

Extracting knowledge from text using SHELDON, a Semantic Holistic framEwork for LinkEd ONtology data

Diego Reforgiato Recupero, Andrea G. Nuzzolese, Sergio Consoli, Valentina Presutti,
Silvio Peroni, Misael Mongiovi
National Research Council
ISTC/STLab
Italy

diego.reforgiato@istc.cnr.it, andrea.nuzzolese@istc.cnr.it, sergio.consoli@istc.cnr.it,
valentina.presutti@istc.cnr.it, silvio.peroni@unibo.it, misael.mongiovi@istc.cnr.it

ABSTRACT

SHELDON¹ is the first true hybridization of NLP machine reading and the Semantic Web. It extracts RDF data from text using a machine reader: the extracted RDF graphs are compliant to Semantic Web and Linked Data. It goes further and applies Semantic Web practices and technologies to extend the current human-readable web. The input is represented by a sentence in any language. SHELDON includes different capabilities in order to extend machine reading to Semantic Web data: frame detection, topic extraction, named entity recognition, resolution and coreference, terminology extraction, sense tagging and disambiguation, taxonomy induction, semantic role labeling, type induction, sentiment analysis, citation inference, relation and event extraction, nice visualization tools which make use of the JavaScript infoVis Toolkit and RelFinder. A demo of SHELDON can be seen and used at <http://wit.istc.cnr.it/stlab-tools/sheldon>.

Keywords

Semantic Web; Machine Reading; Linked Data

1. INTRODUCTION

In order to extract knowledge from text, the Machine Reading paradigm adopts Natural Language Processing (NLP) algorithms and methods. Machine reading is typically much less accurate than human reading, but can process massive amounts of text in reasonable time, can detect regularities hardly noticeable by humans, and its results can be reused by machines for applied tasks [5]. SHELDON performs a hybrid (part of the components are trained, part are rule-based), self-supervised variety of machine reading tasks that

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generates RDF graph representations out of the knowledge extracted from text by dedicated NLP tools. The produced graphs represent an extension and improvement of NLP output, and can be customized to target specific tasks. Several software modules successfully evaluated in the recent past [14, 6, 4, 7, 17, 9, 13, 1, 8, 10, 16, 5] constitute the core components where SHELDON builds on top.

The machine reading capability of SHELDON is based on FRED [14, 4], a powerful component that automatically creates RDF/OWL graphs containing linked data from text. FRED integrates, transforms, improves, and abstracts the output of several NLP tools. Boxer [2] is a deep semantic parser that is called by FRED. Boxer includes a statistical parser (C&C) and generates Combinatory Categorical Grammar trees. Several heuristics are adopted in order to exploit existing lexical resources and gazetteers to generate representation structures according to Discourse Representation Theory (DRT). The latter generates formal semantic representation of text through an event (neo-Davidsonian) semantics. The basic NLP tasks performed by FRED by means of Boxer include: event detection (DOLCE+DnS² [3] is used by FRED), semantic role labeling with VerbNet³ and FrameNet roles, first-order logic representation of predicate-argument structures, logical operator scoping (called boxing), modality detection, tense representation, entity recognition using TAGME⁴, word sense disambiguation (the next version is going to use BabelNet⁵), DBpedia for expanding tacit knowledge extracted from text, etc. Everything is integrated and semantically enriched in order to provide a Semantic Web-oriented reading of texts. FRED is also accessible by means of a Python API, namely *fredlib*⁶. It exposes features for retrieving FRED graphs from user-specified sentences, and managing them.

Uncovering the semantic meaning of hyperlinks has a huge impact on the knowledge that can be extracted from Web data and that can therefore be published in machine readable form. The correspondence with the natural language source can be maintained and this would further benefit the acquired knowledge. SHELDON integrates LEGALO [13],

²DOLCE+DnS Ultralite Ontology. <http://www.ontologydesignpatterns.org/ont/dul/DUL.owl>

³T. V. project. <http://verbs.colorado.edu/mpalmer/projects/verbnet.html>

⁴<http://tagme.di.unipi.it/>

⁵<http://babelnet.org/>

⁶<http://wit.istc.cnr.it/stlab-tools/fred/fredlib>

a novel method for revealing the semantics of links by identifying new semantic relations for them. Using a set of graph pattern-based heuristics, LEGALO extracts from FRED graphs Semantic Web binary relations that capture well the semantics of the underlying links.

SHELDON is able to give a boost to the sentiment analysis practices [15]. One of its components is built on top of SENTILO [17, 7], an independent sentic computing approach which uses both natural language processing techniques and Semantic Web technologies. For a certain sentence expressing an opinion, SENTILO is able to identify its holder, to extract the topics and subtopics that the holder targets, to link them to related events or situations present in the text and to evaluate the sentiment expressed on each topic/subtopic. SENTILO uses a new ontology for opinion sentences, a new lexical resource that enables the evaluation of opinions expressed by means of events and situations, and a novel scoring algorithm for opinion sentences.

SHELDON also performs definitional taxonomy induction, integrating its result into the RDF graph of the text. The component for this task is based on TÌPALO [6]. TÌPALO analyses the Wikipedia page abstracts containing the natural language definition of entities and looks for the most appropriate type for them. TÌPALO relies on FRED for parsing and representing the logical form of a given sentence and induces a taxonomy by reusing WordNet types, WordNet supersenses, and DUL types.

Within academic communities, bibliographic citations earned a huge importance for linking scientific papers to related works, experiments, surveys, etc. SHELDON uses one more method to pursuit the task above. More in detail, SHELDON embeds CITALO [9], a tool that exploits Semantic Web technologies and NLP techniques to automatically infer the purpose of citations. The input is represented by CiTO [12], an ontology which describes the nature of citations in scientific research papers and a paragraph containing a reference to a bibliographic entity. CITALO relies on FRED to extract ontological information from the input sentence.

Besides the graph visualization (displayed using Graphviz⁷), and the triple output for each component, SHELDON provides a data exploration component, built on top of the Semantic Scout [1], which uses the JavaScript InfoVis Toolkit⁸. Finally, it is possible to get a much wider knowledge of the relations between detected DBpedia entities using a SHELDON component that is built upon the expansion algorithm described for RelFinder [8] and that shows further relations between the detected DBpedia entities.

SHELDON provides a REST API for each of its components so that everyone can build online end-user applications that integrate, visualize, analyze, combine and infer the available knowledge at the desired level of granularity. Potentially, each stakeholder interested in semantic aggregate information for multilingual text could be a customer. A start up is going to be founded in UK which will exploit SHELDON's technology (with only commercially-viable components) as one of its main cutting-edge products (we are currently solving some licensing issues).

⁷Graphviz - Graph Visualization Software, <http://www.graphviz.org/>

⁸<http://philogb.github.io/jit/>

2. SHELDON AT WORK

Figure 1 shows the main interface of SHELDON where it is possible to insert some text in any language and select the semantic feature for processing the text. The output produced by SHELDON is in English no matter what the source language is. As the semantic core of SHELDON processes text using English, Bing Translation APIs⁹ are used to translate input text (given in 47 possible languages) in English.



Figure 1: SHELDON front page

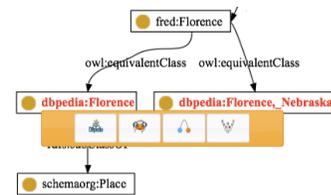


Figure 2: SHELDON's navigation toolbar for identified DBpedia entities

The input text might be given in any of 47 different languages. If it is not English, there is an automatic language detection module¹⁰ that will identify the source language.

For example, the Italian sentence listed in Figure 1 would be correctly translated from :

“povero Mario, tu non conosci Firenze ma ti dirò di più su essa.”

to:

“poor Mario, you don't know Florence but I'll tell you more about it.”

SHELDON will work with the English representation of it.

Besides, using the Google Chrome browser it is possible to use the Google Web Speech API recognition feature¹¹ which would translate the spoken text in natural language text.

SHELDON addresses the following four main tasks:

- If the user chooses to perform machine reading (by pressing the button “Ba” of the toolbar - cf. Figure 1), an RDF output of the related text is shown. Several information such as detected DBpedia entities, events and situations mapped within DOLCE, WordNet and VerbNet mapping, pronoun resolution, and so on are displayed on the graph. Figure 4 shows a part of the graph produced by SHELDON for the example sentence and related to the machine reading component.

⁹<http://www.microsoft.com/web/post/using-the-free-bing-translation-apis>

¹⁰It uses the Language Identification Engine of Apache Stanbol.

¹¹<https://www.google.com/intl/en/chrome/demos/speech.html>

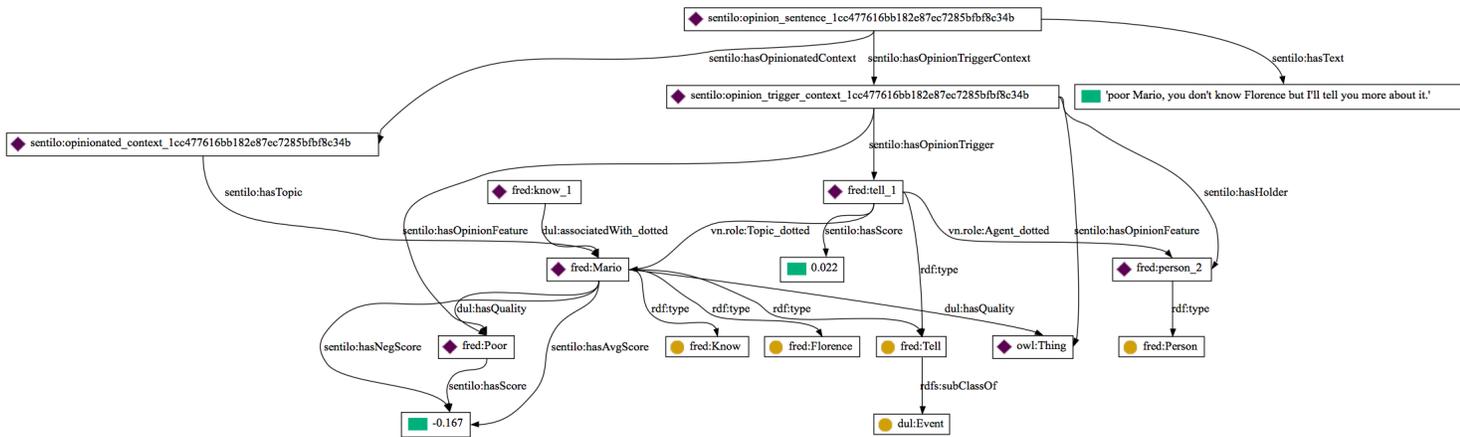


Figure 3: Semantic sentiment analysis output for “povero Mario, tu non conosci Firenze ma ti dirò di più su essa.”

- If the user wants to perform sentiment analysis (by pressing the button “Z” of the toolbar), the RDF graph will be augmented with annotations with concepts with respect to a defined sentiment analysis ontology and numerical scores for the negative adjective, *poor*, correctly associated to the entity *Mario*, and with an opinion score for the opinion trigger verb *tell*. Figure 3 shows the RDF output for the semantic sentiment analysis for the example sentence. If the sentence is more complex, sentiments may be propagated to entities depending on existing relations between them. Details on the sentiment propagation algorithm can be found in [17].
- If the user wants to find all the relations between detected DBpedia entities of the input text, she will choose the relation discovery (by pressing the button “I” of the toolbar). For the example sentence above, SHELDON would not return anything as the only DBpedia entity it recognizes is *Florence*. For sentences containing more than one DBpedia entities, SHELDON returns the relations between them. For example, the French sentence “*Matteo Renzi a été le premier citoyen de l’une des villes plus célèbres de l’Italie, Florence.*” will be correctly translated in English and then feed to the system. A relation (shown in Figure 5) will be returned by SHELDON for the pair of DBpedia entities (*Matteo Renzi, Italy*).
- If the citation typing is chosen (by pressing the button “N” of the toolbar), SHELDON processes the sentence as a citation context, i.e., a piece of text containing an explicit citation (marked as “[X]” in the text) to a scholarly article. In this case SHELDON infers automatically the function of a citation by means of Semantic Web technologies, NLP and Sentiment Analysis techniques. The output is a property of the CiTO ontology¹² [12], which provides a set of 41 properties for describing the nature of citations in scientific research articles and other scholarly works.

Except for the citation typing task (which returns a single property of the CiTO ontology), the SHELDON’s user inter-

¹²CiTO: <http://purl.org/spar/cito>

face returns an interactive RDF graph that can be used by a user for browsing the knowledge resulting from the specific task. When clicking on each DBpedia entity node displayed in a graph, a pop-up menu appears (cf. Figure 2). This menu allows a user to perform different actions, namely:

- visualization of an entity’s page on DBpedia;
- exploratory search with Aemoo¹³ [10] starting from a given entity;
- relation augmenting with [13], which allows to discover new relations for a DBpedia entity by exploiting the outgoing links and the natural language available from the corresponding Wikipedia article;
- typing information augmenting with TÌPALO [6], which returns the most appropriate types for a given DBpedia entity by analyzing the natural language available from the corresponding Wikipedia abstract for such an entity. In particular, by clicking on the DBpedia entity, a new RDF graph composed of `rdf:type`, `rdf:subClassOf`, `owl:sameAs`, and `owl:equivalentTo` statements providing typing information is returned. These ones are aligned to the DBpedia Ontology, WordNet 3.0 in RDF, DUL, and DolceZero.

For the machine reading, the sentiment analysis and the relation finding capabilities it is possible to visualize the complete list of RDF triples (syntactic constructs, offset between words and input sentence, URIs of recognized entities, text span markup specification support using EAR-MARK [11], relations between source and translated text) by choosing a view (RDF/XML, RDF/JSON, Turtle, N3, NT, DAG) other than the Graphical View item which is set by default.

Within the options at the bottom of the produced graphs it is possible to export the graph as a PNG or JPEG image, in order to see the augmented knowledge for the identified DBpedia entities from SHELDON. This is obtained by using a nice GUI built on top of RelFinder which allows navigating the graph through a user-friendly visualization tool that builds upon the Semantic Scout [1] and that uses the JavaScript InfoVis Toolkit.

¹³Aemoo: <http://www.aemoo.org>

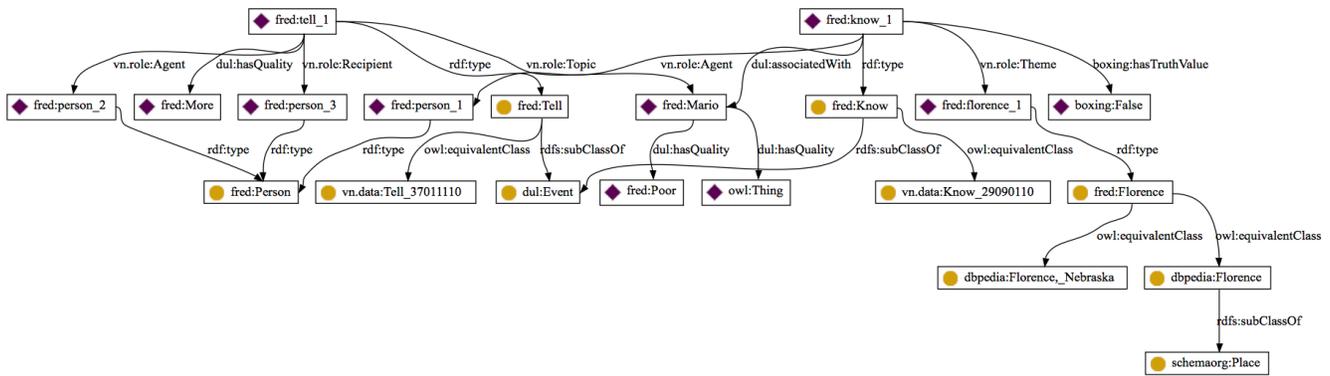


Figure 4: Machine reader output for the Italian text: “povero Mario, tu non conosci Firenze ma ti dirò di più su essa.”

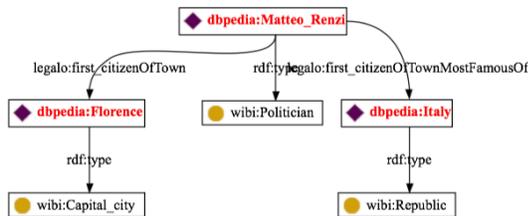


Figure 5: Semantic link identification for the French sentence “Matteo Renzi a été le premier citoyen de l’une des villes plus célèbres de l’Italie, Florence.”

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