COMP5048 - Week 4

Fundamentals of Human Computer Interaction (HCI)

Basics of HCI

- Modality of interaction
- Interaction models

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Modality of Interaction

Interaction

- Interaction with artificial objects (including both physical and virtual)
  - Results of advances of artificial systems
  - Artificial system: a set of components, each of which interacts with each other in an ordered manner
- Advances in computing and networking markedly changed our society and how we interact with artificial systems

Purpose of Interaction

- Advancing human capabilities
- Advancing human communication
- Advancing assistance capability
- Improving experience

Advancing Human Capabilities

- Calculation (this is how it's started …)
- Simple memorization
- Associative memory
- Language translation
- Problem-solving
- Automatic proofing
- Enhancing human cognitive capability (cognitive artificial systems)
- Requires understanding of human activities

Advancing Human Communication

- Combined with advances in networking technologies ✓✓
- Provides new media for human-to-human communication (computer-mediated communication) ✓✓
- Unlike a non-computer-mediated communication, various services can be provided to enhance the communication ✓✓

Number of services can be injected into communication processes

Advancing Assistance Capability

- Many audio/visual products can be interconnected with networks.
- Various white goods now have microcontrollers.
- Mobile/Wearable computing allows us to access networked computers anytime.
- Perceptual user interfaces allow computers to sense our activities in order to provide adaptive services.
    - Turk, M., & George, G. (2000). Perceptual user interfaces. *Communications of the ACM*, *43*(3), 33–34.

Improving Experience

Computer assisted/mediated artificial systems

- Characterised not only by their functional capabilities
- But also by how they can improve our physical/mental experiences

Types of Interactions

- Interactions occur between
  - Human and human (HHI)
  - Human and computer (HCI)
  - Human and machine (HMI)
  - Human and information (HII)
- H*XI* covers all "Human-*X*" interactions

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Multimedia Oriented Modality of Interactions

Modality of Interactions (Multimedia Oriented)

Many different methods are used to represent pieces of information used in interactions

Two basic representation media

Language: text, audio (voice)	Non-language: other media

Language Media

Natural language

Artificial language: convey the information in a simple and accurate manner

Suited for describing complex information in an orderly manner using common grammar and syntax

Non-Language Media

Examples	Purpose
• Facial expression, body language • Pause during a conversation • Body movement	• Support/control language media • Convey information that cannot be easily expressed in language

Vargas' Nine Types of Non-Language Media

1. Action
2. Peripheral language
3. Silence
4. Time
5. Chroma (colour)
6. Human body
7. Body contact
8. Eye
9. Territorial space

Vargas, Marjorie F. (1986). *Louder than words: An introduction to nonverbal communication.* Iowa State University Press.

Action

- Expression by posture and movement of human body. Facial expression also belong to this type.
- Actions might have different meanings depending on recipients’ culture.

Peripheral Language

- Features associated with conversational language
  - Tempo
  - Volume
  - Accent, etc.
- Feeling, personality can be conveyed (subjective)

Silence

Still a medium for interaction

- Pause in conversations ✓
- Intentionally ignore ✓

Time

- Temporal factors, which have significant influence on communication
- Factors based on actions
  - Timing of interruption in conversation
- Factors based on biological rhythms
  - Timing to induce sleepiness

Chroma

- Colour in the environment
- Work on human perception
- Can be used to control communication and action

Eye

- Includes
  - Eye contact
  - Expression in eye
- Under information provider's control

Eye Contact and Facial Expressions

- Facial expressions represent many emotional states of users
- Supported by gestures
- Hard to control consciously
- Differences in looking (active) and seeing (passive)
- Looking in public space might be offensive

Eye Contact and Facial Expressions (cont.)

- Can be used to
  - Control timing of speaker/listener change
  - Monitor responses
  - Display your opinion
  - Display your emotion
  - Express you attitude towards other participants

Human Body

- Characteristics of human body expressed in its age, gender, physique, skin colour, etc.
- Typically based on information recipients' cultural background

Body Contact

Includes

- Real body contact
- Replacement of body contact, which is closely associated with the real body contact

Body Language, Part I

- Linguistic body language
  - Associated with an apparent message (sign language, common gestures)
- Illustrative body language
  - Assists the conveyance of messages (gesture to emphasize the point of messages)

Body Language, Part II

- Negotiation body language
  - Gesture for invitation and patting on the shoulder
- Ceremonial body language
  - Hand-shaking and bowing

Body Language, Part III

- Body language to regulate verbal communication
  - Nodding, touching your chin, arm crossing, etc.
- Adapter body language
  - Yawning, scratching, etc.
- Synchrony
  - Unconsciously imitate the person’s body language when you agree with that person

Territorial Space, Part I

- Interaction distances between humans
- Spatial arrangement of participants
- Could be culturally biased

Territorial Space, Part II

- In human communication, users are very sensitive to their own territorial space
- Territorial space can be violated by:
  - Territorial pollution (verbal, physical)
  - Unsolicited space use
  - Overtaking the territory
- Personal space defines the comfortable interaction space for individual

Territorial Space, Part III

- Stop-distance method: measure the personal space
  - An experimenter getting close to the subject, and the subject will indicate when the experimenter reaches the uncomfortable distance
- Artificial systems could modify the personal space
  - Use of mobile phone in the public space
  - Kids' long phone call at home
  - Online game

Territorial Space, Part IV

Intimate distance: less than 45 cm

- All five senses will be involved
- Very close relationship unless a participant is forced to be in the situation

Individual distance: 45 cm–1.2 m

- Individually interested parties

Social distance: 1.2–3.6 m

- Cannot touch other parties nor see them in detail
- For non-individual conversation

Public distance: more than 3.6 m

- Public lecture, presentation
- You can escape

Summary

- Modality of interaction from multimedia’s point of view
  - Language vs non-language
- Vargas’s nine non-language media
  - Gaze/facial expression
  - Body language
  - Territorial space

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Human Information Processing Model

Human Information Processing Model

- In cognitive psychology, the human is treated as an information processing (IP) unit
- Cognitive process is modelled as a series of information processes on this IP unit
- Understand human cognitive processes such as inference, problem-solving, memory, and learning
- Card, S. K., Moran, T. P., and Newell, A. (1983). *The psychology of human-computer interaction.* Erlbaum.

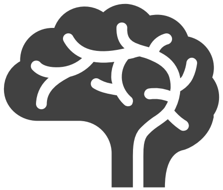
Human as an Information Processing Unit

Computer

Input

Central processing unit

Output



Human

Five sensory devices (input)

Brain: memory and CPU

Body, including speech (output)

Human Memory Unit

Sensory register

- Very short-term storage for five sensory devices

Working memory

- Temporary information storage mechanism
- Limited capacity and function (magic number 7)

Long-term memory

- Declaratory memory
  - Episode memory (for events)
  - Semantic memory (for abstract concept)
- Procedural memory

Pros/Cons of HIP model

Cons

- Very little biologically equivalent explanations

Pros

- Can be simulated
- Can be used to evaluate functions and performances of human interaction

Simulation Using HIP Model: Example I

- Capacity limitation of the working memory
  - The number of items a user needs to remember should be small.
- Example: the time it takes to reach the decision is proportional to the number of available choices (Hick-Hyman law)
- Hick, W. E. (1952). On the rate of gain of information. *Quarterly Journal of Experimental Psychology*, 4, 11–26
- Hyman, R. (1953). Stimulus information as a determinant of reaction time. *Journal of Experimental Psychology*, 45, 188–196
  - A small number of menu windows with many selections will be more effective than a large number of menu windows with small selections.

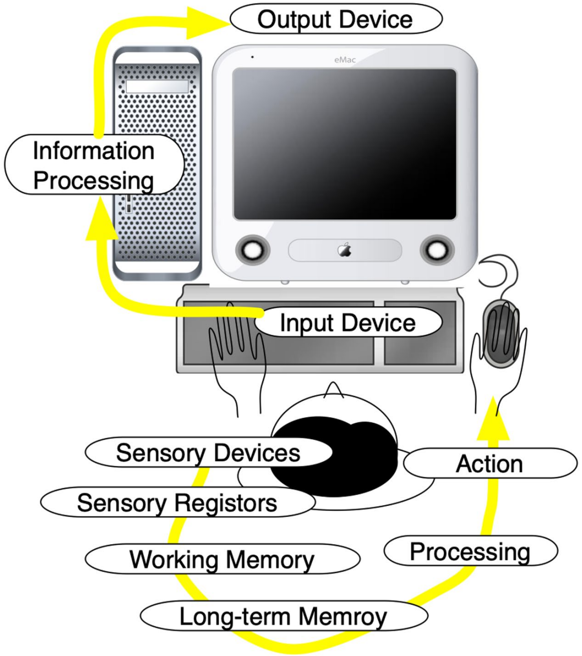
Simulation Using HIP Model: Example II

Example: the time it takes to reach a target using a pointing device depends on the size of and distance to the target (Fitts' law)

- Provides a user interface design guideline: where to place the target objects on the screen

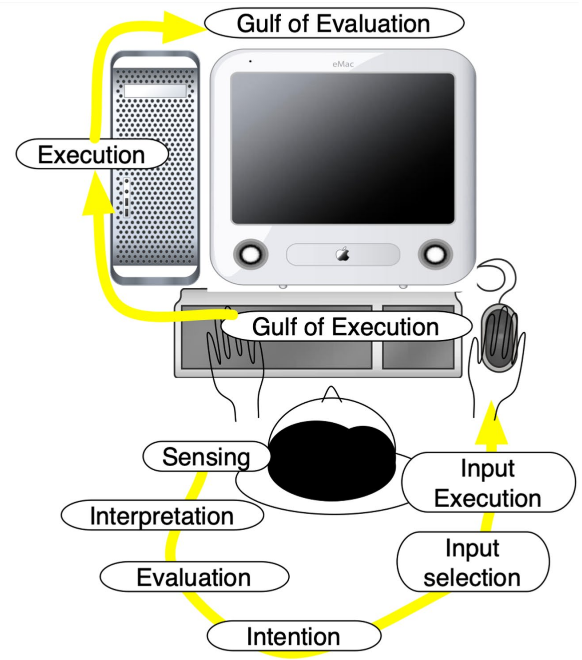
HCI Modelling Using HIP Model

- Two information processing units ✓✓
- Two sides are connected by IOs ✓✓



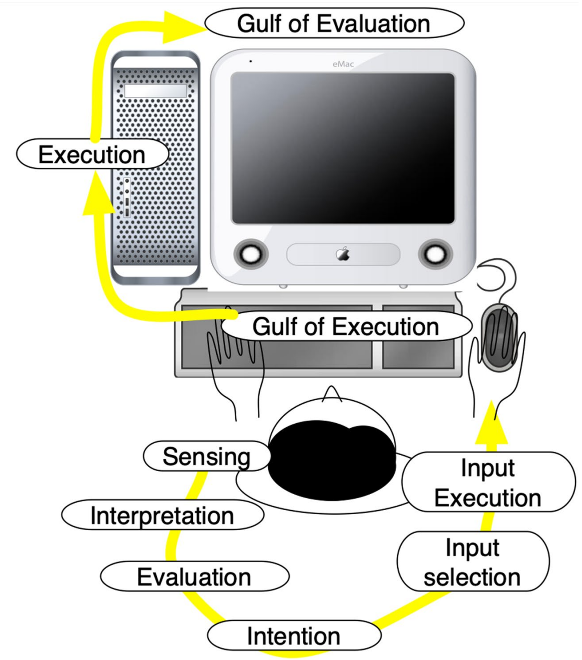
Interaction Cycle in D. Norman's Gulf Model

- Sensing state of an artificial system
- Interpret the sensing results
- Evaluate the interpretation against its own intention
- (Re)set a new intention
- Select a new input
- Execute the new input
- Execution by the artificial system



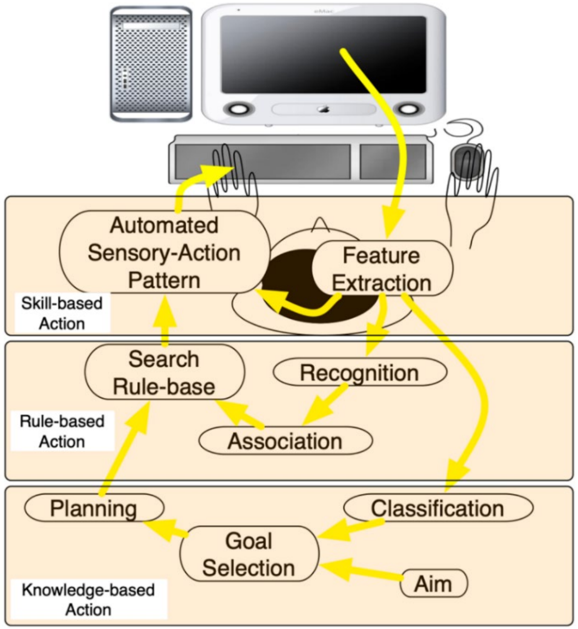
Breakdown in D. Norman's Gulf Model

- This model is useful to analyse/explain various difficulties, ineffectiveness, failure, and breakdown
- Gulf prevents a seamless coupling of two execution systems (computer and human)
- There are two gulfs
  1. Execution (from H to C)
  2. Evaluation (from C to H)



Rasmussen's Decision-Making Control Model

- Three levels of hierarchical control model
  1. Skill-based
  2. Rule-based
  3. Knowledge-based
- Similar to "subsumption architecture" (Brooks@MIT) often used in robot-control
  - Fast but low-quality low-level processing
  - Slow but high-quality high-level processing



Minsky’s Society of Mind: Agent-Based Model

- Treat “human mind” as a group of interrelated agents.
- It provides many interesting possibilities to build the model of mind.

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Ecological Model

Ecological Model

- Closely related to Rasmussen’s SRK-based decision-making model
- Put its focus on the environment rather than the human as an information processing unit
- Analyses how the environment offers relevant information to humans in order to assist any interaction

Ecological Model (cont.)

- It does not analyse (absolute) physical characteristics the environment has
- It analyses:
  - How relevant information can be generated based on humans’ needs
  - How humans obtain such information
  - How humans apply such information to their actions
- Early works were founded upon research on human visual perception

Example of Ecological Model

- Imagine that you’re visiting the powerhouse museum for the first time.
- How would you plan your action in order to achieve your primary objective?
    - To get in, it seems that you need a ticket.
    - What sorts of exhibits?
    - How are they arranged? Etc.

Affordance

- A person will obtain pieces of information from the environment in order to assist their action plan
- Affordance: the pieces of such information available in the environment
  - Gibson, J. J. (1979). *The ecological approach to visual perception.* Houghton Mifflin.

Affordance in a Museum

- Sign for the entrance
- Queue for buying a ticket
- A map of the museum
- Announcements
- Etc.

Affordance Rich/Non-Rich

- Many pieces of affordance are available in a familiar environment.
- In an unfamiliar environment, available affordance is limited.
- **Affordance is defined by the relationship between the subject and its environment.**

Affordance in Australian Football League (AFL)

If you're an experienced player, you can inference many pieces of information from:

- Players' movements around you
- Trajectory of the ball, etc.

Invariant in Affordance

- It is a piece of information, which does not change depending on how the subject moves around the environment.
- It allows the subject plan and achieve a stable action.
- In order to obtain such invariant, the subject is encouraged to actively move around the environment.

Dynamic Touch

- An action that the subject actively applies to objects in the environment in order to obtain invariant
  - Touching, shaking, hitting, etc.
- Gentle to rough: microactivity/action
  - Accumulate microactivities lead to finding of invariant

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Social Interaction Model

Social Interaction Model

- Human society consists of many small and large groups of people
- Such groups try to:
  - Achieve common goals
  - Solve common problems
  - Assure the trust
- These activities are carried out through various interactions within the groups

Group and Community

- A group whose members have apparent roles to achieve a common goal
- A community is a gathering of participants who joined based on their own will
  - A circle, alumni, academic association, volunteer group
  - Traditionally, it indicates geographic locality and association
  - Advances in network technology introduced a new type of community (network community)

Network Community

Community of interest

- Increase the ground coverage through common interests.

Community of practice

- Academic association, union: maintaining good human relationships

Online local communities

- Conventional local communities enhanced through the use of networks.

Features of Group/Community

Tacit rules are not
written regulations,
but rather widely
known rules
E.g. treating
other members
with
respect

There is a clear boundary to identify member and non-member (some even have uniforms … boy/girl scouts).

Through background knowledge and interests, they build strong associations.

There are formal and tacit rules and regulations.

Common Factor in Group and Community

- The group and the community are usually formed based on different objectives.
- However, both entities involve strong awareness of other members through background/tacit knowledge.

Role of Awareness

- Awareness is closely associated with tacit knowledge along with various pieces of background information in the environment.
- Appropriate awareness will add positive information towards the successful completion of tasks in the group/community.
- Awareness-rich communities will be highly likely to succeed.

Summary

Understand interaction through cognitive action models.

1. Human information processing model
2. Ecological model (affordance)
3. Social interaction model (awareness)

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Interaction and Visualisation

Operating on Visual Representations

- Visualisation for visual analytic should facilitate the manipulation of visually represented data
    - A series of feedback loop
    - Overview
    - Zoom in/out
    - Select
    - Filter
    - Find relevant info
- Facilitate exploration of data space

Types of Interaction

- Selection and manipulation
  - Directly working on visual representations of data
- Exploration and navigation
  - Understand and walk through a visually represented space

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Selection and Manipulation

Choosing an Item From a List

$RT = c + k \log_2 b$

- Hick-Hyman Law: the time it takes to reach the decision is proportional to the number of available choices

$$RT = c + k \log_2 b$$

RT: reaction time
c, *k*: constants
b: number of choices

- One menu window with many choices is better than many menu windows, each of which has few choices

Choosing an Item From a List (cont.)

- Humans tend not to do binary search
- Often use linear search
- Usually use mixed approach … but
  - For example, when you have 256 choices,
  - Do you present one menu window with 256 choices, or
  - Do you present nested 8-level binary choice menus?

Searching an Item

Nested menu windows might get a user confused, but allow a small number of comparisons

$$TST = (bt + k + c)\frac{\log_2 N}{\log_2 b}$$

TST: total search time
k, *c*: response time of a user and a system
t: the time it takes for each selection
b: number of selections
d: depth of the nest
N: number of total selections

$$TST = (bt + k + c)\frac{\log_2 N}{\log_2 b}$$

b = 3–8: optimal at *k* = 0.5–1 s, *t* = 0.25–2 s, and *c* = 0.5–1.35 s

Objects Arrangements (Fitts' Law)

The time it takes to reach a target using a pointing device depends on the size of and distance to the target.

$$ID = \log_2 \frac{2A}{W}$$

ID: index representing difficulty of pointing
A: distance to the object
W: width of the object

$$ID = \log_2 \frac{2A}{W}$$

Objects Arrangements (Updated Fitts' Law)

ID is proportional to the sum of:

- Time it takes to recognise the target/pointer
- Time it takes to recognise the distance between the target and pointer
- Time it takes for action

$$ID = \log_2(\frac{A}{W} + 0.5)$$

ID: index representing difficulty of pointing
A: distance to the object
W: width of the object

$$ID = \log_2\left(\frac{A}{W} + 0.5\right)$$

Path Tracing

- Interaction with visualisation may require "continuous tracing/steering" of a visual cue
- Performance of the tracing act is influenced by:
  - Width of the path
  - Difficulty in the type of motor control you need to carry out

$$\boxed{\text{Velocity} = \text{Width of the path} / \text{Motor control coefficient}}$$

Accot, J. & Zhai., S. (1997). Beyond Fitts' law: Models for trajectory-based HC1 tasks. *Proceedings of CHI '97. ACM, 295–302.*

Control Compatibility

- If the control required for the interaction is not compatible with what you already know
  - It might take some time to learn the interaction
- Make the interaction (or user interface in general)
  - Intuitive
  - Familiar to the wider audience
- Utilize good metaphors

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Exploration and Navigation

Interactions for Exploration and Navigation

- Visually sift through massive and complex data to reach something interesting.
  - Change the visual appearance through interactions.
- Move around in the visually represented data space.
  - Change the viewing location/orientation/direction in/on the visual landscape through interactions.

Changing Visual Appearance

Changing the focus of visual attention by:

- Spatial scaling
  - Changing the level of details within the visually represented space
    - Spatial behaviour of individual fish within the school of fish, vs
    - Its impact from *continental shelf and the boundary between cold Arctic water and the warm waters of the Gulf Stream*
- Structural scaling
  - Switch between different levels of hierarchy within the complex data
- Temporal scaling
  - Different time scale

Moving Around Inside the Visualised Space

- Typically uses “spatial navigation metaphors”
  - Landscape: visually represent data points on 2D/3D space like a map/landscape
    - Utilize the real-world navigation knowledge/capability
    - Familiar interactions
  - Provision of the reference point is important
    - Provide the known obvious reference points, or
    - Let a user easily identify/create their own reference points
- Dimension mismatch
  - Different dimension between visualisation space vs interaction space
    - 3D visualisation space controlled by the mouse movement in 2D
  - Different physical visualisation space vs interaction space
    - Visualisation on a computer screen controlled by the mouse on a desk

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Evaluation

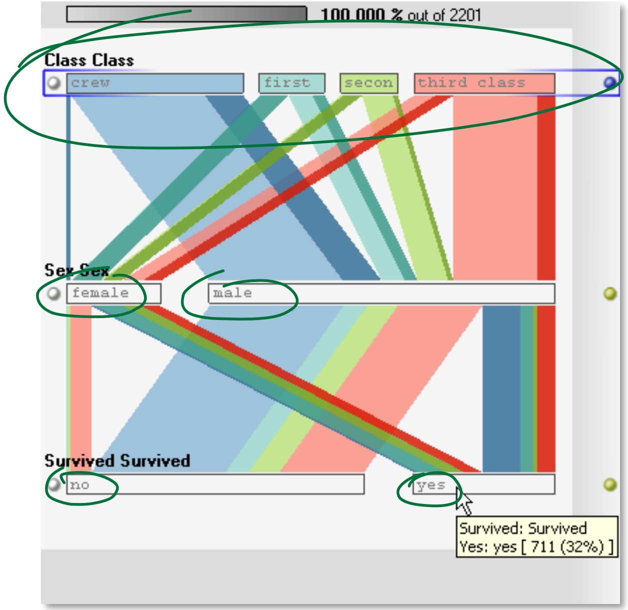
What Is Visualisation?

- A readable (visually inspectable) representation of non-visual data
- A minimal set of requirements for any visualisation (Kosara, 2007)
  - Is based on data
  - Produces an image
  - Is readable and recognizable

Kosara, R. (2007, 4–6 July). Visualization criticism: The missing link between information visualization and art. *2007 11th International Conference Information Visualization* (IV '07),

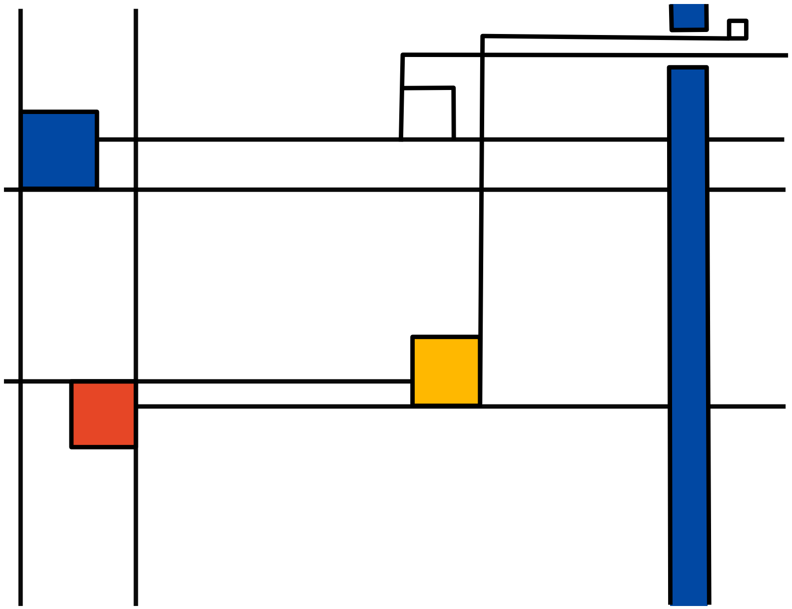
Type of Visualisation, Part I

Readable/recognisable



Type of Visualisation, Part II

Not readable but recognisable

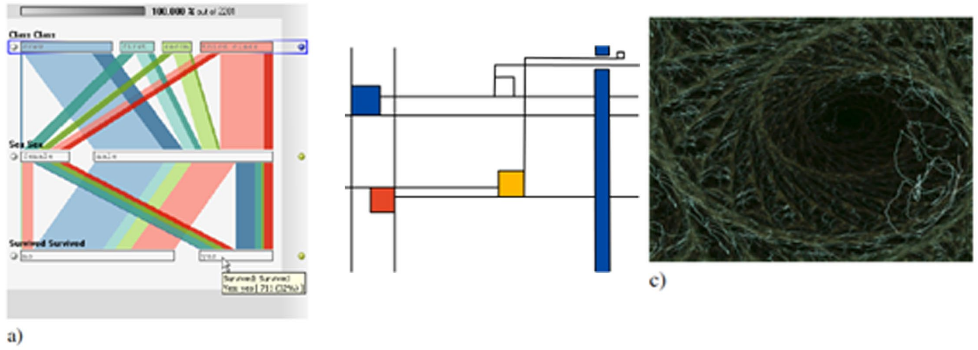


Type of Visualisation, Part III

Neither readable nor recognisable

Screensaver based on music

Type of Visualisation, Part IV



Parallel sets, etc.

Recognizable
Readable

Informative art

Not recognizable
Readable

Music visualization, etc.

Not recognizable
Readable

Pragmatic Visualisation

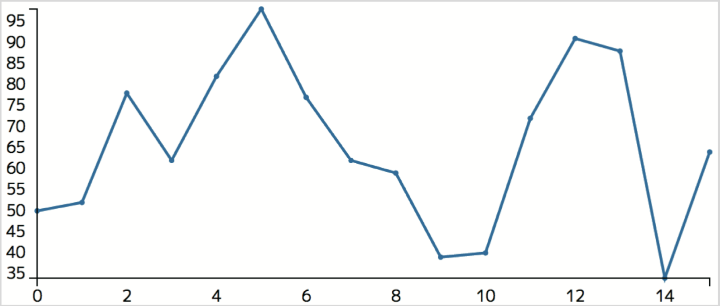
Artistic visualisation

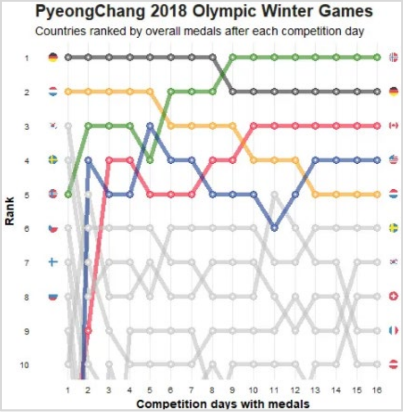
Utilitarian

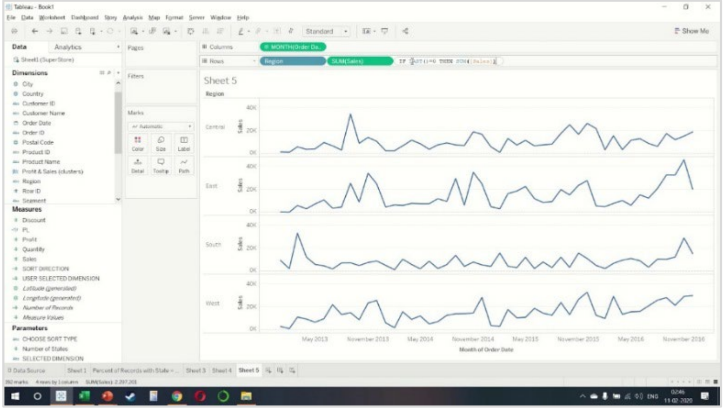
Sublime

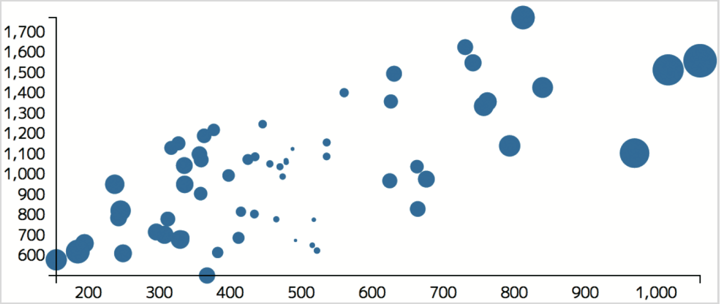
Figure 1. The gamut of data-based visualisation. a) Parallel sets [12] show data about the people on the Titanic, and are readable and recognizable as a visualisation; b) Ambient visualisation [18] visualising a bus schedule is readable but requires more effort and is not readily recognizable as a visualisation; c) Music visualisation like MilkDrop [23] is also based on data, but not readable.

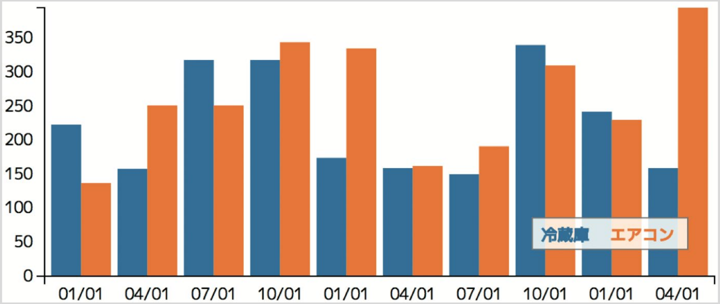
Examples of Visualisation



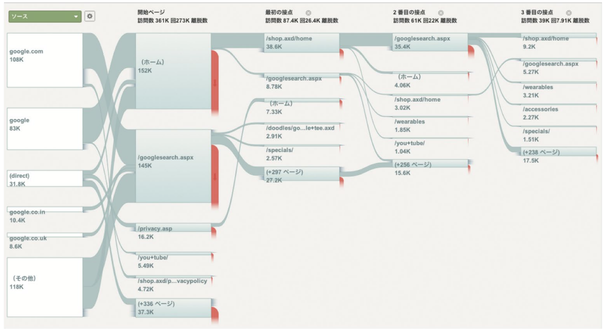




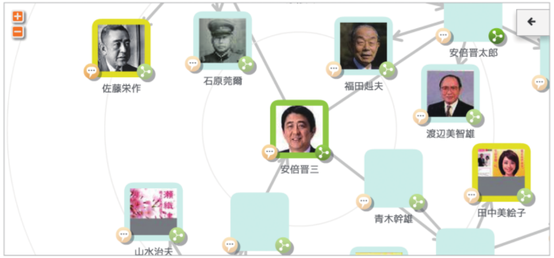




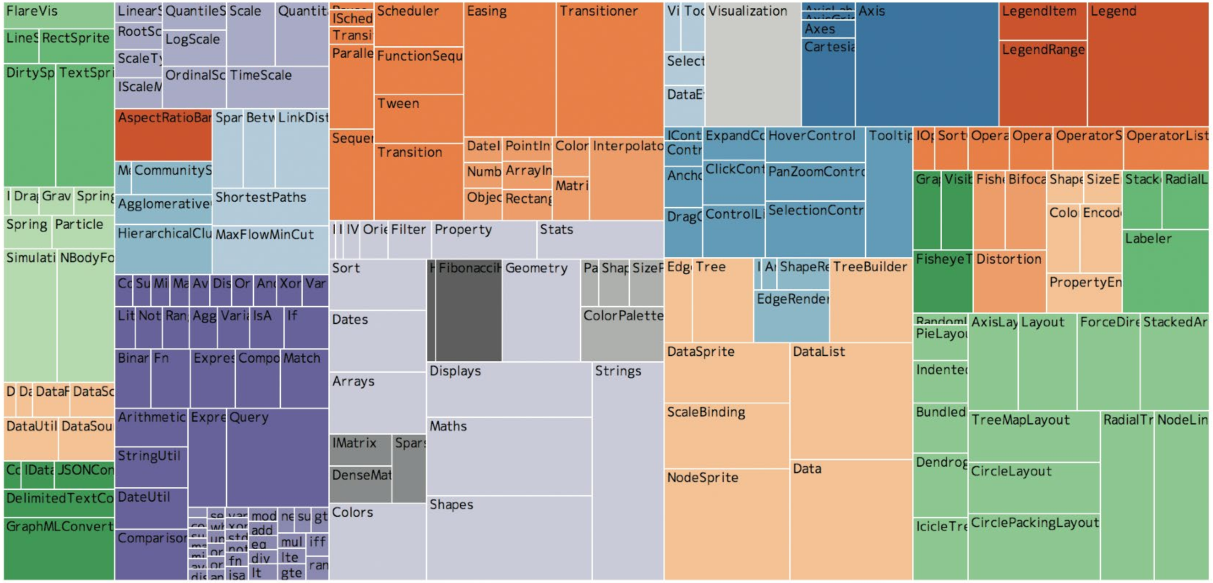
Examples of Visualisation (cont.)



(http://analytics-ja.blogspot.jp/2011/10/blog-post_26.html)



※『スパイシー』
(http://spysee.jp/%E5%AE%89%E5%80%8D%E6%99%8B%E4%B8%89/71814/profile?refl=from_edge_list)



※『d3.js garally』(http://bl.ocks.org/mbostock/4063582)

Benefits of Visualisation

- Increased resources
  - Offload work to the perceptual system
  - External memory
- Reduced search
  - Grouping
  - High data density
- Enhanced recognition
  - Recognition instead of recall
  - Abstraction and aggregation
- Manipulable medium

Card, S., Mackinlay, J., & Shneiderman, B. (1999). *Readings in information visualization: Using vision to think.* Morgan Kaufmann.

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Evaluation Methods

Evaluation

An assessment of visualisation to see if benefits have been provided

Is Good Visualisation Equivalent to Pretty Pictures?

To make better visualisation, we need to:

- Know how people make sense of data
- Evaluate the visualisations

How Do People Perceive Data?

Recall …

- Gestalt principles
  - Similarity
  - Proximity
  - Common region
  - Closure
  - Continuity
  - Connection

How Do People Perceive Data? (cont.)

Visual system (including cognitive process) may yield untruthful results.

- Aoccdrnig to rscheearch at Cmabrigde Uinervtisy, it deosn't mttaer in waht oredr the ltteers in a wrod are, the olny iprmoatnt tihng is taht the frist and lsat ltteer be at the rghit pclae. The rset can be a toatl mses and you can sitll raed it wouthit a porbelm. Tihs is bcuseae the human mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe.

Evaluation Methods

- Interview
- Questionnaire
- Analytic inspection
- Empirical evaluation

Interview

- Qualitative technique
  - Gathering information about users by talking directly to them
  - A method for discovering facts and opinions of the users
- Format
  - It is usually done by one interviewer speaking to one user at a time
  - Structured interviews: a predefined set of questions and users
  - Open-ended interviews: allows for an exploratory approach to uncover unexpected information
- Problems
  - The unstructured nature of the resulting data can be easily misinterpreted

Questionnaire

- Qualitative technique
  - But results can be quantified
- Preparation
  - Keep questions simple, be clear and concise
  - Group questions appropriately/give explanation
- Pilot questionnaire before distributing it
  - It is still unreasonable to think that any one person can anticipate all the potential problems
- Problems
  - It is only as good as the questions it contains

Question Types

- General
  - On average, how much time per week do you spend on this system?

    1) Less than 1 hour
    2) 1 to less than 4 hours
    3) 4 to less than 10 hours
    4) Over 10 hours
- Open-ended
  - What are the features you think helpful, if any?
  - What are the features you think can be improved, if any?

Question Types (cont.)

- Closed
  - Which of the following have you used? (Tick all that apply)

    1) Word processor 2) Database 3) Spreadsheet
  - How easy was it to understand the drawing?

    1) Very easy 2) Easy 3) Average 4) Difficult 5) Very difficult
- Scale
  - Indicate how much effort you devoted for this task based on a scale from 0 to 6?
    - 0 (extremely easy) 1 2 3 4 5 6 (extremely difficult)

Questionnaire Examples

- Established questionnaires will give more reliable and repeatable results than ad hoc questionnaires
- Three questionnaires for assessing the perceived usability of an interactive system
  1. Questionnaire for User Interface Satisfaction (QUIS)
     - Chin, J. P., Diehl, V. A. and Norman, K. L. (1988). Development of an instrument measuring user satisfaction of the human-computer interface. *Proceedings of SIGCHI '88* (pp. 213–218). ACM/SIGCHI.
  2. Computer System Usability Questionnaire (CSUQ)
     - Lewis, J. R. (1995). IBM computer usability satisfaction questionnaires: Psychometric evaluation and instructions for use. *International Journal of Human-Computer Interaction*, *7*(1), 57–78.
  3. System Usability Scale (SUS)
     - Brooke, J. (1986). SUS: A "quick and dirty" usability scale. In P. W. Jordan, B. Thomas, B. A. Weerdmeester, and A. L. McClelland (Eds.), *Usability evaluation in industry.* Taylor and Francis.

Analytic Inspection

- Benefits
  - Generate results quickly with low cost
  - Can be used early in the design phases
- Heuristic evaluation
  - Experts review the systems against a list of principles
- Cognitive walkthrough
  - Starts with a task analysis that specifies the sequence of steps or actions required by a user to accomplish a task
  - Then works through the steps

Empirical Evaluation

- Usability test
  - Think aloud, eye tracking
  - Formative: helps/guides design
  - Against the single UI (visualisation)
  - Identify usability problems
  - Qualitative feedback from users
- Controlled experiment
  - Summative: measure the final result of the task
  - Compare multiple UIs (visualisations)
  - Quantitative results, statistical significance

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Case Study on Graph Visualisation

Aspects of a High-Quality Graph

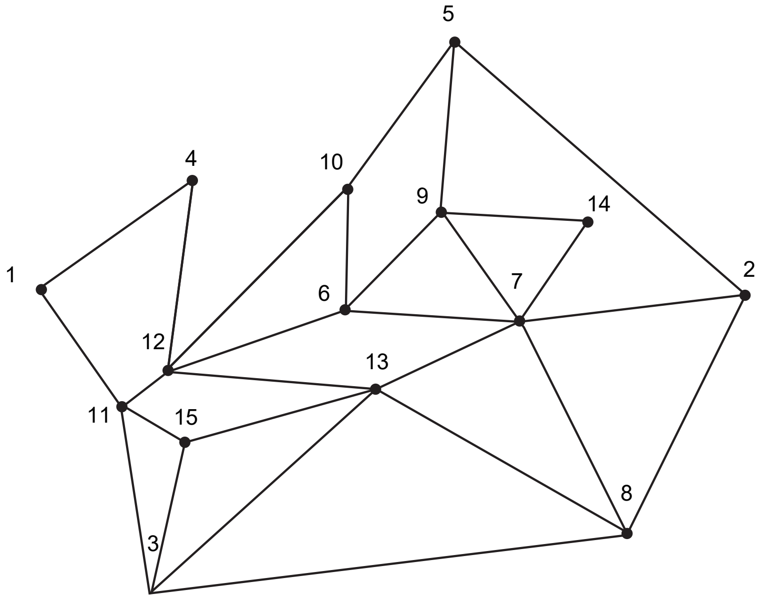
- Efficiency
  - The running time of algorithms should be reasonably fast.
- Elegance
  - Algorithms should be easy to understand and easy to code.
  - Final drawings should be beautiful.
- Effectiveness
  - Graph viewers should understand the underlying data quickly and correctly.

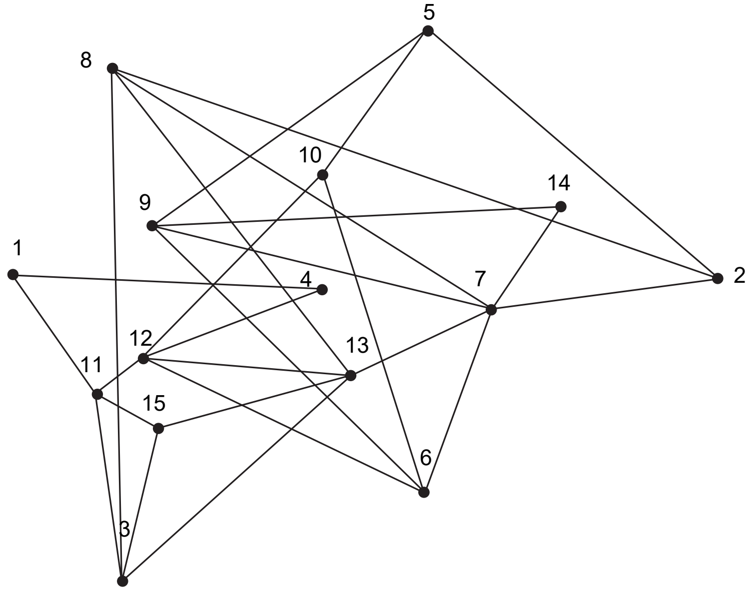
Effectiveness of a Graph

- Visualisation designers are often satisfied with the “coolness” of the technologies they introduced.
  - Technology that looks “cool” to the designer might be too complex or unneeded for real users
- It is assumed that graphs should be effective when drawn conforming to some predefined criteria.
  - Maximise symmetry
  - Minimise edge crosses
  - Maximise angular resolution
- However, common sense and intuition are not reliable.
  - Users, data sets, and tasks are different

Which One Is Better?

We do not know until we actually evaluate them.





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Case Study I on Graph Visualisation

Case Study I: Controlled Experiment on Performance

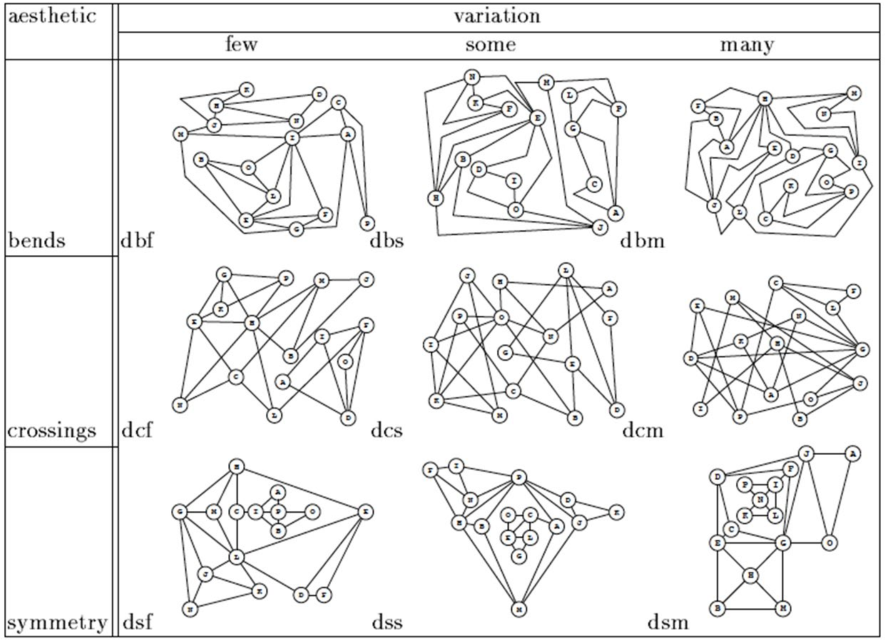


Fig. 1. The Experimental Graph Drawings: dense graph

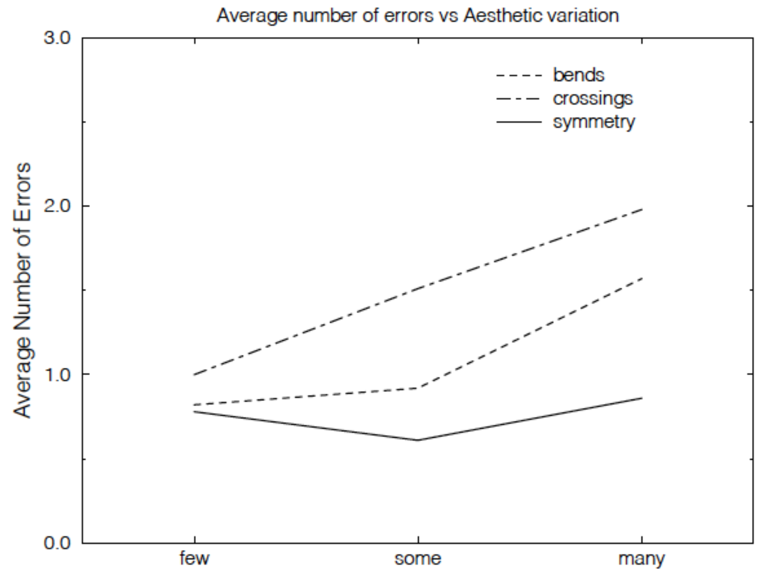
Purchase, H. C., Cohen, R. F., & James, M. (1996). Validating graph drawing aesthetics. In Brandenburg, F. J. (Ed.), *Graph drawing* (pp. 435–446). Berlin, Heidelberg.

Case Study I: Design and Analysis

- On dense/sparse graph
- Bends, crosses, symmetry
- High/medium/low presence
- Accuracy in fixed time (45 seconds)
- Task: find the shortest path between two nodes
- Paper-based, within-subjects, random order a “filler” task

Case Study I: Results and Discussion

- Bends and crossing are important
- Symmetry needs further examination
- A pioneering work that provides empirical evidence for intuition-based aesthetic criteria



bends	6	18	30
crossings	6	24	42
symmetry	4.57	25.7	51.0

Aesthetic Variation

Fig. 3. Results for the dense graph

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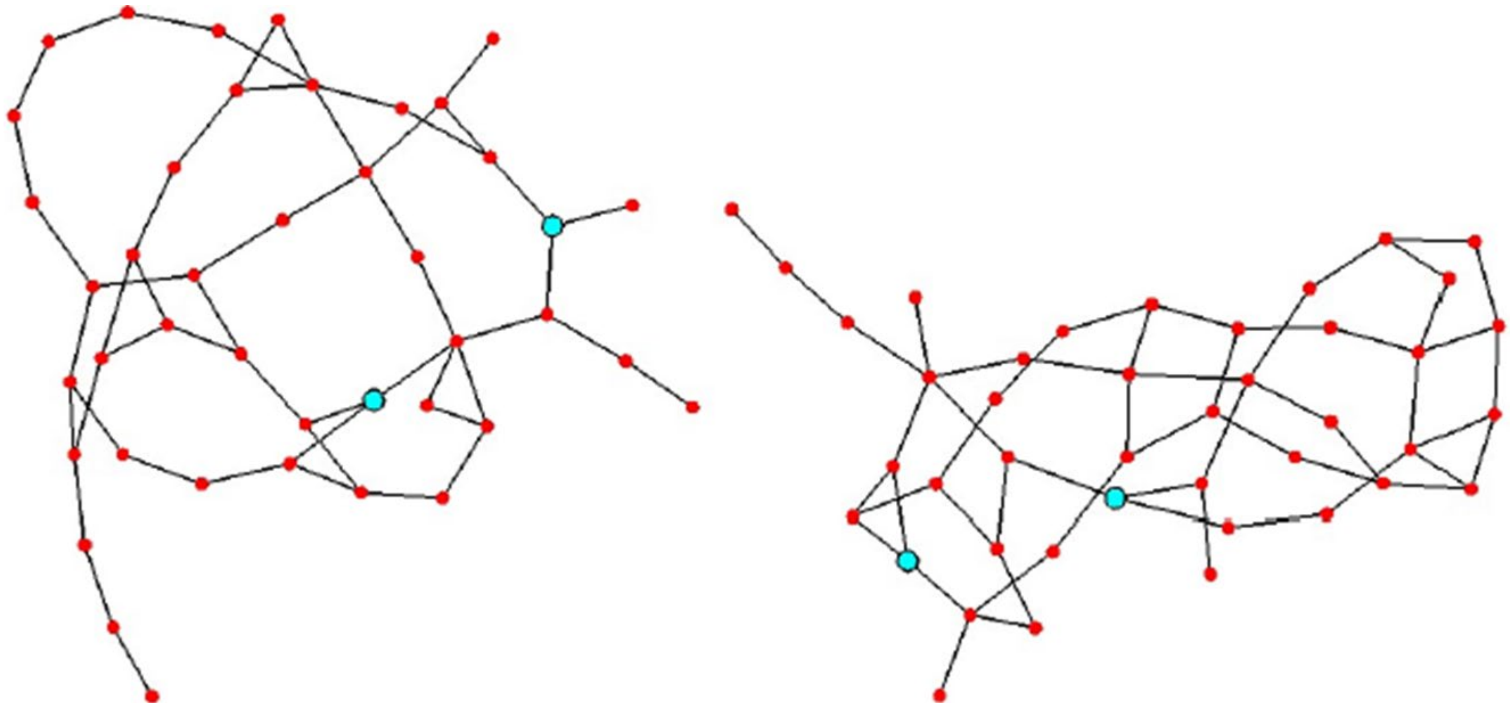
Case Study II on Graph Visualisation

Case Study II: An Experiment Without Manipulation/Interaction



Ware et al. (2003) Cognitive measurements of graph aesthetics. *Information Visualization, 1*(2), 103–110.

Case Study II: Design and Analysis

- Create a set of random graphs, drawn with a spring algorithm
- Highlight two nodes, record the measurements of the predictor variables
  - Continuity, number of crossings, crossing angles, number of branches, shortest path length …
- Record the response variable
  - Response time
- Regress response variable on predictor variables to detect their relationships
- Task: shortest path between two highlighted nodes
- Analysis: correlation and multiple regression
- Finding: path continuity and number of crossing on the shortest path are important factors

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Case Study III on Graph Visualisation

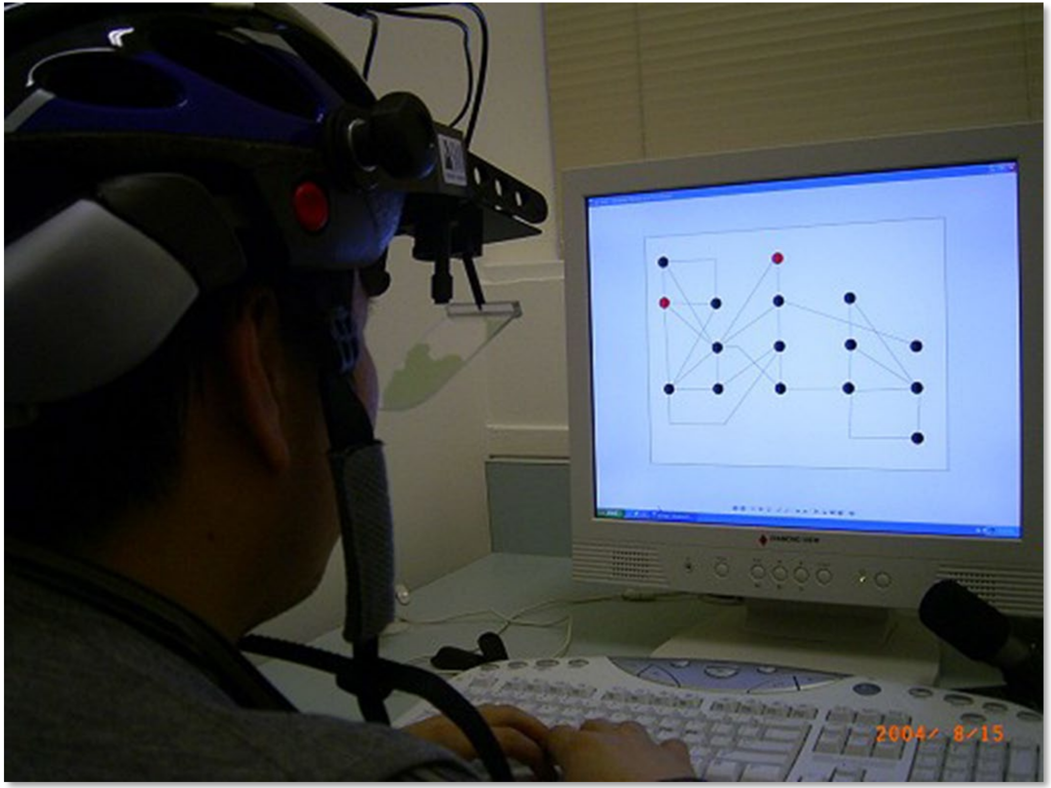
Case Study III: Beyond Time and Error

- Where is the time spent and how is the performance impacted?
- What is the mechanism of crossings affecting performance?
- Time and error performance logging
  - Treat the human as a “black box,” which tells us what but not how and why
- Eye tracking may give insight as to how
- Post-interview and questionnaire tell us why

Case Study III: Beyond Time and Error (cont.)

- Two exploratory eye tracking experiments
  - Ex1: small and sparse graphs ✓✓
  - Ex2: large and dense graphs ✓✓
- Three confirmatory controlled experiments
  - Ex3a: existence of geodesic-path tendency ✓✓
  - Ex3b: effects of geodesic-path tendency ✓✓

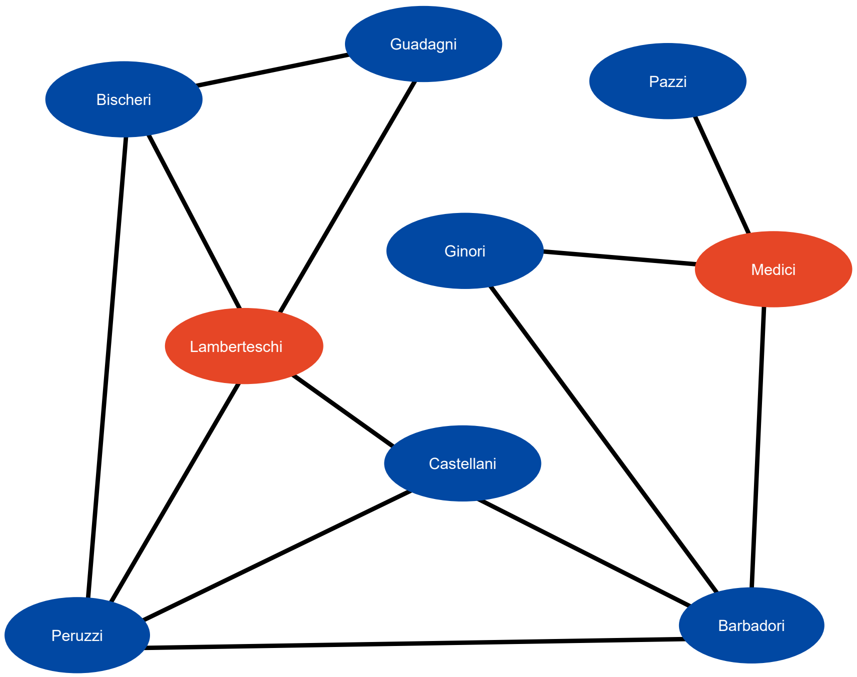
Eye Tracker

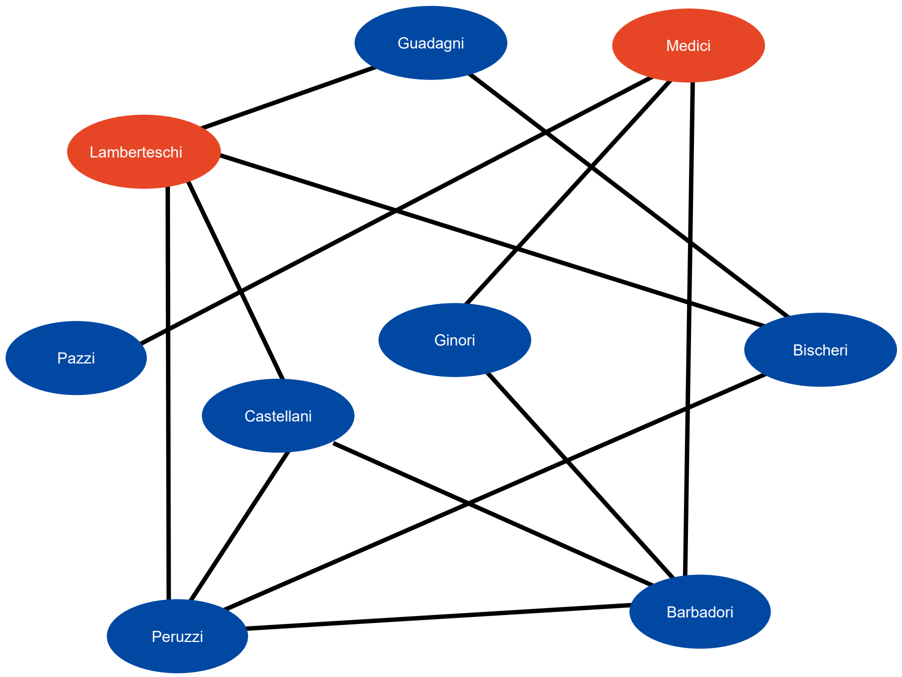


Case Study III, Experiment I: Description

- Task: find the shortest path between two highlighted nodes
- Time, error, and eye movements were recorded
- Questionnaires and interviews

Case Study III, Experiment I: Example of Stimuli



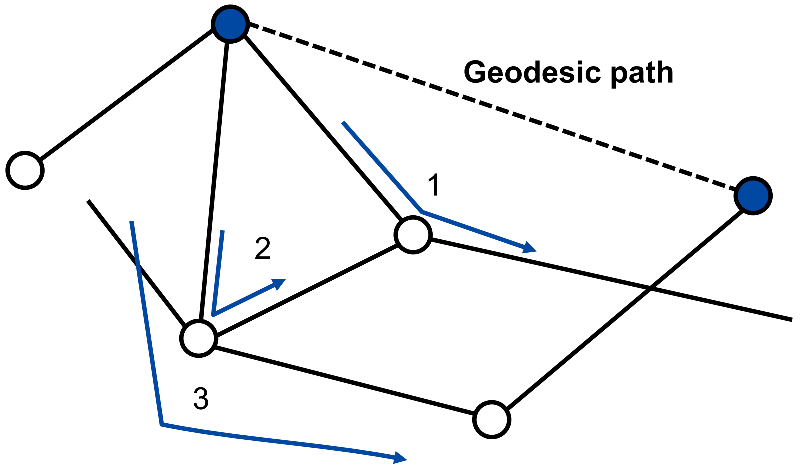


Case Study III, Experiment I: Results of Time and Error

- Overall, subjects spent significantly more time with crossing drawings than with non-crossings.
- However, on some specific instances, this was not the case.

Case Study III, Experiment I: Results of Eye Tracking

- Crossings had little impact on eye movements.
- Geodesic-path tendency: Subjects seemed to follow the geodesic path between the current node and target node.



Case Study III: Possible Reasons for the Lack of Crossing Effect

Crossing angles may inhibit readability (Ware et al., 2003).

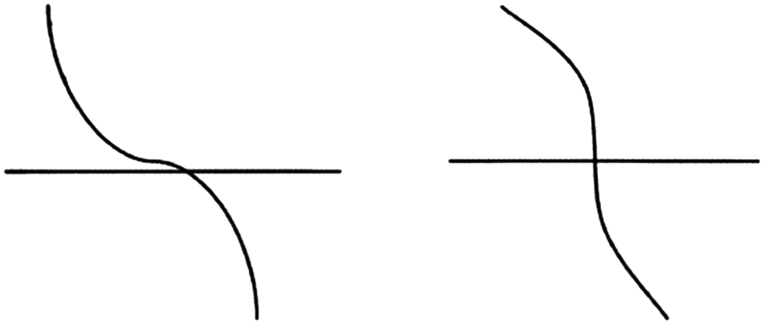


Figure 1. The pattern on the left (a) is perceived as a curved line overlapping a rectangle (b) rather than as shown in (c).

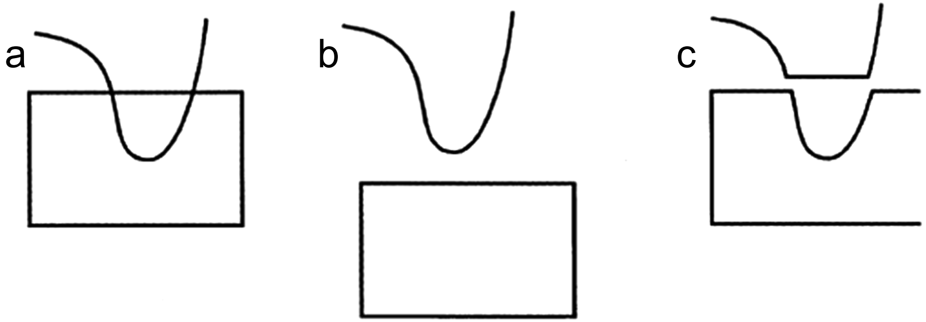


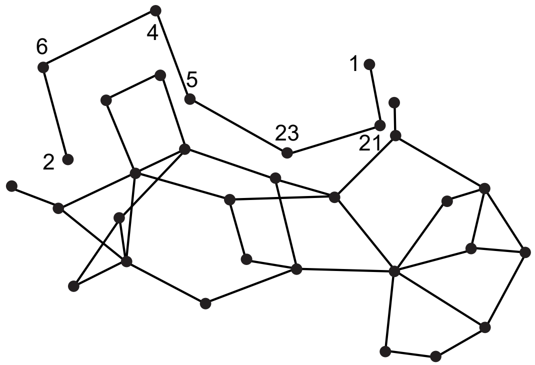
Figure 2. The coarse orientation tuning of edge detectors in the brain suggests that lines that cross at an acute angle as shown on the left are more likely to be confusion than lines that cross nearly at 90° as shown on the right.

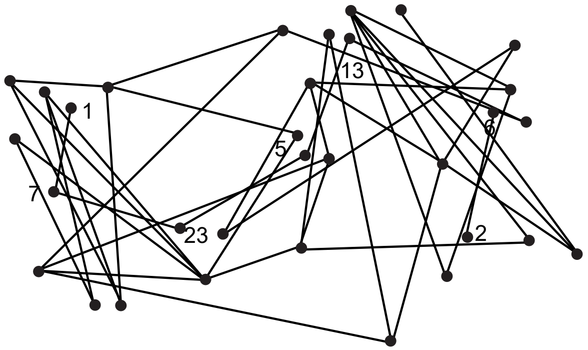
Case Study III, Experiment II: Description

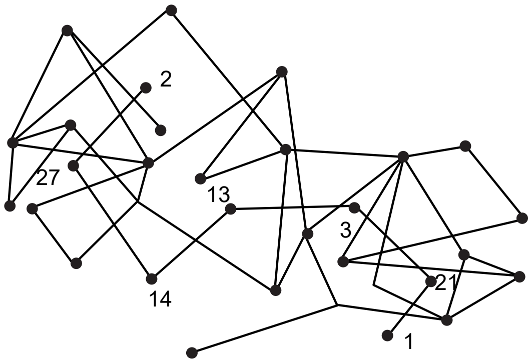
Crossing angle

- Graphs were drawn with three conditions
  1. No crossings on the path
  2. Small-angle crossings
  3. Large-angle crossings

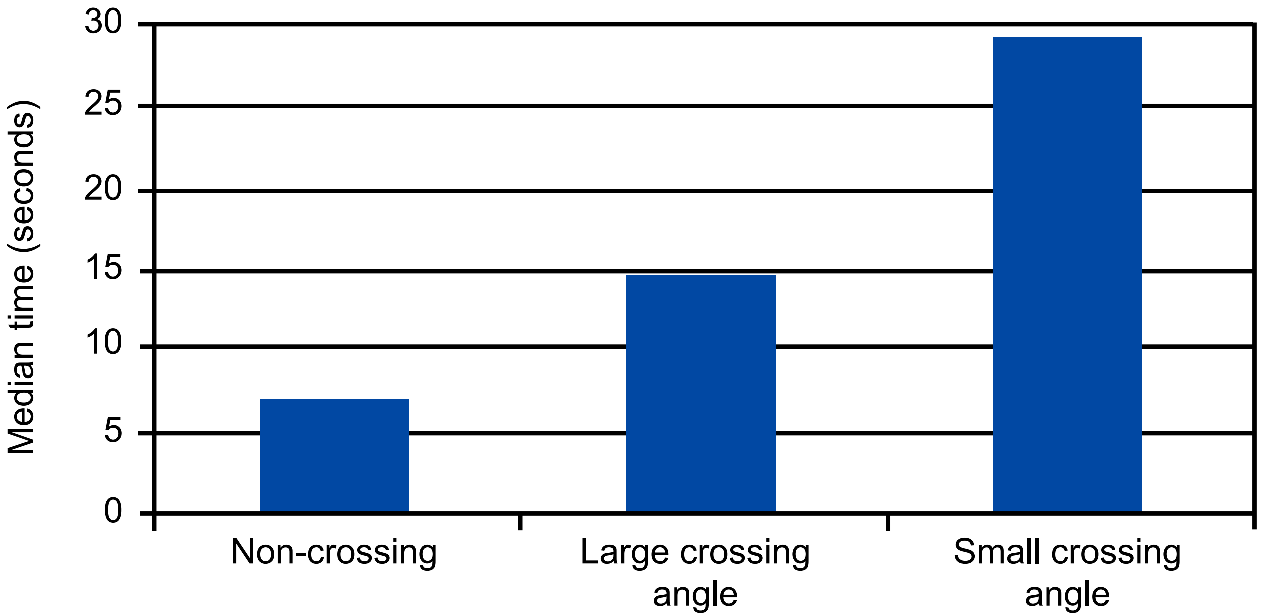
Case Study III, Experiment II: Example of Stimuli







Case Study III, Experiment II: Results



Effects of crossing angles were significant.

Case Study III, Experiment II: Results of Eye Tracking

- No crossings: eye movements were smooth and fast.
- Large crossing angle: eye movements were still smooth, but slower.
- Small crossing angle: eye movements were very slow and no longer smooth (back-forth moves at crossing points).

Summary

To make sure that visualisation is effective, we need:

- Principles and theories to guide the visualisation design
- Once visualisations are produced, we need proper methods and measurements to evaluate them

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