Abstract

We suggest to employ techniques from Natural Language Processing (NLP) and Knowledge Representation (KR) to transform existing documents into documents amenable for the Semantic Web. Semantic Web documents have at least part of their semantics and pragmatics marked up explicitly in both a machine processable as well as human readable manner. XML and its related standards (XSLT, RDF, Topic Maps etc.) are the unifying platform for the tools and methodologies developed for different application scenarios.

1 Motivation

Imagine the following situation: As a consumer you are looking for information about a product. You may be interested in technical details, the price, delivery conditions etc. For many products this type of information is available on web pages of companies. A situation that - despite the differences - is very much alike: As a scheduler of an automobile manufacturer you are looking for subsidiary companies that are able to produce components or raw products for integration in a new production pipeline. Again you might profit from the information that is offered on web pages. An illustrative case are web pages of foundries.

The problem nowadays still is: Although information searched for is available on WWW pages automated processes (‘agents’) will have problems in finding and extracting it.

This motivates the vision of the ‘Semantic Web’ as expressed by Tim Berners-Lee: ‘Semantic Web – a web of data that can be processed directly or indirectly by machines’ [5].

The Semantic Web of the future will very likely be based on direct authoring [3]. That means future documents will contain metadata, semantic tagging will be employed to make intra-document relations explicit, topic maps and other technologies will be used to express semantic relations between documents (inter-document relations). In other words: making semantics and pragmatics of documents explicit via tagging will be an integral part of the document creation process.

In the current situation we have a multitude of existing web pages with valuable contents, far too many to be manually augmented and transformed into Semantic Web documents. We therefore suggest both automatic and semi-automatic augmentation of documents.

We are developing tools and methodologies based on NLP techniques, text technology and knowledge representation for the transformation of existing documents into Semantic Web documents (see Fig. 1).

In the following we suggest to distinguish two types of documents. On the one hand there are enriched documents: These are documents that originate from the web or other sources. They undergo document
analysis and the results of the analysis are directly integrated into the document using XML markup.
On the other hand there are transformed documents that are comprised from explicitly understood pieces of information extracted from other documents.
On the surface enriched documents may have the same 'look and feel' as simple HTML pages, i.e., on a first glance the user may not recognize any difference. The added value of the explicit enrichment with structural and semantic markup becomes apparent when automated processes (agents) are used. Enriched documents are suited for intelligent searches, querying, flexible recombination etc.
The case of document transformation comes into play when pieces of information are reassembled and offered to the user in a uniform way as a document. As an example you can think of a rated overview page that is distilled from a collection of pages, e.g., a structured summary with the results of a comparative search on a collection of web pages from different manufacturers of a product.
A general point to stress: In some sense the terms ‘semi-structured documents’ or ‘unstructured documents’ that are used sometimes are misleading from our point of view. Documents are generally highly structured. The problem is not a lack of structure, the problem is that the structure is not made explicit in traditional documents. Human readers are in most cases able to easily uncover those implicit structures. Thus the major challenge is for automatic conversion of traditional (web) documents into Semantic Web documents: to uncover structure and contents and mark them up explicitly. This will then allow processing and interpretation of the documents by machines.
This paper is organized as follows: first we give a detailed description of our view of Semantic Web documents. Then we describe encoding of information on web pages and mechanisms for transformation of implicit information into explicit data, followed by a realistic application scenario. Finally we discuss some of the open research issues.

Figure 1: Towards the Semantic Web.

2 Towards Semantic Web Documents

The WWW is a fast growing source of heterogeneous information. For web document analysis in general, the analysis of text will have to be complemented by the analysis of other WWW media types: image analysis, video interpretation, voice processing etc. In addition, cross-media references and hypermedia structures need proper treatment. Natural language analysis of textual parts of web documents is no different from ‘normal’ text analysis. For a given complex application in web document analysis we found it fruitful to classify its subtasks into the following three categories:

- subtasks that are primarily WWW specific,
• subtasks that are specific to the application,
• subtasks that are relevant to all NLP approaches.

WWW specific subtasks can be classified as being part of the preprocessing stage. Preprocessing in this sense comprises all those operations that eventually result in a text document in the input format expected by the linguistic tools. In other words, aspects of the source document that are irrelevant or distracting for linguistic processing will be abstracted away during preprocessing and the resulting document will be in a canonical format.

If source documents already contain appropriate metadata some subtasks of preprocessing are reduced to looking up the values of metadata attributes. For now, preprocessing will in many cases include attempts at automatic language identification, domain classification or hyperlink tracing.

2.1 The Power of Markup

XML [1] – and its precursor SGML – offer a formalism to annotate pieces of (natural language) text. To be more precise, if a piece of text is (as a simple first approximation) seen as a sequence of characters (alphabet and whitespace) then XML allows to associate arbitrary markup with arbitrary subsequences of contiguous characters. Many linguistic units of interest are represented by strings of contiguous characters (e.g., words, phrases, clauses etc.). It is a straightforward idea to use XML to encode information about such a substring of a text interpreted as a meaningful linguistic unit and to associate this information directly with the occurrence of the unit in the text. The basic idea of annotation is further supported by XML’s wellformedness demand, i.e., XML elements have to be properly nested. This is fully concordant with standard linguistic practice: complex structures are made up from simpler structures covering substrings of the full string in a nested way. The enrichment of documents is based on this ability to associate information directly with the respective span of text.

3 Information Encoding on WWW Pages

The starting point of our work are web pages as they are found now. In the following we report about results from corpus based case studies.

3.1 Corpus Based Case Studies

We employ a corpus based approach. Investigations do start with the collection of a corpus of representative documents. Then a number of issues are systematically investigated:

• What are the typical structure and contents of document instances in the corpus?
• What information is most likely of interest for which type of users?
• How can this information be located and extracted?
• What are characteristics of the source documents that may make this task easier or more complicated?
• What aspects can be generalized and abstracted from the specific case?

3.2 Variations in Information Presentations

When the focus is on contents, not on surface appearance, then the notion of ‘paraphrase’ is no longer restricted to linguistic units. Our analyses of WWW pages revealed that there are many cases where the same information can more or less be conveyed both in a number of linguistic variations as well as in different non-linguistics formats (‘extended paraphrases’). As an example we take the following excerpt from a web page of a garage manufacturer.

Example 1 Excerpt from Web Page.
Wunschbox-Garagen sind als Typ S mit einer Breite von 2,68m, als Typ N (Breite 2,85m) und als Typ B (Breite 2,98m) lieferbar. Alle Garagen haben eine Höhe von 2,46m.

The phrasal pattern underlying the first sentence

\(<product> \text{is available as} <\text{enumeration of type info}>\)

is found in variations like the following:

\(<product>(\text{pl}) \text{ sind als} <\text{enumeration}> \text{lieferbar}.\>
\(<product>(\text{sg}) \text{ ist als} <\text{enumeration}> \text{erhältlich.}\>
\(<product>(\text{sg}) \text{ gibt es als} <\text{enumeration}>. \ldots\>

Type info in turn is given according to patterns like:

\(<\text{enumeration of type info}> == <\text{type nr} >1 \text{ with} <\text{feature} \text{ of} <\text{value} >1 >,\>
\(<\text{type nr} >2 \text{ with} <\text{feature} \text{ of} <\text{value} >2 >,\>
\ldots
\(<\text{type nr} >i \text{ with} <\text{feature} \text{ of} <\text{value} >i >\>

Note that the second sentence of example 1 needs contextual interpretation because its literal meaning in isolation would be the universally quantified assertion that ‘All garages have a height of 2,46m’ and not the contextually restricted ‘All garages of types S, N and B of this manufacturer have a height of 2,46m’.

3.3 Interaction Between Linguistic Structures and Source Document Markup

There are interactions between list structures in HTML (and XHTML) and linguistic units that have to be accounted for in linguistic analysis of web pages. A simple case is the use of lists for enumerating concepts like in the following example.

**Example 2 Enumerating Concepts.**

\(<p>\text{Die wichtigsten Branchen sind:} <ul>\text{Formen- und Werkzeugbau}</li>\text{Eisenbahnwesen}</li>\text{…}</ul></p>\>

Please note that even such simple structures do need proper treatment of coordination and truncation and that contextual interpretation is obligatory in order to correctly infer semantic relations between list heading and list items.

Very often a partial sentence and an HTML list of sentential complements or other phrases interact like in the following example:

**Example 3 Interaction Between Sentence and List Structure.**

\(<p>\text{Wir produzieren maschinen- und handgeformten Grau- und Sphaeroguss} <ul>\text{ca. 25.000 t Jahresproduktion} <li>\text{mit mehr als 4.000 lebenden Modellen} <li>\text{in mittleren und grosseren Serien} <li>\text{Handformguss bis 800 kg Stueckgewicht} </ul></p>\>

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Here semantic interpretation unavoidably needs sophisticated techniques for the interaction between the list items as phrasal type syntactic structures and the partial case frames created by the partial sentential structures as list headings. In some cases the list item is a full syntactic complement, in others the relation between item and heading is not structural but only on semantic grounds.

Frequently, when processing realistic documents deficiencies of the source material have to be accounted for. An example: the analysis of the HTML sources of foundry web pages revealed that HTML was sometimes misused in the sense that the intended layout

| Garage types | Width | Height |
|--------------|-------|--------|
| S            | 2.68  | 2.46  |
| N            | 2.85  | 2.46  |
| B            | 2.98  | 2.46  |
was not created by the appropriate tagging (which would allow to easily recover the intentions) but by misusing other tags to create a certain surface appearance. Such deficient structures create a problem for automatic analysis.

Examples of HTML misuse include:

- creation of a frame-like layout using tables,
- creation of a list-like layout with <P> and <BR> tags (see example 4).

**Example 4 Misuse of Paragraphs.**

Folgende max. Abmessungen sind möglich: 
<br> - bis zu 14.000 mm Länge
<br> - bis zu 6.000 mm Durchmesser </p>

### 3.4 Tools and Resources

In spite of the specific aspects discussed above analysis of textual (parts of) web pages has a lot in common with document processing in general. We therefore employ the XDOC\(^1\) toolbox for this task and do combine it with web page specific modules.

**Methods**

For the analysis of information from web pages we need different tools and resources. The tools can be divided into:

- Preprocessing tools like raw text extraction (‘HTML cleaner’) and collector of all web pages from a company resp. link tracing tools.
- Interpretation of HTML structures: what is the semantics behind HTML tags?
- Linguistic tools for the semantic interpretation of linguistic structures, like sentences or phrases.

The WWW page preprocessing tools are not directly relevant for the analysis of implicit information, these tools only collect and prepare the web pages. Relevant for the analysis of implicit information is the interpretation of the internal structure of web pages: Which pieces of information are embedded in which HTML structures? Are they relevant for the semantic interpretation of the contents inside the HTML structure? The main focus is on the analysis of linguistic structures, because inside HTML tags (e.g., tables or list structures etc.) we can find continuous text as whole sentences, or on a lower level phrases or simple lists of specific identifier, e.g., nouns or other tokens. For this task we use our document suite XDOC – a collection of linguistic tools (see \[\[\]\] for a detailed description of the functions inside XDOC). In all functions of XDOC the results of processing are encoded with XML tags delimiting the respective piece of text. The information conveyed by the tag name is enriched with XML attributes and their respective values.

In the following subsections we give a short description of separate functions for the analysis of web pages. Examples of the application of these functions are presented in section 4.2.

- **Part-of-Speech (POS) Tagger:** The assignment of part-of-speech information to a token – POS tagging for short – is not only a preparatory step for parsing. The information gained about a document by POS tagging and evaluating its results is valuable in its own right. We use a morphology based approach to POS tagging (cf. \[\[\]\] for details).
- **Syntactic Parsing:** For syntactic parsing we apply a chart parser based on context-free grammar rules augmented with feature structures.
- **Semantic Tagger:** For semantic tagging we apply a semantic lexicon. This lexicon contains the semantic interpretation of a token and a case frame combined with the syntactic valency requirements. Similar to POS tagging, the tokens are annotated with their meaning and a classification in semantic categories like, e.g., concepts and relations.
- **Case Frame Analysis:** As a result of case frame analysis of a token we obtain details about the type of recognized concepts (resolving multiple interpretations) and possible relations to other concepts.

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\(^1\)XDOC stands for XML based document processing.
• **Semantic Interpretation of Syntactic Structures (SISS):** Another step to analyze the relations between tokens can be the interpretation of the specific syntactic structure of a phrase or sentence. We exploit the syntactic structure of domain specific sublanguages to uncover the semantic relations between related tokens.

**Resources**

The resources vary depending on the tools used (like grammars, abbreviation lexicon etc.). For the analysis we need domain resources, e.g., specific taxonomies of the domain, and document specific resources. The document specific resources describe the characteristics of the sublanguage inside the web pages (e.g., which technical terms are used, what are the syntactic types of phrases etc.).

**3.5 Web Page Classification**

For an efficient processing of web pages, which contain relevant information, a simple pre-classification of web pages was developed:

- **Information Pages:**
  Information pages contain continuous text. The information on these pages may be structured in tables or be given as mixed information in the form of continuous text and tables or numerations.

- **Lead Pages:**
  Lead pages contain links to other web pages about a single topic (or a single company). On these pages more links to internal web pages then to external web pages are found.

- **Overview Pages or Portals:**
  Overview Pages contain both text and links to external web pages. Here links to providers with a similar product range or to related topics are found.

This classification was chosen because of its applicability to other domains. Web pages of other industrial sectors are organized in the same manner, for example in producing industry and online dealers, e.g., building industry (doors, windows, garages, real estate), insurances, automotive industry. The classification of web pages into information, lead and overview pages is sufficient for information extraction with regard to the creation of company profiles. Parameters for an automatic classification of web pages are the percentage of absolute text segments and hyperlinks of a web page, for example, the number of internal links (e.g., one topic, company, or domain), external links (e.g., other topics, companies or domains), tokens, and pictures. In evaluating links local directory structure is taken into account. Through specification of criteria (e.g., number of internal links, the rate of internal and external links, the rate of tokens and pictures etc.) the user may affect the classification. Moreover web page classification is influenced by layout based structures (frames, scripts, controlling elements, like buttons).

**4 An Application Scenario**

This section is a case study about the creation of *casting specific company profiles*. There are about 300 German foundries and they are present in the WWW with one or more web pages. A possible scenario is the following: a product cannot completely be produced in a company. In this case company profiles can be used for choosing a supplier company. Companies use the WWW as a kind of ‘yellow pages’ in order to get information about potential suppliers. A company profile includes a variety of information about a specific company. This information comprises product related data (e.g., size and weight of the casting, material, moulding processes and quality assurance resp. certificates) and company related data (e.g., single-piece work, small, middle, and mass production). In addition, the location of the potential supplier is important in order to reduce transportation costs.

Company profiles are applicable in two ways. First, existing company web pages can be enhanced by making implicitly available information explicit via semantic annotation. Second, the proposed semantic annotation of documents is usable in direct
authoring of future company web pages.

4.1 Creation of Company Profiles

For the user it is important to know which products (e.g., boxes, engine blocks, cylinder heads, or axles) for which industrial sectors (e.g., motor industry, wind power industry, machine building industry etc.) are produced by the company in question. This information allows inferences with respect to quality requirements fulfilled by the company during previous production processes. Company profiles also contain data like addresses and additional contact information.

About 60 foundry specific web pages have been analyzed with respect to data required for company profiles. A first result is the following XML-DTD:

Example 5 DTD for a Foundry Company Profile.

```xml
<!DOCTYPE profile [
<!ELEMENT profile (foundry)+>
<!ELEMENT foundry (name, specifics)>
<!ELEMENT name (f_name, contact, address)>
<!ELEMENT contact (tel, fax*, email*, http)>
<!ELEMENT address (street, city, zip)>
<!ELEMENT specifics (scope+, production, quality*)>
<!ELEMENT scope (material, (weight*, dimension*))>
<!ELEMENT dimension (#PCDATA)>
<!ATTLIST dimension for_what (mould | dim) "mould">>
<!ELEMENT production (customer*, product*, i-sector*)>
<!ELEMENT quality (#PCDATA)> ... ]>
```

The DTD is based on web page analyses and gives all details of a company profile for foundries. Not all elements from the DTD are used by each company profile. This kind of DTD is used for presentation of contents. Parts of the DTD (e.g., address information, measures) can be used for analysis of web pages with our NLP tools.

4.2 Instantiation of Elements

In this section we present some examples for the recognition of information which is needed for the creation of a company profile. As an illustrative case we again take profiles of casting companies. In casting a lot of measurements, like mould, weight etc. are relevant. For the detection of measurement information we use the syntactic parser of XDOC. The grammar of the chart parser was extended with rules, which describe structures like: 2500 x 1400 x 600 or 1000 x 800 x 350 / 350 mm. A general pattern for this can be described by the following rules:

- **MS-ENTRY**: number measure (optional)
- **3D-MS-ENTRY**: MS-ENTRY x MS-ENTRY x MS-ENTRY

and for foundry specific dimensions:

- **3D-MS-ENTRY-C**: MS-ENTRY x MS-ENTRY x MS-ENTRY / MS-ENTRY

Measuring units (like mm, kg etc.) are handled in a part of the abbreviation lexicon. Example 6 shows the results of POS tagging of the phrase: ‘Kastenformat 500 x 600 x 150 / 150 mm’.

Example 6 Results of POS Tagging.

```xml
<N>Kastenformat</N> <NR>500</NR> <ABBR>x</ABBR> <NR>600</NR> <ABBR>x</ABBR> <NR>150</NR> <ABBR>/</ABBR> <NR>150</NR> <ABBR>mm</ABBR>
```

Numbers are tagged with NR, nouns with N. The letter ‘x’ – used as a multiplication operator – is in a first step handled like an abbreviation (tag ABBR). In the future we may work with a separate category for these specific symbols. With the rules from above the syntactic parser interprets the results of the POS tagger as the following structure:

Example 7 Results of Syntactic Parsing.

```xml
<3D-MS-ENTRY-C RULE="MEAS4"> <3D-MS-ENTRY RULE="MEAS3"> <MS-ENTRY RULE="MEAS2"> <XR>1000</XR> </MS-ENTRY> <ABBRIr></ABBRIr> <MS-ENTRY RULE="MEAS2"> <XR>800</XR> </MS-ENTRY> <ABBRIr></ABBRIr> <MS-ENTRY RULE="MEAS2"> <XR>350</XR> </MS-ENTRY> </3D-MS-ENTRY> </ABBRIr> </ABBRIr> <MS-ENTRY RULE="MEAS1"> <XR>350</XR> <ABBRIr>mm</ABBRIr> </MS-ENTRY> </3D-MS-ENTRY-C>
```

Now with the SISS approach we are able to assign the different numbers in the phrase to height, length, width and the diameter dimensions of a cylindric 3D-object. The SISS approach splits whole syntactic structure into smaller structures and assigns a sense to these structures. The possible assignments are coded in a lexicon. For this example the assignments are shown in example 8:

Example 8 Excerpt from the Lexicon for SISS.
For each child in a structure the assignments define an interpretation; if the child structure is also a structure, which is separately described in the lexicon, it will be annotated with the tag EXPAND. The semantic sense is described through the element of the tag EXPAND, e.g., dimension-length. A COMPONENT with the element NIL means that this child will not be interpreted.

Another method for the detection of semantic relations between linguistic structures is XDOC’s case frame analysis. A case frame describes relations between various syntactic structures, like a token (noun or verb) and its linguistic complements in the form of noun phrases or prepositional phrases. An example: The german phrase ‘Formanlagen fuer Grauguss’ can be semantically interpreted through the analysis of the case frame of the token ‘Formanlage’ (see example 9). The case frame contains a relation named TECHNIQUE, the filler of this relation must be of the semantic category process (described by the tag ASSIGN-TO) and a syntactic structure of a prepositional phrase with an accusative noun phrase and the preposition ‘fuer’ (tag FORM). In our example the preposition phrase ‘fuer Grauguss’ is recognized as a filler for the relation TECHNIQUE, because the token ‘Grauguss’ is from the semantic category PROCESS.

Example 9 Results of Case Frame Analysis.

Treatment of Coordination To be applicable on a realistic scale, a toolbox for document processing needs generic solutions on all levels of the linguistic system (lexical, syntactic, semantic, discourse).

It is well known that there are always interactions and interdependencies between different levels. An example: In our current work we investigate possible solutions for the issues of coordinated structures. These structures need proper treatment on the lexical level (e.g., treatment of prefix and suffix truncation in POS tagging), syntactic level (e.g., grammar rules for adjective groups, noun groups and mixtures of both) and on the semantic level (e.g., rules to decide about a disjunctive vs. a conjunctive reading).

Complex coordinated structures are relevant in virtually all our technical and medical applications. Thus our solutions should clearly be generic and independent of the domain, but domain knowledge as a resource may be needed for semantic interpretation.

Coordinated structures are relevant for querying documents as well. As a point in case see phrases like Klein- und Mittelserien (in english: small batch and middle production). If you search for Kleinserien with the help of a conventional search engine, you probably will not find web pages with the phrase Klein- und Mittelserien.

Towards Generic Solutions NLP has both an analytic and a generative ‘procedural’ perspective in the sense that grammars are not only used to merely ‘describe’ linguistic structures but to actually analyze or generate them. The analogy for documents would be to not only use descriptions (DTDs, XML
Schemata) to validate already marked up instances but to employ descriptions both for analysis of yet unmarked documents as well as for the generation of documents that obey the rules of a schema.

The move from DTDs to XML Schemata is a big step forward and allows to better model document contents and structure. From the perspective of not only describing but automatically analyzing documents further improvements should be envisaged. Will it be possible to integrate information about the automatic detection of document elements into an extended document description framework? Such a possibility would allow to declaratively configure schemata for documents that could then be exploited for the processing of raw documents that implicitly follow the schema but do not have explicit markup yet.

**Limits of Markup** Where are the limits for enriching documents with XML markup? The basic idea of delimiting spans of text in a document within an opening and a closing tag is simple and convincing. But: will simple well formed markup really suffice? When will we unavoidably have to work with concurrent markup? When will we have to give up the adjacency requirement for text spans and will have to deal with discontinuous structures as well?

6 Conclusion

The vision of the Semantic Web is a stimulating driving force for research in text technology, Computational Linguistics (CL) and knowledge representation. The basic issues are actually not new, but they now receive a much broader attention than before. These different approaches are complementary, combining them will result in synergetic effects.

The focus of the SGML/XML approaches to documents has been on providing means to describe document structures (i.e., DTDs, schemata) and on tools to validate already marked up document instances with respect to an abstract description (i.e., parsers, validators). From an NLP perspective the weakest point in SGML/XML is that the contents of terminal elements (i.e., elements with text only) is simply uninterpreted PCDATA, i.e., strings without their internal structure made explicit. Although in principle markup can go down to the granularity of single characters there is a ‘traditional’ bias in the markup community towards macro level structuring with paragraphs as the typical grain size.

On the other hand, many – but definitely not all – techniques and tools from CL and NLP have their focus on the word, phrase or sentence level. Why not combine macro level structuring with lexical, syntactic and semantic analysis of otherwise uninterpreted PCDATA?

The third field – knowledge representation – is indispensable because semantics needs grounding in formal KR structures. Ontologies (i.e., basic vocabularies for expressing meaningful relations) and worked out a taxonomy of interrelated domain concepts are the backbone of any semantic account of document contents.

Acknowledgement

We have to thank the anonymous reviewers for their comments and our colleagues, J. Kapfer and M. Pirotrowski, for their efforts in thorough proofreading and their constructive criticism.

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