

December 5<sup>th</sup>, 2023

## LECTURE 4 MENTAL MODELS, METAPHORES, HISTORY



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Key-concepts in HCI & IV

## KEY CONCEPTS - AFFORDANCE



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### Key Concepts of HCI

- Usability
- Cognetics – Locus of Attention
- Affordance
  - what sort of operations and manipulations can be done to an object
  - crucial is the Perceived Affordance
- Visibility (Transparency)
- Task orientation – Fit, Analysis



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### Affordance

- In design for Interactivity, James Gibson is best known as the man who gave us the concept of **affordance**.
- An affordance is a resource or support that the environment offers an animal; the animal in turn must possess the capabilities to perceive it and to use it.
- An affordance refers to physical properties of the environmental constraints and to a person's (or other animal) bodily dimensions and capacities.
- An affordance exists, whether it is perceived or used or not.
- It may be detected and used without explicit awareness of doing so.



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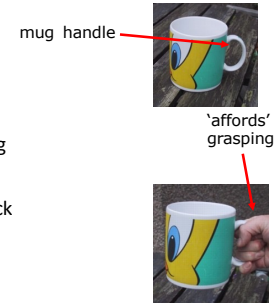
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## Definition of Affordance for Interaction (D.Norman, 1992)

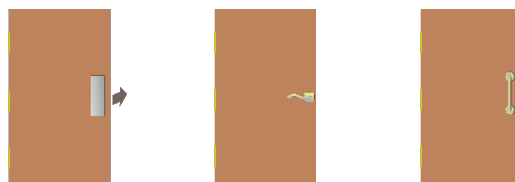
- Important for Interaction: Perceived Affordance
- “What a person thinks can be done with an object.”
- “A technical term that refers to the properties of objects - what sorts of operations and manipulations can be done to a particular object.”
  - In “Psychology of Everyday Things” (POET)
  - Also “Design of Everyday Things” (DOET)
  - Originated from Psychologist JJ Gibson
  - Adapted in weaker form
  - More about conventions of objects than reality
- Graphical Interactive Element in InfoVis

## Affordance

- Psychological term
- For physical objects
  - shape and size suggest actions
    - pick up, twist, throw
  - also cultural – buttons ‘afford’ pushing
- For screen objects
  - button-like object ‘affords’ mouse click
  - physical-like objects suggest use
- Culture of computer use
  - icons ‘afford’ clicking
  - or even double clicking ... not like real buttons!



## Example



Metal plate

Handle

Handle

How does the door afford to be opened ...

Key concepts in HCI & IV

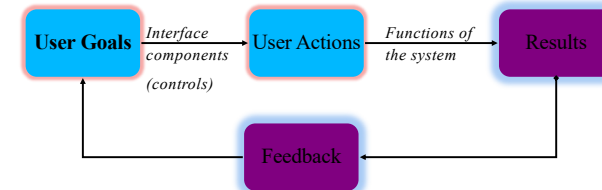
## KEY-CONCEPTS: VISIBILITY

## Key Concepts of HCI/InfoVis

- Usability - Measurement of Success
- Cognetics - Locus of Attention
- Perceptics - Perceiving information with the senses
- Affordance - what sort of operations and manipulations can be done to an object, crucial is the Perceived Affordance
- Visibility (Transparency)
  - mapping between controls and effects should be sensible and meaningful
  - **feedback**
- Task orientation – Fit, Analysis

## Definition of Visibility

*The extent to which functions and their results are visible to the user as well as how easy it is to find and use these functions*



- The User can reason - internalize knowledge in interface/visualization

## Visibility, aka Transparency

- Phones vs. Cars
  - What feedback do you get ...
- Important concept: **constraining interfaces**. restricting the way we can use them
  - GUI: de-activation (greying-out)
  - Categories of constraints:
    - Physical - e.g. disk
    - Logical - rely on knowledge of how world works
    - Cultural - learned conventions ("arbitrary")
  - These categories are (implicitly) used in design;

*How we support our reasoning and thinking on artifacts.*

**MENTAL MODELS  
METAPHORS AND ...**

## Contents

- Knowledge representation
- Mental models
- Schemata
- Relation Mental model to User
- Relation Mental model to Designer
- Metaphors

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## MENTAL MODELS EXAMPLE

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## Case Study

- Food has an expiry date
  - Do not buy food past its expiry date
  - Remove food after expiry date
- Credit cards have an expiry date
  - Can not use Credit Card after expiry date
  - Throw away expired Credit Card
- Email certificates have expiry date  
Passport has expiry date
  - What to do after certificate/passport expires ?
  - **Throw away:**
    - Will block email with certificate! ⇒ *Emails become unreadable and unusable*
    - Will complicate obtaining a new passport!

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## Case Study & Mental Models

- Mental Model of expiry date
  - Seems not to be context sensitive
- As
  - Food, Credit Card: same behavior
- But
  - Email certificate/ Passport: different behavior whilst same mental model is appealed on!
- Design requires a good Mental model
  - Designers use it
  - Users use it
  - Based on former knowledge
- How do we deal with knowledge?

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## Knowledge and HCI / InfoVis

- One should realize:  
*Understanding of the way that knowledge is represented, organized and retrieved is important. It can be used so that then perhaps it is possible to develop interfaces/visualizations that facilitate thinking and problem solving.*
- Prediction of behavior of the machine
- Understanding of visualization, Enable reasoning (comp. Prediction human behaviour)

## KNOWLEDGE REPRESENTATION

## Knowledge Representation

### Symbolic Representation

- Cognition depends on rule-like manipulation of symbolic structures
- *Imagists*
  - Images
  - Picture representation
- *Propositionalists*
  - Propositions
  - Proposition representation

### Sub-Symbolic Representation

- *Connectionists*: Connectionism
  - distributed representations

## Imagists

- Analogical representations underlie mental processing
- Analogical representations are picture like images (of the real world)
  - Buying bread
  - Putting bread on the table
- No thought without images
- Images and Imagery play a role in thinking and reasoning

## Propositionalists

- Propositional representations underlie mental processing
- Proposition representations are abstract language-like statements that make **assertions**
  - The bread is on the table
  - The table is in the garden
- Images are a by-product

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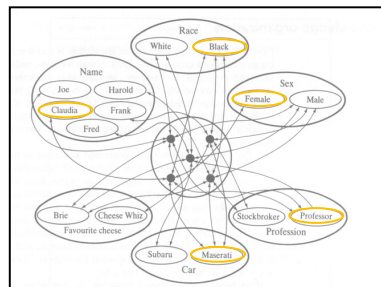
## Connectionists

- Distributed representations
- Distributed representations are Networks of Nodes
- Knowledge is implicit in connections of nodes
- Images and Propositions are complementary
  - Exist at higher level of representation
  - Sub-symbolic: properties of neural network of nodes

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## Connectionism Visualized

Knowledge is in the nodes



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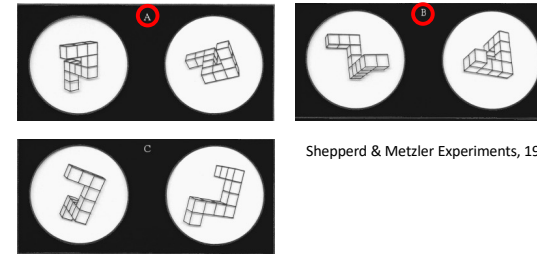
## EXPERIENCING REPRESENTATION

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## Experiments

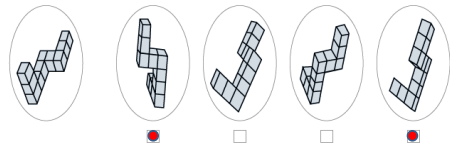
- Are Analogical, Propositional and Distributed representation distinct forms of mental representation?
- In the following experiments the mental ability to rotate an object is addressed.
- (I) The more disparate the view, the more time it takes ...
- (P) Complexity, i.e. # propositions, affects time for mental rotation ...

## Which images are the same?(1)

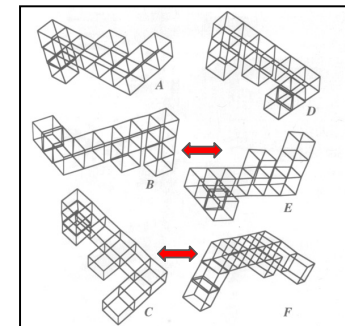


Shepperd & Metzler Experiments, 1971

## Which images are similar to '1'?



## Which images are the same?(2)



## Mental Manipulation of Objects

- Experiments by Metzler & Shepard (1971-1982)
- Case study of rotation
  - Rotation is a mental process
  - With/Without Hidden line removal
  - Small/Large rotations between similar objects
- Not the 2D picture was rotated, rather the underlying 3D object
- Rate of rotation  $\sim 60^\circ/\text{s}$ 
  - The farther apart, the longer it takes.
- Effect of hidden lines: complexity!

## MENTAL IMAGES & MEMORY

## Mental Images – Visual Memory

- Mental images are transitory
  - maintained by cognitive effort
- Relatively simple images can be kept
  - Cognitive load is low
- Operations can be done on mental Images
- Visual imagery same neural machinery as vision
  - fMRI show same activations (areas) in the brain
- Mental & External imagery can be combined
  - Cognitive load is high, very active visual reasoning
  - Attribute vision to Active vision (lecture 3)

## MENTAL MODELS



## Mental Models

- Scottish psychologist Kenneth Craik (1943)
  - Mind constructs small scale models of reality to anticipate events, to reason and to underlie explanation
- A mental model is acquired through ...
  - Interaction
  - Explanation
- A mental model is constructed from ...
  - Perception
  - Imagination
  - Interpretation of discourse
- A mental model represents ...
  - Explicitly what is true
  - Not what is false

## Schemata: definition

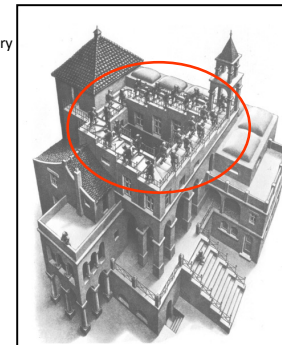
- A schemata is a network of knowledge based on previous experience
- Schemata are static, as a sequence of events is played back
- Schemata can sometimes be represented by a metaphor
- A script is a special schema, a scenario for a defined situation

## Schemata: example

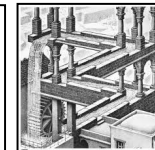
- Walking into a restaurant with a group of people
  - Look at menu outside
  - Enter with the party
  - Wait for the waiter
  - Be seated, be asked for a drink
  - Choose from the menu and order ...
- Taking the train to Amsterdam CS from Leiden CS
  - Make sure there is enough budget on your OV-card
  - Look at time-table for next train
  - Go to the platform, Check-in
  - Wait for the train to arrive ...
  - [this schemata has been “re-inforced” recently]

## Mental Conflicts

The scene looks ordinary  
but ...



Actions on stairs  
confuse state ...



## Mental model: definition

- **Mental models** are models people have of themselves, others and the things with which they interact. People form mental models through experience, training and instruction (D. Norman).
- A **mental model** is a **dynamic** mental representation allowing people to:
  - make **predictions** about future states
  - make **inferences** and
  - imagine situations not experienced before.
  - So, helps reasoning and internal representation.

## Mental Mismatch



Mental model elevator,  
actions correspond

Not corresponding to stairs

New mental model,  
other actions, visual momentum  
Action coupling: embodied cognition

## MENTAL MODEL IN INTERACTION

## Tasking and Mental Model

- **Object-Action Model**
  - User knows which actions can be applied on objects
  - e.g. word processor:
    - words are objects
    - select, copy, change font, delete etc. are actions
- **State-Transition Model**
  - How actions changes the state of the model
  - e.g. ATM:
    - card input / PIN input / service select / amount request / cash withdrawal / card output / sales slip
- **Complex systems have both**
  - e.g. PowerPoint presentation
    - draw / text edit / slide edit / slide presentation

## Different Mental Models

- Functional Mental Model
  - Knowing what to do : the how
  - Referred as the **how-to-use-it** model
  - Context sensitive
  - For a driver a functional model of a car is sufficient
- Structural Mental Model
  - Understanding a structure: the why
  - Referred to as the **how-it-works** model
  - Context free
  - For a mechanic a structural model of a car is a necessity

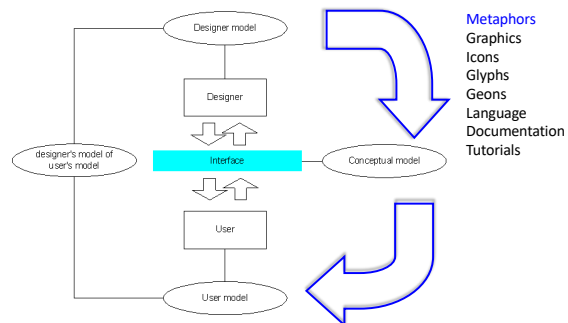
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## Applied to Design

- System Model
  - Systems hardware & software components
- Designer Model
  - Conceptual model of the designer/Information engineer
- System Image
  - User interface (screen design, interface, interaction design)
- User Model (= Mental Model)
  - Conceptual model of the user

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## Users & Designers



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## MENTAL MODEL IN INFOVIS

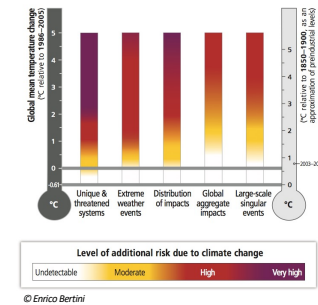
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## Mental Model types in Infovis

- Three types of mental model in infovis
  - The visualization
  - The data
  - The world
- Interaction in Data Visualization
  - Static visualization: linear narrative
    - Non-interactive
  - Dynamic visualization: non-linear
    - Interactive, supports exploration

## Visualization Mental Model in Infovis

- The visualization model
  - Understanding what you see
  - Previous experiences
  - Exploration helps in understanding
- *Example*
  - Previous experience
  - Is this a Bar-Chart
  - Would interaction help to explore?



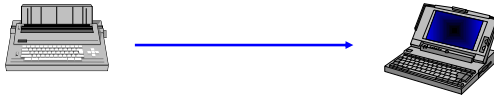
## Data & World Mental Model in InfoViz

- The data model
  - Understand the nature of the data
  - Understand the unit of measurement
  - Understand the order of Magnitude
  - *We will learn more data types*
- The world model
  - What is visualized, relation the phenomena in the world.
  - Mapping of Conceptual models to Systems image
  - Basis for exploration

## METAPHORES

## Metaphor

- To map familiar to unfamiliar knowledge: helps understanding and learning in new domain
- The transference of the relation between one set of objects to another set for the purpose of brief explanation (Webster's revised)
- I. metaphora,  
fr. to carry over, transfer; meta: beyond, over



## Analogy

- Analogy suggests that the mode of operation of the analogon is completely the same as the original
- A resemblance of relations; an agreement or likeness between things in some circumstances or effects, when the things are otherwise entirely different. (Webster's revised)
  - 1. Similarity in some respect between things that are otherwise dissimilar: "the operation of a computer presents an interesting analogy to the working of the brain" (WordNet)
  - 2. (logic) inference that if things agree in some respects they probably agree in others (WordNet)

## Metaphors in daily life

- Lakoff & Johnson
  - "...the way we think, what we experience, and what we do every day is very much a matter of metaphor."
- In our language & thinking - "argument is war"
  - ... he attacked every weak point
  - ... criticisms right on target
  - ... if you use that strategy
  - ... soccer is war!
- In our language & thinking - "time is money"
  - ... this GUI really saves me time
  - ... installing the latest version was a waste of time
  - ... on what subject did you spend most of your time

## METAPHORES IN INTERACTION

## Interface/Interaction: Metaphors

- The **book** metaphor
  - Strength and weakness
- The **internet** metaphor
  - Strength and weakness
- The **desktop** metaphor
  - History and examples
- The **social** metaphor
  - In development
- The **spatial** metaphor
  - In InfoVis

## Composite Metaphors

- While analyzing a metaphor, often more than one metaphor is found.
- Example: desktop
  - Menu, is a metaphor from a restaurant
  - Button is a metaphor of an electrical device
- Users develop mental model to deal with composite metaphors

## The Book Metaphor

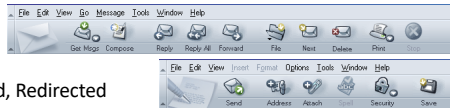
- (Early application of) CD-Rom in multi media
  - Content page
  - Page numbering
  - Index
  - Help navigating the data
- Disadvantages of the book metaphor
  - Not capable of dynamic look-up
  - Turning pages does not fit with fast search
  - ... a bit limited in current use

## Modern Book Metaphor



## Internet Metaphor

- Creating metaphor has come “after the fact”
  - Internet is a phone
  - Internet is a highway
  - Internet is surfing
- Good interface Metaphors can not be applied to pre-existing technologies
- So, Start with a good Metaphor from the beginning
- Email:
  - Transition of “mail”
  - Has an address
  - Send, Received, Forwarded, Redirected



## The Desktop Metaphor

- Started at Xerox PARC
  - Xerox Star (next slide)
  - Bitmapped screens made it possible
- Not meant to be a real desktop
  - Idea is to organize information in away to allow people to use it comparable to the way they use information on their desktops
  - Allow windows to overlap
  - Make the screen act as if there were objects on it

## Xerox Desktop Metaphor



Xerox PARC (Palo Alto Research Centre) and the Xerox Star

## Social Metaphor

- Modeling interface to rules and forms of social behavior
  - Related to spatial metaphor (environment)
- No concrete object/concept
  - Not functionality but Style/Form
  - Social agents
- Social Interaction is often collaborative
  - Human  $\leftarrow \rightarrow$  Human
  - Human  $\leftarrow \rightarrow$  Artificial agents
- Public virtual spaces, or Digital Hangout
  - Social Media
- Relates to basic HCI metaphors

## Social Metaphor



2nd life, a gathering of avatars – a gathering of identities

## SPATIAL METAPHORES

## Spatial Metaphor

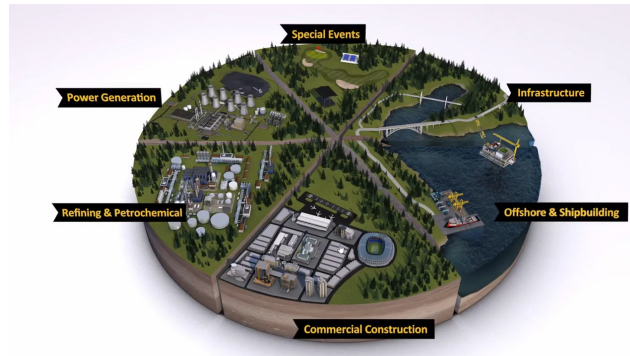
- Humans are adapted to 3D space
  - Spatial metaphor results in natural interaction
- Access functionality by acting in realistic space
  - The normal desktop (2.5D)
  - Gaming (3D virtual world: e.g. Quake, 2<sup>nd</sup> life)
- Issue in information organization
  - Virtual space same problems a Real Space
- Use related problems in improvement of technology

## Spatial Metaphors ...

- 3D interaction (in the (G)UI ) is often thought about and implementations are now finding their way to applications and users.
- Jared White: " *A real 3D interface may be many years from fruition, but use of computers will be unnecessarily restricted in both cognitive and functional sense, and also in the social sense as long as we are living in a flat, two-dimensional virtual world.*"  
August 2004, adapted by fiv.



## Spatial Metaphor



## Spatial metaphor & 3D Interface

- Interacting in Spatial metaphor
  - Action coupling
  - Devices
  - Mental model for Device operation
- Devices
  - Translating position to 3D system – proprioception.
  - Pointing devices
  - VR devices

## Other Spatial interactions ...



Make interactive objects physical ...

## Spatial (3D) Interaction

- Increasingly present in a lot of interfaces
  - iTunes
  - iPod, New SmartPhones (LIDAR)
  - 3D and pseudo 3D interaction
- Interaction with objects.
  - Wii
  - Leap Motion
  - Kinect
  - Myo
- Links (Hypertext) suggest spatial relations
- Relates to basic Interaction Metaphores

## METAPHORES IN INFOVIS

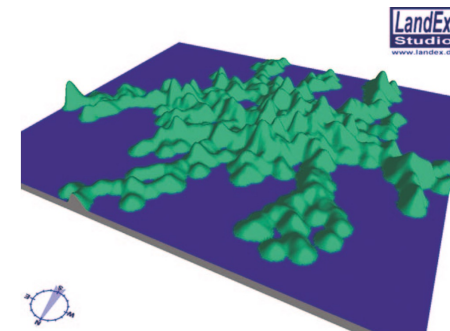
## Interaction - Infovis

- Interaction crucial in information visualization
- Exploration provides understanding
  - Data comprehension (Data Mental Model)
  - Deal with abstractions (World Mental Model)
- Interactive elements
  - Deal with high dimensionality
  - Understanding of datapoint
- Metaphores
  - Support mental model
  - Inferences

## Basic Level InfoVis Metaphores

- Direct Manipulation Metaphore:
  - DATA are Physical OBJECTS
- Navigation Metaphor
  - DATA is in SPACE
  - Distances have a meaning.
- Human Interaction Metaphore:
  - COMPUTERS are PEOPLE
  - Connect with People through Computer networks

## InfoVis: Landscape Metaphor

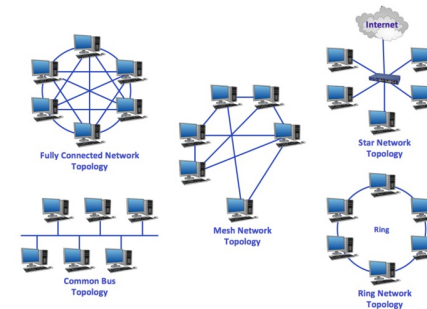


## InfoVis: Network Metaphor (1)

- What is the origin of the network concept?
- Adapted in a lot of fields of research/engineering
  - Abstract relation
  - Direct representation of relations
- Graph representation,
  - Nodes
  - Segments (links)
- Very natural to information workers
  - All kinds of applications
  - Social analysis, Text mining, Bioinformatics  
Workflow, Information analysis, Design ...

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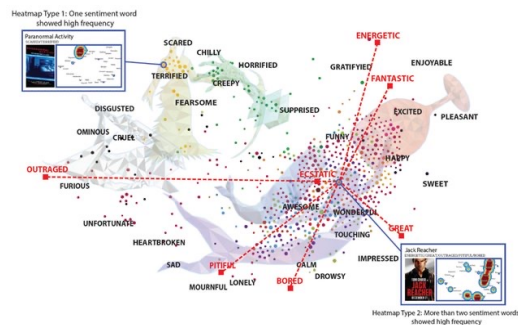
## InfoVis: Network Metaphor (2)



Graph representation, with Nodes and Segments (links) – Abstract Network has a topology

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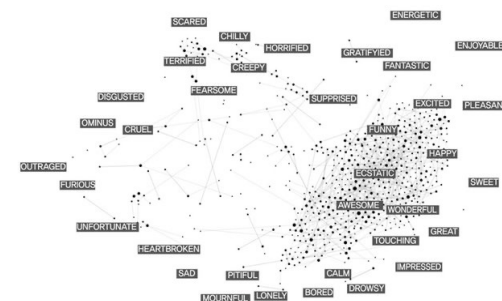
## InfoVis: Network Metaphor (3)



### Pseudo Graph representation, with Clustering for Similarity (Sentiment analysis)

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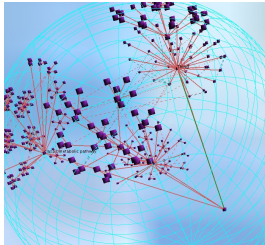
## InfoVis: Network Metaphor (4)



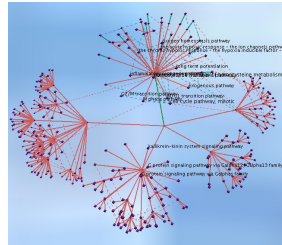
Graph representation, with Clustering for Similarity (Sentiment analysis)

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## InfoVis: Network Metaphor (5)



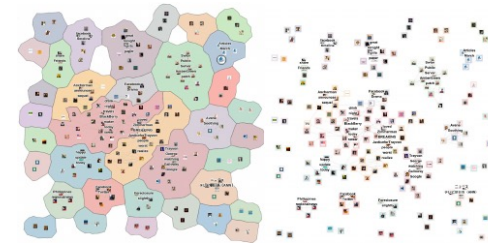
A Hyperbolic projection – Klein model



B Hyperbolic projection – Euclidean

- Graph representation, with Nodes and Segments (links) – Abstract
- Same information visualized with different geometrical structures
- A,B Pathway Ontologies (Biomedical); distances are projected in different manners
- Network topologies are different, information dispersed in different manner.

## InfoVis: Map Metaphor

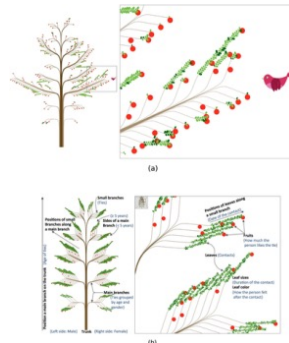


- Map stresses the distances in the graph (right),
- Map clusters the nodes that are closer together
- Color information demonstrates labels
- Transformation for different representations of same data

## InfoVis: Botany, Tree Metaphor



- Tree representation,
- often in graph
  - Segments have different meaning
  - Transformation for processing and visualization



## InfoVis: Metaphors

### Link to Visual strong concepts

- |                            |                |
|----------------------------|----------------|
| – Landscape, has           | – Tree, has    |
| • Elevations               | • Height       |
| • Vegetations              | • Stem/Root    |
| • Land-use                 | • Branches     |
| • Directionality (compass) | • Leaves       |
| – Map, has                 | – Network, has |
| • Cartography              | • Nodes        |
| • Distance                 | • Links        |
| • Boundary                 | • Strength     |
| • Label                    | • Distance     |
|                            | • Topology     |

## Review #4



- Affordance, Visibility
- Knowledge representation
- Mental Models, definitions
- Mental Models and Design
- Schemata, definitions & examples
- Metaphors, definitions & examples
  - Interfaces / Interaction
  - Information Visualization

## Example – “Wii point at Paintings”

