The Art and Science of Depiction

Denotation system

Fredo Durand
MIT- Lab for Computer Science

Invention of linear perspective

• Why so late?
  – Different goal
  – Different background
  – Advent of measurement
  – Mathematic analytical skills
  – Single viewpoint assumption
**Accidental/generic**

- From the objective geometric point of view
  - Accidental viewpoint
  - Generic viewpoint
- From the subjective analysis point of view
  - Assume viewpoint is generic
  - Thus, the alignment cannot be accidental

**Prototypes**

- Solso
Maximum size

• Kosslyn
• Imagine a horse in the distance
• Imagine it moves continuously towards you
• When does it “overflows” your visual field?

Maximum size

• Kosslyn
• Imagine a horse in the distance
• Imagine it moves continuously towards you
• When does it “overflows” your visual field?
• 20° for strict overflow
• 40-60 ° for lax overflow
**Maximum size**

- Kosslyn
- Imagine a horse in the distance
- Imagine it moves continuously towards you
- When does it “overflows” your visual field?
- 20° for strict overflow (equivalent 100mm)
- 40-60° for lax overflow (30-50mm)

---

**Denotation system**

- Silhouette:
  - 2D (regions)
  - Picasso, *Rite of Spring*
- Line Drawing
  - 1D (lines)
- Optical
  - 0D (points)
Denotation system

- Silhouette:
  - 2D (regions)

- Line Drawing
  - 1D (lines)
  - Picasso, *Portrait of Stravinsky*

- Optical
  - 0D (points)

Denotation system

- Silhouette:
  - 2D (regions)

- Line Drawing
  - 1D (lines)

- Optical
  - 0D (points)
  - Picasso, *Paul as Arlequin*
A fourth denotation system

• Sculpture
  – 3D (volume)
  Picasso, Head of a Woman (Fernande), 1909

• Silhouette:
  – 2D (regions)

• Line Drawing
  – 1D (lines)

• Optical
  – 0D (points)

Introduction to denotation systems

• Difference between drawing and paintings
• The multiple role of e.g. lines
• What denotes what in the picture?
Plan

- Introducing denotation systems
- Line drawing
- A catalogue of primitives

Denotation system

- Scene
- Scene primitive
- Picture primitive
- Marks
Denotation system

- Scene
  - Objects, parts
- Scene primitive
  - Volumes, surfaces, lines and points of the scene.
- Picture primitive
  - Regions, lines and point in the picture
- Marks
  - Physical marks on the canvas

Denotation system

- Scene
- Scene primitive
- Picture primitive
- Marks
- Dimensions
- Extendedness
- Mapping
**Stages of vision**

- Bottom-up and top-bottom

---

**Marks vs. primitive**

- The mark is only the physical realization of the primitive
- They can have different dimensionality
Marks vs. primitive

- Mosaic
- Primitives = lines
- Marks = points (or small regions)

Marks vs. primitive

- Seurat, La Grande Jatte (detail)
Marks vs. primitive

- Paul Siemsen Picasso
Marks vs. primitive

• Giuseppe Arcimboldo
  *Summer*, 1563

Marks vs. primitive

• Victor Ostromoukhov, Artistic halftoning
Marks vs. primitive

- Chuck Close *Stanley* 1980-81

Denotation

- Example of a cylinder and a disc
Denotation: optical

• Example of a cylinder and a disc
• Picture point denote scene point
• 0 (dot) => 0 (visible point)

Denotation system

Denotation: optical

• Charles Bell Chicago 1980

Denotation system
**Denotation: line drawing**

- Example of a cylinder and a disc
- Picture line denotes scene line
- 1 (line) => 1 (scene occluding contour and edge)

**Denotation: outline drawing**

- Example of a cylinder and a disc
- Picture line denotes scene line
- 1 (line) => 1 (scene occluding contour)
- No internal edge
**Denotation: silhouette**

- Example of a cylinder and a disc
- Picture region denotes scene visible region
- $2_{10}$ (region) $\Rightarrow$ $2_{10}$ (visible region)
- Edge becomes more fuzzy and less salient

![Diagram of cylinder and disc with denotation system](image1)

---

**Silhouette vs. outline**

![Diagram comparing silhouette and outline](image2)
Silhouette vs. outline

Denotation system

Silhouette vs. outline

Denotation system
Silhouette vs. outline

Denotation system
Silhouette vs. outline

Thanks to science, your hair will look as good as everyone in your chat room thinks it does.

Denotation system 37

Denotation: volume

• Example of a cylinder and a disc
• Picture region denotes scene volume
• $2_{10}$ (extended region) $\Rightarrow 3_{100}$ (extended volume)
• $2_{11}$ (circular region) $\Rightarrow 3_{110}$ (disc)
Denotation: volume

- Example of a cylinder and a disc
- Picture region denotes scene volume
- \(1 \text{ (line)} \Rightarrow 3_{100} \text{ (extended volume)}\)
Denotation: volume

- 1 (line) => $3_{100}$ (extended volume)
- Related to the *structural skeleton*
3D and 2D attributes

- Show colored or numbered dice to children (6-7)
- The still draw a rectangle
- But different colors 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

Denotation: volume

Fig. 4.4 A child’s attempts to draw the mold mark on a ball. (a) The child’s drawing of the ball. (b) An adult drawing, including the mold mark. (c) “I can’t draw it here because it’s not outside the ball.” (d) “I can’t draw it here because it’s not inside the ball.” (e) “And I can’t draw it here because it won’t show up. So I can’t do it.” From Willats (1985), courtesy of Cambridge University Press.
Denotation analysis

Denotation system

Denotation analysis

Denotation system
**Denotation: special case**

- Alexander Calder, *Cow*, 1926

**Lineal/pictorial**

- Heinrich Wölfflin, 1916
- Renaissance vs. Baroque
- The line and drawing vs. the brush stroke
Lineal/pictorial

- E.g. Michelangelo vs. Rembrandt

Plan

- Introducing denotation systems
- Line drawing
- A catalogue of primitives
**Line drawing polyhedral objects**

- [Clowes 71, Huffman 71, Waltz 75]
- Computer vision
- Analyze line drawing
- Label regions, analyze occlusions
- Classify edges and vertices of the line drawing

**Labeling edges**

- Convex +
- Concave -
- Occluding -> (object on the right)
Labeling corners

Denotation system
**Labeling junctions**

- The arrow is always in the same direction (because of occlusion)

---

**Labeling**

---

[Diagram of labeled junctions]

---

Denotation system
**Ambiguous/impossible**

Fig. 5.6. Labelings for (a) unambiguous, (b) ambiguous, and (c) impossible drawings of rectangular objects. The "impossible" labeling is marked with an asterisk.

Denotation system
**Ambiguous/impossible**

Extension to shadowed scenes

- Waltz 1975
Line drawing of smooth objects

- Only one kind of edge
  - occluding contour
- Two types of vertices
  - T-junction
    (a.k.a. T-vertex)
  - End-junction
    (a.k.a. cusp)
Line drawing of a torus

cusp  t-vertex

fold
Line drawing of a torus

- Cusp
- T-vertex
- Fold

Drawing of smooth objects

- Walt Disney sketch for Mickey's Parrot 1938
Drawing of imaginary smooth object

- Paul Klee
- “As the figure grows little by little before our eyes an association of ideas may easily tempt us into objective interpretation. For with a bit of imagination every complex structure lends itself to a comparison with familiar forms in nature”

Ambiguous/impossible

Fig. 5.8. Labelings for (a) unambiguous, (b) ambiguous, and (c) impossible drawings of smooth objects. The “impossible” labeling is marked with an asterisk.
Ambiguous/impossible

• Klee
Little Baroque Basket 1939

Denotation system

Ambiguous/impossible

• Pratt Institute
Gresh Mc Ginn

Denotation system
**Ambiguous/impossible**

- Pratt Institute
- Gresh Mc Ginn

**Just for fun**

- Theory of singularity
- Evolution of the drawing when the viewpoint moves
- Structure changes at *visual events*
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
Drawing of smooth objects

• Klee, *Naked on the Bed*, 1939
Drawing of smooth objects

• Picasso, *Portrait of Stravinsky*

• Katsuka Shunsho, Japanese, 1782
A second look

- Cup
- Table

Plan

- Introducing denotation systems
- Line drawing
- A catalogue of primitives
**Picture primitive**

- Points
- Lines
- Regions

**Scene primitive**

- View independent vs. view dependent
  - 3D
  - 2D
  - 1D
  - 0D
3D and 2D scene primitives

- 3D
  - Volume
  - Extendedness (sphere, disc, lump)
- 2D
  - Surface

1D scene primitives

- View independent
  - Very thin objects (string, etc.)
  - Edge
  - Reflectance edge
  - Shadow edge
  - Transparency edge
  - Surface contours
- View dependent
  - Occluding contour
  - Silhouette
1D scene primitives

• View independent
  – Very thin objects (string, etc.)
  – Edge
  – Reflectance edge
  – Shadow edge
  – Transparency edge
  – Surface contours
• View dependent
  – Occluding contour
  – Silhouette
1D scene primitives

- **View independent**
  - Very thin objects (string, etc.)
  - Edge
  - Reflectance edge
  - Shadow edge
  - Transparency edge
  - Surface contours
- **View dependent**
  - Occluding contour
  - Silhouette
**1D scene primitives**

- View independent
  - Very thin objects (string, etc.)
  - Edge
  - Reflectance edge
  - Shadow edge
  - Transparency edge
  - Surface contours
- View dependent
  - Occluding contour
  - Silhouette

**Transparency**

- Lissitzky
**1D scene primitives**

- **View independent**
  - Very thin objects (string, etc.)
  - Edge
  - Reflectance edge
  - Shadow edge
  - Transparency edge
  - Surface contours

- **View dependent**
  - Occluding contour
  - Silhouette

---

**Surface contours**
Surface contours

Surface contours
1D scene primitives

• View independent
  – Very thin objects (string, etc.)
  – Edge
  – Reflectance edge
  – Shadow edge
  – Transparency edge
  – Surface contours

• View dependent
  – Occluding contour
  – Silhouette

Edge detection
**Edge detection**

- Contour film

**Edge detection**

- Matisse, *Loulou*
**Edge detection**

- Matisse, *Loulou*

---

**0D scene primitives**

- Generic visible point
- View independent
  - Corner
  - X-junction for shadow
- View dependent
  - T-junction
  - Cusp
  - X-junction for transparency
A complex example

• Tom Purvis 1935

Denotation system
A complex example

- E Mc Knight
  Kauffer 1947

A complex example

- Ingres
A complex example

- Klee, *Oh But Oh!*, 1937

Denotation system
Backlighting

- Line drawing…

Complex system

- Henry Wolf
  *Nude*
**Drawing**

- Dürer, *Head of a Man*

- Raphael
**Drawing**

- Georges Seurat *Sous la Lampe* 1882-83

![Georges Seurat's *Sous la Lampe*](image)

**Simplification**

- Picasso *The Bull* 1945

![Picasso's *The Bull*](image)