Journal of Visual Languages and Computing 47 (2018) 44–61

Contents lists available at ScienceDirect

Journal of Visual Languages and Computing

journal homepage: www.elsevier.com/locate/jvlc

Enabling effective tree exploration using visual cues

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ARTICLE INFO

Keywords:
Interactive visualization
Tree visualization
Visual cue
DOITree
Topological preview

ABSTRACT

This article presents a new interactive visualization for exploring large hierarchical structures by providing visual cues on a node link tree visualization. Our technique provides topological previews of hidden substructures with three types of visual cues including *simple cues, tree cues* and *treemap cues*. We demonstrate the visual cues on Degree-of-Interest Tree (DOITree) due to its familiar mapping, its capability of providing multiple focused nodes, and its dynamic rescaling of substructures to fit the available space. We conducted a usability study with 28 participants that measured completion time and accuracy across five different topology search tasks. The *simple cues* had the fastest completion time across three of the node identification tasks. The *treemap cues* had the highest rate of correct answers on four of the five tasks, although only reaching statistical significance for two of these. As predicted, user ratings demonstrated a preference for the easy to understand *tree cues* followed by the *simple cue*, despite this not consistently reflected in performance results.

1. Introduction

Hierarchical structures are observed in many forms, such as the organizational structure of a file system, the structure of a classification system, and the organization structure and taxonomy of objects, such as animals, plants, airplanes, etc. Such hierarchical structures not only play significant roles in their own right, but also provide means for representing the structure of a complex domain in a simplified form [1]. With the rapid growth of data, a hierarchical data set often contains thousands or even millions of items. Interactive visualization, with capability for deep exploration at different levels of granularity, is crucial for analysts in the knowledge discovery process. Such visualization can potentially provide benefits on viewing and exploring complex hierarchical information as well as visually analyzing key information hidden in the structures.

Existing visualization techniques for two-dimensional hierarchical structures (or trees)can be classified as connection, enclosure or hybrid [2]. Effectiveness of each approach is primarily evaluated in terms of the properties of the data in specific domains of application. The connection approach, such as *Classical Hierarchical View* [3], *Radial View* [4], *Balloon View* [5], *Rings* [6], *Space-Tree* [7], and *Hyperbolic Browser* [8], displays the relationships explicitly using node-link diagrams. Enclosed or space-filling approaches, such as *Treemaps* [9–11] and *Voronoi Treemaps* [12], are usually more effective when being applied to data sets to illustrate attributed properties. Hybrid techniques, such as *Space-Optimized Tree* [13] and *EncCon Tree* [14], combine both enclosure and connection in their visualization. Such hybrid methods are also applied to other visualization types such as social networks [33]. The traditional algorithms of tree layouts were summarized in Di Battista et al [15] and Herman et al [16].

Classical hierarchical views are universally adopted by various users and applications due to their simple and familiar layouts. Techniques were typically developed based on the original Reingold and Tilford's algorithm [3]. They utilize a modular approach to positioning nodes where child nodes are positioned below their ancestor for commonly top-down orientation, or on the right-side for left-to-right orientation. The Reingold and Tilford's algorithm were enhanced by Kennedy [16],

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https://doi.org/10.1016/j.jvlc.2018.06.001
Received 20 January 2016; Received in revised form 25 January 2018; Accepted 11 June 2018
Available online 14 June 2018
1045-926X/

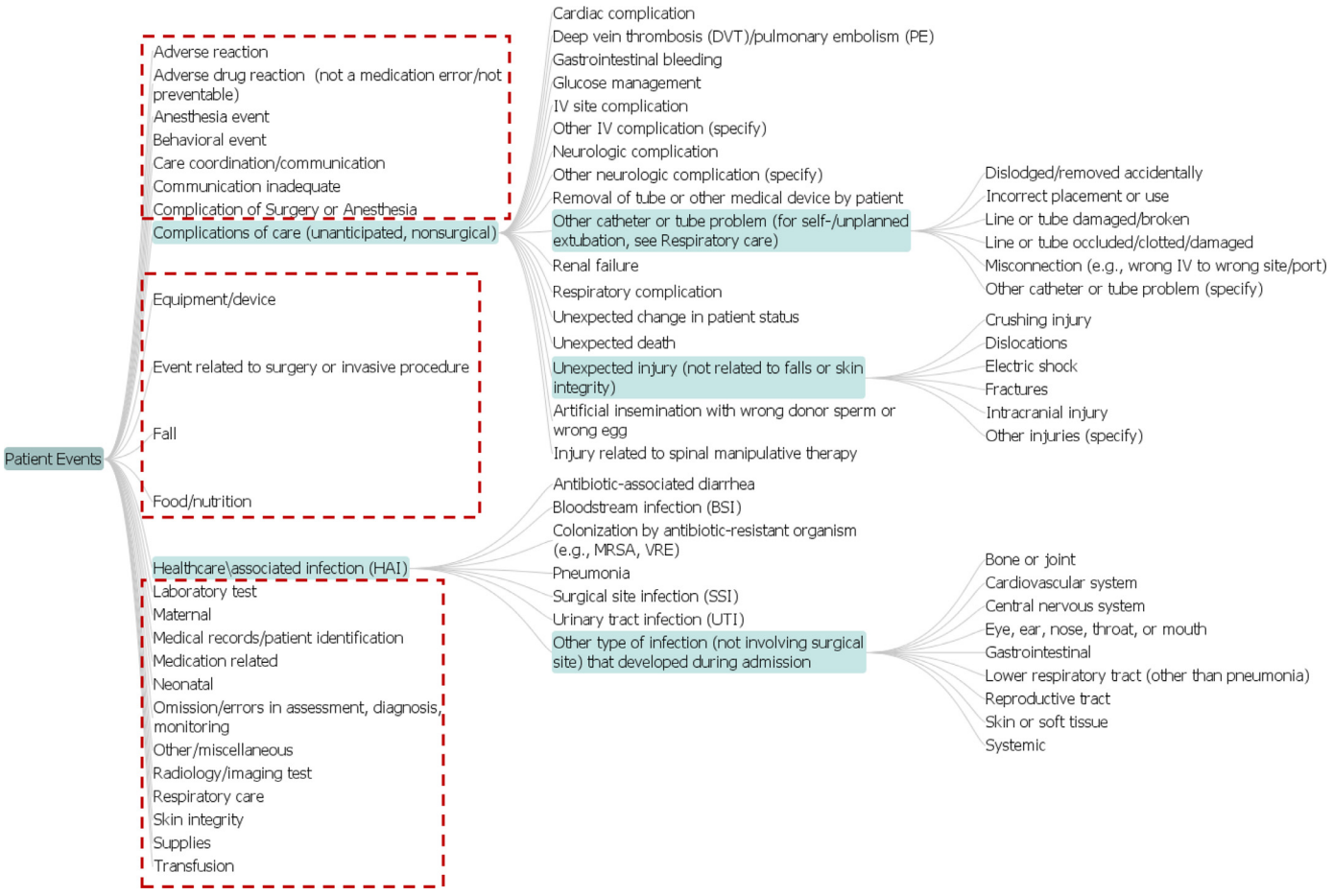

Fig. 1. A visualization using *DOITree* that has no visual cues to preview the topological structure of the hidden branches. The figure does not show what nodes have additional children and could be expanded, even in the focus area (highlighted by red-dash rectangles).

Herman et al. [17], and Bruggenmann–Klein and Wood [18]. The original classical layouts, however, tend to expand dominantly in one dimension, which reduces practicality for visualizing large data sets due to the limitation of display space.

To overcome the above limitation, various interaction techniques have been applied to the classical hierarchical views, such as zooming [19], fisheye-view [20,21] and 1D distortion [22]. The zooming approach reduces the amount of context in the display and enlarges the focused area(s). This reduction is done by filtering the information by selecting a subset of the data along a range of numerical values of one or more dimensions. Although zooming is a natural way to navigate through a tree hierarchy, this technique also suffers from loss of context during the navigation. Retaining some context information, the fisheye view and distortion techniques enlarge an area of interest using distortion, while other portions of the image are shown with successively less detail. However, these approaches have their own difficulties, where the distorted views could prevent the user from perceiving the information easily in a natural way.

Other interactive visualization methods provide a focus + context view by showing the sub-structures of interest while shrinking others. Among those, *SpaceTree* [7] and *DOITree* [23,24] are the popularetechniques for large tree visualizations. *SpaceTree* combines a zooming environment with conventional tree layouts that can dynamically layout structures to best fit the available screen space. Although *SpaceTree* is an excellent method for exploring large hierarchical data sets, the expansion view is only applicable to a single focused branch (or substructure) at a particular time. The limitation of a single focus point is addressed by *DOITree,* which use multi-focal tree layout algorithms that optimize the display when one or more nodes are expanded. Additionally, visual cues provide ongoing information about the content of hidden branches, with smooth animations showing when nodes are focused or shrunk.

Use of visual cues for the hidden branches has demonstrated effectiveness in exploring large hierarchical structures [7,24]. In the exisitng techniques, the visual cues are very limited, due to using unshaded triangles whose sizes are proportional to the weight or number of nodes in the branches. Although this view provides some hints of the hidden structures, the visualizations do not provide a clear representation of the hidden structures, such as the exact number of child nodes or their properties. This limitation could reduce its perceptual effectiveness in exploring large structures.

The present article extends the interactive visualization techniques proposed by Nguyen et al [29] that provide informative visual cues to enhance the readability of hidden structures in an interactive tree visualization. The topological previews of the shrunk substructures are presented with three visual cue types, including *simple cues, tree cues*