Hypenet: Visualizing Dynamic Hypergraphs

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Abstract

We present Hypenet, a novel technique to visualize dynamic hypergraphs. Such structures can model multiple types of data, such as computer networks with multiple destination addresses (multicast) or co-authorship networks with multiple authors per article. Hypenet visualizes the evolving topology of the hypergraph in a compact way, allowing users to detect patterns and inconsistencies. We describe our technique and show how it applies to the case of the history of publications of the Eurovis conference, revealing interesting patterns that enable the analyst to tell a story about data and create hypotheses.

Categories and Subject Descriptors (according to ACM CCS): Graph/Network Data

1. Introduction

Dynamic networks are used to model the behavior of entities (as graph vertices), with relations (as graph edges) changing over time. Such relationships can involve multiple entities, and typically, one edge is added between each pair of entities involved in a relationship. For example, co-authorship networks include one edge between each pair of authors that share a publication. Representing them using traditional techniques, like node-link diagrams [KBV04], tend to produce visual clutter. In addition, relationships cannot be properly separated.

These relationships can also be modeled as *hyperedges*, leading to a *hypergraph* structure. Usually, hypergraphs are visualized using set visualization approaches [AMA*16], like Euler Diagrams [DvKSW12] or variations of node-link diagrams [PT11]. However, these techniques don't scale well, in terms of number of vertices and in number of hyperedges that can be represented, and they usually do not address well time varying data. In order to tackle these problems, we introduce *Hypenet*, a novel visualization technique to explore Dynamic Hypergraphs.

2. Hypenet

Hypenet is inspired by the Biofabric visualization technique [Lon12], also used by van den Elzen et al. [vdEHBvW14].

As shown in Figure 1, Hypenet visualizes Dynamic Hypergraphs representing each vertex as an horizontal narrow rectangle. Time is split in time intervals or time-slots (TSs), separated by a small gap. Hyperedges are drawn as vertical line segments connecting their vertices, spanning from the first to the last vertex of the hyperedge
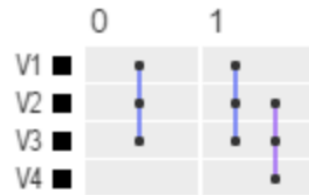
Figure 1: *Hypenet with dashed lines to help estimate hyperedge lengths.*

and showing a point at the intersection of the hyperedge and the vertices it contains.

Visual Attributes Enhancements To improve the readability of hyperedges, Hypenet alternates two colors (blue and purple in Figure 1) for adjacent hyperedges. This facilitates the visual tracking of long lines preventing the sight from jumping from one edge to a neighbor during long scans involving visual saccades.

Hypenet provides typical hovering, zoom and pan features to help users in navigating in the data space.

Ordering and Packing Ordering vertices highly impacts the comprehension of graphs and helps to perform tasks, such as searching for vertices by name (alphabetical order) or searching for communities and outliers [BBR*16] (similarity order). Hypenet provides four different orderings:

- Original vertex order: we provide this ordering by default;
- Alphabetical order: to easily find vertices by name;

- Optimal Leaf Ordering: similar vertices, according to adjacency similarity, are moved close-by [BJGJ01];
- Barycenter Heuristic: like the previous, but using a fast heuristic [MS05].

Van den Elzen et al. [vdEHBvW14] introduced an ordering method to move similar vertices far-away from each other to favor long edges. In Hypenet, long edges are detrimental to hyperedge packing and we chose not to provide that ordering.

All the connections existing inside a TS are shown inside the horizontal bounds of its time-span; this imposes that a TS should be large enough to fit the hyperedges. After ordering the vertices we need to order and pack the hyperedges. Ordering hyperedges by their intrinsic time inside each TS generates edge occlusion and highly variable edge density, making it impossible to control the legibility of the hyperedges. Relaxing the intrinsic time ordering of edges in each TS and using the *first fit decreasing* bin packing algorithm [CGJ97] improves the use of available space on the screen. The effectiveness of this heuristic depends a lot on the structure of the graph.

3. Case Study
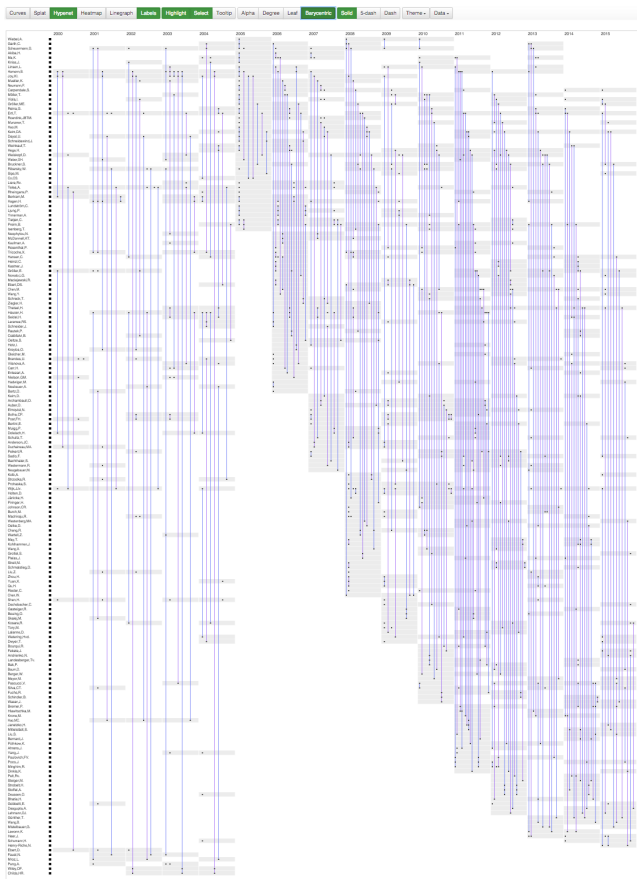
Figure 2: *Hypenet visualization of 15 years of Eurovis dataset (2000-2015)*

Figure 2 shows the co-authorship network of the Eurovis conferences 2000–2015 using our Hypenet technique. Only authors having at least two coauthors in in that period are shown. Authors are ordered vertically according to the *barycenter* heuristic [MS05].

Starting from 2005 the relationships among vertices become more dense and the number of vertices and edges increase and involve most of the authors in the dataset. In 2005 about 20% of authors are visualized at the top, but in previous editions, relationships are more equally distributed. The phenomenon can be explained because, in the period 1999–2004, Eurovis was a symposium, known as SymVis. Starting from 2005 the venue became the Eurovis conference, and since then the number of publications and authors have increased every year. In particular the editions of 2006 and 2011 have had a large number of participants.

The diagonal grayed blocks reveal the ordering capability of grouping the most related items taking into account the evolution over time. The upper block in TS 2005 is composed by only the authors attending Eurovis 2005. The second block in 2006 considers new authors, and keeps above it the people that were previously involved.

Interestingly, the community of Eurovis appears quite compact, and almost all people in the dataset that published at SymVis continued to publish at least one paper when Eurovis became a conference. However, the last gray block ends before the last vertex in the list, keeping a group of (6) people that participated to SimVis but never published in Eurovis. More investigation is needed to understand the reason of these drop-outs.

4. Conclusions

We have presented Hypenet, an organized and scalable visualization technique to visualize Dynamic Hypergraphs. Hypenet implements visual attribute encodings and interaction strategies to improve the redability of hyperedges. We also provide vertex ordering strategies and hyperedges packing to facilitate the identification of patterns. The paper also presents the case of visualizing data of 15 years of Eurovis, revealing the evolution of the conference and identifying the 2005 as the year of the big change.

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