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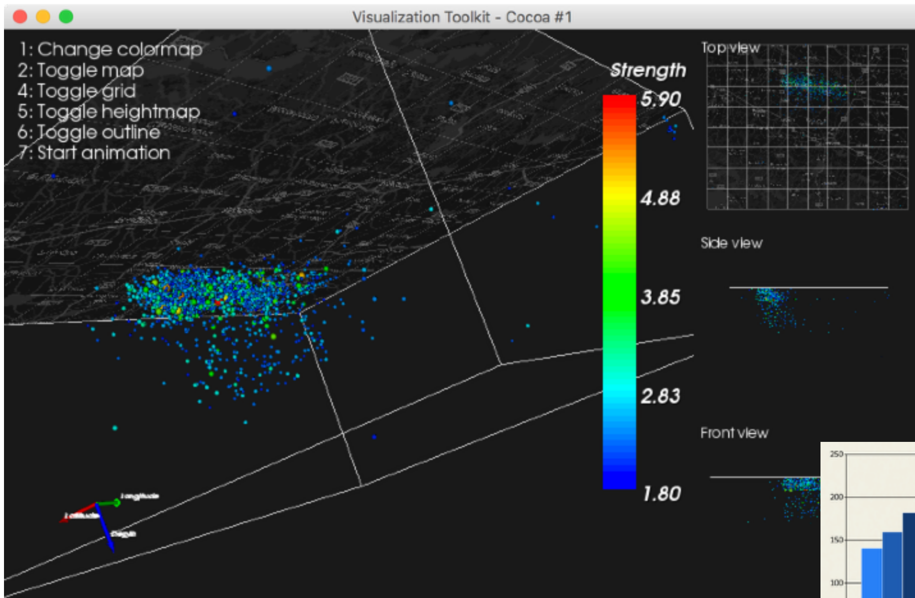
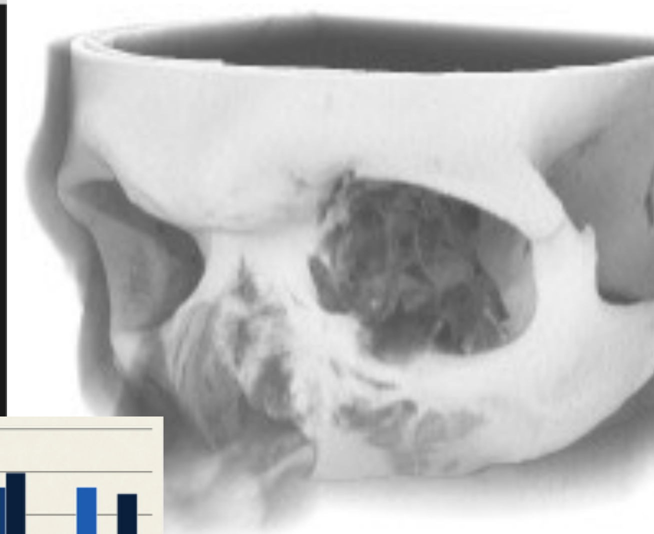
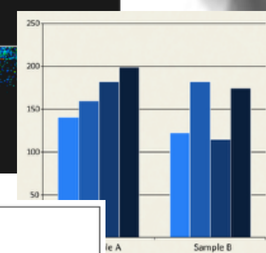
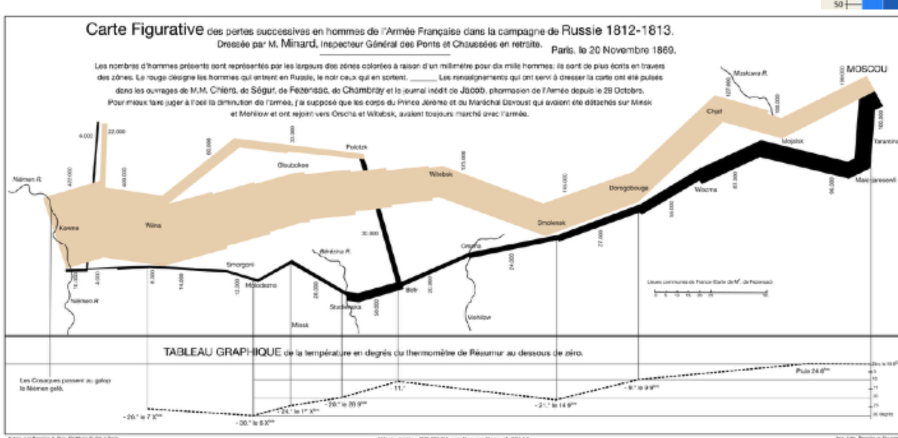
Visual Information and Interaction

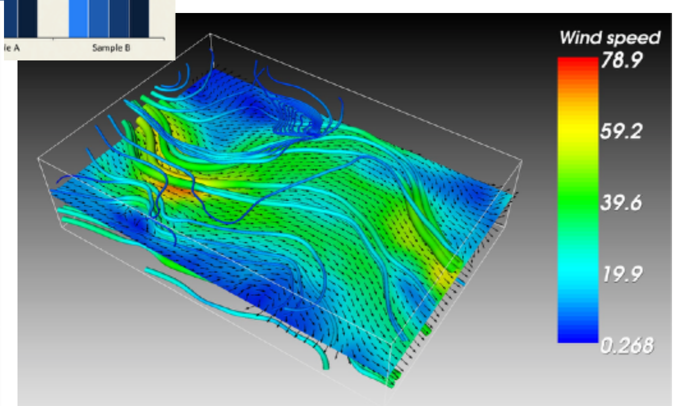
Scientific Visualisation, 5hp











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Teachers

Anders Hast

Associate Professor

Computer Graphics/

Visualisation

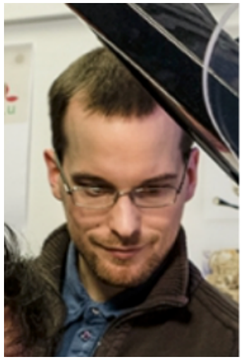
Stefan Seipel

professor

Computer Graphics

Fredrik Nysjö

PhD student



Raphaela Heil

PhD student

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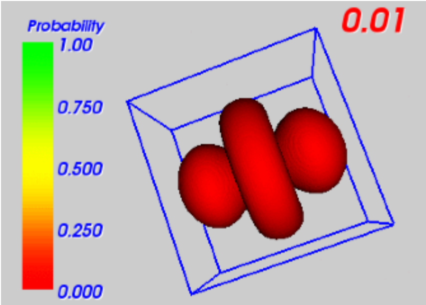
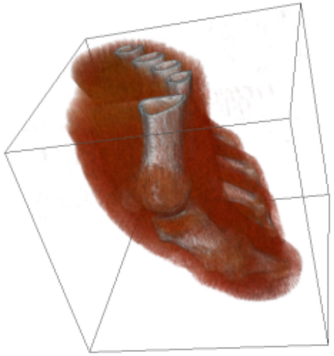
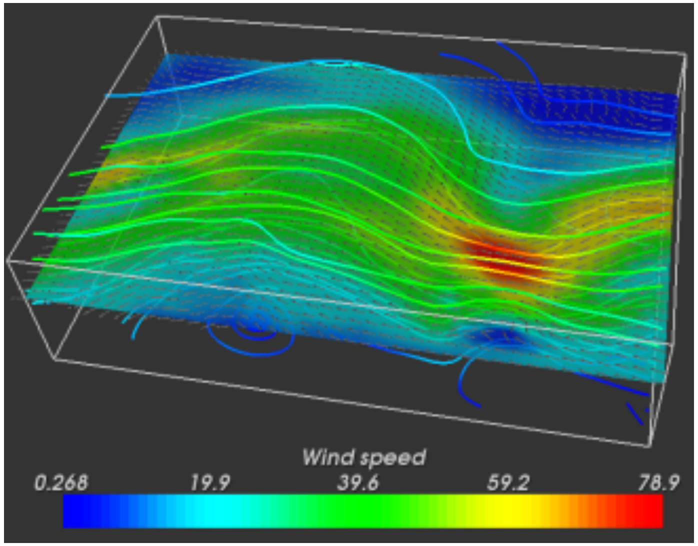
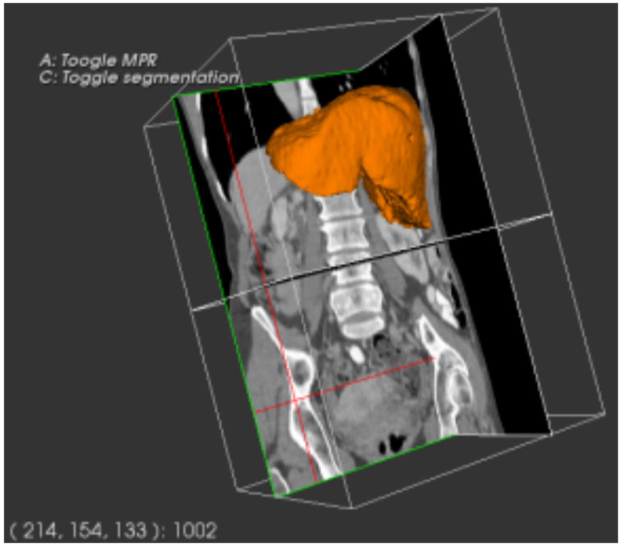
Assignments

Two mandatory assignments









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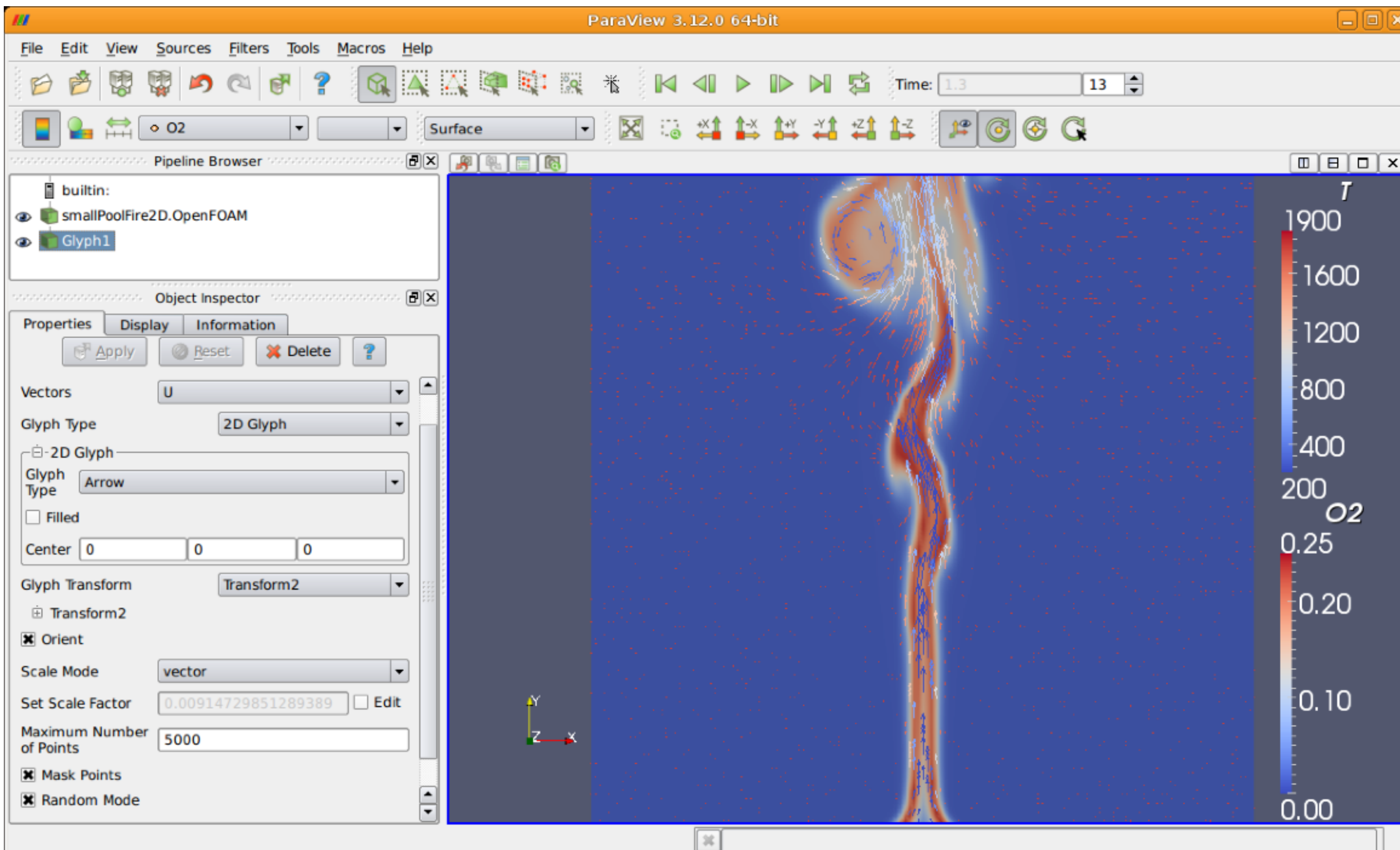
You will be using Paraview

- Learn about different visualisation techniques
- Learn how to use Paraview for using them in practice



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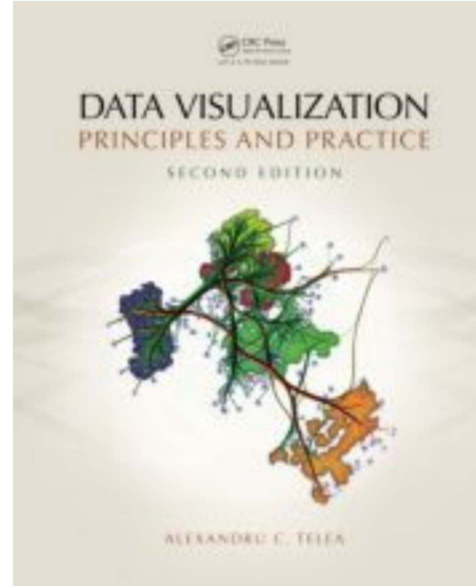
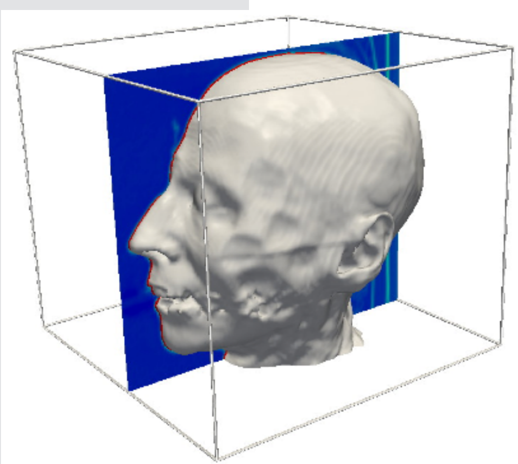
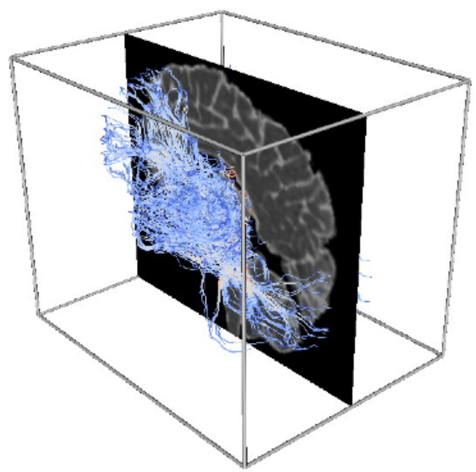
Text book

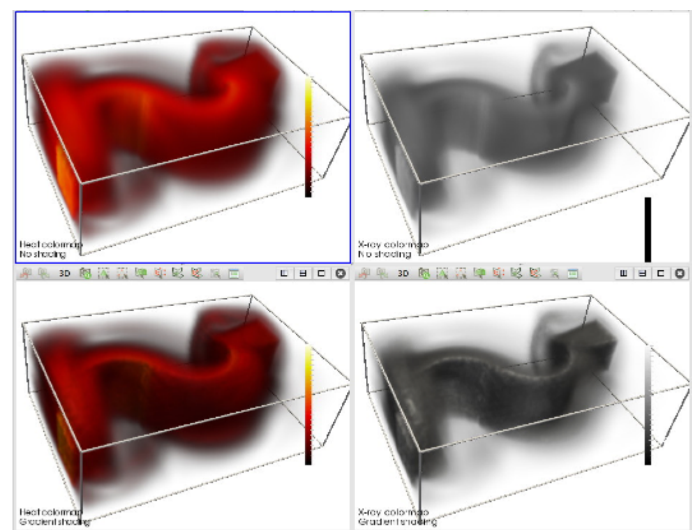


Alexandru C. Telea

Data Visualization: Principles and Practice (2nd edition, 610 pages)







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Studenportalen

All info is on Studentportalen

Please see “Course Information”, where you find the schedule with reading suggestions

BUT, always check TimeEdit for recent changes!

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Course Evaluation & Actions Taken

+

Students often do more than they should since the visual content is interesting to work with.

-

Last year there was several changes in the schedule due to teachers obligations that messed things up - will not happen this year!

Labs in VTK were hard to do because the tutorial went off line - We changed to Paraview!

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Dictionary

vi·su·al·ize

- To form a mental image of; envisage: *try to visualise the scene as it is described*
- To make visible

”Visualisation offers a way to see the unseen”

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"A picture is worth a thousand words"

When **large** and **complex** data sets are resulting from experiments and computations, visualisation is a way to get deeper **insight** and **knowledge**.

You will learn how

- to select appropriate methods, possibilities and limitations with methods,
- and to use Paraview to visualise.

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Visualisation purposes

- Communication of information *(emphasising, narrating)*
- Improve understanding *(illustrating, interpreting, finding)*
- Decision support *(analysing, extrapolation)*
- Answering questions *(diagnosing, interpreting)*
- Support creativity *(inspiration)*
- ***Making new discoveries through interaction!***

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Graphs are one type of visualisation

Example:
Which Swedish town(s) have warmer than 20 C
and less than 10 mm of rain?

	Temp.[C]	**Rain [mm]**
Gävle	18,5	3,1
Göteborg	24,1	11,7
Halmstad	19,8	10,3
Karlskrona	19,9	4,8
Kiruna	13,7	5,4
Lund	22,1	13,3
Malmö	23,2	14,8
Mora	17,8	6,1
Stockholm	19,9	6,3
Sundsvall	16,5	6,7
Umeå	14,3	13,2
Uppsala	19,4	9,7
Västerås	17,8	13,1
Örebro	21,1	7,6
Östersund	13,8	15,3

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Visualisations help us getting insight

When data is complex: Collected/Computed

- When numeric data is to bee understood
- When complex relations must be understood
- When multiple variables have to be analyzed

Visualisation is not a substitute to, but **in addition to**, statistical analysis and other quantitative methods

Visualisation takes advantage of human sensory abilities

- Pattern recognition, Trend discovery, etc.

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Graphs are one type of visualisation

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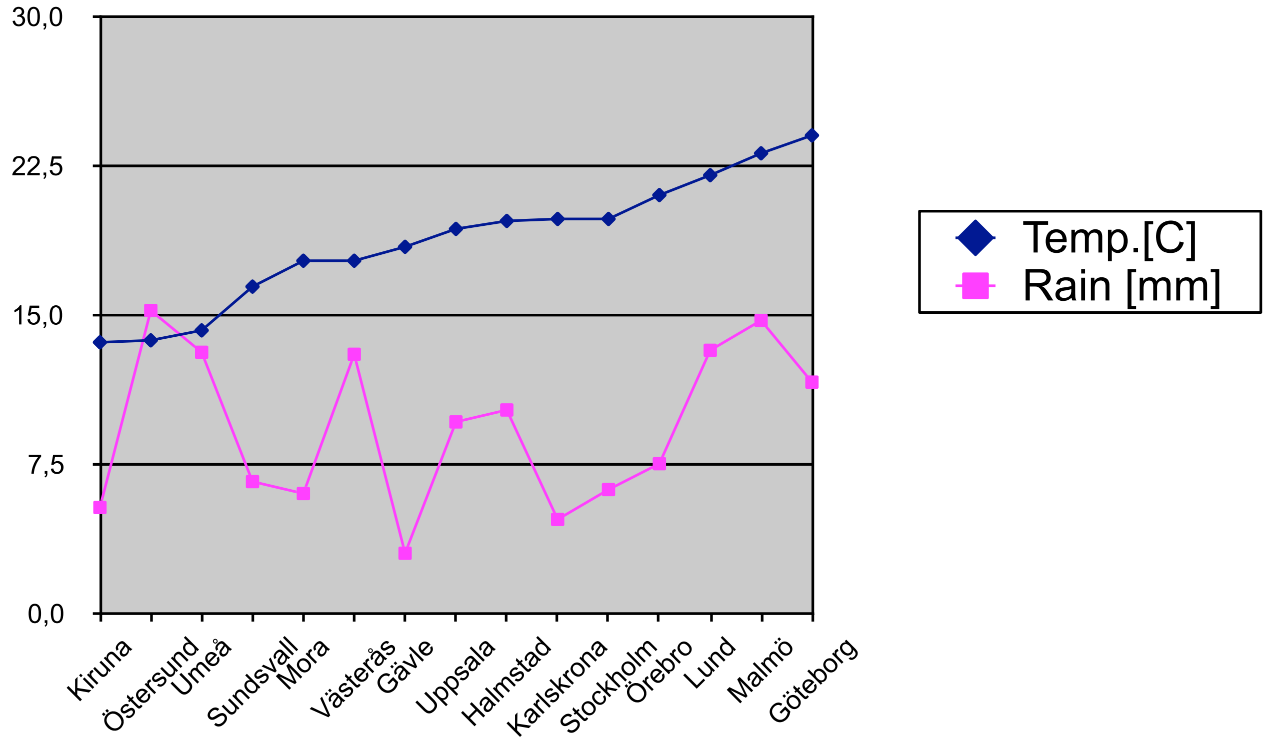

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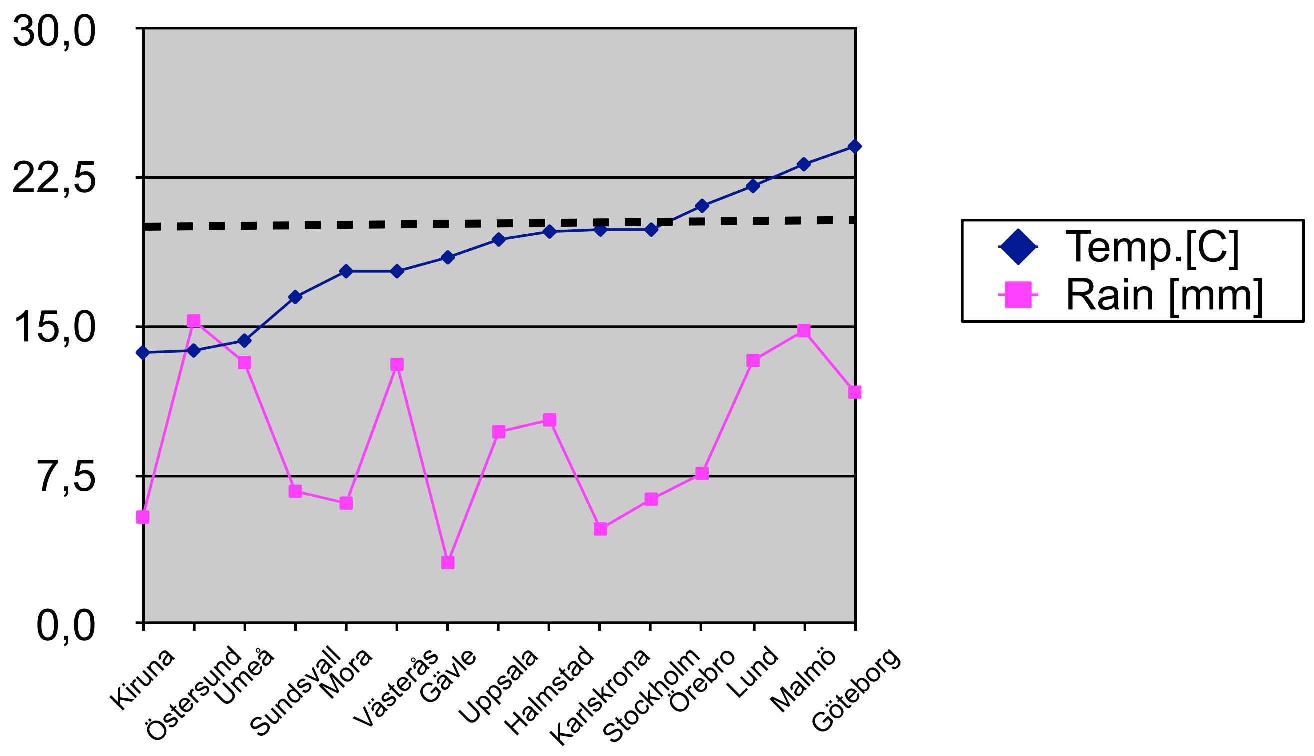

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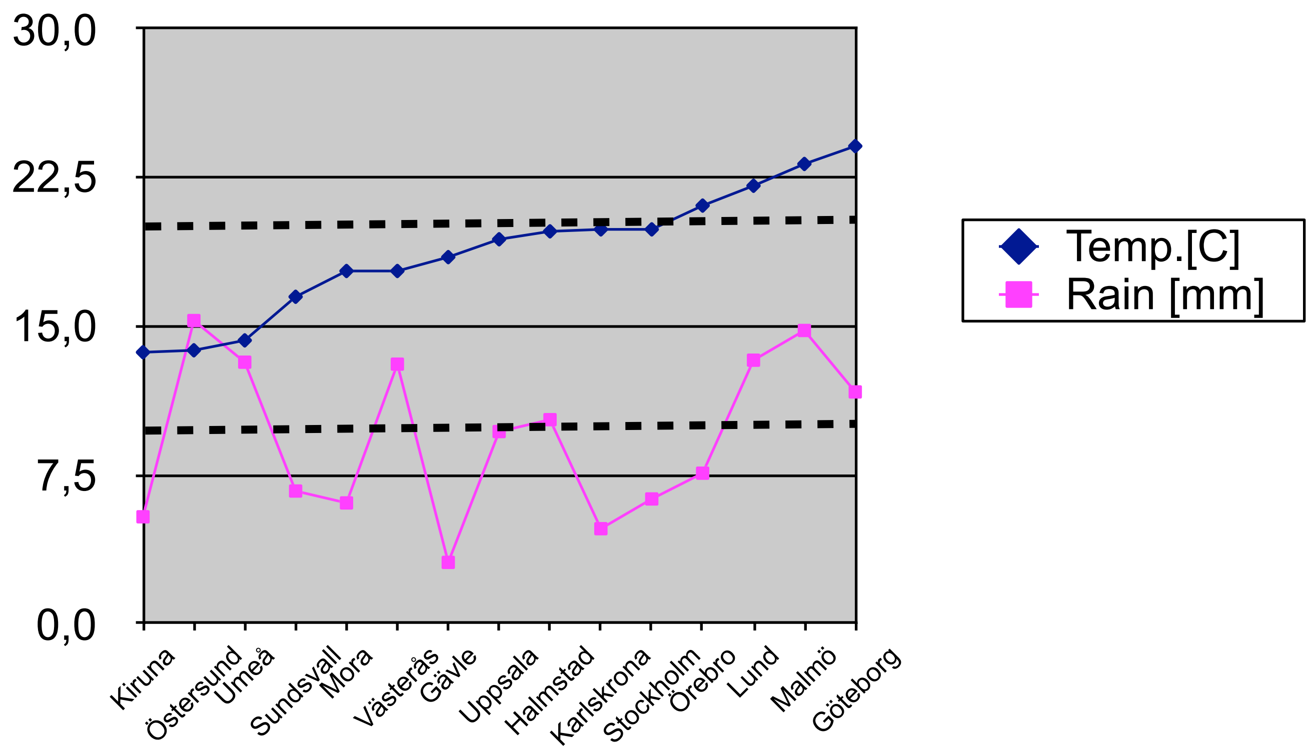

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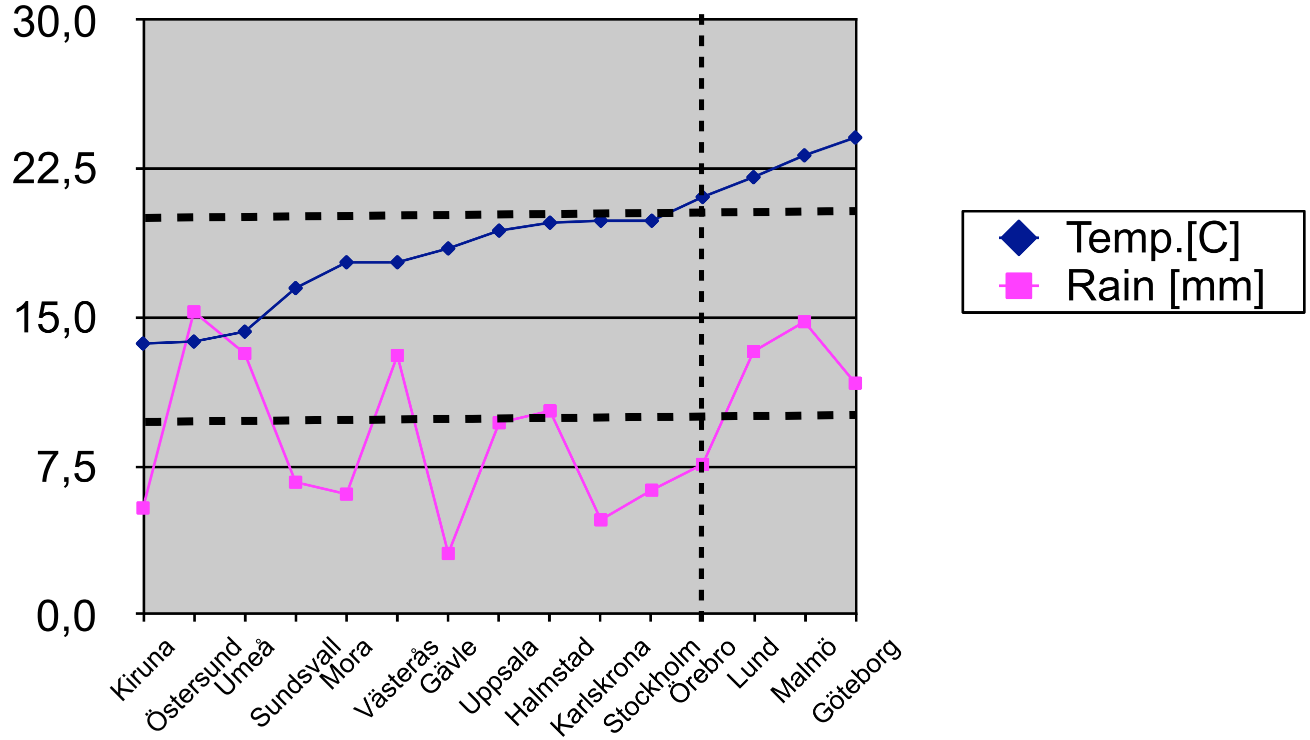

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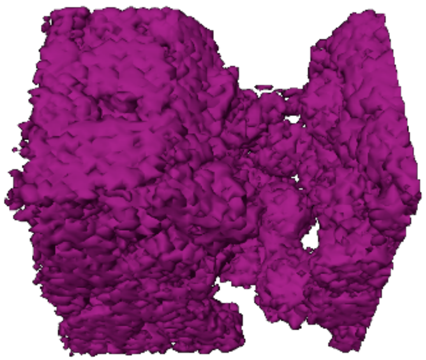
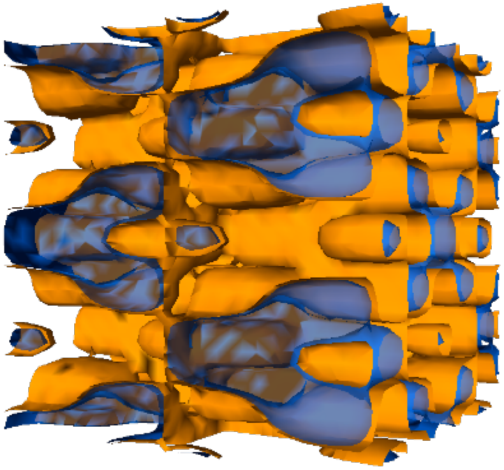
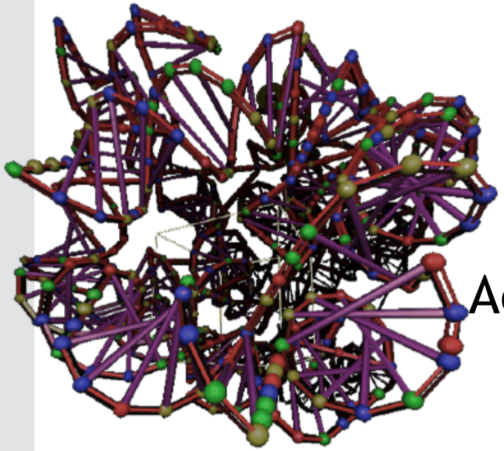
Some more sophisticated examples



Nuclear, Quantum, and Molecular Modeling

Structures, Fluids, and Fields





Advanced Imaging and Data Management

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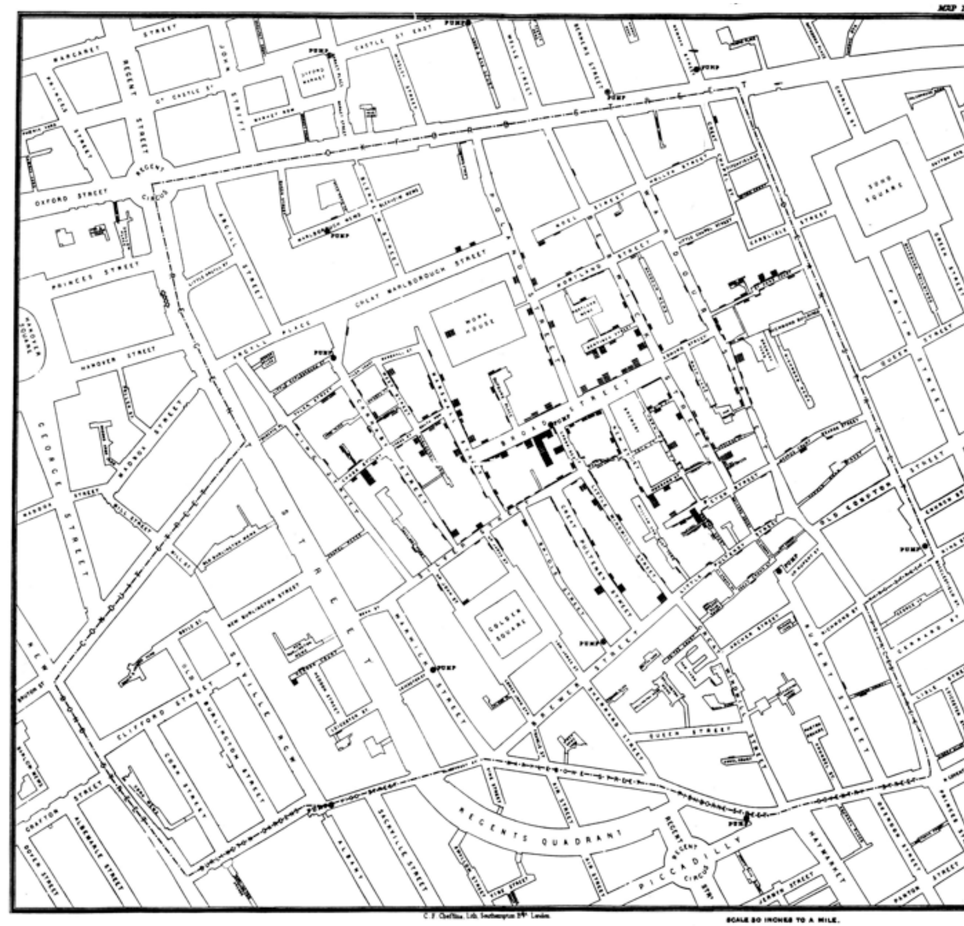
Some classical examples

Dr. John Snow; The Cholera Epidemic in London 1854

Used *spot-map* to graphically depict cholera incidents.

Spatial clusters *led to him to the hypothesis* that cholera was communicated through contaminated water.

Identification and removal of contaminated pump led to reduced mortality and partly confirmed his hypothesis.



Note: The visualisation did not prove anything. But was influential to the development of the novel hypothesis which was later proved true.


OXFORD STREET
REGENT CIRCUS
GT CASTLE ST
MARLBOROUGH MEWS
PUMP
PRINCES STREET
HANOVER SQUARE
HANOVER STREET
ARGYLL STREET
ARGYLL PLACE
GREAT MARLBOROUGH STREET
WORK HOUSE
PORTLAND STREET
NOEL STREET
CARLISLE STREET
SOHO SQUARE
FRITH STREET
GREEK STREET
BROAD STREET
GEORGE STREET
MADDOX STREET
NEW BURLINGTON STREET
GREAT PULTENEY STREET
GOLDEN SQUARE
OLD COMPTON STREET
RUPERT STREET
BREWER STREET
QUEEN STREET
CLIFFORD STREET
OLD BURLINGTON STREET
SAVILLE ROW
CORK STREET

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Florence Nightingale

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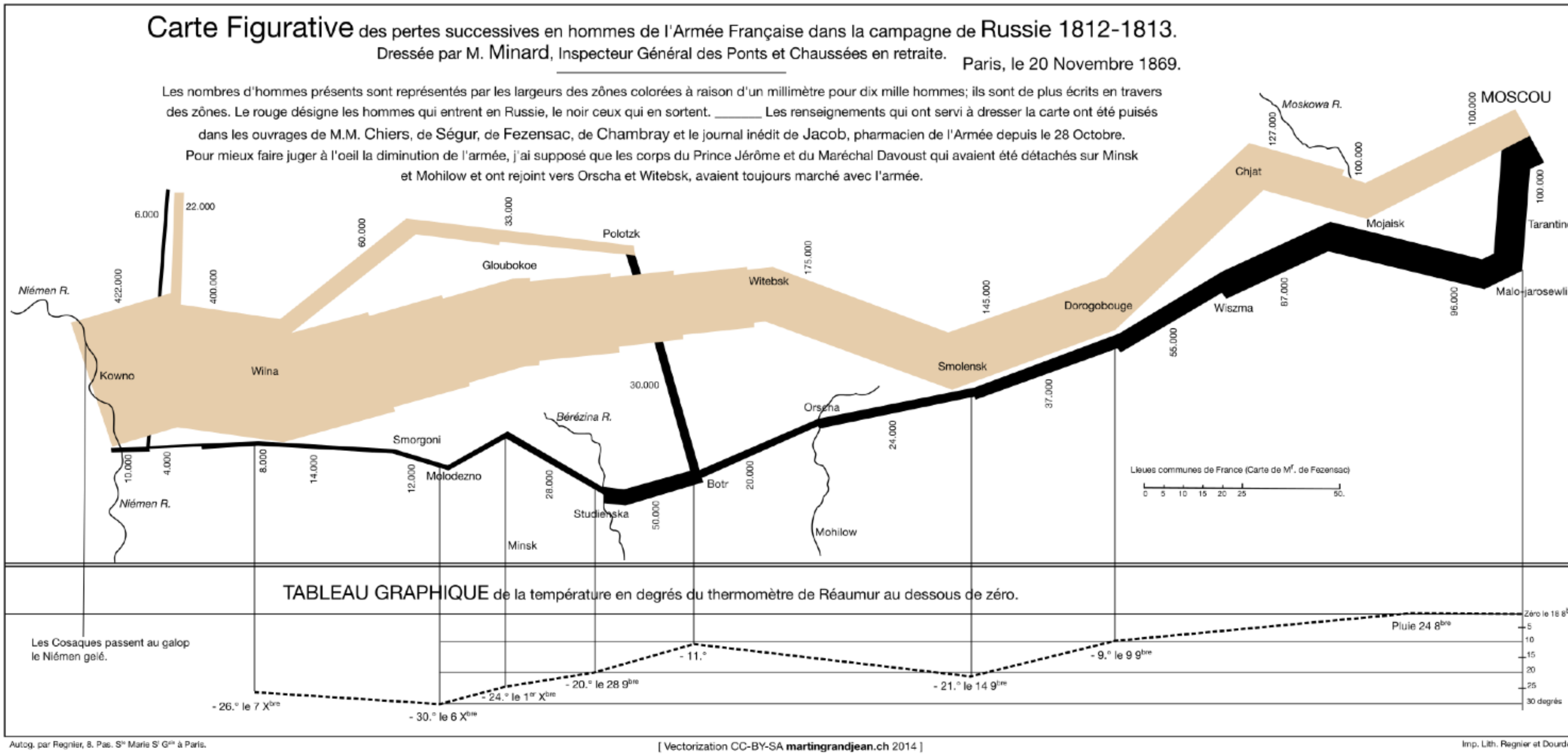
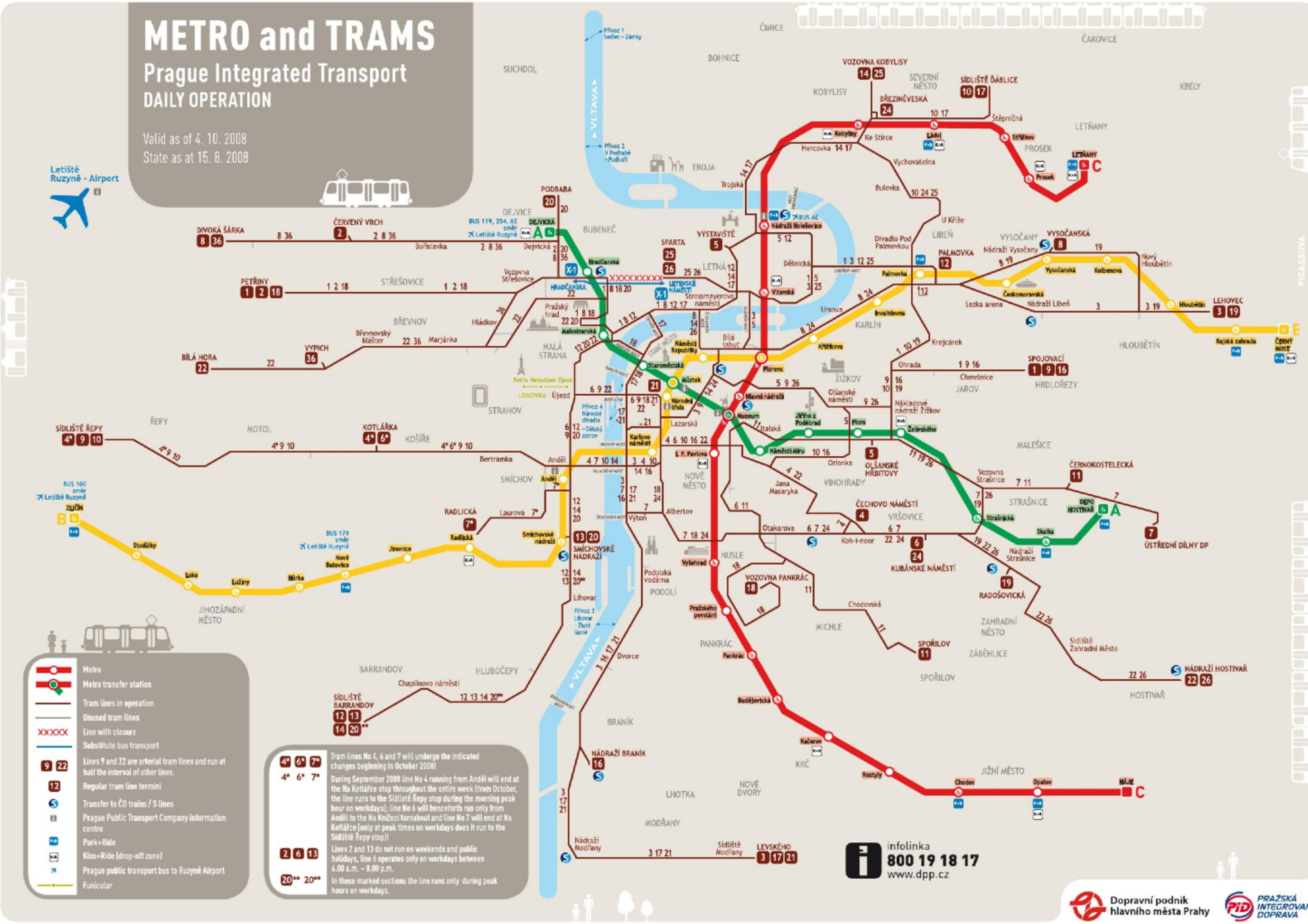
Charles Minard's 1869 flow map of Napoleon’s March





METRO and TRAMS
Prague Integrated Transport
DAILY OPERATION
Valid as of 4. 10. 2008
State as at 15. 8. 2008
Letiště Ruzyně - Airport
Metro
Metro transfer station
Tram lines in operation
Unused tram lines
XXXXX Line with closure
Substitute bus transport
Lines 9 and 22 are arterial tram lines and run at half the interval of other lines.
Regular tram line termini
Transfer to ČD trains / S lines
Prague Public Transport Company information centre
Park+Ride
Kiss+Ride (drop-off zone)
Prague public transport bus to Ruzyně Airport
Funicular
Tram lines No 4, 6 and 7 will undergo the indicated changes beginning in October 2008!
During September 2008 line No 4 running from Anděl will end at the Na Kotlářce stop throughout the entire week (from October, the line runs to the Sídliště Řepy stop during the morning peak hour on workdays); line No 6 will henceforth run only from Anděl to the Na Knížecí turnabout and line No 7 will end at Na Kotlářce (only at peak times on workdays does it run to the Sídliště Řepy stop)!
Lines 2 and 13 do not run on weekends and public holidays, line 6 operates only on workdays between 6.00 a.m. – 8.00 p.m.
In these marked sections the line runs only during peak hours on workdays.
infolinka
800 19 18 17
www.dpp.cz
Dopravní podnik hlavního města Prahy
PRAŽSKÁ INTEGROVANÁ DOPRAVA

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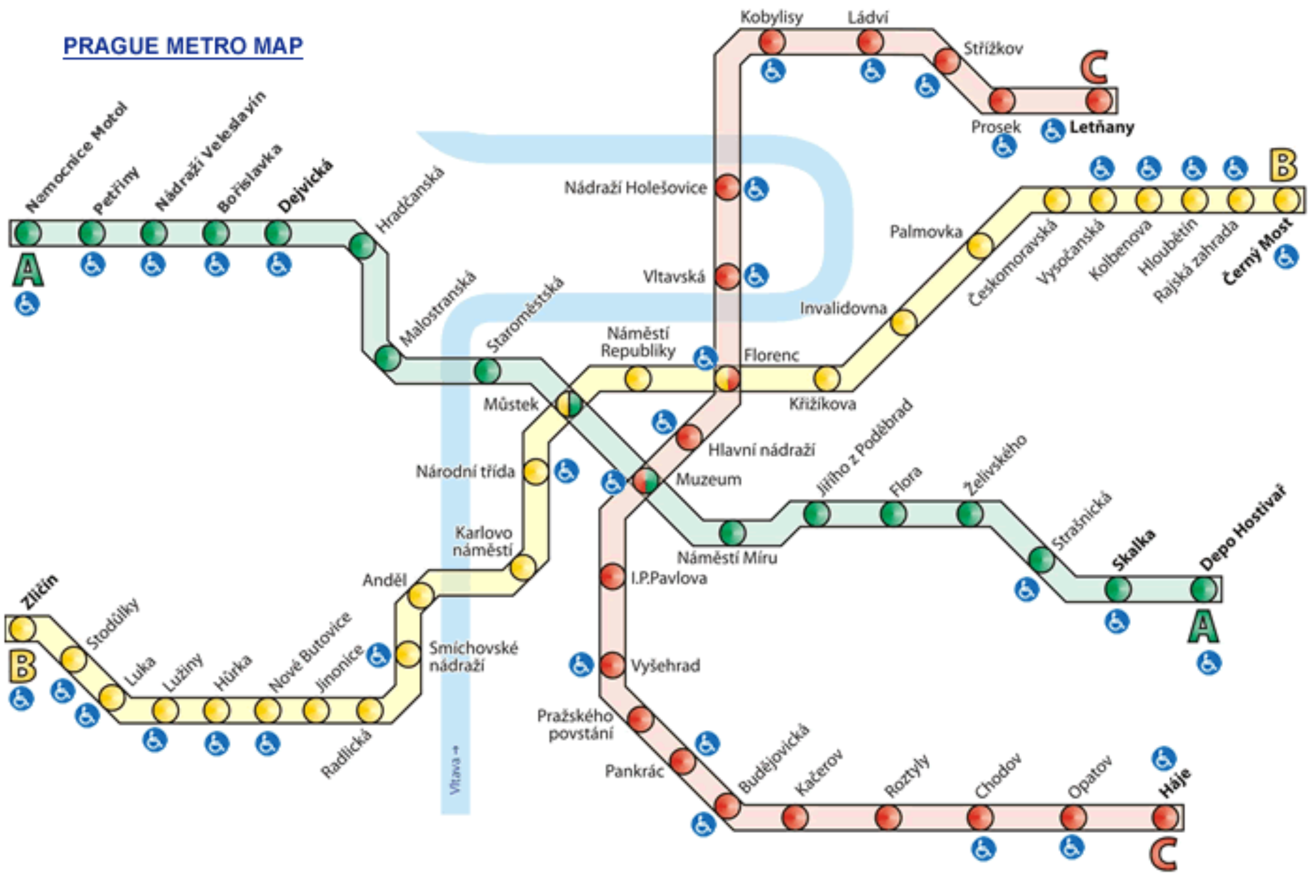
Not spatially correct, but more useful!



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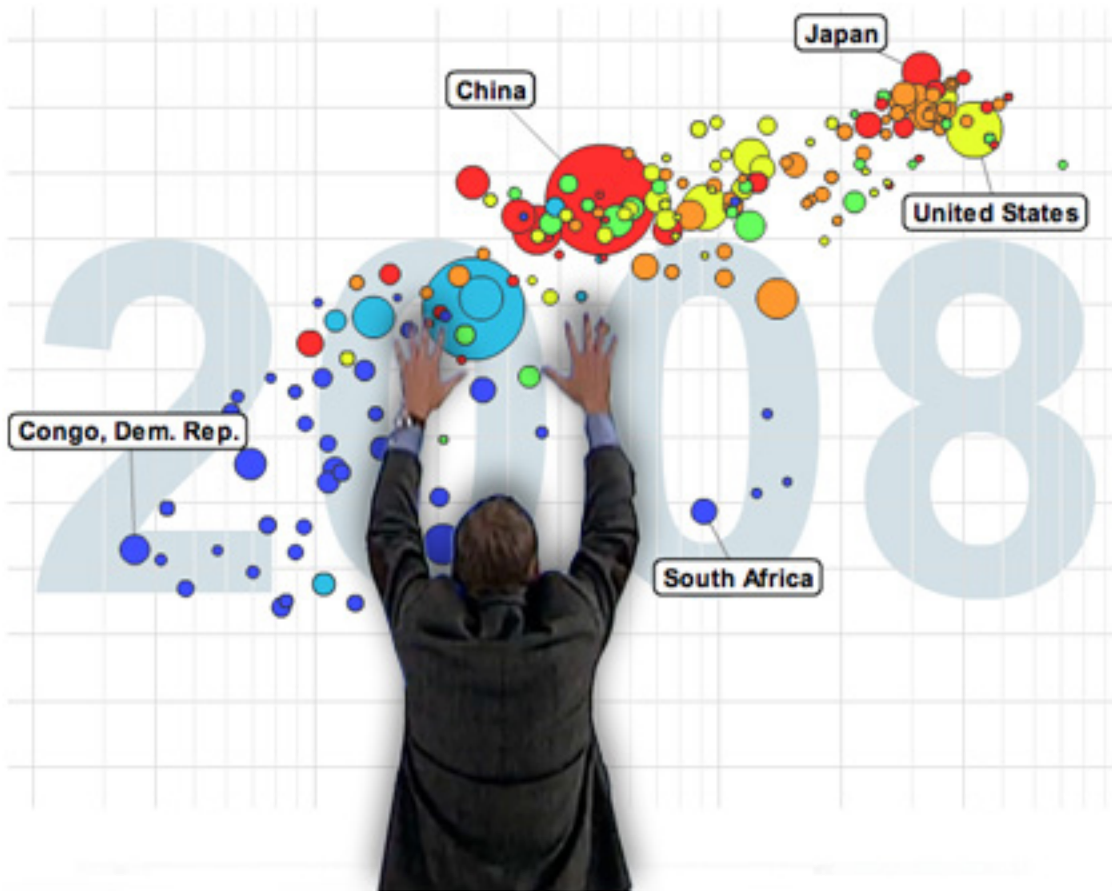
Can be used to get insight!



Hans Rosling

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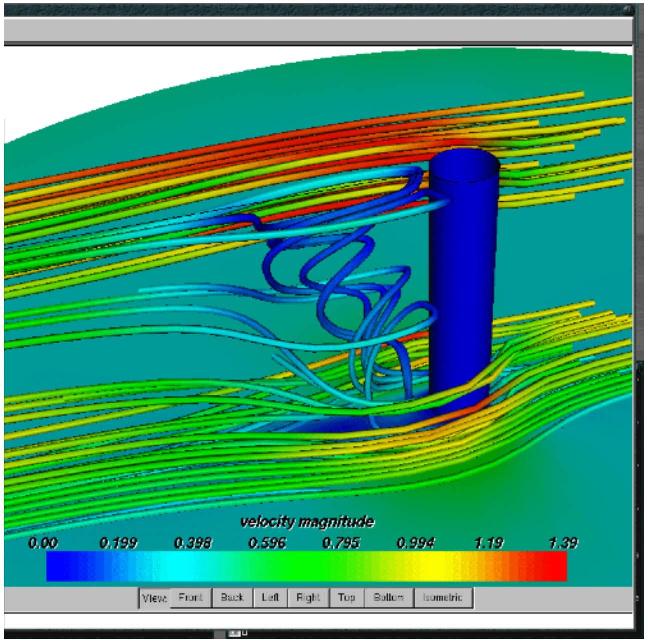
Scientific Visualisation

- Scientific visualisation is the process of ***exploring***, transforming, and viewing data as images
- The data describes natural or physical phenomena or quantities
- Often observed (measured) or simulated data

- Visualisation is often interactive
- We are not trying to create realistic images, but to visualise data in an informative way
- Application dependent



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Conclusion

Visualisations show data in different ways

- Which way is more useful?
- Which way tells a story?

Chose the one that fulfils your purpose!

But can also be misleading…

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Ch 3: Computer Graphics Primer

Creating images with a computer – 3D

Computer Graphics

Computer graphics aims at creating pictures by mimicking the image formation process that occurs in conventional photography.

Purposes:

Simulate real things (entertainment)

Make visible what cannot really be seen

-> CG is the foundation of Visualisation

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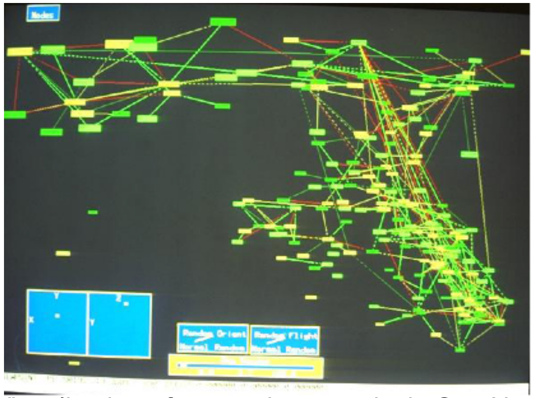
Computer Graphics - Examples

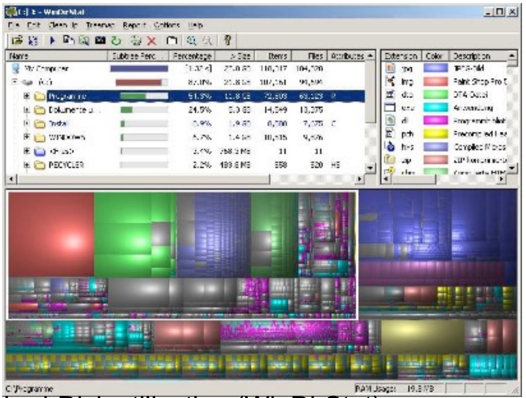
Simulate and visualise real things

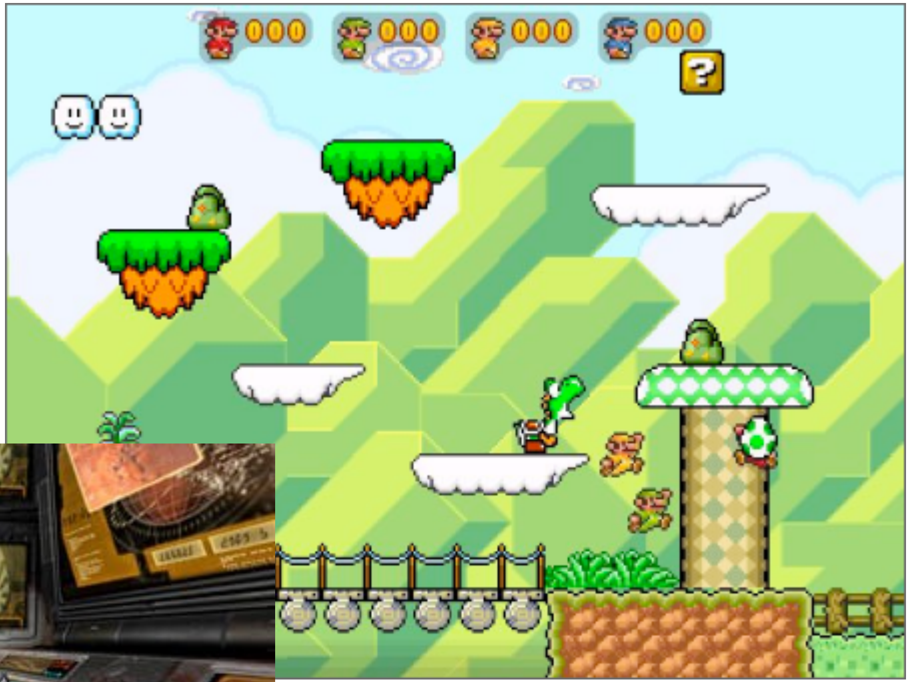

Interior design (Linus Karlsson, CCG 2011)


Interactive Games

Make visible what cannot really be seen


Visualisation of semantic networks in SemNet.


Hard-Disk utilization (WinDirStat)




40 137
57
50


The SIMS 3
WORLD-EXCLUSIVE FIRST LOOK!

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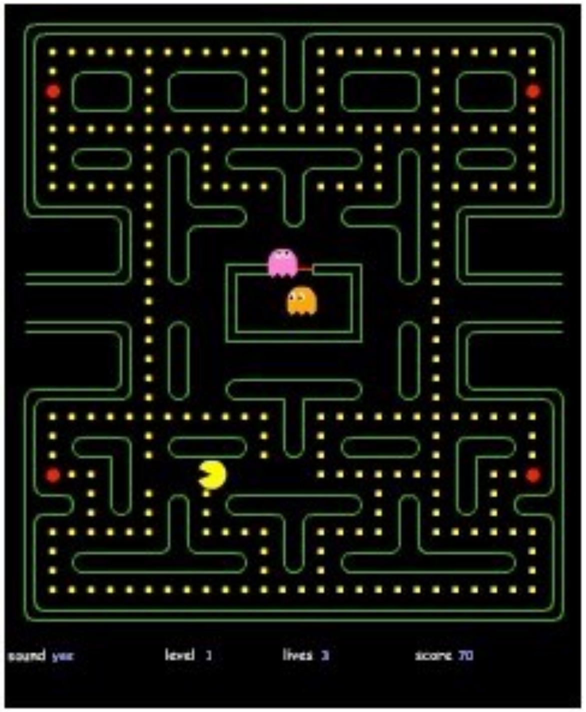

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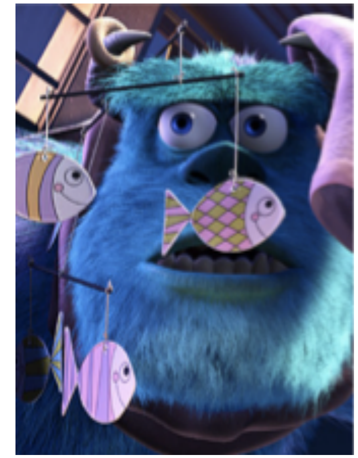

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Computer Graphics - Ingredients

What is needed to mimic photography i.e. to render images with a computer?

- Virtual objects: 3D models, geometry, material properties
- Virtual light sources: position, color, attenuation, etc.
- Virtual camera: position, direction, lens projection
- Illumination model: Rendering algorithms that model the propagation of light and its interaction with objects in the scene.

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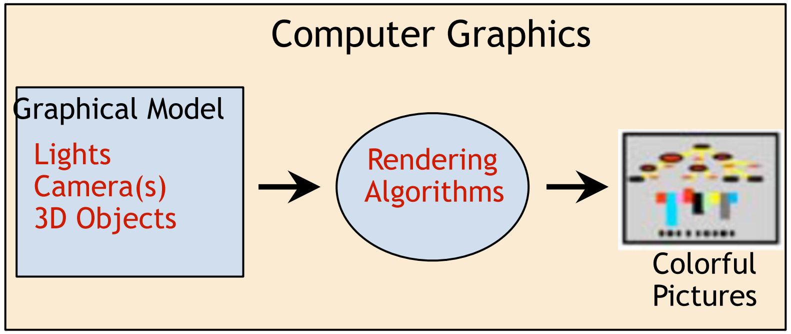
Computer Graphics & Visualisation

Graphical rendering is **one** pillar of Scientific/Information Visualisation



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Computer Graphics & Visualisation

Graphical rendering is **one** pillar of

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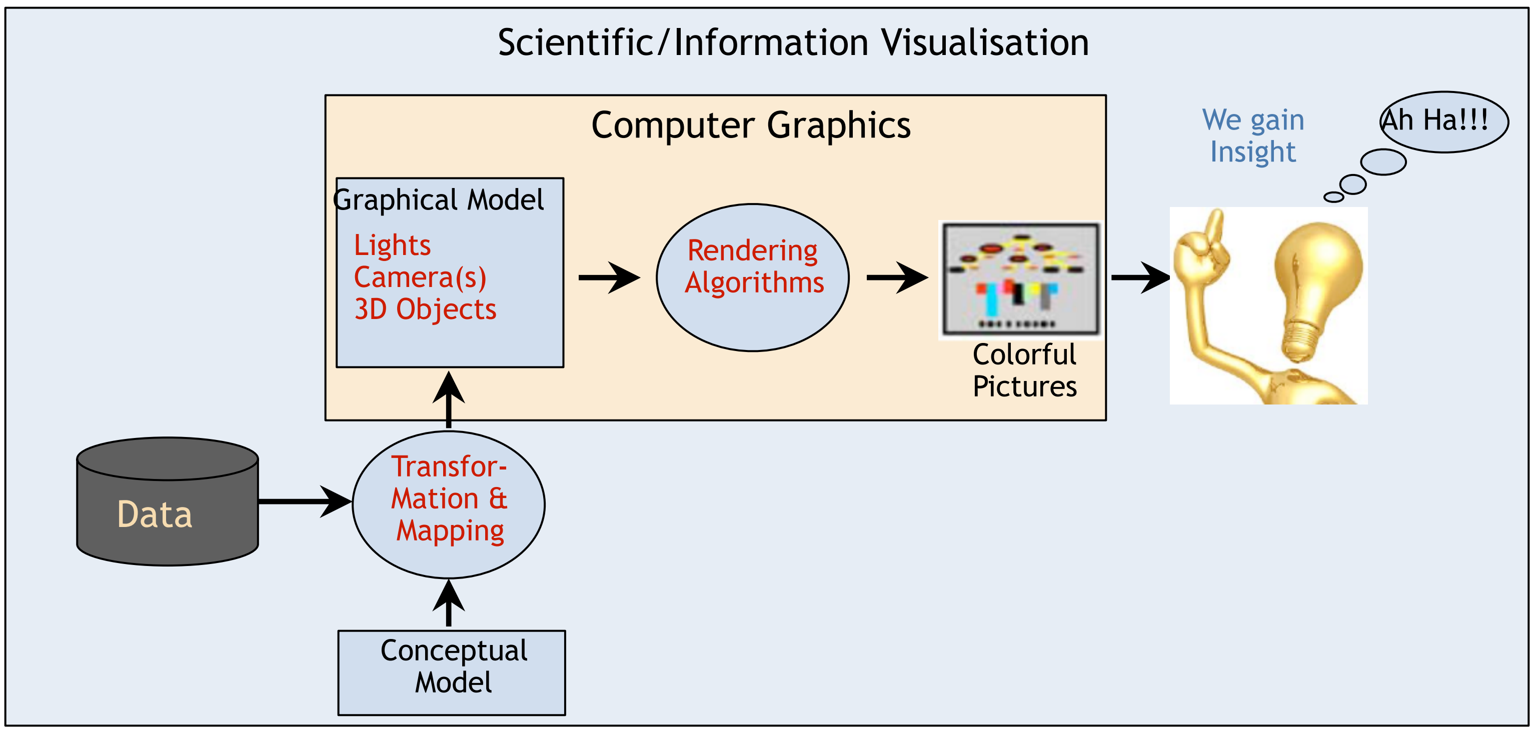

Visualisation is more than computer graphics !

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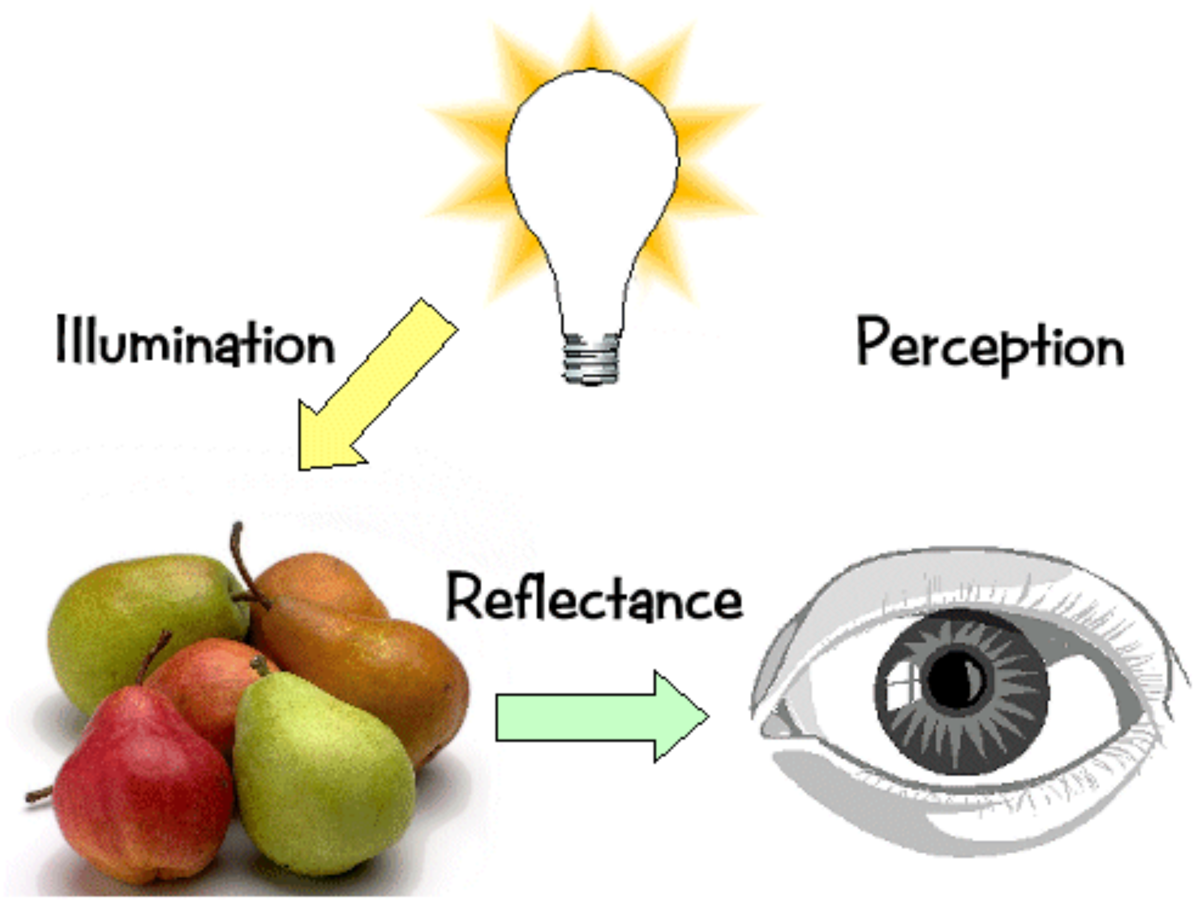
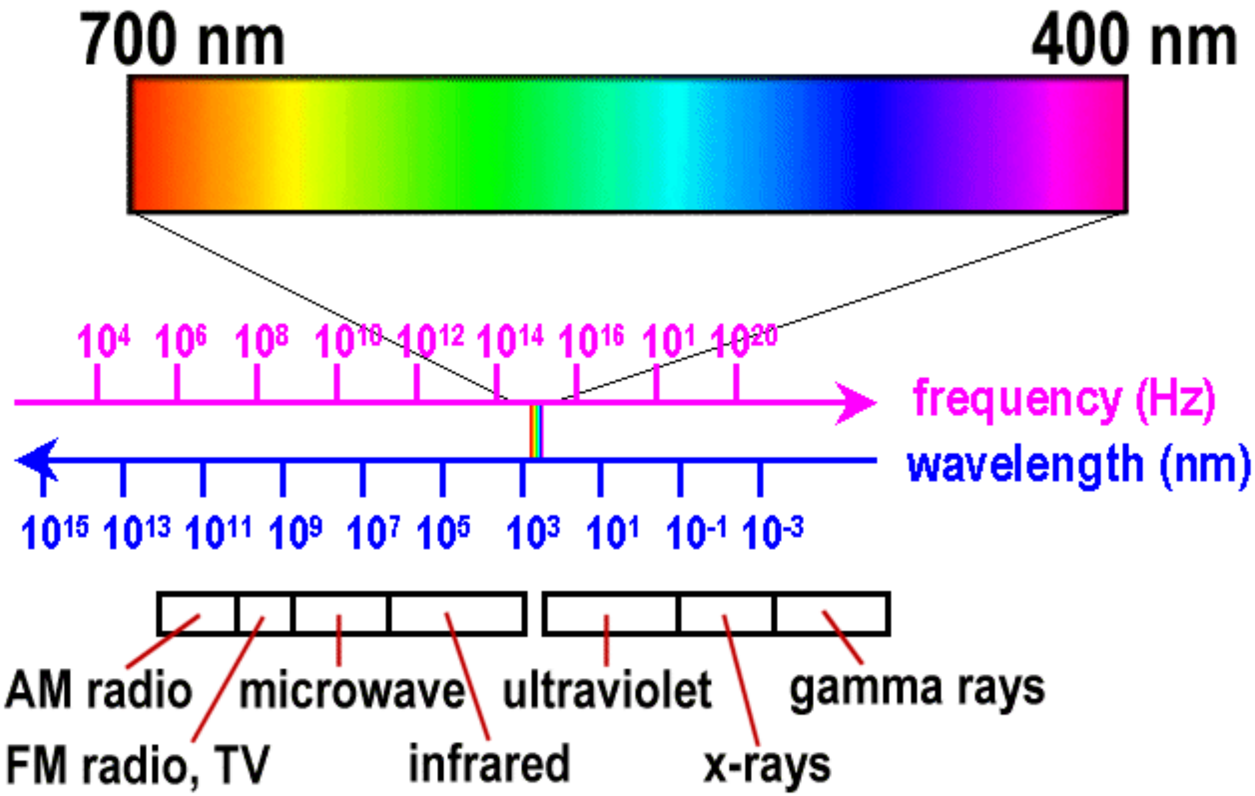
3.2 Elements of colour



Visible spectrum



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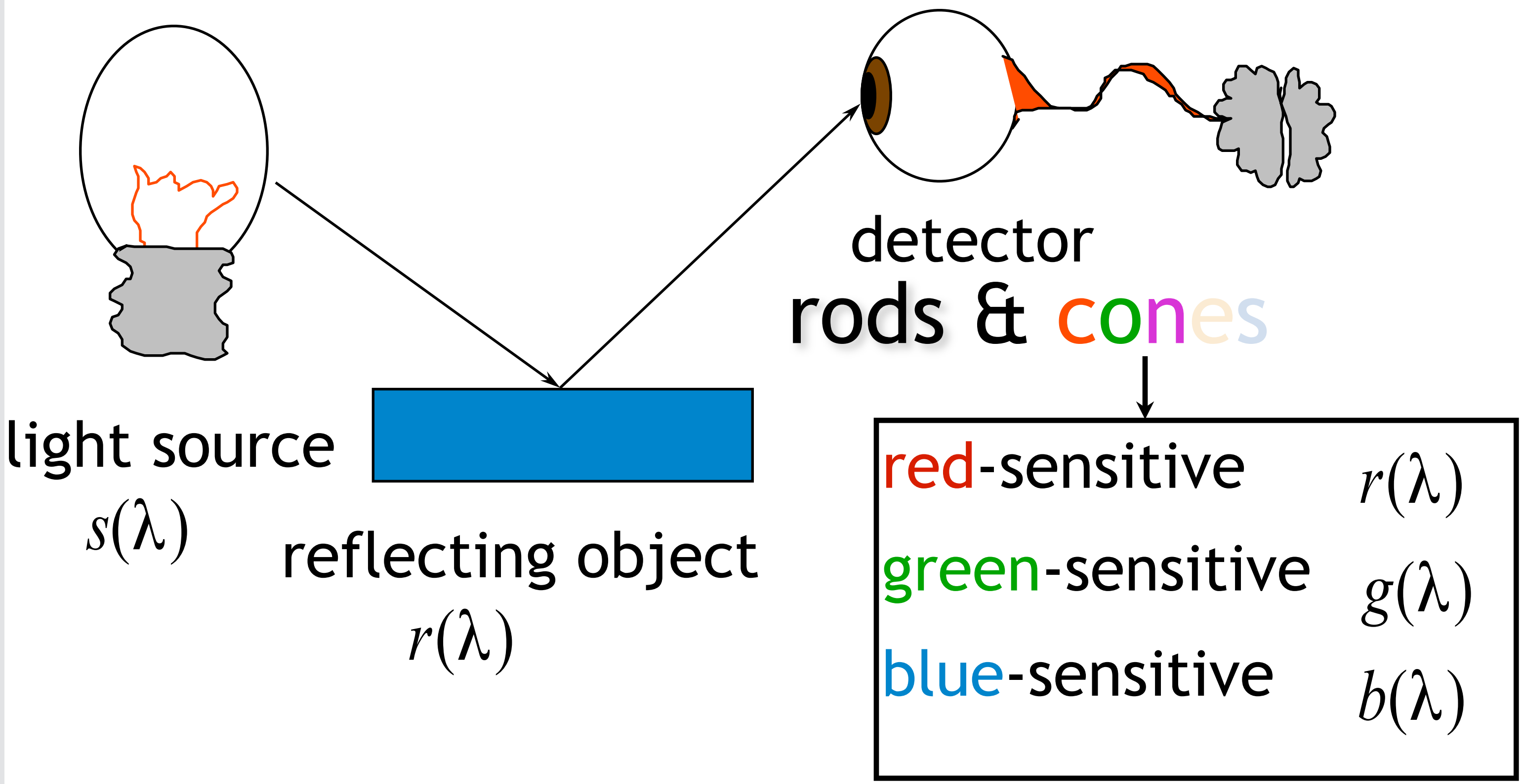
Colour

The eye's and the brain's impression of electromagnetic radiation in the visual spectra

How is colour perceived?



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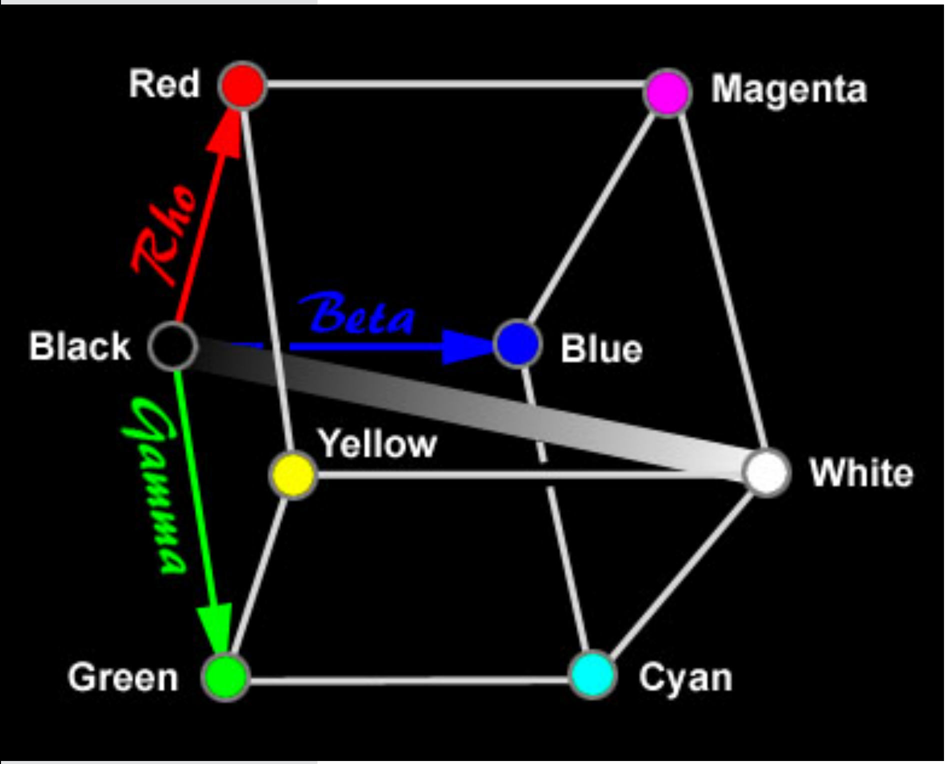
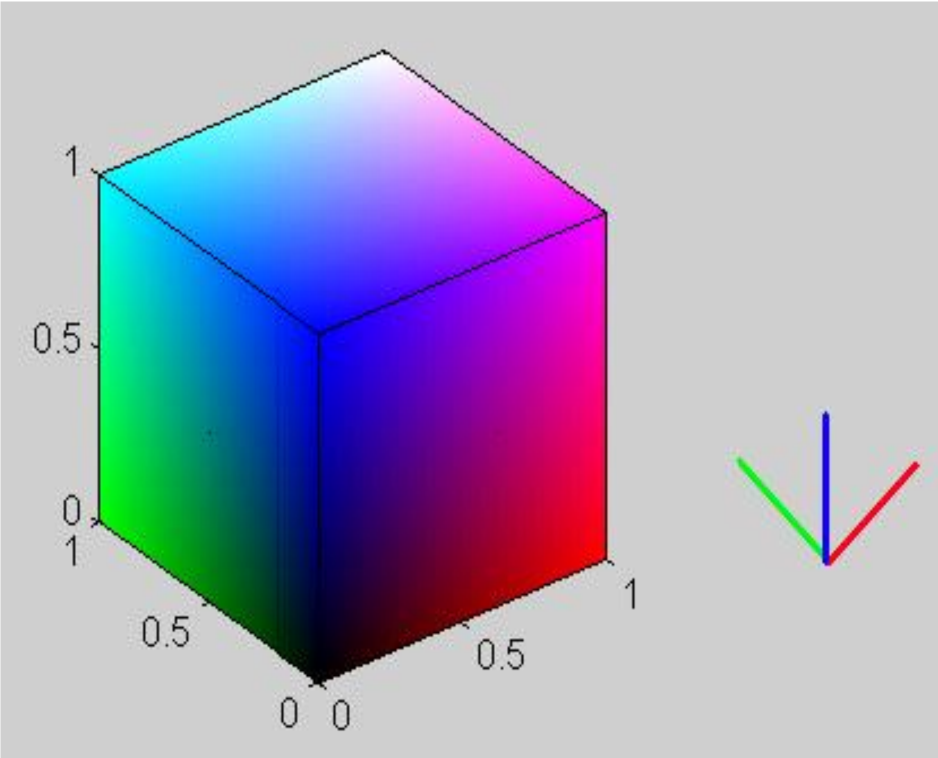
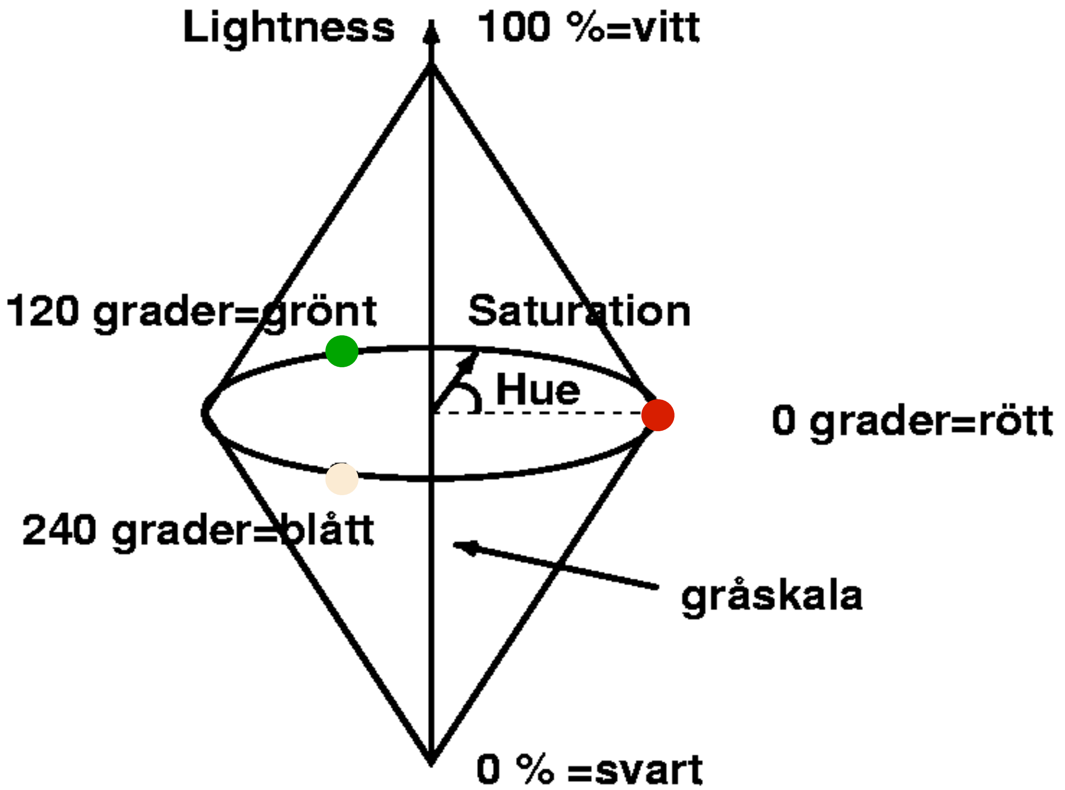
RGB color space

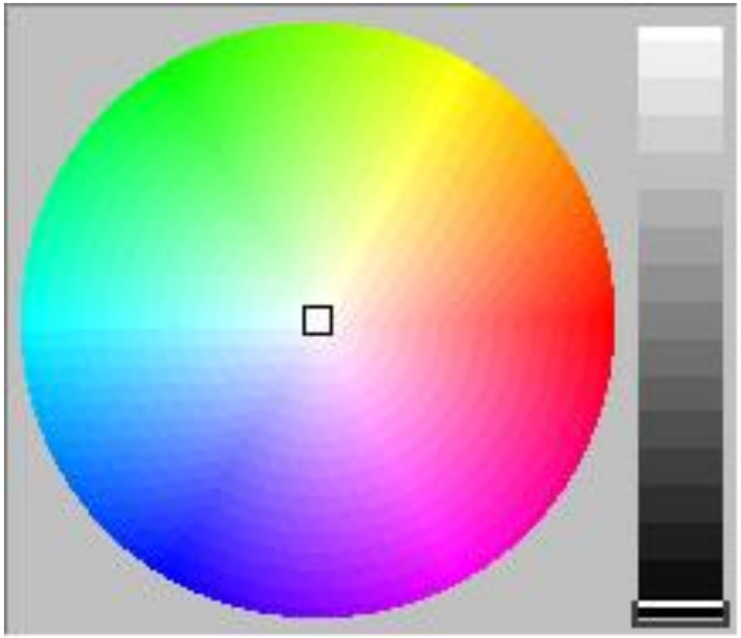




RGB - for additive colour mixing, e.g., on a computer screen

HLS colour space
Hue Lightness Saturation





Hue: dominant wavelength, tone
Lightness: intensity, brightness
Saturation: purity, dilution by white

Important aspects:
- Intensity decoupled from colour
- Related to how humans perceive colour

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Color angles for the hue

0°	= Red
60°	= Yellow
120°	= Green
180°	= Cyan
240°	= Blue
300°	= Magenta

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3.3 Lights

- Point Light: Light is emitted in all directions from a single point in space
- Parallel Light: One can simplify by assuming an infinitely distant point light source
  - Far distance implies parallel rays
- Intensity is constant compared to 1/ $distance^2$ relationship

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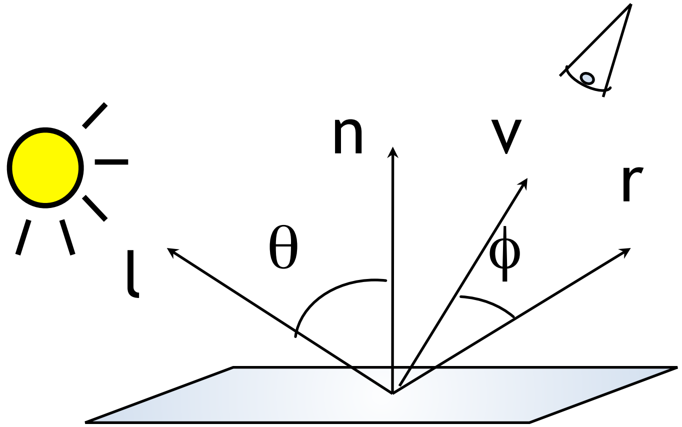
3.4 Surface properties

The Phong reflection model =

Ambient reflection +

Diffuse reflection +

Specular reflection



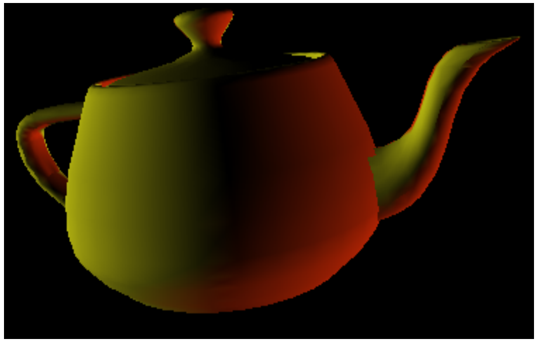
$$I = c_a + c_d(n \cdot l) + c_s(v \cdot r)^{specularity}$$

Putting it all together

$$I = c_a + c_d(n \cdot l) + c_s(v \cdot r)^{specularity}$$

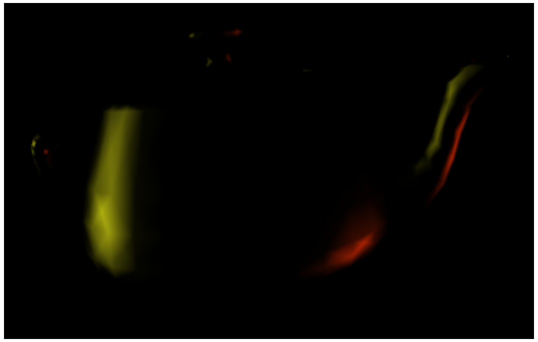
ambient

+



diffuse

+



specular

=>

composed color

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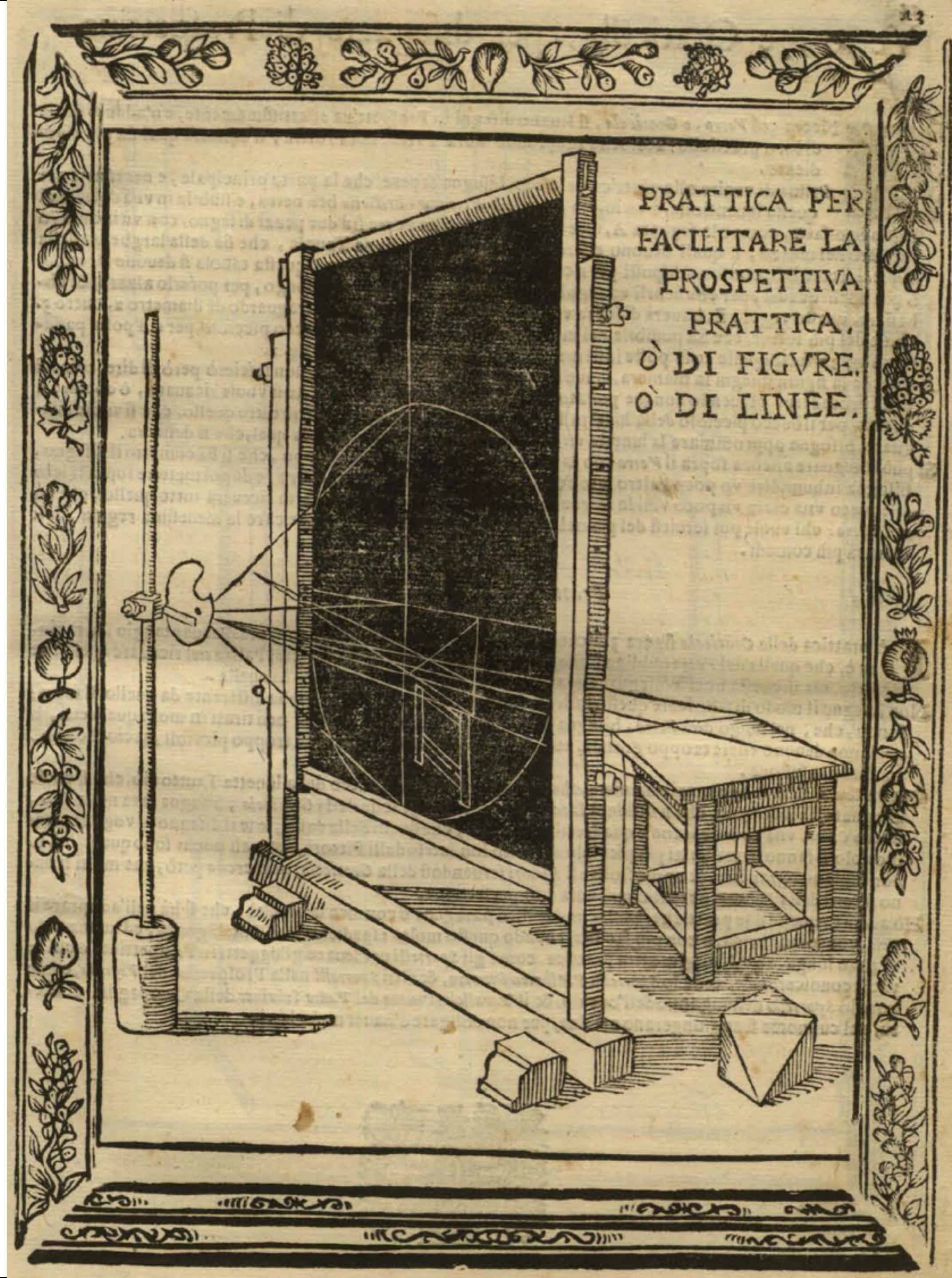

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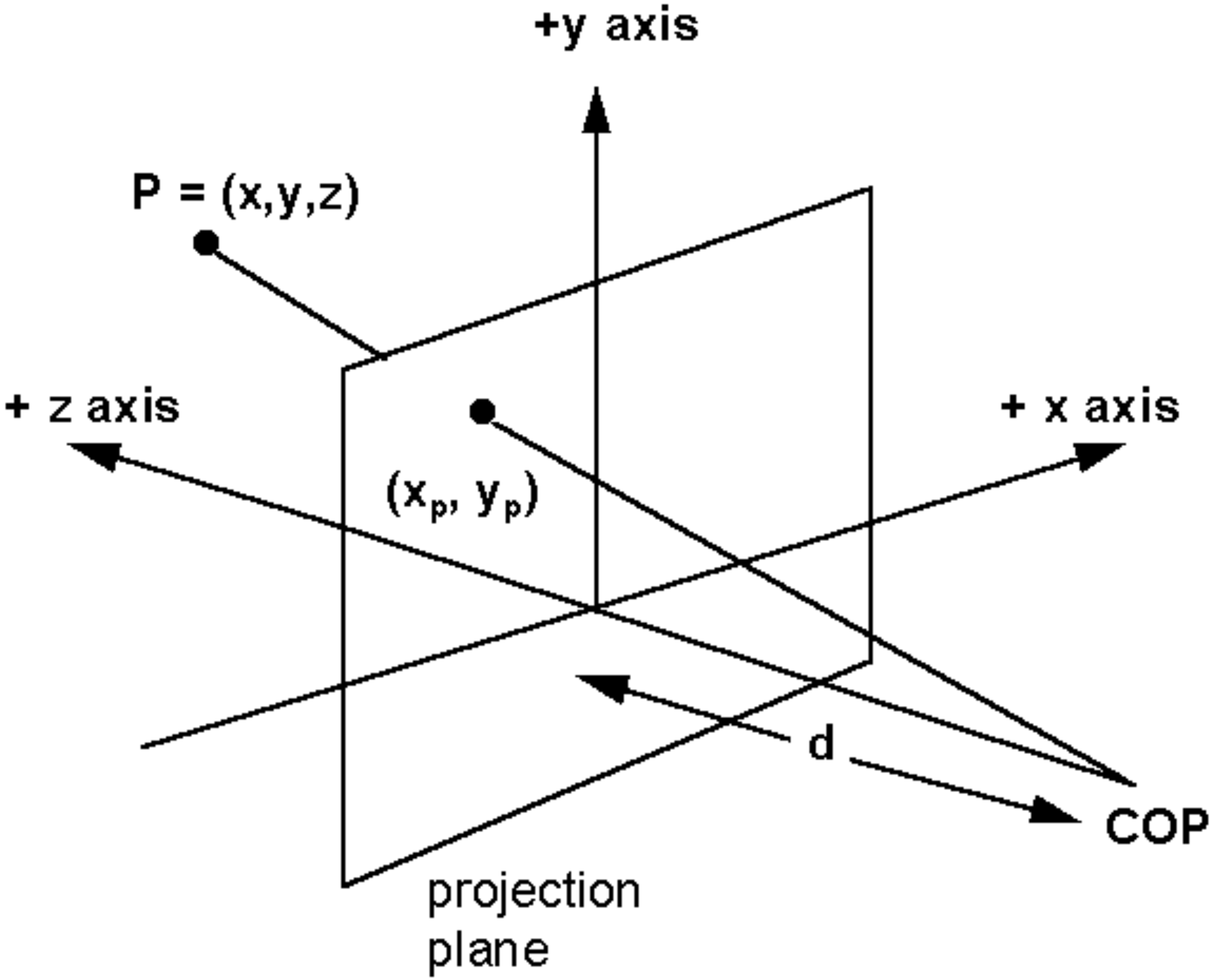

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3.5 Cameras

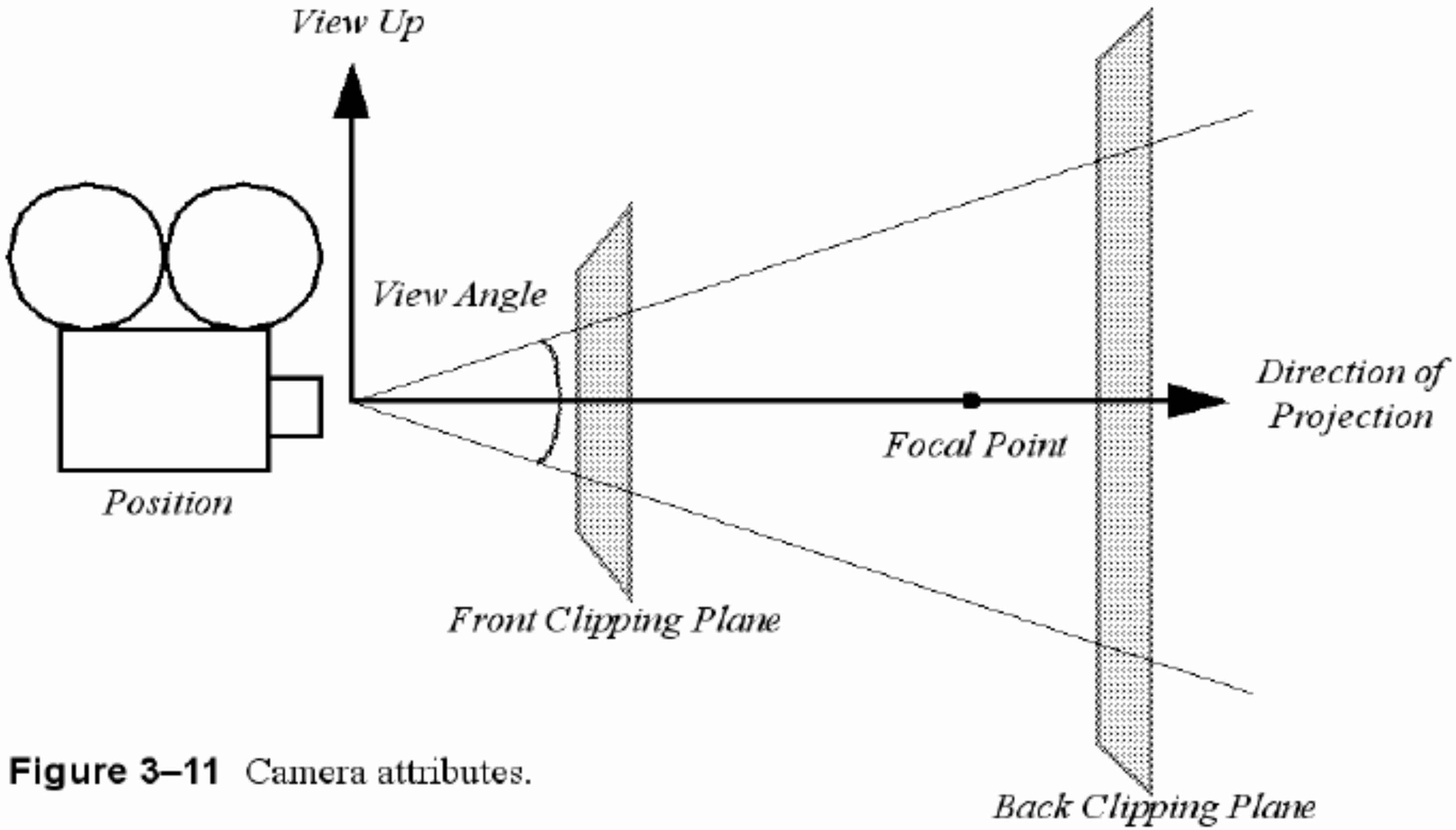

Figure 3–11 Camera attributes.

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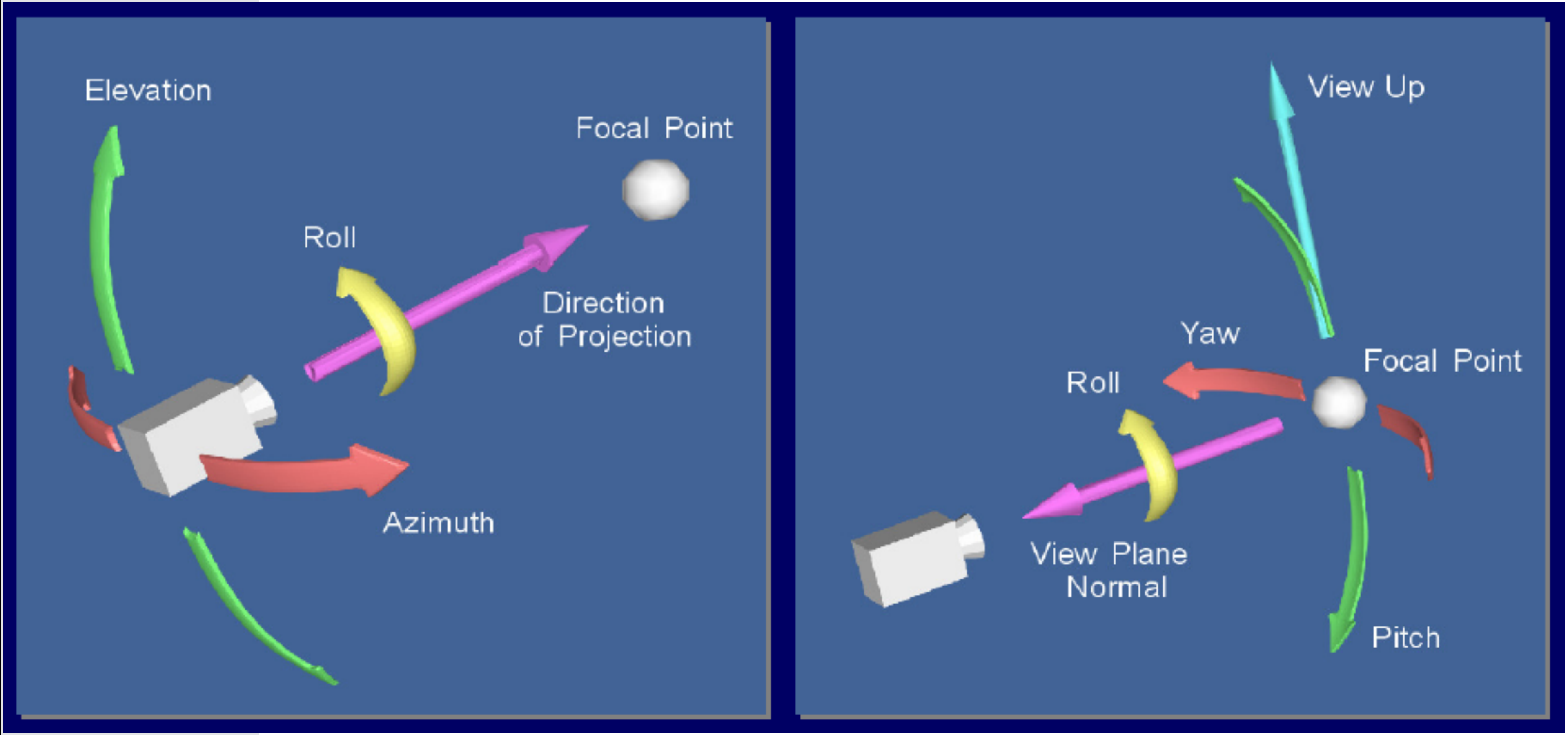
Camera movements



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3.6 Coordinate systems

4 coordinate systems

- Model: where the object is defined
- World: 3D space where actors are positioned
- View: what is visible to the camera
- Display: (x, y) pixel locations

See Figure 3-14

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3.7 Coordinate transformations

- 3D to 3D and 3D to 2D
- Homogeneous coordinates
- 4x4 transformation matrices
- Rotation, translation, scaling
- (Perspective) projection

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Coordinate transformations

○ Matrix-Vector Multiplication

Transformation represented as a $M_{n,k}$ where n=4, k=4.

The resulting matrix has n=4 rows and l=1 columns

$$P' = M \cdot P = \begin{bmatrix} m_{11} & m_{12} & m_{13} & m_{14} \\ m_{21} & m_{22} & m_{23} & m_{24} \\ m_{31} & m_{32} & m_{33} & m_{34} \\ m_{41} & m_{42} & m_{43} & m_{44} \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} m_{11}x + m_{12}y + m_{13}z + m_{14} \\ m_{21}x + m_{22}y + m_{23}z + m_{24} \\ m_{31}x + m_{32}y + m_{33}z + m_{34} \\ m_{41}x + m_{42}y + m_{43}z + m_{44} \end{bmatrix}$$

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Coordinate transformations

- Basic geometric transforms

Scale

$$\mathbf{S} = \begin{bmatrix} S_x & 0 & 0 \\ 0 & S_y & 0 \\ 0 & 0 & S_z \end{bmatrix}$$

Translation

Doesn't work…

Rotations

$$\mathbf{R_x} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix}$$

$$\mathbf{R_y} = \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix}$$

$$\mathbf{R_z} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

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Coordinate transformations

- Homogenous Coordinates!

Scale

$$\mathbf{S} = \begin{bmatrix} S_x & 0 & 0 & 0 \\ 0 & S_y & 0 & 0 \\ 0 & 0 & S_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Translation

$$\mathbf{T} = \begin{bmatrix} 1 & 0 & 0 & d_x \\ 0 & 1 & 0 & d_y \\ 0 & 0 & 1 & d_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Rotations

$$\mathbf{R_z} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

etc…

Vector

$$\mathbf{v} = (x, y, z, 0)$$

Point

$$\mathbf{p} = (x, y, z, 1)$$

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Coordinate transformations

- Projective transform (3D -> 2D) (x,y,z,1) -> (x_p,y_p,const,1)

Perspective Projection Matrix:

$$P = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 1/d & 0 \end{pmatrix}$$

Vertex (normalized homogenous coordinates):

$$V = (x, y, z, 1)$$

Vertex projection:

$$V' = P \times V = (x, y, z, z/d)$$

Vertex normalization:

$$V_N' = \left(\frac{x}{z/d}, \frac{y}{z/d}, d, 1\right)$$

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3.9 Rasterisation (scan conversion)

Converting a explicit geometric representation into raster image

Primitives: Point, Line, Polyline, Polygon, Triangle Strip

e.g. Line drawing

DDA – digital differential analyzer

(Bresenham algorithm)

e.g. Polygon filling

Flood filling

Scan conversion

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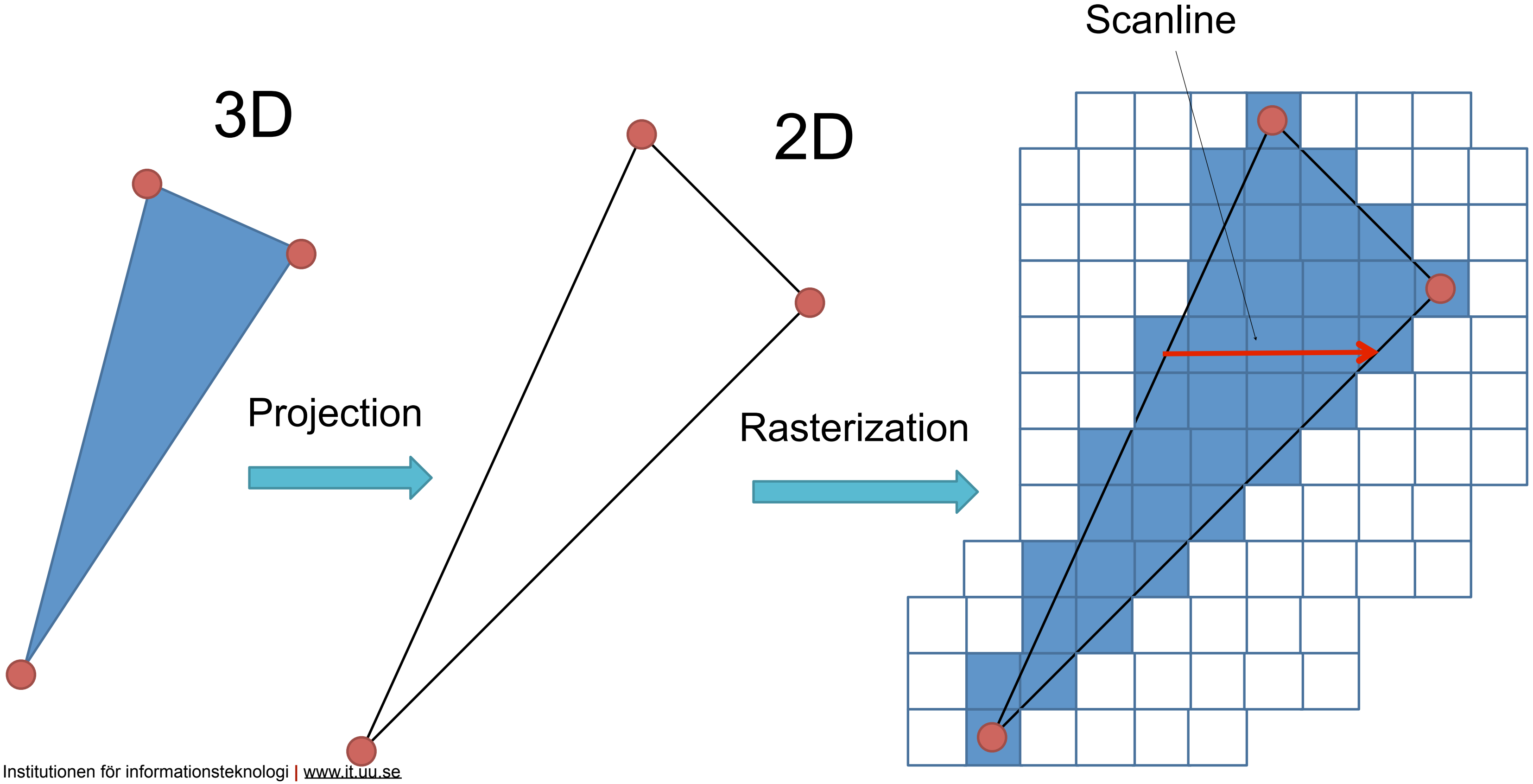
Rasterization

- Pixel colour is set in a scanline fashion



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Polygonal shading

Various shading modes differ in how often the illumination equation is evaluated during rasterization!

$$I = c_a + c_d(n \cdot l) + c_s(v \cdot r)^{specularity}$$

Flat
Per polygon

Gouraud
Per vertex

Phong
Per pixel

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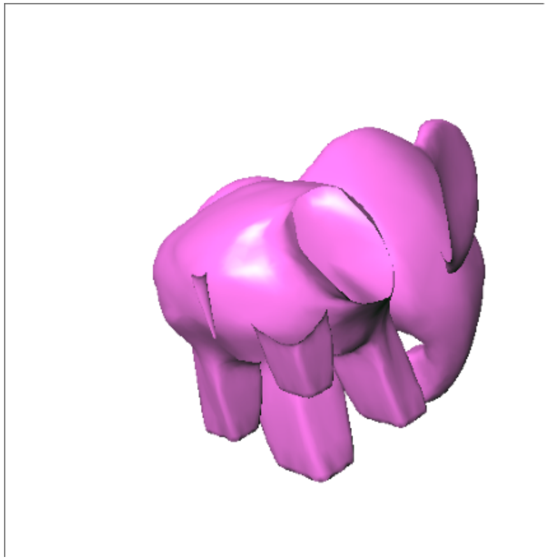
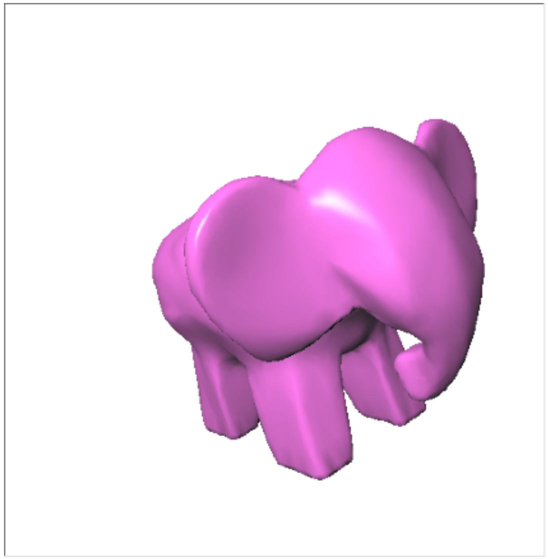
Hidden Surface Removal (HSR)





Same object (polygons), shading and and perspective,
but different appearance

Incorrect occlusion occurs if graphical primitives are rasterized

* in arbitrary order

* without visibility control

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z-buffer algorithm

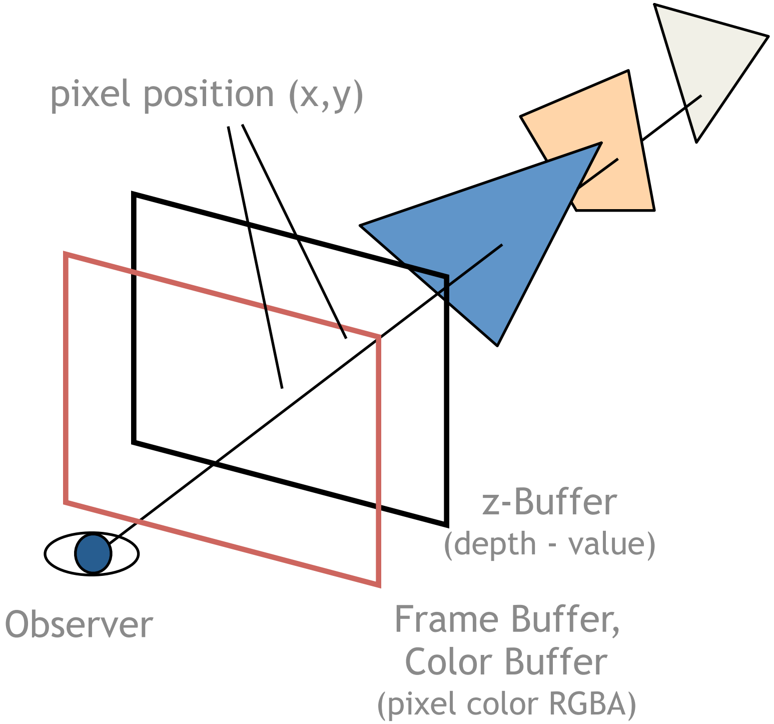
z-Buffer Algorithm: Image space hidden surface algorithm -> it maintains **visibility control per pixel.**

Objects are rendered without specific order

Depth test is performed in the rasterization process for every pixel

z-Buffer stores the closest distance of an object that has been drawn at pixel position (x,y)

Maintains correct occlusion



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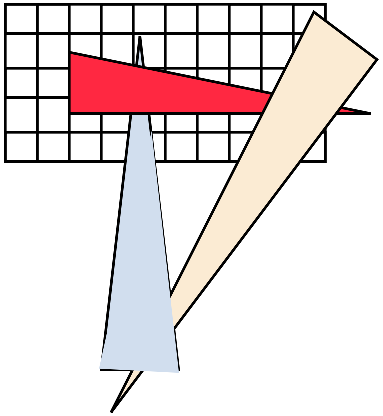
z-buffer algorithm (Ed Catmull)

```
fill z-buffer with infinite distance
for all polygons
   for each pixel
      calculate z-value
      if z(x,y) is closer than z-buffer(x,y)
         draw pixel
         z-buffer(x,y)=z(x,y)
      end
   end
end
```



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Conclusion

Visualisation helps to understand the data and get insight on the data

It also is a tool to discover the data and find “hidden truths” in the data

Visualisation use Computer Graphics