A Billiard Metaphor for Exploring Complex Graphs

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ABSTRACT

Exploring and revealing relations between the elements is a frequent task in exploratory analysis and search. Examples include that of correlations of attributes in complex data sets, or faceted search. Common visual representations for such relations are directed graphs or correlation matrices. These types of visual encodings are often - if not always - fully constructed before being shown to the user. This can be thought of as a top-down approach, where users are presented with a full picture for them to interpret and understand. Such a way of presenting data could lead to a visual overload, specially when it results in complex graphs with high degrees of nodes and edges. We propose a bottom-up alternative called Billiard where few elements are presented at first and from which a user can interactively construct the rest based on what s/he finds of interest. The concept is based on a billiard metaphor where a cue ball (node) has an effect on other elements (associated nodes) when stroke against them.

CCS CONCEPTS

• **Information systems** → *Search interfaces*; • **Human-centered computing** → *Graph drawings*;

KEYWORDS

Visualization, interaction, correlation

1 INTRODUCTION

Relations between elements of data, such as correlations, links between pages or news topic similarities, are often depicted by means of directed graphs or correlation matrices. In both cases, visual elements are fully constructed before shown to the user. We call this a top-down visual approach, in which a user is given an overall picture to browse, decompose and understand. This is regardless of the complexity –in terms of the amount of elements and relations– a visual representation might have. Such is specially the case of data that produces complex graphs with high degrees of nodes and edges (e.g. complete graphs). Common visual approaches for such cases can be argued to lead, at times, to cluttering elements and visual overload.

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In this paper we propose what we call a bottom-up alternative based on a billiard metaphor, where a small part of the visual representation is given and from which the user can interactively construct what s/he finds of interest. In this way we aim at relieving the user from the noise complex graphs could entail.

In the billiard metaphor, a given element has a stronger relation with others it is able to push farther. Elements which are pushed the least are analogously the least related ones. Based on this metaphor, the user can choose which relations to see by directing and caroming (striking) a cue ball towards the elements of interest.

We carried out a preliminary evaluation of a prototype through which we aimed at getting an idea of its usability as well as to know how the metaphor was perceived in the context of correlations. We observe that the majority of respondents find the prototype to be useful and the metaphor to be coherent with the task at hand i.e. exploring correlations. We also received suggestions for improvement from our participants, which will be taken into account for future work.

2 RELATED WORK

Visualization of relations among multiple elements has taken different forms. Azzopardi [1] used a wave metaphor where different data points generate ripples that, when coming across, create varied patterns. In another work, concentric circles are used for categorizing historical information by applying different angles between edges, while also encoding time as length [4]. Here, category clusters are shown all at once, thus introucing the issue of cluttering labels. For location-based and time varying correlations, Chen et al. [3] developed a 3D static solution where, due to the computational intensive nature of their task, data needed to be sampled by domain experts.

In the domain of causal relations, Kadaba et al. [5] found that participants were 5% more accurate and 8% faster when working with animated visualizations rather than static. Visualization of complex search results has similarly taken a wide variety of forms, e.g. Ahn and Brusilovsky [9] propose an adaptive visualization based search system that allows its users to interact with search results in order to reach their final information goal. Chau [2] instead explores the effect of using glyphs when presenting search results, the findings indicate that glyphs alleviate understanding in complex tasks, but do not help when the task is simple.

3 THE BILLIARD PROTOTYPE

The billiard metaphor is used as a way to depict the relations among elements by means of distance. As described before, the user is to start with a simple visual representation containing only elements (nodes) with which s/he can interact. Relations (edges) –or in this case, correlations– are to be later constructed based on what the user chooses to explore.

A prototype was implemented using Java 8 and JavaFX. For the following example as well as for the evaluation we used a weather data set from the National Oceanic and Atmospheric Administration (NOAA) [7]. For evaluation purposes, the data was pre-loaded into the tool. The exploratory process in this data set is similar to that of exploring search results. However, due to the complexity of search, this data set was used in order to mitigate effects based on query selection and the suitability of results.

The initial setting when running the prototype can be seen in Figure 1 (a), where elements (gray circles) are arranged around a "drop zone" (blue circle). Here the user is to drag and drop into the drop zone any element whose correlations/relations are of interest. On release, all other elements will be pushed away based on their correlated value to the dropped one (Figure 1: (b) and (c)). In our example, temperature is the element of interest while the others are subjects of its "influence". Dew, latitude and longitude, in this case, are the most highly correlated elements. Latitude, however, is negatively correlated and this is represented by the red line.

The user can further explore other correlation/relation values among the remaining elements after dragging and dropping a first element of interest. By hovering over a second element (Figure 1 (d)) the user will see the possibility of expanding its associated correlations with the remaining elements. At this point, there is no need for dragging and dropping. The user can now expand other relations by clicking on any other element of interest (Figure 1, (e) and (f)). The last two steps, hovering and clicking, can be repeated until there are no more elements to strike/expand.

The prototype allows zooming and panning at any time. Furthermore, it is possible to highlight other already expanded paths by selecting an element of interest. In a highlighted family of elements, ancestors are always shown in blue whereas children in green. All other elements are demoted with gray color and lower opacity.

Finally, to contribute to the billiard metaphor experience, all expanding correlations are animated i.e. the user will see elements moving away after dropping or clicking.

4 EVALUATION

The goal of our qualitative study was to evaluate the usability of the prototype tool and to learn how the metaphor was perceived for the task of exploring correlations.

4.1 Procedure

A formative evaluation of the prototype was carried out with 9 participants. Contextual information, questions, and answers were given and taken using Google forms. The aim of the evaluation was to collect the impressions of the participants about the functionality and usability of the prototype, and the intuitiveness and understandability of the billiard metaphor for exploring correlations. Inspired by the ten heuristics presented by Nielsen [6], we elaborated an online questionnaire dividing it in: perceived usefulness, views and interface, perceived easy to use and learning, and opinions/additional comments. Answers were given on a Likert scale from 1 to 5 (Table 1), where 1 represented *Not easy* / *Not clear* / *Not really*, whereas 5 *Very easy* / *Very clear* / *Yes it is*. Opinions and comments were given as free text.

4.2 Results

We describe the results in two categories regarding the perceived usefulness of the prototype: positive (useful) or negative (not useful), where the former represents answers over 3 in the 1 to 5 Likert scale, whereas the latter represents answers which are equal or below 3.

The results from the perceived usefulness show that over 60% of the respondents find the prototype to be useful for the task of finding the highest (positive and negative) correlated elements to the attribute of interest. Some related comments were:

- "The position of the nodes/the length of the lines instantly tells me which nodes are correlated and to what degree."
- "At first, I thought that the shorter the distance between the nodes, the stronger the correlation"

Regarding users' perception on views and interface, over 60% of the respondents replied that the metaphor would have advantage over directed graphs. However, there is a spread opinion on how well elements are presented i.e. there are positive and negative responses alike with a slight tendency towards the positive side:

- The prototype "naturally guides a path among attributes."
- "It becomes messy when I explore too many nodes."

Similarly, the perceived ease of use and learning aspects received varied opinions with also a tendency to the positive side:

- "It was very intuitive and graphically pleasing."
- "at first, did not understand the meaning of colors and thickness of edges."

Most negative feedback relates to cluttering issues when too many nodes have been expanded. Many critics came along with plausible solutions:

- "an option to collapse a explored node could increase the flexibility of the exploration".
- "maybe provide legends?"

The results provide insight on the usefulness of the metaphor as well as the needed improvements for a viable implementation.

5 DISCUSSION

From the participants' responses, we find that many agree that the information was clearly shown and the prototype was an intuitive way to perceive correlation. However, more than half of the participants stated that it was not easy to browse through the elements.

As mentioned by one of the participants, the prototype supports iterative searches on relationships but there seems to be a limitation when the number of relations of each element increases. It seems clear that, by keeping the history of played steps, we deviated from our goal of avoiding visual overload. It is only at the beginning, when not many correlations have been explored, that the prototype tool is found to be truly clear and easy to understand. These negative

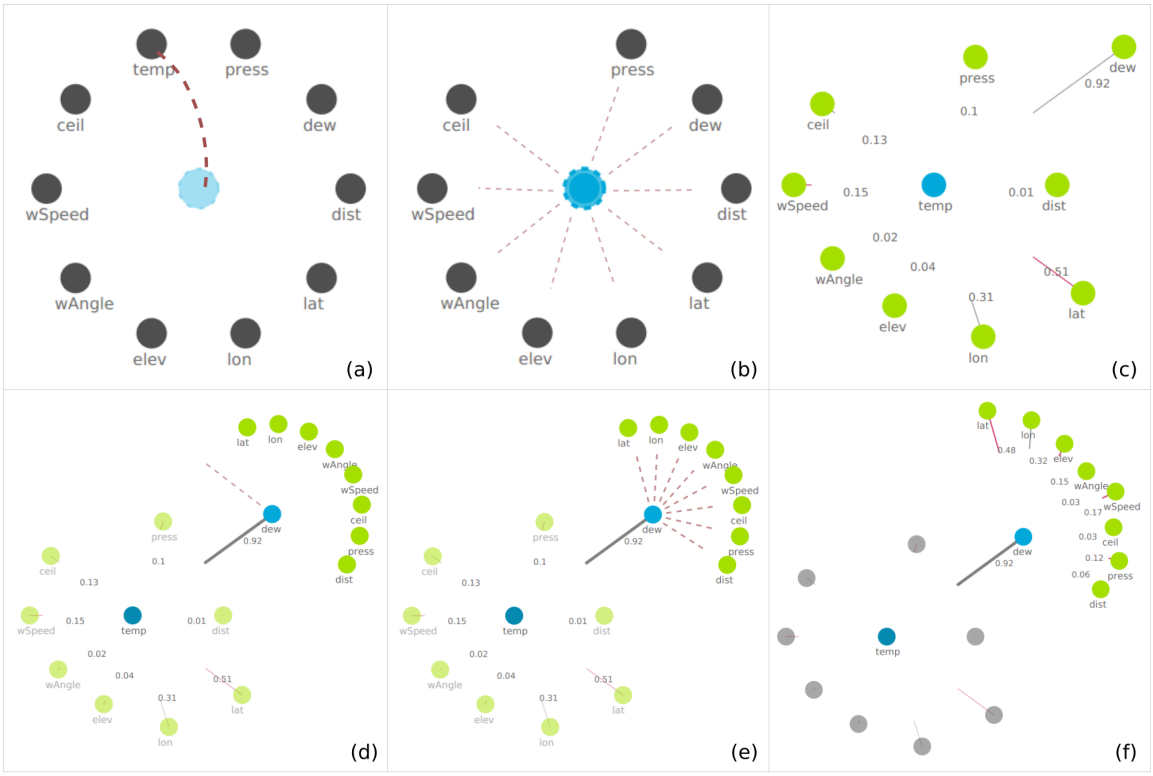

Figure 1: Billiard prototype sequence: (a) shows the initial setup where all data attributes are placed around a "drop zone". The dashed red arrow is a reference to the action taken by the user (drag and drop *temp* into the drop zone). (b) shows the effect *temp* will have on the other elements. (c) depicts *temp* correlations with other elements. (d) hovering over *dew* will show the possibility of expanding its correlations with the remaining elements. (e) illustrates the effect that clicking on *dew* has on other elements. (f) depicts *dew's* correlations by means of distance.

	Negative			Positive	
	1	2	3	4	5
How easy is it to find the highest POSITIVELY correlated variable?	33	0	0	33	33
How easy is it to find the highest NEGATIVELY correlated variable?	33	0	11	22	33
Is the information shown clear? (e.g. attributes and correlations)	11	11	11	44	22
Is it easy to browse/navigate through the elements?	11	22	22	33	11
Is it easy to differentiate between correlations (difference in value between one another)?	11	11	22	44	11
Would you consider this visual metaphor to be an intuitive way of perceiving correlation?	11	0	22	44	22
Would you consider the tool to be easy to use?	11	33	11	22	22
Would you consider the billiard metaphor to have an advantage over a correlation matrix?	22	0	33	44	0
Would you consider the billiard metaphor to have an advantage over a directed graph?	11	11	11	44	22
Total (%)	43.21			56.79	

Table 1: Survey results. Numbers in colored boxes represent percentage of users who selected a given option for a given question. In total, 57% of the answers were positive whereas 43% negative.

impressions can also be, in our opinion, associated to the given task. It is possible that exploring correlations does not intuitively lead to the creation of paths.

To create a better prototype, we need to better manage the visual overloading issue by hiding unnecessary information which the user is not interested anymore. This can be solved by having a expand/collapse button for each element. From the result, our prototype helps in showing a path of correlated attributes, but not in displaying an overview. It made clear the importance of an overview thumbnail at the corner of the prototype [8].

Many participants expect that the metaphor will show better performance than directed graphs. This is still merely a subjective opinion and would have to be further investigated.

6 CONCLUSIONS AND FUTURE WORK

We have described a visual metaphor to depict and explore relations among different elements in high-dimensional data. A prototype was developed and an evaluation was conducted to have a first impression on its usability as well as the intuitiveness of the metaphor.

So far, the results from the evaluation show that both the metaphor and the prototype can bring potential benefits to the visualization and exploration of high-dimensional data. To exploit and understand such potential, the following actions should take place:

- Enable expand and collapse functions for each element so that the user can hide unnecessary information.
- Perform a study comparing our solution to correlation matrices as well as directed graphs.
- Evaluate the billiard metaphor using other types graph related data such as links between web pages, news topic similarities or post sharing in social networks.
- Carry out an extended evaluation which includes performance metrics as well as a larger number of participants.

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