WordNet Explorer: Applying Visualization Principles to Lexical Semantics

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Abstract

Interface designs for lexical databases in NLP have suffered from not following design principles developed in the information visualization research community. We present a design paradigm and show it can be used to generate visualizations which maximize the usability and utility of WordNet. The techniques can be generally applied to other lexical databases used in NLP research.

1 Introduction

Despite the growing dependence on statistical methods, many NLP techniques still rely heavily on human-constructed lexical resources such as WordNet (Fellbaum, 1998). While development on WordNet continues, the interfaces for interacting with WordNet have not progressed to take advantage of advances in the field of information visualization. Currently available interfaces, both textual and graphical, focus on regions of local interest, for example by searching for the relationships for a single synset. In this work, we follow a well-accepted design paradigm to create a working prototype of a visualization suite for WordNet which allows for an overview of the data, as well as the ability to focus on specific synsets of interest and obtain details (see Figure 1).

WordNet contains 28 different types of relationships, but the most widely used part of WordNet is the hyponymy (IS−A) partial order. In this work we focus on the noun hyponymy (IS−A) relationships in English WordNet (v2.1), rooted under the concept "entity" and having $73,736$ nodes (synsets) and $75,110$ edges. However, the visualizations produced can be generalized to any partial order of a lexicon.

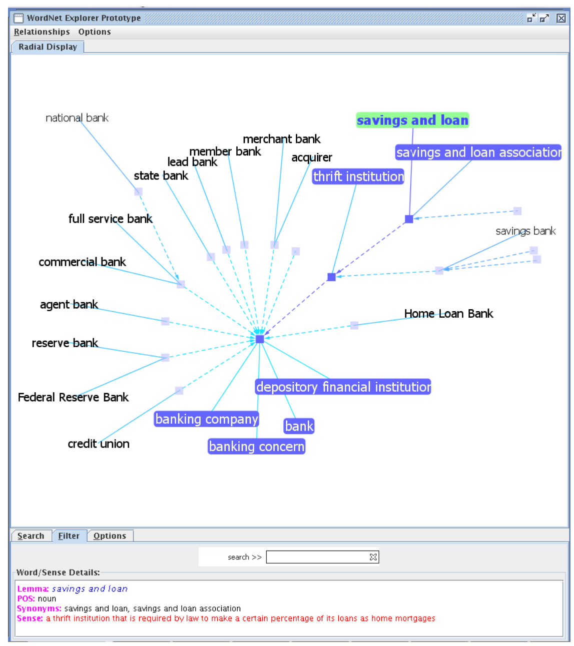

Figure 1: WordNet Explorer animated radial visualization of noun hyponymy rooted at the synset {*bank, banking concern, banking company, depository financial institution*}. *Savings and loan* is highlighted, as are all its hyperonyms. Square nodes represent synsets, textual nodes are synset members. Directed dashed edges represent the hyponymy relationship. A panel on the bottom shows the detailed information about the word currently under the mouse pointer. Nodes more than 3 edges from the central focus are collapsed, for example, the hyponyms of *savings bank*.

We draw upon a prominent design paradigm from the information visualization research community to create a visual interface for exploring the WordNet hyponym partial order. Ware (2000) suggests five advantages of effective information visualization:

- **Comprehension:** Visualization provides an ability to comprehend huge amounts of data.
- **Perception:** Visualization reveals properties of the data that were not anticipated.
- **Quality control:** Visualization makes problems in the data immediately apparent.
- **Detail + Context:** Visualization facilitates understanding of small scale features in the context of the large scale picture of the data.
- **Interpretation:** Visualization supports hypothesis formation, leading to further investigation.

We give these advantages to users of WordNet by following a principled design approach to a visualization of the data. In the following sections we will describe related work in WordNet interfaces and present our interactive, animated radial graph and TreeMap visualizations of WordNet hyponymy.

2 Related Work

Many interfaces for WordNet exist, the most popular of which is the WordNet Search[1] which is part of the publicly available WordNet package. This interface allows interactive text-base recursive expansion of synset relations using an interface similar to tree-like file system explorers. WordNet TreeWalk (Bou, 2003) provides a GUI for WordNet Search, adding relation- and part of speech-specific icons to the view, enhancing discernibility. WordNet Connect (Fong, 2003) produces static node-link illustrations of paths between two synsets in WordNet with a particular focus on computing semantic opposition involving change of state verbs. The shortest path-finding algorithm is parameterized to allow for weighting of relationship types. Similar edge-weighing is available in the WordNet Relationship Browser (Alcock, 2004), which also has path-finding as its primary function. It reports the shortest path between synsets as a textual list of relationships. Several more information visualization oriented interfaces for WordNet have been developed, but not widely reported in the literature. The commercially available Visual Thesaurus (ThinkMap, 2005) uses WordNet as its backing data and shows relationships between words using a force-directed layout algorithm which treats edges between words as springs and iteratively moves nodes until the graph settles to a minimum energy state. Similarly, the open source Visual WordNet Project (Kuo, 2005) uses force-directed layout to view all relationships of a single synset of interest, allowing for refocus to a new synset by clicking on it. Finally, Kamps and Marx (2002) created a visualization of WordNet synonymy using the implicit relationship of membership in the same synset to draw edges between words.

With the exception of (Kamps and Marx, 2002), the existing interfaces for WordNet either provide for drill-down textual or graphical interaction starting at a single synset of interest or provide path-tracing between two synsets. No visualization has yet been able to show a full picture of WordNet hyponymy, giving context as well as detail.

[1]http://wordnet.princeton.edu/perl/webwn

3 Design Paradigm

The most influential and succinct design framework is the information-seeking visualization paradigm of Shneiderman (1996): “Overview first, zoom and filter, then details-on-demand”. This three-step description of visualization usage can be read as a design guideline summarizing many of the requirements of effective information visualization design. Most importantly, it captures the need for visualizations to be effective on both a macro and micro level. A visualization first provides an *overview* of the entire data set, displaying high-level features of the data to allow the user to then specify a region of interest. *Zoom and filter* functionality allows the user to target a region of interest using one of several methods: (1) remove the context from the display, (2) provide more detail on a focal region, abstract and display surrounding data, or (3) show detail in a new window, highlight region of enlargement on the overview display. We provide the first two forms. Finally, *details-on-demand* provides more detailed features of the data, for example by opening a list of synsets containing word when it is selected with the mouse.

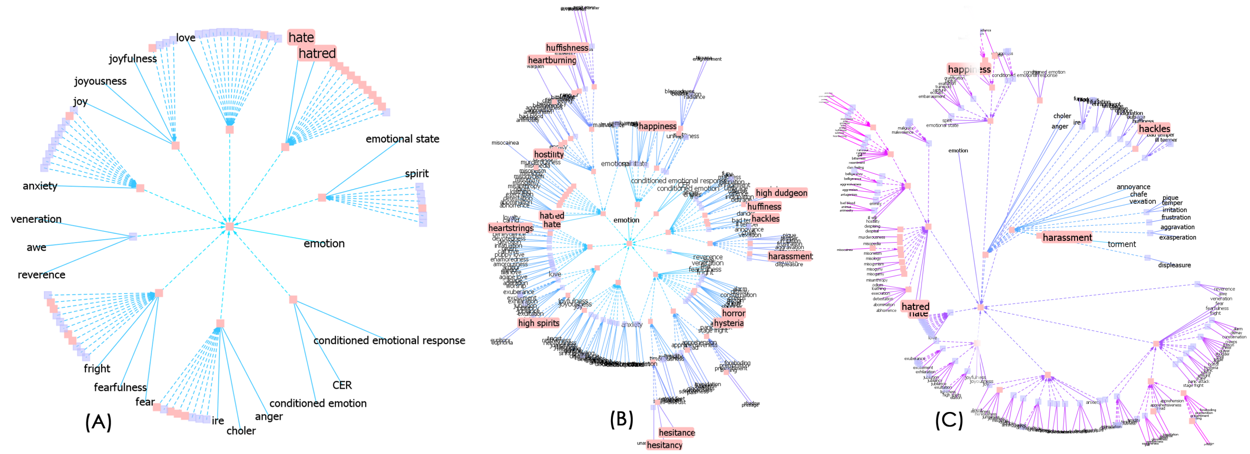

Figure 2: **(A)** Hyponymy of "emotion" filtered at depth 2. Words starting with "h" and collapsed nodes containing search results are highlighted in pink. **(B)** Graph from (A) changed so that subtree rooted at the synset containing "love" is the central focus node, expanding its radial extent. **(C)** All highlighted search results from (A) expanded.

4 Animated Radial Graph

Our first visualization is a 2-dimensional radial layout of a node-link diagram, in which nodes are arranged on concentric rings depending on their distance from a central *focus* node (see Figure 2A). Distance is measured by using a minimal spanning tree from the focus node. Following the polar animation technique of Yee *et al.* (2001), the layout can be smoothly reoriented to make any node the central focus, allowing for easy distance measurement (see Figure 2B,C). Pan and zoom functions are provided for the entire visual space. A *root* search box is provided to load data into the visualization. As the user types in the search box, the number of available senses is constantly updated. If no synsets match the search query, the query is stemmed and tried again. A numbered listing of sense glosses can be used to assist selection of a synset of interest. After searching, the root synset of interest is assigned as the initial focus node and all its hyponym synsets and their word members are loaded into the visualization. Synsets nodes are rendered as small squares, word nodes are rendered as text with font size decreasing with distance from the central focus, to minimize overlap. Synset membership relations between word and synset nodes are shown as undirected solid lines and synset hyponym relations are shown as dashed directed edges pointing to the hyperonym (parent) node.

4.1 Filtering

The system can be used to explore the entire WordNet hyponymy structure, but the animation slows with more than $75,000$ nodes and label overlap is a serious issue. Problems of scale are well-managed by following the visualization design paradigm: we provide several techniques to visually abstract the data. First, we provide a highlight search function which visually highlights nodes whose label matches any of the given search terms. *Highlight nodes* have pink background and larger font size, and are drawn on top of all other nodes, minimizing occlusion of search results. Second, we implement generalized fisheye views (Furnas, 1986) to collapse all subtrees which are more than a user-specified distance from the central focus node. The presence of highlight nodes within collapsed subtrees is indicated by coloring their first visible parent node (see Figure 2A). Alternatively, all highlight nodes can be exempted from the distance filter, effectively abstracting the graph to all synsets within a given distance from the focus or highlight nodes (see Figure 2B). Finally, double clicking on a node of interest restricts the visualization to the hyponyms of the corresponding synset. Highlighting and fisheye filtering are provided in real time.

4.2 Details on Demand

Because the layout is radial and can be re-centered to focus on any node, to facilitate understanding of

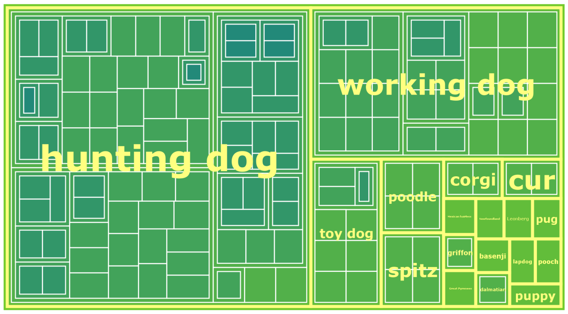

Figure 3: A TreeMap of the hyponyms of the domestic animal sense of dog. Child nodes are contained within the parent. Mouse over reveals the word associated with the node.

the direction of hyponym relations in the visualization, directed edges are used between synset nodes. When the mouse pointer rests over a node, all hyperonyms of that node are highlighted in blue (see Figure 1). Depending on user preference, the synset nodes along the trace, which are usually squares, can be expanded to reveal the sense gloss. This makes the task of reading the `IS-A` hierarchy for a synset of interest very easy, especially in the case where the central focus node of the layout is not the root of the hyponymy structure. Details of the synset under the mouse pointer are provided in the synset details window at the bottom of the interface.

5 TreeMap

The design paradigm we have followed is generalizable to other types of lexical visualizations. We have used it to build a complementary visualization called a TreeMap (Bruls et al., 2000), which uses node size to reflect the number of hyponyms under a synset. TreeMaps provide a good overview visualization of large amounts of data due to their efficient use of space. In Figure 3 each word is given a node of equal size. Word nodes are clustered within their parent node so that synsets with more hyponyms will be represented by a larger rectangle. Zoom and filter are provided by a search highlight facility as in the animated radial graphs, as well as the ability to double click a synset to filter the graph to only its hyponyms. Details are provided by interactive tooltips. Our visualizations use the prefuse toolkit (Heer, 2004) and access WordNet through the Java WordNet Library (Didion, 2003).

6 Conclusion and Future Work

By following accepted design principles of information visualization we believe WordNet Explorer provides improved access to WordNet, with the potential to assist discovery of interesting phenomena in the data as well as enhance quality control of the database. A fuller picture of WordNet will require visual representation of the other parts of speech and relationships beyond noun hyponymy. It is unlikely a single visualization will be able to reveal the entire structure of WordNet; future research will continue to augment this suite of coordinated views to help computational linguistics researchers better understand and use relational lexical databases.

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