# Scientific Visualization and Virtual Reality

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# Structure of this course

- Lectures
- Paper presentations (P)
- Visualization ~~project~~ assignments (V)

your grade = 0.25*P + 0.75*V

# Lectures

- Monday 11:00-13:00 in G2.02
- Wednesday 15:00-17:00 in C1.112

Except Wednesday December 10:
Demos at SURFsara
Collaboratorium

# Preliminary lecture program

- Introduction to Scientific Visualization
- Scientific Visualization I
- Scientific Visualization II
- Visualization of (bio-)medical data
- Virtual/Augmented Reality Environments
- Student lectures on seminal papers in Scientific Visualization and Virtual Reality

# Blackboard

- “Course Documents” →
  - “Lecture Papers”: papers to read for this course
    - Two in there now, so start reading!
  - “Lecture sheets”: sheets presented at lecture
    - Available after each lecture
  - “Visualization Project”: documentation for projects
  - Papers to read for student presentations
- Assignments
- Announcements

# Visualization ~~project~~ assignments

See Blackboard:
“Course Documents” → “Visualization Project”

- Read “ParaView tutorial” and “VTK Tutorial”

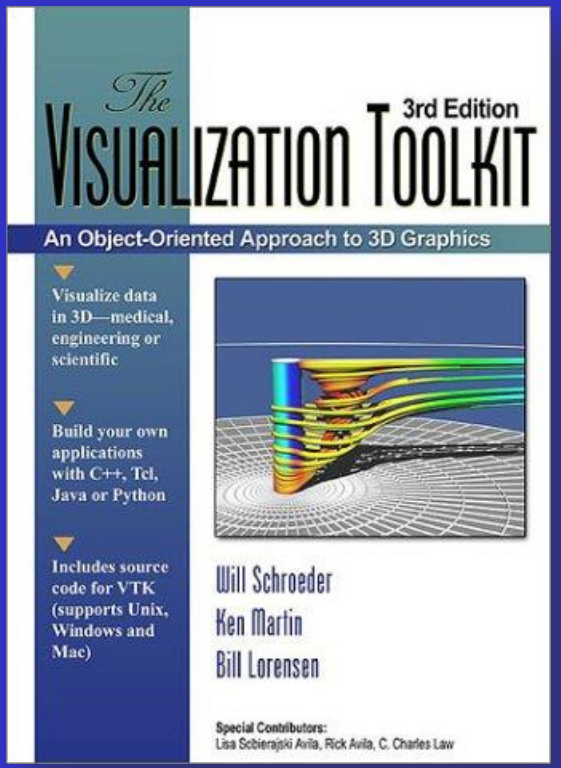
- More information during next lecture.

# Course material

- Papers on Blackboard

- The visualization Toolkit: An Object-Oriented Approach to 3D Graphics.
  W. Schroeder, K. Martin and B. Lorensen,
  Kitware Inc. publishers

  http://www.vtk.org/VTK/help/book.html



# Scientific Visualization: an introduction

# Overview

- Visualization of information and scientific data
- Applications
- Visualization architectures

# Visualization

- Visual representation of information
  - Effective communication of information
  - Clear and with integrity
  - Stimulate engagement


Image source: http://affirmyourlife.blogspot.com/2009/08/visualization-affirmations.html

# Visualization

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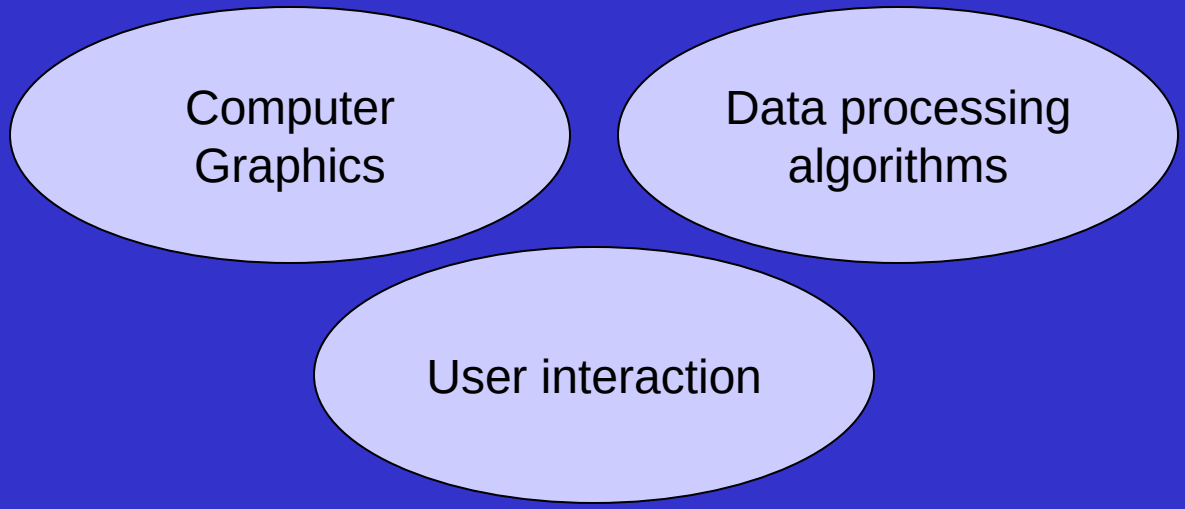

| X | Y | X | Y | X | Y | X | Y |
|---|---|---|---|---|---|---|---|
| 10,00 | 8,04 | 10,00 | 9,14 | 10,00 | 7,46 | 8,00 | 6,58 |
| 8,00 | 6,95 | 8,00 | 8,14 | 8,00 | 6,77 | 8,00 | 5,76 |
| 13,00 | 7,58 | 13,00 | 8,74 | 13,00 | 12,74 | 8,00 | 7,71 |
| 9,00 | 8,81 | 9,00 | 8,77 | 9,00 | 7,11 | 8,00 | 8,84 |
| 11,00 | 8,33 | 11,00 | 9,26 | 11,00 | 7,81 | 8,00 | 8,47 |
| 14,00 | 9,96 | 14,00 | 8,10 | 14,00 | 8,84 | 8,00 | 7,04 |
| 6,00 | 7,24 | 6,00 | 6,13 | 6,00 | 6,08 | 8,00 | 5,25 |
| 4,00 | 4,26 | 4,00 | 3,10 | 4,00 | 5,39 | 19,00 | 12,50 |
| 12,00 | 10,84 | 12,00 | 9,11 | 12,00 | 8,15 | 8,00 | 5,56 |
| 7,00 | 4,82 | 7,00 | 7,26 | 7,00 | 6,42 | 8,00 | 7,91 |
| 5,00 | 5,68 | 5,00 | 4,74 | 5,00 | 5,73 | 8,00 | 6,89 |

A B C D

“Anscombe’s quartet”, F.J. Anscombe, “Graphs in Statistical Analysis”, American Statistician, 27 (February 1973), 17-21.

| X | Y | X | Y | X | Y | X | Y |
|---|---|---|---|---|---|---|---|
| 10,00 | 8,04 | 10,00 | 9,14 | 10,00 | 7,46 | 8,00 | 6,58 |
| 8,00 | 6,95 | 8,00 | 8,14 | 8,00 | 6,77 | 8,00 | 5,76 |
| 13,00 | 7,58 | 13,00 | 8,74 | 13,00 | 12,74 | 8,00 | 7,71 |
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| 14,00 | 9,96 | 14,00 | 8,10 | 14,00 | 8,84 | 8,00 | 7,04 |
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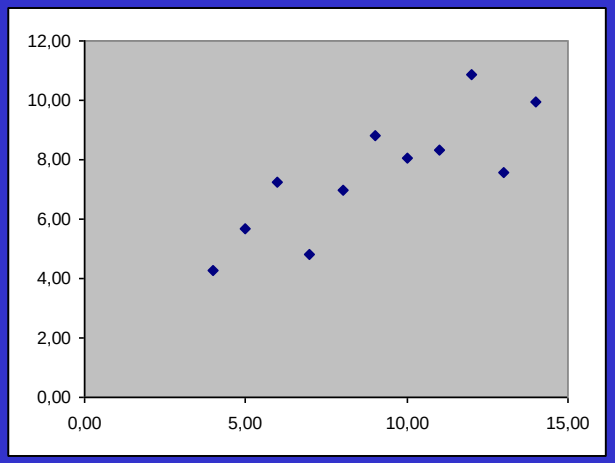
A B C D

$\mu_x = 9.00$, $\sigma_x = 3.32$
$\mu_y = 7.50$, $\sigma_y = 2.03$
linear regression: $y = \frac{1}{2}x + 3$

“Anscombe’s quartet”, F.J. Anscombe, “Graphs in Statistical Analysis”, American Statistician, 27 (February 1973), 17-21.

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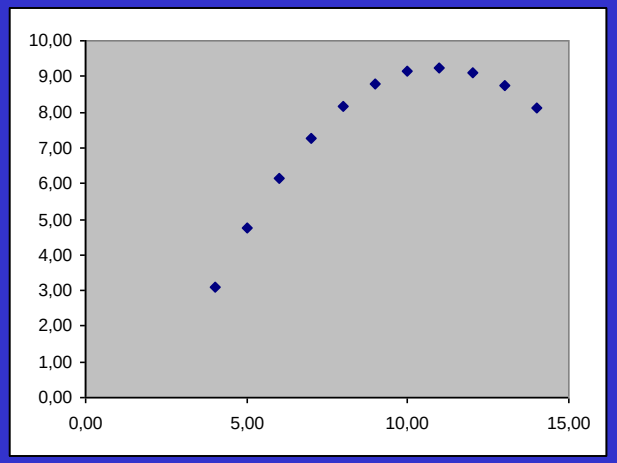
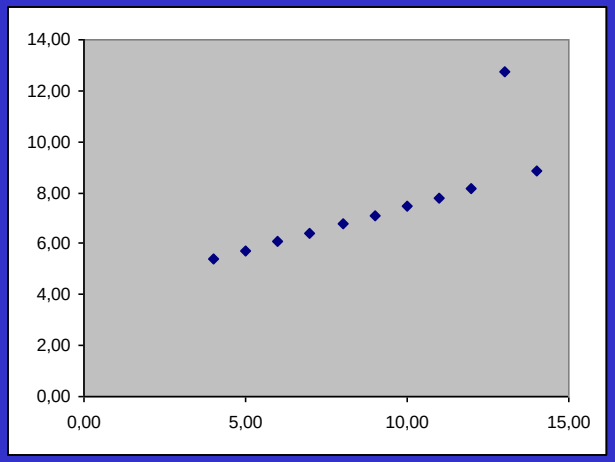
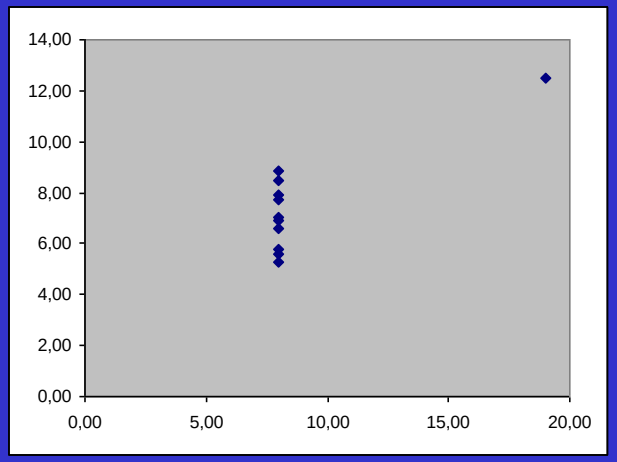



B




C

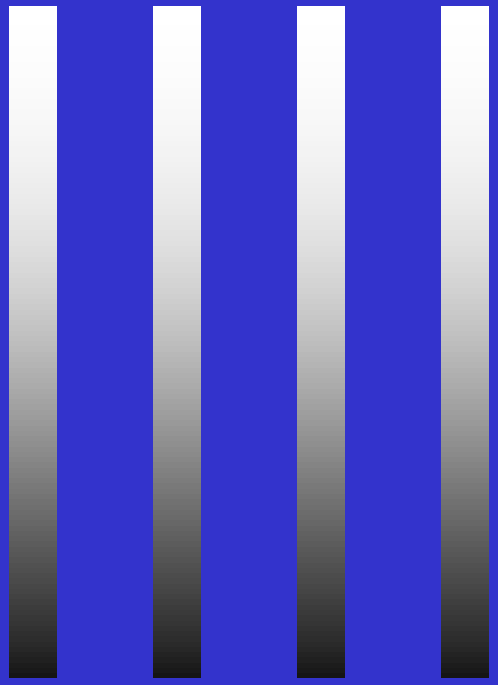



D

“Anscombe’s quartet”, F.J. Anscombe, “Graphs in Statistical Analysis”, American Statistician, 27 (February 1973), 17-21.

# Visualization …

- … helps researchers see patterns in data
- … a balance between science and design
- … done incorrectly, it can hurt understanding



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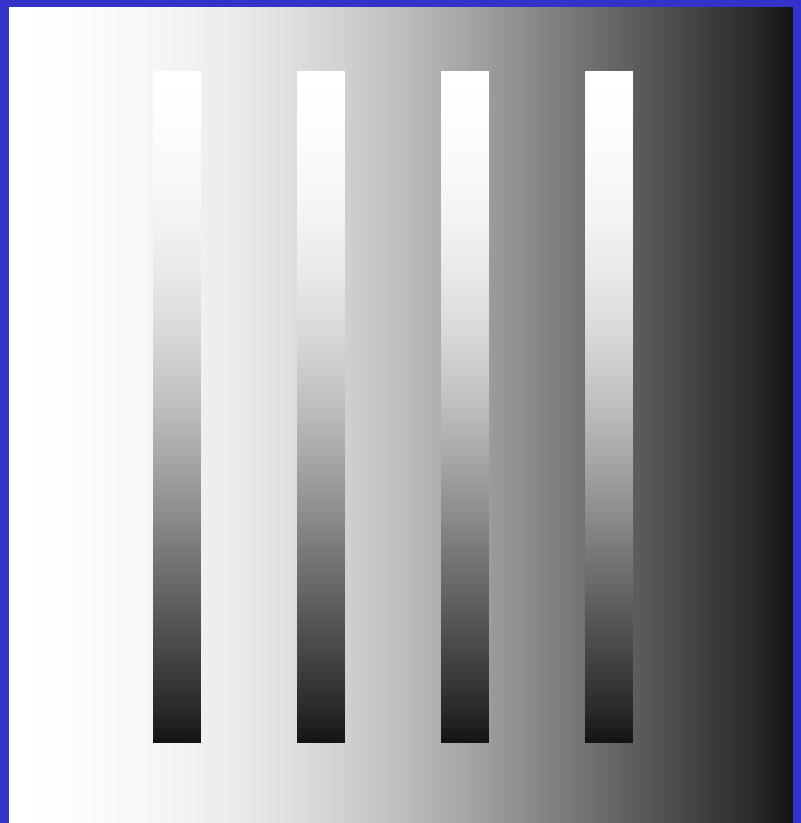
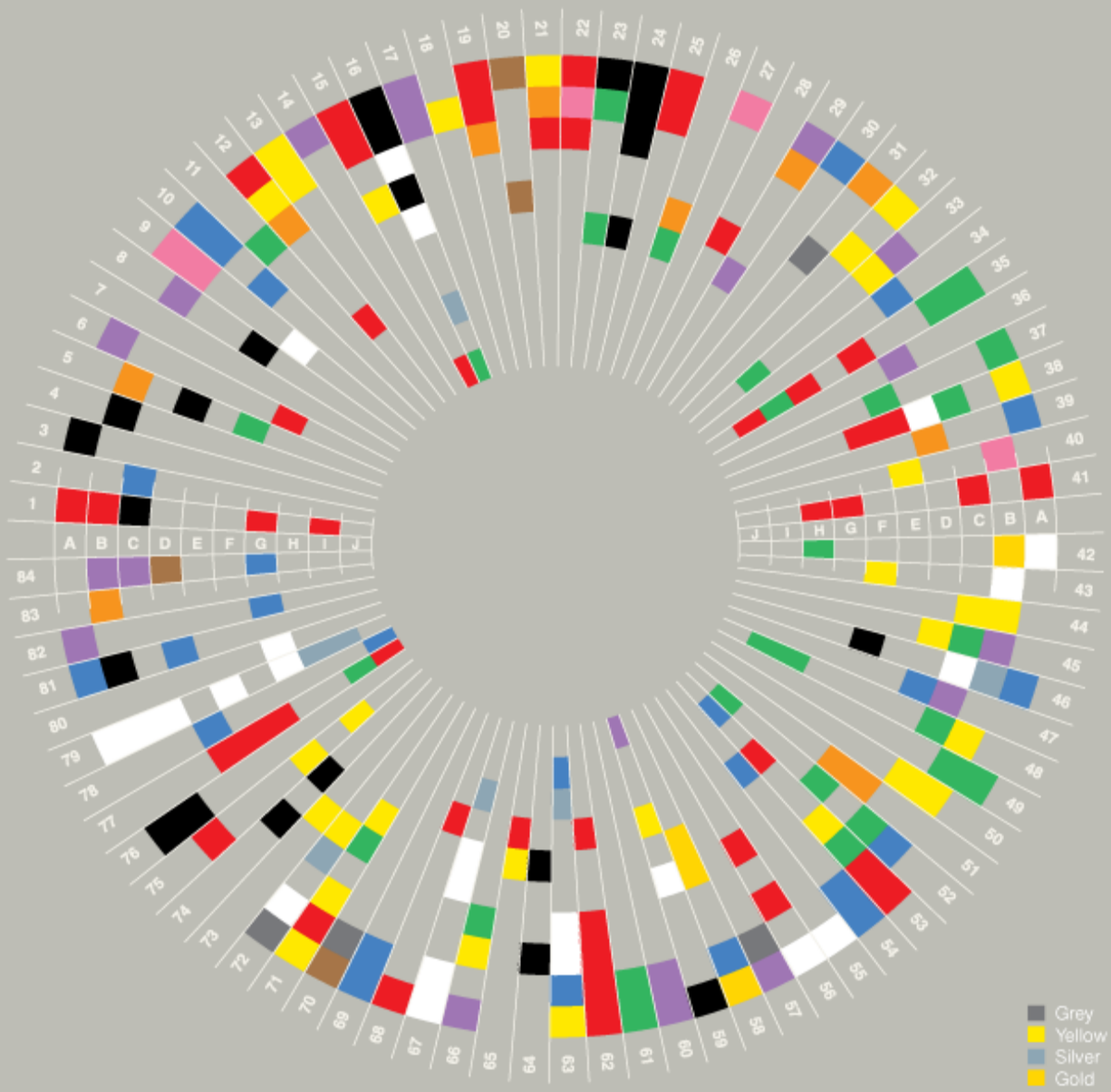


# Colours In Culture




| | |
|---|---|
| A | Western / American |
| B | Japanese |
| C | Hindu |
| D | Native American |
| E | Chinese |
| F | Asian |
| G | Eastern European |
| H | Muslim |
| I | African |
| J | South American |

| | |
|---|---|
| 1 | Anger |
| 2 | Art / Creativity |
| 3 | Authority |
| 4 | Bad Luck |
| 5 | Balance |
| 6 | Beauty |
| 7 | Calm |
| 8 | Celebration |
| 9 | Children |
| 10 | Cold |
| 11 | Compassion |
| 12 | Courage |
| 13 | Cowardice |
| 14 | Cruelty |
| 15 | Danger |
| 16 | Death |
| 17 | Decadence |
| 18 | Deceit |
| 19 | Desire |
| 20 | Earthy |
| 21 | Energy |
| 22 | Erotic |
| 23 | Eternity |
| 24 | Evil |
| 25 | Excitement |
| 26 | Family |
| 27 | Femininity |
| 28 | Fertility |
| 29 | Flamboyance |
| 30 | Freedom |
| 31 | Friendly |
| 32 | Fun |
| 33 | God |
| 34 | Gods |
| 35 | Good Luck |
| 36 | Gratitude |
| 37 | Growth |
| 38 | Happiness |
| 39 | Healing |
| 40 | Healthy |
| 41 | Heat |
| 42 | Heaven |
| 43 | Holiness |
| 44 | Illness |
| 45 | Insight |
| 46 | Intelligence |
| 47 | Intuition |
| 48 | Religion |
| 49 | Jealousy |
| 50 | Joy |
| 51 | Learning |
| 52 | Life |
| 53 | Love |
| 54 | Loyalty |
| 55 | Luxury |
| 56 | Marriage |
| 57 | Modesty |
| 58 | Money |
| 59 | Mourning |
| 60 | Mystery |
| 61 | Nature |
| 62 | Passion |
| 63 | Peace |
| 64 | Penance |
| 65 | Power |
| 66 | Personal power |
| 67 | Purity |
| 68 | Radicalism |
| 69 | Rational |
| 70 | Reliable |
| 71 | Repels Evil |
| 72 | Respect |
| 73 | Royalty |
| 74 | Self-cultivation |
| 75 | Strength |
| 76 | Style |
| 77 | Success |
| 78 | Trouble |
| 79 | Truce |
| 80 | Trust |
| 81 | Unhappiness |
| 82 | Virtue |
| 83 | Warmth |
| 84 | Wisdom |



source: Pantone, ColorMatters & web sources

# Visualization taxonomy

- **Scientific visualization** (“scivis” or “datavis”)
  - Data with an implicit or explicit geometric structure
    - Measurements, results from simulations or experiments
- **Information visualization** (“infovis” or “infographics”)
  - Data with an abstract structure
    - Relations, data structures, databases
- **Visual analytics**
  - Interactive environments for the detection of the expected and discovery of the unexpected

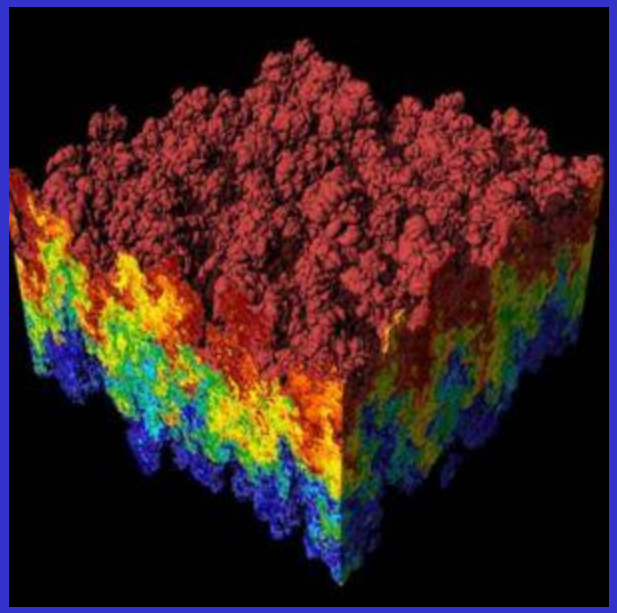
# Scientific visualization

- Scientific visualization deals with all aspects that are connected with the visual representation of data sets from scientific experiments or simulations to achieve a deeper understanding or a simpler representation of complex phenomena.

Martin Rotard, Daniel Weiskopf, and Thomas Ertl, *Curriculum for a Course on Scientific Visualization*, Eurographics / ACM SIGGRAPH Workshop on Computer Graphics Education (2004)

# Scientific visualization

Scientific visualization is concerned with exploring data and information visually to gain understanding and insight.



*A scientific visualization of an extremely large simulation of a Raleigh-Taylor instability caused by two mixing fluids.*

"Using the computer to display real-world objects that cannot normally be seen, such as the shapes of molecules, air and fluid dynamics and weather patterns. Scientific visualization requires enormous computing resources, and the supercomputer centers and national laboratories throughout the world are always at the forefront of such activity."

Computer Desktop Encyclopedia

# Scientific visualization

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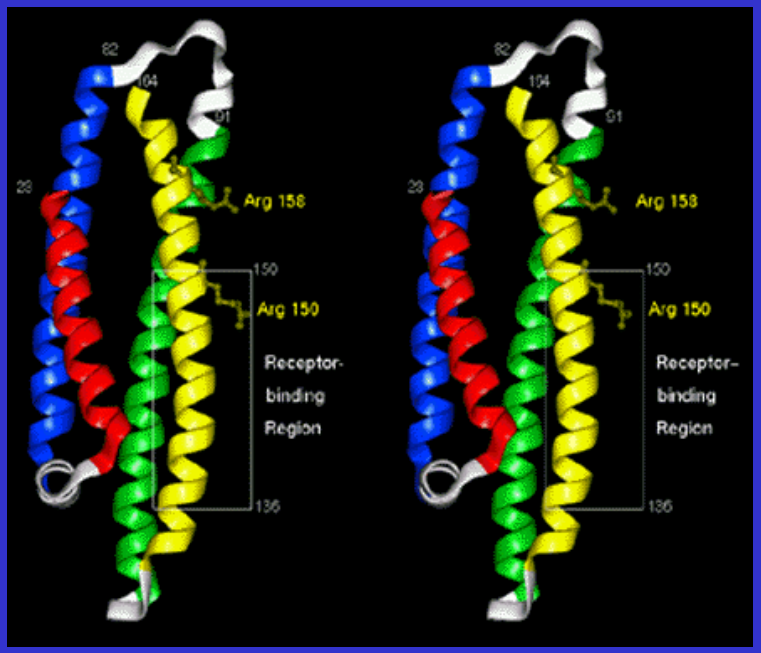
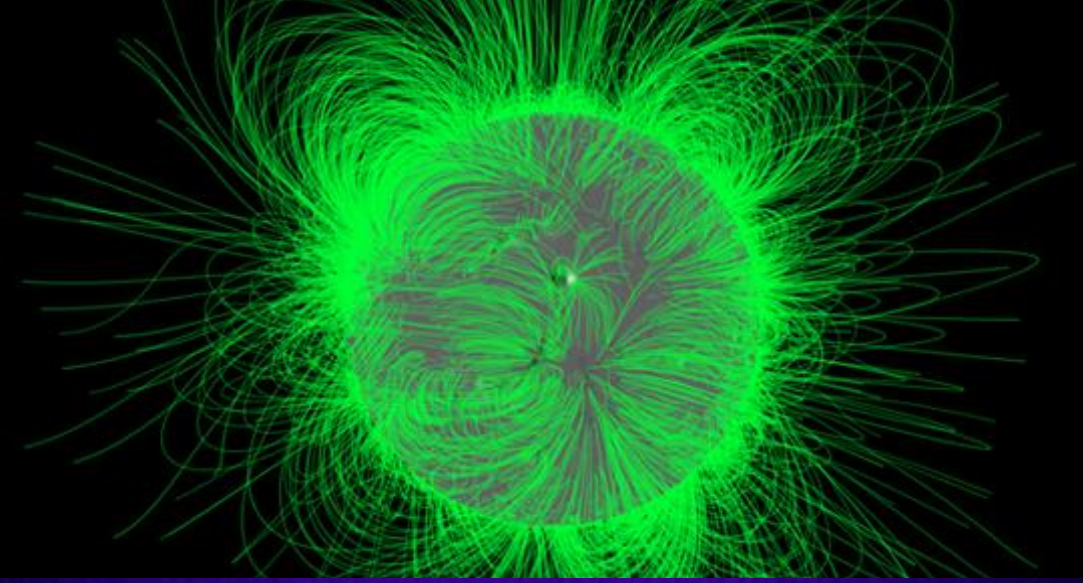
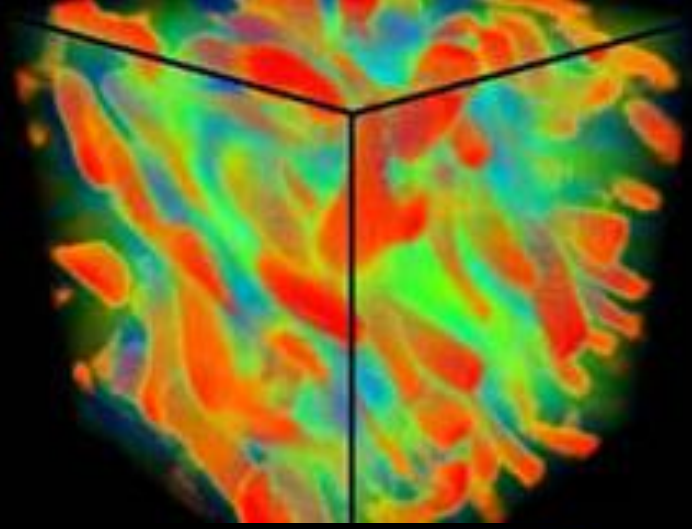


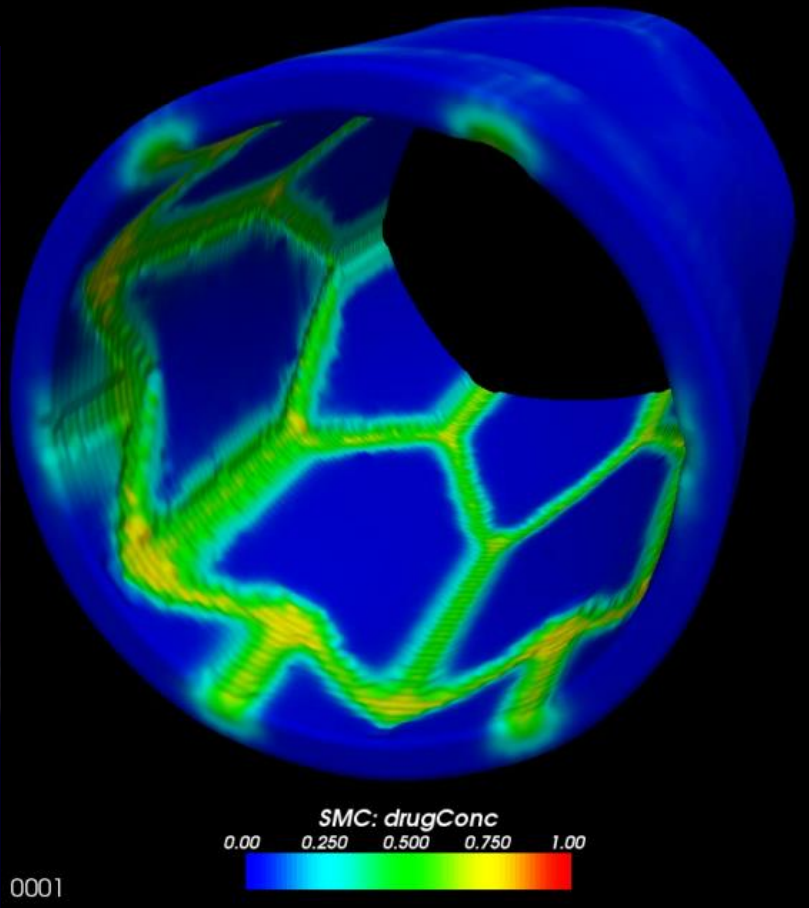

*3D four-helix bundle structure of the molecule is represented as a ribbon model. The 3D image of this molecule helps researchers better understand it and its interaction with other molecules.*

"Process of graphically displaying real or simulated scientific data. It is a vital procedure in the creative realization of scientific ideas, particularly in computer science. Basic visualization techniques include surface rendering, volume rendering, and animation. High-performance workstations or supercomputers are used to show simulations, and high-level programming languages are being developed to support visualization programming. Scientific visualization has applications in biology, business, chemistry, computer science, education, engineering, and medicine."

Britannica Concise Encyclopedia



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1.00
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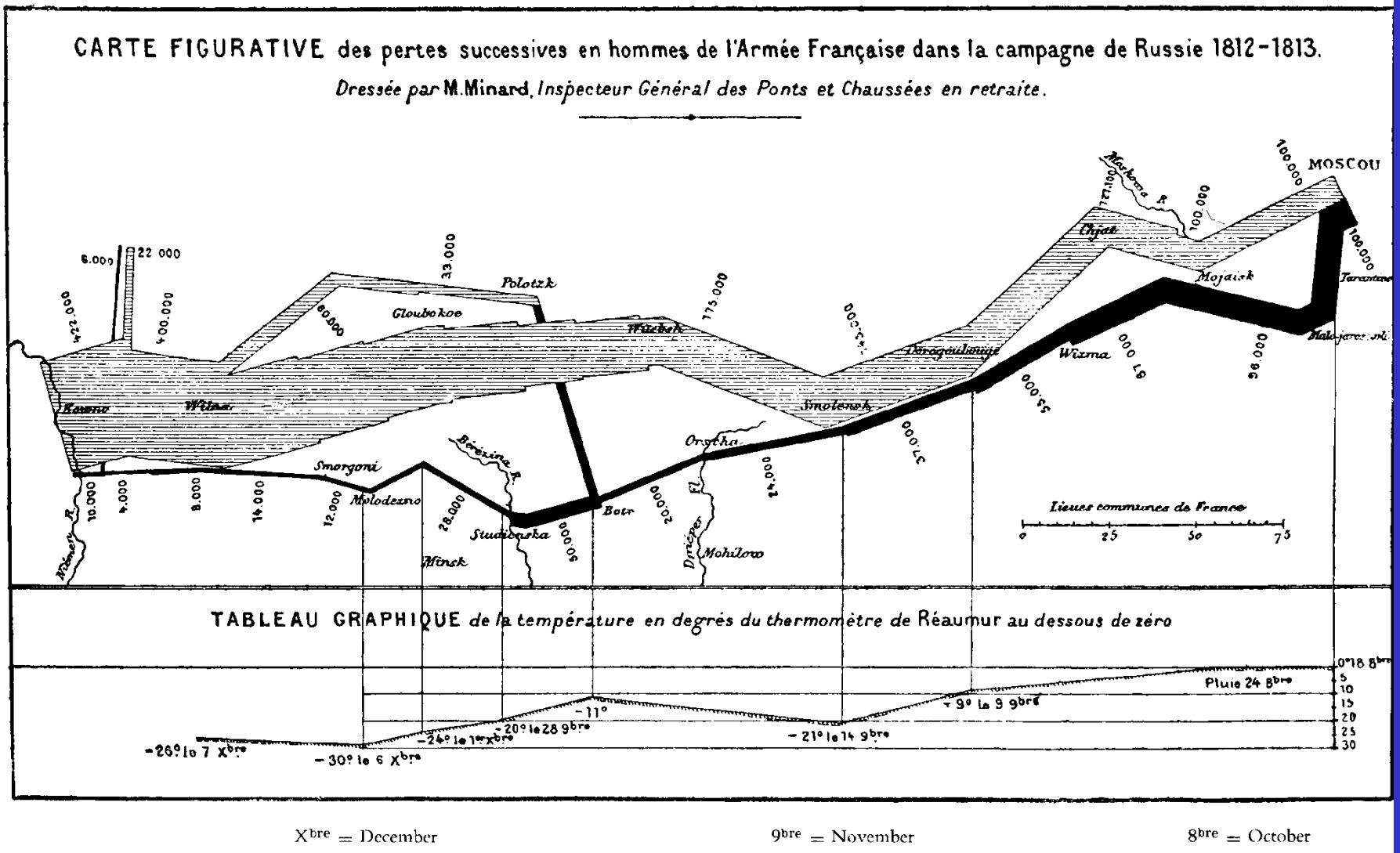
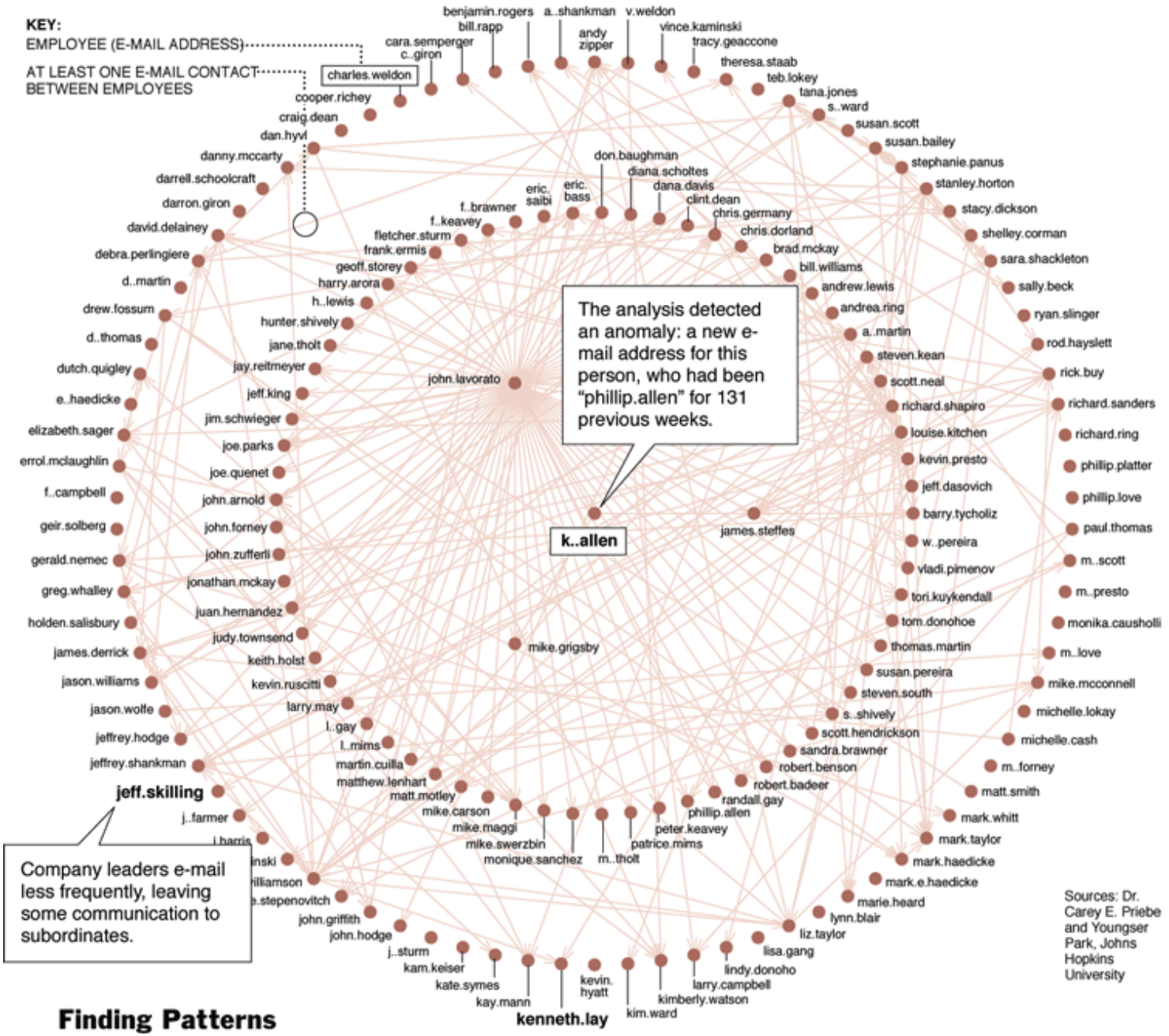
# Information visualization



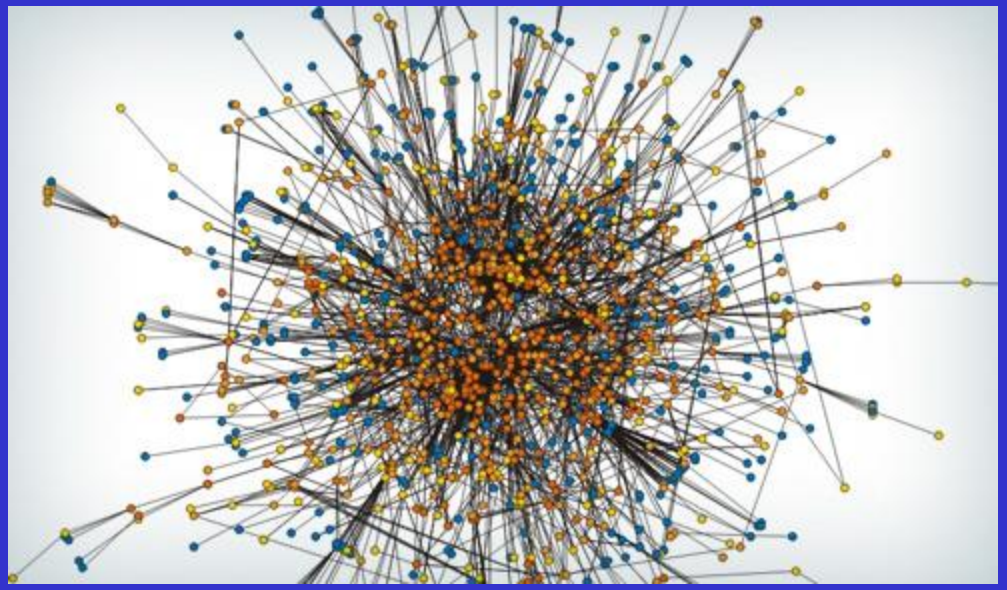

Xbre = December 9bre = November 8bre = October

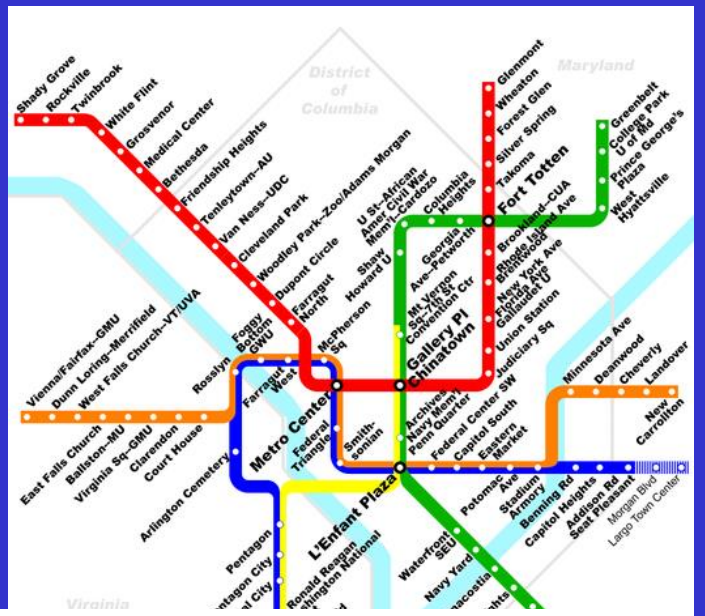


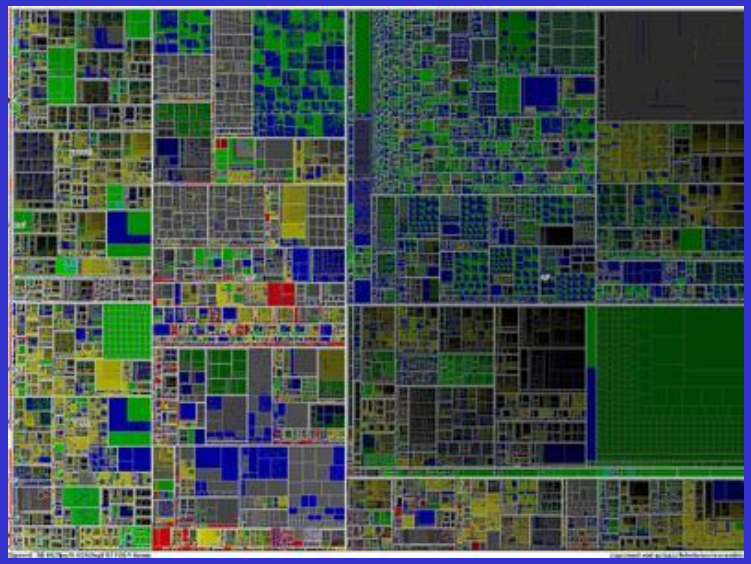

## Finding Patterns In Corporate Chatter

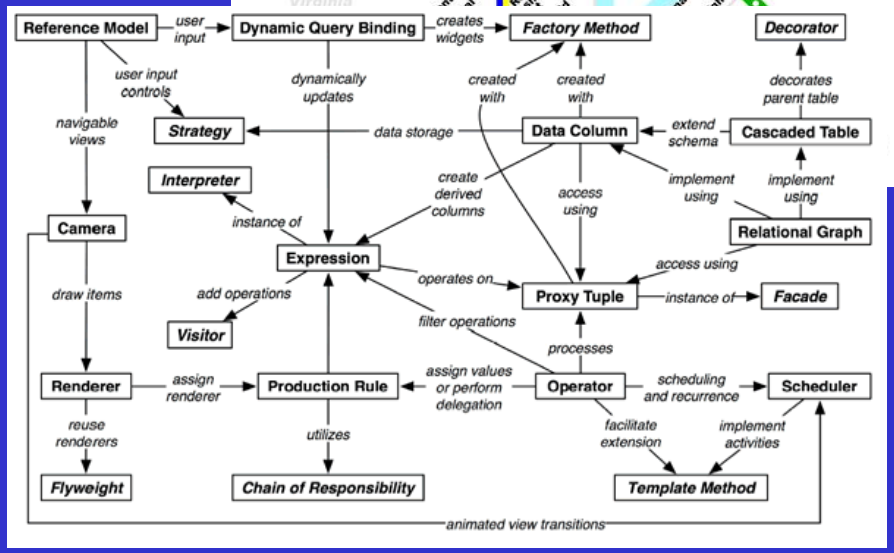
Computer scientists are analyzing about a half million Enron e-mails. Here is a map of a week's e-mail patterns in May 2001, when a new name suddenly appeared. Scientists found that this week's pattern differed greatly from others, suggesting different conversations were taking place that might interest investigators. Next step: word analysis of these messages.

# Information visualization

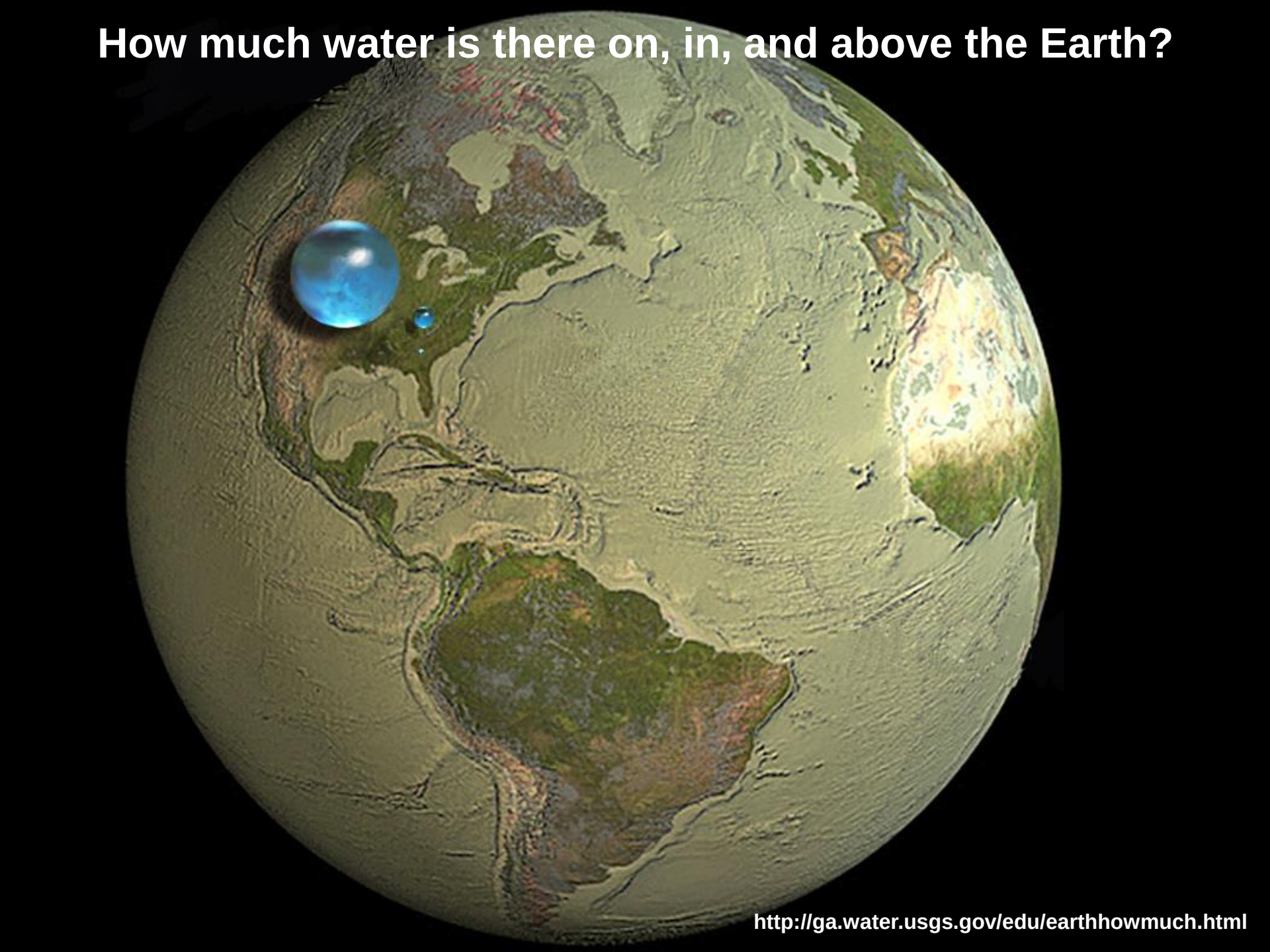




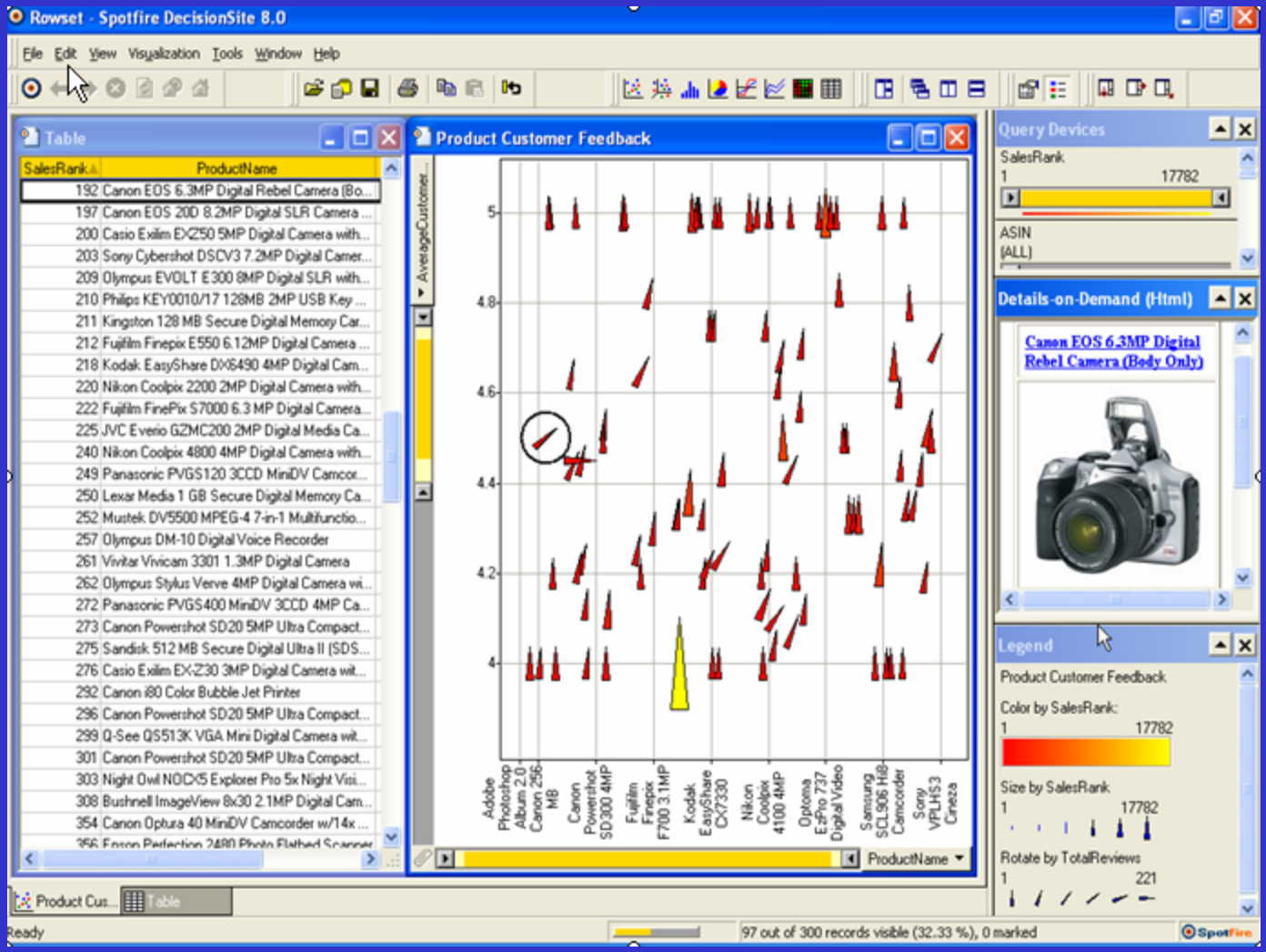


# How much water is there on, in, and above the Earth?

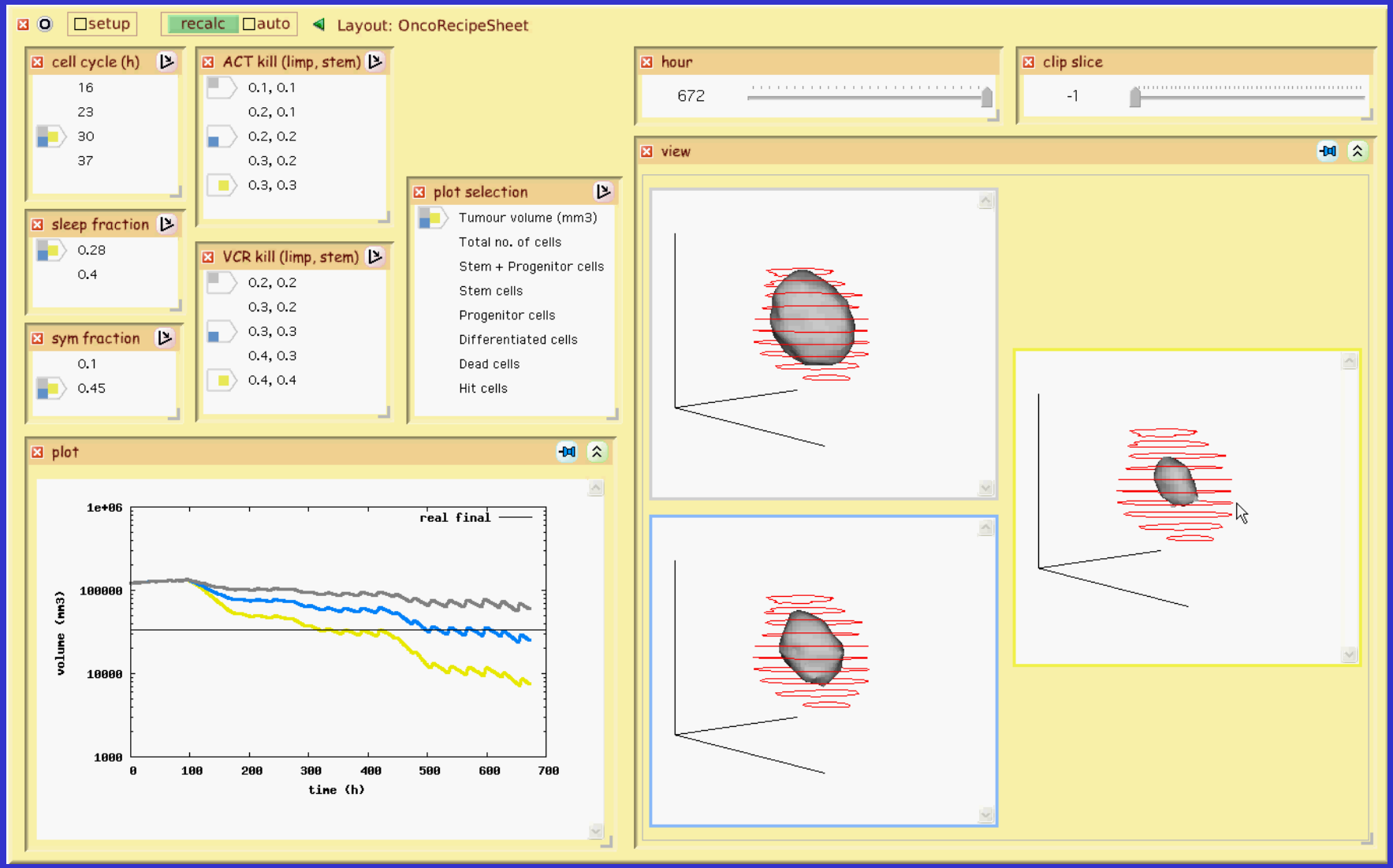


http://ga.water.usgs.gov/edu/earthhowmuch.html

# Visual analytics



# Visual analytics



# Visual mapping

# Visual mapping

Visualization is the process of mapping data items to visual attributes

- "Data encoding"

Process:

- Classify data types
- Determine which visual attributes represent data types most effectively

# Data types

- Nominal
- Ordinal
- Quantitative
  - Interval
  - Ratio

# Nominal, ordinal, quantitative

- Nominal
  - Apples, oranges, pears, …
  - Operations: =, !=
- Ordered
  - A, AA, AAA, …
  - Operations: =, !=, <, >, <=, >=
- Quantity interval (location of zero is arbitrary)
  - December 6, 1968; (lat 43, lon 137)
  - Operations: =, !=, <, >, <=, >=, -
- Quantity ratio (location of zero is fixed)
  - 189cm, 90kg
  - Operations: =, !=, <, >, <=, >=, -, /

# Nominal, ordinal, quantitative

| ID | Class | Family | Name | Height | Weight |
|---|---|---|---|---|---|
| 1 | 2 | Bears | Teddy | 18.2 | 90.2 |
| 2 | 2 | Bears | Lisa | 21.3 | 34.4 |
| 3 | 2 | Rodent | Bart | 4.2 | 0.64 |
| 4 | 3 | Rodent | Tom | 5.3 | 0.82 |
| 5 | 1 | Rodent | Jerry | 5.7 | 0.5 |
| 6 | 1 | Dog | Rex | 10.8 | 12.1 |
| 7 | 4 | Dog | Lisa | 5.6 | 9.8 |

**O N N N Q Q**

# Mapping data to visual attributes

# The Semiology of Graphics

- Semiology: the study of symbol systems

**Jacques Bertin (1918-2010)**

"graphics is a set of signs that allow you to transcribe the existing relations of difference, order or proportionality amongst qualitative or quantitative data"

*Sémiologie Graphique. Les diagrammes, les réseaux, les cartes*. With Marc Barbut [et al.]. Paris : Gauthier-Villars, 1967. (Translation 1983. *Semiology of Graphics* by William J. Berg.)

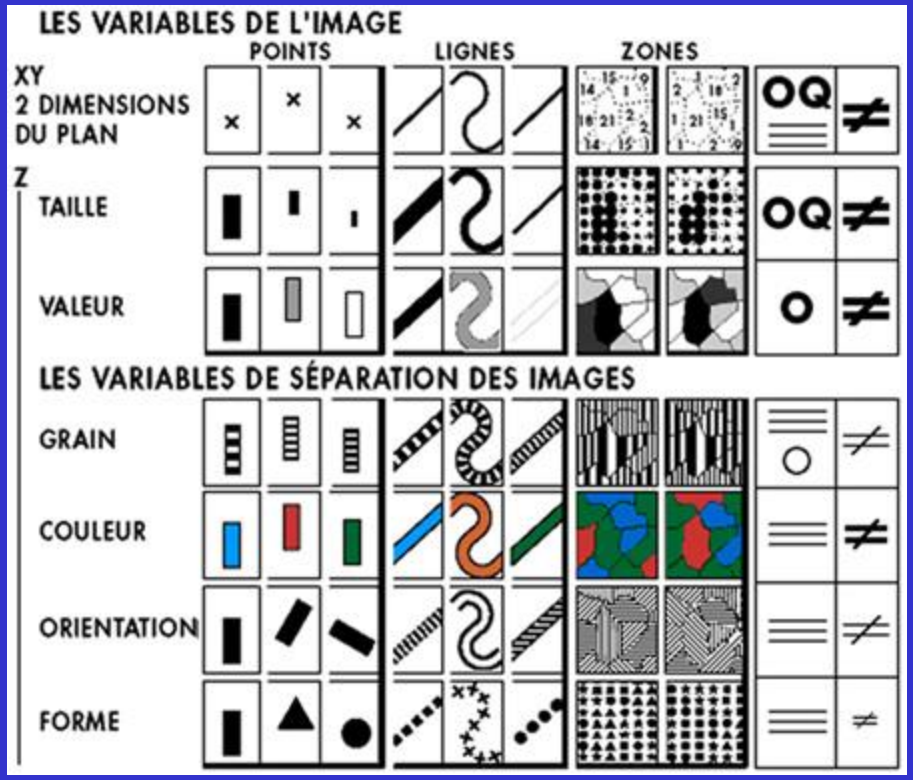
# The Semiology of Graphics

Jacques Bertin (1918-2010)

Seven visual variables:

1. Position
2. Size
3. Value
4. Texture
5. Colour
6. Orientation
7. Shape

Note that Bertin disregards 3D and animation (4D).



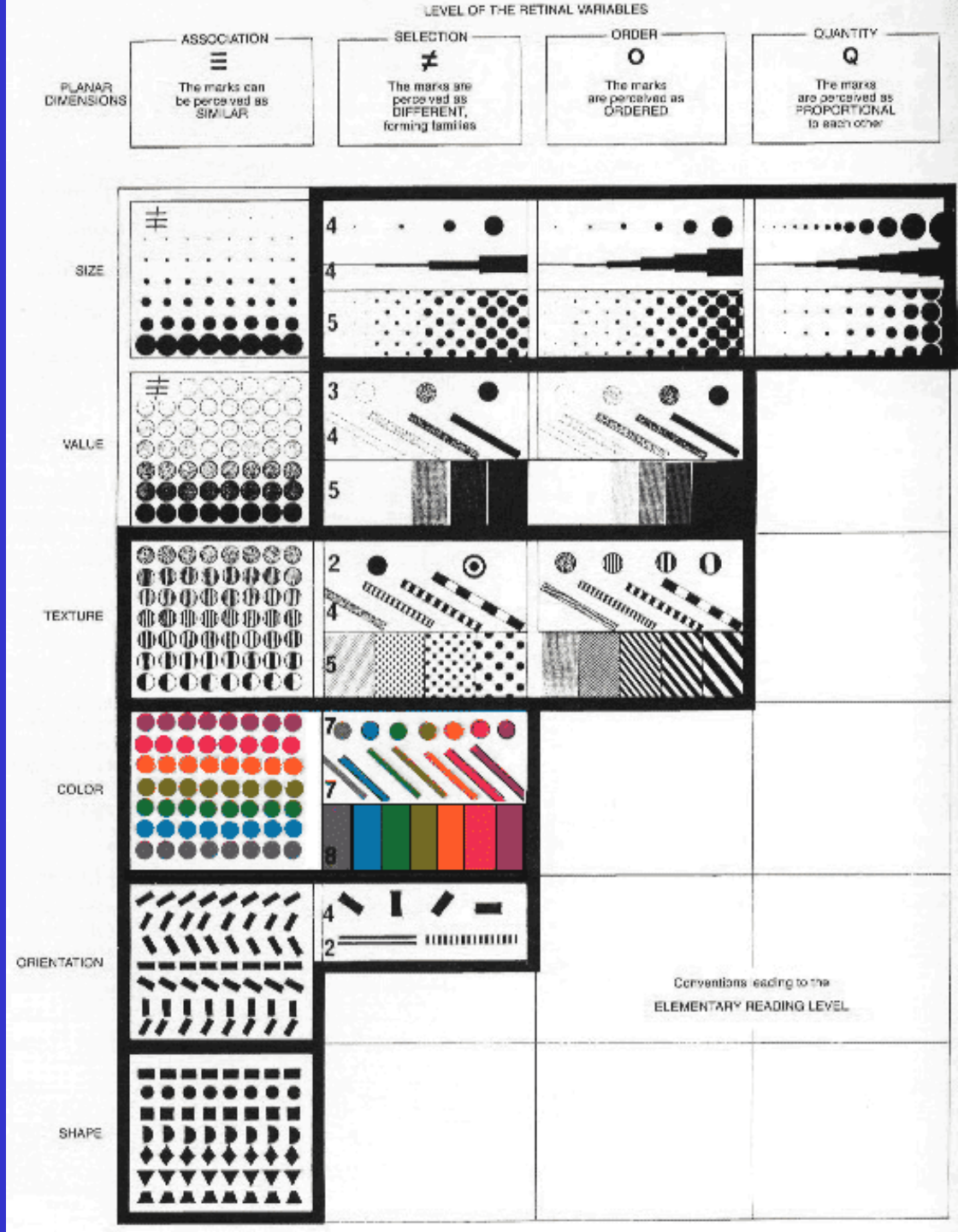
# Bertin’s “Levels of organization”

| | | | |
|---|---|---|---|
| Position | N | O | Q |
| Size | N | O | Q |
| Value | N | O | Q |
| Texture | N | O | |
| Colour | N | | |
| Orientation | N | | |
| Shape | N | | |

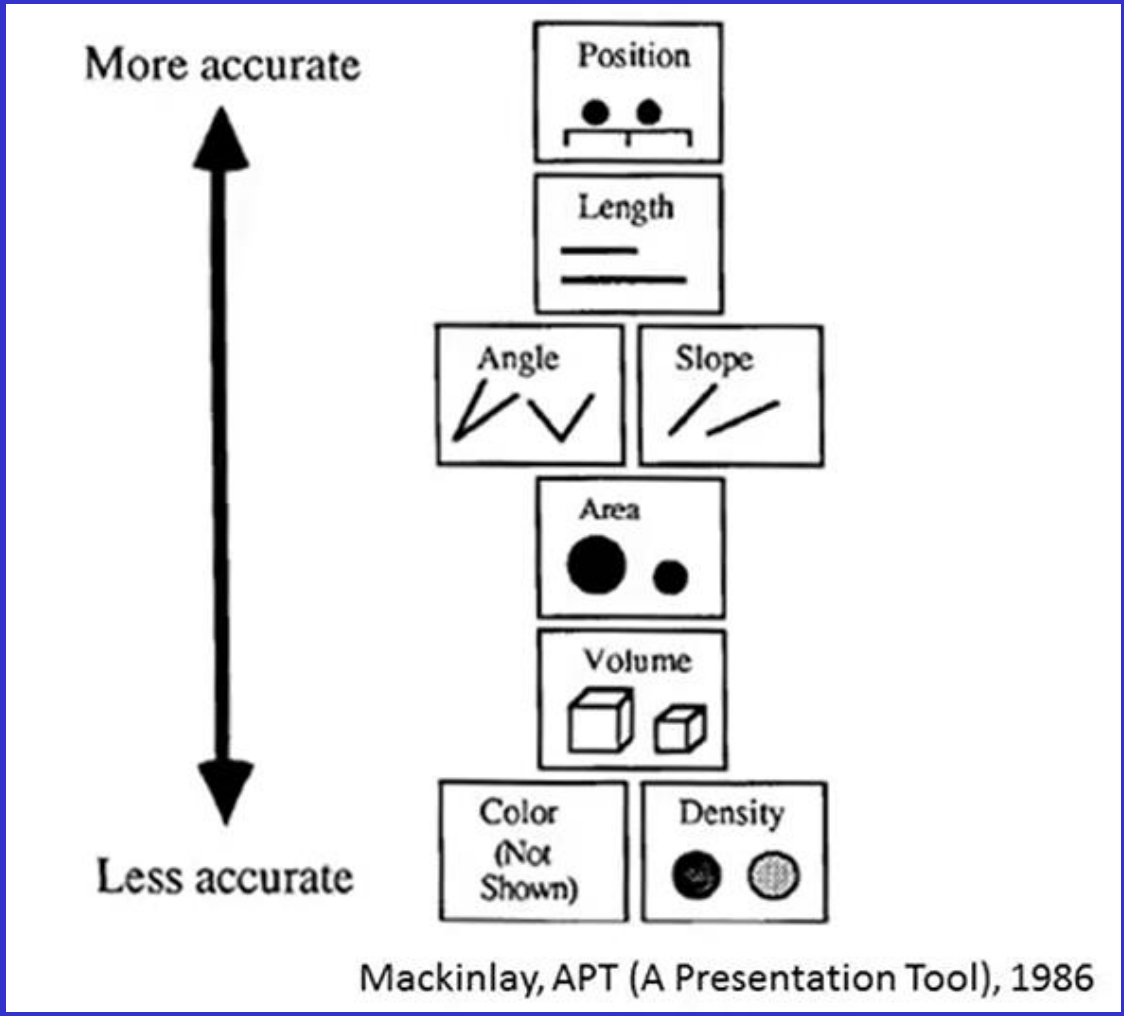
**N Nominal**
**O Ordered**
**Q Quantitative**

# Bertin's "Level of Organization"

- Association
  - Perceived as **similar**
- Selection
  - Perceived as **different** families
- Order
  - Perceived as **ordered**
- Quantity
  - Perceived as **proportional**



# Perceptual properties




Mackinlay, APT (A Presentation Tool), 1986

# Remember this

- All representations of information are subjective interpretations of the information, not the information itself.
- The challenge in visualization is to find a representation that is both efficient and appropriate.
- The purpose of visualization is to inform, not to misinform.
- Any visualization is limited in its interpretation.

# Assignment

- Find an appealing visualization, e.g. from
  - http://www.visualcomplexity.com/
  - http://www.sci.utah.edu/vissuccess/
  - http://vis.ncsa.illinois.edu/gallery.html
  - http://www.math.yorku.ca/SCS/Gallery/
  - http://prefuse.org/gallery/
  - http://manyeyes.alphaworks.ibm.com/manyeyes/visualizations
  - http://www.bewitched.com/
  - http://visual-analytics.org/
  - http://www.informationisbeautiful.net/
  - …
- For next week's session prepare 1 or 2 slides (in PPT or PDF) with:
  - The image (duh…) and its source
  - Background, i.e. what does the visualization represent?
  - Effectiveness, i.e.  how useful is the visualization ?
  - Esthetics, i.e. why is the visualization appealing?
  - Methods, i.e. how was the visualization produced?
- Email to me: R.G.Belleman@uva.nl
  - Deadline: Friday, October 31st, 18:00
- Be prepared to present it in ~1 minute during next Monday's session.