Eurographics Conference on Visualization (EuroVis), Posters Track (2017)
A. Puig Puig and T. Isenberg (Editors)

Hypenet: Visualizing Dynamic Hypergraphs

Paola Valdivia[1,3] Paolo Buono[2] and Jean-Daniel Fekete[3]

[1]University of São Paulo, Brazil
[2]University of Bari Aldo Moro, Italy
[3] Inria, France

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

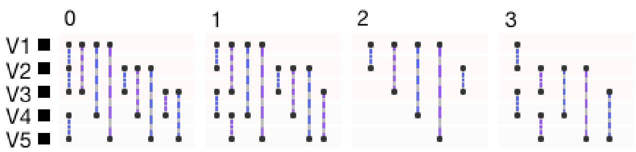

Figure 1: *Detail of the Hypenet technique. Dashed lines help estimating hyperedges length. Alternate colors prevent the sight from jumping to the neighbour edge in long scans.*

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. Another visual enhancement uses dash patterns on hyperedges instead of solid lines to help estimate the segment length. The number of dashes in an edge is fixed to 5 so the longer the dash the longer is the edge. This enable the users to estimate the length of the edge. Hypenet alternates shades every three rows to facilitate following nodes horizontally.

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 commu-

DOI: 10.2312/eurp.20171162

nities and outliers [BBR*16] (similarity order). Hypenet provides several different orderings:

- Original vertex order: default ordering;
- Alphabetical order: to easily find vertices by name;
- Optimal Leaf Ordering: according to adjacency similarity, similar vertices are moved close-by [BJGJ01];
- Barycenter Heuristic: like Optimal Leaf Ordering, 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* 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.

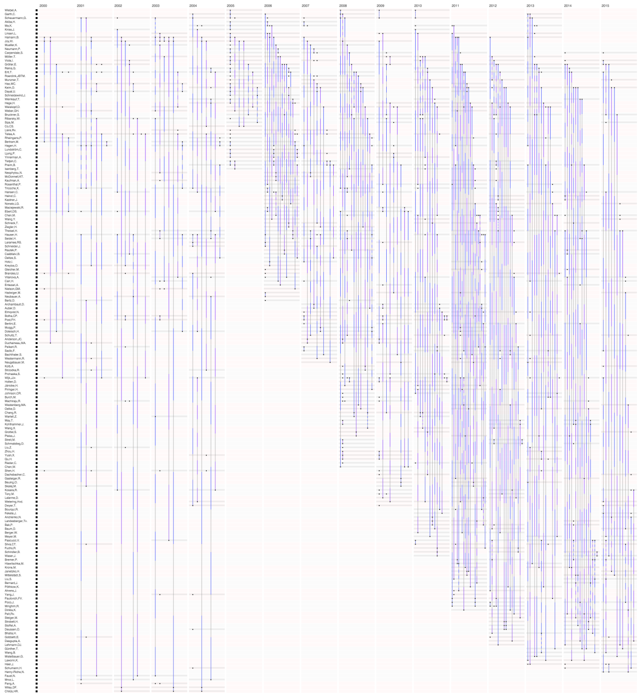

Figure 2: *Hypenet visualization of 16 years of Eurovis dataset (2000-2015)*

3. Case Study

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 that period are shown.

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 readability 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 16 years of Eurovis, revealing the evolution of the conference and identifying the 2005 as the year of the big change.

5. Acknowledgments

Grant 2016/10532-8 from São Paulo Research Foundation (FAPESP). The views expressed are those of the authors and do not reflect the official policy or position of the São Paulo Research Foundation. This work is partially supported by the Italian Ministry of Economic Development (MISE) under grant PON Industria 2015 MI01_00294 “LOGIN”.

References

[AMA*16] ALSALLAKH B., MICALLEF L., AIGNER W., HAUSER H., MIKSCH S., RODGERS P.: The state-of-the-art of set visualization. *Computer Graphics Forum 35*, 1 (2016), 234–260. 1

[BBR*16] BEHRISCH M., BACH B., RICHE N. H., SCHRECK T., FEKETE J.-D.: Matrix Reordering Methods for Table and Network Visualization. *Computer Graphics Forum* (2016). 2

[BJGJ01] BAR-JOSEPH Z., GIFFORD D. K., JAAKKOLA T. S.: Fast optimal leaf ordering for hierarchical clustering. *Bioinformatics 17*, suppl 1 (2001), S22–S29. 2

[CGJ97] COFFMAN JR. E. G., GAREY M. R., JOHNSON D. S.: Approximation algorithms for bin packing: A survey. In *Approximation Algorithms for NP-hard Problems*, Hochbaum D. S., (Ed.). PWS Publishing Co., Boston, MA, USA, 1997, pp. 46–93. 2

[DvKSW12] DINKLA K., VAN KREVELD M. J., SPECKMANN B., WESTENBERG M. A.: Kelp diagrams: Point set membership visualization. *Computer Graphics Forum 31*, 3pt1 (2012), 875–884. 1

[KBV04] KE W., BORNER K., VISWANATH L.: Major information visualization authors, papers and topics in the acm library. In *Proceedings of the IEEE Symposium on Information Visualization* (Washington, DC, USA, 2004), INFOVIS '04, IEEE Computer Society, pp. 216.1–. 1

[Lon12] LONGABAUGH W. J.: Combing the hairball with biofabric: a new approach for visualization of large networks. *BMC Bioinformatics 13*, 1 (2012), 275. 1

[MS05] MÄKINEN E., SIIRTOLA H.: The barycenter heuristic and the reorderable matrix. *Informatica (Slovenia) 29*, 3 (2005), 357–364. 2

[PT11] PAQUETTE J., TOKUYASU T.: Hypergraph visualization and enrichment statistics: how the egan paradigm facilitates organic discovery from big data. *Proc. SPIE 7865* (2011), 78650E–78650E–18. 1

[vdEHBvW14] VAN DEN ELZEN S., HOLTEN D., BLAAS J., VAN WIJK J. J.: Dynamic network visualization with extended massive sequence views. *IEEE Transactions on Visualization and Computer Graphics 20*, 8 (Aug 2014), 1087–1099. 1, 2