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Mining Semantics for Culturomics – Towards a Knowledge-Based Approach



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ABSTRACT

The massive amounts of text data made available through the Google Books digitization project have inspired a new field of big-data textual research. Named *culturomics*, this field has attracted the attention of a growing number of scholars over recent years. However, initial studies based on these data have been criticized for not referring to relevant work in linguistics and language technology. This paper provides some ideas, thoughts and first steps towards a new culturomics initiative, based this time on Swedish data, which pursues a more knowledge-based approach than previous work in this emerging field. The amount of new Swedish text produced daily and older texts being digitized in cultural heritage projects grows at an accelerating rate. These volumes of text being available in digital form have grown far beyond the capacity of human readers, leaving automated semantic processing of the texts as the only realistic option for accessing and using the information contained in them. The aim of our recently initiated research program is to advance the state of the art in language technology resources and methods for semantic processing of *Big Swedish text* and focus on the theoretical and methodological advancement of the state of the art in extracting and correlating information from large volumes of Swedish text using a combination of knowledge-based and statistical methods.

Categories and Subject Descriptors

H.3.1 [Content Analysis and Indexing]; H.3.3 [Information Search and Retrieval]; H.3.7 [Digital Libraries]; I.2.4 [Knowledge Representation Formalisms and Methods]; I.2.7 [Natural Language Processing]

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General Terms

Algorithms, Experimentation, Management, Standardization.

Keywords

culturomics, semantics, language processing, Big data, Swedish.

1. INTRODUCTION

The main aim of our recently initiated research program, *Knowledge-based culturomics*, is to advance the state of the art in language technology resources and methods for deep linguistic processing of Swedish text. In this way, we can provide researchers in several fields with more sophisticated tools for working with the information contained in the large volumes of digitized text, e.g., by being able to correlate and compare the content of texts and text passages on a large scale. The project focus is on the design, integration and adaptation of language-processing components for semantic analysis (e.g., entities, relations, events and their structure, their semantic roles, and coreference between their arguments). The results will provide researchers with more sophisticated tools for working with the information contained in large volumes of digitized text and develop methodology and applications in support of research in disciplines where text is an important primary research data source, primarily the humanities and social sciences, but which also will benefit everyone else who works within the (Swedish) language landscape.

2. CULTUROMICS

Culturomics is an emerging new research area born of the combination of large-scale digitization and basic language processing. It started out as a methodology for studying culture and language development over time using the massive Google Books dataset [44, 50]. With the availability of big unstructured text data [49], such as in the form of millions of digitized books or other large collections of text (and data) as in the healthcare sector [32], the possibilities of culturomics are almost limitless. The practice of culturomics, as presented by the originators of the concept, is inspired by work originating in computer science,

especially information retrieval, where the input data generally is made up by linguistically unanalyzed text units – “bags of words” – but where we occasionally also see some attempts to benefit from deeper linguistic processing, for example *topic models* [7, 30]. The main objective of culturomics is to assemble and reorganize data in order to offer researchers from various disciplines a new playground to investigate quantitatively, e.g., broad cultural trends and the cultural developments of various societies through time. Culturomics also relies on statistically-oriented techniques in order to track long-term, macro-scale patterns of written language use and derive conclusions about language that have never previously been possible in the study of human language. For instance, Acerbi et al. [1] analyze trends in the past century of mood words (emotion-related words) in books using the Google n-gram database.

Michel et al. [44] mention that big data “will furnish a great cache of bones from which to reconstruct the skeleton of a new science.” and that “there are strong parallels to the completion of the human genome (analogously to genomics, proteomics and other -omic technologies). Just as that provided an invaluable resource for biologists, Google’s corpus will allow social scientists and humanities scholars to study human culture in a rigorous way”. Note, that in a wider sense the goal of culturomics is related to the idea of *macroanalysis* by Moretti [46] who coined the term “distant reading” in which “the reality of the text undergoes a process of deliberate reduction and abstraction”. According to this view, understanding language (e.g., literature) is not accomplished by studying individual texts, but by aggregating and analyzing massive amounts of data [34]. In this way it becomes possible to design experiments for investigating novel uses of language and its development that otherwise would be impossible to conduct, e.g., quantifying the difference between writing styles [3].

We are certainly about to see new developments in the exploration of cultural trends in the near future by the use of new enhanced culturomics initiatives applied on big data worldwide. *Twitterology*, a subfield of culturomics, is such a development that focuses on large tweets corpora [54] and *Culturomics 2.0* proposed by e.g., Leetaru [40], a new development that can be used to defuse some of the criticisms raised against culturomics [31]. Moreover, Goldberg and Orwant [28] have recently created and released a dataset of syntactic n-grams based on the Google Books corpus, which contains over 10 billion unique items covering various syntactic structures, including temporal metadata which can facilitate research into lexical semantics over time.

3. RESOURCES

This project deals with written Swedish language using available digital text collections and corpora. Therefore, we strongly believe that the basic premise of the culturomics endeavor is eminently timely. Large amounts of new Swedish text are produced constantly while older texts are being digitized apace in cultural heritage projects – e.g., in the Digidaily¹ project and the Swedish Literature Bank.² The volumes of Swedish text available

¹ Digidaily is a project co-financed by the European Union's Structural Funds. The Swedish Royal Library and the National Archives have to date digitized almost 300,000 pages of Swedish newspaper text from the 17th century onwards.

² The Swedish Literature Bank contains over 100,000 pages of classical Swedish literature in digital text editions. The aim of the

in digital form have grown far beyond the capacity of even the fastest reader, leaving automated semantic processing of the texts, such as production of semantically-oriented structured data and feature/value set extraction, as the only realistic option for accessing and using this information. However, advanced technologies that require semantic processing are still very much in their infancy for almost all languages, Swedish being no exception. The data we started using comes from the University of Gothenburg's Swedish Language Bank (Språkbanken, SB³). SB maintains, develops and annotates a corpus collection of over one billion words of modern texts and close to one billion words of historical texts. SB's corpus collection already contains the full Swedish Wikipedia and about 390 MW of Swedish blogs. Collecting large amounts of text from the web is of course not a technical problem [3], but it does raise interesting issues of how to work effectively with very large volumes of text.

4. LANGUAGE TECHNOLOGY AND SEMANTIC PROCESSING

Natural language is not simply a set of invariant words. It has linear and hierarchical structure, and the data encountered in different databases, archives and real time, social media texts, is “noisy” thanks to, e.g., variations in spelling, capitalization, inflection, and ambiguities of various kinds. This project has started using semantically-oriented tools and resources, a brief description of which is provided below, in order to effectively deal with many of the linguistic issues encountered in raw data.

4.1 Entities and Coreference

Named entity recognition (NER) is a core subtask in Information Extraction and has emerged as an important supporting component with many applications in various human language technologies. The automatic recognition and marking-up of names (in a wide sense) and various other related kinds of information, e.g., time, measure expressions and/or terminology, has turned out to be a recurring basic requirement. Hence, NER has become a core language technology of great significance to numerous applications and a wide range of techniques. However, the nature and type of named entities vary, depending on the task under investigation or the target application. In any case, person, location and organization names are considered “generic”, in the sense that all NER systems incorporate a mechanism to identify these basic entities. In this work we apply a system using rather fine grained named entity taxonomy with several main entity types and subtypes. For instance, the type person incorporates peoples’ names (forenames, surnames), groups of people, animal/pet names, mythological names, theonyms and the like, for peoples’ names, even gender identification is performed. In previous studies with the same system, acceptable figures on precision and recall have been reported [12, 13]. Discourse entities are the real, abstract, or imaginary objects introduced in a text. A correct detection and identification of the entities

Swedish Literature Bank is to be a free cultural-historical and literary resource for research, teaching and popular education. The main task is to collect and digitize literary works and the most important works of the humanities, and to make the material available in a way that makes it possible for users to work with it.

³ For a more detailed description of the linguistic infrastructure in Språkbanken visit: <<http://spraakbanken.gu.se/>> moreover, SB's constantly evolving corpus search interface [11] is open for general use here: <<http://spraakbanken.gu.se/korp/>>.

mentioned in a text is crucial for its understanding. As entities may be mentioned two or more times, a coreference solver is needed to link the expressions that refer to the same entity [6, 48]. A coreference solver builds sets of equivalence classes referring to these mentions in the text, e.g., linking an anaphor and its antecedent, as being references to the same real-world entity or object. Coreference solving is considered complex and sometimes a show-stopper in semantic applications.

4.2 Relations and Events

There are two basic ways to structure and further explore text data in textual resources of various kinds. Apart from annotating the unstructured text with entities we also need to identify relations both between entities and between events. Semantic relations are a connection between combinations of things (here named entities) in text. Semantic relations are usually binary, and can be expressed as grammaticosemantic links between lexical units, e.g. named entities, for example: *X father-of Y* or *father-of(X, Y)* where X and Y are instances of named entity types; by syntactic dependencies, which approximate the underlying semantic relationships [15]; or by conventional RDF S-V-O triples, which is a universal representation of relations. Moreover, semantic relations are often terminological relations, e.g. *Part-of* or *Is-a* or static relations such as *Born-In*. On the other hand, events, (see below), are dynamic.

In this work we do not differentiate between these different types but let the data “decide” what relations and events are present. Events (in linguistics usually defined in short as “things that happen”) are structurally far more complex processes than relations and often are expressed in natural language with the help of predicates (e.g., verbs) that assign event-specific semantic roles to each participating entity, linking them to (syntactic) arguments. These relations between event predicates and arguments (predicate-argument relations) are the focus of semantic role labeling methods that automatically assign roles to arguments of a predicate. An event is exemplified with the help of the sample sentence provided in Figure 1: *Öroninflammation (akut otitis media, AOM) är en vanlig barnsjukdom och den vanligaste orsaken till att barn erhåller antibiotikabehandling.* ‘Ear infections (acute otitis media, AOM) is a common childhood disease and the most common reason that children receive anti-

biotic treatment.’ This sentence contains several events, for instance a *Causation* event, triggered by the predicate *orsaken*, ‘the reason’, and a *Medical-Treatment* event, triggered by the predicate *erhåller* ‘(they) receive’. For event recognition we have started experimentation with the Swedish FrameNet++ (Section 4.3); therefore these two event names are instantiated using two frames with the same name in FrameNet++.

4.3 Frame Semantics and FrameNet

The FrameNet approach is based on the linguistic theory of frame semantics [25] supported by corpus evidence. A semantic frame is a script-like structure of concepts which are linked to the meanings of linguistic units and associated with a specific event or state. Each frame identifies a set of frame elements, which are frame specific semantic roles (both core and non-core ones).

Furthermore, roles may be expressed overtly, left unexpressed or not explicitly linked to the frame via linguistic conventions. In this work, we only deal with the first type of such roles. Semantic lexicons, such as FrameNet, are an important source of knowledge for semantic parsing (Section 4.4). Despite the belief that certain Natural Language Processing (NLP) tasks, such as statistical machine translation and speech recognition, could be performed more efficiently and less expensively by pure statistical means [29], FrameNet relies on expert annotations and much less data than e.g., Google’s n-gram database (sequences of *n* words), in order to capture semantic subtleties that cannot be captured by statistical means. Therefore, we believe that “big data” will need NLP, but the NLP also in its turn needs “big data”, since current approaches based merely on e.g., n-gram modeling and collocation scores are hardly more than advanced means of conducting naïve searches and a new way of performing frequency analysis. On the other hand, FrameNet documents the range of semantic and syntactic combinatory possibilities of frame evoking lexical units (LU), phrases and clauses by abstracting away from syntactic differences, which can be beneficial for a deeper exploration of language. An LU can evoke a frame, and its syntactic dependents can fill the frame element slots (see the annotations in Fig. 1). The Swedish FrameNet++ [10], SweFN++, is a lexical resource under active development in SB, based on the English version of FrameNet. It is found on the SweFN website,⁴ available as a free resource under a CC BY

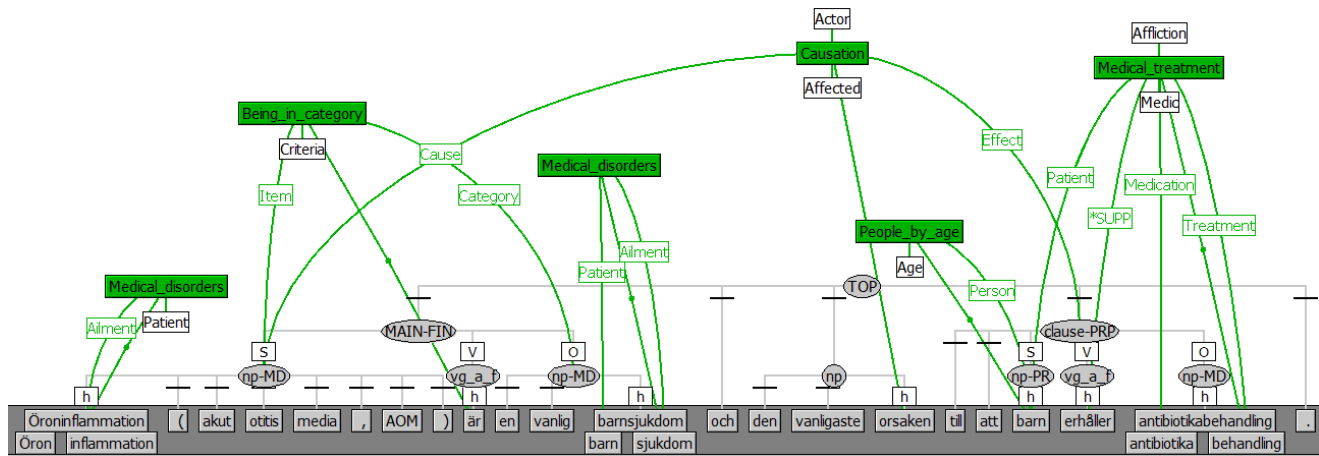


Figure 1. Annotated sentence in SALTO [14], using a combination of shallow syntax and frame semantics. Here, gray labels are the result from the syntactic analysis and the green boxes are frames and (a subset of) their elements.

license.

⁴ <http://spraakbanken.gu.se/eng/swefn>.

between sentences that cannot be detected using word counts alone. Sentences are given a sparse representation in terms of concepts based on a term-document matrix constructed from Wikipedia documents (Figure 4). Our second contribution is to adopt an integrative approach using multiple similarity kernels: bag of words, sparse representation of Wikipedia topics, syntactic similarity (parse tree similarity) etc. For this we use a technique we recently developed [33] based on multiple kernel learning and a classical geometrical representation of graphs; for details see [33].

6. CONCLUSIONS AND FUTURE WORK

This paper has presented some initial work and ideas developed in an ongoing project in the area of culturomics, which we believe is a research field with promising future [8] because we are faced with new bodies of evidence, a breeding ground for knowledge and new ideas and for testing new methodologies. Therefore the real challenges and opportunities lie ahead and will emerge in due course. The project will focus on the theoretical and methodological advancement of the state of the art in extracting and correlating information from large volumes of Swedish text using a combination of knowledge-based and statistical methods. One central aim of this project will be to develop methodology and applications in support of research in disciplines where text is an important primary research data source, primarily the humanities and social sciences.

The innovative core of the project will be the exploration of how to best combine knowledge-rich but sometimes resource-consuming natural language processing with statistical machine-learning and data-mining approaches. In all likelihood this will involve a good deal of interleaving. One example: Topic models based on documents as bags-of-words could be used for preliminary selection of document sets to be more deeply processed; the results of the semantic processing subsequently being fed into other machine-learning modules, back to the topic models in order to refine the selection, or for processing by semantic reasoners. In order to guide this development, visual analytics will be invaluable. If the results of processing can be represented as graphs – which are often a natural representation format for linguistic phenomena in texts or text collections – a whole battery of network analysis tools will be at the researcher’s disposal. We can use them to find clusters of similar documents or entities, pinpoint those documents that were most influential to the rest, or perform any of a number of other tasks designed for network analysis.

Moreover, a goal of the project which will ensure its visibility is to replicate the IBM Watson system for Swedish with knowledge extracted from different sources such as Swedish Wikipedia, Språkbanken’s contemporary and historical newspaper corpora, the classical Swedish literary works available in the Swedish Literature Bank, etc. The selection of text for the project will be restricted to readily available digital text collections and corpora. Digitization will not fall within the scope of the project. Existing text collections and corpora are already large and broad enough to ensure the viability of the methods. Furthermore, a large number of resources (e.g., Swedish FrameNet and other lexical resources) and tools are available, such as entity taggers, semantic role labelers, syntactic parsers (including converters that can transform constituent parse trees into dependency graphs) and the like. Some of the tools are at a more preliminary stage (e.g., a coreference solver [6]) while other are mature and extensively tested with various types of big data (e.g., named entities [12,

13]). Nonetheless, all resources have to be adapted and “glued” together in order to be capable of obtaining the desired goals of our culturomics project.

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