Opening the Black Box of Interaction in Visualization

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VIS Tutorial 2014

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2. TU Darmstadt, Darmstadt, Germany
3. Dominikus Baur Interfacery
PART I: INTERACTION ACTIVITIES

Speaker: Tatiana von Landesberger
Part 1: Interaction activities

**Activities:** What the user does to trigger a change in the computer (*Action*)

**Metaphor:** What the user thinks the computer is doing and vice versa (*Understanding*)

**Architecture:** What the computer actually does (*Reaction*)
Part 1: Interaction activities

**Activities:** What the user does to trigger a change in the computer (*Action*)

**Metaphor:** What the user thinks the computer is doing and vice versa (*Understanding*)

**Architecture:** What the computer actually does (*Reaction*)
Overview of Part 1

- 6W’s of User’s Interaction and interaction loop
- Systematization of interaction
  - Human (Ws) and System (Vis)
- Vis/VA-focused systematizations:
  1. Visualization
  2. Visual Data Mining
  3. Reasoning
- Third view: Interaction Support
Motivation

• System developers:
  • What to include in my system

• Researchers:
  • What is there and what is missing

• Users:
  • What to expect from the system

• Developers, researchers, ...:
  • Canonicum for evaluation and system testing
Motivation

Make it easier for you...

Systematization of perspectives ...
What is interaction from user’s point of view?

USER’S ACTION AND THE INTERACTION LOOP
6Ws of Interaction

**Why** do we interact?
- What is the goal?

**What** is the purpose?
- What is the intended effect of interaction?

**How** do we interact?
- Which means do we use/have at disposal?

**Who** interacts?
- Who are the users interacting? What is their background?

**When** do we interact?
- When is interaction needed?

**Where** is interaction used?
- Where users interact?

[adapted & merged Roth13, Jansen et al 13]
6Ws of Interaction

**WHY** do we interact?
- What is the goal?

**WHAT** is the purpose?
- What is the intended effect of interaction?

**HOW** do we interact?
- Which means do we use/have at disposal?

**WHO** interacts?
- Who are the users interacting? What is their background?

**WHEN** do we interact?
- When is interaction needed?

**WHERE** is interaction used?
- Where users interact?

[adapted & merged Roth13, Jansen et al 13]
6Ws of Interaction

**WHY** do we interact?
- What is the goal?

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- What is the intended effect of interaction?

**HOW** do we interact?
- Which means do we use/have at disposal?

**WHO** interacts?
- Who are the users interacting? What is their background?

**WHEN** do we interact?
- When is interaction needed?

**WHERE** is interaction used?
- Where users interact?

Context of interaction

Effects and means

[adapted & merged Roth13, Jansen et al 13]
6Ws of Interaction

**WHY** do we interact?
- What is the goal?

**WHAT** is the purpose?
- What is the intended effect of interaction?

**HOW** do we interact?
- Which means do we use/have at disposal?

**WHO** interacts?
- Who are the users interacting? What is their background?

**WHEN** do we interact?
- When is interaction needed?

**WHERE** is interaction used?
- Where users interact?

[adapted & merged from Roth13, Jansen et al 13]
Hierarchic View on Interaction

**WHY** do we interact?

**WHAT** is the purpose?

**HOW** do we interact?
Norman’s Model of Interaction

EXECUTION

1. Establish a goal (Why?)
2. Form intention/identify task (What?)
3. Specify action sequence (How?)
4. Execute action

EVALUATION

5. Perceive the state of the system (How?)
6. Interpret the system’s state (What?)
7. Evaluate the outcome (Why?)
8. Take further action (compare outcome with goal)

Execution/Evaluation loop

[Norman88]
Preliminary Summary

1. 6Ws of interaction:
2. Hierarchic nature of interaction
3. Execution/Evaluation loop
Which interactions exist?

INTERACTION SYSTEMATIZATION
TWO VIEWS ON INTERACTION
What is interaction → Systematization

1. 6Ws of interaction:

2. Hierarchic nature of interaction

3. Execution/Evaluation loop
What is interaction →
Systematization

1. 6Ws of interaction:

2. Hierarchic nature of interaction

3. Execution/Perception loop

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What is interaction → Systematization

1. 6Ws of interaction:

2. Hierarchic nature of interaction

3. Execution/Perception loop

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Human ↔ Visualization

**WHY**
Subjective perception

**WHAT**
What should be modified in the view (goal/intention)

**HOW**
How it should be modified (which action)

Visualization changes
What in the visualization is modified
How this is done (software/hardware)

[adjusted Roth13]
Human ↔ Visualization

WHY

WHAT

HOW

[Card et al.99]
Human ↔ Visual Analytics

WHY

WHAT

HOW

Visualization

Data

Models

Knowledge

View manipulation

Transformation

Mapping

Model building

Model visualization

Information mining

Parameter refinement

Feedback loop

[Keim et al. 2008]
Information Visualization Model

[Card et al. 99]
Information Visualization Model

Data Visual

[Card et al.99]
Visualization → Visual Analytics

Simple Information Visualization Model

Visualization

Data

Knowledge

View Manipulation

Mapping

Transformation

[Keim et al. 2008]
Visualization → Visual Analytics
Simple Data Mining Model

Data → Transformation → Data Mining/Models → Parameter refinement → Information mining → Knowledge

[Keim et al. 2008]
Visual Analytics Model

[Keim et al. 2008]
3 Ways of Visual Analytics

Way 1: InfoVis

Data → Visualization → Knowledge

- Mapping
- Transformation
- Model building
- Model visualization
- Parameter refinement
- View manipulation

Feedback loop

Information mining
3 Ways of Visual Analytics

Way 2: Visual Data Mining

[Keim et al. 2008]

Feedback loop

Visualization

Data

Model building

Mapping

Transformation

Model visualization

View manipulation

Knowledge

Information mining

Parameter refinement

Models

[Keim et al. 2008]
3 Ways of Visual Analytics

Way 3: Provenance/Sensemaking/Reasoning

[Keim et al. 2008]
Interaction Need in Visual Analytics

Support all 3 ways via visual means

Feedback loop

[Keim et al. 2008]
Systematization of Interaction

1. Information Visualization
   - Keim02
   - Pike et al 09
   - Roth13
   - Jansen, Dragicevic 13
   - Parsons & Sedig 14
   - Dix & Ellis 98
   - Spence07
   - Yi et al. 07
   - Shneiderman 96

2. Visual Data Mining
   - Bertini & Lalanne 09
   - ...]

3. Reasoning
   - Heer & Shneiderman 12
   - Gotz & Zhou 08
   - Kerren & Schreiber 12
   - ...]

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Systematization of Interaction

WHY

WHAT

HOW

1. Information Visualization
   - [Keim02]
   - [Pike et al 09]
   - [Roth13]
   - [Jansen, Dragicevic 13]
   - [Shneiderman 96]
   - [Parsons & Sedig 14]
   - [Dix & Ellis 98]
   - [Spence 07]
   - [Yi et al. 07]
   - [Zhou & Fesner 98]
   - [Wybrow et al 14]

2. Visual Data Mining
   - [Bertini & Lalanne 09]
   - [Heer & Shneiderman 12]
   - [Gotz & Zhou 08]
   - [Yi et al. 07]

3. Reasoning
   - [Keim 02]
   - [Parsons & Sedig 14]
   - [Dix & Ellis 98]
   - [Spence 07]
   - [Zhou & Fesner 98]
   - [Wybrow et al 14]
   - [Jansen, Dragicevic 13]
   - [Roth13]
   - [Zhou & Fesner 98]
   - [Yi et al. 07]

Vis Tutorial: Opening the Black Box of Interaction in Visualization – H.-J. Schulz, T. v. Landesberger, D. Baur
Levels of Systematization: Example

[Why] [What] [How]

[Yi et al 07] Select, Explore, Reconfigure, Encode, Abstract/Elaborate, Filter, Connect

Vis Tutorial: Opening the Black Box of Interaction in Visualization – H.-J. Schulz, T. v. Landesberger, D. Baur
Levels of Systematization:
Problem of ambiguous terms

Why

Select, Explore, Reconfigure, Encode, Abstract/Elaborate, Filter, Connect

What/where in the pipeline?
Pipeline-Focused Interaction Systematization

1. Information Visualization
   - [Shneiderman 96]
   - [Pike et al 09]
   - [Roth 13]
   - [Keim 02]
   - [Parsons & Sedig 14]
   - [Dix & Ellis 98]
   - [Spence 07]
   - [Yi et al. 07]
   - [Wybrow et al 14]
   - [Jansen, Dragicevic 13]
   - [...]

2. Visual Data Mining
   - [Bertini & Lalande 09]
   - [...]

3. Reasoning
   - [Heer & Shneiderman 12]
   - [Gotz & Zhou 08]
   - [Kerren & Schreiber 12]
   - [...]

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1. Information Visualization

[Keim02] [Pike et al 09] [Roth13] [Wybrow et al 14] [Jansen, Dragicevic 13]
[Parsons & Sedig 14] [Dix & Ellis98] [Yi et al. 07]
[Shneiderman 96] [Spence07] [Zhou & Fesner98] [...]

2. Visual Data Mining

[Bertini & Lalanne 09]

3. Reasoning

[Heer & Shneiderman12] [Gotz & Zhou 08]
[Kerren & Schreiber12] [...]

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Unified VA Interaction Systematization

1. Visualization
   - Data changes
     - Selection
     - Editing
   - Visualization changes
     - Scheme: type and mapping
     - Parameters

2. Data mining
   - Data changes
     - Selection
     - Editing
   - Data mining changes
     - Scheme: data processing type
     - Parameters

3. Reasoning
   - Data changes
     - Analytic process tracking
     - Editing (annotation)
   - Reasoning changes
     - Scheme: change analysis type
     - Parameters

[von Landesberger et al. 2014]
INFOVIS – FOCUSED SYSTEMATIZATIONS

3 Ways of Visual Analytics: InfoVis (Way 1)
1. Visualization Systematizations

1. Information Visualization

- [Shneiderman 96]
- [Keim02]
- [Pike et al 09]
- [Roth13]
- [Jansen, Dragicevic 13]
- [Parsons & Sedig 14]
- [Dix & Ellis 98]
- [Spence 07]
- [Yi et al. 07]
- [Wybrow et al 14]
- [Zhou & Fesner 98]
- [...]

Infovis pipeline based systematization
1. Visualization Systematization

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InfoVis Interaction: View Transformation

Vis Tutorial: Opening the Black Box of Interaction in Visualization – H.-J. Schulz, T. v. Landesberger, D. Baur
InfoVis Interaction: View Transformation

- **Navigation**
- **Pan, zoom, scroll,**... 

**Navigation in visible space**

Source: maps.google.com
InfoVis Interaction: View Transformation

• Navigation
• Pan, zoom, scroll,...

Source: maps.google.com

Problem: Cumbersome, time consuming, “lost in space”
InfoVis Interaction: View Transformation Navigation

Topology-Aware Navigation in Large Networks

[ Moskovich et al. 09 ]
InfoVis Interaction: View Transformation

- Navigation
  - Pan, zoom, scroll,...
- Highlighting
  - Hover
  - Select+highlight
  - Brushing and linking
  - Magic lenses

Highlighting important information
InfoVis Interaction: View Transformation

- Navigation
  - Pan, zoom, scroll,...
- Highlighting
  - Hover
  - Select+highlight
  - Brushing and linking
  - Magic lenses
- View reconfiguration
  - (Re-)arrange multiple views on the screen
  - Open/close new views

Configuring multiple views
InfoVis Interaction: Visual Mapping

Vis Tutorial: Opening the Black Box of Interaction in Visualization – H.-J. Schulz, T. v. Landesberger, D. Baur
InfoVis Interaction: Visual Mapping

- Visualization type
- Type of visualization
  - Scatterplot/matrix
  - Node-link/matrix
- Type of mapping
  - E.g. color/size/form

[van den Elzen & van Wijk 13]
InfoVis Interaction: Visual Mapping

- Visualization type
- Type of visualization
- Type of mapping
- Mapping parameter
- Data $\leftrightarrow$ mapping
- E.g. color scheme

[van den Elzen & van Wijk 13]
InfoVis Interaction: Visual Mapping

- Visualization type
- Type of visualization
- Type of mapping
- Mapping parameter
- Data $\leftrightarrow$ mapping
- E.g. color scheme

[van den Elzen & van Wijk 13]
InfoVis Interaction: Visual Mapping

- Visualization type
- Type of visualization
- Type of mapping
- Mapping parameter
- Data to be mapped
- E.g. color scheme

Further specifics
- E.g. type of layout, sorting
InfoVis Interaction: Data Manipulation

```plaintext
<table>
<thead>
<tr>
<th>#Words</th>
<th>#Sentence</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>9</td>
</tr>
<tr>
<td>100</td>
<td>20</td>
</tr>
<tr>
<td>80</td>
<td>7</td>
</tr>
</tbody>
</table>
```

[Card et al 99]
InfoVis Interaction: Data Manipulation

• Data navigation
  • drill down, expand, filter, ...

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InfoVis Interaction: Data Manipulation

- **Data navigation**
  - drill down, expand, filter, ...

- **Top down**
  - Filter, details on demand

- **Bottom up**
  - Expand on demand

- **Middle out**
  - Start in the middle

[von Landesberger et al 11]
InfoVis Interaction: Data Manipulation

- Data navigation
  - drill down, expand, filter, ...
- Top down
  - Filter, details on demand
- Bottom up
  - Expand on demand
- Middle out
  - Start in the middle

Search, Show Context, Expand on Demand

[van Ham & Perer 09]
InfoVis Interaction: Data Manipulation

- Data navigation
  - drill down, expand, filter, ...

- Data transformation
  - Normalization (lin, log, exp,..)
  - Aggregation (manual, according to data,...)
  - ...

Source: Gapminder.org
InfoVis Interaction: Data Manipulation

- Data navigation
  - drill down, expand, filter, ...

- Data transformation
  - Normalization (e.g. lin, log)
  - Aggregation
    - Manual
    - According to data attributes
    - According to data structure (e.g. communities)
  - Etc.
2. Graph simplification by structure
InfoVis Interaction: Data Manipulation

- Data navigation
  - drill down, expand, filter, ...
- Data transformation
  - Normalization (lin, log, exp, ..)
  - Aggregation (manual, according to data, ...)
- Data editing
  - Change values
  - Create data
    - Individual values
    - Whole datasets
InfoVis Interaction: Data editing
InfoVis Interaction: Data creation

PC/DC

On the Highway to Data

[Bremm et al 2012]
Summary: InfoVis Interaction

![Diagram showing the process of transforming raw data into visual form through data tables, visual structures, and view transformations, with human interaction]

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</tr>
</tbody>
</table>

#Words → Size
#Sentences → Color
Way 2: Visual data mining

VISUAL DATA MINING INTERACTION
VA Interaction Systematization

1. Information Visualization

2. Visual Data Mining

[Bertini & Lalanne 09]

[...]
Visual Data Mining

• Computationally enhanced Visualization (V++)

• Visually enhanced Mining (M++)

• Integrated Visualization and Mining (VM)

[Bertini & Lalanne09]
Visual Data Mining Interaction

• Manipulating and tuning:
  
  **Vis:**
  changing representation or visual representation

  **DM:**
  changing model parameters

• Changing the scheme:

  **Vis:**
  changing the visual mapping or visual representation

  **DM:**
  changing the data model

[Bertini & Lalanne09]
Visual Data Mining Interaction

- Manipulating and tuning:
  - **Vis:** changing representation parameters
    - For example: changing color scheme
  - **DM:** changing model parameters
    - For example which motif is searched
Visual Data Mining Interaction

• Changing the scheme:

  **Vis:**
  changing the visual mapping or visual representation

  For example: changing node-link diagram to adjacency matrix

  **DM:**
  changing the data model

  For example motif search vs clustering
Visual Data Mining Interaction: Motif search and Visualization

[von Landesberger et al 09]
Way 3: Feedback loop

**SENSEMAKING, PROVENANCE, REASONING**
VA Interaction Systematization

1. Information Visualization

2. Visual Data Mining

3. Reasoning

[Heer & Shneiderman12]
[Gotz & Zhou 08]
[Kerren & Schreiber12]
[...]

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Reasoning/Provenance Systematization

Data & View Specification

View Manipulation

Process & Provenance

Visualization

Provenance

[Heer & Shneiderman12]
**Reasoning/Provenance**

**Visualization**

**Visual history & annotation**

---

[von Landesberger et al 14]
Reasoning/Provenance

Visualization

Visual history & annotation

[von Landesberger et al 14]
Reasoning/Provenance

Visualization

Visual history & annotation

[von Landesberger et al 14]
Reasoning/Provenance

Visualization

Visual history & annotation

[von Landesberger et al 14]
Reasoning/Provenance

Visualization

Visual history & annotation

Same interaction type → aggregation

[von Landesberger et al 14]
Reasoning/Provenance

Visualization

Visual history & annotation

Same interaction type → aggregation using interaction systematization

[von Landesberger et al 14]
Reasoning/Provenance

Visualization

Visual history & annotation

Aggregated interaction

[von Landesberger et al 14]
Reasoning/Provenance

Visualization

Visual history & annotation

[von Landesberger et al 14]
Reasoning/Provenance

Visualization

Visual history & annotation

“Go back” - review/revise

[von Landesberger et al 14]
Reasoning/Provenance

Visualization

Visual history & annotation

“Go back” - review/revise

[von Landesberger et al 14]
Reasoning/Provenance

Visualization

Visual history & annotation

Start a different exploration path

[von Landesberger et al 14]
Reasoning/Provenance

Visualization

Visual history & annotation

Start a different exploration path

[von Landesberger et al 14]
Systematization of Interaction

WHY

WHAT

HOW

1. Information Visualization
   - Keim02
   - Pike et al 09
   - Roth13
   - Jansen, Dragicevic 13

2. Visual Data Mining
   - Bertini & Lalanne 09
   - Shneiderman 96

3. Reasoning
   - Heer & Shneiderman12
   - Gotz & Zhou 08
   - Kerren & Schreiber12

[...]
Systematization of Interaction - according to InfoVis Pipeline

WHY

WHAT

HOW

1. Information Visualization
   - [Keim02]
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   - [Roth13]
   - [Jansen, Dragicevic 13]
   - [Shneiderman 96]
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   - [Dix & Ellis 98]
   - [Spence07]
   - [Yi et al. 07]

2. Visual Data Mining
   - [Bertini & Lalanne 09]
   - [Bertini & Lalanne 09]

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   - [Heer & Shneiderman 12]
   - [Gotz & Zhou 08]
   - [Kerren & Schreiber 12]

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InfoVis-Focused Systematization: Problem of ambiguous terms

WHY

WHAT

HOW

“Change mapping”

Why? What for? How exactly?
SYSTEMATIZATION:
INTERACTION SUPPORT
Interaction hierarchy

WHY
- cognitive activity
- sub-activities
  - tasks
    - sub-tasks

WHAT
- actions, reactions, perceptions
  - VR{s}
    - R{s}
      - P{s}
        - A{s}

HOW
- CA
  - SA{s}
    - T{s}
      - ST{s}
        - ...
Interaction hierarchy

Time & cognitive burden

WHY
- cognitive activity
- sub-activities
  - tasks
  - sub-tasks

WHAT

HOW
- actions, reactions, perceptions

[Sedic & Parsons 10]
Three Dimensions:

Human → Interaction support → Visualization

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Interaction support

- Slow/cumbersome
- High cognitive burden
- Full control

“manual”

“smart”
“data-driven”
“supported”
“DOI-based”

• Fast
• No cognitive burden
• No control

“automatic”
Interaction support

- Slow/cumbersome
- High cognitive burden
- Full control

"manual"

- "DOI-based"
- "supported"
- "data-driven"
- "smart"

- Fast
- No cognitive burden
- No control

"automatic"
Interaction support

Supported
- Snap to grid
- Edgelens

"manual"

[Wong & Carpendale03]
Interaction support

Data driven
- Topology-aware navigation
- Data-aware selection

- Slow/cumbersome
- High cognitive burden
- Full control

“manual”
Interaction support

Guidance
• Small multiples
• DOI-based exploration

• Fast
• No cognitive burden
• No control

“automatic”
Interaction support

**Smart**
- Tableau
  “show me”

**“smart”**
- Fast
- No cognitive burden
- No control

**“manual”**
- Slow/cumbersome
- High cognitive burden
- Full control

“manual”

“automatic”

[Heer et al 08]
Interaction support

Automatic
- NodeTrix

Editing NodeTrix using drag and drop interactions

- Fast
- No cognitive burden
- No control

“automatic”
Part 1: Interaction actions

SUMMARY
Summary

WHY

WHAT

HOW
THANK YOU

Q&A
Next: Interaction architecture

**Activities:** What the user does to trigger a change in the computer (Action)

**Metaphor:** What the user thinks the computer is doing and vice versa (Understanding)

**Architecture:** What the computer actually does (Reaction)