Visualizing word senses in WordNet Atlas

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Abstract

This demo presents the second prototype of WordNet Atlas, a web application that gives users the ability to navigate and visualize the 146,312 word senses of the nouns contained in the Princeton WordNet. Two complementary, interlinked visualizations are provided: an hypertextual dictionary to represent detailed information about a word sense, such as lemma, definition and depictions, and a zoomable map representing the taxonomy of noun synsets in a circular layout. The application could help users unfamiliar with WordNet to get oriented in the large amount of data it contains.

Keywords: WordNet, visualization, web applications

1. Introduction

This paper describes a web application[1] designed to allow the navigation among the 146,312 word senses of the nouns of the WordNet lexical database (Miller, 1995; Fellbaum, 1998; Miller, 2006). It is composed of an interactive dictionary and a zoomable map. The dictionary gives details of word senses such as lemma, part of speech, definition and depictions, representing the information in a graphical layout that resembles that of a paper dictionary. The map shows the taxonomy derived from hypernymy-hyponymy links between synsets in a sunburst layout (Stasko and Zhang, 2000). It shows a general overview of the WordNet structure, and gives the user the ability to concentrate on details on demand (Shneiderman, 1996) by using a semantic zooming approach (Cui, 2011).

The described prototype is a complete redesign of the one presented in our previous work (Abrate et al., 2012). The new application presents various improvements, the most important of which being a new layout for the map, and more information about word senses, such as depictions obtained from the ImageNET (Deng et al., 2009) project.

We believe that this visualization could provide users unfamiliar with WordNet (like students, teachers or non-linguist researchers) a way to quickly obtain an overview of its structure, as well as an intuitive interface to explore its large database.

1.1. Web interfaces to WordNet

The size of the data set is a major challenge in visualization, leading to problems like algorithm complexity, display cluttering, poor readability and difficulties in navigation (Cui, 2011). The English WordNet 3.0 contains more than 155,000 words linked to 117,000 synsets, defining more than 200,000 word-synset pairs. Words and synsets are interconnected by 300,000 links of 28 different types. Because of its size and complex topology, a complete visual representation of this graph using a standard node-link diagram would result in a particularly heavy graphic to process and display, and would probably be too big and complex to grasp.

These issues have led to the creation of many different applications for visualizing and exploring the WordNet graph. Usually, the user can search for a word or a synset that becomes the central node in a visualization based on a *force-directed graph* (Eades, 1998) and continue the navigation by clicking on other nodes while they dynamically adjust to better fit in the screen space. The visualization is however never complete, as it never comprises the whole graph, but only a small part connected to the central node. Moreover, the position of the displayed nodes varies whenever the user issues a new query, possibly leading to confusion. This is particularly true in cases in which even issuing the same query twice could lead to completely different representations in term of node positions.

WordVis[2], Synonym[3] and Javascript VisualWordnet[4] show the graph from the vantage point of a selected word or synset. They center the selected node in the view, showing details about it and deleting the nodes that become not directly connected to it.

WordNet Editor[5], Visuwords[6] and the visualization tool[7] described in the work by Kamps (Kamps, 2002) actually allow a deeper exploration of the graph: the user can click on a node and the connected nodes are added to the view, without deleting the old ones. The disadvantage of these approaches is the progressive performance deterioration as nodes and links are added.

Treebolic[8] uses a different kind of graph visualization compared with the previous ones: the nodes position is computed as soon as the graph is drawn, they remain still (they don't adjust their position to better fit the screen), and a *fisheye view* (Furnas, 1986) is used to focus on the details. Even in this case, though, the graph is partial and centered in a specific word sense.

[1] Available at http://wafi.iit.cnr.it/wordnetatlas

[2] http://wordvis.com/

[3] http://code.google.com/p/synonym/

[4] http://kylescholz.com/projects/wordnet/

[5] http://wordventure.eti.pg.gda.pl/wne.html

[6] http://www.visuwords.com/

[7] http://staff.science.uva.nl/ kamps/wordnet/

[8] http://id.asianwordnet.org/visualize/treebolic/

ImageNet[9] takes a different approach to visualization. Strictly speaking, it is not a WordNet visualization, it is instead a large dataset of images organized according to the WordNet noun hierarchy. For each word, hundreds of images are gathered to depict it. The images are collected from various search engines by issuing queries in various languages and then verified by humans. A user could leverage ImageNet to visually explore a simplified version of the WordNet structure.

Wordnik[10] is an on-line dictionary featuring a variety of ways to let the user understand the meaning of a word. Besides definitions coming from multiple sources (including WordNet), one can find examples, images, audio pronunciations, related words and comments from other users. Like the traditional WordNet Search[11], WordNet Fast Search[12] and many others, it lacks a graphical overview of its content, but is an example of the kind of hypertextual interface that inspires our dictionary view.

2. WordNet Atlas design

WordNet Atlas is designed for end users like computer scientists that are not familiar with computational linguistics and/or WordNet, or other technicians that may want to exploit WordNet in their projects but first want to explore it.

In particular, we have in mind our partners in the GLObal Semantic System (GLOSS) project, funded by Regione Toscana, Italy. Within this project, scientists and Protezione Civile (civil defence) staff members are committed to the retrieval and the analysis of data in the environmental and public security domain. The partners have to instruct the system by editing a domain wordnet, typically this means adding new word senses to the generic wordnet. WordNet Atlas will be used to help them understand what a wordnet is, and what its role and importance in the project are.

We also believe that the application may prove to be very useful for presentation or teaching purposes, or for the promotion of WordNet to a broader audience, given its capability to scale from a meaningful overview to the details of WordNet structure.

The interface of WordNet Atlas provides the user with a familiar search input field from which she can start exploring, continuing in the map and in the dictionary view. The map view and the dictionary view are interconnected, in the sense that if a word sense is clicked in the dictionary or a synset is clicked in the map the other changes consequently. This behavior integrates seamlessly with the standard user agent interface, so the user is able to exploit the familiar navigation buttons, the browser history and bookmarks to navigate word senses and synsets.

2.1. The map view

The map view is best suited for exploring the structure of the noun subnet. It is conceived to have the same characteristics of web mapping applications such as Google Maps or Bing Live Maps: the user can pan the environment, zoom out for an overview of the whole and zoom in for observing the details of a particular area. This kind of interfaces are called Zooming User Interfaces (ZUI): according to their paradigm the visual representations of the data are displayed with different Level Of Detail depending on the zoom level (semantic zooming).

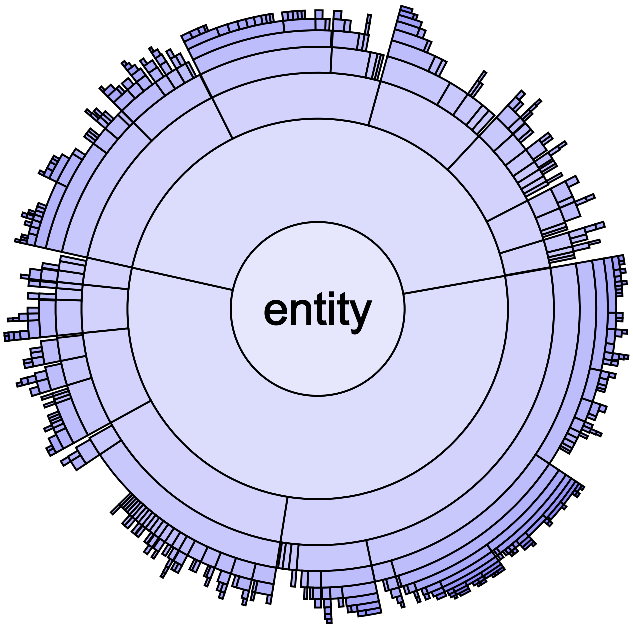


Figure 2: Overview

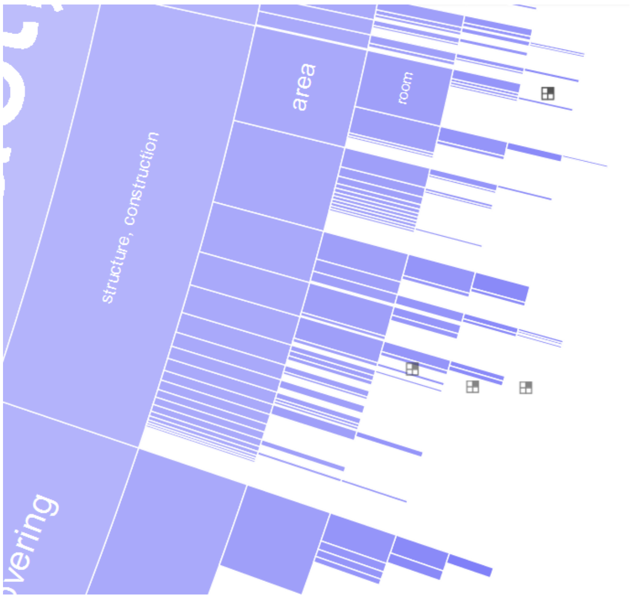
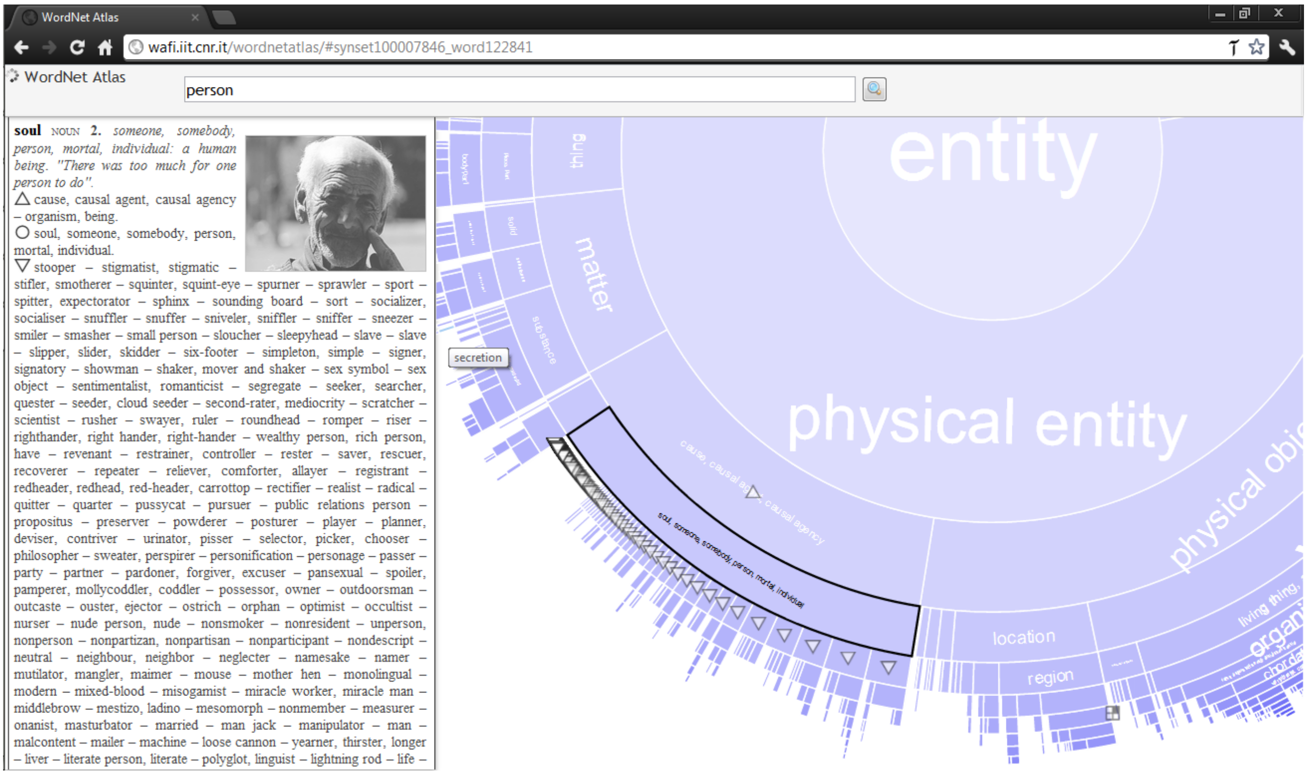


Figure 3: Detail

We chose to organize the noun subnet graph using a *sunburst layout*, a radial space-filling variant of the node-link diagram that allows a better usage of space (Andrews and Heidegger, 1998). Nodes are drawn as sections of a ring, and the nodes that would have been linked together in the node-link diagram are drawn adjacent in the sunburst layout, so that the layout itself offers an intuitive view of the hierarchy. The taxonomy we derived has 19 levels of depth, so in our graphical representation there are 19 rings, each

[9] http://www.image-net.org/
[10] http://www.wordnik.com/
[11] http://wordnetweb.princeton.edu/perl/webwn
[12] http://askbluey.com/wordnet


WordNet Atlas
wafi.iit.cnr.it/wordnetatlas/#synset100007846_word122841
WordNet Atlas
person
entity
physical entity
physical object
matter
thing
substance
secretion
location
region
living thing
organism
cause, causal agent, causal agency
soul, someone, somebody, person, mortal, individual

soul NOUN **2.** *someone, somebody, person, mortal, individual: a human being. "There was too much for one person to do".*
△ cause, causal agent, causal agency – organism, being.
○ soul, someone, somebody, person, mortal, individual.
▽ stooper – stigmatist, stigmatic – stifler, smotherer – squinter, squint-eye – spurner – sprawler – sport – spitter, expectorator – sphinx – sounding board – sort – socializer, socialiser – snuffler – snuffer – sniveler, sniffler – sniffer – sneezer – smiler – smasher – small person – sloucher – sleepyhead – slave – slave – slipper, slider, skidder – six-footer – simpleton, simple – signer, signatory – showman – shaker, mover and shaker – sex symbol – sex object – sentimentalist, romanticist – segregate – seeker, searcher, quester – seeder, cloud seeder – second-rater, mediocrity – scratcher – scientist – rusher – swayer, ruler – roundhead – romper – riser – righthander, right hander, right-hander – wealthy person, rich person, have – revenant – restrainer, controller – rester – saver, rescuer, recoverer – repeater – reliever, comforter, allayer – registrant – redheader, redhead, red-header, carrottop – rectifier – realist – radical – quitter – quarter – pussycat – pursuer – public relations person – propositus – preserver – powderer – posturer – player – planner, deviser, contriver – urinator, pisser – selector, picker, chooser – philosopher – sweater, perspirer – personification – personage – passer – party – partner – pardoner, forgiver, excuser – pansexual – spoiler, pamperer, mollycoddler, coddler – possessor, owner – outdoorsman – outcaste – ouster, ejector – ostrich – orphan – optimist – occultist – nurser – nude person, nude – nonsmoker – nonresident – unperson, nonperson – nonpartizan, nonpartisan – nonparticipant – nondescript – neutral – neighbour, neighbor – neglecter – namesake – namer – mutilator, mangler, maimer – mouse – mother hen – monolingual – modern – mixed-blood – misogamist – miracle worker, miracle man – middlebrow – mestizo, ladino – mesomorph – nonmember – measurer – onanist, masturbator – married – man jack – manipulator – man – malcontent – mailer – machine – loose cannon – yearner, thirster, longer – liver – literate person, literate – polyglot, linguist – lightning rod – life –

Figure 1: The interface of the web application. The dictionary view on the left and the map on the right.

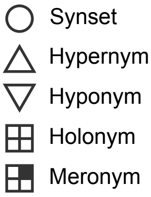


Figure 4: The most relevant symbols used in the application

in a slightly different color, to further improve spatial orientation. Each ring is divided into sectors representing the synsets, whose angular size depends on the number of leaves in the corresponding subtree. So the dimension of a sector is proportional to the number of leaves that node has in its subhierarchy. The nodes in each ring are ordered by size, from the biggest to the smallest. Abstract synsets are placed in the top part of the map, instead physical ones are at the bottom.

Due to performance reasons and to avoid information overload, the tree is never drawn completely: only sectors having a sufficient extent are shown, while giving the user the impression to be looking at the whole WordNet structure. By zooming in and focusing on an area, more details in the structure are revealed, as more sectors reach a sufficient extent.

In addition to the fact that hypernymy/hyponymy relation is shown somehow inherently by the chosen layout, the semantic links between the synsets are shown in the map by using a set of icons, rather than arrows or other kinds of connectors. These icons play a similar role of that of placemarks in web mapping applications. The use of placemarks also cope with a problem that arises when converting the WordNet hypernymy/hyponymy graph in a simple tree: multiple hypernyms for a synset are not shown in the sunburst layout. This is balanced by the use of placemarks, in the sense that even if a semantic link in not visible in the hierarchy it is still retrievable by looking at the placemarks.

Sectors and placemarks are clickable. A click shows the placemarks related to a synset in the map, and selects the first word sense (in alphabetical order) of that synset in the dictionary.

2.2. The dictionary view

The second visualization, complementary to the map, is an hypertextual dictionary shown at the left side of the interface, in which each entry describes a word sense. As it happens with the map, users have an overview of the amount of information that is available in the database. This is achieved by giving them the illusion that the whole dictionary was loaded in the scrollable section of the interface (infinite scrolling technique). The act of scrolling is somewhat similar to the panning action in the map since it allows to navigate the dictionary content. The size of the scrollbar handle gives an overview of the number of word senses in the WordNet database, and its vertical position is a clue about the position of the current word in the dictionary. In addition, to help the users locating content, the scrollbar is provided with marks that indicate the beginning of the sections containing words starting with each letter of the alphabet.

Like a paper dictionary, each entry displays a word, its part-of-speech, the number of the word sense, a list of synonym words, a definition and some example sentences. Then the hypernyms of the current synset are listed, followed by all the words in the current synset, by the list of hyponyms, and, if any, by the list of meronyms and holonyms. Each list is marked with a distinctive icon, the same used in the map as placemarks. The user can navigate among senses by clicking the links in the dictionary. The current selection is reflected in the map view. A depiction of the synset for the selected word sense is also given, by gathering images from ImageNet and displaying them in a slideshow.

3. Implementation overview

This work is based on the analysis of an SQL version of the WordNet 3.0 database. Since hypernymy-hyponymy relations are the most frequently encoded ones[13], we tried to identify a taxonomy-like hierarchy rooted on the synset "entity", thus focusing on noun synsets only. The resulting structure is that of a *tangled tree*, i.e. a tree that contains a few (2.6%) nodes that can have multiple parents. This approximated structure is only used to place the synsets in the map. The original links are all preserved and showed in the map as placemarks.

Par.	Nodes	Internal	Leaves	Types	Inst.
0	1	1	0	1	0
1	79,901	16,680	63,221	72,962	6,939
2	2,134	463	1,671	1,388	746
3	63	12	51	30	33
4	12	0	12	3	9
5	3	1	2	1	2
6	1	0	1	0	1
Total	**82,115**	17,157	64,958	74,385	7,730

Table 1: Count of synset nodes, grouped by number of parents. Only a small fraction of the total has more than one parent.

More information about our analysis is available in (Abrate et al., 2012).

The hierarchical structure is used as input in a preprocessing step: starting from the root node, the tree is traversed to create the sunburst layout graphical properties. For each synset, the fixed position of the corresponding circular sector within the space of the graphic is computed. This step is performed offline because of the obvious performance issues involved in doing such computations on demand in a data set of this size.

The resulting geometrical features are then stored into a GeoSpatial database (PostGIS), i.e. a database optimized to handle with spatial regions and to answer to geometrical queries.

The client-server interaction is implemented by leveraging the AJAX technology and the JSON interchange format to define a REST-style web API: each word sense is thus given a dereferenceable URI, that provides a JSON[14] representation of it. A different AJAX call is issued every time the user updates the viewport of the map by zooming or panning. The bounds of the new viewport are sent to the server, that uses the power of the geospatial queries to retrieve only the sectors that overlap the viewport and that have an extent big enough to be visible to the user.

The client-side code makes use of jQuery[15] for handling user events and for the implementation of the dictionary view, while using SVG[16] and the RaphaelJS[17] library for the map view. Some HTML5 features are used to support a seamless integration of the application with browser's standard behaviors such as clicking the back button, navigating the history and bookmarking the page.

In order to obtain ImageNET depictions of word senses, a third type of AJAX call is performed to access the ImageNET API[18]. A dedicated jQuery plugin[19] is then used to display the resulting images in a slideshow.

4. Future work

We know that the application is far from being bug-free and that it can be improved in many ways, such as in the quality of the interaction and in the amout of conveyed information. One of the first improvements we have in mind is the inclusion of the other three WordNet subnets, verbs, adjectives and adverbs, linked to the current one. In our future research we are interested in disambiguating all words found in synset definitions and in the examples, and linkifing them to point to the correct word sense. For example, if the word "space" is found within a definition, we want to distinguish between the "outer space" and the "mathematical space" and point to the correct one both in the map and in the dictionary.

As soon as the system reaches a sufficient level of completeness, we will search for confirmation of the usefulness of the presented visualization technique: we are willing to conduct a series of user evaluation tests of the application, comparing it with other interactive representations of WordNet found in literature.

5. Acknowledgements

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[17] http://raphaeljs.com/

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