Vertigo zoom: combining relational and temporal perspectives on dynamic networks

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ABSTRACT

A well-designed visualization of dynamic networks has to support the analysis of both temporal and relational features at once. In particular to solve complex synoptic tasks, the users need to understand the topological structure of the network, its evolution over time, and possible interdependencies. In this paper, we introduce the application of the vertigo zoom interaction technique, derived from film-making, to information visualizations. When applied to a two-and-a-half-dimensional view, this interaction technique enables smooth transitions between the relational perspective (node-link diagrams and scatter plots) and the time perspective (trajectories and line charts), supporting a seamless visual analysis and preserving the user's mental map.

Categories and Subject Descriptors

H.5.m [**Information Systems**]: Information Interfaces And Presentation (e.g., HCI)—*Miscellaneous*

General Terms

Design

Keywords

Dynamic networks, information visualization, interaction, 2.5D, vertigo zoom

1. INTRODUCTION

Visualization of dynamic networks is a research topic that has been drawing increasing attention in recent years, because of their applications to several fields. Dynamic networks are exploited to model diverse phenomena, for example social interactions between human beings (sociology), digital connections between electronic devices (communications), relationships between proteins (biology), and interdependencies of industrial sectors or regional markets (economics). Whatever application domain we consider, a good visualization of dynamic networks has to support the analysis of the relational aspect (what is the structure of the network) as well as the temporal aspect (how the network evolves over time), and should also enable a seamless switching between them [9]. In particular, when dealing with a two-and-a-half-dimensional visualization [5], which aims to enable the inspection of both structure and dynamics in a single view, users should be allowed to seamlessly switch their focus between the temporal and the relational perspective.

We introduce the *vertigo zoom* interaction technique in order to support those alternated changes of perspective, as the main contribution of this paper. An additional contribution is a smooth transition between scatter plots of network analytic measures and line charts to represent their evolution over time, aiming to enhance the comprehension of both. In the following, we describe the problem of dynamic networks visualization (section 2), present the *vertigo zoom* interaction technique (3), discuss it in comparison with related work (4), and outline our future plans for upcoming evaluation (5).

2. PROBLEM DESCRIPTION

In order to visualize dynamic networks, we have to choose amongst various visual representations (e.g., node-link diagrams, or matrix-based diagrams), and also choose a certain rule for positioning nodes in the space, i.e. a layout, which preserves the user's mental map [7] across evolving network states. An adequate visualization of dynamic network should also provide an effective mapping of the time dimension. In case of discrete-time domain, in particular, we need an effective criterion by which the diagrams referring to each time point are arranged and shown; regarding this issue, we can choose amongst various options, like for example: animation, superimposition, juxtaposition, and two-and-a-half-dimensional (2.5D) view [8].

Aside specific advantages and disadvantages, all these views share the aim of supporting the visual analysis of both the structure and the evolution of the network. During a task-based qualitative user-study, we observed that users alternate and also combine different views, aiming to solve com-

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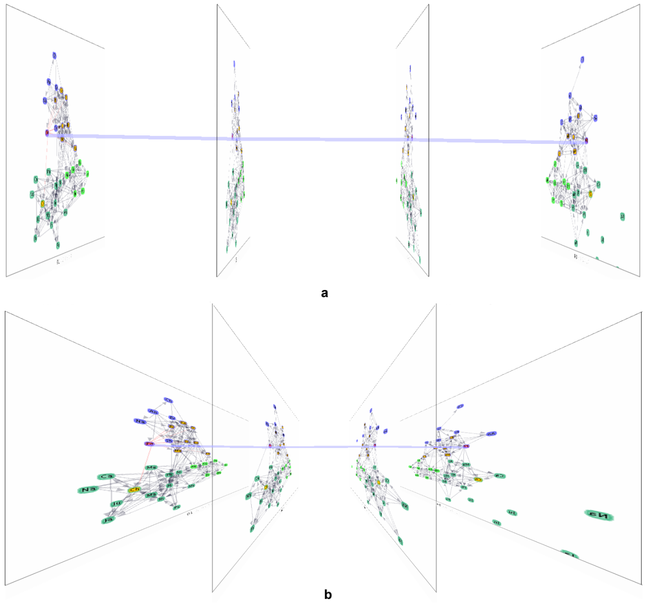

Figure 1: Two-and-a-half-dimensional views of a dynamic network with different values of the field of view: a) 30 degrees; b) 120 degrees.

plex synoptic tasks that demand the understanding of both relational and temporal aspects (e.g.: when identifying which employee has joined/left the organization in a certain period, and analysing the organizational consequences). Thus, to better support the visual analysis, the mental map has to be preserved not only across the subsequent states of the network over time, but also across the various views exploited by users to solve their tasks, for example by ensuring smooth animated transitions between views to maintain the exploration context. According to some of the subjects involved in our study, these transitions not only helped them with preserving the mental map, but also served as a live explanation of the visualization metaphors, "saving one from reading many pages of a manual".

Considering in particular the 2.5D view, it has the clear advantage of explicitly mapping time to a specific spatial dimension, that might be used to encode also additional information, like node trajectories visualizing structural changes over time. A node trajectory is visualized as a line connecting different instances of a given node across different time-slices; its slope can show movements from the core to the periphery or vice versa. Moreover, the temporal evolution of selected graph-theoretical measures associated to nodes can be visualized by changing the color and the thickness of trajectories along the time axis. But, the 2.5D view is affected by some problems, like distortion and overlapping. To better explain these issues in detail, we refer to the 2.5D views provided by a software prototype for visual analytics of dynamic social networks [8], using a dataset consisting of 38 employees of a small enterprise over 4 time points. The degrees of distortion and overlapping are correlated to the scene perspective (fig.2), more precisely the camera angle of view or the field of view (FOV). If the FOV is too narrow (fig.1a), node trajectories drawn along the horizontal axis are visible but we get a foreshortened view of the node-link diagrams with a lot of distortion and compression; if the FOV is too broad (fig.1b), the node-link diagrams are shown in a better angle but there are more occlusions, more overlapping amongst them, and the added half dimension is less clearly visible. Optimizing the FOV can mean to minimize distortion, or minimize overlapping and occlusion. But, going back to the need of combining temporal and relational perspectives, we also notice that a narrow FOV enables a better analysis of temporal trends (node-link diagrams are parallel to the line of sight and barely visible, while trajectories along the time axis are visually prominent); while a broad FOV eases the inspection of the network topology (diagrams become more orthogonal to the line of sight, and partly overlap trajectories). Thus, we should also find the value of FOV that optimizes the trade-off between these contrasting needs.

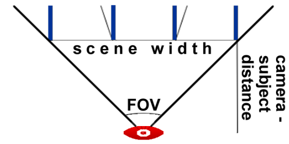

Figure 2: The geometric relationship amongst field of view (FOV), scene width, and camera-subject distance.

3. THE VERTIGO ZOOM

Our proposed solution to the above described problems is not based on a method that tries to find the 'best' value for the field of view, but rather on an interaction technique that allows users to interactively change and adapt it to their particular data, tasks, and personal preference. The *vertigo zoom* is a well-know technique in filmmaking, named after Alfred Hitchcock's movie Vertigo (1958), also exploited in 3D computer graphics [4]. It is a synchronized combination of a dolly movement and a zoom.

In filmmaking (as well as computer graphics), what we call 'zoom' actually is not performed by changing the FOV, i.e. the focal length of the (virtual) lens, because this would introduce an unwanted distortion of the scene; a zoom-in is realized by a dolly movement: the camera gets closer to the scene, so that the scene is magnified without any perspective distortion. The *vertigo zoom*, conversely, combines a dolly movement and a change of the focal length to produce a change of the perspective without any magnification. The movement of the camera and the change of its FOV have to be synchronized, so that the width of the scene is preserved (fig.2), according to the equation:

$$distance = \frac{width}{2\tan\left(\frac{1}{2}FOV\right)} \tag{1}$$

While this well-known technique is extensively used in motion pictures as well as in computer games for creating dramatic effects, we propose its adoption for information visualization, as an interaction technique supporting smooth transitions between different perspectives. Considering 2.5D visualizations of dynamic networks, a change of the FOV, controlled by the user by a simple scroll gesture (on either the mouse or the touch-pad), would enable seamless switches between the relational and the temporal perspectives.

The utility of this interaction technique is not limited to visualizations based on force-directed node-link diagrams.

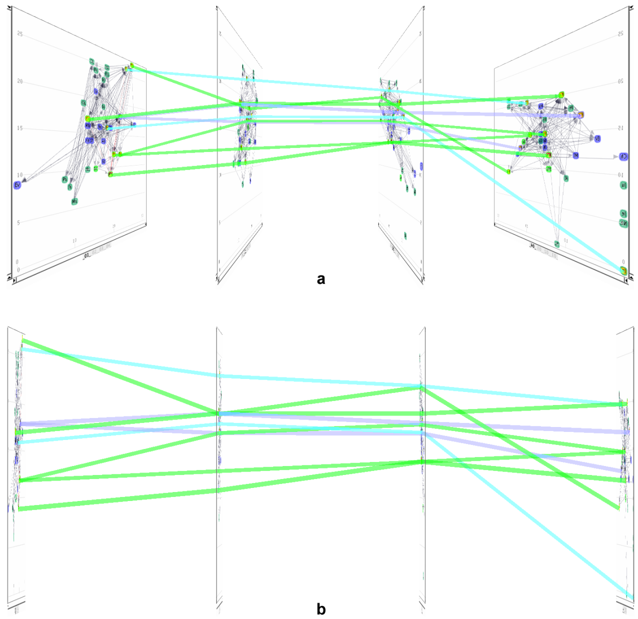

Figure 3: a) 2.5D visualization showing scatter plots of network centralities (FOV=60 degrees). b) 2D line chart showing the temporal evolution of network centralities (FOV=5 degrees). The transition between the two views can be controlled interactively by the *vertigo zoom*.

Scatter plots using centrality measures as variables have been used to visualize static social and biological networks [6, 11] as well as dynamic networks using superimposition [14]. We can build a 2.5D visualization by stacking subsequent scatter plots (fig.3a), and then explore it by using our *vertigo zoom* interaction. In case of scatter plots the horizontal and vertical coordinates convey directly the variables they refer to (in the example of fig.3a, eigenvector centrality and clustering coefficient). This is different from force-directed node-link diagrams, where only the relative positions of nodes have a meaning, By using the vertigo zoom to decrease the field of view and reach the maximum temporal perspective, the 2.5D visualization based on scatter plots is flattened into a line chart, enabling the focused analysis of a single variable for all nodes (fig.3b). The other variable can be visualized separately (by rotating the view of 90 degrees around the horizontal axis), or jointly (by re-increasing the FOV). In other words, by interactively varying the field of view, the user can focus on a single variable and analyse its temporal evolution without any perspective distortion, or s/he can bear a certain amount of distortion and inspect the temporal evolution as well as the correlation of two variables, and s/he can always smoothly pass from the one end to the other.

4. RELATED WORK

2.5D visualizations have been used for other types of data than dynamic networks. VisLink [3], for example, is not intended for the analysis of temporal data, but for comparing different visual representation of the same dataset. It does not offer the possibility to change the field of view, but provides a few predefined arrangements in the 3D space of the 2D visualizations. Caleydo [12] can be seen as an extension of VisLink, with five visualizations arranged as faces of a cube. In this case the FOV is also fixed, but users can switch from the cube view to a plain small multiples view to remove perspective distortion. Streit et al. [18] propose also a gazed-based focus adaptation, which rotates the cube in order to minimize distortion of the face the user is looking at; but a limitation of this approach is the need for an eye tracking device to detect user's gaze, and also the trade-off between accuracy and cost of such a device. Ahmed and Hong [1] discuss various interaction techniques for navigating 2.5D graph layouts, but they explicitly exclude the change of the FOV, considering it a secondary camera feature. The commonality shared amongst all the mentioned approaches is the use of smooth animated transitions. McGuffin et al. [13] have found that these transitions are crucial to help users understand how exactly the 3D arrangement is deforming the 2D visualizations; their empirical study was focused on volume rendering and scientific visualization, but VisLink [3] supported their validity also for information visualization, and we also found a similar result in our aforementioned user-study. While Heer and Robertson [10] provide a taxonomy of animated transitions between 2D data graphics, we are not aware of any similar work for the 3D case.

2.5D views are only one of the possible options for the visualization of dynamic networks. The *in situ* exploration technique introduced by Hadlak et al. [9], specifically for large dynamic networks, leverages the same concepts of VisLink. It features different visualizations of the same dataset and uses visual links to connect different instances of the same data item across visualizations, but it is purely two-dimensional; and the seamless exploration and the preservation of the mental map are retained as key features also in this case.

While Oliveira and Gama [14] use a static superimposition view to deal with scatter plots of network centralities evolving over time, animated scatter plots are a common choice to visualize the correlation and the evolution of multivariate temporal data [15, 16]; nevertheless, advantages and disadvantages of animations versus static visualizations are still not totally clear.

5. DISCUSSION AND NEXT STEPS

A glance at the related work shows that although the *vertigo zoom* appears to be interesting and promising, it is only one of several techniques aimed to support the visual analysis of dynamic networks. The switch between the temporal and the relational perspectives can also be attained by using classical interactions, like zoom, pan, and rotation in 3D space, or by switching to a different view through a smooth transition. In order to verify the effectiveness of the *vertigo zoom* in comparison with the other techniques, we plan to perform a comparative evaluation by running a set of controlled experiments. Several aspects which might influence the use and the utility of the *vertigo zoom* should be considered. A factor to be considered is the type of diagrams constituting the 2.5D visualization, either node-link diagrams or scatter plots. Another aspect to take into account is the effect of size and density of the network, as well as the number of time points. Lastly, the initial field of view could also affect users' perception. Steinicke et al. [17] suggest to match the geometric FOV of the visualization with the display FOV, that is the angle of view at which users looks at their screens, and can be calculated on the base of the estimation of the average size of the computer screen as well as the average distance of users' eyes from the screen (they report an average display FOV between 28 and 60 degrees). But it is also worth noting that their suggestion refers to realistic rendering of 3D objects and environments, and its applicability to information visualizations cannot be taken for granted.

We have formulated a number of hypotheses to be verified in the upcoming evaluation: our first hypothesis is that classical 3D interactions (pan, zoom, and rotation) are difficult for the user, because they request her/him to control a 6-degrees-of-freedom interaction with a 2D interface (mouse) on a 2D screen. This hypothesis is supported by related literature [2, 3], and has been partially suggested by our previous user study with visualizations of dynamic networks (in particular by observing subjects' performances at a synoptic task demanding the identification of simple temporal patterns and their impact on the relational properties, even if interactions in a 3D space were not our main focus). A second hypothesis is that using the *vertigo zoom* interaction technique is more efficient than switching to another visual representation or 2D view. We assume that the *vertigo zoom*, despite a relevant amount of perspective distortion, preserves the visual encoding and the overall geometric context, and then supports users in maintaining their mental map and their orientation.

Finally, we want to point out that our present contribution, introducing the *vertigo zoom* interaction technique, refers explicitly to the visual analysis of dynamic networks. But as our future steps we also plan to extend its application to other information visualizations leveraging 2.5D as well as 3D layouts.

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