Demonstrating Interactive Multi-resolution Large Graph Exploration

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***Abstract*—We present a scalable, interactive graph visualization system to support multi-resolution exploration of million-node graphs in real time. By adapting a state-of-the-art graph algorithm, called Slash & Burn, our prototype system generates a multi-resolution view of graphs with up to 69 million edges under a few seconds. We are experimenting with interaction techniques that help users interactively explore this overview and drill down into details. While many visualization systems for million-node graphs require dedicated servers to process the graphs, our prototype runs on a commodity laptop computer. We aim to handle graphs that are at least an order of magnitude (100M edges) larger than what current systems can support.**

We demonstrate our system's usage, benefits, and scalability using two large graphs: a LiveJournal friendship network with 69 million edges, and a related-movies network from Rotten Tomatoes with 200K edges.

***Keywords*-interactive graph visualization; multi-resolution; hubs and spokes; graph decomposition**

I. Introduction

Given a large graph with million or billion nodes and edges, how to visualize it? Showing every single node and edge will not work, due to limited screen size. Furthermore, this may not be the right approach, since the visual complexity will be overwhelming. Recent research [1], [2], [3] investigated how to create overviews of large graphs, visualize those views, and allow users to interactively drill down. However, they often only work for graphs with well-defined hierarchies (e.g., graphs that are *trees*), or need to first transform the graphs into hierarchies.

How do we visualize more general kinds of graphs without depending on or assuming any hierarchical structures? Can we visualize such graphs at scale, say with 100 million nodes and edges (order of magnitude larger than what current systems support)? Can we support all these by using one commodity computer, without requiring the graph to fit in the main memory [2], or a dedicated client-server architecture [1]? These are the foci of our investigation. To summarize, we aim to make the following contributions:

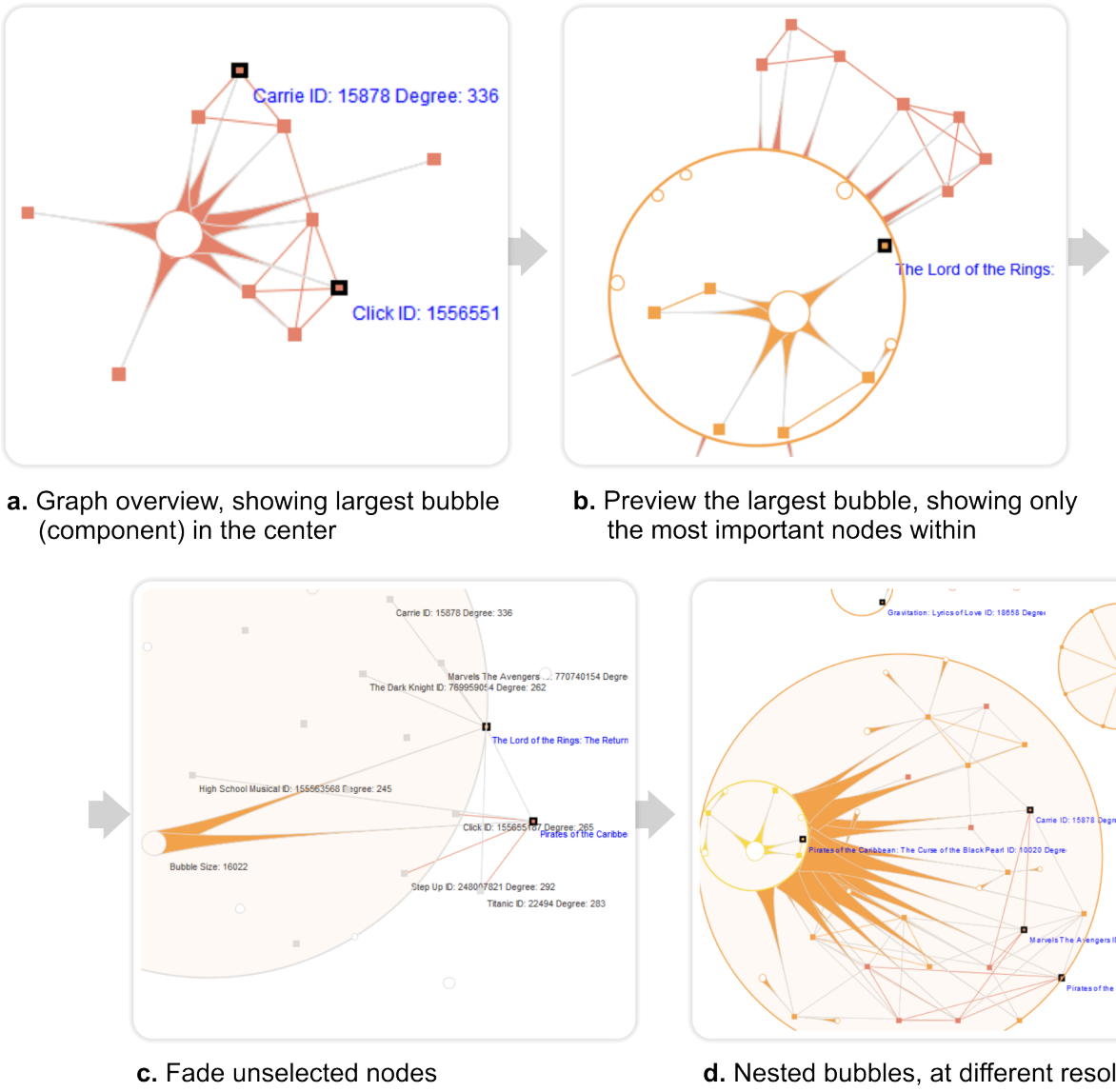
- We present a prototype system that supports multi-resolution exploration of large graphs with up to *69 million* edges.
- We adapt a fast, state-of-the-art graph algorithm, called *Slash & Burn* (Section III) that can create a multi-resolution graph overview under a few seconds.
- We present techniques that help users interactively explore the multi-resolution view via *prioritized visualization* (Section III), which helps the user determine what to visualize and explore.

II. Scenario

Here, we introduce the major visualization and interaction features of our prototype in a brief scenario. We will prepare a *guided tour* that is based on this scenario to introduce the demonstration audience to our system.

Alice is a data scientist at Rotten Tomatoes (RT), who wants to better understand which movies are considered similar by RT users. She has constructed a graph from her data of *related movies*, where each node in the graph is a movie, and an edge connects two movies if a user has suggested that they are similar. Crawled from Rotten Tomatoes, this graph has roughly 200,000 nodes and 150,000 edges.

Our tool first presents an overview to Alice (Fig. 1a). It shows the top 10 movies (called *bridges*) with the highest degrees (they have the highest number of related movies). It also shows the top 10 components (called *bubbles*) which have the largest number of movies within them. This first overview gives Alice some idea about what the most popular movies are, how they are connected among themselves, and to the rest of the movies ("hidden" within the components/bubbles). Among the top 10 movies, Alice sees some popular ones, such as *Titanic* and the *Dark Knight*. She is intrigued that all of them are connected to the large



a. Graph overview, showing largest bubble (component) in the center

b. Preview the largest bubble, showing only the most important nodes within

c. Fade unselected nodes

d. Nested bubbles, at different resolutions

Figure 1. (a) Overview of the top 10 movies and top 10 components (bubbles) of the Rotten Tomatoes *related movies* graph; largest component shown in the center. Node are movies; an edge connects two movies if they are similar. (b) *Previewing* a component (bubble) shows only a few, most "important", movies and components within in, to reduce visual complexity; the user can expand the bubble further to show more nodes. (c) A *broken-down* bubble showing all edges within a bubble and across bubble boundary; here, only edges connected to a selected movie is shown. (d) Bubble preview works across levels.

component in the center (with many movies in it), even for horror movie *Carrie* and comedy movie *Click*. She decides to check out what are inside the bubble.

By pressing the "+" key on her keyboard, Alice can *preview* (visualize) the contents of the component, while keeping the nodes and edges outside the component in place. At first, only a few, most "important" movies (highest degrees) and sub-components are shown. Alice wants to see a few more, so she pressed "+" a few more times; more nodes and components show up inside the big component (Fig. 1b).

Alice sees that *Lord of the Rings* is in this component and she remembers a few horror scenes in this chivalric movie. This seems to be a good clue for tracing the hidden relationship between the movies *Carrie* and *Click*. She double clicks the previewed components to *break it down*, which reveals all edges between the nodes inside and outside of the component.

Now the screen is cluttered with too many edges. To reduce visual complexity, Alice selects *The Lord of the Rings*, and invoke an action (not shown in figure) to fade away the unselected nodes (shown in gray color). Now, she

sees only *The Lord of the Rings* and the names of movies directly connected to it. It turns out *Pirates of the Caribbean* is one of those neighbors and she cannot help but smile about Jack Sparrow's witty humor. Then she holds down the *shift* key and select *Pirates of the Caribbean* too. This reveals that *Carrie* is similar to *The Lord of the Rings*; *The Lord of the Rings* and *Pirates of the Caribbean* share some characteristics; and finally, humor connects *Pirates of the Caribbean* and *Click* (Fig. 1c) .

Now Alice moves on to other movies. She interactively previews and breaks down a few more bubbles, at different parts of the graph, at various levels of abstraction (Fig. 1d).

III. Design Rationale and Algorithm Overview

A. Algorithm to generate graph overview

The general design principle that drives our design is **to prioritize what to visualize**, since the graph is large, but our screen real estate is limited. While this idea is implicit in recent works (e.g., [1], [4]), we use it as our first principle to guide our design.

In the visualization community, one common approach is to transform the graph into a tree (or tree-like structure), which is simpler to visualize and interact with, since nodes will then have well-defined parent-child relationships. In the visualization, we can then treat a parent node as the high-level representation of its children. However, this approach unavoidably changes the semantics of the original graph (e.g., from graph with cycles into a tree). Can we generate an explorable overview for more general kinds of graphs without such transformation?

Zinsmaier et al. [5] explored an alternative approach, to render million-node graphs by exploiting density-based node aggregation, assuming a given graph layout. However, it is unclear how it would work for real-world scale-free graphs, since their high-degree nodes would pull many nodes towards them, making the graph look like a "hair ball".

We surveyed data mining literature for solutions, and identified a state-of-the-art graph algorithm, called Slash & Burn [6], that could help use reduce visual complexity in a scalable and principled manner. Its design is based on the observation that most real-world graphs have power law degree distributions; such a graph have few hub nodes with very high degrees, while the majority of the nodes have low degrees. This means if we remove these highest degree hub nodes (e.g., top 25) and their edges, we will *shatter* the graph into smaller components, each being a *meta node* that may contain many nodes and edges—we call these nodes "bubbles", and visually we treat them as a higher-level representation of the nodes within it.

Due to its power law degree distribution, a graph can be quickly shattered by iteratively applying the above algorithm to components at each round. (All components eventually contain few number of nodes, say 50.) Here, we could only give a high-level description of the Slash & Burn algorithm due to limited space. We refer the readers to [6] for details.

A desirable effect of adapting this algorithm is that now we can rank both the nodes and components by their "importance". In our description above, we defined the "top" nodes as those having the highest degrees; but we can flexibly use "highest PageRank scores", or something else, instead. Similarly, components may be ranked by the number of nodes that they contain, or by other statistics.

B. Interaction technique to "preview" component

It is not sufficient to only create an overview visualization. We also need to provide interaction techniques for the user to explore and drill down. But, a component can contain tens of thousands of nodes and edges (as in the largest connected component of a million-node graph). We would not want to show all of them.

Fortunately, as we described above, nodes within a component are ranked (e.g., by node degrees). This inspires us to design an interaction technique that allow the user to choose how many nodes and edges they may want to visualize, based on how large they expanded a bubble (component), as if *previewing* or taking a glimpse into the contents of a component. The user can preview multiple bubbles that at different levels at the same time (Fig. 1d).

C. Scaling to large graphs

Current visualization systems often require dedicated servers to process their graphs (even for million-node scale), to run algorithms on them, and to compute their layouts [4], [1]. Is this always necessary? This question drives us to explore how much we can do with a single commodity machine. With our prototype, we are able to create a multi-resolution views for graphs from up to 69 million edge graph, in under 5 seconds. These views can be interactively explored, in real time. A main technique that we use to scale to such large graphs, is to avoid storing the graph in memory; specifically, we keep the graph's "edge list" on the hard drive, which would otherwise take up a lot of memory. We are now testing our prototype on even larger graphs, with 100 million edges and more.

IV. Demonstration Plan

A. Present State of Demo

Our current prototype system, as described above, is ready for use and exhibition in a demonstration. It can already handle graphs with tens of millions of edges in real time. However, we will continue to improve and polish it.

B. Datasets

In our demo, we will use the Rotten Tomatoes *related-movies* graph, as described in Section II. It contains about 150,000 edges; nodes are movies and an edge connects two movies if some Rotten Tomatoes users have voted them to

be similar. For this graph, we have a *dictionary* to translate the node IDs to movie names, so when the user mouse over a node, he would be able to find out which movie it represents; also, since movie datasets are generally easy to understand, our audience will be more engaged.

To demonstrate our system's capability in handling big graphs in real time, we will use a LiveJournal network, which consists of around 69 million edges. In this graph, nodes are people and edges between nodes indicate friendship links [7].

C. Demonstration Details

We will prepare two ways for the audience to try and learn about our system. One way is through a *guided tour* based on the scenario we described in Section II, which covers the major interaction and visualization features. The second way is to allow the audience to explore the system on their own, while accompanied by our presenters. Through either approach, the audience will learn about the main methods for exploring and navigating a graph with our system, which include:

- How to break down large bubbles into smaller ones via the intuitive interaction techniques we previously described.
- How to preview bubbles how this functionality helps select the most important or interesting nodes to avoid visually overwhelming the user.
- How to collapse previewed bubbles to revert entire or part of the visualized graph to previous state.
- Basic operations that we support in the graph visualization, such as panning and zooming.

We will explain visualized elements such as shapes of nodes/edges, colors for different levels, shaded areas, etc. We will also show the audience how to load and visualize their own graph with our system.

D. Equipment and Setup

1) What we plan to bring:

- A laptop running our software
- A monitor to provide the audience with better viewing experience
- A poster to describe the high-level ideas of our approach, and to attract and engage potential audience

2) Requested Setup:

- A table and two chairs
- A poster board (for our A0-sized, 3 feet by 4 feet poster) and poster pins
- A power strip with at least two sockets

V. Conclusions and Work in Progress

We will demonstrate a scalable, interactive graph visualization system to support multi-resolution exploration of million-node graphs in real time. Thus far, our prototype can handle graphs up to 69 million edges on a laptop computer. We are experimenting with various visualization and interaction techniques to allow users to fluidly navigate and explore and drill down in the graphs.

We will demonstrate our system's usage, benefits, and scalability using two large graphs: a LiveJournal friendship network with 69 million edges, and a related-movies network from Rotten Tomatoes with 200K edges.

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