

textNet: Directed, Multiplex, Multimodal Event Network Extraction from Textual Data

Elise Zufall¹ and Tyler Scott¹

¹ UC Davis Department of Environmental Science and Policy

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Introduction

Network measurement in social science typically relies on data collected through surveys and interviews. Document-based measurement is automatable and scalable, providing opportunities for large scale or longitudinal research that are not possible through traditional methods. A number of tools exist to generate networks based on co-occurrence of words within documents (such as the [Nocodefunctions](#) app ([Levallois et al., 2012](#)), the “[textnets](#)” package ([Bail, 2024](#)), [InfraNodus](#) ([Paranyushkin, 2018](#)), and many more). But there is, to our knowledge, no open-source tool that generates network data based on the syntactic relationships between entities within a sentence. *textNet* allows a user to input one or more PDF documents and create arbitrarily complex directed, multiplex, and multimodal network graphs. *textNet* also works on arbitrarily long documents, making it well suited for research applications using long texts such as government planning documents, court proceedings, regulatory impact analyses, and environmental impact assessments.

Statement of Need

Network extraction from documents has typically required manual coding. Furthermore, existing network extraction methods that use co-occurrence leave a vast amount of data on the table, namely, the rich edge attribute data and directionality of each verb phrase defining the particular relationship between two entities, and the respective roles of the entity nodes involved in that verb phrase. We present an R package, *textNet*, designed to enable directed, multiplex, multimodal network extraction from text documents through syntactic dependency parsing, in a replicable, automated fashion for collections of arbitrarily long documents. The *textNet* package facilitates the automated analysis and comparison of many documents, based on their respective network characteristics. Its flexibility allows for any desired entity categories, such as organizations, geopolitical entities, dates, or custom-defined categories, to be preserved.

Directed Graph Production

As a syntax-based network extractor, *textNet* identifies source and target nodes. This produces directed graphs that contain information about network flow. Methods based on identifying co-occurring nodes in a document, by contrast, produce undirected graphs. *textNet* also allows the user to code ties based on co-occurrence in a designated piece of text if desired.

Multiplex Graph Output

Syntax-based measurement encodes edges based on subject-verb-object relationships. *textNet* stores verb information as edge attributes, which allows the user to preserve arbitrarily complex topological layers (of different types of relationships) or customize groupings of edge types to simplify representation.

Multimodal Graph Output

Multimodal networks, or networks where there are multiple categories of nodes, have common use cases such as social-ecological network analysis of configurations of actors and environmental features. Existing packages such as the *manynet* package (Hollway, 2024) provide analytical functions for multimodal network statistics. *textNet* provides a structure for tagging and organizing arbitrarily complex node labeling schemes that can then be fed into packages for multi-node network statistical analysis. Node labels can be automated (e.g., the default entity type tags for an NLP engine such as *spaCy* (Honribal et al., 2021)), customized using a dictionary, or based on a hybrid scheme of default and custom labels. Any node type is possible (e.g., species, places, people, concepts, etc.) so this can be adapted to domain specific research applications by applying dictionaries or using a custom NER model.

Avoids Saturation

Co-occurrence graphs have the tendency to generate saturated subgraphs, since every co-occurring collection of entities has every possible edge drawn amongst them. By contrast, *textNet* draws connections not between every entity in the document or even the sentence, but specifically between pairs of entities that are mediated by an event relationship. This leads to sparser graphs that preserve the ability for greater structural variance, and correspondingly, network analysis of structural attributes of the graphs.

Installation

The stable version of this package can be installed from Github, using the *devtools* package (Wickham et al., 2022):

```
devtools::install_github("ucd-cepb/textnet")
```

The *textNet* package suggests several convenience wrappers of packages such as *spacyr* (Benoit et al., 2023), *pdftools* (Ooms, 2024), *igraph* (Csárdi et al., 2024), and *network* (Butts et al., 2023). To use the full functionality of *textNet*, such as pre-processing tools and post-processing analysis tools, we recommend installing these packages, which for *spacyr* requires integration with Python. However, the user may wish to preprocess and parse data using their own NLP engine, and skip directly to the *textnet_extract()* function, which does not depend on *spacyr* or Python integration.

Overview and Main Functions

The package architecture relies on four sets of functions around core tasks:

- [OPTIONAL] Pre-processing: *pdf_clean()*, a wrapper for the *pdftools::pdf_text()* function which includes a custom header/footer text removal feature; and *parse_text()*, which is a wrapper for the *spacyr* package and uses the *spaCy* natural language processing engine (Honribal et al., 2021) to parse text and perform part of speech tagging, dependency parsing, and named entity recognition (NER). Alternatively, the user can skip this step and load parsed text directly into the package. Externally produced data must be converted to standards outlined in the package manual.
- Network extraction: *textnet_extract()*, which generates a graph database from parsed text based upon tags and dependency relations. The object returned from *textnet_extract()* consists of a *nodelist*, an *edgelist* with a rich set of edge attributes, a *verblist*, and a list of potential synonyms for disambiguation.
- Disambiguation: tools for cleaning, recoding, and aggregating node and edge attributes, such as the *find_acronyms()* function, which can be paired with the *disambiguation()* function to identify acronyms in the text and replace them with the full entity name.
- Exploration: the *export_to_network()* function for exporting the graph database to *igraph* and *network* objects, *top_features()* for viewing node and edge attributes, and

86 combine_networks() for aggregating multiple document-based graphs based on common
87 nodes.

88 The figure below summarizes the functionality of *textNet* and the flow of function outputs.
89 Optional data cleaning features are shown with dotted arrows.

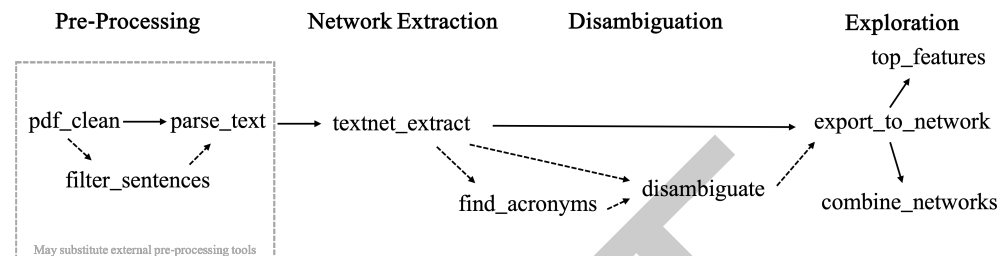


Figure 1: Workflow of *textNet* Functions

90 Applications

91 *textNet* has applications in governance network scholarship, as demonstrated by Zufall and
92 Scott (2024) and by ongoing work on groundwater governance at the UC Davis Center for
93 Environmental Policy and Behavior. Additional potential applications include legal scholarship,
94 social-ecological network analysis, government planning documents, court proceedings, archival
95 research, communication and media research, and other fields interested in exploring events
96 and entity relationships in textual data.

97 Potential Further Analyses

98 *textNet* is compatible with standard network analysis tools in R. Functionality from *ggraph*
99 (Pedersen & RStudio, 2024), *sna* (Butts, 2024), *igraph* (Csárdi et al., 2024), *network* (Butts
100 et al., 2023), and other network visualization and analysis packages can be used to further
101 explore the extracted networks.

102 The *ggraph* package has been used to create the network visualization seen here, using a
103 weighted version of a *igraph* constructed using the “old_new_parsed” sample data in *textNet*.

New Network



Figure 2: Representation of the Event Network of the New Plan

The network-level attributes output from `export_to_network` can also be analyzed against exogenous metadata that has been collected separately by the researcher regarding the different documents and their real-world context. The extracted networks can also be analyzed through a variety of tools, such as an Exponential Random Graph Model or a Temporal Exponential Random Graph Model.

Vignette

More information about the entity network extraction algorithm and an example start-to-finish data processing and analysis workflow can be found in the vignette for this package. The vignette uses sample data that travels with the *textNet* package.

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