Interaction in Visual Model-based Reasoning

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Oct 28th, 2010

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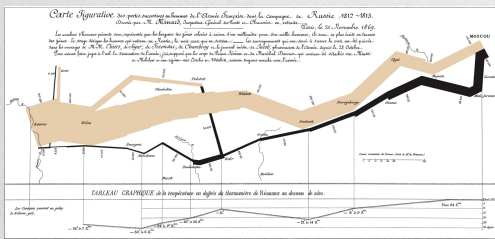
information **interfaces**

Interaction in InfoVis ?

- the communication between user and the system
  [Dix et. al. 2004]

- the dialogue between a human and a computer
  [Foley et. al. 1995]

- the analytic discourse between human and information
  [Thomas and Cook, 2005]
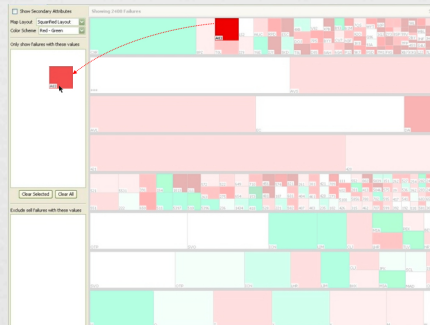
Interaction: Visualization-Centric Perspective
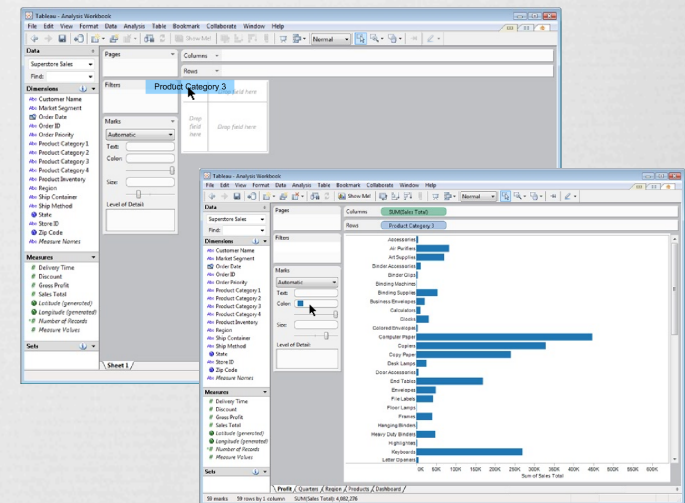
- Interaction = interaction techniques?

static visualization   interactive visualization   visualization construction

Interaction: Information-Centric Perspective

- **Select**: mark something as interesting

- **Explore**: show me something else

- **Reconfigure**: show me a different arrangement

- **Encode**: show me a different representation

- **Abstract/Elaborate**: show me more or less detail

- **Filter**: show me something conditionally

- **Connect**: show me related items

[Yi et al. 2007] 4

Goal of this work:
Interaction from a human-centric perspective

- Interaction can't be fully understood by treating human cognition as a black box

- Unpacking the blackbox

The Internal / External Dynamics

- Distributed Cognition
    - High level framework applicable across domains
    - More detailed formulation specific to InfoVis needed

Questions addressed in this paper

- What do we mean by "Internal Representations" in InfoVis?

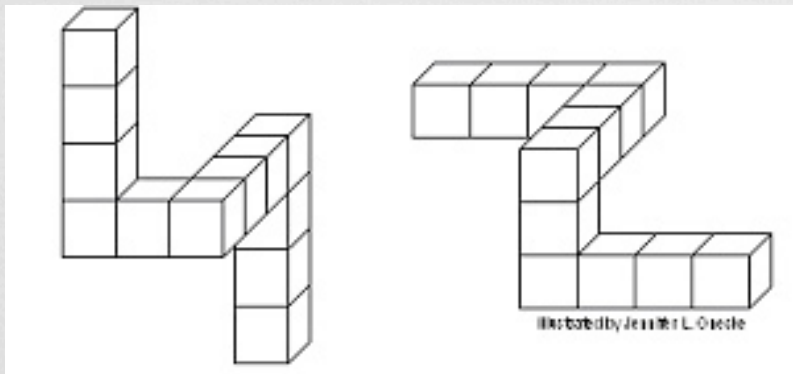- A unified approach to understanding interaction
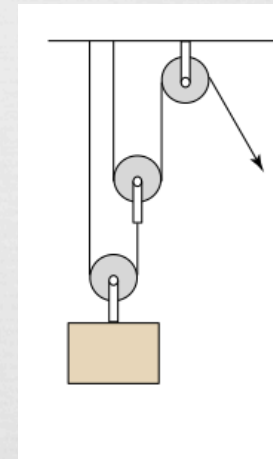
Internal Visualizations

Visualize *verb*

1. to make visible
2. to see or form a mental image of

[merriam-webster.com]

[Shepard and Metzler 1971]

[Hegarty 2004]

Internal Information Visualization?

Mental Model or "Mental Muddle"?

- An overloaded / ambiguous term [Payne 2004]
    - folk theory
    - problem space
    - homomorphism
    - expectation
    - representation derived from language, perception and imagination
    - …

- Is mental model an applicable concept for InfoVis? What do we mean by mental models in InfoVis?

Mental Models in HCI

- Emphasizes the *behavioral* aspect of a system

  A mental model of a device is user's belief of "how a device works in terms of its internal structures and processes".

  [Kieras and Bovair 1984]

Mental Models in Cognitive Science

- Johnson-Laird's theory of mental model

- Emphasizes the *structural* aspects of models

- Analogues of what they represent, preserving relations between entities

- Given a problem, people *construct* and *simulate* mental models for an answer

```
Facts:
1) Tom is older than Kate
2) Tom is older than Bob
```

model 1   Tom Kate Bob
model 2   Tom Bob   Kate

Applicability to InfoVis

- Is "mental model" as used in these works a reasonable concept to describe internal representations of external visualization?

- Concerns
  - **Format**: Image or spatial configuration?
  - **Mechanism**: Simulation
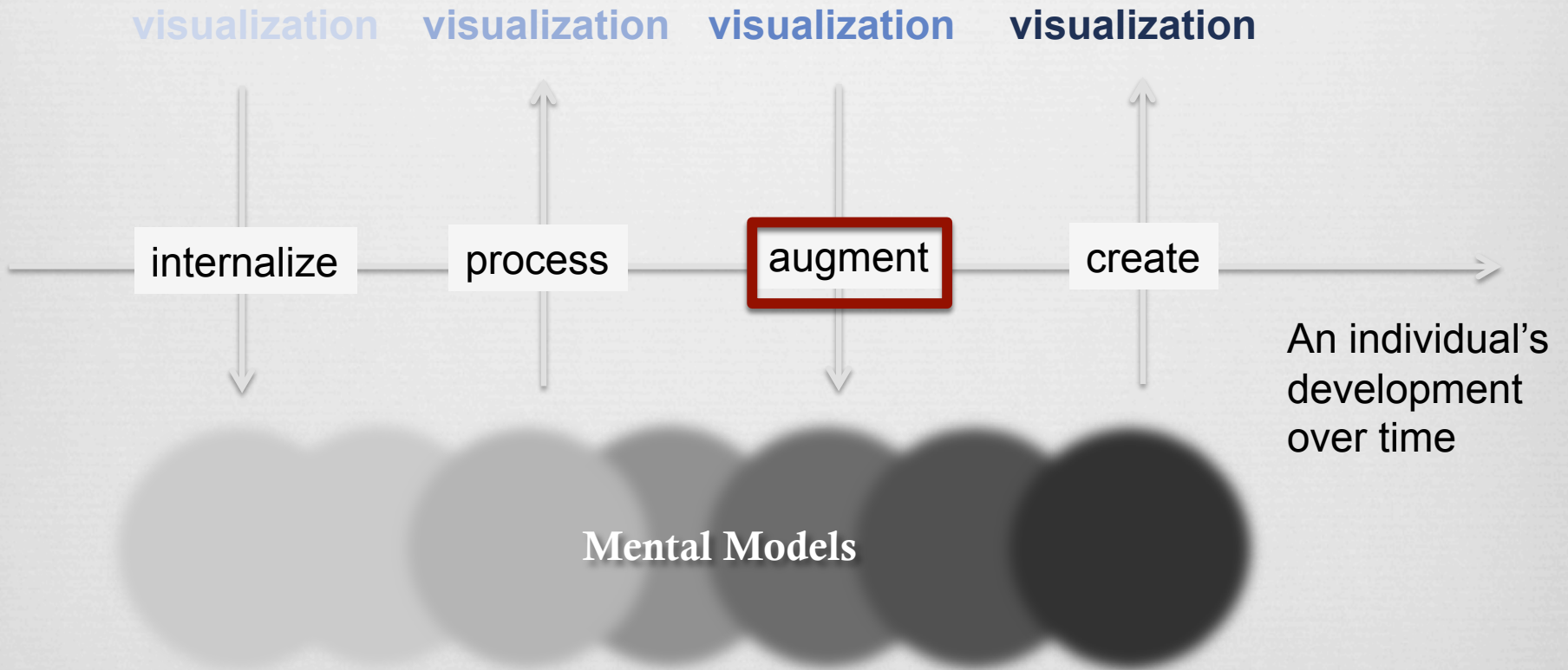 - **Data**: Is information about the data part of a mental model?

Mental Model in InfoVis

- A mental model of an external interactive visualization system is a functional analogue representation where :

  - The *structural* and *behavioral* properties of external systems are preserved

  - Mental model can preserve schematic, semantic or item-specific information about the underlying data.

  - Given a problem, a mental model of an interactive visualization can be *constructed* and *simulated* in working memory for reasoning.

Internal/External Dynamics

visualization   visualization   visualization   **visualization**

internalize   process   augment   create

An individual's development over time

Mental Models

Why do we interact?
A holistic approach

Augmentation: the need for modeling in a distributed system

1. Compensate for the inadequacies of pure mental model-based reasoning

   - Working memory is limited
   - Item-specific information is crucial

2. Maintaining internal / external coupling

   - External visualizations does **not** simply replace mental models
   - Minimize cognitive load

Interaction = Construction and manipulation of a distributed model

Pure mental modeling
Mental simulation
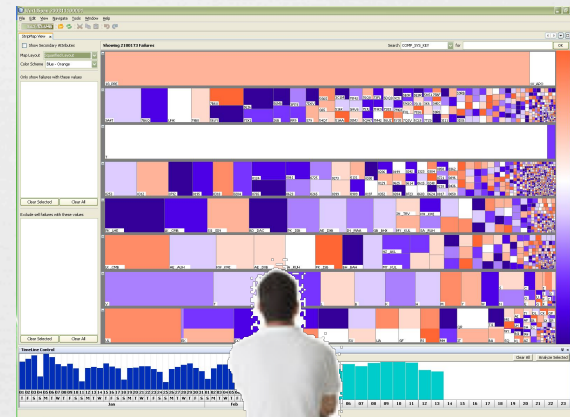
Modeling in a distributed system
Physical action + Mental simulation
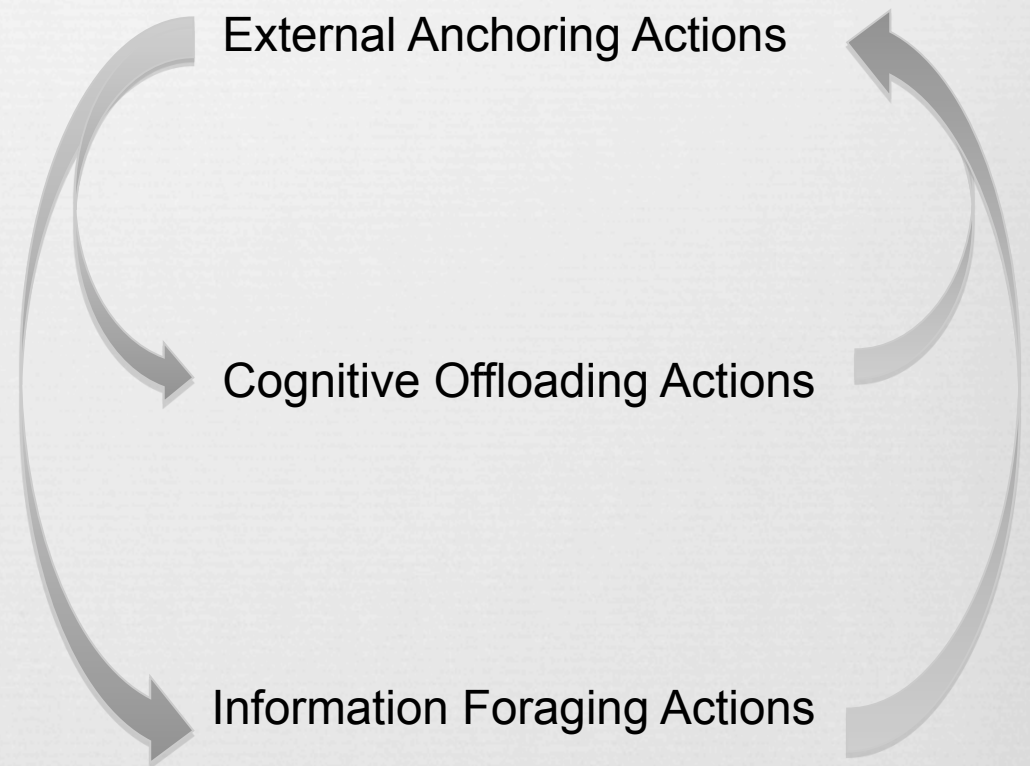
Three Purposes of Interaction

Actions

- External Anchoring
- Information Foraging
- Cognitive Offloading

Operations

- Low-level, habitual
- depending on the environmental affordances and constraints

External Anchoring Actions

Cognitive Offloading Actions

Information Foraging Actions

Implications on Design

- Semantic distance as an important design concept
  - Can a given visualization truly augment mental model
  - "Is it possible to ask questions as intended by the analysts using the visualizations?"
  - Analytic gaps [Amar and Stasko, 2004]

- The role of users in model construction and manipulation

  Manipulators of a given model vs. Constructors of novel models

Implications on Evaluation

- Outcome of using visualization for reasoning **NOT** determined by properties of visualization design

- Characterizing individual differences in terms of model-based reasoning ability

- Tracking model simulation on-the-fly
  - Observe and interpret user interaction
  - Think-aloud protocol

Implications on Theory

- Towards an elaborated theory of mental models in InfoVis
    - Clarifying issues on the format and processing
    - Explore regularities and variations in human mental modeling abilities

- A more precise model of interaction
    - Issue of parallel operations and their coordination
    - Interaction between model-based reasoning and other cognitive processes

Acknowledgments

Award IIS-0915788

VACCINE Center