Knowledge Visualisation
IAT814

Week 1 Lecture 1
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Welcome to IAT 814:

- Should be better termed “Visualization: Perception and Design” but we have what we have
- What this course is about …
- Course logistics
  - Evaluation
  - Location
  - Resources

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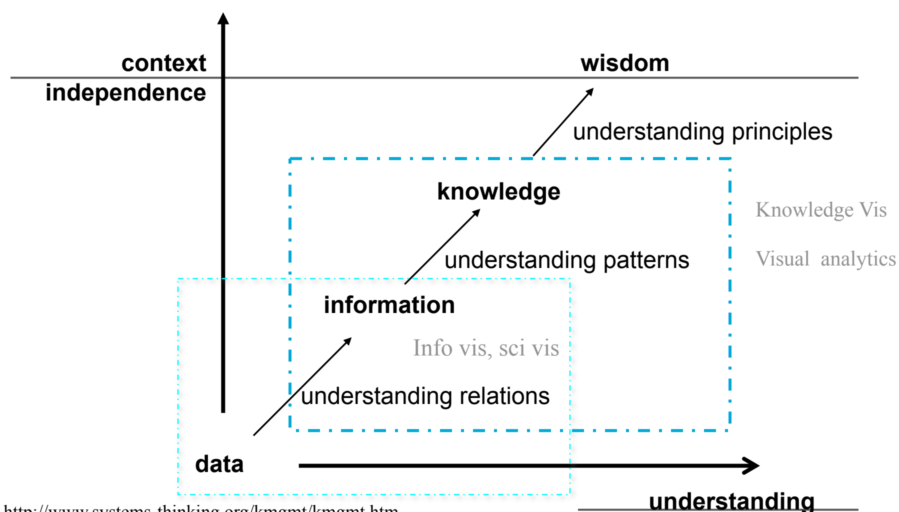
What is visualisation?

- The formation of mental visual images
- The act or process of interpreting in visual terms or putting into visual form
- A tool or method for generating images from complex multidimensional data fed into a computational processor

Visualization - from data to wisdom



http://www.systems-thinking.org/kmgmt/kmgmt.htm

Advantages of visualisation

- Comprehend huge amounts of data
- Emergent properties and relations
- Detect problems and inconsistencies in data
- Facilitates understanding of large- and small-scale features of the data
- Facilitates hypothesis formation: the forming of new questions and insights

What is visualization(take 2)?

- Solve problems by finding patterns in graphical displays of data
- Thinking with visualization involves:
  - Constructing visualization queries on displays
  - Visual search strategies through eye movements and attention to relevant patterns
  - Visual notification and attention “redirection” to new patterns and events

- When it's done well ……

The Real Problem

"What information consumes is rather obvious: it consumes the attention of its recipients. Hence a **wealth of information** creates a **poverty of attention**, and a need to **allocate** that attention efficiently among the overabundance of information sources that might consume it."

~Herb Simon
(Nobel Prize Winner)
as quoted by Hal Varian
Scientific American 9/1995

Foundation for a science of data visualization

- What are the advantages of visualising data?
- What do we need to understand about how to exploit those advantages?

Figure 1.1 Passamoquoddy Bay visualization. Data courtesy of the Canadian Hydrographic Service.

Essential issues

- What mental models most effectively carry various kinds of informations ?
- Which definable and recognizable visual attributes of these models are most useful for conveying specific information either independently or in conjunction with other attributes ?
- How can we most effectively induce chosen mental models in the mind of an observer ?
- How can we provide guidance on choosing appropriate models and their attributes to a human or automated display designer ?

------- G. Robertson

- Progress in [scientific] visualization can be accelerated if workers could more readily find visualization techniques relevant to a given problem

---Wehrend and Lewis

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Why Should We Be Interested In Perception and Visualisation?

- High bandwidth to the brain (70% of all receptors ,40+% of cortex, 4 billion neurons)
- We can see much more than we can mentally image
- We can perceive patterns (what dimensionality?)

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Visualization based on science – not recognition of arbitrary symbols

- Semiotics of graphics: Bertin, Saussure
- Is it about learning the significance of arbitrary diagrams and the craft of designing visual languages?
- No – the perceptual system is predisposed through both its inherent structure and development to be sensitive to certain features
- What can vision research teach us?
  - Understanding of perceptual mechanisms is fundamental to a science of visualisation
- Experimental semiotics

Sensory vs. Arbitrary Symbols

- Sensory:
  - You can see and understand without training.
  - Match the way our brains are wired
  - Object shape, color, texture
- Arbitrary:
  - Must be learned
  - Having no perceptual basis
  - The word “dog”

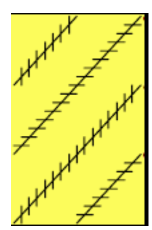
Properties of Arbitrary Representations

- Formally powerful
- Capable of rapid change
- May already be learned (summation notation)

- Dangers
  - Can be hard to learn
  - Can be easy to forget
  - May vary with culture and application (different disciplines use different symbols or codes for the same concept and the same symbol for different concepts)

Properties of Sensory Representations

- Can be understood without training·
- Resistant to instructional bias·
- Is processed very quickly, and in parallel·
- Is valid across cultures



- Danger: Poor mappings can be misunderstood, quickly and without effort, even with instruction and training.

A psychology of visualization

- Sensory symbols
  - "symbols and aspects of visualisations that derive their expressive power from their ability to use the perceptual power of the brain without learning".
- Can't be unlearned or ignored
- Immediate processing
- Cross-cultural validity
- Empirically testable (ha!)

Course organisation

- Course organization *mostly* follows the text
- Parallel processing to extract low level properties of a scene – Ch 1, 2, 3, 4 and 5
- Pattern perception – Ch 5, 6, 7, 8
- Sequential goal directed processing – Ch 9, 10, 11
- Course outline, week by week, will be on the website with slides

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And thus … the course outline

1. **Foundation for a science of visualization and introduction**
2. **An introduction to the human visual systems and displays**
3. **Optics, Display and Contrasts**
4. **Colour theory and colour for information display**
5. **Visual attention and things that pop out**
6. **Patterns for visualizing structure**
7. **Motion-based patterns**
8. **Objects and object-based displays**
9. **3D space perception, Stereo and 3D display**
10. **Images, words and gestures/motion and movement**
11. **Tools for visualizing multidimensional data**
12. **No class - individual project meetings**
13. **Interacting and Thinking with Visualizations**

Class structure

- 3 hour lectures (give or take)
- First half: I lecture on topic of the week
- Second half : student presentations and discussion

Course Evaluation

- 3 components:

1. 2 Visualisation critiques (20%, 10% each)
   - Part 1. Find an example of practice, critique and present
   - Part 2. Discuss from perceptual perspective!
   - We will revisit these.
2. Research critique (20%) -
   - critical review of recent research, presentation and report
3. Final project (60%)
   - Group or individual
   - Research paper
   - Design proposal of technique or method to address a visualization challenge
   - presentation

Resources

- Course textbook:
  - Colin Ware. Information Visualisation: Perception for Design.
- Course web/wiki site
  - https://wiki.sfu.ca/spring09/iat814g100/

Stages of visualization

- Collect the data (lab work, simulation, archives, ……)
- Transform the data
  - Into a format readable and manipulable by the visualisation software
  - Into the form most likely to reveal information (we'll return to this)
- Visualisation algorithms and computational treatments run on graphics hardware or software renderers (the computational machinery)
- Human views and interacts with the visualisation
  - Changes parameters, techniques, view options
- User studies to evaluate effectiveness
  - This often doesn't happen!

Two-stage model of perceptual processing

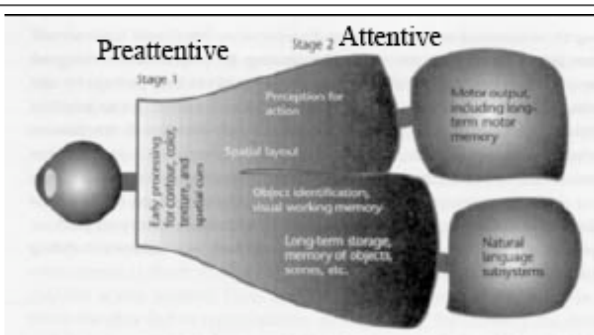

Figure 1.11 This schematic diagram presents an overview of a two-stage model of human visual information processing.

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What makes/is a good visualisation?

- Understanding means making a model that captures the essence of a system
- A model is an abstraction with the *important things in* and the *unimportant out*
- *Different visualizations* provide different levels of detail,show and hide different things; so *support different abstractions*
- Good visualizations are those that are *useful* to aid understanding, not just *realistic* representations (what color is a carbon atom?)
- Good visualizations map the important part of the tasks onto techniques that show the relevant characteristics best

Data characteristics and visualisation goals

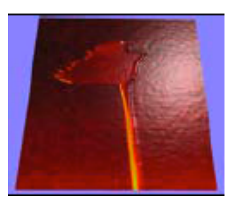
- Why classify data and visualisation goals?
  - No known silver bullet
  - Helps select what technique(s) to try
  - Helps predict other uses for good techniques
  - Some tools and approaches only work with some formats

Data characteristics

- Dimensionality
  - Number of data sets
  - Space/subspace for each (Scalar/vector field)
  - Visualization space where the data is embedded
  - Type of each value field
- Nominal, ordinal, interval, ration
- Other
  - Continuous vs. discrete
  - Spatial frequency
  - Missing or special values?
- Structure of the sampling

Dimensionality

- Of the space in which the fields are embedded (2D/3D)
- Of each data field (point, line, surface, volume)
- Of the data type in each field



Types of values

- Nominal: names without ordering
  - Continents: Africa, America, Asia, Australia, Europe
- Ordinal: Less than relationship holds
  - Rental cars: Economy, Compact, Mid-sized, Full-sized
- Interval: Relative measurements, no absolute zero
- Height of AFM scan or location
- Ratio: Absolute zero (can say "twice as much as")
  - Account balance, Height above sea level, *not* height

Data characteristics cont

- Continurous/discrete
  - Sampling of the field
  - Values in each sample
- Spatial/temporal frequencies on data
- Missing values
  - Interpolate
  - Show as missing explicitly?
  - Ignore?
- Special values
  - Of particular interest to visualize
  - Thresholds, ratio scales (consider sea level relative values)

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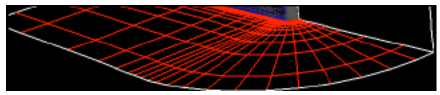
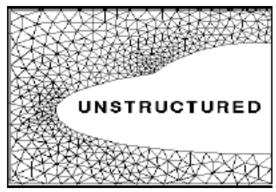
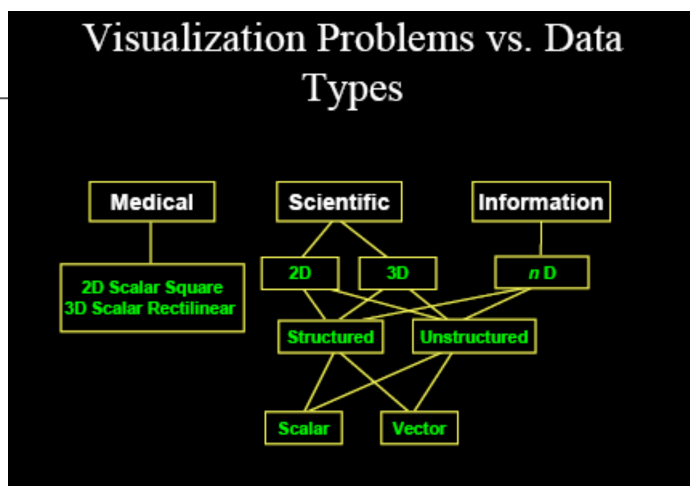
The sampling grid

- Structured
- Rectilinear
- Curvature



- Unstructured
- Point clouds
- tetrahedral





Task analysis

- High level goals - middle level tasks -- atomic actions
- Determine tasks before determining visual representations and interaction tools
- Tasks too often determined informally or implicitly
- Each representation may serve one high level goal
  - Class of representations more likely

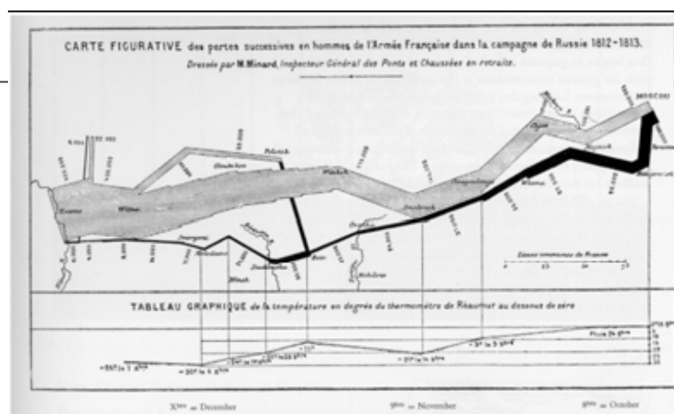
Visualisation Goals

- Debugging
  - Quality control of simulations, measurements
- Exploration
  - Gaining new (unexpected, profound) insights
  - Increasing scientific productivity
  - Making invisible visible
- Presentation
  - Enhancing understanding of concepts and processes
  - Visual medium of communication
- Others?

Exploration tasks

- Identify and distinguish objects
  - Categorise objects
- Compare vallues
  - Discover extremes and distributions (qualitative)
  - Look up values (quantitative)
- Recognise patterns/structure
  - Identify clusters
  - Discover phases
  - Correlations between data sets
  - “what’s going on here”?

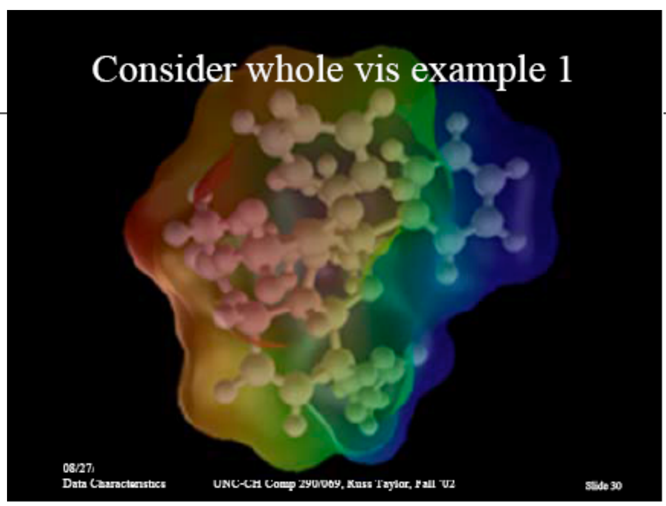
specialized → general



- Tufte. The Visual Display of Quantitative Information. p41

Consider the whole

- An interactive visualisation is more than a single technique
- Interplay between techniques
  - 3D colour-mapped objects?
    - Don't vary lightness
- Multiple variables?
  - Map to different perceptual channels
- Integrated vs. separate
  - May separate in space (parallel presentation)
  - In time (animation, user switches)
- Combine if you can effectively



Summary

- Data Characteristics
- For each technique, consider what dimensions and types of data it can support
- For each visualization, consider the best space to display it in
- Consider spatial frequency and missing values
- Visualization Goals
- Consider what tasks need to be done to achieve the visualization goals
- Consider what tasks are to be achieved, and which techniques are well suited for each