A Method to Explore Multivariate of Adjacency Matrix Nodes in Immersive Environment

Yanning Jin, Tiemeng Li*, Songqian Wu, Shiran Liu

Abstract—We propose a focus view model, which uses parallel coordinates in immersive 3D space to compare multivariate between multiple nodes. This model adds a new spatial dimension to the 2D adjacency matrix and allows observing and comparing multi-nodes and multi-attributes in a single view without blocking Region of Interest (ROI) edge information. This model can improve the efficiency of retrieving and comparing multiple attributes between multiple nodes. Also, the location mapping of MVF is easy to understand, learn and use.

Index Terms—Adjacency Matrix, Parallel Coordinate, Multivariate, Immersive Environment

1 Introduction

In graph visualization, adjacency matrix is a common visualization method, which expresses the relationship between N nodes through an N × N matrix [1]. Multivariate node attributes are also an important information in adjacency matrix, but only a little space is left for attributes display since adjacency matrix expresses whether the relationship exists between two nodes and makes key information not conspicuous. This problem is often solved by Focus+Context technique.

Focus+Context (F+C) technique displays node multiple attributes mainly by embedded view and multi-view method. In embedded view, attributes of the corresponding two nodes is superimposed on the edge of the focus, which will lead to occlusion of edge information (such as color mapping). The multi-view changes the encoding of the focus area for attributes displacement, so the original edge information will be completely covered. Hence, analyst has to constantly switch between the two views in the process of data analysis. Hence, showing both edge and node attributes without occlusion is a challenge in the traditional F+C focus view.

The use of immersive environments for data visualization, has been an emerging data analysis technique because immersive environment provides the third spatial dimension that forms endless display space. In addition, the spatial area or layout of objects in the immersive environment form a metaphor of the real world, which is helpful for users' understanding.

We propose a focus view model named Multivariate Fence (MVF). MVF uses the third spatial dimension of immersive environment to reduce information occlusion, improve the efficiency of retrieving and comparing multi-attributes between multi-nodes and enhance the comprehensibility and learnability of the relationship between nodes and edges of adjacency matrix. We also provide a controlled experiment to evaluate the performance of the MVF.

2 Design of MVF

MVF is mainly composed of attribute points, axes and links. The overall parallel coordinate is divided into two parts, vertically placed on the left and top of ROI.

2.1 Axis and Point

Nodes are represented as axes, multiple attribute values of nodes are mapped on the same axis with length, and color maps attribute categories. In order to alleviate unevenly distribution and severe occlusion,

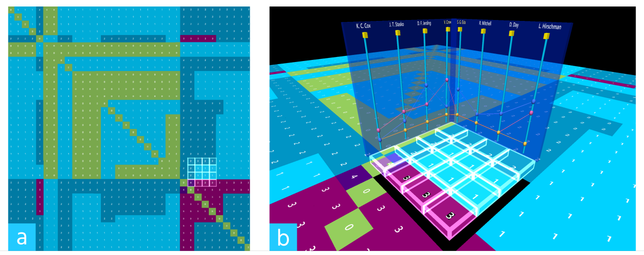

Fig. 1. Multivariate Fence-A focus view model for adjacency matrix showing node attributes: (a) Customized focus area (b) Perspective view of MVF.

we use different scales for different attributes on one axis, that is to say, large and small extreme values of each attribute is used as their own scale (see Fig. 2(a)).

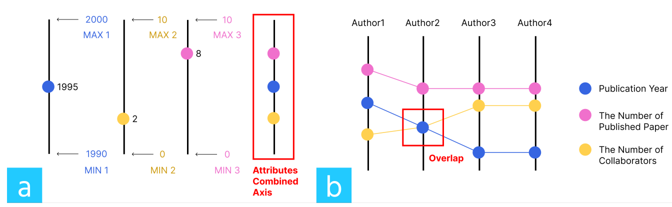

Fig. 2. (a) Axis mapping with different scales (b) The overlap of attribute points.

2.2 Link

Connect points of the same attribute on adjacent axes in turn, and the color map of link matches the color of the attribute. By using links, the attribute coincide points can be identified so that the occlusion can be alleviated. Link also makes it easier to observe changes and to identify outliers (see Fig. 2(b)).

2.3 Placement

Axes: Each node is represented by an axis. The position of the axis is consistent with that of the nodes in the traditional adjacency matrix (see Fig. 3(b)). This axis position can reduce the learning cost and the redundant information in the graph (see Fig. 3(c)).

MVF: The display position of MVF changes with ROI (see Figure 3(a)). In this way, users are free to filter out unnecessary information. In order to avoid the occlusion of focus and context edge information, parallel coordinate is placed perpendicular to the adjacency matrix plane, divided into two segments placed on the left and above of ROI

• *Tiemeng Li is with Beijing Univerty of Posts and Telecommunications. E-mail: tiemeng2000@gmail.com.*

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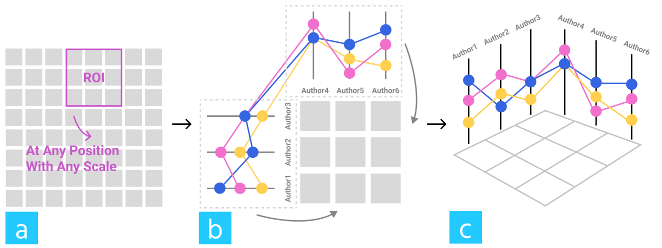

Fig. 3. Details of MVF. (a) Customized ROI (b) MVF plane graph.

(see Fig. 3(c)). This approach focuses the analyst's range of view and shortens perspective shifts.

3 SCENARIOS FOR COMPARISON

To verify the performance of MVF, we compared MVF and traditional embedded chart view (EBC) with same ROI (see Fig. 4). Data set is used to visualize adjacency matrix, with author as node and the number of cooperation as edge.

The whole figure contains 34 nodes with 1156 edges, and each node includes three attributes: the year of the earliest paper publication, the number of published papers, and the number of collaborators. The focal view composed of 8 nodes and 16 edges is selected for comparison.

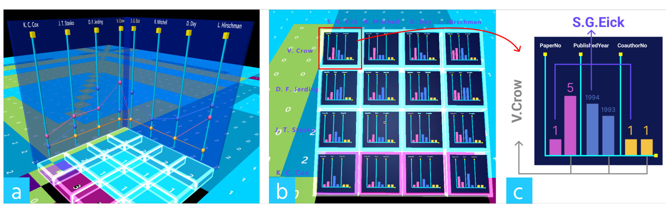

Fig. 4. Comparison Scenarios: (a) Multivariate Fence (b) Embedded Bar Chart (c) Details of EBC model.

3.1 Scene1: Adjacency Matrix with MVF

The parallel coordinates are divided into two segments, arranged on the left and above of the ROI. The axes representing nodes is placed at the central point of the corresponding edges, and the attributes of each node are mapped on the corresponding axis. Links are used to join the same properties of adjacent nodes (see Fig. 4(a)).

3.2 Scene2: Adjacency Matrix with EBC

Node attributes are embedded into the edge.Each edge contains a total of six attributes corresponding to two nodes, which are presented as a bar chart (see Fig. 4(b)). Each group of attributes has two values belonging to two nodes respectively, and each group of attributes is placed in the same order. That is to say, the left side of each group of attributes represents the attributes of the same node, and the right side represents another node (see Fig. 4(c)).

4 USER STUDY

We conducted a controlled experiment of Scene1 and Scene2 to compare the performance of MVF and EBC in retrieving and comparing multivariate between multiple nodes.

We recruited 12 graduate students, including 4 males and 8 females: half of 12 students complete 6 tasks in order in MVF scenario, and others complete same tasks in same order in EBC scenario. After the experiment, users were asked to fill out likert scale to reflect subjective satisfaction.Measures included: task completion time and Likert scale.

4.1 Tasks

Six tasks are set according to Table 1, involving one attribute to test the retrieval performance of MVF and multiple attributes to test the comparison performance of MVF.

Table 1. Task taxonomy

	view nodes only	view edges then nodes	view edges and nodes over again
involving one attribute	T1	T3	T5
involving attributes	T2	T4	T6

4.2 Likert Scale

There are 5 options for each question in the scale: strongly disagree (1), disagree (2), uncertain (3), agree (4), strongly agree (5). These questions include the following:

Table 2. Likert scale question setting

	multivariate placement	no redundant attributes	MVF/EBC model
Comprehensive	Q1	Q5	Q9
Easy to Retrieve	Q2	Q6	Q10
Easy to Compare	Q3	Q7	Q11
Easy to Learn	Q4	Q8	/

4.3 Results

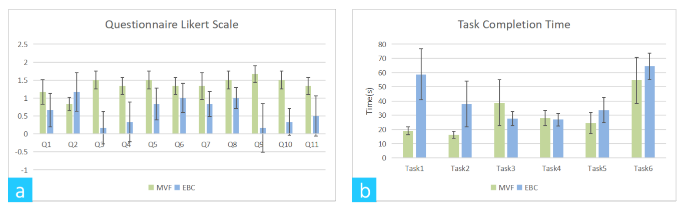

Fig. 5. Experiment results: (a)Task Completion Time of all 6 tasks (b)Results of Questionnaire Likert Scale Error bars indicate the standard deviation of the measured mean

1) **MVF is faster in the case of direct retrieve and comparison of attributes through nodes** Task1: MVF(M=19.08s, SD=2.23s), EBC(M=58.73s, SD=35.86s), $p<0.05$; Task2: MVF(M=16.23s, SD=4.81s), EBC (M=37.85s, SD=8.70s), $p<0.01$.

2) **MVF is easier to understand** Q9: MVF(M=1.67s, SD=0.52s), EBC(M=0.17s, SD=1.47s), $p<0.05$.

3) **The position mapping of the author attribute is easy to compare** Q4: MVF(M=1.33s, SD=0.52s), EBC(M=0.33s, SD=1.21s), $p<0.05$.

4) **Multivariate placement is easier to learn** Q3: MVF(M=1.50s, SD=0.55s), EBC(M=0.33s, SD=0.45s), $p<0.01$.

5 CONCLUSION

We propose a focus view model of adjacency matrix named Multivariate Fence, using parallel coordinates and the third spatial dimension to provide detail visualization. In this way, all information of ROI will not be blocked, and the location conforms to users' cognition of traditional adjacency matrix. We also conducted a user study to evaluate the performance of MVF. The results show that MVF the position of multivariate help users to retrieve, compare node attributes more quickly, and more helpful to understand and learn the relationship between edges. In future work, we will apply our model in other multivariate graphs.

ACKNOWLEDGMENTS

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