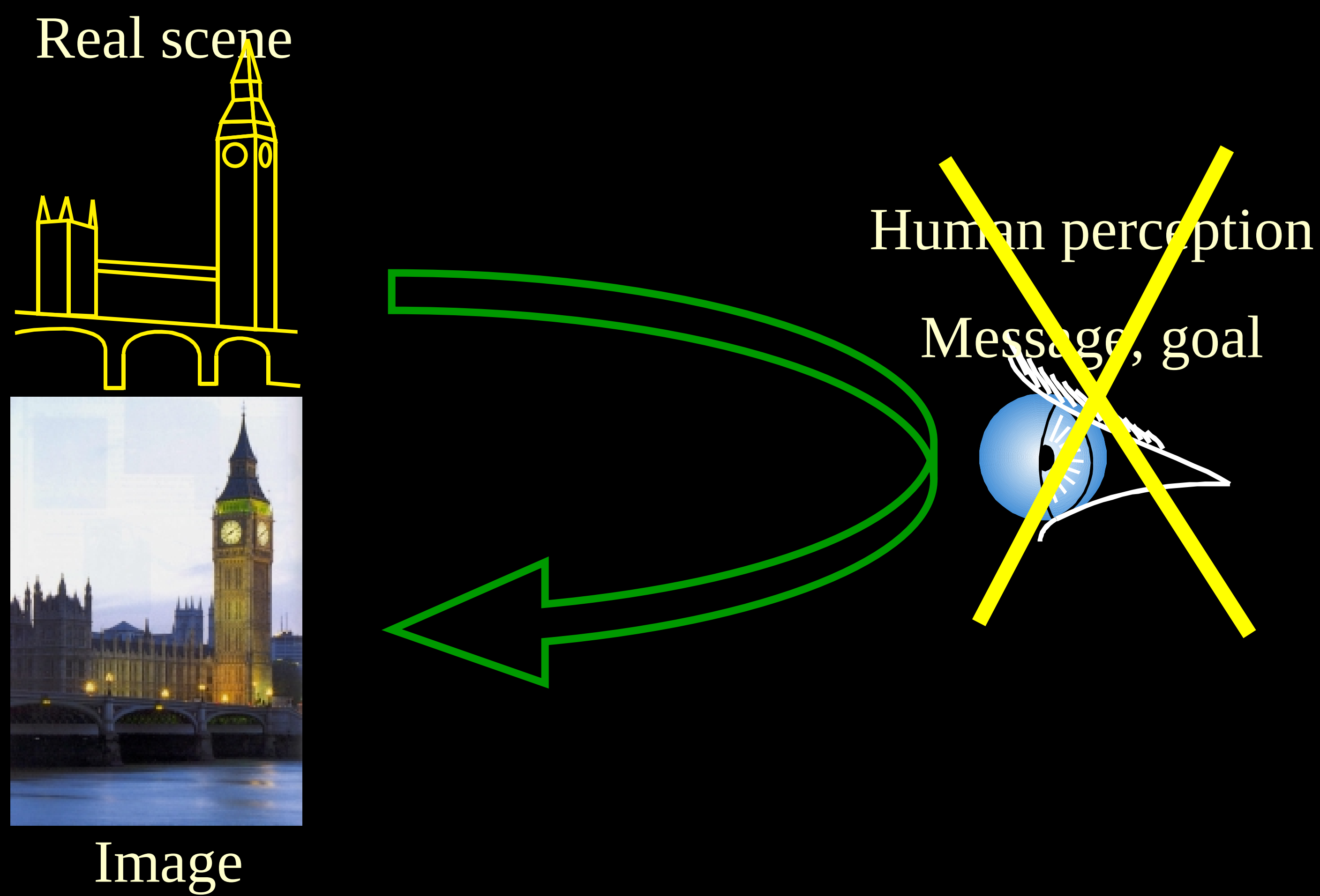
Depiction as optimization

- "Best" picture reaching goals and respecting constraints



Realistic image simulation

- Realistic image simulation:
  There is an analytical direct formulation



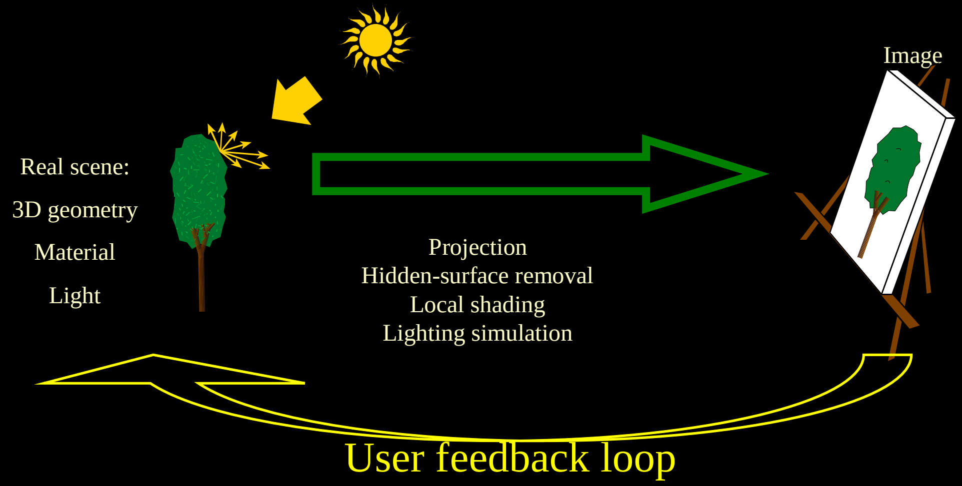
The computer solves the optimization

- Route maps [Agrawala 01]
- Lighting optimization [Schacked 01]
- Composition [Gooch 01]
- Paint with relaxation [Haeberli 91, Hertzman 01]

- Define the energy function
- Exploration of a highly-non-linear parameter space
- Or come up with a set of direct rules [He 96]

When the human solves

- Fast feedback
- Relevant degrees of freedom
- Uniform and meaningful parameter space
- Controls in image space
- High-level controls related to goals & constraints
- Pictorial techniques to alter the picture



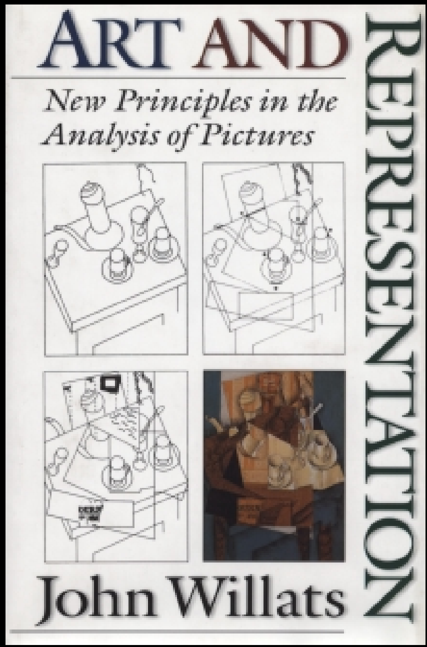
General case: computer+human

- The computer solves some issues,
  the human has control and adds the “magic”
- Decouple relevant dimensions of depiction
- Exciting challenge:
  Convergence of games and movies

Framework: Representation systems

- Adaptation of Willats [1997]
- With inspiration from cartography

- Decompose depiction into orthogonal issues
- Vocabulary
- Modularity
- Coarse-grain definition of style



Representation systems

- Spatial
  - Eye-balled perspective
- Primitives
  - Lines
- Attributes
  - Color, thickness
- Marks
  - Physical stroke

Toulouse Lautrec, *Femme rousse nu-tête*, 1891

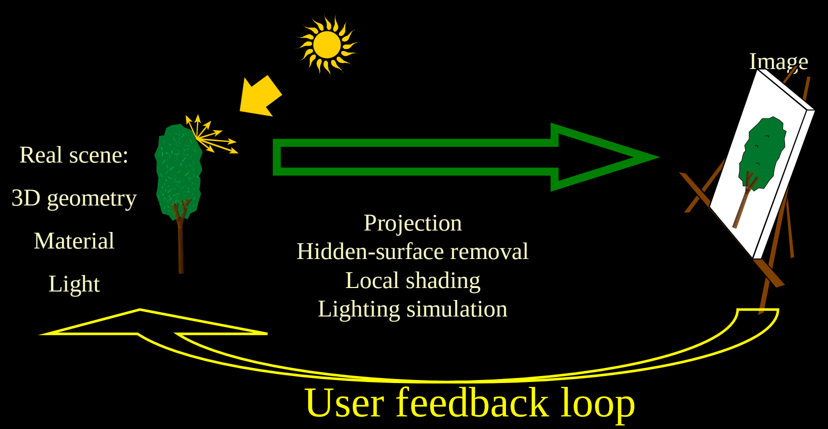
Classification with dimensions

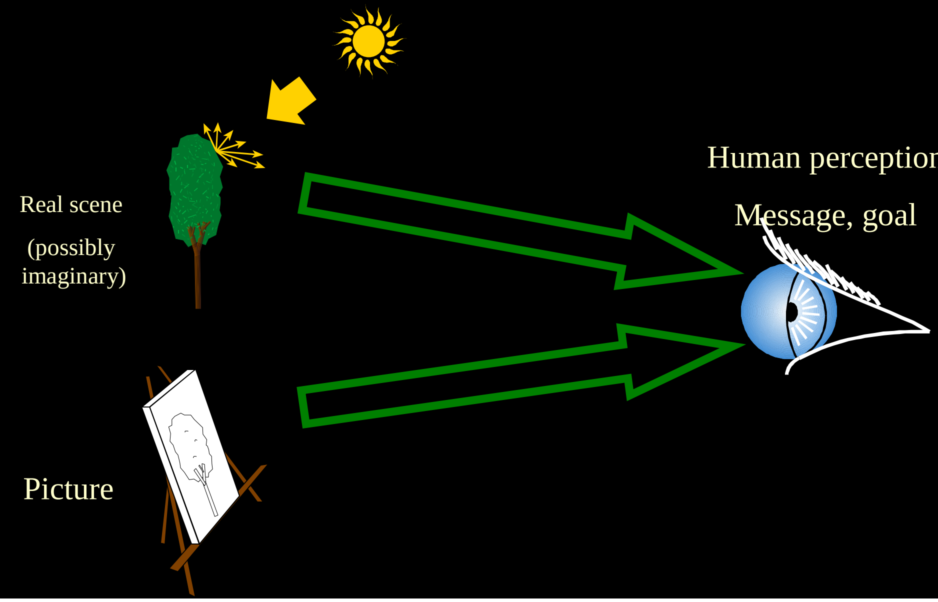
- Inputs and outputs
- 3D: object space
  (3D colors, intrinsic colors, light intensity)
- 2D: picture space (2D coordinates, extrinsic color)
- 2.5D: Intermediate representations
  - Z-buffer, normal maps, G-buffer, etc.

- Perspective matrix: 3D→2D spatial system
- Realistic local shading: 3D→2D attribute system
- Painting with light: 2D→3D attribute system

Imaging vs. interaction

- Direct picture making always decreases dimension
  - Globally, 3D→2D
- Interaction might require to increase to propagate picture-space goals & constraints





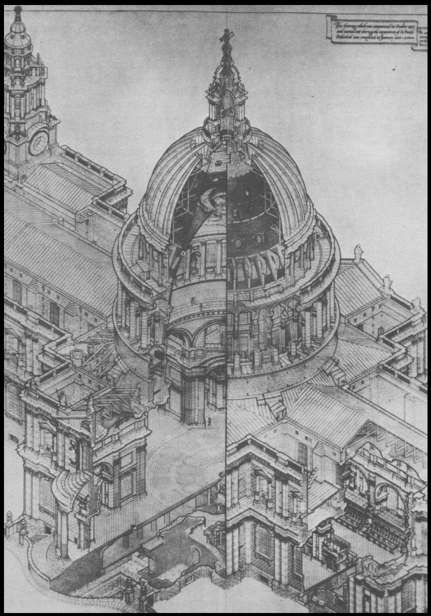
Spatial systems

- Map 3D spatial properties and 2D spatial properties

perspective

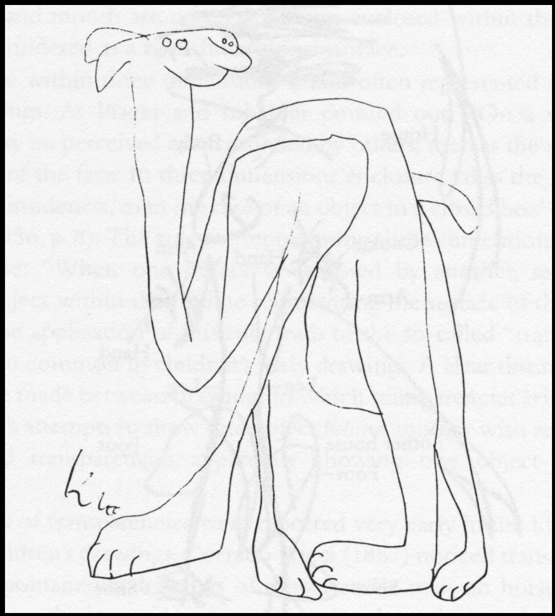
Criveli

orthographic



Brooks-Greaves

topological



Klee

symbolic

De la Francesca

Examples of spatial techniques

- 3D $\rightarrow$ 2D
  - 4*4 perspective matrices
  - Non-linear projections
- 2.5D $\rightarrow$ 2D
  - View warping [Chen 93]
- 2D $\rightarrow$ 2D
  - Correcting perspective distortions [Zorin 95]
- 2D $\rightarrow$ 3D
  - Image-based modeling [e.g. Debevec 96]
  - Sketch-based modeling [Zeleznik 96]
  - View-dependent geometry [Rademacher 99]

Primitive systems

- Map 3D primitives (points, lines, surfaces, volumes) to 2D primitives (points, lines, regions)

2D regions

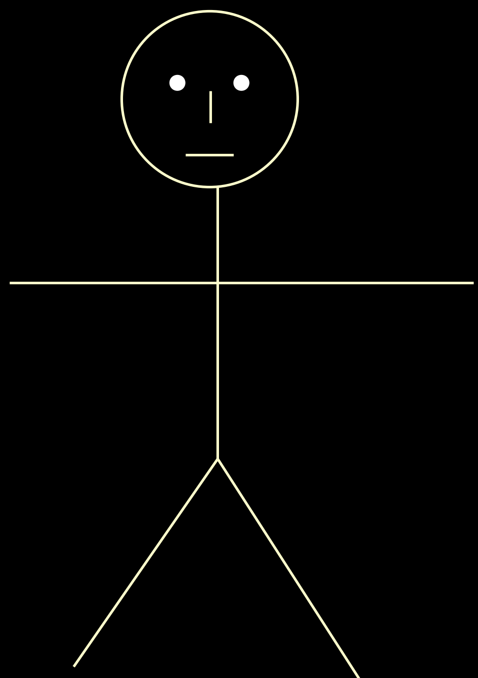
1D lines

0D continuous points

Picasso

Primitive systems

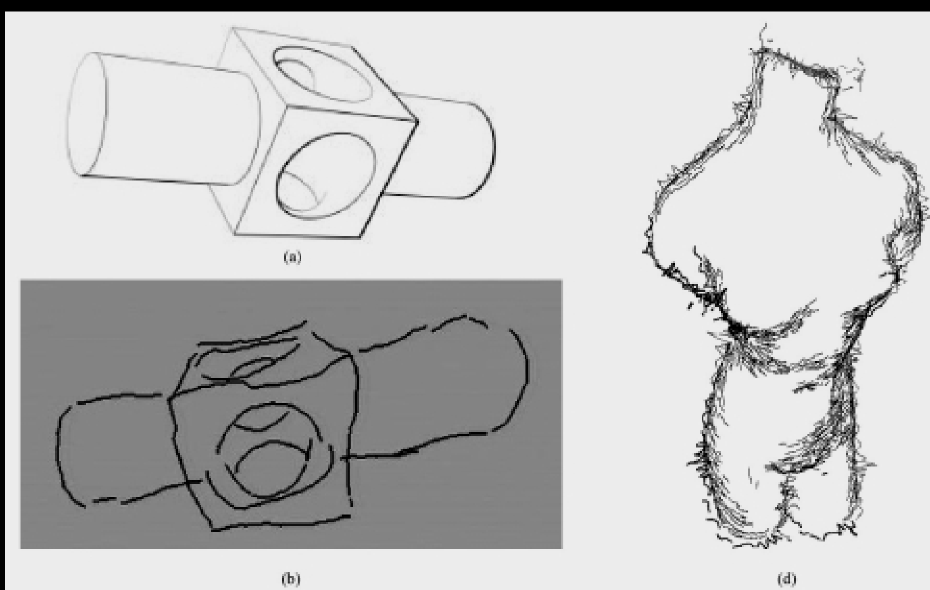
- Map 3D primitives (points, lines, surfaces, volumes) to 2D primitives (points, lines, regions)
- Can be complex



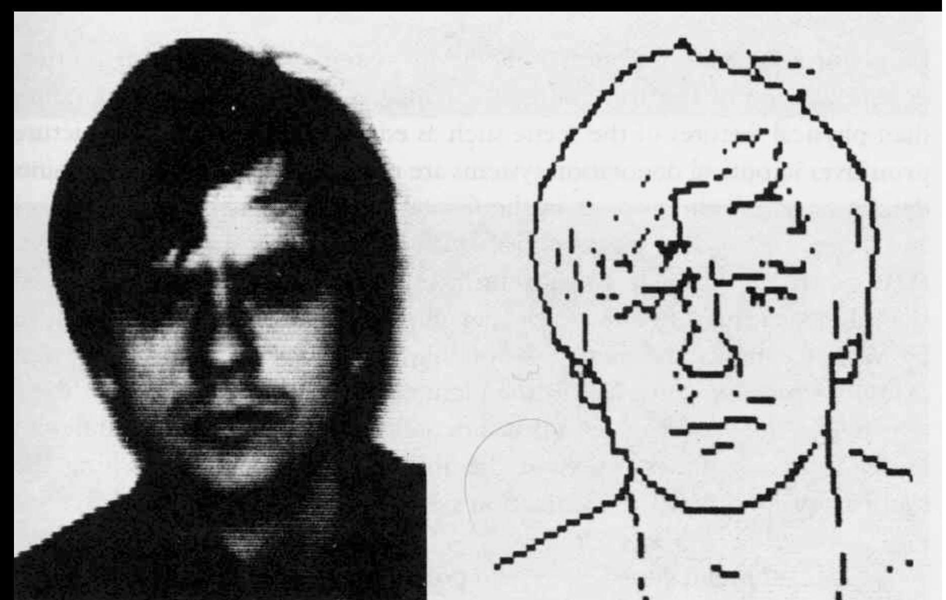
Arm:
Elongated 3D volume
$\longrightarrow$ 1D line primitive

Examples of primitive techniques

- Classical graphics: continuous point
- Silhouette rendering:
  - 3D → 2D: e.g. [Markosian 97]
  - 2.5D → 2D z-buffer-based, e.g. [Saito 90, Raskar 99]
  - 2D → 2D edge detection, e.g. [Canny 86, Pearson 90]



3D → 2D [Markosian 97]



2D → 2D [Pearson 90]

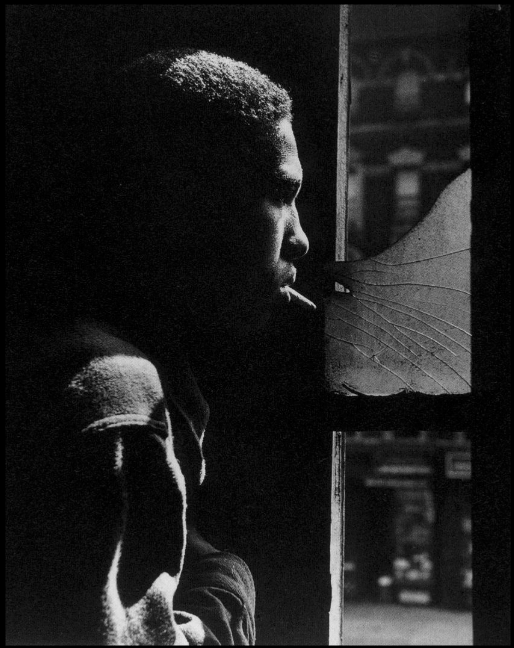
Attributes systems

- Assign visual properties to primitives
  - E.g. Color, texture, thickness, wiggleness, orientation

Color: Extrinsic

McCurry

Color:Extrinsic B/W



Park

Color:Intrinsic hue

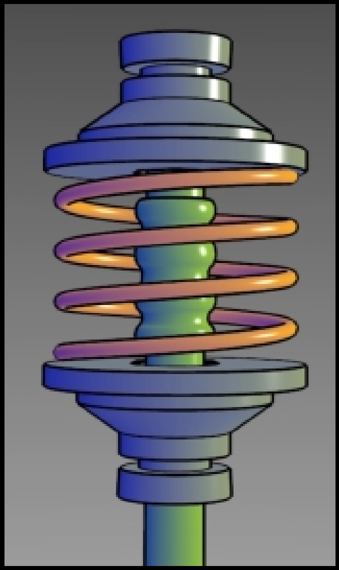
Jawlensky

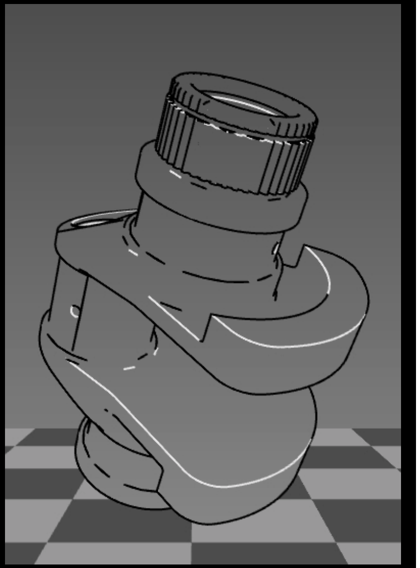
Thickness

Polke

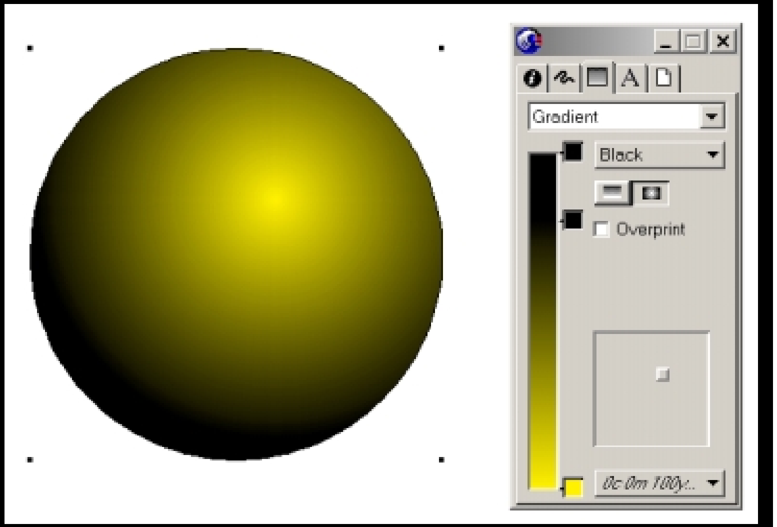
Examples of attribute techniques

- 3D → 2D
  - Realistic shading
  - NPR shading [Gooch 98]
  - Line shading [Gooch 99]



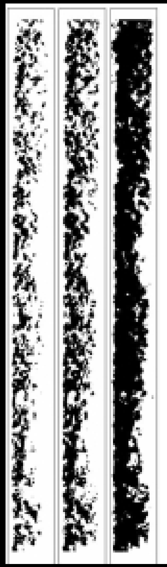
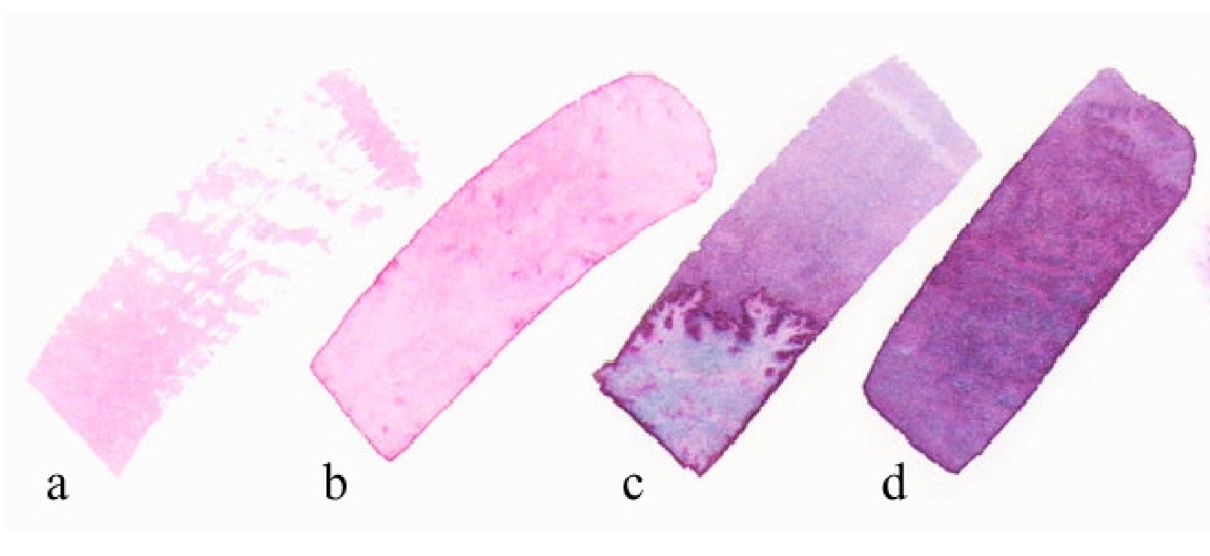


- 2.5D → 2D
  - Comprehensible rendering [Saito 96]
  - Lumo [Johnston 02]
- 2D → 2D
  - Painting/drawing systems
  - Brightness/contrast/saturation



Mark systems

- Implementation of the primitives placed at their spatial location with their attributes
- Medium simulation, physical strokes

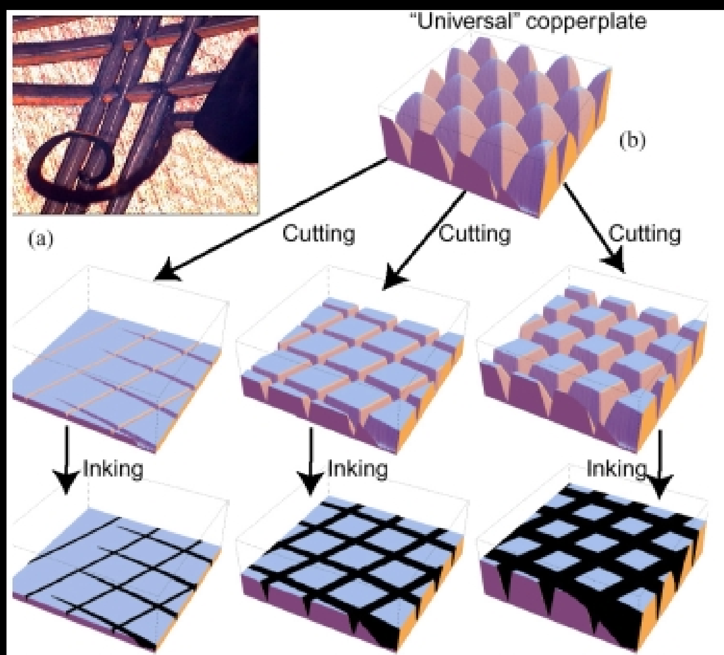




Marks vs. primitives

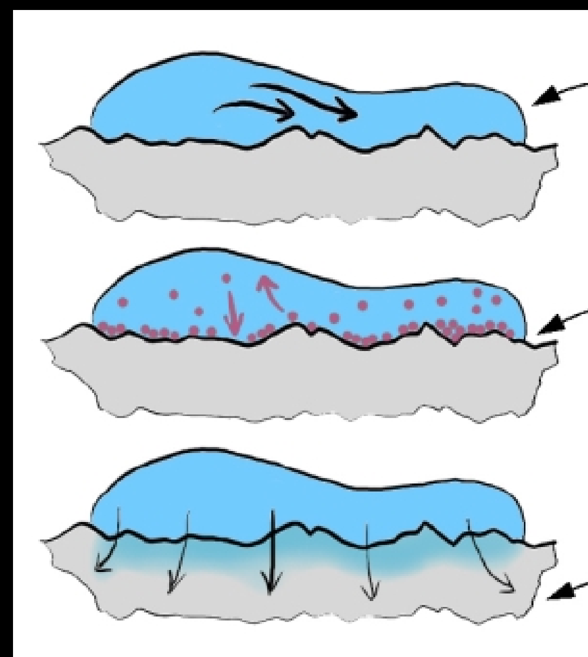
- Discrete 0D marks, but 1D line primitives

NPR marks

- Most NPR papers have a mark component
- Watercolor [Curtis 97]
- Engraving [Ostromoukhov 99]
- Issue of temporal coherence

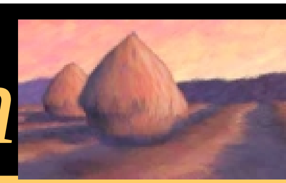


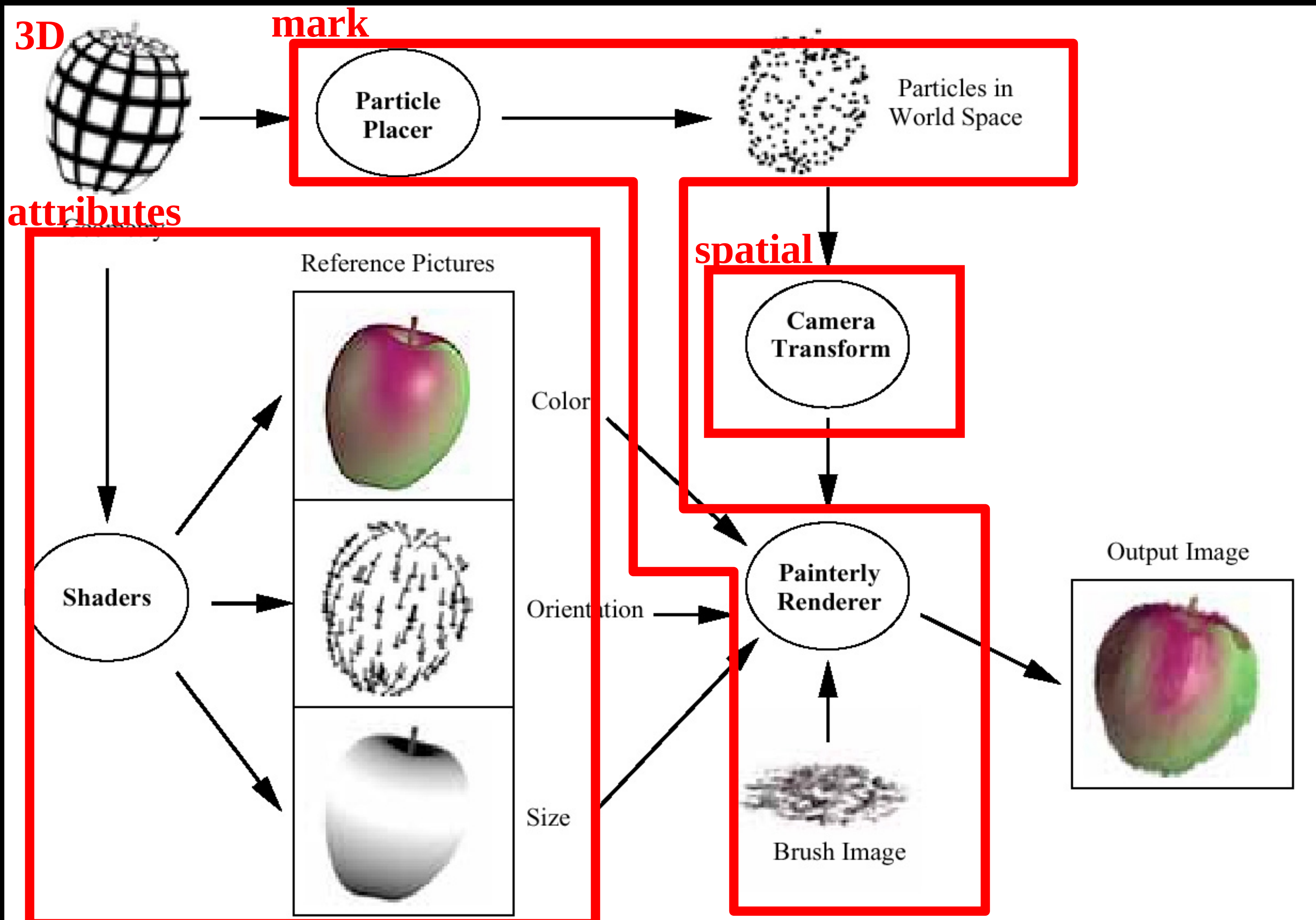
[Ostromoukhov 99]



[Curtis 97]

Meier's painterly animation

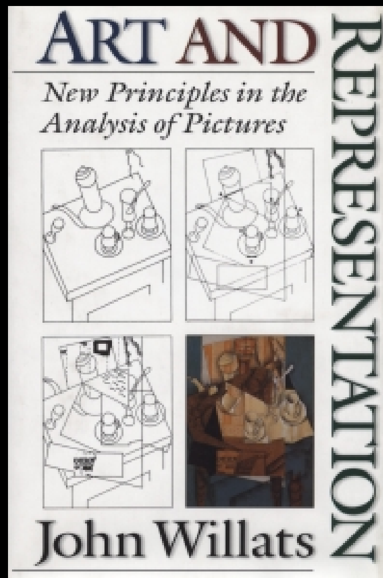


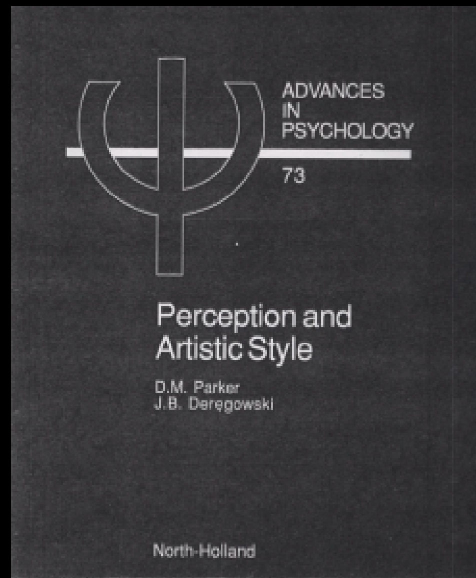


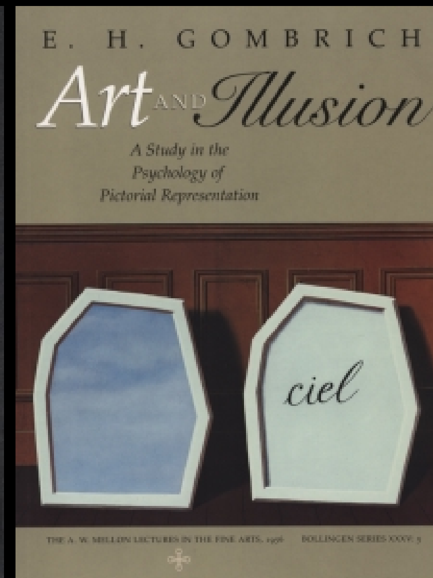
Invitation

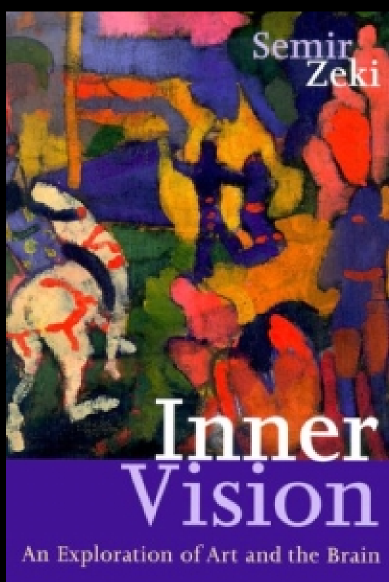
- Express PR & NPR techniques in this framework
- Find-out missing categories
- Use it for modularity
- Extension to animation
- Complex coupling between representation systems
- Finer notion of style
- Abstraction
- Different pictures, different users, different contexts
- Back to art history & perception

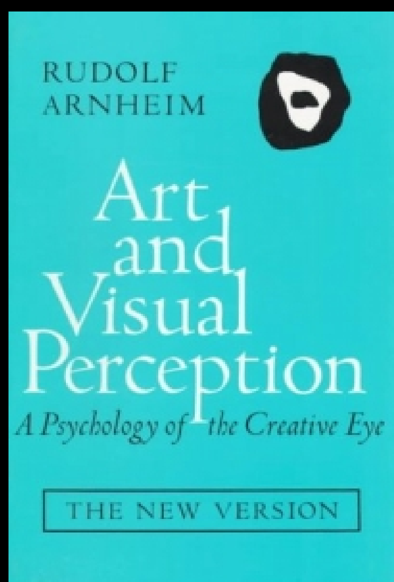
Further reading

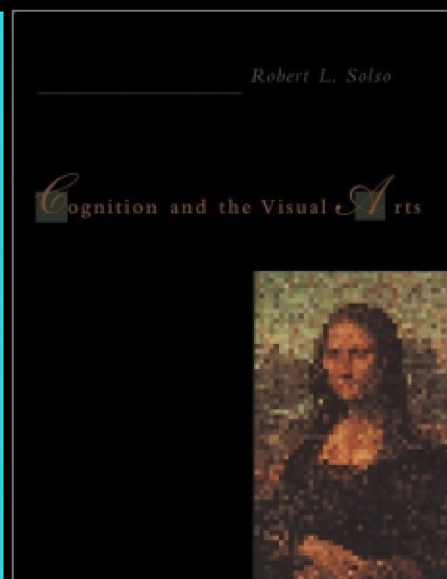


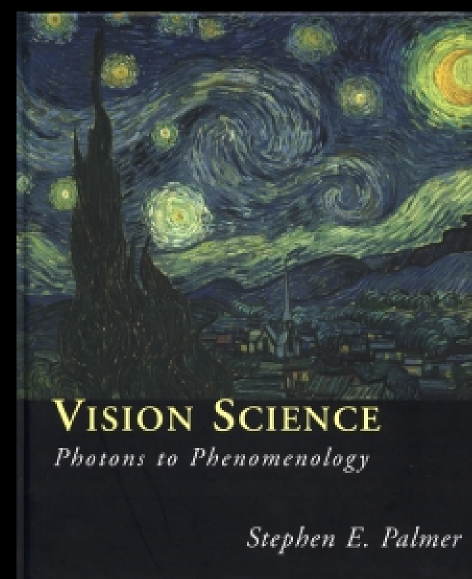












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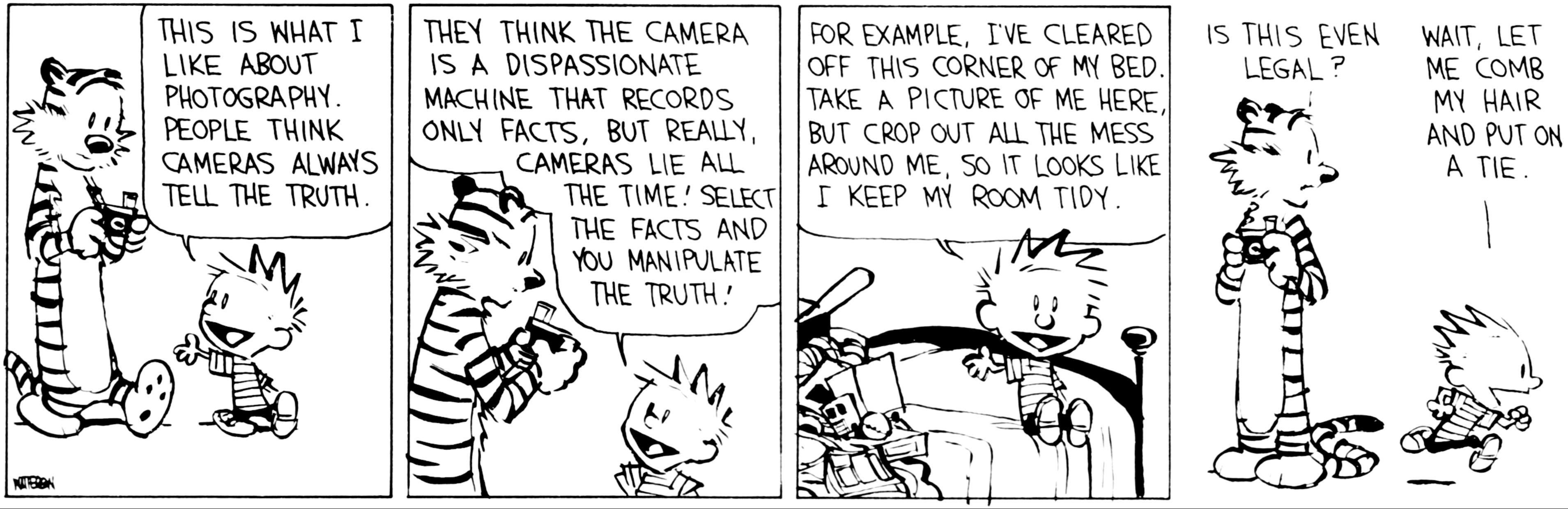
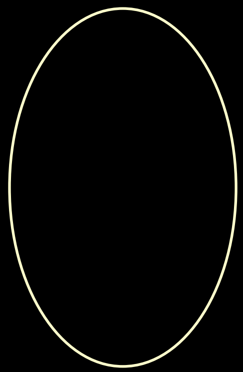
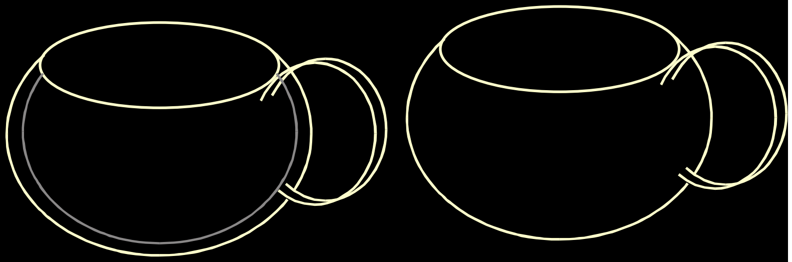


Mapping of curvature

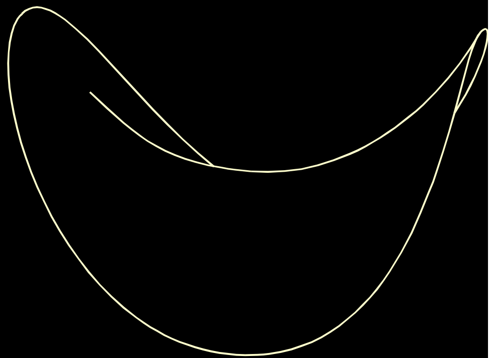
- Convex: positive curvature
  - 3D example: Egg
  - 2D: Convex contour



- Concave: negative curvature
  - 3D example: Interior of cup
  - 2D: Nothing, hidden contour



- Saddle: mix of positive and negative curvature
  - 3D example:Saddle (surprising!)
  - 2D: Concave contour



Mapping of curvature

- Small plate under the cup

Mapping of curvature

- But some artists map 3D concave objects to 2D concave outlines
- This maps the property of concavity
- The left view of the plate is more “correct” but does not convey the notion of concavity

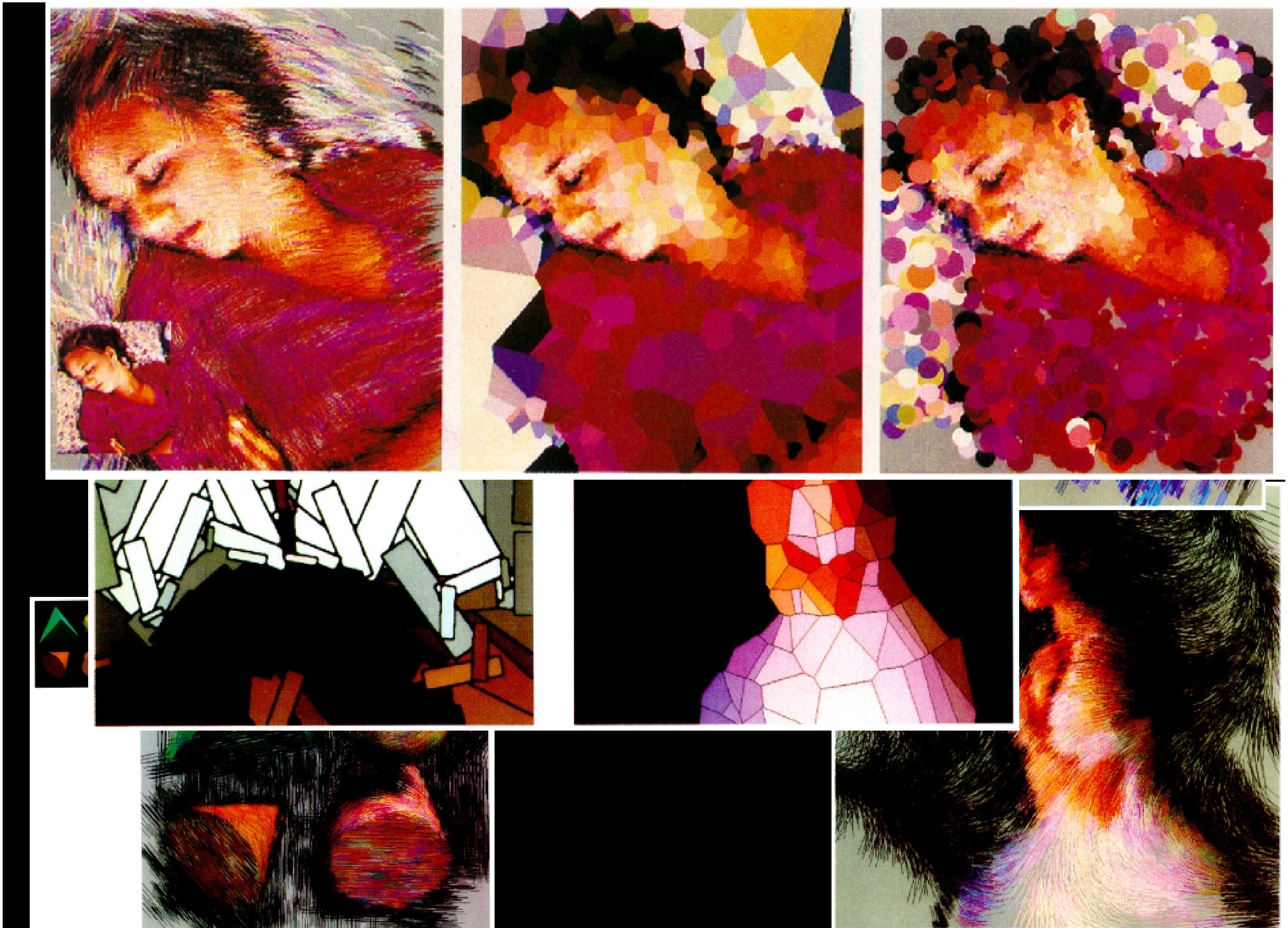


Figure 6. Using a second image to control brush stroke direction.

Summary

- Images: direct optical recording/simulation
- Pictures: more general visual representation
- Depiction is more than direct rendering
- Complex interaction/mapping between 3D and 2D
- Depiction is an optimization problem