Interactive visualization of dynamic rule networks

Minu Francis
University of Illinois, Chicago
mfranc31@uic.edu

Pooja Donekal
University of Illinois, Chicago
pdonek2@uic.edu

Surbhi Arora
University of Illinois, Chicago
sarora23@uic.edu

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Abstract
The project helps in creating Site graphs, modelling the influences among rules at different time intervals. This helps in visualizing how a rule affects the other in the system and how that influence changes over time. The challenging part lies in creating a clutter-free visualization due to its volume. The data set is huge and is subjected to increase as well. This motivated us to choose matrix visualization as it avoids clutter and helps in providing a clear view of changes in data. To compare the influences, we are making use of Parallel Coordinates which delivers a clean visualization to mark noticeable changes like positive influence turning negative etc.,.

Author Keywords
Dynamic Influence Maps; Matrix Visualization; Parallel Coordinates;

Introduction
The project we are working on corresponds to dynamic influence maps, where we need to model the influences amongst different rules. The challenges lie in avoiding clutter, due to large data set and also frame the comparison of influences as time passes.

One common and most important frameworks to deal with such kind of network visualizations is a force directed layout. Novelty in our visualization lies in

choosing a different approach, Matrix Visualization to show the influences among various rules at different time intervals provided.

Matrix visualization helps in reducing clutter. Be it even 1000 nodes, it is very much viable to show a clean visualization displaying the right information. So, with the help of Matrix we are able to visualize the rules and their influences over different time intervals. Difference in magnitude of the influence is noticeable from the width and color of nodes in matrix. Matrix also helps in visualizing only the positive influence nodes, negative influence nodes and clusters among nodes with high influence.

We are using visualization, Parallel Coordinates, to compare the influences among rules as time passes. The vertical axis represents rules, while the horizontal axis corresponds to the time units. The vertical coordinates, repeat themselves to span the whole horizontal axis. Nodes are connected indicating the influences among rules. Also, the user can filter among different options to have a view of reduced data, like only highly influenced rules, weakly influenced rules etc.

So, these two visualizations will help in achieving the two challenges as mentioned: To depict the rules and their influences by reducing clutter; To have a view to compare the influences over time.

Related Works

Useful methods to visualize protein interactions has been used [1]. D3 was used as the tool to create the visualization. In addition, other visualization techniques have also been used.[1] provides an interactive exploration of dynamic networks using an integrated combination of an enhanced animated node – link diagram along with an animated distance matrix representation. The node link approach was not chosen due to limitations in a network visualization. More nodes lead to more clutter and there is limit on the number of nodes that can be visualized in a node – link diagram. A matrix visualization avoids the clutter formed due to a large network. Increase in number of nodes do not lead to a visual clutter. Matrix visualization gives equal importance to all network links and focusses on visualizing the data associated with the network rather than just the structure of the network. [2] deals in detail with this concept of using matrix representation for network data visualization in detail. [3] provides several novel features to support the exploration of social networks with a matrix-based representation, in addition to the standard interactive filtering and clustering functions. [4] provides an insight into the domain that has been taken in to consideration. This paper discusses about one dimensional diffusion of proteins over DNA and provides details on the interaction.

Analysis Task

The purpose of this visualization is to analyze the influences of different rules on each other. We have a data set which consists of rules and their influences on each other. Rules can influence the other in positive way which is like attraction force between two rules or in a negative way. In order to analysis the rules influences over the time our main visualization task was to create an Interactive web visualization that automatically creates "site graphs" from a JSON file. Our Matric visualization can effectively manage highly complex site graphs so that visual clutter (e.g., link crossings, color choices) is mitigated as much as possible. Second task was to display the influence of certain rules describing a

biochemical system which change over time. This can be seen in the Timeline visualization. Also, the similar influence map is showed in form of cluster in matrix visualization. Clustering can help the user to analyze which rule effects the same set of rules in similar fashion. Comparison of rules over various time intervals can be easily seen in the Parallel Coordinate visualization.

Visualization Details

Matrix

We are showing the complete data set for a particular time interval in a matrix format. Other visualizations are also available for networks like force layout, chord diagram etc. However, all of those experience clutter, when edges between nodes are more. To combat this shortcoming, we have opted matrix as it forms one of the basic techniques to visualize network data with no clutter even when number of nodes and edges are high. In this visualization, we have used color as channel to represents the influence of one rule on another. Rows of the matrix represents the rules which are influencing and columns represent the rules which are influenced by rows' rules. Green represents the positive influence and red color indicates negative influence. Lighter shade represents the low magnitude of influence and darker color shows high magnitude. We have decided the color shade based on number of digits. If magnitude is 0-9, it will be lightest shade and the magnitude between 10000000- 999999999 will be the darkest shade. Legend explains the accurate ranges for different shades of color.

Visualization includes a slider to view data at different time intervals. Slider is implemented using d3.slider function. By choosing a particular time interval user can view data for the same or drag the slider to view the changes over the time. Animation is enabled by clicking "Start Animation". It automatically displays influence at different time slots. It basically drags the slider handle automatically for the entire time span. User can stop the animation at any point using "Stop Animation" button. Also, user can restart the animation.

This visualization includes different type of filtering. The view can be filtered using positive and negative influence buttons. When user clicks positive influence only positive influences are displayed for all the rules. Same can be applied for negative influences.

Clustering the data was one of the main challenges. We have added clustering based on the similar influences. When user clicks "Influence Clustering" button, rules which are influenced by the same set of rules come together. The major observation is that, if you change a rule, whole cluster under its influence will change. For example, rules like "grb2.Sos" and "grb2/Sos" are influenced only by each other. Change in one causes change in other. Hence they are clubbed together.

In this visualization, we also have sorting functionality i.e. "Sort by influence". When user clicks this button, rules represented as columns rearrange in decreasing order of total influence. Here rules are sorted based on the magnitude of the influence, not the color. Rule which has maximum influence comes first, irrespective of the color.
Lastly, we have "Original order" button which brings back the matrix into its original form.

Time Line

We incorporated another visualization to view the complete data at once, more specific to provide a comparison view. The main visualization task of this is to compare the change in influences among different rules at different time intervals in a convenient way. Parallel Coordinates technique is used to visualize the timeline data.

Pair of rectangles is drawn for every time interval, with the left hand side indicating the influencing and right hand side corresponding to the influenced rules. Paths are drawn from rules on left to the rules on right, with the color indicating type of influence. Hovering over it, shows the thickness scaled according to the magnitude and also the text explaining the influence.

When you click on the rectangles to the left, data corresponding to only those rules are enabled while others are disabled providing a filtered view of comparison among rules. This helps in observing the changes only with respect to the clicked rules at different time intervals. Dropdown to the top left screen provides user an option to have filtered view of data as per time units. Hence, the user can have the view reduced with respect to rules or time intervals alone Clicking on “Back To matrix View’ will take the user back to Matrix Visualization.

Case Study

As explained earlier, the visualizations below, help the user in observing the data in different views and answer various questions specific to each user in detail. The visualization deals with the following tasks :

- Matrix Visualization to describe the influences among different rules provided in the data, Figure 1.
- Filtered Views according to influence can be observed in Figure 2. This is just to have a clear view of positive and negatively influenced rules separately.
- Clustered view in Figure 3 provides a way to visualize clusters among rules according to their similar behavior. For example, rules A and rules B observe the same behavior under Rules C,D,E. This implies that any changes on A by C, D, E would reflect the same change in B and hence A,B,C,D,E are grouped into one cluster.
  In figure 3, rules in columns 3 and 4 , rows 2,3,4,5 are grouped into one cluster as they observe similar behavior.
- The same clustering can be observed among positive and negatively influenced rules separately, Figure 4 and Figure 5.
- Figure 6 provides a view to have the influences sorted in descending order, helping the users to find the which rule is influenced the most (taking absolute value for the negative influences) .
- The same view can be observed both for positive and negative influences separately in Figures 7 and 8, to know which is influenced positively and negatively the most.

In the Figure 2, a matrix is visualized with different rules. Rows correspond to the influencing rules while columns correspond to the rules getting influenced. Node values indicate type and magnitude of the influence. Green color represents positive influence and red color represents negative influence. Brightness of the colors vary with magnitude.

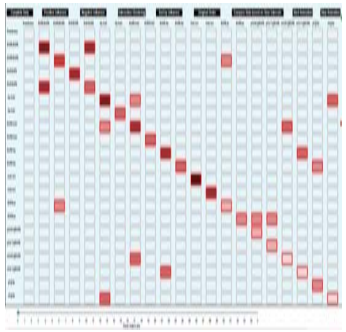

Figure 1 Negative Influence

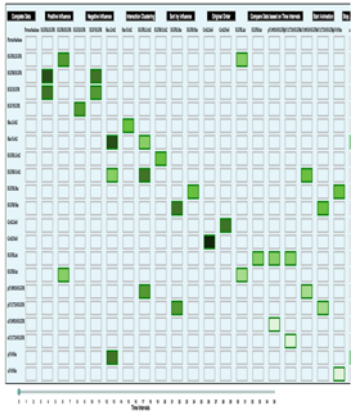

Figure 2 Positive Influence

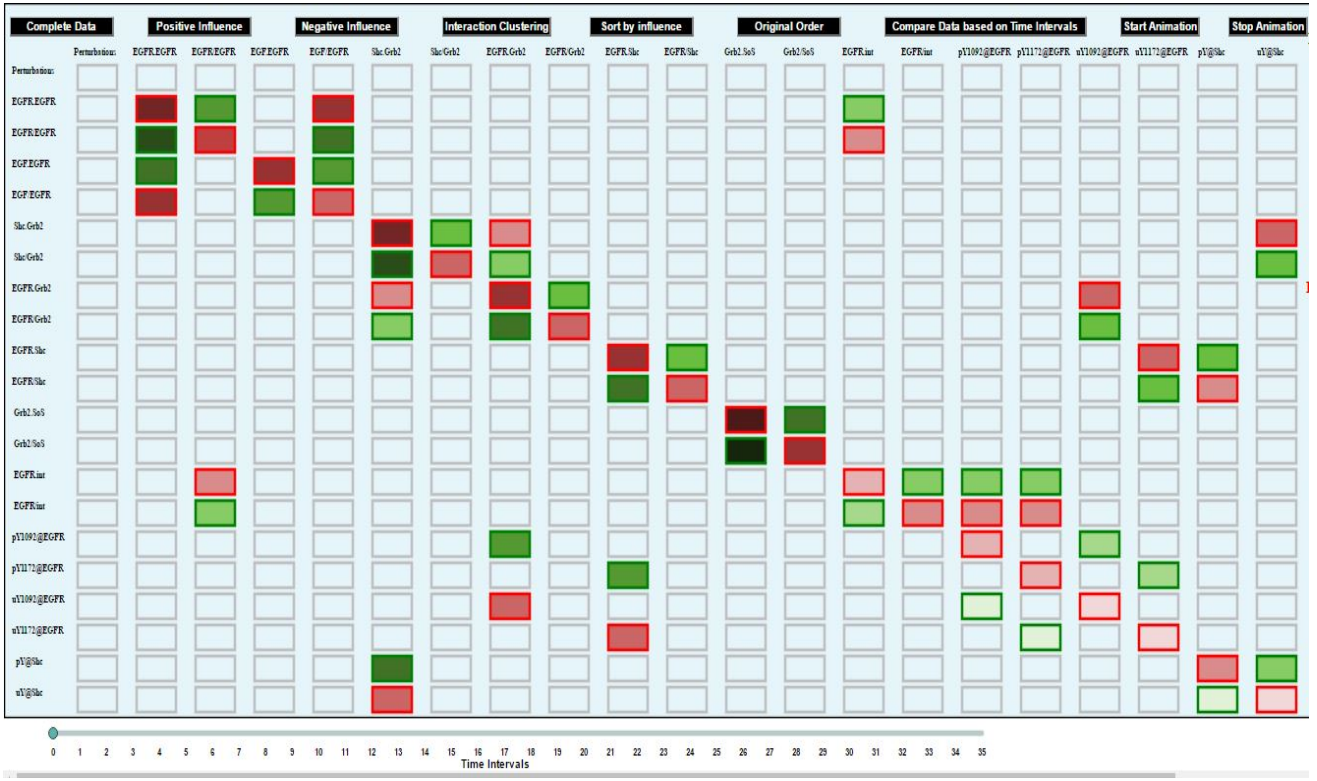

Figure 3: Matrix Visualization

Darker shade indicates strong influence while lighter shade indicates a weaker influence. On hovering over a node, the user would be able to read the information regarding influence. There are different buttons provided at the top, which on hover describe their purpose, to have different views of specific information as required by the user.

Slider below helps the user to slide the visualization for different time intervals as provided in the data set.

0 -> 0-10 time units, 1-> 2-12 time units etc. As the user slides, different matrices are drawn which will help in observing the changes in influence over different time intervals.

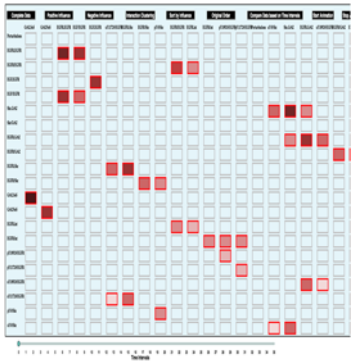

Figure 4 : Clustered View in negative influences

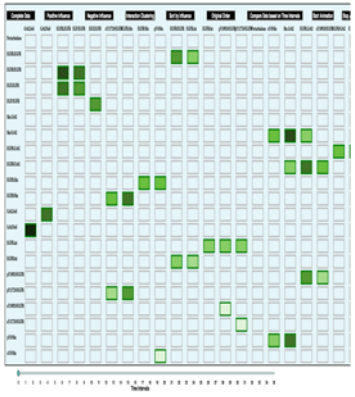

Figure 5: Clustered View in positive influences

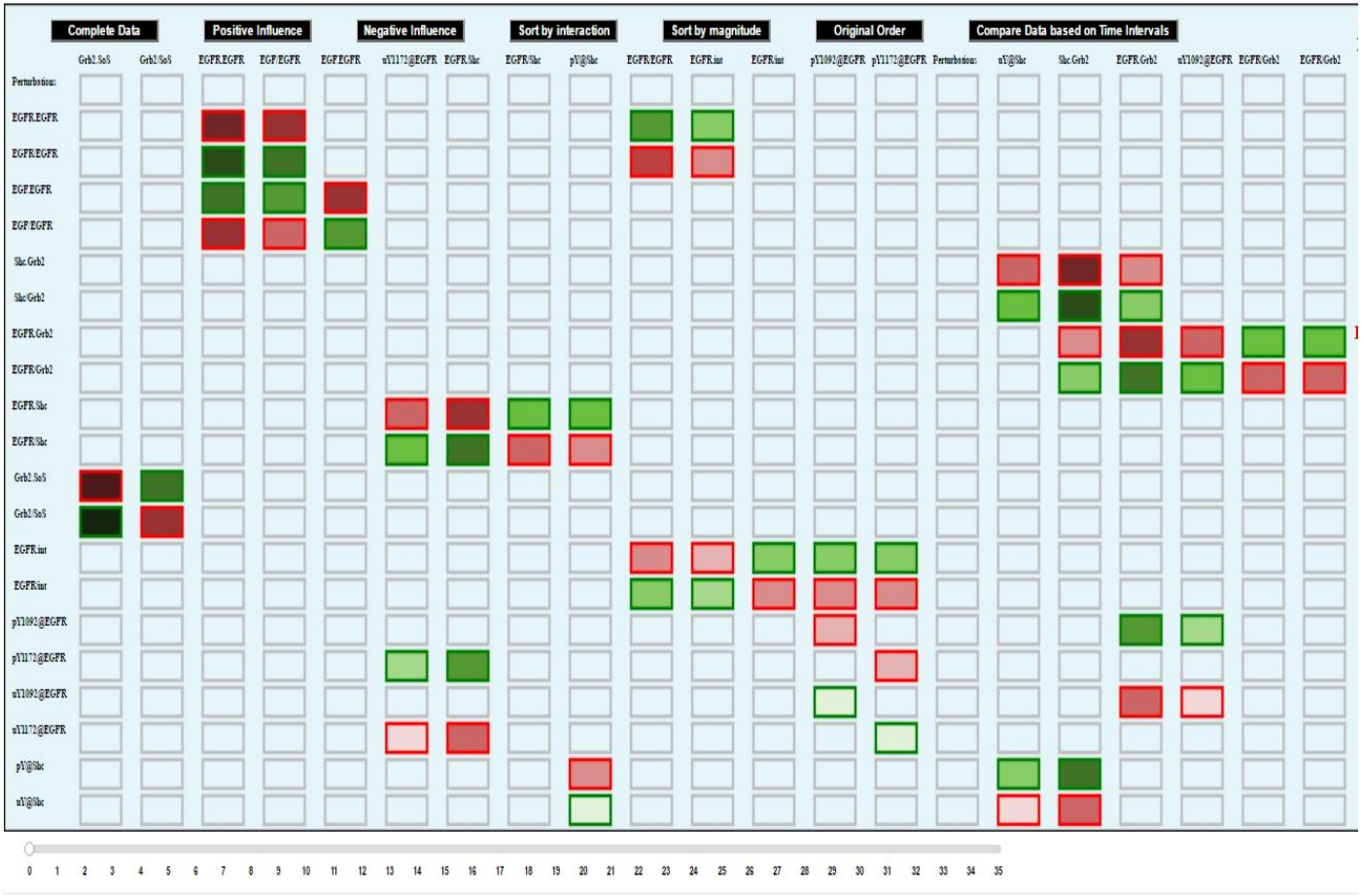

Figure 6 : Clustered View

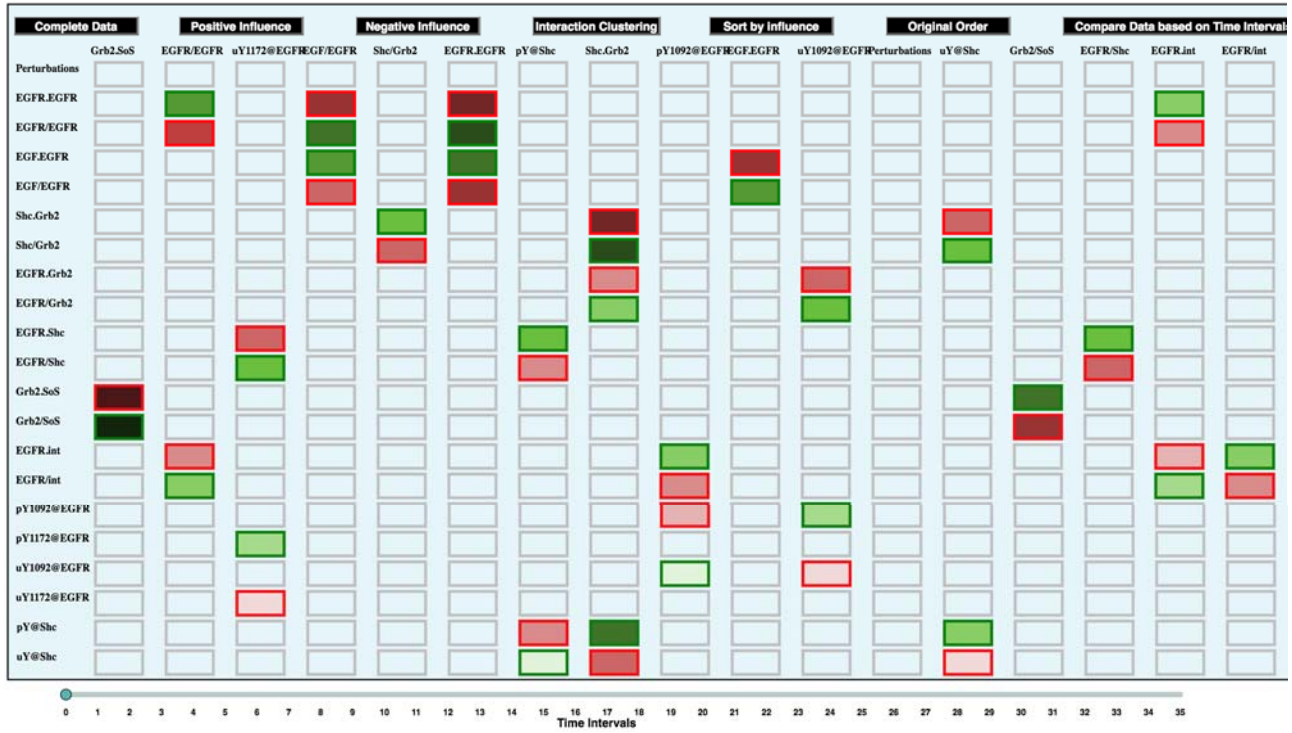

Figure 7 Sorted Order of Influences (Descending Order)

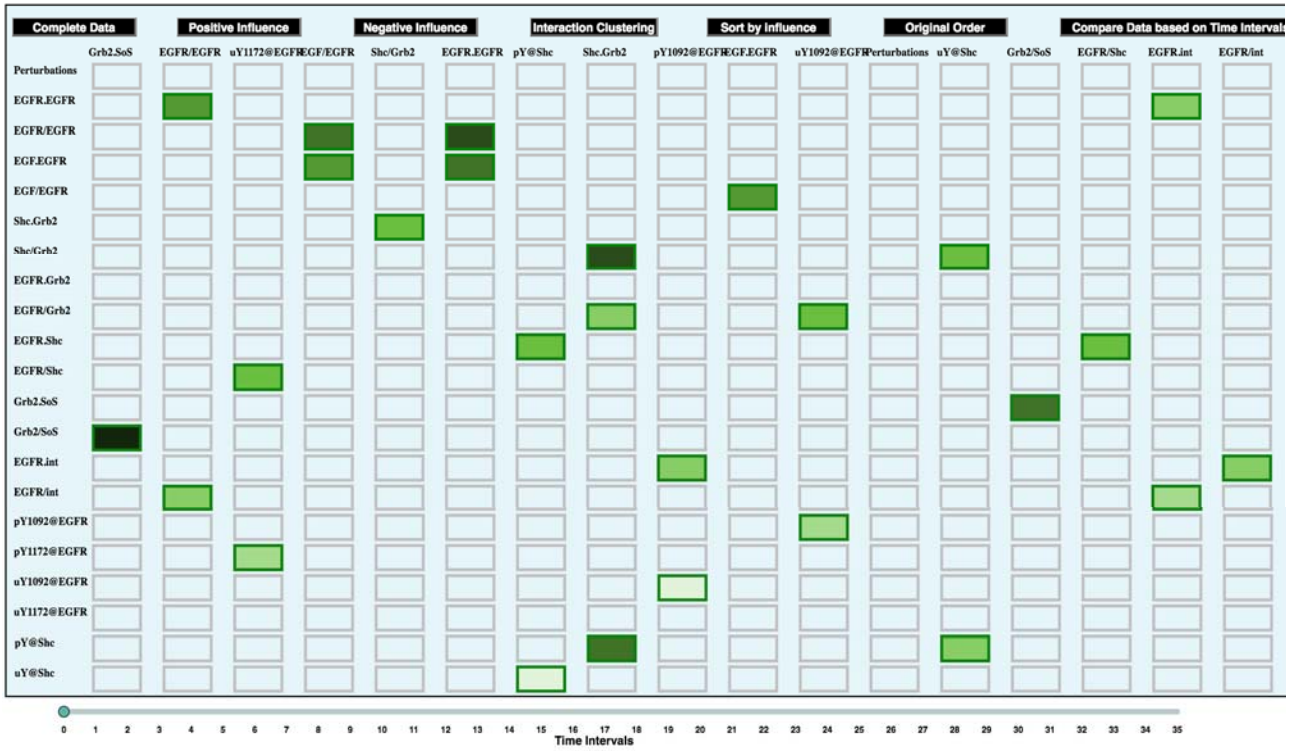

Figure 8 Sorted Order in Positive Influences

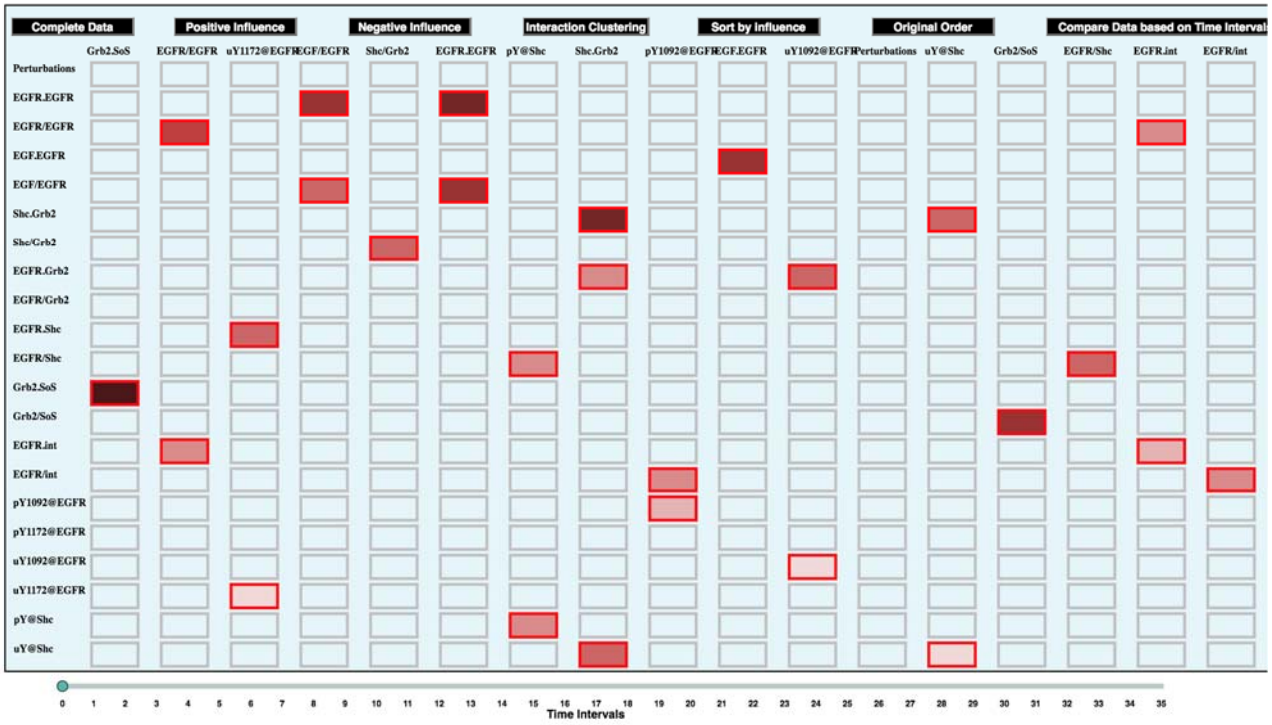

Figure 9 Sorted Order in Negative Influences

- Time Line View On clicking the ‘Compare data by Time’, you land on to a timeline view.

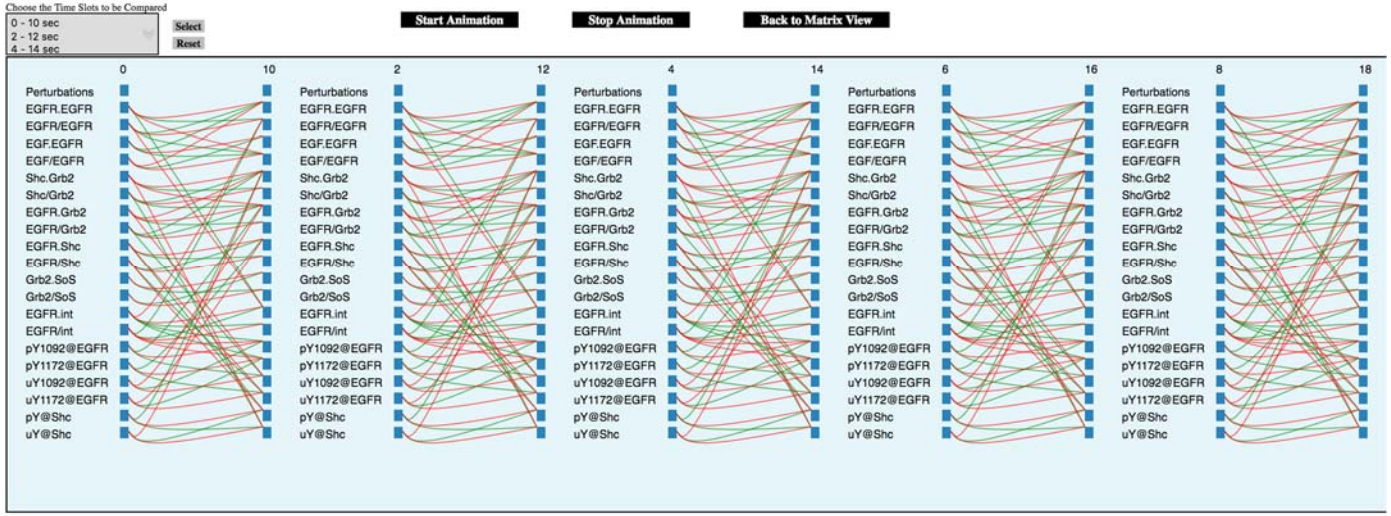

Figure 10 Timeline View

This visualization helps in comparing the change in influences among different rules at different time intervals in a convenient way. Parallel Coordinates technique is used to visualize the timeline data. Each pair of vertical coordinates correspond to a time range. Numbers at the top indicate start and end of each time range for which the data is provided. Rule names are also provided against each rectangle. Paths are drawn from left side rules to right side rules. Color of the path indicates type of influence (Red for negative and green for positive influence. On hovering over the path, the thickness is highlighted indicating the magnitude of influence and also text appears providing details of the influence.

The left side of each pair of rectangles are clickable. On clicking a particular rule (rectangle), only data corresponding to that rule is visible. Next click on a different rule preserves the previous click data and also adds on the new rule information. In this way, by clicking on multiple rectangles, data corresponding to only those rules can be compared over different time intervals, providing a filtered view with respect to rules

Filtered view with respect to time intervals: Dropdown list to the left of the window provides the user with an option to select only the time intervals he/she is

interested to compare the data on. On choosing multiple/single time slots and click on ‘Select’ button, data can be viewed only with respect to the selected time intervals using which the user can visualize a filtered view with respect to selected time intervals. ‘Reset’ button would take the us back to TimeLine Visualization.

Expert Feedback

User feedback is a major input for any visualization task, as the final product should cater to the user’s requirements in the best possible manner. In order to achieve this, user feedback sessions were held and suggestions were taken into consideration during further implementation. Major suggestion was that various options could be added to filter the data. If providing various functionalities all at once is not possible, different UI elements (like buttons) could be kept to incorporate the desired characteristics. Another suggestion was to use a better combination of colors.

Conclusion and Future Work

The project deals with creating dynamic site graphs in the form of a matrix and also provides a timeline visualization which allows the users to compare

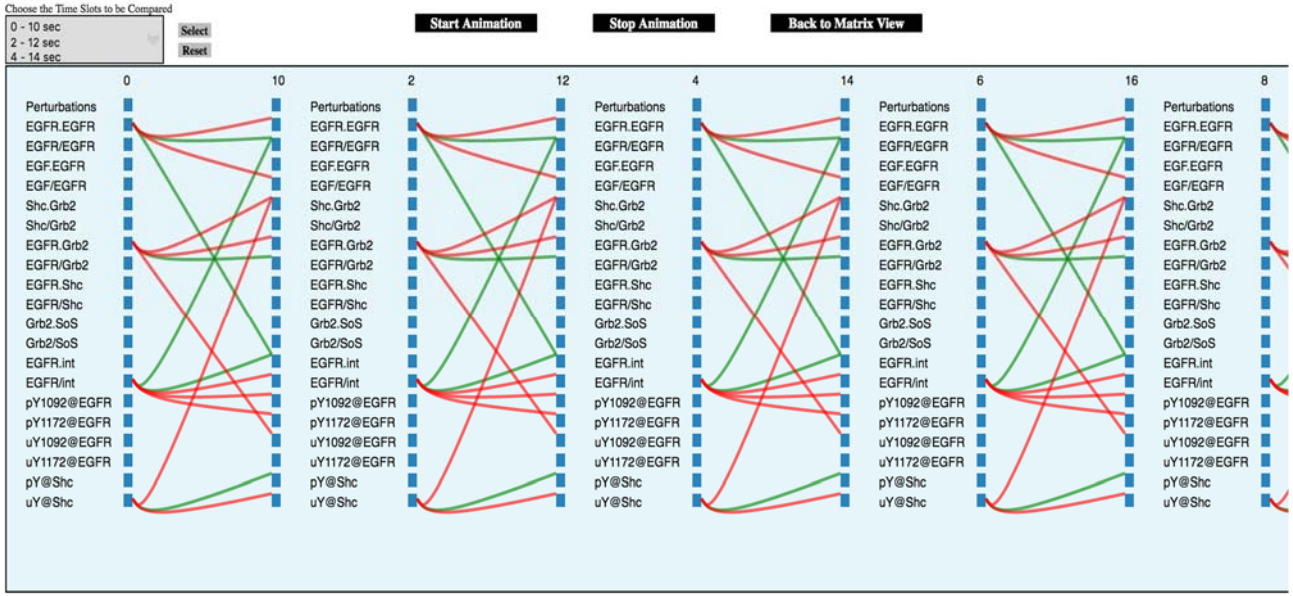

Figure 11 TimeLine View with filtered Rules

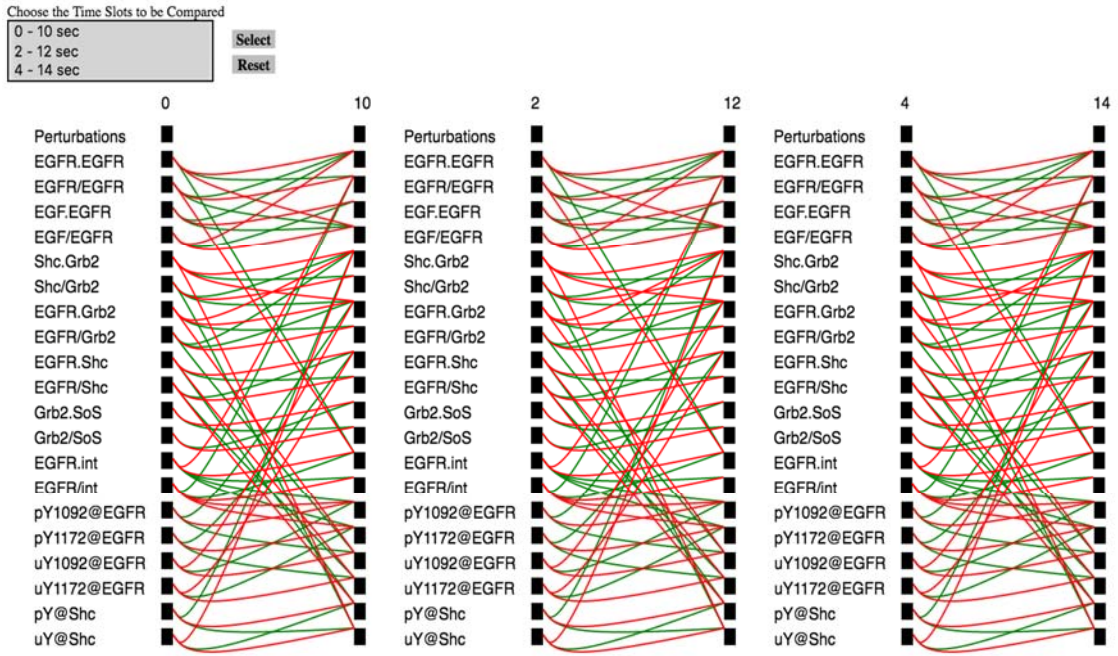

Figure 12 TimeLine View filtered based on Time Slots

interactions at different time intervals. Matrix visualization allows to visualize the data in the network rather than the structure of the network and also diminishes clutter when the number of nodes increase. The comparison of data at different time intervals is provided by the Timeline visualization.

The current system that has been developed provides clustering based on the total magnitude of the influence. Various other clustering patterns can be implemented in the future. The timeline visualization can also be modified to support clustering.

References

1. Visualizing Dynamic Brain Networks Using an Animated Dual-Representation. Eurographics Conference on Visualization (EuroVis) (2015)
2. Visualizing network data. RA Becker, SG Eick, AR Wilks - IEEE Transactions on Visualization and Computer Graphics, 1995 - ieeexplore.ieee.org
3. Nathalie Henry and Jean-Daniel Fekete MatrixExplorer: a Dual-Representation System to Explore Social. http://msr-waypoint.com/en-us/um/people/nath/docs/Henry_infovis06.pdf
4. Jason Gorman and Eric C Greene

   Visualizing one-dimensional diffusion of proteins along DNA.

   http://www.nature.com/nsmb/journal/v15/n8/pdf/nsmb.1441.pdf