Human-centered Network Visualization

Michael Sedlmair
Visualization & Data Analysis Group
Data
Visualization

Look at / Interact
Definition: Visualization (Vis)

“Computer-based visualization systems provide visual representations of datasets intended to help people carry out some task more effectively.”

Interactive visual analysis

“Computer-based visualization systems provide visual representations of datasets intended to help people carry out some task more effectively.”

Tableau  
SAS  
IBM Watson Analytics  
Improvise

*not pretty pictures*
Why a human in the loop?

“Computer-based visualization systems provide visual representations of datasets intended to help people carry out some task more effectively.”

**not needed if fully automatic solution exists (and is trusted)**

**Ill-defined / ill-structured problems:**

- no single optimal solution
- no clear objective measures

**Examples:**

- exploratory analysis of scientific problems
- (collaborative) decision-making problems
- model building & validation

Effective support of ill-defined tasks!

“Computer-based visualization systems provide visual representations of datasets intended to help people carry out some task more effectively.”

Metrics of success:

• Novel — entirely new insights
• Faster — speed up common workflows
“Computer-based visualization systems provide visual representations of datasets intended to help people carry out some task more effectively.”
Why visual representations?

“Computer-based visualization systems provide visual representations of datasets intended to help people carry out some task more effectively.”
Visualization research

**technique-driven**
- New algorithms
- New visualization techniques

**problem-driven**
- Understand users & tasks
- Design studies
Visualization research

My research focus

 technique-driven

 Graph Drawing

 problem-driven

 Network Visualization
Today’s goal: Graph/network visualization and around

1. Technique-driven research
   - Trends in graph drawing
   - Trends in visualization — Related to graph drawing

2. Problem-driven research
   - Design Study Example — RelEx: Visualization of overlay networks
   - Design Study Methodology — Why care?
Outline

1. Technique-driven research
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   - Trends in visualization — Related to graph drawing

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   - Design Study Methodology

3. Summary
Networks & Graphs
Graph Drawing

- The classical graph drawing problem is to develop algorithms to draw graphs nicely.

Graph

A - B, C, D
B - A, C, D
C - A, B, D, E
D - A, B, D, E
E - C, D

Nice graph drawing
Example

<table>
<thead>
<tr>
<th>$X$</th>
<th>Adjacent to $X$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mary</td>
<td>Peter, Albert, DavidF, Peter</td>
</tr>
<tr>
<td>Judy</td>
<td>Bob, Alan</td>
</tr>
<tr>
<td>Peter</td>
<td>Mary, DavidF, Jon</td>
</tr>
<tr>
<td>DavidF</td>
<td>Albert, Joseph, Peter, Mary</td>
</tr>
<tr>
<td>Jon</td>
<td>Peter, Joseph, DavidE</td>
</tr>
<tr>
<td>DavidE</td>
<td>Jon, Joseph, Albert</td>
</tr>
<tr>
<td>Joseph</td>
<td>DavidE, Jon, DavidF</td>
</tr>
<tr>
<td>Bob</td>
<td>Judy, Alan</td>
</tr>
<tr>
<td>Alan</td>
<td>Bob, Mary, Judy</td>
</tr>
<tr>
<td>Albert</td>
<td>DavidF, Mary, DavidE</td>
</tr>
</tbody>
</table>
Example
Example

Terrorist network

Eliminate
Example

Mobile phone network:
* nodes: people
* edges: phone calls

Good deal $$$$
Example

Transport network:
* nodes: places
* edges: train lines
Example

Transport network:
* nodes: places
* edges: train lines

Shortest path?
What algorithm give good drawings of graphs?

Bad

Good
Quality measures for networks

- Classical quality measures
  - minimize edge crossings
  - minimize bends
  - ...

- Human subject experiments found crossings & bends to be most important \textit{wrt} readability
  - Purchase et al., 1997
  - Ware et al 2002
  - Huang et al 2004
Different kinds of layouts

grid-based

orthogonal

straight-line
Force-directed layouts

https://bl.ocks.org/mbostock/4062048
Human-centered layout

1. User study
2. Develop algorithm
3. Evaluate algo-created layouts against human-created layouts

Kiefer et al. (InfoVis 2015).
HOLA: Human-like Orthogonal Network Layout
Scalability — Too many nodes and/or edges
Showing all the data?

Hairball

https://twitter.com/axelmaireder/media
Measures: **Faithfulness** VS. **Readability**

Faithfulness measures how well the diagram represents the data.  
(a mathematical concept)

Readability measures how well the human understands the diagram.  
(a psychological concept)

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Quan Nguyen et al. (PacificVis 2013). On the faithfulness of graph visualizations
In small graphs: faithfulness usually given

—> optimize readability
In large graphs: faithfulness usually not given

→ tradeoff between faithfulness & readability

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Edge bundling

Sacrifice faithfulness, gain readability

Holten (InfoVis 2006).
Hierarchical Edge Bundles: Visualization of Adjacency Relations in Hierarchical Data
Edge bundling

US migration graph

Holten & van Wijk (EuroVis 2009). Force-Directed Edge Bundling for Graph Visualization.
What about edge crossing?

- Some quality measures that work well for small graphs (such as edge crossing) seem to lose their importance the larger a graph gets.

How many edge crossings do you see?

http://eppsnet.com/images/facebook-hairball.png
Instead: “Show me the structure”

“Diagram A is better than diagram B because diagram A shows the structure of the graph, and diagram B does not show the structure.”
For a good quality drawing, the shape of the drawing should be faithful to the input graph.
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Alternative representations
Adjacency Matrix

Michael Behrisch, et al. (EuroVis STARs 2016). Matrix Reordering Methods for Table and Network Visualization.

https://bost.ocks.org/mike/miserables/
Adjacency Matrix (physical)

Jacques Bertin, 1968

Matrix or Node-link?

• Study
  - 36 users
  - 9 networks
  - 7 tasks —> measure time & errors

• Results
  - **Node-link** only for:
    - small graphs (~20 nodes)
    - path finding tasks
  - Else **Matrix**

• Limitations

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Ghoniem et al. (InfoVis 2004). A Comparison of the Readability of Graphs Using Node-Link and Matrix-Based Representations.
Additional encodings
Color and width

Additional encodings

• Nodes, e.g. through color
• Edges, e.g. stroke-width

https://bl.ocks.org/mbostock/4062045
Size

More complex data

Stef van den Elzen and Jarke J. van Wijk (InfoVis 2014)
Multivariate Network Exploration and Presentation:
From Detail to Overview via Selections and Aggregations
Visual Encoding: Color?

—> Achim!

noncontiguous small regions of color: only 6-12 bins

Visual Encoding: Color?

--> Achim!

noncontiguous small regions of color: only 6-12 bins
Rainbow color maps?

—> Achim!

Maureen Stone
Solutions, e.g. ColorBrewer

http://colorbrewer2.org/#type=sequential&scheme=BuGn
Popout
Popout
Popout
Popout: combining channels?

How many blue rectangles?
Interaction
(as a way of dealing with scalability)
Interactive highlighting

Inherent design tradeoff:

- Amount of data shown
- Time (Interaction/Animation)
Multiple Views + Linking and brushing

Mutually coordinated visualization of product and supply chain metadata for sustainable design.
Journal of Mechanical Design. 2015 Dec 1;137(12):121101.
Multiple Views + Linking and brushing

http://medientransparenz.validproject.at/
Demo: Bike Sharing Atlas

• Goal
  - visualize open data of 380 bike sharing networks

• Nodes: Stations
  - current status (full/empty)
  - filling levels record over 10 month (each 15 minutes)
  - …

• Edges: trips
  - (only for very few networks really available)

Role of network vis in network problems?
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The ominous “user”

- Classical HCI pitfall: **The Elastic User**
- Are our techniques really helping users?
- What exactly are their tasks, problems, and challenges?
- How to effectively combine existing and new techniques to help solving these problems?
Visualizing the internet?

Tamara Munzner (IEEE CG&A 1998)
Exploring Large Graphs in 3D Hyperbolic Space

http://www.huffingtonpost.com/travis-bradberry/small-things-people-use-tr_b_10169120.html
goal: help **people** with their ill-defined (network) problems

How to involve humans into our design and research processes?
“A design study is a project in which visualization researchers analyze a specific real-world problem faced by domain experts, design a visualization system that supports solving this problem, validate the design, and reflect about lessons learned in order to refine visualization design guidelines.”

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Michael Sedlmair, Annika Frank, Tamara Munzner, Andreas Butz.
RelEx: Visualization for Actively Changing Overlay Network Specifications.
Domain: In-car Electronics
Physical network (Hardware)

~100 ECU (nodes)
Physical network (Hardware)

- ~100 ECU (nodes)
- 10-15 Bus systems (edges)
Logical Network (Software)

~100 ECU (nodes)

ECU

ECU

ECU

ECU

signal a

e.g. “speed”
Logical Network (Software)

~100 ECU (nodes)

~10k signals (edges)
Tasks: Mapping

logical

physical

= signal path
RelEx:
Problem characterization
Problem characterization & abstraction
(3 month)

• Understanding
  - Talking/Observing
  - Focus groups
  - Analyzing previous tools
  - Reading

• Abstracting & requirements
Tasks: Multi-objective optimization

Ill-defined constraints
bandwidth ... delay/real time ... path length ... load balance ... reliability ... money ...

-- engineer, BMW --
Tasks: External Change Requests

logical

physical

signal path

Change
(trivial requests might lead to complex changes)
Low Level Tasks

Queries about relations

Which ECU is communicating with which ECU?
Which signals do they exchange?
What is the path the signals take? ...
Low Level Tasks

Query complexity

complex queries

simple queries

physical
logical
signal path

Query complexity

78
Low Level Tasks

Query complexity

simple queries 2-way relations

physical logical signal path

79
Low Level Tasks

Query complexity

complex queries

Overview

physical

logical

signal path
Low Level Tasks

Query complexity

complex queries

simple queries

Unsupported need: Logical Overview

Unsupported need: All path of a Signal

physical

logical

signal path
RelEx: Design
RelEx: Relation Explorer
**ReLex:**

Logical Overview

**Logical Network**

- multigraph
- 100 nodes/10k edges
**RelEx: Logical Overview**

**Logical Network**

- multigraph
- 100 nodes/10k edges
**RelEx: Logical Overview**

**Logical Network**
- multigraph
- 100 nodes /10k edges

**Signal Count Network**
- directed graph
- 1k weighted edges

**Guideline [Ghoniem 2004]**
Matrix for dense graphs

**Visual Encoding:**
Size-Coded Matrix
RelEx: Logical Overview
RelEx:
All Paths of a Signal

Guideline [Ghoniem 2004]
Node-link for path following tasks

Signal Path Network

filtered by signal
MORE STUFF: Support of Current Practices
video with different use cases:
http://www.cs.ubc.ca/labs/imager/tr/2012/RelEx/
RelEx: Evaluation
Evaluation

during design (formative)

• iterative paper prototyping
• agile design: 6 deployed releases
  - 3 lead users (domain experts)
• usability studies with
  - 4 users: domain experts & HCI students

after design (summative)

• field study with final release
  - 7 engineers / 5 weeks
• think aloud study
  - 10 engineers / 1h sessions
• 3-month post study - adoption?
**Novel insights:**

Bus communication patterns
Novel insights: Bus communication patterns

Within-bus

Between-bus
Novel insights: Bus communication patterns

introvert vs. extrovert
Novel insights: Bus communication patterns

introvert vs. extrovert
Speedup

“RelEx gives me a more compact, way faster access to the information I need”

BMW engineer
(translated from German).

Adoption

• 3-month post study
• 15+ engineers
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design studies:
long and winding road with many pitfalls!
How to do design studies?

- 9-stage framework
- 32 pitfalls
- Why design studies

9-stage framework

User-centered design

Participatory design

Usability Engineering

Contextual design

Action research

Ethnography

Grounded theory

PRECONDITION
personal validation

CORE
inward-facing validation

ANALYSIS
outward-facing validation

learn ➔ winnow ➔ cast ➔ discover ➔ design ➔ implement ➔ deploy ➔ reflect ➔ write
32 pitfalls:
Example pitfall — premature collaboration

I’m a domain expert! Wanna collaborate?

Of course!!!
Considerations!

Have data?
Have time?
Have need?

Interesting problem?

...
Roles!

... or maybe a fellow tool builder?

Are you a user???
32 pitfalls:
Example pitfall — no reflection

Reflection is where research emerges from engineering
Transferability: relate to other design studies
RelEx: Reflection
Previous work: Focus on social network analysis

• radically different task and data abstractions
Previous work:
Social network analysis

Task abstraction:
• find clusters
Previous work: Social network analysis

Task abstraction:

- find clusters
- find high-degree nodes
Previous work: Social network analysis

Task abstraction:

• find clusters
• find high-degree nodes
• find bridging nodes
Previous work: Social network analysis

Task abstraction:
- find clusters
- find high-degree nodes
- find bridging nodes
- understand temporal dynamics
  - passively notice changes
Abstraction Innovation

Social network analysis

Tasks
• find clusters, high-degree/bridge nodes
• passive changes

Data
• single network
• node scalability
  - sparse edges

Overlay network optimization

Tasks
• traffic optimization
• active changes

Data
• three related networks
  - physical, logical, overlay
• path scalability
  - dense edges, few nodes
Why do design studies?

- DESIGN STUDY METHODOLOGY
- SUITABLE
- NOT ENOUGH DATA

problem characterization & visualization tool
Why not just ask a social scientist?

- problem
- characterization
- mapping
- visualization
- tool
Challenge: “Visualization Cookbook”

abstract data & task

data analysis technique
Challenge: “Visualization Cookbook”

- Understand problems (user/task/data)
  - abstraction
  - taxonomies & theories
- Mapping
  - problems to techniques
  - combine visual & computational

Challenge: “Visualization Cookbook”

vast amounts of research on human-centered data science necessary, e.g. design studies.
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Summary

• Drawing networks
  - Challenge: Scaling up
  - Challenge: Graphs in Context

• Problems, Tasks, Users
  - Challenge: Understand problems
  - Challenge: Mapping to solutions
Visualization: The Human Lens to Networks/Data
Thank you!

michael.sedlmair@univie.ac.at
Visualization & Data Analysis Group