Visualizing Complex Systems
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Beck et al., Dynamic Graph Visualization

Fabian Beck, Michael Burch, Stephan Diehl, and Daniel Weiskopf. "A Taxonomy and Survey of Dynamic Graph Visualization." Computer Graphics Forum 36(1), 2017.

Beck et al., Dynamic Graph Visualization

Overview of article:

- hierarchical taxonomy of techniques

- classified by their representation of time

    - either animated

    - or using a timeline

- challenges for future research

History of research on dynamic graphs

1990s - A sub-problem of Graph Drawing: "node-link diagrams need to be animated without destroying the user's mental image of the diagram"

- mental map / cognitive map

History of research on dynamic graphs

2000s – Dynamic graphs for information visualization:

- specialized approaches for particular application domains

- alternatives to animated node-link diagrams

2010s – Prolifieration of different techniques into many application domains

Animation - "time-to-time mapping"

- dynamic stability – needed to preserve a mental map of the data

- on-line vs. off-line

on-line: how do organize a useful layout when you don't know what the data will look like in the future?

off-line what do you do with nodes that aren't used in a particular time-step?

Animation

- **compound graphs:** where a group of similar data points is represented as a single node; where structure within the data is indicated using a hierarchical representation

- **animated adjacency matrix:** nodes represented as items in a row/column; edges indicated as colored cells at the intersection of two nodes

Timeline - "time-to-space mapping"

Node-link approaches:

juxtaposed: copies of the nodes at each time-step are placed alongside each other

superimposed: copies of the nodes at each time-step are stacked on top of each other

integrated: timeline info is embedded in the node-link diagram

Timeline - "time-to-space mapping"

Matrix-based approaches:

"The challenge is to connect the spatial encoding of time with the matrix information", but "more readable for larger and denser graphs"

intra-cell: each cell contains a timeline representation

layered: matrices for each time-step are layered or juxtaposed

list-based: [easier to show it]

How to evaluate?

Algorithmic evaluation: speed, accuracy (according to a particular layout metric)

User studies:

- is a user's mental map preserved? augmented?

- are people more comfortable with animation or timeline approaches?

Which approach is best? (it depends...)

timeline:

- quicker response time

- reveals more findings over longer time periods (non-adjacent time-steps)

animation:

- more accurately fulfill tasks

- better supports tracing of nodes + paths over time

- reveals more findings between adjacent time-steps

Applications

social networks: chats, online communities, blogger's interests, interaction networks in literature, propagation of topics in tweets, ...

documents (citation, topics, hyperlinks): co-authorship networks, research topics, co-citation networks, wikipedia links, ...

software engineering: execution dynamics, information flow between processes, object interactions, call graphs, distributed software, author-file relationships, ...

other: biological pathways, chemical reactions, gaze-tracking data, evolution of internet, communication networks, stock portfolios, geographical migration, traffic data, movie-actor relationships, ...

Research Challenges

Evaluation: "only a few questions have been evaluated so far. Although most efforts have concentrated on the importance of the mental map, it is only partially clear for which tasks and to what extent the mental map needs to be preserved"

Visual scalability: "So far, scalability has only played a minor role in designing most dynamic graph visual-ization approaches"

Hybrids: "there are a number of hybrid variants that appear to be promising: for instance, the combination of node-link diagrams and matrices ... combinations of animation and timeline approaches have not yet been fully explored"

Research Challenges

Extended data dimensions: "An open question is how to visualize a hierarchical structure that changes more significantly along with the dynamic graph" + Dynamic multivariate graphs, dynamic graphs with uncertainty information, geo-located graphs, graphs representing continuous time (instead of discrete time-steps).

Interaction: "Navigation in dynamic graphs can have multiple dimensions: users might navigate in space (i.e. the static graph) as well as in time." "annotating and editing a dynamic graph structure is not well studied."

Other: new visual metaphors; comparison tasks, analytic methods for filtering/clustering; real-time data; visualizing graph dynamics (derived data); new application domains ...

Is this taxonomy useful?

Your next assignment is to start sketching out how you will visualize your dynamic dataset.

- Is it helpful to think in terms of previous approaches?

- Or is it more useful to let the data itself inspire you?

- Are there enough similarities between different domains so that research in dynamic graphs is generalizable?

- What is your preferred methodology for generating an effective visualization technique?