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Natural Language Processing as a Foundation of the Semantic Web

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Abstract

The main argument of this paper is that Natural Language Processing (NLP) does, and will continue to, underlie the Semantic Web (SW), including its initial construction from unstructured sources like the World Wide Web (WWW), whether its advocates realise this or not. Chiefly, we argue, such NLP activity is the only way up to a defensible notion of meaning at conceptual levels (in the original SW diagram) based on lower level empirical computations over usage. Our aim is definitely not to claim logic-bad, NLP-good in any simple-minded way, but to argue that the SW will be a fascinating interaction of these two methodologies, again like the WWW (which has been basically a field for statistical NLP research) but with deeper content. Only NLP technologies (and chiefly information extraction) will be able to provide the requisite RDF knowledge stores for the SW from existing unstructured text databases in the WWW, and in the vast quantities needed. There is no alternative at this point, since a wholly or mostly hand-crafted SW is also unthinkable, as is a SW built from scratch

and without reference to the WWW. We also assume that, whatever the limitations on current SW representational power we have drawn attention to here, the SW will continue to grow in a distributed manner so as to serve the needs of scientists, even if it is not perfect. The WWW has already shown how an imperfect artefact can become indispensable.

Contents

1

Introduction

> *In the middle of a cloudy thing is another cloudy thing, and within that another cloudy thing, inside which is yet another cloudy thing ... and in that is yet another cloudy thing, inside which is something* ***perfectly clear and definite."***
>
> — Ancient Sufi saying

The newly developing field of Web Science has been defined as "the science of decentralised information systems" [10] which clearly covers a very broad area. Nonetheless the core focus of Web Science is the Semantic Web (SW) conceived of as a more powerful, more functional and more capable version of our current document and language centric World Wide Web (WWW). This paper focusses on the question of what kind of object this SW is to be. Our particular focus will be its semantics and the relationship between knowledge representations and natural language, a relationship concerning which this paper wishes to express a definite perspective. This is a vast, and possibly ill-formed issue, but the SW is no longer simply an aspiration in a magazine article [11] but a serious research subject on both sides of the Atlantic

and beyond, with its own conferences and journals. So, even though it may be beginning to exist in a demonstrable form, in the way the WWW itself plainly does exist, it is a topic for research and about which fundamental questions can be asked, as to its representations, their meanings and their groundings, if any.

The position adopted here is that the concept of the SW has two distinct origins, and this persists now in two differing lines of SW research: one, closely allied to notions of documents and natural language (NL) and one not. These differences of emphasis or content in the SW carry with them quite different commitments on what it is to interpret a knowledge representation and what the method of interpretation has to do with meaning in natural language.

We shall attempt to explore both these strands here, but our sympathies will be with the NL branch of the bifurcation above, a view that assumes that NL is, in some clear sense, our primary method of conveying meaning and that other methods of conveying meaning (formalisms, science, mathematics, codes, etc.) are parasitic upon it. This is not a novel view: it was once associated firmly with the philosophy of Wittgenstein [197], who we shall claim is slightly more relevant to these issues than is implied by Hirst's immortal, and satirical, line that "The solution to any problem in artificial intelligence (AI) may be found in the writings of Wittgenstein, though the details of the implementation are sometimes rather sketchy [79]."

Later parts of the paper will explore the general issue of language processing and its relevance to current, and possibly future, techniques of web searching, and we shall do this by means of an examination of the influential claims of Karen Spärck Jones that there cannot be "meaning codings" in the SW or Internet search. Having, we believe, countered her arguments, we go on to examine in particular the meaning codings expressed in ontologies, as they play so crucial a role in the SW. Our core argument is that such representations can be sound as long as they are empirically based. Finally, we turn to a methodology for giving such an empirical base to ontologies and discuss how far that program has yet succeeded.

There are a number of NLP technologies which will not be discussed here; some have relationships to the Internet but they are not yet basic

technologies in the way those of content representation and search are that we will discuss in the body of this paper. These include automatic summarisation, text mining, and machine translation (MT).

MT is the oldest of these technologies and we will touch on its role as a driver behind the introduction of statistical and data-based methods into NLP in the late eighties. MT has a history almost fifty years long, and basic descriptions and histories of its methods can be found in Nirenburg et al. [130]. The oldest functioning MT system SYSTRAN is still alive and well and is believed to the basis of many of the language translations offered on the Internet such as Babelfish MT. This is a service that translates a webpage on demand for a user with a fair degree of accuracy. The technology is currently shifting with older language pairs being translated by SYSTRAN and newer ones by empirical application of statistical methods to text corpora.

Text mining (TM) [90] is a technique that shares with Information Retrieval (IR) a statistical methodology but, being linked directly to the structure of databases, does not have the ability to develop in the way IR has in recent decades by developing hybrid techniques with NLP aspects. TM can be seen as a fusion of two techniques: first, the gathering of information from text by some form of statistical pattern learning and, secondly, the insertion of such structured data into a database so as to carry out a search for patterns within the structured data, hopefully novel patterns not intuitively observable.

Another well-defined NLP task is automatic summarisation, described in detail in [110] and which takes an information source, extracts content from it, and presents the most important content to the user in a condensed form and in a manner sensitive to the user's or application's needs. Computers have been producing summaries since the original work of [108]. Since then several methods and theories have been applied including the use of $tf * idf$ measures, sentence position, cue and title words; partial understanding using conceptual structures; cohesive properties of texts (such as lexical chains) or rhetorical structure theory (RST). Most summarisation solutions today rely on a 'sentence extraction' strategy where sentences are selected from a source document according to some criterion and presented to the user by concatenating them in their original document order. This is a robust and

sometimes useful approach, but it does not guarantee the production of a coherent and cohesive summary. Recent research has addressed the problems of sentence extracts by incorporating some NL generation techniques, but this is still in the research agenda.

We will give prominence to one particular NLP technology, in our discussion of language, the SW and the Internet itself: namely, the automatic induction of ontology structures. This is a deliberate choice, because that technology seeks to link the distributional properties of words in texts directly to the organising role of word-like terms in knowledge bases, such as ontologies. If this can be done, or even partially done, then it provides an empirical, procedural, way of linking real words to abstract terms, whose meanings in logic formulas and semantic representations has always been a focus of critical attention: how, people have always asked, can these things that look like words function as special abstract bearers of meaning in science and outside normal contexts? Empirical derivation of such ontologies from texts can give an answer to that question by grounding abstract use in concrete use, which is close to what Wittgenstein meant when he wrote of the need to "bring back words from their metaphysical to their everyday uses" [197, Section 116].

As noted above, Web Science has been defined as "the science of decentralised information systems" [10] and has been largely envisaged as the SW which is " a vision of extending and adding value to the Web, ... intended to exploit the possibilities of logical assertion over linked relational data to allow the automation of much information processing." Such a view makes a number of key assumptions, assumptions which logically underlie such a statement. They include the following:

- that a suitable logical representational language will be found;
- that there will be large quantities of formally structured relational data;
- that it is possible to make logical assertions i.e., inferences over this data consistently;
- that a sufficient body of knowledge can be represented in the representational language to make the effort worthwhile.

We will seek to directly and indirectly challenge some of these assumptions. We would argue that the fundamental decentralised information on the web is text (unstructured data, as it is sometimes referred to) and this ever growing body of text needs to be a fundamental source of information for the SW if it is to succeed. This perspective places NLP and its associated techniques like Information Extraction at the core of the Semantic Web/Web Science enterprise. A number of conclusions follow from this which we will be exploring in part in this paper.

Of fundamental relevance to our perspective is that the SW as a programme of research and technology development has taken on the mantel of artificial intelligence. When Berners-Lee stated that the SW "will bring structure to the meaningful content of Web pages, creating an environment where software agents roaming from page to page can readily carry out sophisticated tasks for users" [11], this implied knowledge representation, logic and ontologies, and as such is a programme almost identical to which AI set itself from the early days (as a number of authors have pointed out e.g., Halpin [70]). This consequently makes the question of how NLP interacts with AI all the more vital, especially as the reality is that the World Wide Web consists largely of human readable documents.

The structure of this paper is as follows: In Section 2, we look at the SW as an inheritor of the objectives, ideals and challenges of traditional AI. Section 3 considers the competing claim that in fact the SW will consist exclusively of "trusted databases." In Section 4, we turn to the view that the SW *must* have its foundation on NL artefacts, documents, and we introduce the notion of ontology learning from text in this section as well. This is followed by a brief conclusion.

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