The Power of Visualization

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CS448b – Visualization

Winter 2006

Definition [www.oed.com]

1. The action or fact of visualizing; the power or process of forming a mental picture or vision of something not actually present to the sight; a picture thus formed.

   1883 Academy 14 July 31 Investigations into the phenomena of visualisation.

   1884 GURNEY & MYERS in 19th Cent. July 72 In the next stage of visualisation the percipient sees a face or figure projected or dejected, as it were, on some convenient surface.

   1894 Athenæum 10 Nov. 638/2 [The book had] a power of visualization that gave it a claim to real originality.

Definition [www.oed.com]

2. The action or process of rendering visible.

    1936 Amer. Jrnl. Cancer XXVII. 49 The hexagonal tube..offers distinct advantages with its flat sides permitting good visualization.

    1960 New Scientist 28 July 305/3 Echo sounding..is now being applied to the visualization of structures within the body.

    1973 Nature 17 Aug. 410/1 Direct visualization of biological material at this level would tell us much about the structure and mode of action of macromolecules.

    1982 Listener 23/30 Dec. 42/3 The cinematic visualisation of the script..belongs entirely to Welles and his technicians

Visualization is the
Use of Graphical Techniques
to Convey Information and
Support Reasoning

Power of Visualization

Representations

This is not a pipe, The treachery of images, Rene Magritte

Number Scrabble

Given: The numbers 1 through 9

Goal: Pick numbers so that 3 numbers sum to 15

Example:

    A takes 8

    B takes 2

    A takes 4

    B takes 3

    A takes 5

    B takes?

Another Game: Tic-Tac-Toe

X	O	X
	X	
O		

Where should O play?

Problem Isomorphs [H. Simon]

4	3	8
9	5	1
2	7	6

Number Representations

Counting – Tallying

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Adding – Roman numerals

XXIII + XII = XXXIIIII = XXXV

Multiplication – Arabic number systems
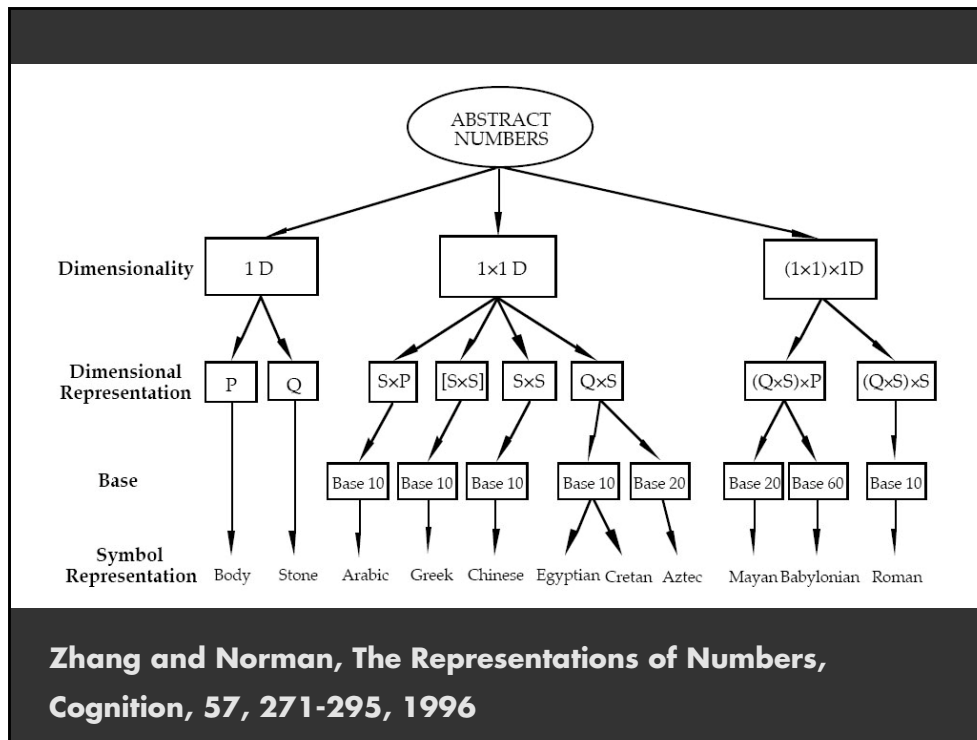
Long-Hand Multiplication

$$
\begin{array}{r}
34 \\
\times\ 72 \\
\hline
68 \\
238 \\
\hline
2448
\end{array}
$$

Long-Hand Multiplication

$$
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34 \\
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$$

Bar chart — Time (Sec.) on y-axis (0 to 120): Mental ≈ 108, Paper & Pencil ≈ 12
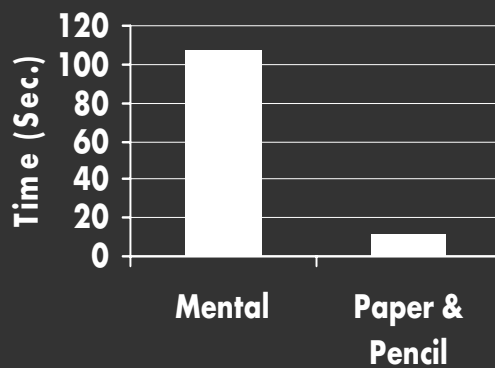
From Introduction to Information Visualization,
Card, Schneiderman, Mackinlay

Zhang and Norman, The Representations of Numbers, Cognition, 57, 271-295, 1996

Distributed Cognition

External (E) vs. Internal (I) process

		Roman	Arabic
1.	Separate power & base	I	E
2.	Get base value	E	I
3.	Multiply base values	I	I
4.	Get power values	I	E
5.	Add power values	I	E
6.	Combine base & power	I	E
7.	Add results	I	E

Arabic more efficient than Roman

Power of Representations

- **Distributed cognition**
  - **Internal representations (mental models)**
  - **External representations (cognitive artifacts)**
- **The representational effect**
  - **Different representations have different cost-structures / "running" times**
  - **Big idea in computer & cognitive science**

Visual Inference
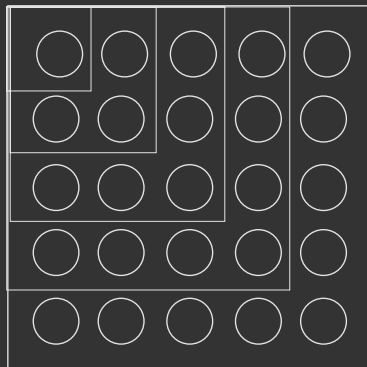
Visual Proof:

$1+3+5+7+9=5^2$
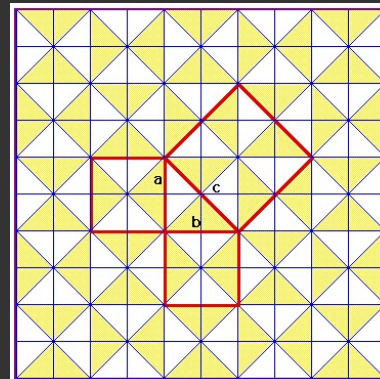
Pythagorean Theorem:
Chinese Proof by Dissection

Amplifies Cognition

1. **Provide natural perceptual mapping**
   - **Discriminate different things**
   - **Estimate quantities**
   - **Segment objects into groups**
2. **Enhance memory**
   - **Minimize information in working memory**
   - **Change recall to recognition**
   - **Facilitate combining things into chunks**
   - **Transform to a more memorable form**

Amplifies Cognition

3. **Reduce search time**
   - **Retrieve information in neighborhood**
   - **Natural spatial index**
   - **Preattentive (fast, parallel) search process**
4. **Perceptual inference**
   - **Map inference to visual pattern finding**
   - **Enforce constraints**

Amplifies Cognition

5. Control attention
   - Highlight to focus attention
   - Control reading order
6. Provide context
   - Style provides cultural cues
   - Aesthetics makes tasks enjoyable
   - Alternatives encourage creativity

Purposes / Pragmatics

1. Record information
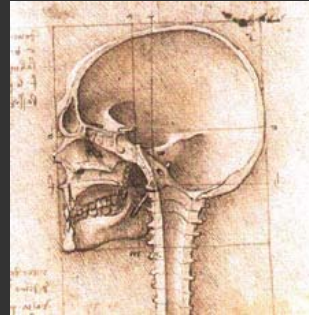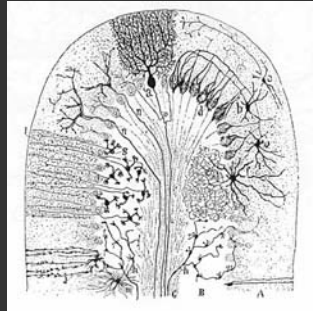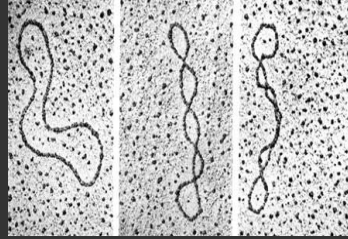
2. Visual languages
   Chemical diagrams
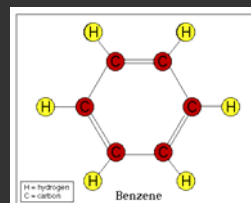
3. Support collaboration
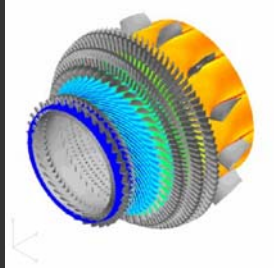   Shared whiteboard

Inspire

Challenges

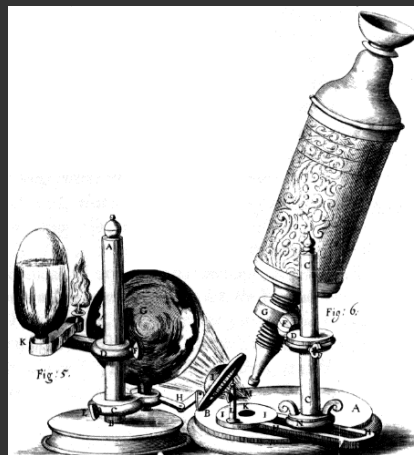## More and More Data

Ctr for Int. Turbulence Simulation
    PW6000 Turbine
    93.8 million cell mesh
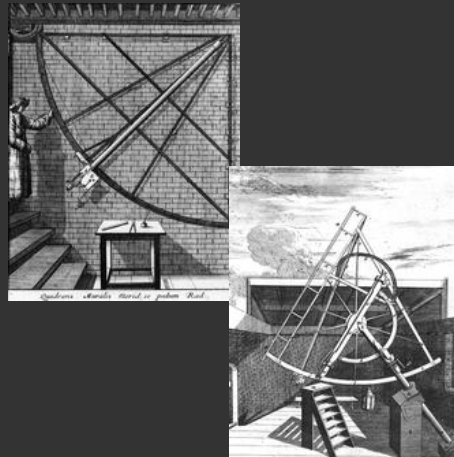   **5700 time steps, 30 iter/ts**
    5970 hours on 1K proc

Sloan Digital Sky Survey
    Robotic telescope
    5x6 2048x2048 CCD sensors
    40 TB of imagery
    100 million object catalog

Observation of Unseen Worlds

Hooke's Microscope

Flamsteed's Telescope

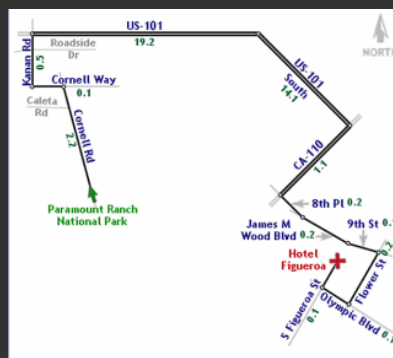# Challenges

Principles for designing effective visualizations

Better tools to produce visualizations

Route Maps

Overlaid Route

Sketched Route

1. **Find cognitive and perceptual principles**
2. **Optimize the visualization according to these principles**

Agrawala and Stolte, Rendering Effective Route Maps, SIGGRAPH 2001

Consequences

Challenger Disaster

HISTORY OF O-RING DAMAGE ON SRM FIELD JOINTS

	SRM No.	Cross Sectional View			Top View		Clocking Location (deg)
		Erosion Depth (in.)	Perimeter Affected (deg)	Nominal Dia. (in.)	Length Of Max Erosion (in.)	Total Heat Affected Length (in.)	
61A LH Center Field**	22A	None	None	0.280	None	None	36°--66°
61A LH CENTER FIELD**	22A	NONE	NONE	0.280	NONE	NONE	338°-18°
51C LH Forward Field**	15A	0.010	154.0	0.280	4.25	5.25	163
51C RH Center Field (prim)***	15B	0.038	130.0	0.280	12.50	58.75	354
51C RH Center Field (sec)***	15B	None	45.0	0.280	None	29.50	354
41D RH Forward Field	13B	0.028	110.0	0.280	3.00	None	275
41C LH Aft Field*	11A	None	None	0.280	None	None	--
41B LH Forward Field	10A	0.040	217.0	0.280	3.00	14.50	351
STS-2 RH Aft Field	2B	0.053	116.0	0.280	--	--	90

*Hot gas path detected in putty. Indication of heat on O-ring, but no damage.
**Soot behind primary O-ring.
***Soot behind primary O-ring, heat affected secondary O-ring.

Clocking location of leak check port - 0 deg.

OTHER SRM-15 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY AND NO SOOT NEAR OR BEYOND THE PRIMARY O-RING.

SRM-22 FORWARD FIELD JOINT HAD PUTTY PATH TO PRIMARY O-RING, BUT NO O-RING EROSION AND NO SOOT BLOWBY. OTHER SRM-22 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY.
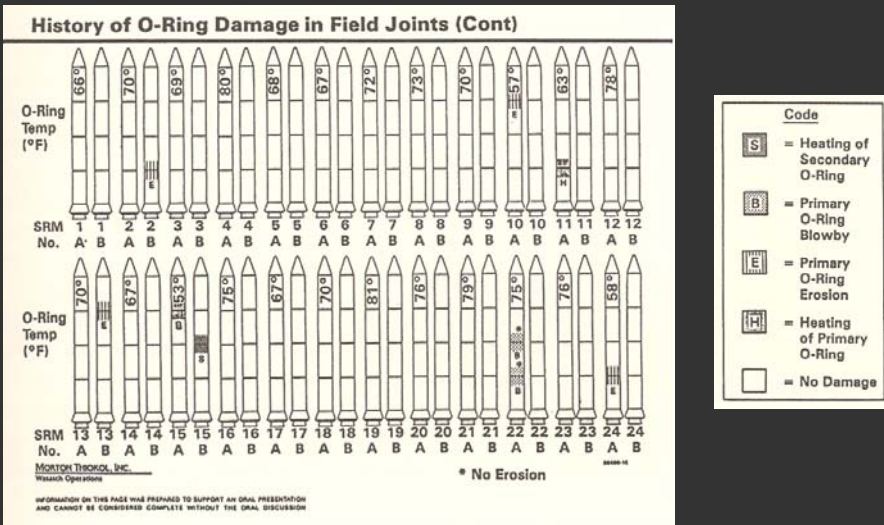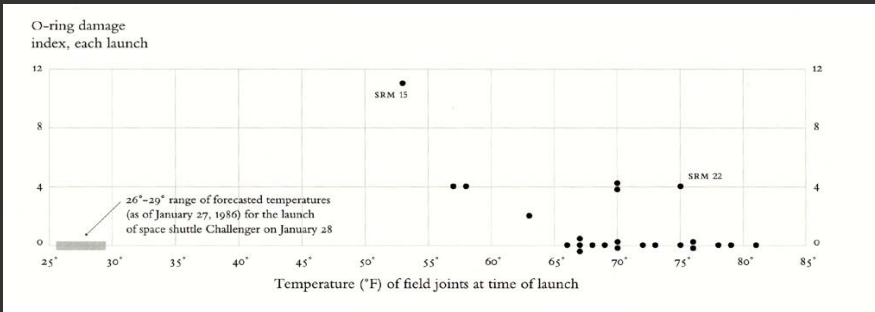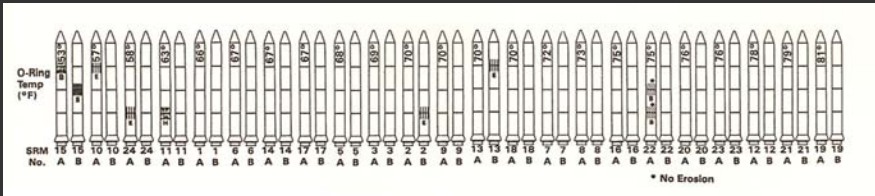
1 of 13 pages of material faxed to NASA by Morton Thiokol

From The Challenger Disaster, E. Tufte, Visual Explanations

Challenger Disaster

BLOW BY HISTORY
SRM-15 WORST BLOW-BY
  ○ 2 CASE JOINTS (80°), (110°) ARC
  ○ MUCH WORSE VISUALLY THAN SRM-22

SRM 22 BLOW-BY
  ○ 2 CASE JOINTS (30-40°)

SRM-13A, 15, 16A, 18, 23A 24A
  ○ NOZZLE BLOW-BY

HISTORY OF O-RING TEMPERATURES (DEGREES - F)

MOTOR	MBT	AMB	O-RING	WIND
DM-4	68	36	47	10 MPH
DM-2	76	45	52	10 MPH
QM-3	72.5	40	48	10 MPH
QM-4	76	48	51	10 MPH
SRM-15	52	64	53	10 MPH
SRM-22	77	78	75	10 MPH
SRM-25	55	26	29	10 MPH
			27	25 MPH

1 of 13 pages of material faxed to NASA by Morton Thiokol

Challenger Disaster

E. Tufte, pp. 46-47 , Visual Explanations

Challenger Disaster

O-ring damage index, each launch

SRM 15

SRM 22

26°–29° range of forecasted temperatures
(as of January 27, 1986) for the launch
of space shuttle Challenger on January 28

Temperature (°F) of field joints at time of launch

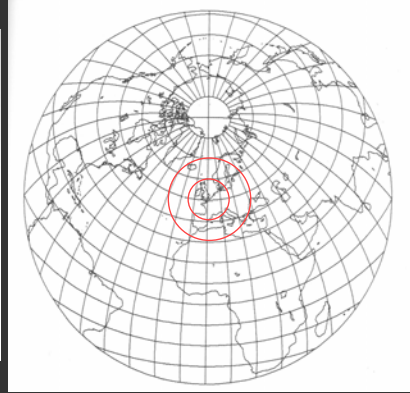**Redrawn by E. Tufte, p. 49 , Visual Explanations**

Topics

1. Data and Image Models

Bertin, The Semiology of Graphics
http://www.sciences-po.fr/cartographie/cartographie_html/5_page5theorie/graphique_bertin2001/index.html
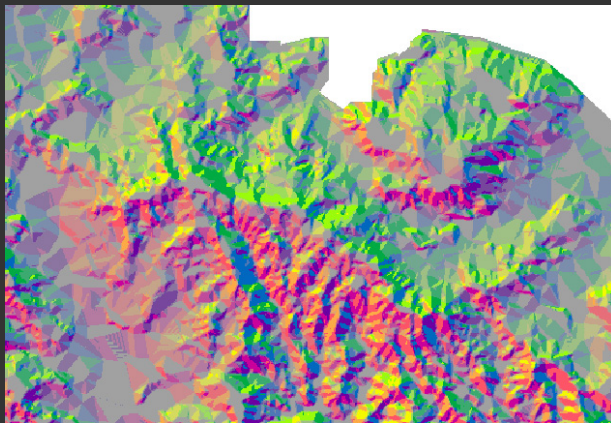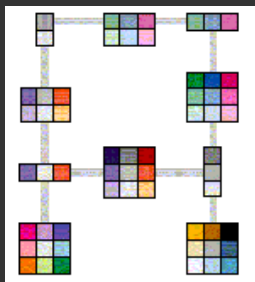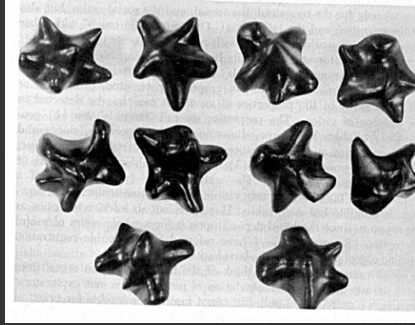
2. Perception and Cognition

[Mackinlay, Automating the Design of Graphical Presentations of Relational Information, ACM TOG 5:2, 1986]
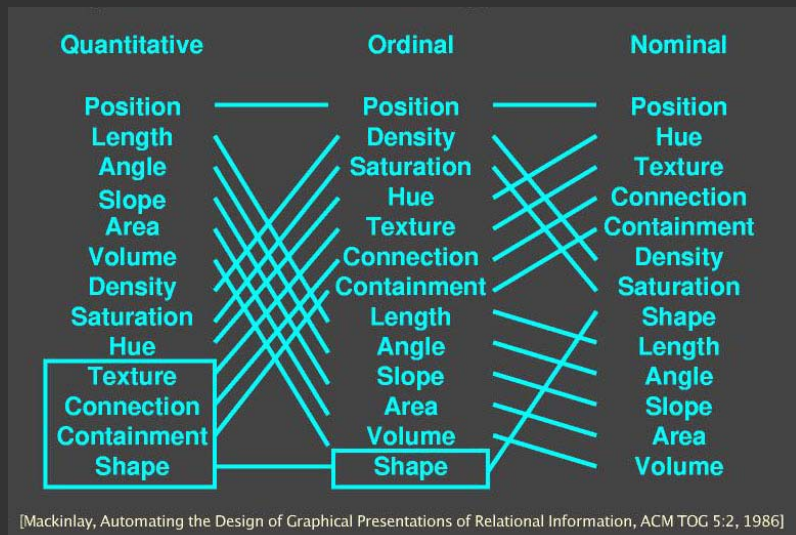
3. Spatial Encodings

Equiheading vs. Equidistance Projection

4. Color

From C. Brewer

5. Interaction

Gibson's Experiment
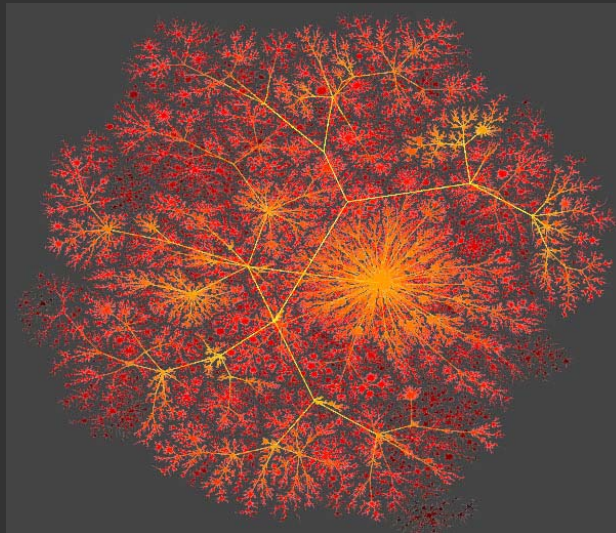**Goal: Match 2 shapes**
Active touch: 96%
Passive (rotation) 72%
Passive (imprint) 49%

From J. J. Gibson (1966)
The Senses Considered as a Perceptual
System, p. 124

Thanks to David Kirsh for this example.

6. Drawing Trees and Graphs

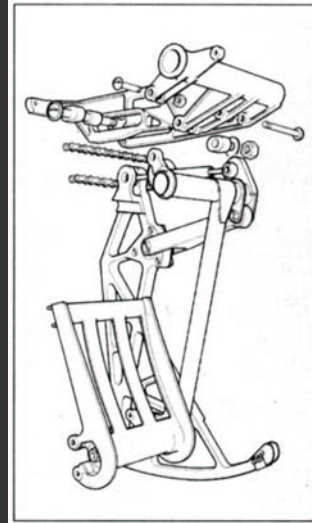Internet colored by distance from a source host
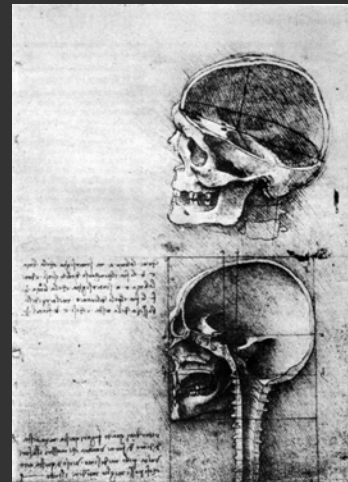www.lumeta.com

7. Conveying Shape

Good views
Lines
Shading
Texture

From Gooch[2]

8. Conveying Structure

Karl Heinz Hoehne's Voxel-Man
Images of the Visible Man

Leonardo's Notebooks

9. Motion and Animation

Outside-In, Geometry Computing Center

10. Self-Illustrating Phenomena