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A visualisation technique for large temporal social network datasets in Hyperbolic space ☆

Uraz Cengiz Turker, Selim Balcisoy *

Sabanci University, Orhanli, University Street No: 27, 34956 Tuzla, Istanbul, Turkey

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ABSTRACT

Visualisations of temporal social network datasets have the potential to be complex and require a lot of cognitive input. In this paper, we present a novel visualisation approach that depicts both relational and statistical information of evolving social structures. The underlying framework is implemented by the usage of *Hyperbolic Geometry* to support focus context rendering. The proposed method guarantees representing prominent social actors through scaling their representations, preserves user's mental map, and provides the user to reduce visual clutter by means of filtering.

1. Introduction

In recent years visualisation of large temporal social network datasets has become one of the hot topics in information visualisation domain. Existing techniques rely on relational information to compute layouts as node-link diagrams and omit network metrics [1]. Therefore, as experienced in [2,3] analysts employ at least two software suits such as Net-Draw [4] and ORA [5] in parallel to understand the structure and the communication channels between actors of evolving social network datasets. Without loss of generality, we can summarize the requirements for visualising temporal social network datasets as follows: The underlying method must use an appropriate visual language to combine information space and the visualisation space. The technique must reflect the evolution of the network through minimizing the topological differences between adjacent images [6]. Finally the method must highlight the important aspects of the data with interactive, topology preserving clutter reduction techniques. In this paper, we address these requirements and propose a *Hyperbolic Temporal Layout Method* (HTLM for short) which uses nodes as visual metaphor for social actors, and links for social relations. HTLM draws the layout in the Hyperbolic space and project this Hyperbolic space in an Euclidean sphere. As illustrated in Fig. 1, it derives prominences of nodes from user selected network metrics, then uses these values to position prominent nodes close to the centre of the Hyperbolic space and others on circular orbits. Therefore, users can recognize prominences of nodes by comparing their distances to the centre. Our layout method represents evolution of a social network by performing a few topological modifications on the layout to enhance dynamic stability. The major contributions of this paper are as follows:

- We propose a Hyperbolic temporal layout method that represents the evolution of relations amongst network actors and structural patterns of a social network.
- We propose encoding user defined network metrics into a temporal layout to improve the information density of the generated visuals.
- We introduce a visual clutter control mechanism for HTLM which can significantly reduce overall visual clutter without modifying the topology of the layout.

We evaluate the proposed layout method on several synthetic and well known real-life temporal social

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* Corresponding author.
E-mail addresses: urazc@sabanciuniv.edu (U. Cengiz Turker), balcisoy@sabanciuniv.edu (S. Balcisoy).

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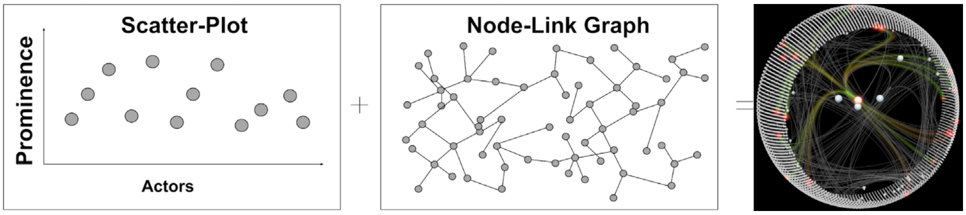

Fig. 1. We use actor prominence values according to a given network metric to calculate layout hence provide both relational and structural information to the user.

network datasets through using multiple network metrics. We measure the dynamic stability of the HTLM with two fundamental network metrics: *Average Distance* and *Orthogonal Ordering*. We conducted a usability study to evaluate the effectiveness of the proposed method. This paper is organized as follows: the following section reviews existing work that relates to our method. In Section 2, we present the analogy that we have drawn to control nodes' sizes. In Section 3, we discuss the details of our method. Performed case study with synthetic and real-life datasets is explained in Section 4. We present quantitative test results in Section 5. In Section 6, we conclude with the discussion of the layout and present future work.

2. Related work

In this section we briefly summarize the existing literature, since HTLM spans several aspects of visualisation spectra, we split this section into appropriate subsections.

2.1. Social network analysis

Social network analysis is the study of social actors and their relations through formal methods to reveal statistical properties [7]. In [8] Henry et al. divide computer based social network analysis spectra into two subcategories as *menu based systems* and *exploration systems*. Menu based systems such as Pajek [9] and Ucinet [10] provide advanced functionalities to domain-experts to evaluate social network datasets. Exploration systems generate visualisations of network datasets and provide interaction mechanisms such as zooming and filtering to convey details to the user. In [3] Henry et al. described how synthesizing a node-link diagram with matrix representation enhances user performances in terms of readability. In [11] Lee et al. propose an iterative graph representation technique with no global view of the dataset. Exploration of network data through coordinated views is presented in [12]. The semantic substrates [13] utilize visual attributes of data items to represent statistical properties of dataset. Moreover, it can visualise temporal social network datasets through static images with limited scalability.

2.2. Temporal graph drawing

Temporal graph drawing techniques utilize animations and use variations of force directed methods to represent temporal social network datasets as node-link graphs [14]. In [15] a modified GRIP algorithm is used to produce animations of evolving graphs. Kumar and Garland [16] proposed a hierarchical force-directed layout technique that sorts nodes according to weights. This method stratifies nodes into levels, therefore a user can easily get disoriented while exploring relations between the nodes. Besides, it is reported that this method does not scale well for large datasets [1]. In [1] Frishman and Tal proposed a promising solution to represent large temporal datasets. It uses a modified force-directed algorithm that runs on the GPU by passing data values to textures to calculate the layout. This technique advances the layout calculation performance of a force-directed method and its scalability. PieSpy can visualise small temporal datasets based on Fruchterman–Reingold method, where the initial topology of the layout is obtained randomly [17]. Condor [18] uses an algorithm called *sliding frame* to represent the evolution of the dynamics of a social network through time. SoNIA [19] is a graph animation tool that generates videos of animated graphs based on different layout techniques with little interactivity. A similar approach has been presented in [20]. This method uses a mixture of force directed placement and circular layout placement on the 2D surface.

As these methods follow a force-directed placement algorithm, they produce visuals based on relational information amongst social actors. In comparison, our method encodes the network metrics into layout, so users can perform not only relational but also statistical analysis on a given temporal network.

2.3. Quantitative visualisation techniques

As 2D scatter-plots cover main properties of other approaches such as 2D bar-charts, and 2D pie charts, throughout this paper we use *scatter-plot* as a general term to refer 2D quantitative visualisation techniques. Scatter-plots are one of the oldest visualisation techniques to express statistical properties of a dataset. Generally, scatter plots use two axes of Cartesian coordinates to form spatial mappings of the data where each axis corresponds to one data attribute. The main idea behind scatter-plots is to represent dependency between different data attributes [21]. The first scatter-plot representation of a temporal social network is given by Moreno's drawings [22]. The graphic provides user to observe change of roles of social actors as time progresses. While, this representation method is widely applied and well suited to many real-world networks, it is inapplicable when both the time span and the number of network items get larger. Gapminder's Trendanalyzer [23] and similar approaches [24] address this issue through the usage of animations. These techniques do not use an axis to represent time, they however