TimeMatrix: Visual Representation for Temporal Pattern Detection in Dynamic Networks, VAST 2018 Mini-Challenge 3

Tommy Dang*
Computer Science Department, Texas Tech University

Vung V. Pham†
Computer Science Department, Texas Tech University

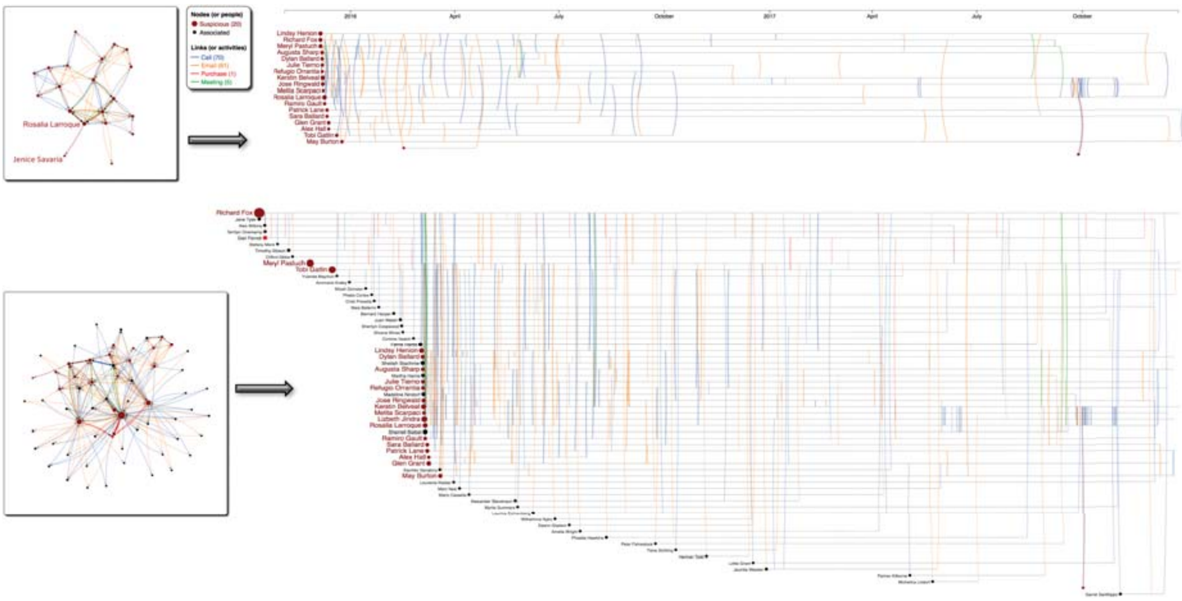

Figure 1: *TimeMatrix* visualization for the *VAST 2018 - MC3* dataset: Activities of 20 Kasios employees (red nodes) that the insider has identified as being suspicious: (left) Network view - Node sizes are computed based on their activities (right) Timeline view - Each dashed horizontal line presents a timeline of the employee whose name is printed at the beginning of his/her timeline.

Abstract

This work proposes a visual analytic technique for visualizing temporal pattern detection in networks. The force-directed layout is a popular way to highlight structures of a network however it does not allow to present the dynamic features (how communities change over time). We target this problem by forcing nodes to display vertically and using the horizontal space for representing the timeline of entities. To show the connection between nodes, the edges are drawn vertically to avoid edge-crossings. This work also presents the result of applying the solution to the *VAST 2018 - Mini Challenge 3* dataset, which led to the Honorable Mention: *Representation of Small-Scale Temporal Patterns* for the challenge.

1 Introduction

Traditional node-link diagrams do not include temporal information, which is a critical component in many application domains such as social network or biological pathways. To add the time element to these layouts, researchers have used the third dimension [1] or presented multiple snapshots for each time point [2]. The first approach requires user interactions, such as rotating, filtering, and zooming, to get to the point of interest, while the second approach requires more mental efforts, such as memorizing and visual mapping, in order to link multiple snapshots for comparisons.

In this paper, we propose a visual analytic technique, called *TimeMatrix*, for integrating temporal information into traditional network representation. *TimeMatrix* is unique in that it represents nodes as horizontal lines, and edges as vertical lines which are color-coded by connection types. Our proposed visualization has two main components as depicted in Figure 1 on the *VAST 2018 - Mini Challenge 3* dataset: The network view on the left and the timeline view on the right.

- Nodes are Kasios International employees, darker red nodes are suspicious people (as identified by the insider). Links (or arcs) are color-coded by activity category. We use arrows and clock-wise curvatures to indicate activity direction. The network view is implemented using Cola.js. We adopted the Flow Layout to force employees at the destinations of these activities (people who are receiving a call, receiving an email, selling something to a buyer, or being invited to a meeting) occupy lower positions in the network.
- The timeline view shows the same input data, focusing on when an activity occurs. Each horizontal dashed line represents an employee's lifetime [4]. Links never intersect in a *TimeMatrix* visualization as they are always drawn vertically, making it clear which nodes are connected [3]. Color encoding allows us to view the relationships that nodes with many edges have with other nodes [5].

From the group of 20 suspicious employees, we expand another

*e-mail: tommy.dang@ttu.edu
†e-mail: vung.pham@ttu.edu

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network level to identify other associated factors (black nodes) as depicted in the lower panel of Figure 1. We can see that there are a lot of activities in the last two months of 2015. The interactions in this group are reduced and replaced by smaller groups. As depicted, there are many calls and emails exchanged between smaller people in October 2017. Within these associated employees, *Gail Feindt* is responsible for 24 different purchases. The purchase transaction between *Rosalia Larroque* and *Jenice Savaria* seems suspicious.

2 VAST 2018 - Mini Challenge 3

This section describes how *TimeMatrix* can be used to answer questions in the *VAST 2018 - Mini Challenge 3*.

Questions: Using the combined group of suspected bad actors, show the interactions within the group over time.

- Characterize the group's organizational structure and show a full picture of communications within the group.
- Does the group composition change during the course of their activities?
- How do the group's interactions change over time?

Figure 2 shows all activities (calls, emails, meetings, and purchases) within the group of 20 suspicious and 42 associated employees. We filter only phone calls in Figure 3. A similar decrease can be observed for emails.

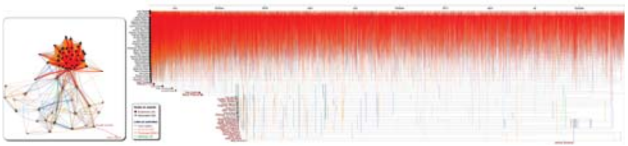

Figure 2: All activities within the group of 62 62 bad actors.

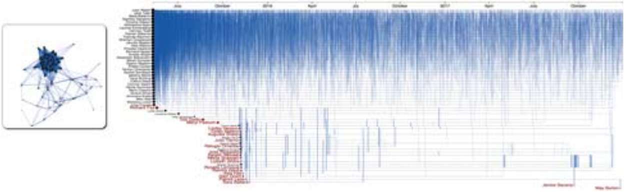

Figure 3: Phone calls within Kasios are decreased over time.

Figure 4 shows purchases within the group of 62 bad actors. As depicted, *Gail Feindt* (the red node) appears to be the primary distributor (of the purchases), the transaction between *Rosalia Larroque* and *Jenice Savaria* stands out as a suspicious purchase.

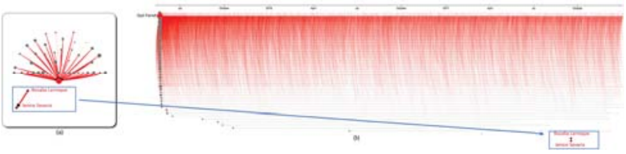

Figure 4: Purchases within the group of 62 bad actors are stable over time.

The group's organizational structure can be inferred partially through the meetings as depicted in Figure 5. This organizational structure changes over time. For example, *Richard Fox* does not invite *Madeline Nindorf* and *Julie Tierno* any longer after 2016. Instead, he met *Meryl Pastuch* who involved indirectly in the suspicious purchase.

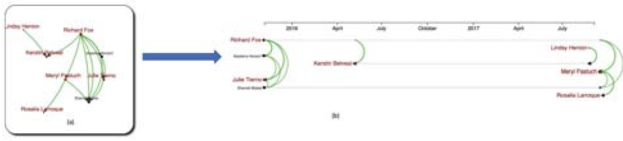

Figure 5: Meetings within the group of 62 bad actors

Figure 6 inspects the suspicious purchase: (a) Network view of related people within the 4-level separation from the *Jenice Savaria* (b) Timeline view of the same network where time is expanded from August 20 to October 20 of 2017. From this view, we can see that *Rosalia Larroque* had called *Jenice Savaria* several hours before the suspicious purchase happened. *Rosalia Larroque* was on the phone with *Kerstin Belveal* while she performed the purchase and the communication (emails and calls) continued several days after the purchase (as it happened several days before). Notably, the transaction was performed in the early morning (around 4 am on Wednesday 20, 2017) as we mouse over the arc/link.

Figure 6: Inspecting the suspicious purchase of Rosalia Larroque and Jenice Savaria.

3 Implementation

The source codes, the demo video, and the report of the patterns discovered for the VAST 2018 - MC3 dataset can be found from the Github page[1] of this project.

4 Conclusions

This paper presents a two linked view visualization for a dynamic network. The timeline view of *TimeMatrix* overcomes two main limitations of force-directed layout: the "hairball" problem and no temporal information. Our use case in Section 2 successfully demonstrated the application of *TimeMatrix* on the *VAST 2018 - Mini Challenge 3* dataset, which led to the Honorable Mention:*Representation of Small-Scale Temporal Patterns* for the challenge. The main limitation of this technique is that it only works well on the smaller scale or highly fluctuated networks where community structure varies a lot over time.

References

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