

The Art and Science of Depiction
Denotation system

Fredo Durand
 MIT- Lab for Computer Science

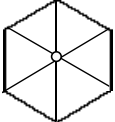
Invention of linear perspective

- Why so late?
 - Different goal
 - Different background
 - Advent of measurement
 - Mathematic analytical skills
 - Single viewpoint assumption

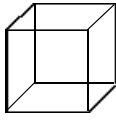
Denotation system 2

Accidental/generic

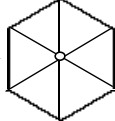
- From the objective geometric point of view



Accidental viewpoint




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



Denotation system 3

Prototypes

- Solso



Denotation system 4

Maximum size

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

Denotation system 5

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

Denotation system 6

Maximum size

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

Denotation system

7

Denotation system

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



Denotation system

8

Denotation system

- Silhouette:
 - 2D (regions)
- Line Drawing
 - 1D (lines)
 - Picasso, *Portrait of Stravinsky*
- Optical
 - 0D (points)



Denotation system

9

Denotation system

- Silhouette:
 - 2D (regions)
- Line Drawing
 - 1D (lines)
- Optical
 - 0D (points)
 - Picasso, *Paul as Arlequin*



Denotation system

10

A fourth denotation system

- Sculpture
 - 3D (volume)
 - Picasso, *Head of a Woman (Fernande)*, 1909
- Silhouette:
 - 2D (regions)
- Line Drawing
 - 1D (lines)
- Optical
 - 0D (points)



Denotation system

11

Introduction to denotation systems

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



Denotation system

12

Plan

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

Denotation system

13

Denotation system

- Scene
- Scene primitive
- Picture primitive
- Marks

Denotation system

14

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

15

Denotation system

- Scene
- Scene primitive
- Picture primitive
- Marks

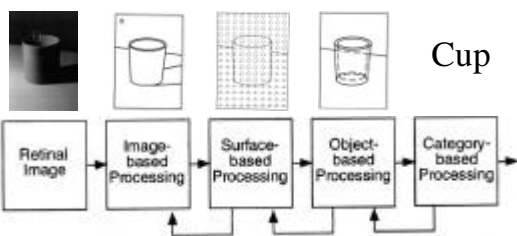
- Dimensions
- Extendedness
- Mapping

Denotation system

16

Stages of vision

- Bottom-up and top-bottom



Denotation system

17

Marks vs. primitive

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

Denotation system

18

Marks vs. primitive

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



Denotation system

19

Marks vs. primitive

- Seurat, La Grande Jatte (detail)



Denotation system

20

Marks vs. primitive

- Paul Siemsen
Picasso



Denotation system

Marks vs. primitive



Denotation system

22

Marks vs. primitive

- Giuseppe Arcimboldo
Summer, 1563

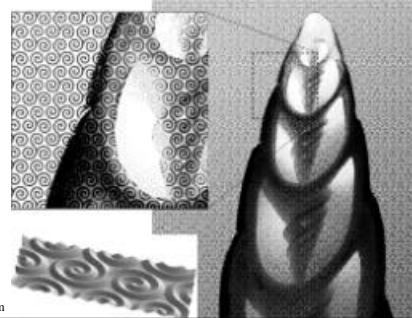


Denotation system

23

Marks vs. primitive

- Victor Ostromoukhov, Artistic halftoning



Denotation system

24

Marks vs. primitive

- Chuck Close *Stanley* 1980-81

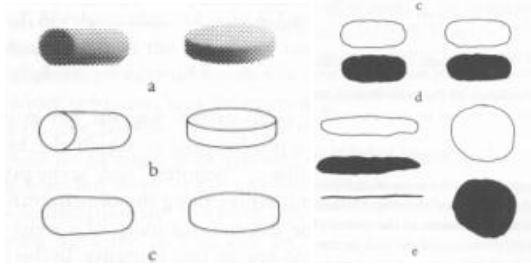


Denotation system

25

Denotation

- Example of a cylinder and a disc

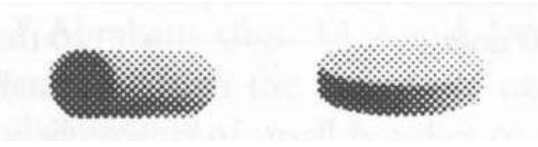


Denotation system

26

Denotation: optical

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

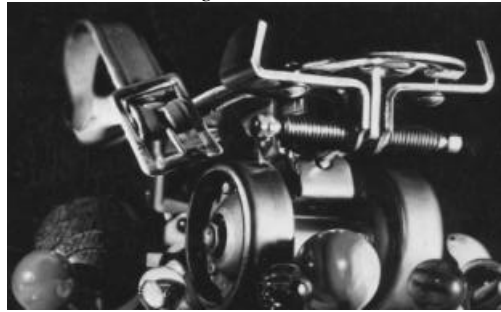


Denotation system

27

Denotation: optical

- Charles Bell *Chicago* 1980

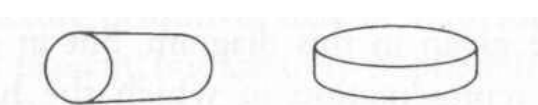


Denotation system

28

Denotation: line drawing

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

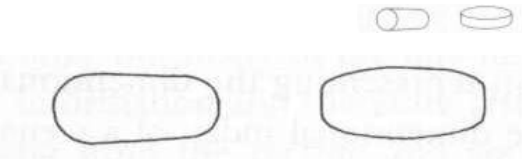


Denotation system

29

Denotation: outline drawing

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

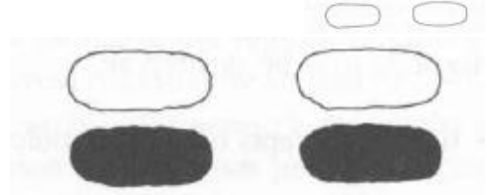


Denotation system

30

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



Denotation system

31

Silhouette vs. outline



Denotation system

32

Silhouette vs. outline



Denotation system

33

Silhouette vs. outline



Denotation system

34

Silhouette vs. outline



Denotation system

35

Silhouette vs. outline



Denotation system

36

Silhouette vs. outline



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 system

38

Denotation: volume

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

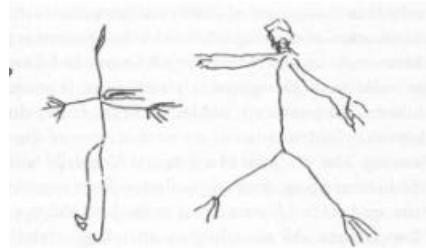


Denotation system

39

Denotation: volume

- 1 (line) \Rightarrow 3_{100} (extended volume)

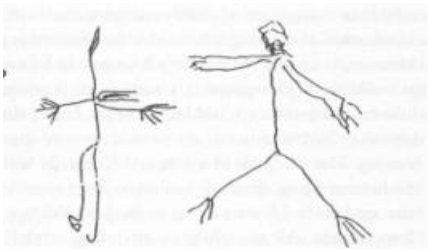


Denotation system

40

Denotation: volume

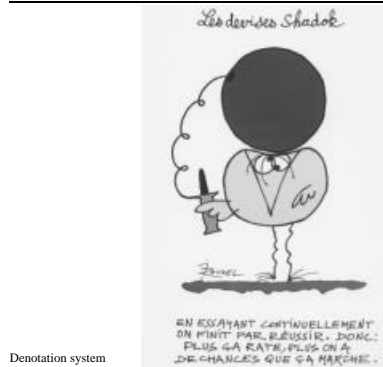
- 1 (line) \Rightarrow 3_{100} (extended volume)
- Related to the *structural skeleton*



Denotation system

41

Denotation: volume

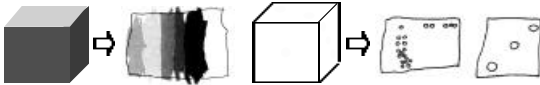


Denotation system

42

3D and 2D attributes

- Show colored or numbered dice to children (6-7)
- They 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 system

43

Denotation: volume

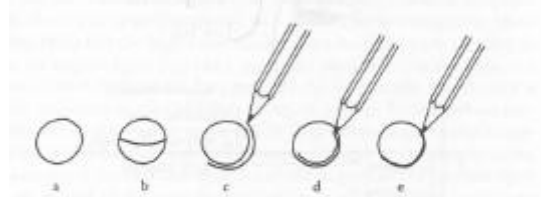
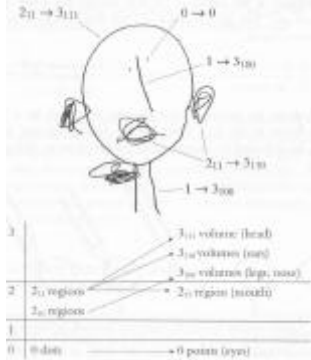


FIG. 4.4. A child's attempts to draw the mold mark on a ball. (a) The child's drawing of the ball. (b) An adult drawing, including the mold mark. (c) "I can't draw it here because it's not outside the ball." (d) "I can't draw it here because it's not inside the ball." (e) "And I can't draw it here because it won't show up. So I can't do it." From Willan (1983), courtesy of Cambridge University Press.

Denotation system

44

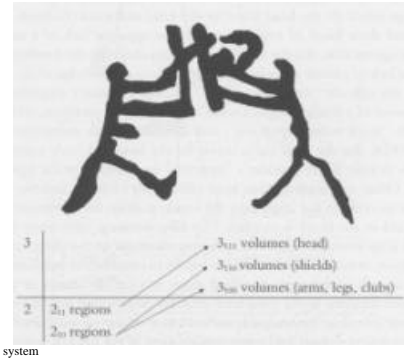
Denotation analysis



Denotation system

45

Denotation analysis



Denotation system

46

Denotation: special case

- Alexander Calder, *Cow*, 1926



Denotation system

47

Lineal/pictorial

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

Denotation system

48

Lineal/pictorial

- E.g. Michelangelo vs. Rembrandt



Denotation system

49

Plan

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

Denotation system

50

Line drawing polyhedral objects

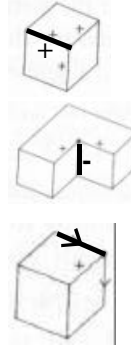
- [Clowes 71, Huffman 71, Waltz 75]
- Computer vision
- Analyze line drawing
- Label regions, analyze occlusions
- Classify edges and vertices of the line drawing

Denotation system

51

Labeling edges

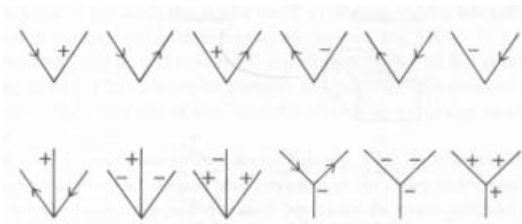
- Convex +
- Concave -
- Occluding ->
(object on the right)



Denotation system

52

Labeling corners



Denotation system

53

Labeling corners

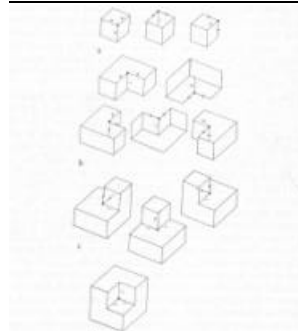


Fig. 3.3. Complete listing of possible pictures of corners in drawings of rectangular objects. From Huffman (1971), courtesy of Edinburgh University Press.

54

Labeling junctions

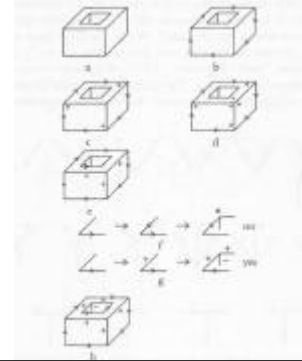
- The arrow is always in the same direction (because of occlusion)



Denotation system

55

Labeling



Denotation system

56

Ambiguous/impossible

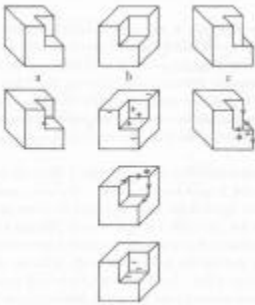
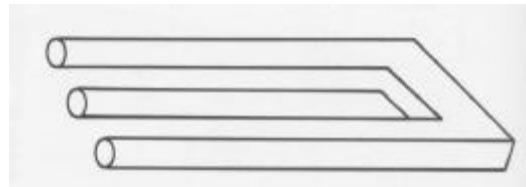


Fig. 5.6. Labelings for (a) unambiguous, (b) ambiguous, and (c) impossible drawings of rectangular objects. The "impossible" labeling is marked with an asterisk.

Denotation system

57

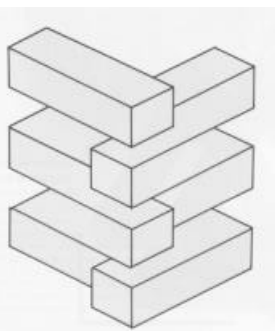
Ambiguous/impossible



Denotation system

58

Ambiguous/impossible

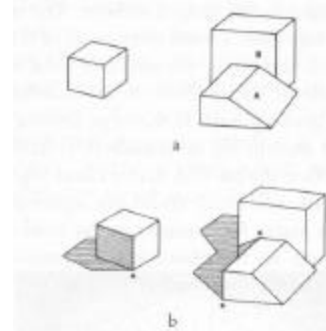


Denotation system

59

Extension to shadowed scenes

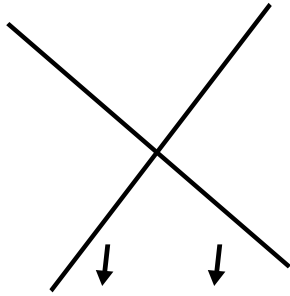
- Waltz 1975



Denotation system

60

Line drawing of smooth objects

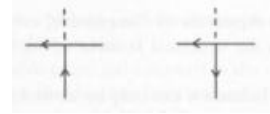


Denotation system

61

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)



Denotation system

62

Line drawing of a torus

Denotation system

63

Line drawing of a torus

cusP t-vertex

Denotation system

64

Line drawing of a torus



Denotation system

65

Drawing of smooth objects

- Walt Disney sketch for Mickey's Parrot 1938



Denotation system

66

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"



Denotation system

67

Ambiguous/impossible

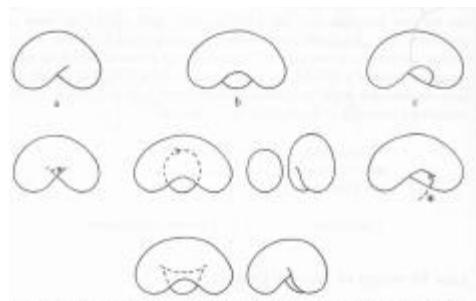


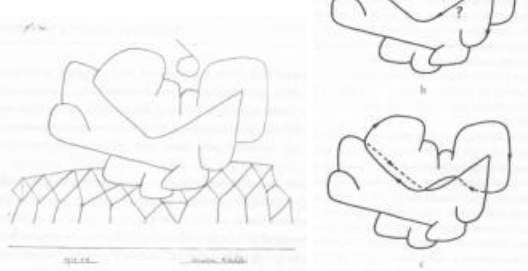
FIG. 5-8. Labelings for (a) unambiguous, (b) ambiguous, and (c) impossible drawings of smooth objects. The "impossible" labeling is marked with an asterisk.

Denotation system

68

Ambiguous/impossible

- Klee
- *Little Baroque Basket* 1939



Denotation system

69

Ambiguous/impossible

- Pratt Institute
- Gresh Mc Ginn



Denotation system

70

Ambiguous/impossible

- Pratt Institute
- Gresh Mc Ginn

Denotation system

71

Just for fun

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



Denotation system

72

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?)

Denotation system

73

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



Denotation system

74

Drawing of smooth objects

- Klee, *Naked on the Bed*, 1939

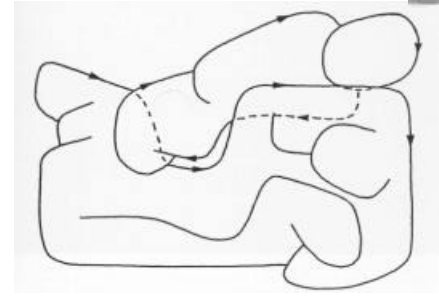


Denotation system

75

Drawing of smooth objects

- Klee, *Naked on the Bed*, 1939



Denotation system

76

Drawing of smooth objects

- Picasso, *Portrait of Stravinsky*



Denotation system

77

Drawing of smooth objects

- Katsuka Shunsho, Japanese, 1782



Denotation system

78

A second look

- Cup
- Table



Denotation system

79

Plan

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

Denotation system

80

Picture primitive

- Points
- Lines
- Regions

Denotation system

81

Scene primitive

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

Denotation system

82

3D and 2D scene primitives

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

Denotation system

83

1D scene primitives


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

Denotation system

84

1D scene primitives


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



Denotation system 85

1D scene primitives

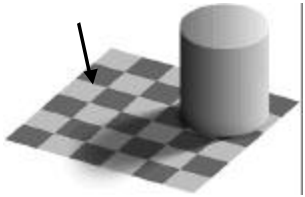
- View independent
 - Very thin objects (string, etc.)
 - Edge
 - Reflectance edge
 - Shadow edge
 - Transparency edge
 - Surface contours
- View dependent
 - Occluding contour
 - Silhouette



Denotation system 86

1D scene primitives

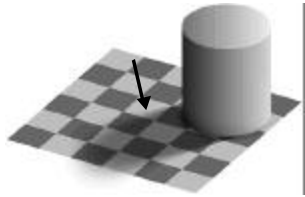
- View independent
 - Very thin objects (string, etc.)
 - Edge
 - Reflectance edge
 - Shadow edge
 - Transparency edge
 - Surface contours
- View dependent
 - Occluding contour
 - Silhouette



Denotation system 87

1D scene primitives


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



Denotation system 88

1D scene primitives

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



Denotation system 89

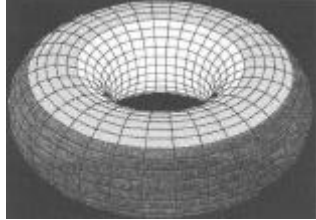
Transparency

- Lissitzky
 

Denotation system 90

1D scene primitives

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



Denotation system

91

Surface contours



Denotation system

92

Surface contours



Denotation system

93

Surface contours



Denotation system

94

1D scene primitives

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



Denotation system

95

Edge detection



Denotation system

96

Edge detection

- Contour film



Denotation system

97

Edge detection

- Matisse, *Loulou*



Denotation system

98

Edge detection

- Matisse, *Loulou*



Denotation system

Disappears rather quickly, doesn't it.

99

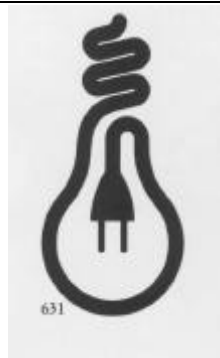
0D scene primitives

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

Denotation system

100

A complex example



Denotation system

101

A complex example

- Tom Purvis 1935



Denotation system

102

A complex example

- E Mc Knight Kauffer 1947



Denotation system

103

A complex example

- Ingres



Denotation system

104

A complex example

- Klee, *Oh But Oh!*, 1937

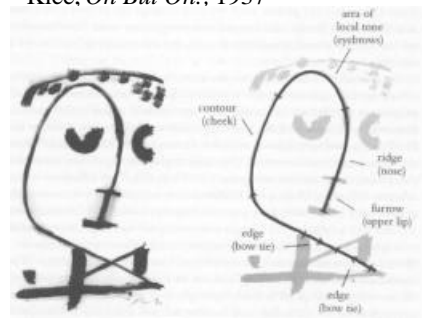


Denotation system

105

A complex example

- Klee, *Oh But Oh!*, 1937



Denotation system

106

Backlighting

- Line drawing...



Denotation system

107

Complex system

- Henry Wolf *Nude*



Denotation system

108

Drawing

- Dürer,
Head of a Man



Denotation system

109

Drawing

- Raphael



Denotation system

110

Drawing

- Georges Seurat *Sous la Lampe* 1882-83

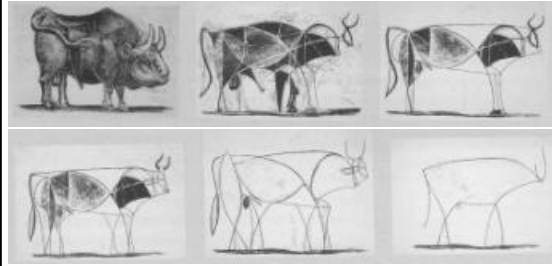


Denotation system

111

Simplification

- Picasso *The Bull* 1945



Denotation system

112