Počítačová grafika 2
InfoVis

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Motivation

- Visual Thinking & Understanding

- Orientation,position,identification,
- direction/navigation [Roam]
- Coordinate systems, 6W
- 30 000 things… [Biederman87]
- Psychological Review 1917, Vol. M, No. 2, 115-147, 1987
- Recognition-by-Components: Theory
- of Human Image Understanding

- Managing Time and Memory
- Enhance Understanding

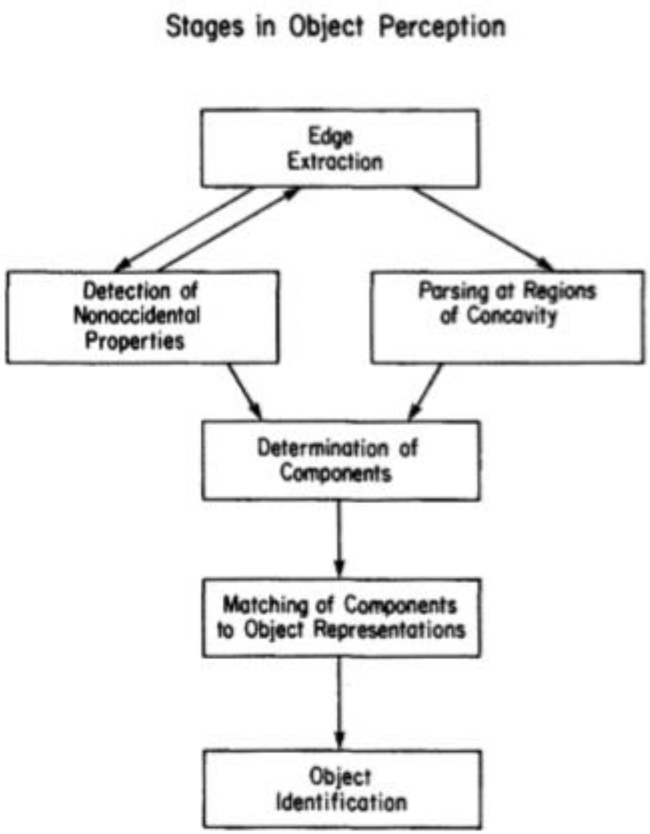
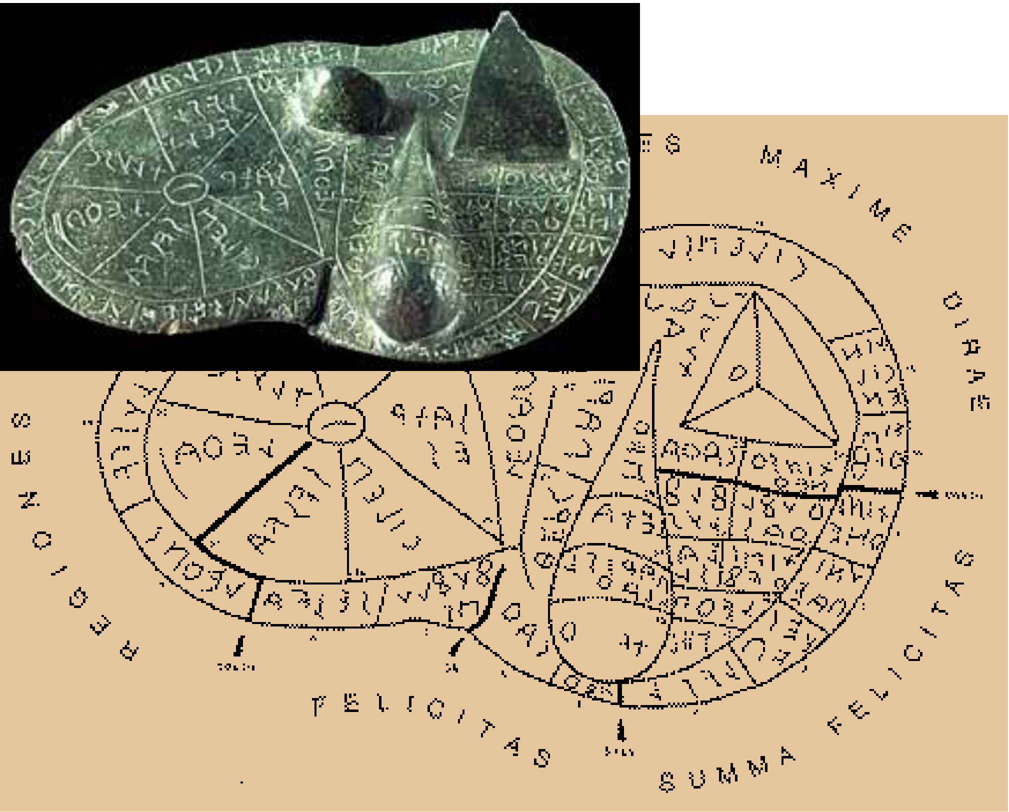


Figure 2. Presumed processing stages in object recognition.

Viz. Course Contents

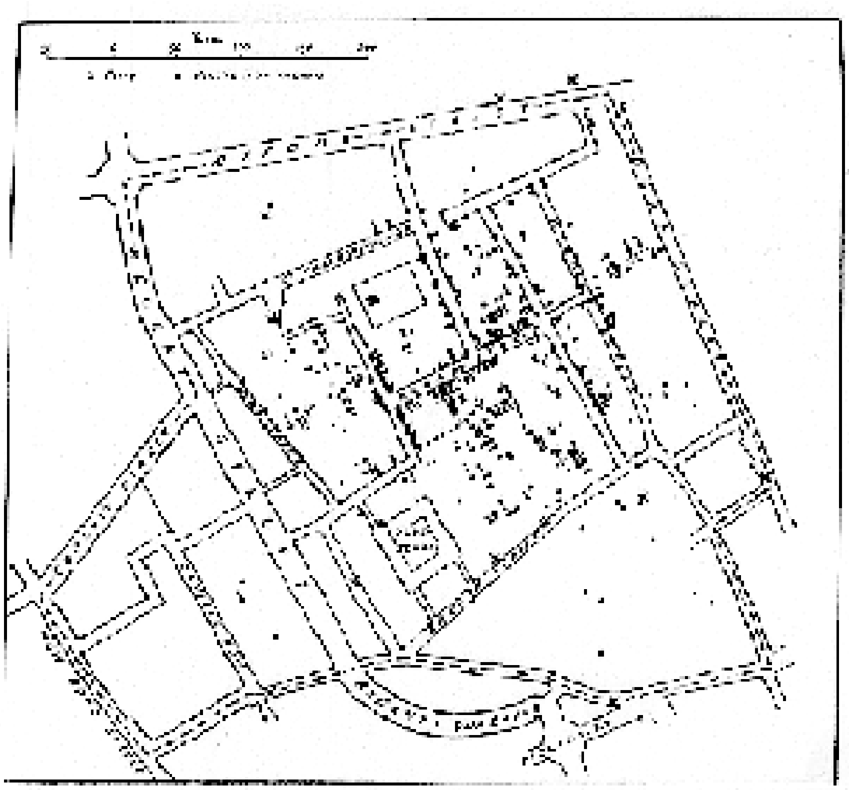
- 1. Introduction, motivation
  reference model, scenarios, graphics and visualization difference
- 2. Data
  data types, coordinate representations, data connectivity
- 3. Mathematical models and languages
- 4. Representation
  scalar, vector, tensor, multivariate, using color, glyphs
- 5. Visualization software
- 6. Information Visualization
  graph drawing, algorithm animation, …
- 7. Recent Directions
  data sonification, visualizing relativity, NPR in scientific visualization...
- (NPR >> Expressive Rendering, factorization, schematization, less details)

Etruscan Liver, Cholera in London



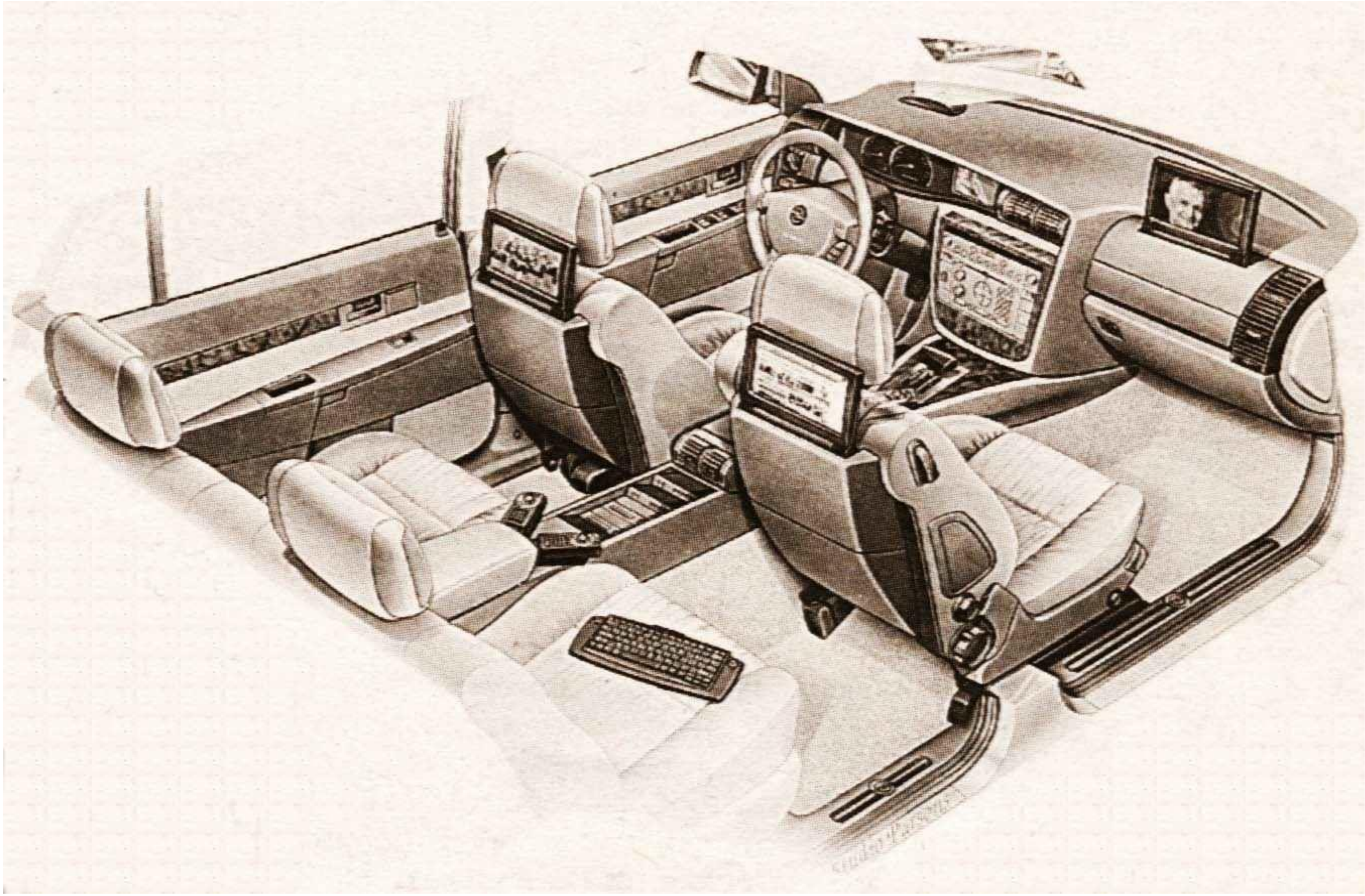
Sheep Liver & Names of Gods

http://www.ou.edu/class/ahi4163/files/bronz12.html



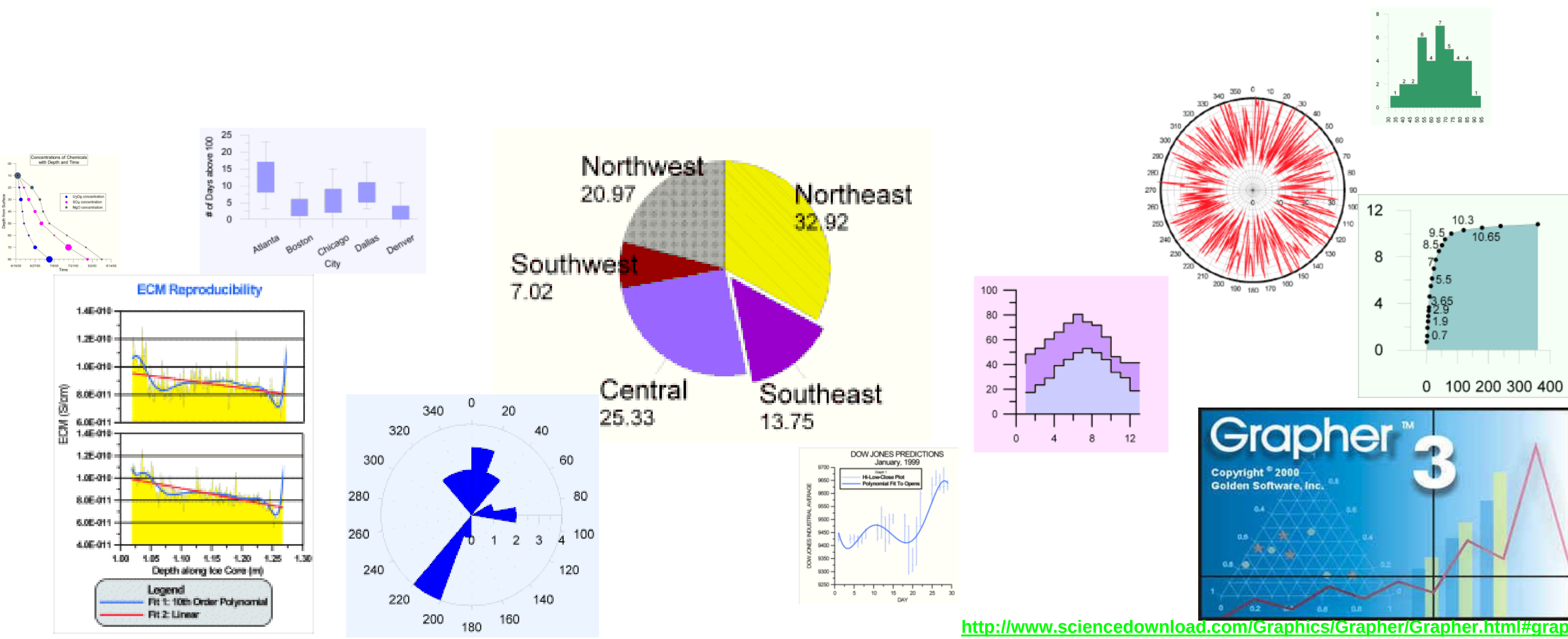
The idea of representing data visually has been around for much longer than computer based visualisation. The linking of the spread of cholera to water supply provides an early example of the use of visualisation in problem analysis. During the 1853-54 cholera outbreak in London, Dr. John Snow identified a large grouping in the Soho area. He went on to plot the homes of the 500 victims who died in the first 10 days of September 1854 on a map of the area. This simple representation of the data he had collected showed that the grouping of cholera sufferers in the area was centred round a particular water pump. Investigation of this water pump established that it had been contaminated by a leaking cesspool.

Opel OMEGA



Visualization Areas

- Scientific Visualization
- Bussines Visualization: no new knowledge
- Language: VEGA/Lite



http://www.sciencedownload.com/Graphics/Grapher/Grapher.html#graphtypes

VEGA-LITE, VUX

Vega-Lite: A Grammar of Interactive Graphics

Arvind Satyanarayan, Dominik Moritz, Kanit Wongsuphasawat, and Jeffrey Heer

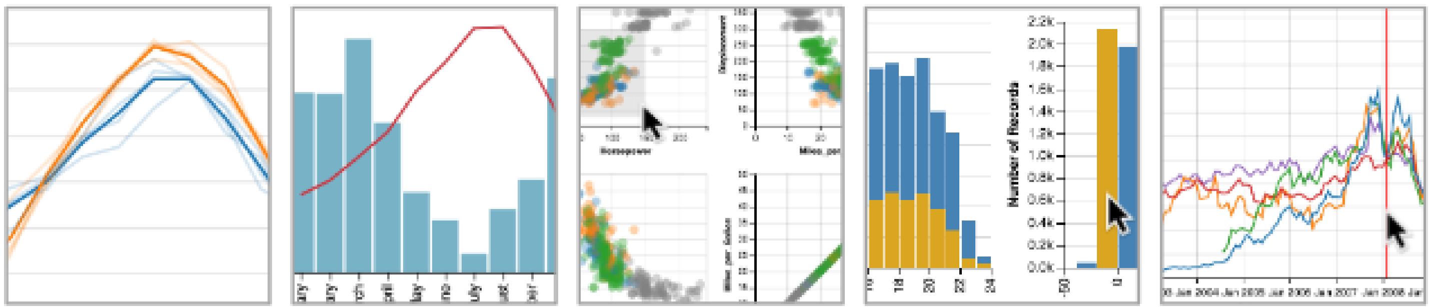


Fig. 1. Example visualizations authored with Vega-Lite. From left-to-right: layered line chart combining raw and average values, dual-axis layered bar and line chart, brushing and linking in a scatterplot matrix, layered cross-filtering, and an interactive index chart.

Visual Usability: Principles and Practices for Designing Digital Applications, MK 2013
Tania Schlatter,Deborah Levinson

Scientific Visualization

- Visualization of Data Sets
- Information Visualization:
- - graph drawing [Nish04], [DiB99]
- - algorithm animation
- - ...
- ___________________________________

- T. Nishizeki and M. S. Rahman, Planar Graph Drawing, World Scientific, Singapore, 2004.
- G. Di Battista, P. Eades, R. Tamassia, I. G. Tollies, Graph Drawing: Algorithms for the visualization of Graphs, Prentice-Hall Inc., 1999.

Visualization Topics

ACM CC: Visualization: Topics:

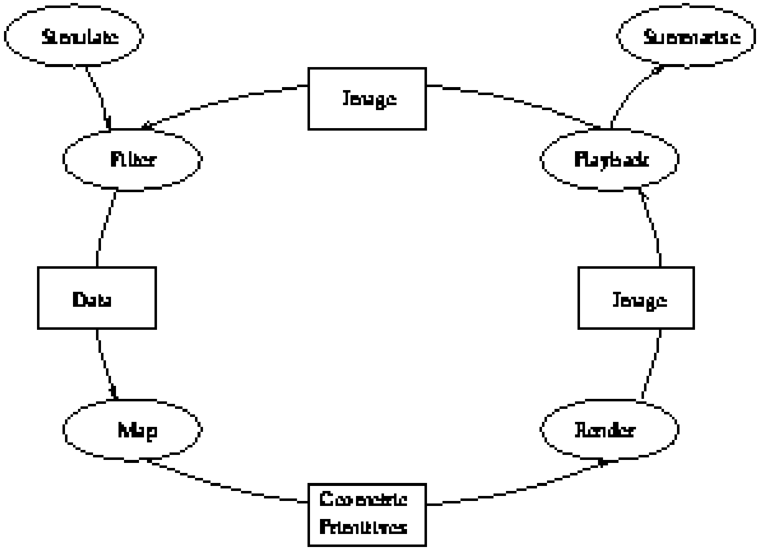
- **Basic viewing and interrogation functions for visualization**
- **Visualization of vector fields, tensors, and flow data**
- **Visualization of scalar field or height field: isosurface by the marching cubes method**
- **Direct volume data rendering: ray-casting, transfer functions, segmentation, hardware**
- **Information visualization: projection and parallel-coordinates methods**

Vis. Educational Goals

ACM CC: Visualization: Learning objectives:

- **Describe the basic algorithms behind scalar and vector visualization.**
- **Describe the tradeoffs of the algorithms in terms of accuracy and performance.**
- **Employ suitable theory from signal processing and numerical analysis to explain the effects of visualization operations.**
- **Describe the impact of presentation and user interaction on exploration.**

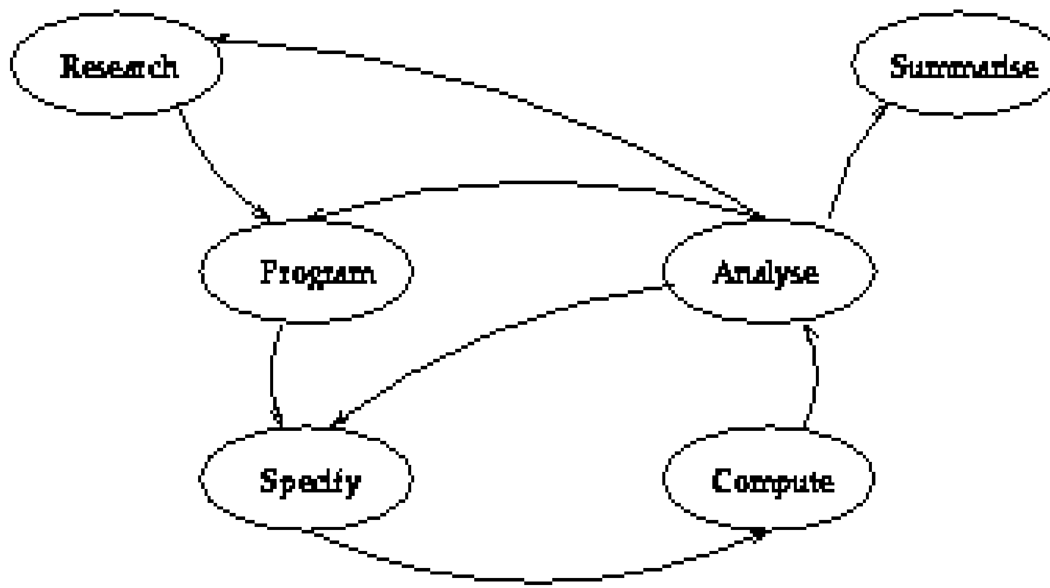
Visualization Workflow



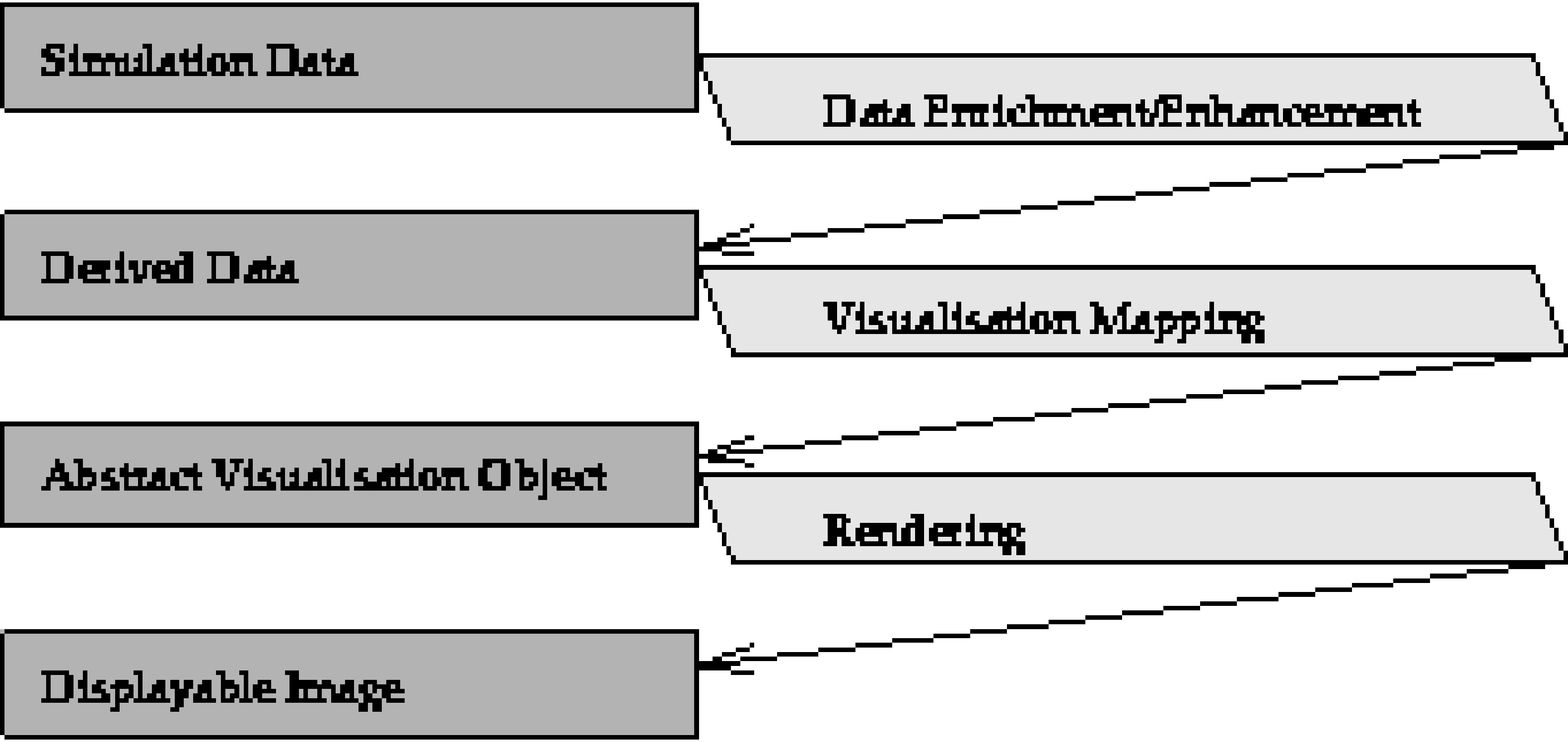
Computational cycle

Analysis cycle

http://www.epcc.ed.ac.uk/epcc-tec/documents/SciVis-course/SciVis.book_47.html



Visualization Pipeline



Visualization Projects

No. 1: DNA structure (GRID) HUMAN GENOME

ASCI - weapons, military

Relativistic effects, storm, weather

Time - Alp glaciers

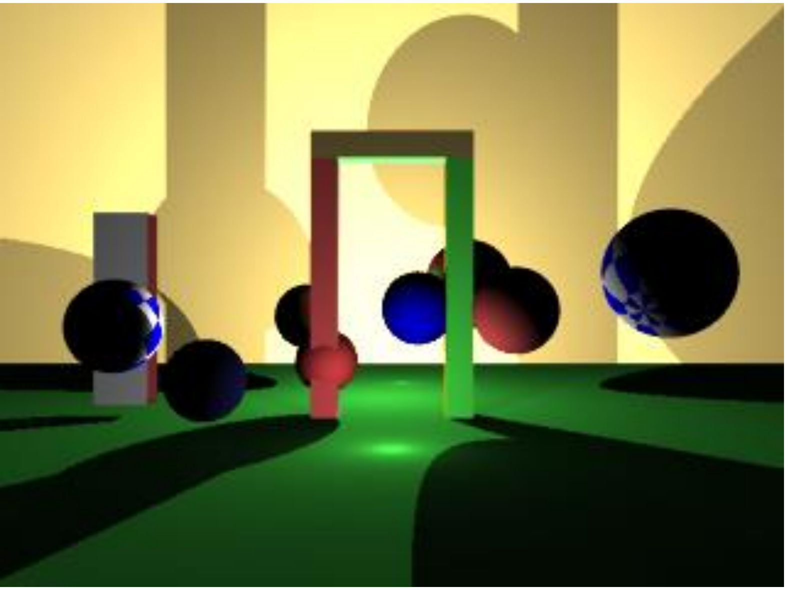
Chemistry - computed chemicals

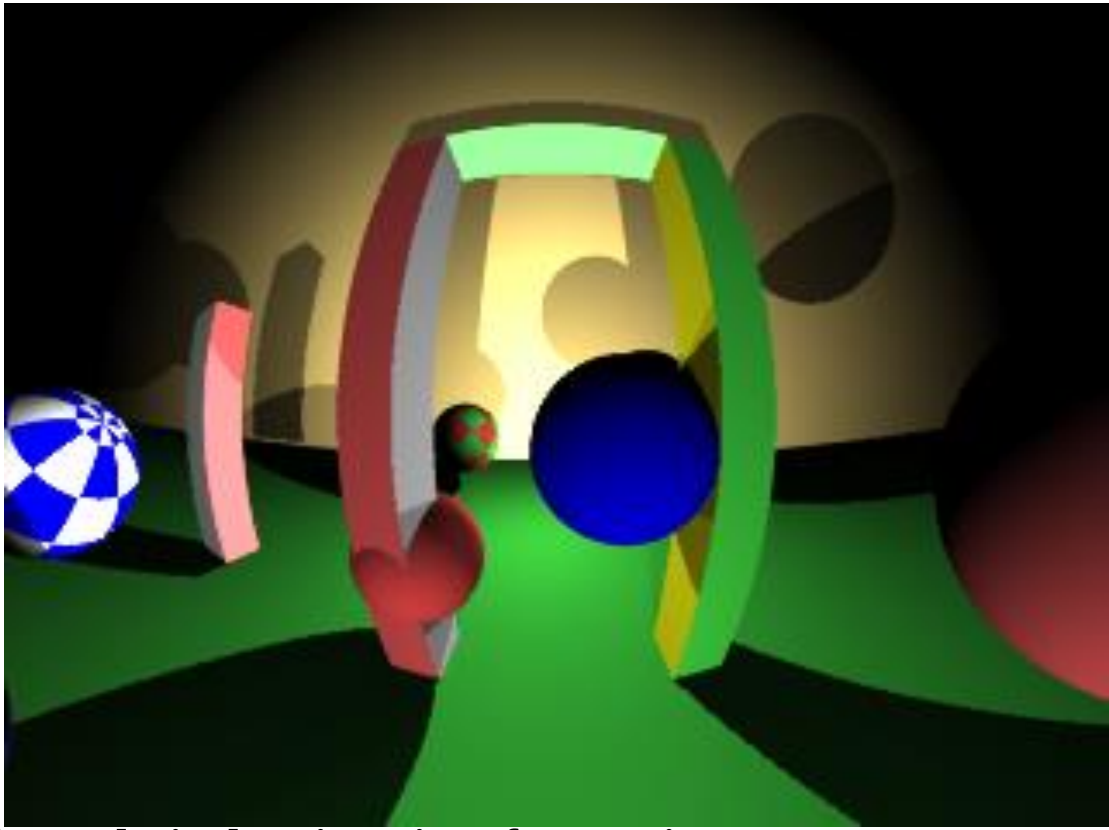
Sociology, politics, Big Bang, web traffics…

… and many others

Relativistic Effects

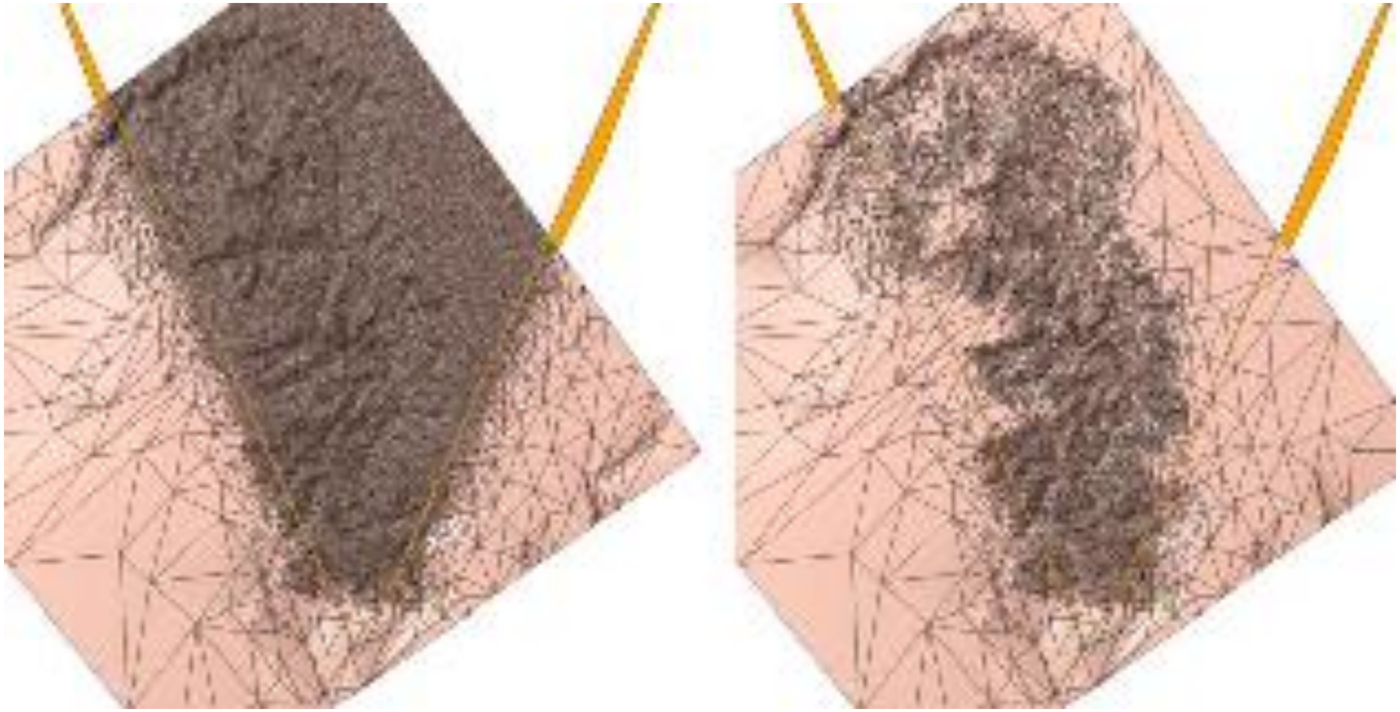
Motionless camera   and camera moving towards the scene with 0.9c velocity. Covered sides of objects can be seen.

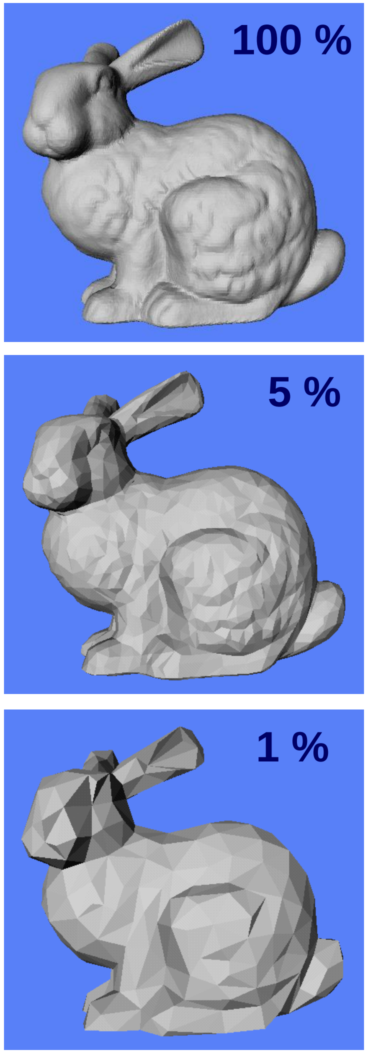




Karina Murawko, Radosław Mantiuk ,Technical University of Szczecin, PL

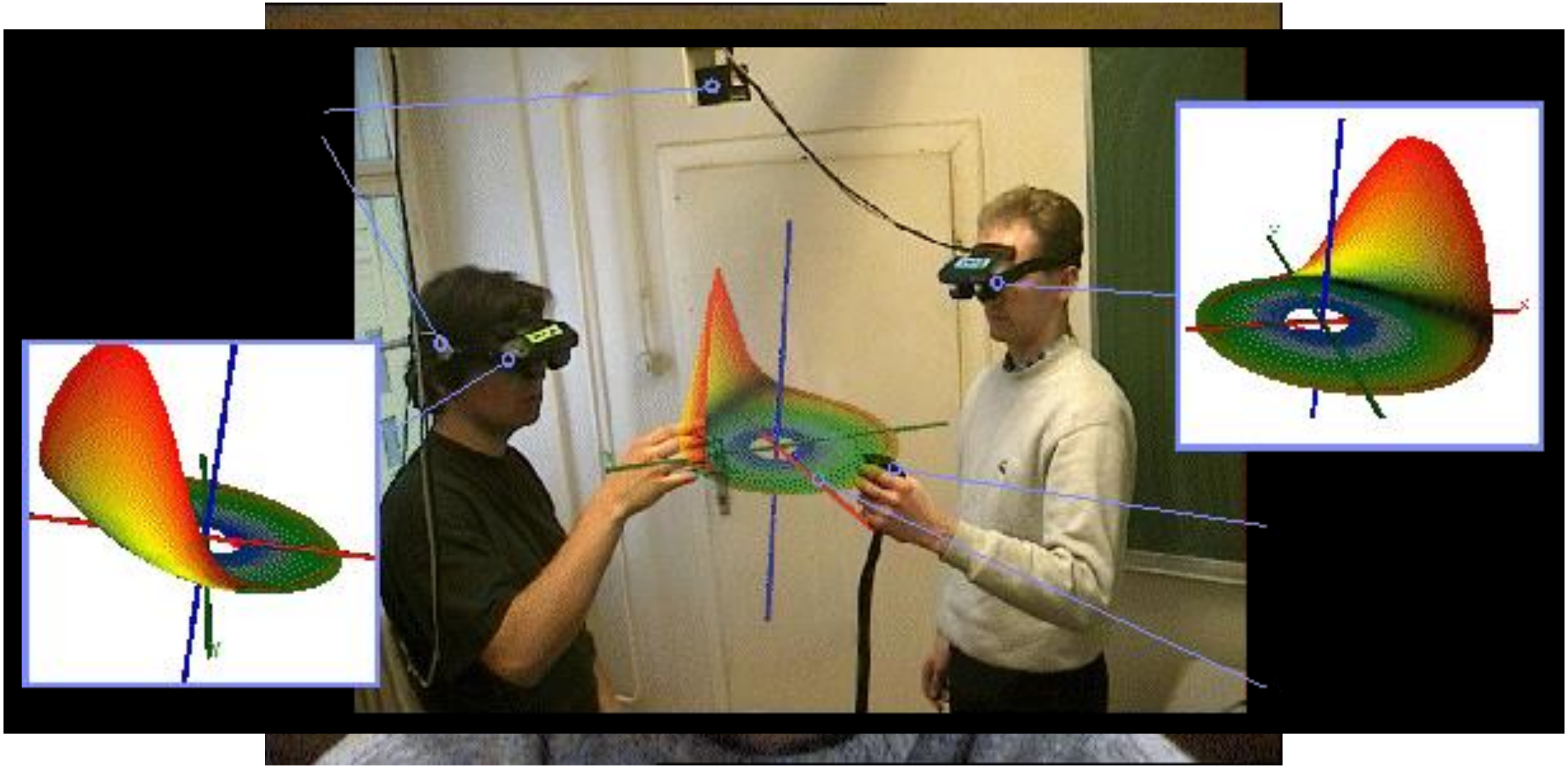
Multiresolution Analysis





Markus Grabner, ICG TUG

Augmented Reality



Dieter Schmalstieg, TU Wien

Graph Drawing

- 1736 Euler

Kruja, E. et al. 2001. A Short Note on the History of Graph Drawing.
GD 2001: pp 272-286. [online]
http://www.merl.com/publications/docs/TR2001-49.pdf

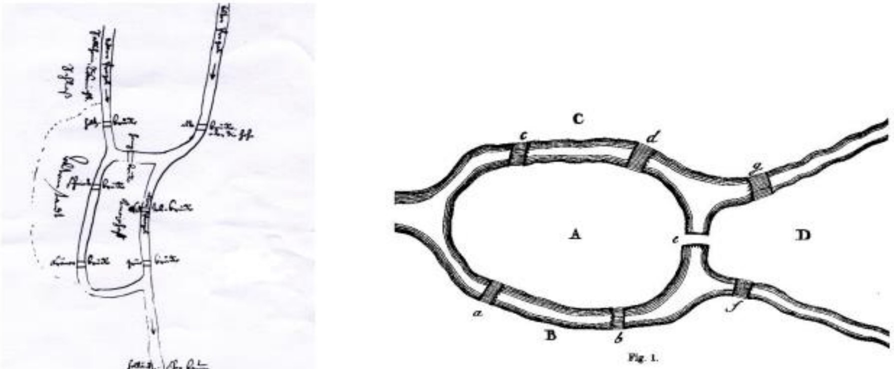


Fig. 9. Ehler's sketched map of Königsberg, 1736 (left), and Euler's more polished version [12]. Euler included one more sketched map (a variant of the first with more bridges included) in his paper, but no abstract graph drawing of the problem. Reproduced with permission.

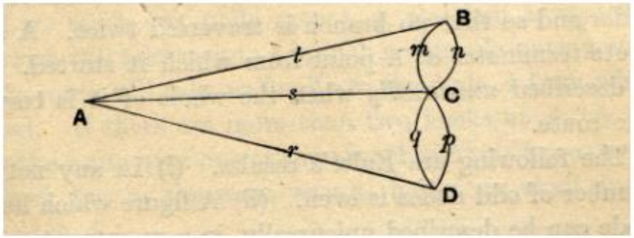


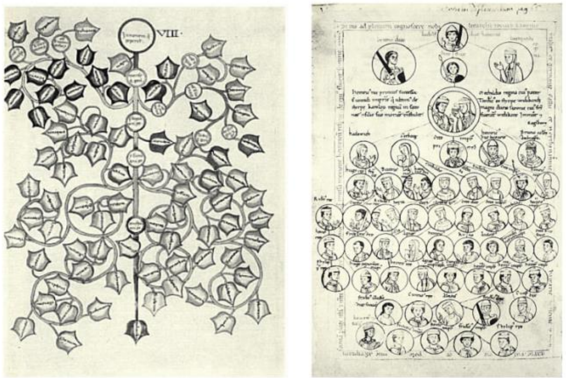
Fig. 10. Ball's 1892 graph-drawing abstraction of the bridges of Königsberg. The nodes represent the land areas and the edges represent the bridges connecting them.

Graph Drawing before Graphs

- Kruja, E. et al. 2001. A Short Note on the History of Graph Drawing. GD 2001: pp 272-286. [online] http://www.merl.com/publications/docs/TR2001-49.pdf

Fig. 1. Depictions of Morris gameboards from the 13th century. The nodes of these graph drawings are the positions that game counters can occupy. The edges indicate how game counters can move between nodes. Reproduced with permission.

Fig. 7. Musical intervals drawn in a square of opposition from the 11th century. The nodes (corners) represent numbers and the edges represent named ratios between them (e.g., "octave" and "fifth"). Reproduced with permission.



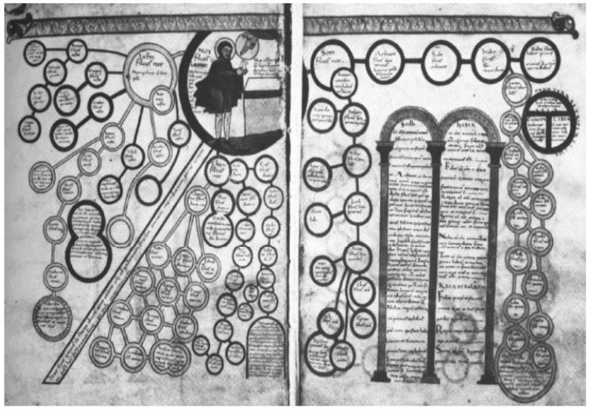


Fig. 2. Family trees that appear in manuscripts from the Middle Ages. Note that the top drawing is spread over two pages in the original manuscript. Reproduced with permission.

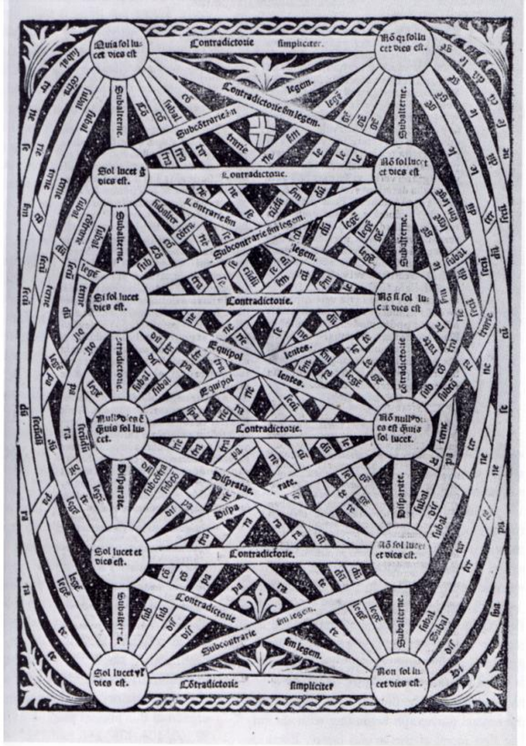


Fig. 6. A more complex square of opposition from the 16th century. It is a symmetric drawing of K_{12} with labeled nodes and edges. Reproduced with permission.

GD before Graphs 2

- Kruja, E. et al. 2001. A Short Note on the History of Graph Drawing. GD 2001: pp 272-286. [online] http://www.merl.com/publications/docs/TR2001-49.pdf

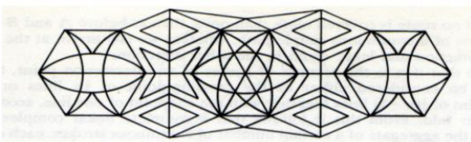


Fig. 12. A graph drawing from 1847 that can be drawn in a single stroke. Reproduced with permission.

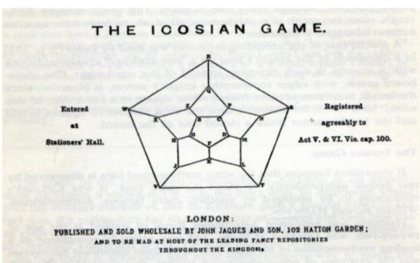


Fig. 13. Hamilton's *Icosian Game* from 1857. Reproduced with permission.

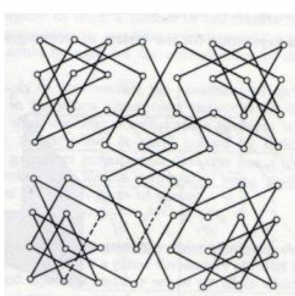


Fig. 11. Vandermonde's 1771 graph drawing of a Knight's Tour. This is actually a drawing of a subgraph of the graph that represents all possible knight moves. In that graph the nodes represent squares on a chessboard and edges represent legal moves. Reproduced with permission.

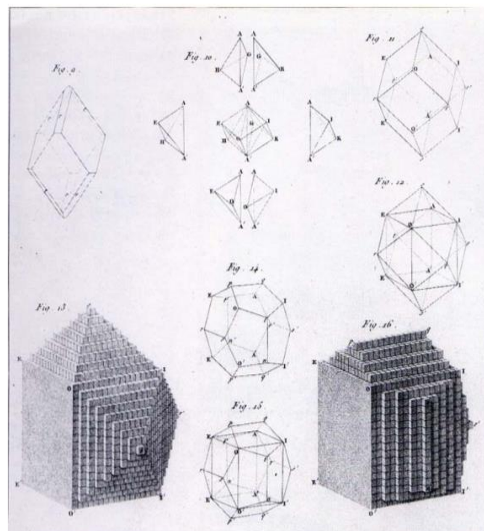


Fig. 15. Drawings from 1784 that depict the geometry of crystal structures but that also foreshadow the use of 3D graph drawing. The graph nodes correspond to corners or apexes of the physical crystal. Edges connect neighboring nodes. Reproduced with permission.

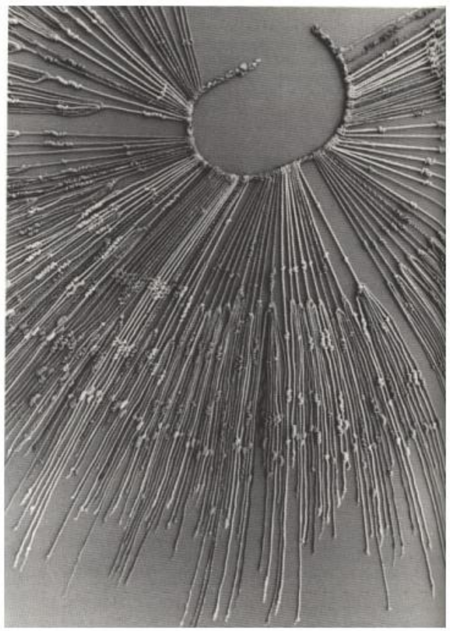
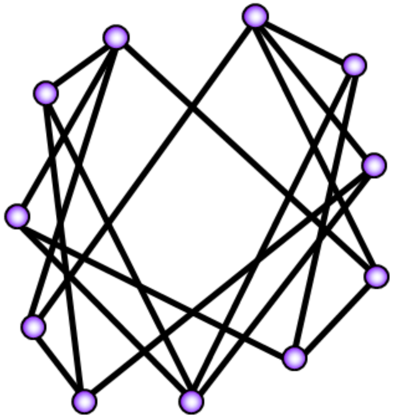


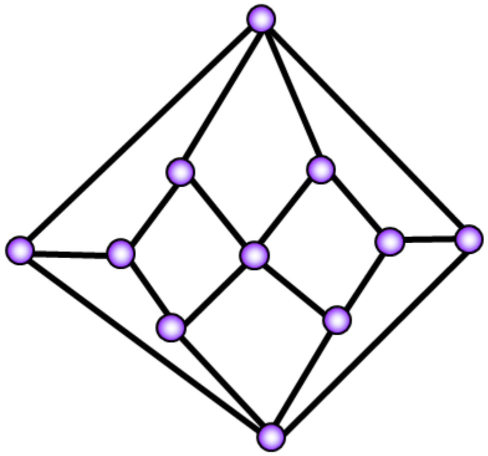
Fig. 8. A quipu in the collection of the Museo National de Anthropologia y Arquelogía, Lima, Peru [4]. Photograph by Marcia and Robert Ascher. Reproduced with permission.

Planar Graph Drawing

- Nishizeki, T. & Rahman, S. 2004. Planar Graph Drawing. World Scientific 2004.



structure of the graph is difficult to understand



structure of the graph is easy to understand

Graph Drawing Styles

- Nishizeki, T. & Rahman, S. 2004. Planar Graph Drawing. World Scientific 2004.

- **Planar**
- **Polyline**
- **Straight Line**
- **Convex**
- **Orthogonal**
- **Box-Orthogonal**
- **Rectangular**
- **Box-Rectangular**
- **Grid**

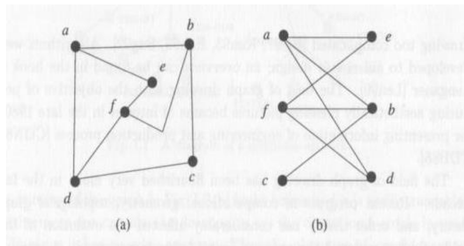
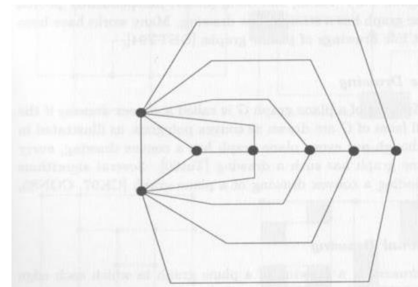


Fig. 1.3 (a) A planar drawing, and (b) a non-planar drawing of the same graph.



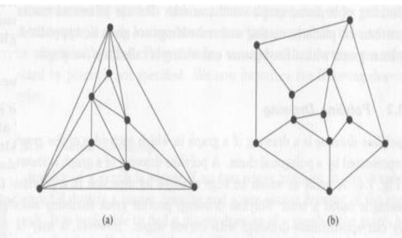


Fig. 1.5 (a) A straight line drawing, and (b) a convex drawing.

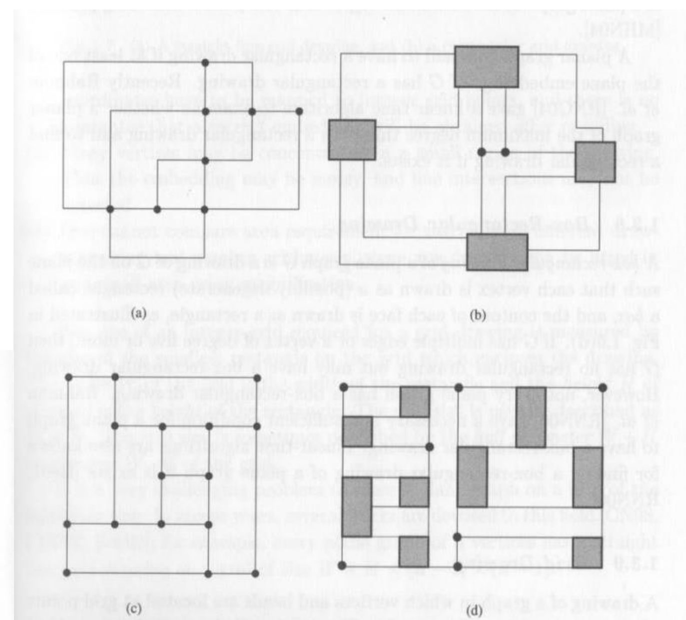


Fig. 1.6 (a) An orthogonal drawing, (b) a box-orthogonal drawing, (c) a rectangular drawing, and (d) a box-rectangular drawing.

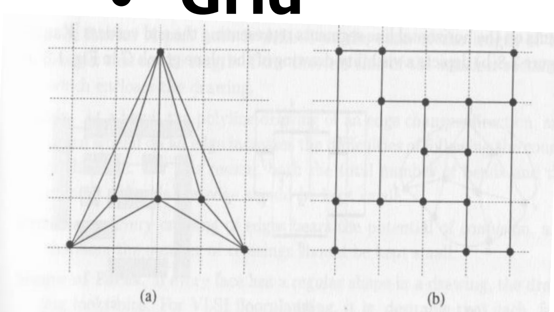


Fig. 1.7 (a) A straight line grid drawing, and (b) a rectangular grid drawing.

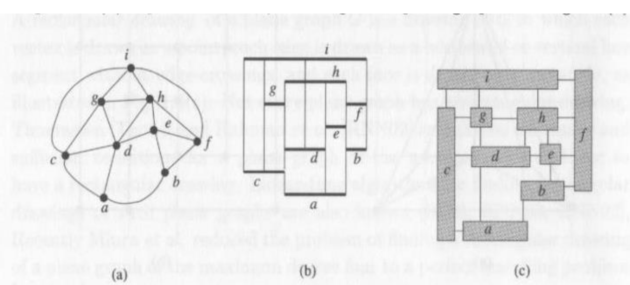
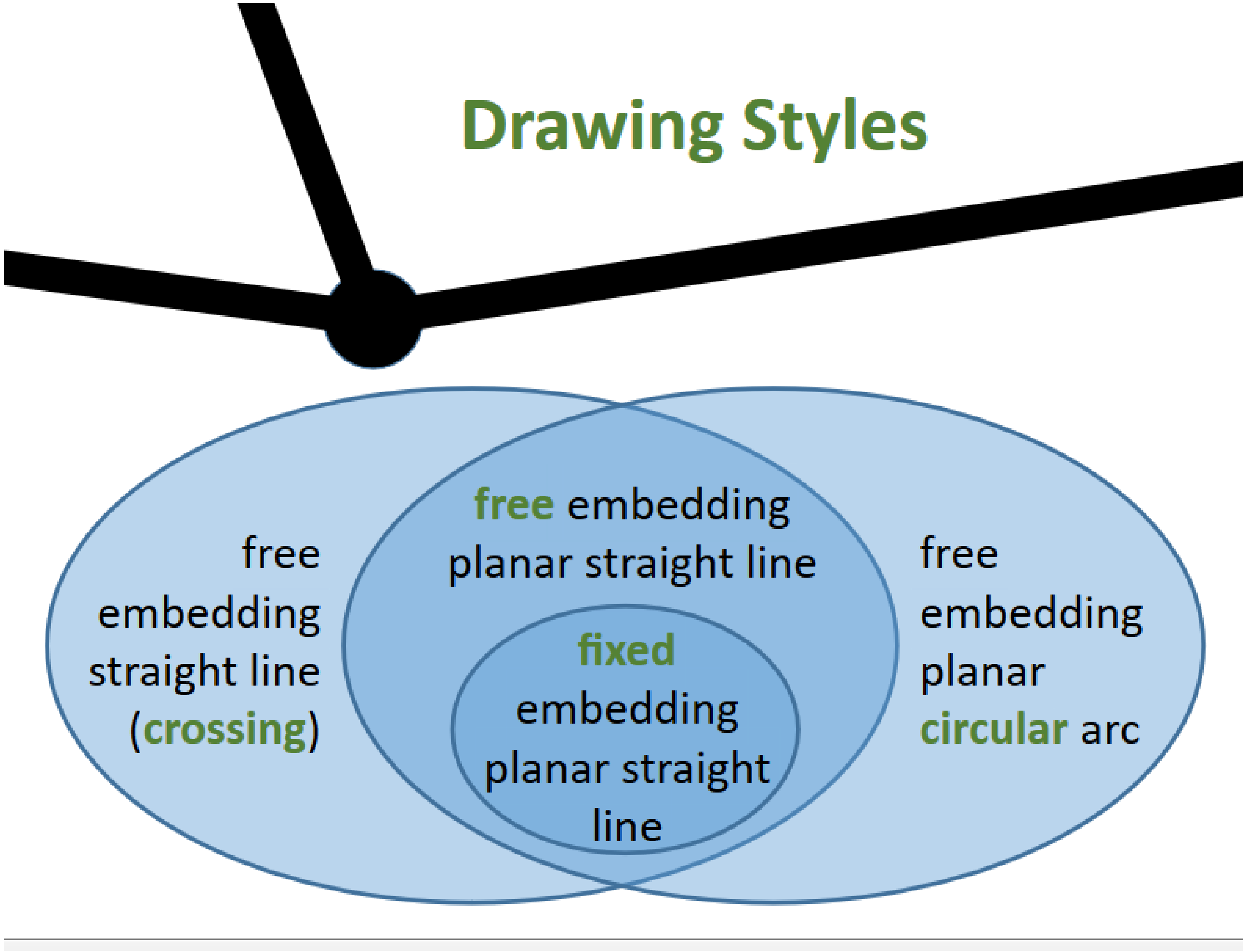


Fig. 1.8 (a) A plane graph G, (b) a visibility drawing of G, and (c) a 2-visibility drawing of G.

Planar Drawing Styles



Aesthetics…

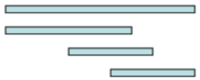
Aesthetics Formalized

- discrete criteria
  - crossings
  - bends
  - load factor (overlaps of nodes)
  - congestion (parallel edges)
  - edit complexity (insertions, deletions, moves)
- symmetry
  - center father above the children
  - geometric symmetry (rotation, reflection)
  - graph symmetry, graph isomorphy
- constraints
  - Sesame street relations (left-right, top-down)
  - place distinguished nodes (e.g. center, at the border)
  - clustering

- resolution or geometric criteria
  - area (2), volume (3D), height, width, aspect ratio
  - edge length (sum, max, all uniform (Hartfield&Ringel, Pearls..))
  - angular resolution (avoid small angles)
  - uniform node distribution
  - integrality, grid drawings/embeddings
    - all nodes
    - all nodes and bends of polylines
    - all nodes and edges (grid embedding)
    - sizes of all faces (Hartfield&Ringel, Pearls in Graph Theory)

Drawing Styles

- polyline drawings
  reduce bends, no sharp angles, polish by with Bezier splines
- straight-line
  uniform (short) edge length
- orthogonal drawings
  minimize bends
- planar drawings
  minimize crossings and bends
- grid embeddings
  grid coordinates for nodes and bend-points
- visibility
  horizontal bar nodes and vertical visibility



Formalization

an information theoretic approach to aesthetics

Max Bense, designer at Bauhouse school (1930)

$$\text{aesthetics} = \frac{\text{order}}{\text{complexity}} = \frac{\text{redundancy}}{\text{information}}$$

order	= regularity
complexity	= descriptional complexity, bit representation
redundancy	= log n – H(∑)
information	= information content

”nice“ if well-ordered, symmetric
”nice“ if high redundancy, not overloaded, not compressed

Properties of graph drawing

Area

A drawing is useless if it is unreadable. If the used area of the drawing is large, then we have to use many pages, or we must decrease resolution, so either way the drawing becomes unreadable. Therefore one major objective is to ensure a small area. Small drawing area is also preferable in application domains like VLSI floorplanning.

Aspect Ratio

Aspect ratio is defined as the ratio of the length of the longest side to the length of the shortest side of the smallest rectangle which encloses the drawing.

Bends

At a bend, the polyline drawing of an edge changes direction, and hence a bend on an edge increases the difficulties of following the course of the edge. For this reason, both the total number of bends and the number of bends per edge should be kept small.

Properties of GD 2

Crossings

Every crossing of edges bears the potential of confusion, and therefore the number of crossings should be kept small.

Shape of Faces

If every face has a regular shape in a drawing, the drawing looks nice. For VLSI floorplanning, it is desirable that each face is drawn as a rectangle.

Symmetry

Symmetry is an important aesthetic criteria in graph drawing. A symmetryof a two-dimensional figure is an isometry of the plane that fixes the figure.

Angular Resolution

Angular resolution is measured by the smallest angle between adjacent edges in a drawing. Higher angular resolution is desirable for displaying a drawing on a raster device.

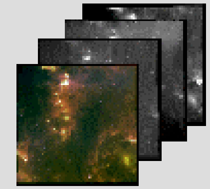
Visualization of Data

- **1D**
- **2D**
- **3D**
- **4D**
- **nD**

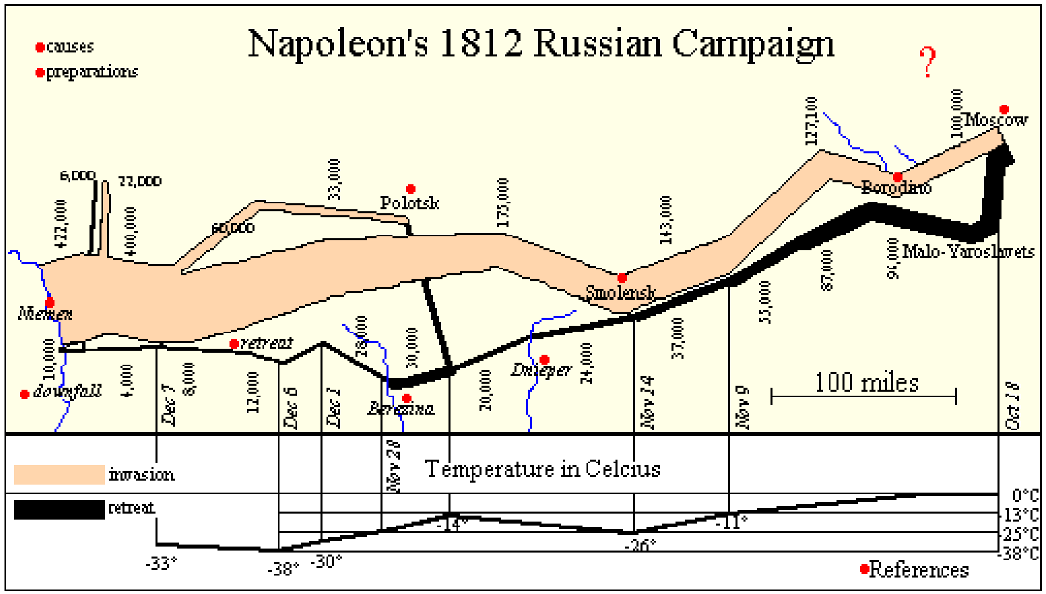
"to visualize":
form a mental vision, image, or picture of (something not visible or present to sight, or of an abstraction); to make visible to the mind or imagination

The Oxford English Dictionary, 1989

March of the Napoleon Army



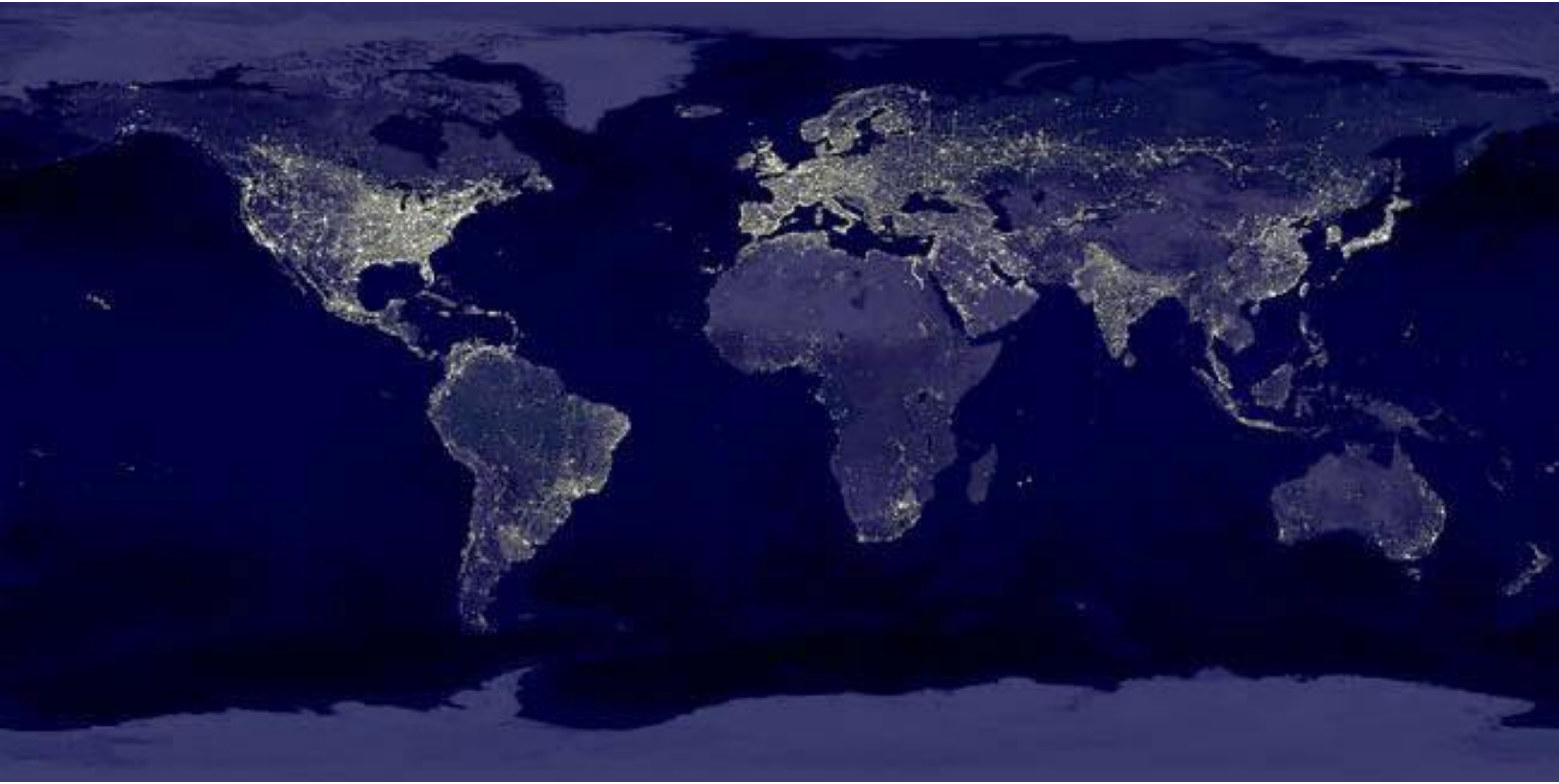
Examples of Visualization



This graphic is an adaptation of M. Charles Joseph Minard´s „March of the Napoleon Army" by Sunny McClendon, as part of an Information Design Class at the University of Texas at Austin.

Earth in the Night

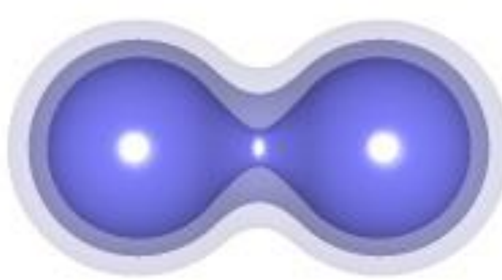
2D



http://antwrp.gsfc.nasa.gov/apod/ap001127.html

Volume .. Surface

sampled data



geometric model

3D reconstruction

image synthesis

discrete voxel space

isosurfacing

voxelization

continuous geometric space

volume rendering

surface rendering

image

3D

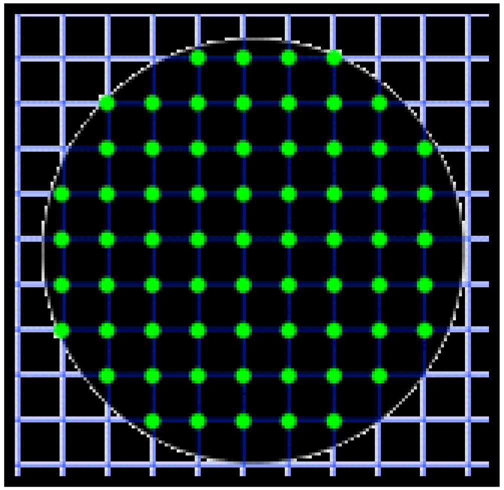
Marching Cubes

<u>Algorithm:</u>

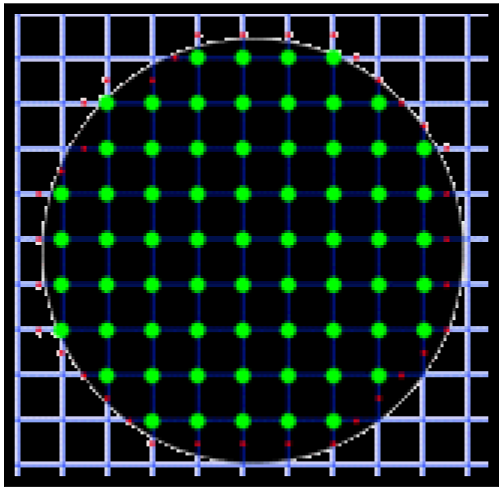
- **<u>Step 1:</u> Find by thresholding the densities in given voxels („Flood Fill“-like method)**
- **<u>Step 2:</u> Extract the surface through IN/OUT relation of the voxel corners. 8 corners ≅ 256 possible variations for the spanning surface parts**

<u>Disadvantage:</u> One threshold per volume (eventually heuristics)

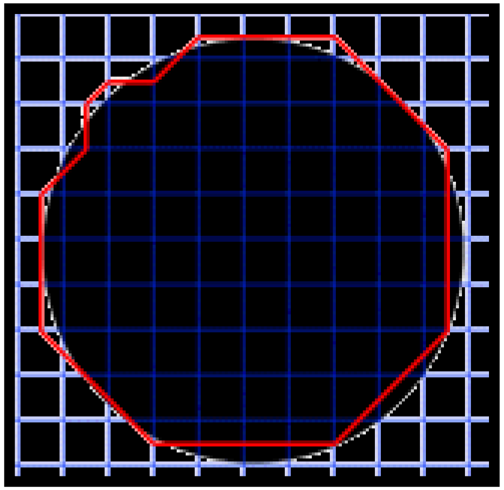
2D Example



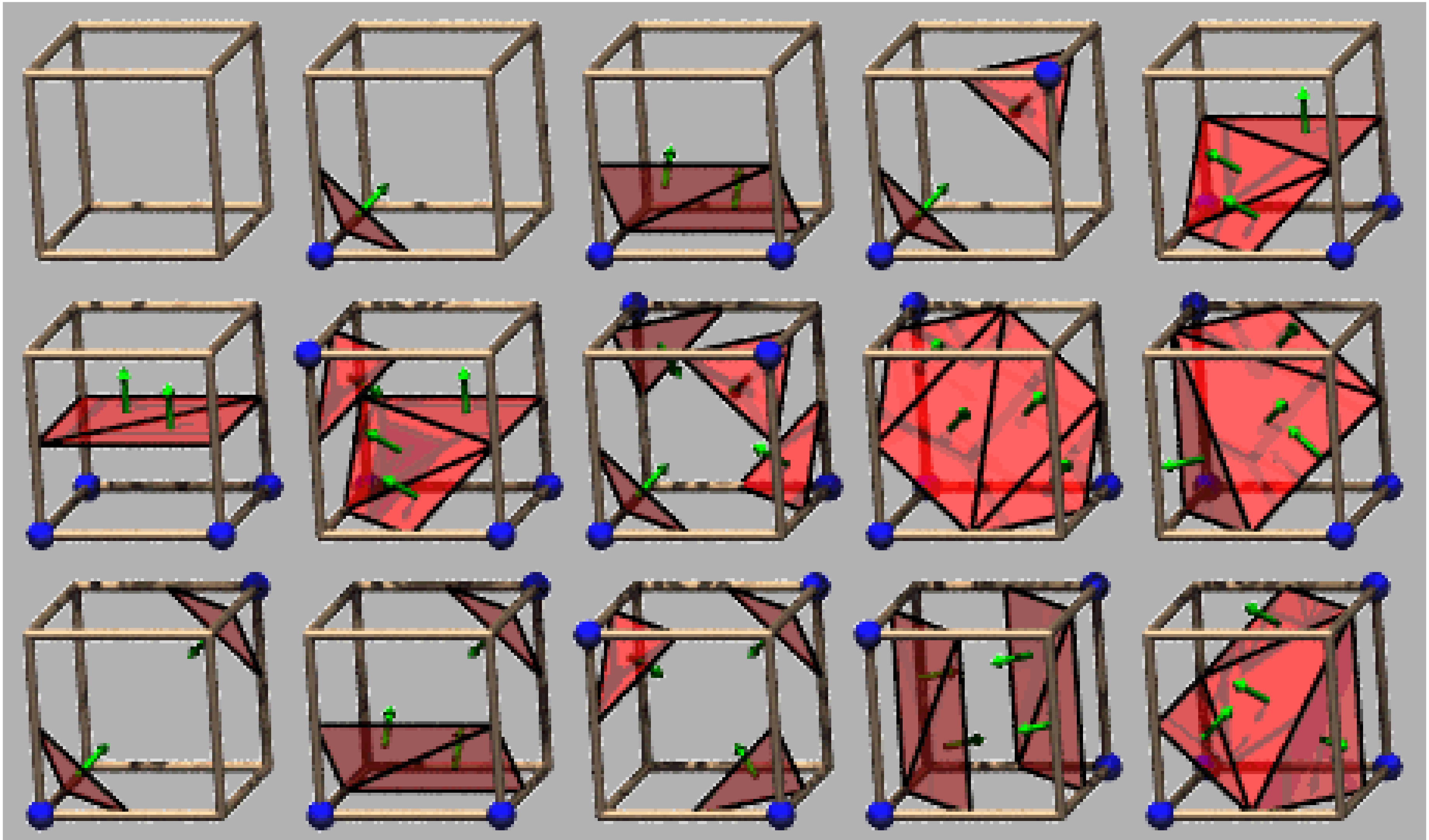
Original



Raster Points



Contour Extracted



The 15 Cube Combinations

Ray Casting

Disadvantages of the given method:

- **Geometric inbetweens necessary**
- **binary decision**

Remedy:

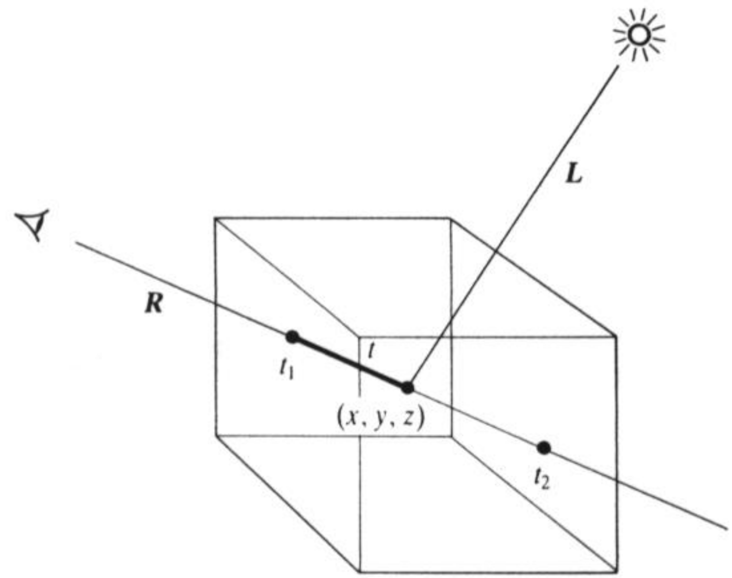
- **Ray Tracing using transparent ev. semi-transparent voxels**
- **parallel rays casted through data volume**

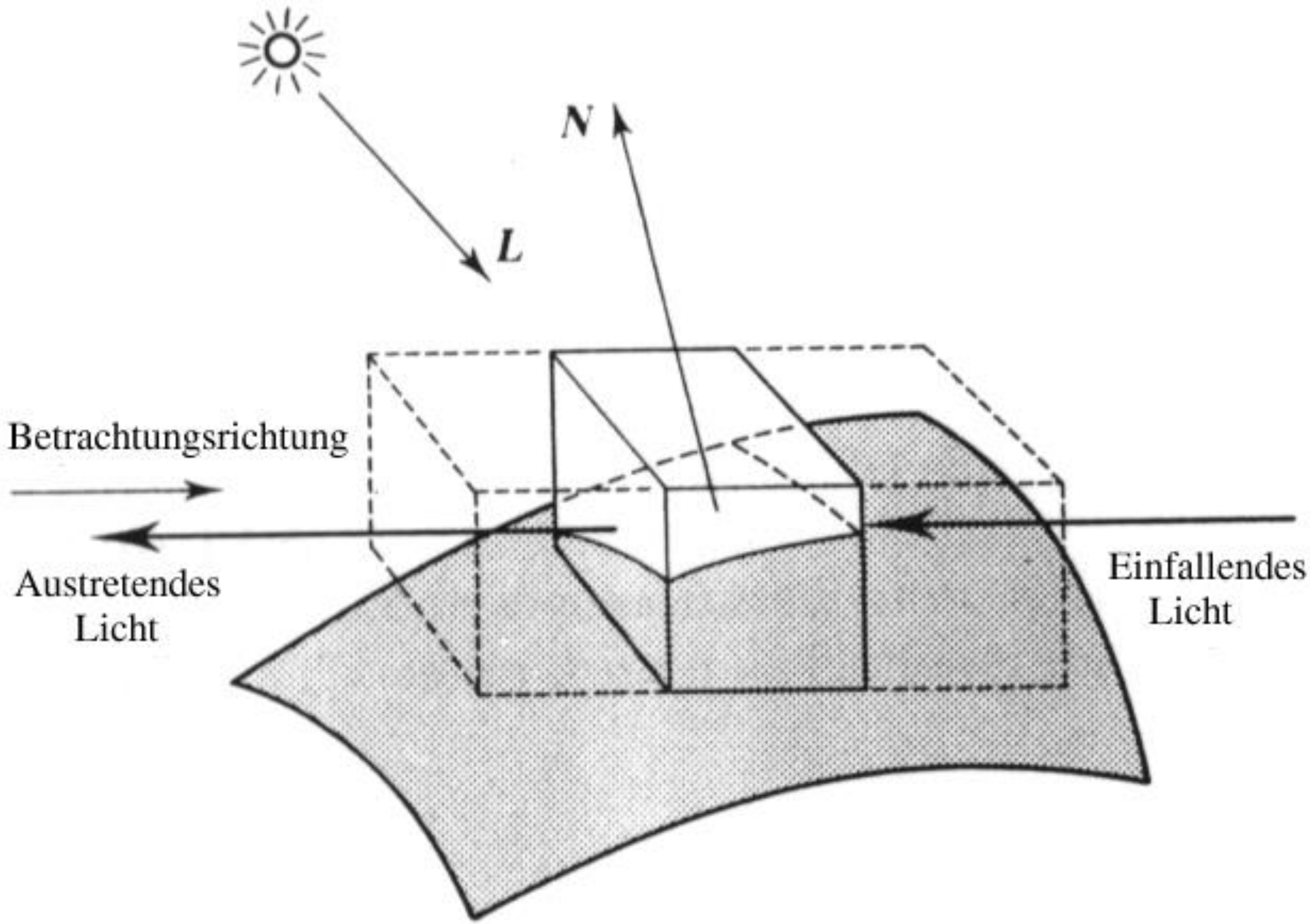
Light contribution of ray R

– **Intensity of volume element (voxel):**

– **Attenuation along the ray:**

– **Total light intensity:**




N
L
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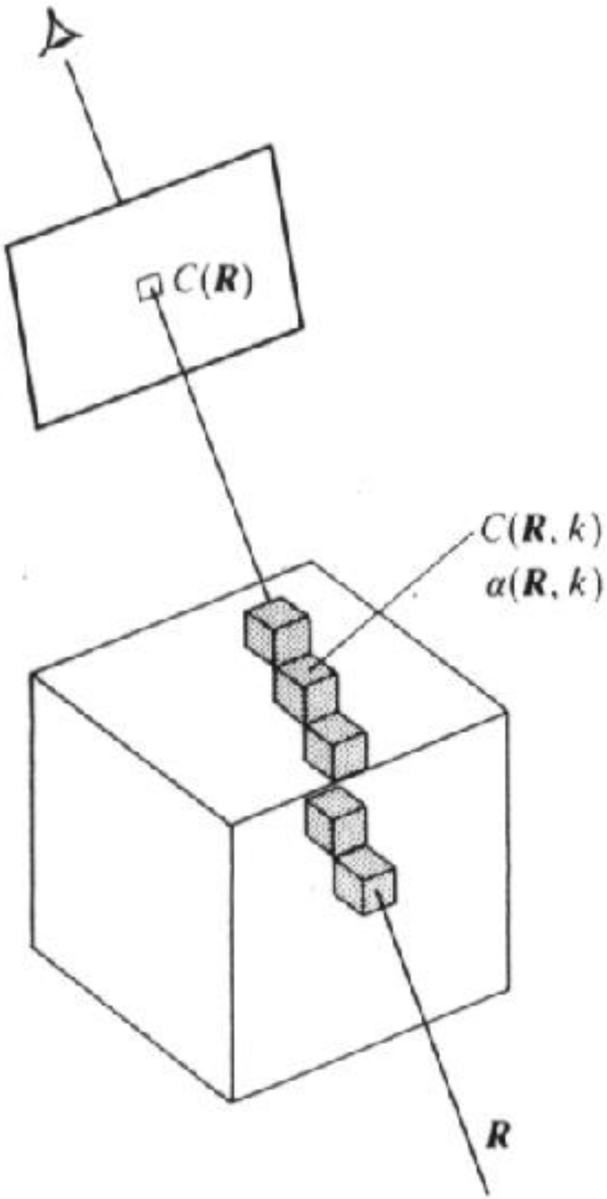
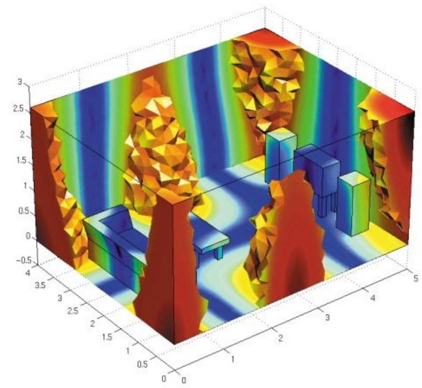
Austretendes
Licht
Einfallendes
Licht

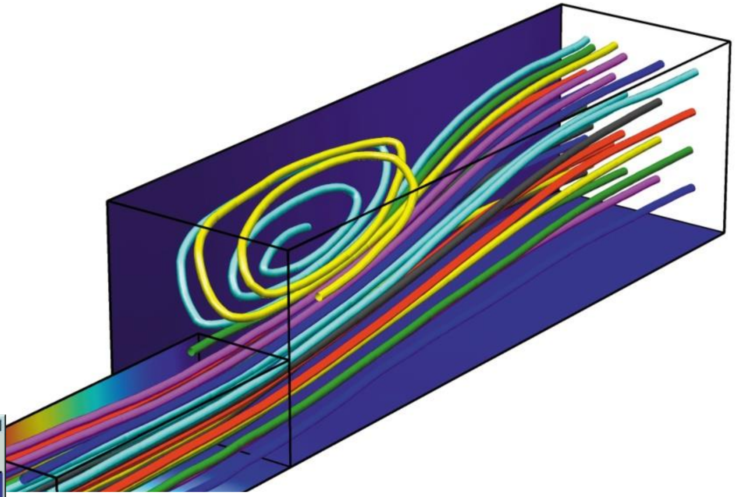


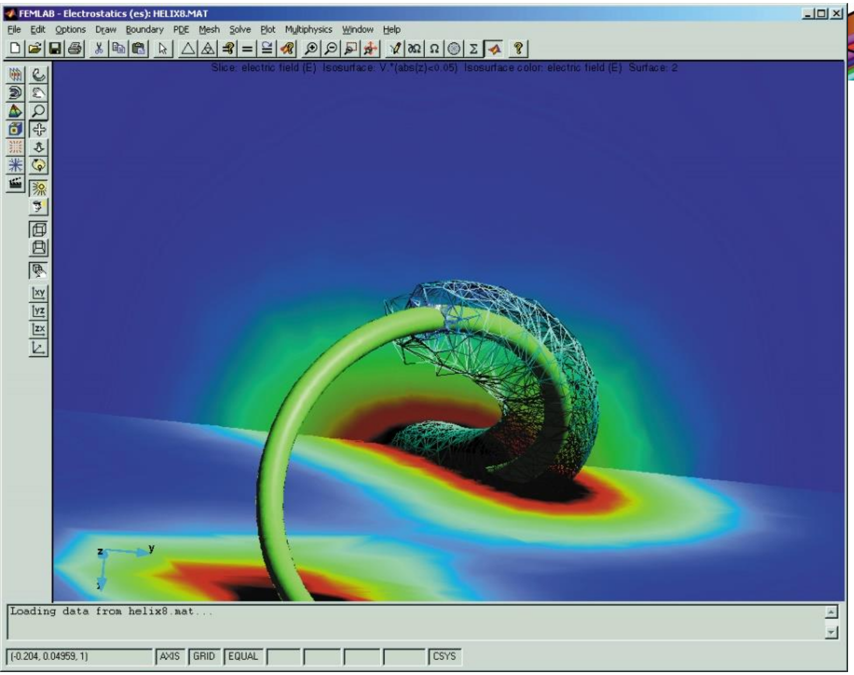
$C(\boldsymbol{R})$
$C(\boldsymbol{R}, k)$
$\alpha(\boldsymbol{R}, k)$
$\boldsymbol{R}$

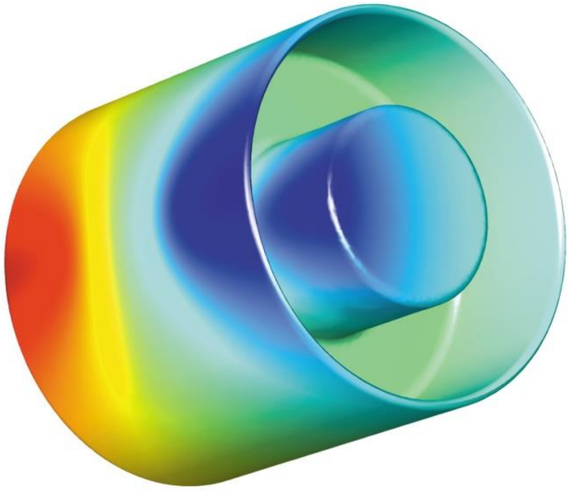
MatLab: www.femlab.com

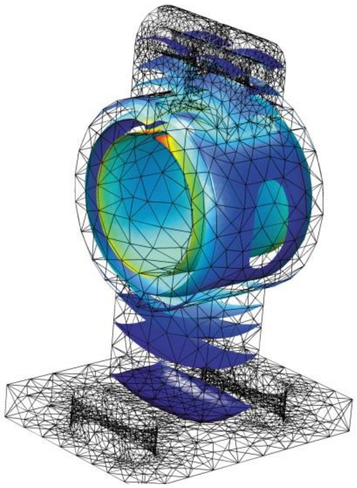
moreD

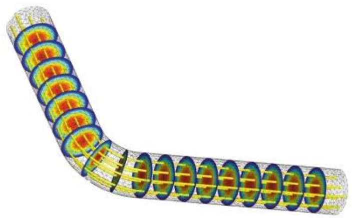










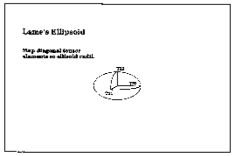


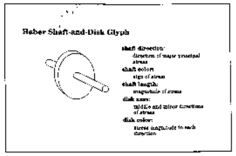
Visualization of Data

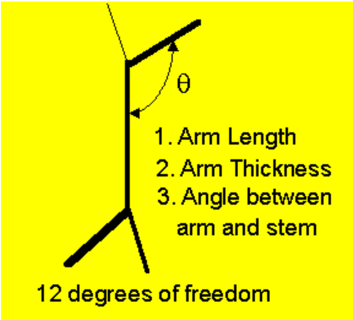
- 1D, 2D, 3D: Rendering
- 4D: Animation
- nD - in general: Open Problem
- Glyphs, faces by statistician Herman Chernoff
- http://people.cs.uchicago.edu/~wiseman/chernoff/
- other metaphors: terrain, garden, IFS...

Glyphs

- **UNICODE glyphs: A, @, 7, α, β, γ, δ, Σ, θ, ω… ?, *, §, … symbolic information**
- **Visualization glyphs**







ASCII Convention

- **Bits >> Images (Rosetta)**

USASCII code chart

Bits				b_7 b_6 b_5	0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
b_4	b_3	b_2	b_1	Column / Row	0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	DLE	SP	0	@	P	`	p
0	0	0	1	1	SOH	DC1	!	1	A	Q	a	q
0	0	1	0	2	STX	DC2	"	2	B	R	b	r
0	0	1	1	3	ETX	DC3	#	3	C	S	c	s
0	1	0	0	4	EOT	DC4	$	4	D	T	d	t
0	1	0	1	5	ENQ	NAK	%	5	E	U	e	u
0	1	1	0	6	ACK	SYN	&	6	F	V	f	v
0	1	1	1	7	BEL	ETB	'	7	G	W	g	w
1	0	0	0	8	BS	CAN	(	8	H	X	h	x
1	0	0	1	9	HT	EM	)	9	I	Y	i	y
1	0	1	0	10	LF	SUB	*	:	J	Z	j	z
1	0	1	1	11	VT	ESC	+	;	K	[	k	{
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Edward Tufte Tips

on Powerpoint and Presentation Design

- Three simple suggestions from Edward Tufte:

- **Show up early** Something good is bound to happen—if there's no need to fix a mechanical problem or resolve a room conflict, you can always mingle with the audience.
- **How to start** –Clearly tell the audience: What the problem is, who cares, and what your solution is…
- **Always provide a handout** –Text on paper can provide more information than verbal communication (e.g. it takes 22 minutes to read the top half of the New York Times aloud). – This allows them to become engaged. – Assures that each point is covered (even if you forget something).

Tufte: Aims

- Don’t unneccessarily segregate text & graphics– don’t turn them into silos.
- Aim for the truth. Truth wins.
- Aim for simplicity. Don’t dumb, down however.
- Avoid distracting animations and clip art.
- Of course practice, practice, practice.

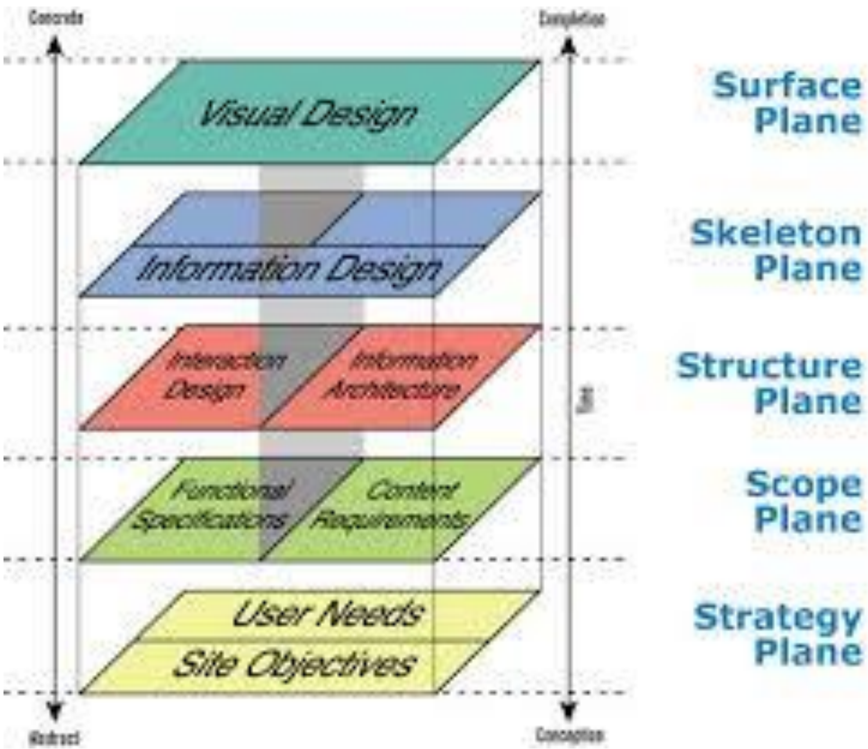
Tufte: What to Avoid

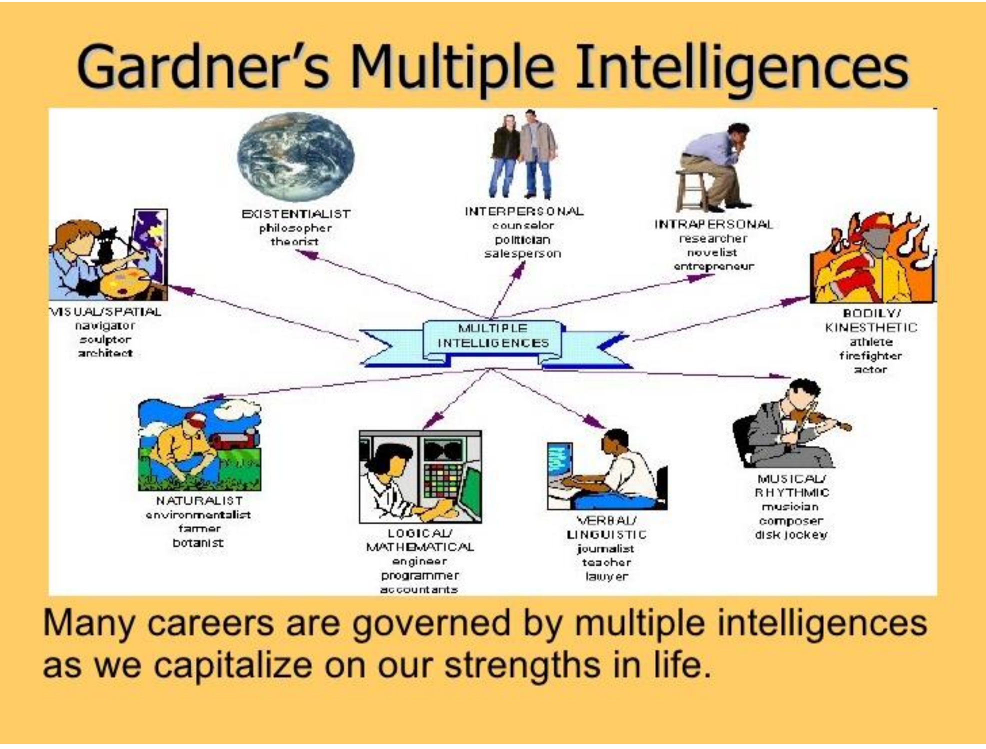
Death by Powerpoint:

- It is used to guide and **to reassure a presenter**, rather than to enlighten the audience;
- It has **unhelpfully simplistic** tables and charts, resulting from the low resolution of early computer displays;
- The outliner causes ideas to be arranged in an unnecessarily deep hierarchy, itself subverted by the need **to restate the hierarchy** on each slide;
- **Enforcement of the audience's linear progression** through that hierarchy (whereas with handouts, readers could browse and relate items at their leisure);
- **Poor typography and chart layout**, from presenters who are poor designers and who use poorly designed templates and default settings (in particular, difficulty in using scientific notation);
- **Simplistic thinking**, from ideas being squashed into bulleted lists, and stories with beginning, middle, and end being turned into a collection of disparate, loosely disguised points. This may present an image of objectivity and neutrality that people associate with science, technology, and —bullet points.

Authoring

- Mental operations?
- Objects, semiotic representations, metaphors…
- Meaning





Sensemaking

- Story

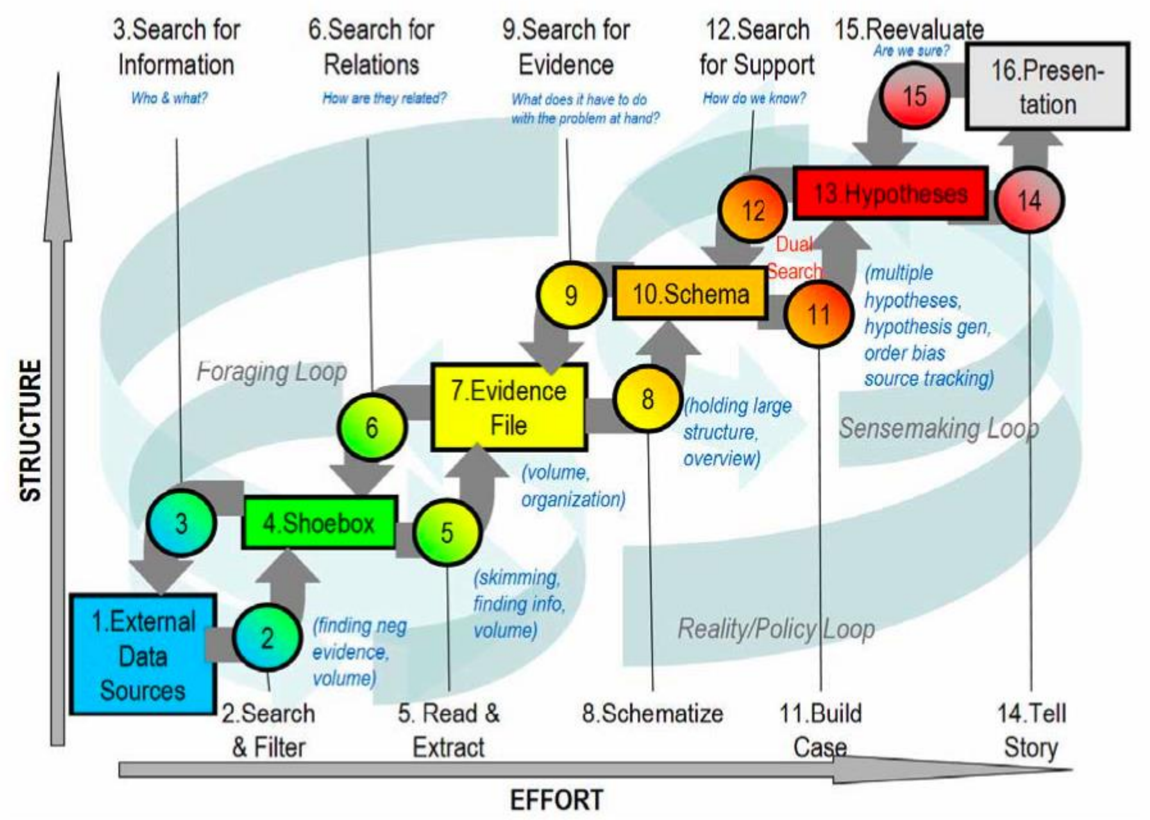
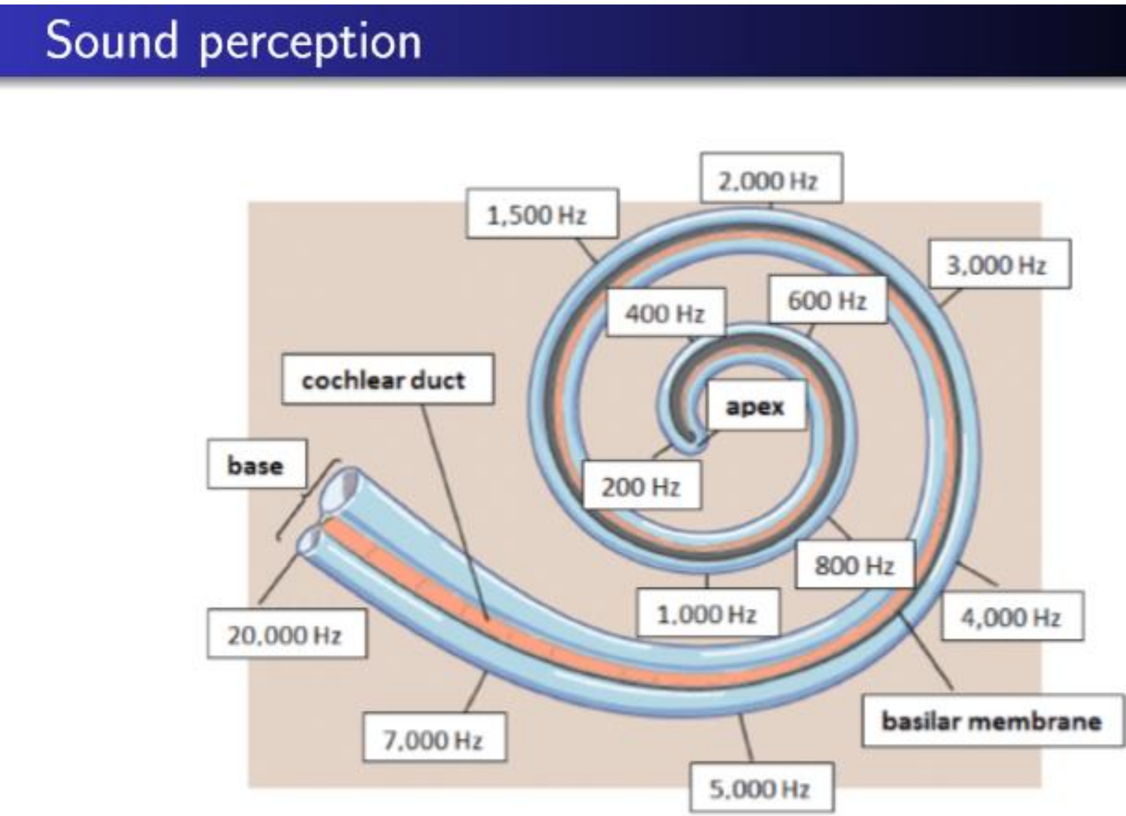
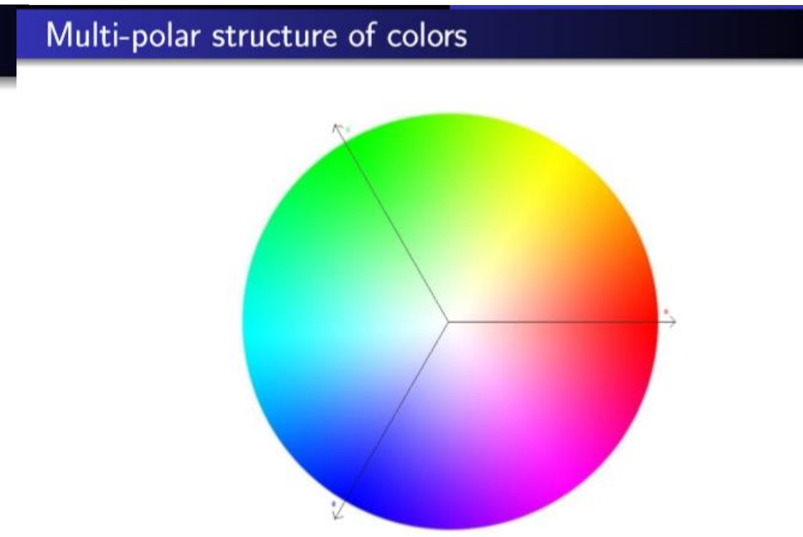
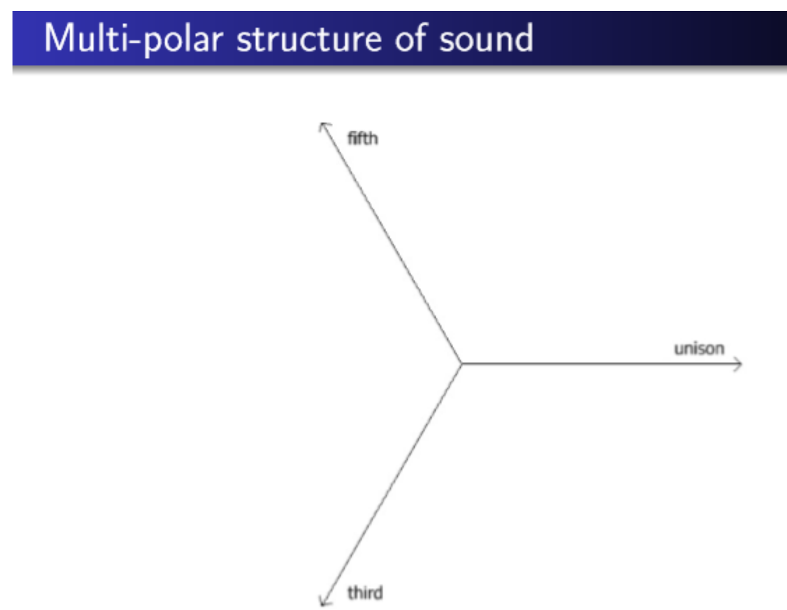


Figure 1.1: *The sensemaking process described by Pirolli & Card [PC05]. The Exploration process within visualization is analogous to the foraging loop, e.g. collecting evidence in a shoebox, while analysis is the consideration of this evidence. Ultimately any hypothesis or evidence found must be presented in one way or another.*

Sound Perception

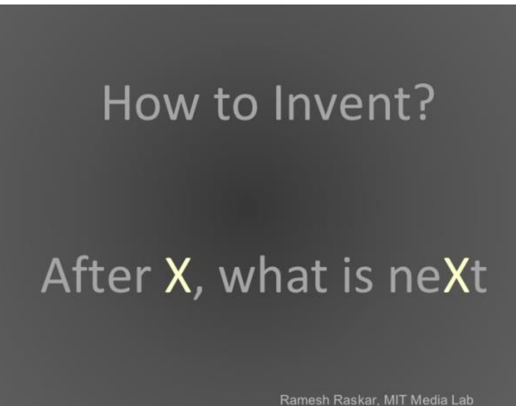




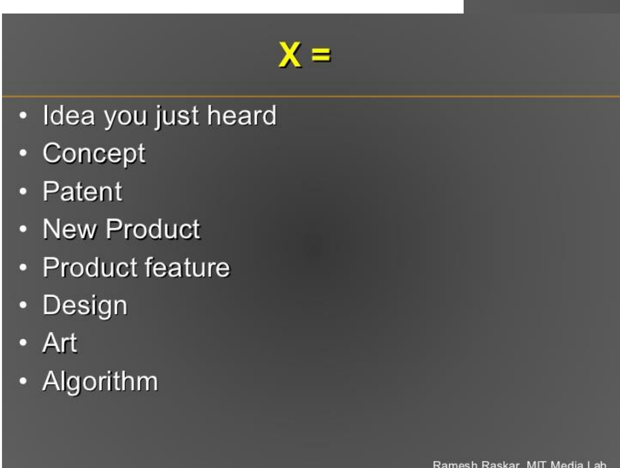


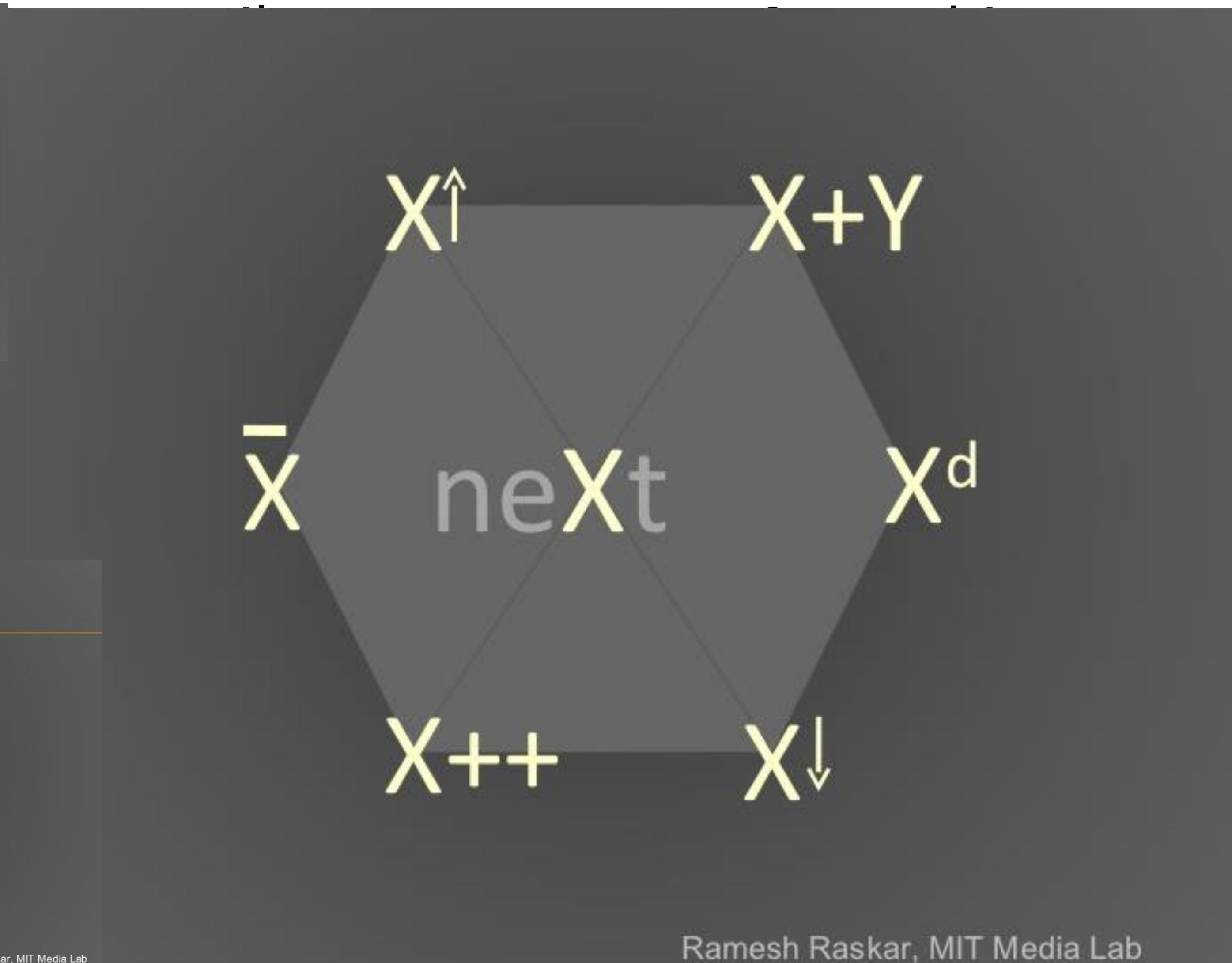
- Time 1D >> 2D, 3D
- Raskar D--, D++ 2/6

Raskar Hexagon

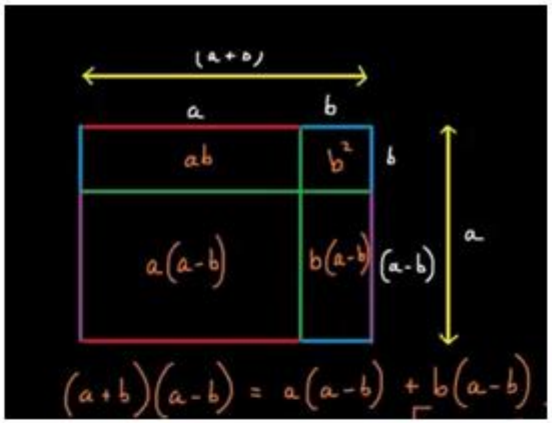


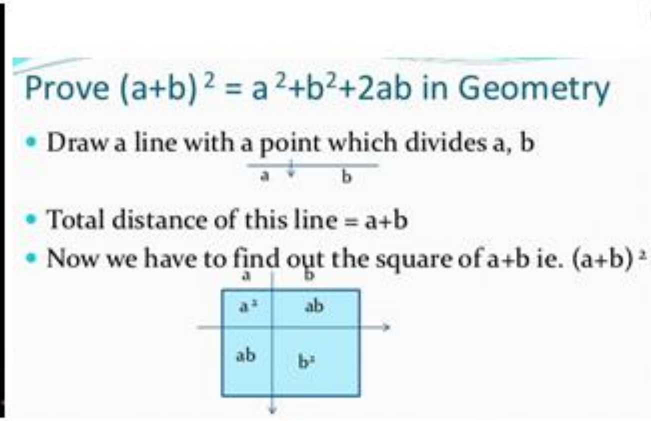
- **neXt**

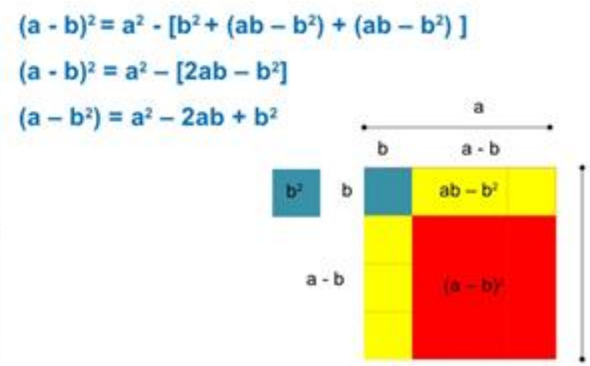


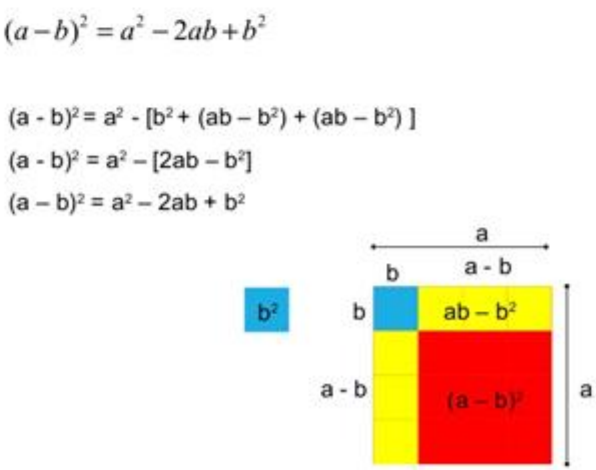


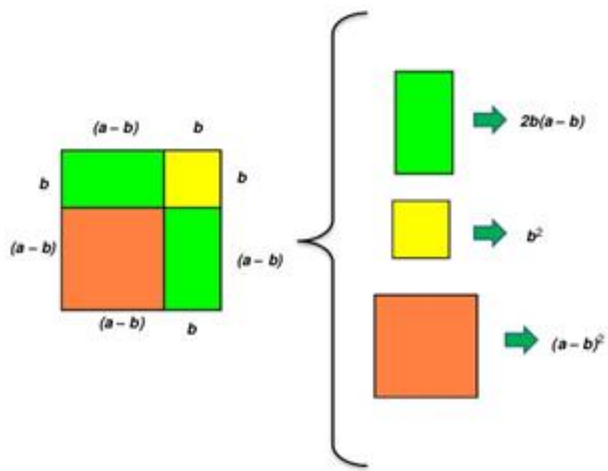
Visual Proofs

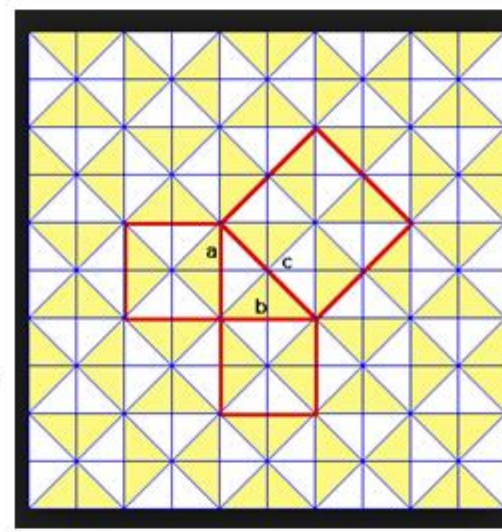












Four Universes

Output/input space

Graphics output primitives (e.g. triangle) **Input data record (e.g. location, string)**

Hardware/software layer (bits/pixels/inputs only, run time) NOW

Implementation for given hardware and software platform

Representation for computer (encoding, e.g. ASCII code, signed integer)

Mathematic model (or another conceptual model)

Real world problem (e.g. hunger by Berne: stimulus, time structure, contact, e.g. needs by Maslow: safety, selfactualization, transcendence)

VAR Big Picture K

Imagine, please, the user above this page and read it from the bottom line to this line, in a reversed ordering of lines. The user shares affective and cognitive responses, e.g. bisociation, hermeneutic gap filling…

VIS **<<< visualization… activization >>>** **HCI**

e.g. no clue, visible meaning or entymeme e.g. observe only or (inter)act

Uncertainty: unsure meaning, e.g. symptom, strife, misunderstood meaning, incomplete data or method not clear… like filtering

Depth of Immersion: e.g. curiosity, empathy, identification… like calibration

No story, no game Story Interactive Story Story and game Game Interactive Storytelling

Story environment: ostension, exposition, argumentation, description, narration or a move in the game (**game loop** 1..8)

1. Observe, 2. Set goals, 3. Prepare, 4. Commit and execute
5. Compare against goals (and, eventually, stop)
6. Evaluate for self (and, eventually, stop)
7. Evaluate for others (and, eventually, stop)
8. Go to 1

Visualisation metaphors **(Rhetorics)** **HCI metaphors**

e.g. cartographic map with weather forecast e.g. desktop metaphor, phone, walk, fly, repeat

Patterns recognized, e.g. visual rhyme, Propp function in a fairy tale, music motif

Semiotic layer: iconic, indexed, symbolic, signal, or symptom representation

Object space (user can pick an object and manipulate/interact with it)

Graphics (multimedia) objects with geometric support (shape) and characteristic function (color, sound)

Output/input space

Graphics output primitives (e.g. triangle) Input data record (e.g. location, string)

Hardware and software layer (bits/pixels/inputs only, run time)

Implementation for given hardware and software platform

Representation for computer (encoding, e.g. ASCII code, signed integer)

Mathematic model (or another conceptual model)

Real world problem (e.g. hunger by Berne, stimulus hunger, time structure hunger, contact hunger, e.g. needs by Maslow)

Počítačová grafika 2
InfoVis

Andrej FERKO

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19. apríla 2018, FMFI UK