Transparent Layering for Visualizing Dynamic Graphs Using the Flip Book Metaphor

Holger Stitz, Samuel Gratzl, Stefan Luger, Nils Gehlenborg and Marc Streit

Abstract— Visualizing dynamic graphs is challenging because changing node and edge attributes as well as topological alterations need to be encoded in the visual representation. However, existing approaches such as animation, juxtaposition, and superimposition do not scale well. In this poster we propose a novel layering approach for visualizing dynamic graphs where the graph for each point in time is a single layer and parts of each layer are slightly shifted based on a degree-of-interest (DOI) function. In contrast to 2.5D representations that also use layering, users cannot freely change the viewing perspective but are restricted to the top view, avoiding occlusion and distortion problems. We demonstrate the layering approach by applying the concept to two graph visualizations: a node-link diagram and a radial hierarchy visualization.

Index Terms—Graph visualization, time, degree-of-interest function.

1 Introduction

The goal of dynamic graph visualization is to communicate both topological as well as attribute and edge changes in the network over time. As well established approaches for representing static graphs cannot be effectively applied for visualizing temporal changes in graphs, more specialized techniques have been proposed. The literature differentiates between techniques where time is mapped to time (animation) or to position (juxtaposition and superimposition). However, both alternatives have a limited scalability in terms of number of nodes and edges as well as number of time steps. In this poster we present a layering approach based on a flip book metaphor. The static graph for each time point is considered as a semi-transparent layer. Parts of each layer can be shifted according to a degree-of-interest (DOI) function defined for each node and edge over time.

2 Related Work

In recent work, Beck et al. [2] and Kerracher et al. [5] survey different visualization methods for dynamic graphs. The predominant techniques are:

Animation that maps time to time (see Figure 1a). In the flip book metaphor this corresponds to rapidly flipping the pages. The playback time can be modified and stopped, however, in any case it takes time to watch the sequence, which can get tedious with an increasing number of time steps.

Juxtaposition represents the time steps using small multiples [6] (Figure 1b). In the flip book metaphor this corresponds to tearing out the pages and positioning them side-by-side. However, comparing subsequent time steps and tracking changes of nodes and edges is a cognitively demanding task.

Superimposition stacks the static graph representation of each time step as layers on top of each other (Figure 1c). In the flip book metaphor this corresponds to the top view onto the book that has semi-transparent pages. As overlapping nodes and edges are prone to hide attribute changes, this technique has its disadvantages.

More specialized approaches are integrated views or 2.5D representations. Integrated views [9] weave the timeline into the graph representation, resulting in extensions as time progresses. However, this approach is restricted to types of dynamic graphs where nodes and edges are added in an additive fashion, limiting its general applicability. In contrast, 2.5D representations (e.g., [3, 4]) separate the dynamic graph in different 2D layers and place them in 3D space, leading to a 2.5D representation. Changes between each layer can then be visualized by drawing edges between the layers. The layering of 2.5D representations is in principle related to the proposed approach. However, we do not position the layers in a 3D scene, but stack them slightly shifted in a flat 2D representation. In contrast to 2.5D representations that suffer from occlusion and distortion, our approach fixes the camera to provide a top-view on the graph and users cannot freely rotate the layers.

3 Layering Approach

In a flip book, page content gradually changes from page to page. By rapidly flipping the pages, the observer is able to inspect the content in an animated fashion. In Section 2 we use the flip book metaphor with semi-transparent pages to explain three common approaches for representing dynamic graphs: animation, juxtaposition, and superimposition. Here we propose an extension to the superimposition approach where the individual semi-transparent layers — each representing the graph at a single time step — are stacked on top of each other. This approach encodes time and attribute changes in position and brightness to ensure scalability by aggregating non-relevant subgraphs defined by a DOI function on all nodes and edges.

The DOI determines the relevance of an element (node or edge) for the user's task. Based on the DOI function model proposed by Abello et al. [1], we integrate multiple aspects into a combined DOI. On the one hand, we include user-driven components, such as results from filter and search operations. On the other hand, we include automatic components, expressing attribute and graph changes over time. Elements with a low DOI value are less relevant and therefore can be aggregated. This allows users to focus on relevant areas of the graph, while keeping the remaining graph as context.

In our approach, we do not specify how time or changes are exactly encoded in position and/or brightness, as this is highly application dependent. We demonstrate the generic approach by means of two different visualization techniques.

3.1 Node-Link Diagram

Figure 2 shows an example of a dynamic node-link diagram with the layering approach applied. In this example individual time step layers are stacked slightly vertically shifted onto each other, encoding time in position. To be able to handle a large number of time steps, the shift is logarithmically scaled. In addition, time is redundantly encoded in brightness, such that old time steps fade to white. The combination of encoding time in position and brightness forms a black-to-white gradient on nodes and edges.

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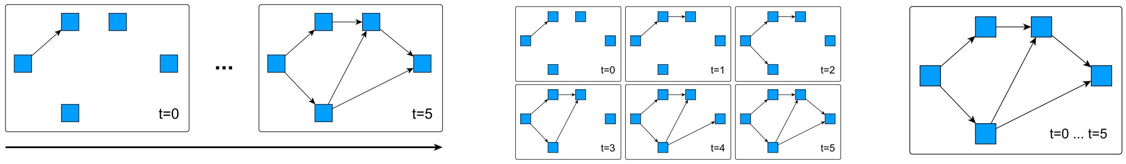

(a) *Animation* **(b)** *Juxtaposition* **(c)** *Superimposition*

Fig. 1: *Different methods for visualizing a dynamic graph: (a) Time is mapped to time, resulting in an animation. In (b), each time step is shown as static graph side-by-side. In (c), the static graphs for each time step are stacked onto each other.*

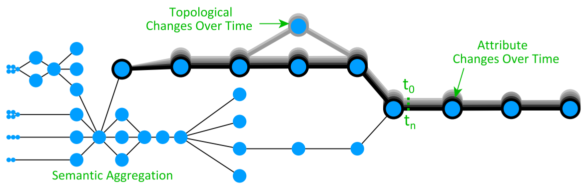

Fig. 2: *A node-link diagram with time encoded in the vertical position of the nodes and attribute changes encoded using brightness. Parts of the graph with a low DOI value are aggregated.*

Furthermore, the DOI value of each element is used in two ways. First, it drives the aggregation, such that only elements with small and similar DOI values are aggregated. In Figure 2, the lower left part of the graph is aggregated in two levels. The first aggregation level reduces the size of node glyphs and the contained data representations similar to a semantic zoom. The second level further reduces the glyph size and additionally subsumes graph motifs, similar to the work by Maquire et al. [7]. Second, the DOI influences how much the element is shifted between the layers, emphasizing the elements' change over time. While static elements appear as a single instance, highly changing ones have shifted layers. In Figure 2 the top right part of the graph is changing over time, including topological and attribute changes.

In summary, applying our approach on a dynamic node-link diagram can be interpreted as using a rubber sheet [8] for each semi-transparent flip book page. Static parts of the diagram (which correspond to a low DOI) are aggregated by squeezing the rubber sheet locally, whereas highly changing ones (high DOI) are locally stretched.

3.2 Radial Hierarchy Visualization

Figure 3 visualizes a hierarchical network flow in a radial visualization. The black circle in the center represents the root node and arcs on each ring correspond to nodes in a certain hierarchy level. Edges between two levels are connections within the network. The width of the edges encode the used bandwidth.

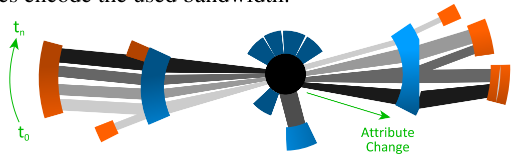

Fig. 3: *A radial hierarchy visualization with arc nodes and edges, encoding time as brightness and attribute changes as node position.*

In contrast to the first example, the position of the nodes encodes attribute changes and edge brightness combined with their relative position encode time. The more the connection between two nodes jitters, the higher the corresponding DOI, and the more the two nodes are separated. Similarly, stable connections are hidden by attaching the corresponding level segments to their parent, resulting in a partial sunburst visualization [10]. In Figure 3 the horizontal arcs have varying connections over time, while the vertical arcs have stable connections that are attached to their parent node.

4 Discussion

Layout Algorithm Algorithms that compute the layout for an individual time step need to consider the space required by the shift of other time steps. Also, within the same time step different DOI values and aggregation levels appear, which may also change during the analysis. Therefore, layout algorithms need to find the right balance between computing a scalable compact layout and preserving the user's mental map between DOI changes.

Topological Changes The approach of stacking and shifting individual time steps of a dynamic graph works for small topological changes. However, large changes generate problems regarding the layout algorithm, as well as the precise tracking of changes among multiple time steps, since the most frequent time step is on top.

5 Conclusion

In this poster we introduce the flip book metaphor for illustrating previous approaches as well as our novel layering approach for visualizing dynamic graphs. We extend the superimposition approach by combining it with a flexible DOI function, which influences how nonrelevant parts of the graph are aggregated. Changes in time are encoded in position and/or brightness. In future work, we plan to apply our approach to further graph visualization techniques and use the approach for large scale provenance and network flow exploration.

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