Interactive Poster: Exploring Time-Varying Hypergraphs

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ABSTRACT

Time-varying graphs occur frequently in many applications, e.g., as social networks or as ad-hoc computer networks. This interactive poster focuses on hypergraphs (graphs with edges that connect more than two nodes) and introduces a novel overview+detail concept for their visual exploration. It combines a bipartite view for detailed inspection and comparison with the computation of structural measures over time for a larger scale investigation. The visualization (Section 1), its use for exploration (Section 2), its application to a simulated biochemical reaction network (Section 3) and future research directions (Section 4) are presented in this extended poster abstract.

Index Terms: I.3.8 [Computing Methodologies]: Computer Graphics—Applications; H.5.2 [Information Systems]: Information Interfaces and Presentation—User Interfaces

1 VISUALIZING TIME-VARYING HYPERGRAPHS

The visual exploration of time-varying graphs has been investigated under many different angles – see e.g., [4, 6, 9]. Yet, so far not much attention has been paid to hypergraphs – even though they occur in several application fields, e.g., circuit board layout or biological networks. The problem of visualizing time-varying hypergraphs incorporates two challenges at once: visualizing hypergraphs and visualizing time-varying graphs, where "time-varying" can mean anything from just the edge weights are changing up to fluctuations of the entire structure. We propose a simple transformation that reduces the hypergraph structure to a bipartite graph and maps all possible changes to its node attributes. This way, we can develop an effective visualization for this bipartite graph with changing node attributes and map all the different possibilities of a changing hypergraph onto it.

Given a hypergraph $G_{hyper}(t)$ at time point t, there are two stages to this transformation:

1. Generate the bipartite graph $G_{bipa}(t)$ by applying the Koenig's transformation [8] that transforms each hyperedge into a new node and connects all incident nodes with it.

2. Generate the final graph $G_{super}(t)$ by merging all the different $G_{bipa}(t)$ into one big supergraph and adding a new attribute to the nodes that is set to 0 if a node is not part of $G_{bipa}(t)$ or to 1 if it is.

In case the network is not a binary one, where nodes and edges are either there or not (on/off), but one with gradual transitions (fade-in/fade-out), this can be modeled likewise in the second step by allowing continuous values for the new node attribute. So, no matter how complex the given hypergraph was and what kind of changes over time it undergoes, this transformation yields a bipartite graph with a static structure for each time step, in which all changes are captured in node attribute values.

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For our example of a biochemical reaction network, the hypergraphs $G_{hyper}(t)$ represent the chemical substances being present and the reactions taking place at time point t. The time series of all hypergraphs $G_{hyper}(t)$ gives a step by step representation of a whole chain of occurring reactions. Yet, while each step shows nicely what is happening at that moment, it is hard to put this in the context of the whole reaction chain which is not shown in its entirety. This is where the construction of the supergraphs $G_{super}(t)$ comes in: by aggregating all the individual time steps into the whole biochemical reaction network, this can be used to show the context of the individual changes. Also, this example is actually a fade-in/fade-out network that incorporates the presence of nodes naturally through the node attributes *concentration* for the substances and the *kinetic rate* for the reactions. If the concentration drops to 0, that substance is no longer part of the network. And if a reaction rate goes down to 0, it has ceased to generate products out of reactants.

So, the problem has been reduced in the end to visualize bipartite graphs with changing node attributes over time. While this can be done easily with a standard visualization technique for bipartite graphs [5] in conjunction with some color coding for the attributes and animation for the time, interactive exploration and querying of such graphs needs a few more thoughts.

2 EXPLORING TIME-VARYING HYPERGRAPHS

The exploration of any kind of data does only lead to insight if the used tools suit task and data. For our case of time-varying hypergraphs this calls for a highly interactive visualization that allows to spot time points of interest in the series of individual hypergraphs, to compare hypergraphs from different time points, and to interactively query them on different levels of scale – individually or in the context of the entire time series. To achieve this, we couple instances of our table-based visualization for bipartite graphs [7] as low-level detail views with a high-level view of the entire time series in a time-line representation. The time line shows different precomputed graph measures that capture structural aspects of the graph. Examples for possible structural measures to be used here are the graph complexity [1] or the amount of structural change between $G_{hyper}(t)$ and $G_{hyper}(t+1)$ using graph edit distances [2]. Plotted against the time, they reveal the ups and downs of the overall structural changes in the reaction network, pointing at possibly interesting time points to explore in detail.

It goes without saying, that both views (bipartite detail and time-line overview) are linked with each other, so that changes in one view are reflected in the other. So, once a time point or time interval of interest has been identified in the overview, its selection opens up detailed bipartite views. Apart from the fact that multiple bipartite views can be arranged side by side to allow their comparison, they also provide multiple ways of interacting with them – e.g., table-lens, clickable edges, filters, manual and script-based selection, etc. [7]. These can be used to adapted the bipartite view, for example by filtering all nodes with a concentration of 0 or a reaction rate of 0 respectively to see only the currently active part. This is basically a back-transformation from $G_{super}(t)$ to $G_{bipa}(t)$. Among each other, the bipartite views are also linked together, so that interactions with one view are carried out in all of the bipartite views. Selecting a node from a bipartite view, adds its numerical attributes (e.g. its concentration) to the time-line, so that the value observed

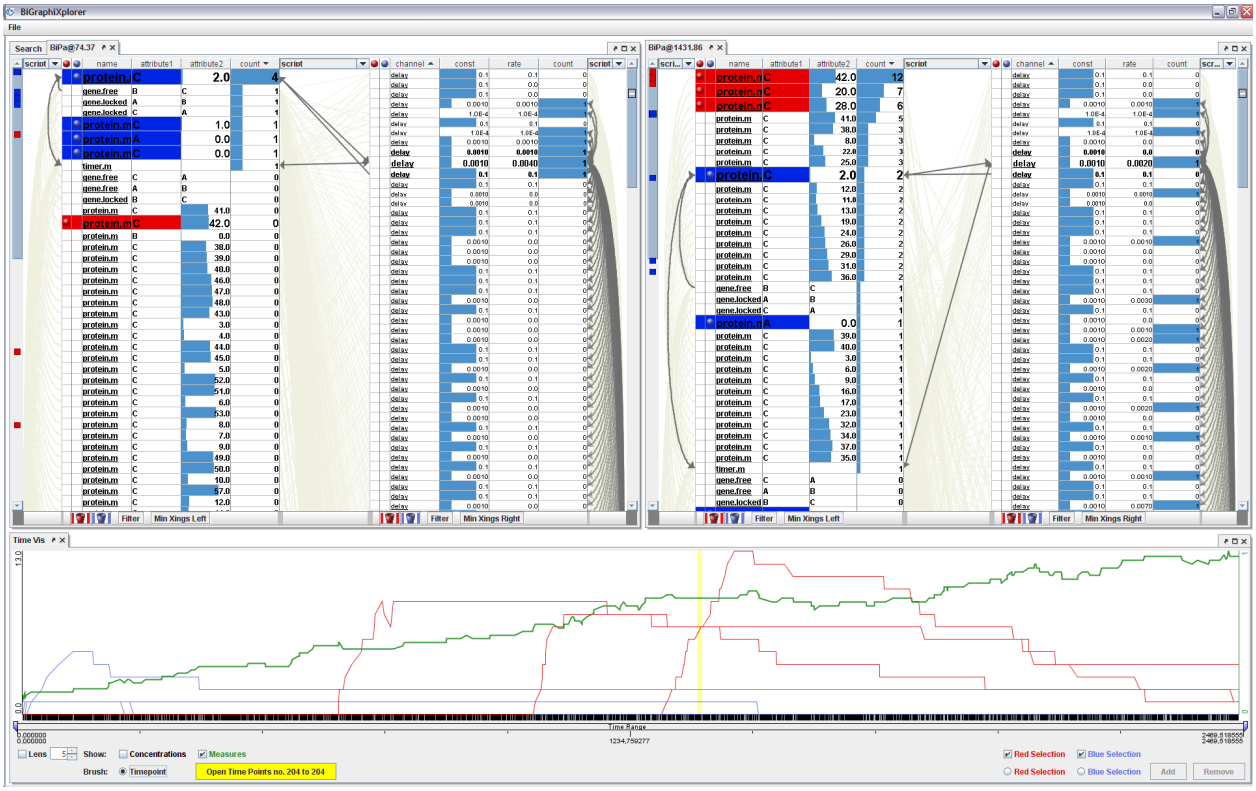

Figure 1: Screenshot of our visualization tool for time-varying hypergraphs. In the overview at the bottom, it shows the concentration of a few selected chemicals of our example, as well as the structural complexity as a green curve. Above that, two table-based bipartite graph views show details of the network at two different time steps.

at that very time point can be observed in context. This setup results in a natural back and forth between overview and detail.

3 Applying our Visual Exploration Concept

We have implemented our overview+detail visualization to explore detailed traces of stochastic simulation runs. These simulations have been carried out with a model of a biochemical reaction network as well as a set of starting concentrations. Then the simulation is done a few hundred times and the visualization of its output with our tool is used to investigate outliers identified in the time-line. It is currently applied by computational system biologists to debug their models and gain a better understanding of their inner workings: individual simulation runs can be singled out and glanced over in the time line view. If it shows anything unexpected or unusual, the user can close in on the time points of interest and investigate in the bipartite view in detail to find out what has happened. So far, the first feedback we got from the application experts was positive. Apparently, already a number of bugs were identified in the model as well as in the simulator by using our visualization. A screenshot showing our tool in action can be seen in Fig. 1

4 Future Work

This poster presents a tool for the visual exploration of hypergraphs. The tool covers so far two levels of scale: the individual hypergraph at a certain time step $G_{hyper}(t)$ in a bipartite view and the entire time series of all these hypergraphs in an overview. Yet, as it was mentioned, stochastic simulation runs produce hundreds of these time series. So, we plan to extend our visualization concept to this additional level that shows all simulation runs, allows to compare them, and to select individual time series of interest for a closer inspection. On top of that, we aim to couple our visualization with the open-source simulation framework JAMES II [3] to make our concept available to a wider audience.

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References

[1] D. D. Bonchev and G. A. Buck. Quantitative measures of network complexity. In D. D. Bonchev and D. H. Rouvray, editors, *Complexity in Chemistry, Biology, and Ecology*, pages 191–235. Springer, 2005.

[2] X. Gao, B. Xiao, D. Tao, and X. Li. A survey of graph edit distance. *Pattern Analysis and Applications*. to appear.

[3] J. Himmelspach and M. Röhl. JAMES II – experiences and interpretations. In A. M. Uhrmacher and D. Weyns, editors, *Multi-Agent Systems: Simulation and Applications*. Taylor and Francis, 2009.

[4] G. Kumar and M. Garland. Visual exploration of complex time-varying graphs. *IEEE Transactions on Visualization and Computer Graphics*, 12(5):805–812, 2006.

[5] K. Misue. Drawing bipartite graphs as anchored maps. In *Proc. of APVIS 2006*, pages 169–177, 2006.

[6] M. Pohl and P. Birke. Interactive exploration of large dynamic networks. In *Proc. of VISUAL 2008*, pages 56–67, 2008.

[7] H.-J. Schulz, M. John, A. Unger, and H. Schumann. Visual analysis of bipartite biological networks. In *Proc. of EG VCBM 2008*, pages 135–142, 2008.

[8] O. N. Temkin, A. V. Zeigarnik, and D. Bonchev. *Chemical Reaction Networks: A Graph-Theoretical Approach*. CRC Press, 1996.

[9] K.-P. Yee, D. Fisher, R. Dhamija, and M. Hearst. Animated exploration of dynamic graphs with radial layout. In *Proc. of IEEE InfoVis 2001*, pages 43–50, 2001.