Utilizing the World Wide Web as an Encyclopedia: Extracting Term Descriptions from Semi-Structured Texts

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Abstract

In this paper, we propose a method to extract descriptions of technical terms from Web pages in order to utilize the World Wide Web as an encyclopedia. We use linguistic patterns and HTML text structures to extract text fragments containing term descriptions. We also use a language model to discard extraneous descriptions, and a clustering method to summarize resultant descriptions. We show the effectiveness of our method by way of experiments.

1 Introduction

Reflecting the growth in utilization of machine readable texts, extraction and acquisition of linguistic knowledge from large corpora has been one of the major topics within the natural language processing (NLP) community. A sample of linguistic knowledge targeted in past research includes grammars (Kupiec and Maxwell, 1992), word classes (Hatzivassiloglou and McKeown, 1993) and bilingual lexicons (Smadja et al., 1996). While human experts find it difficult to produce exhaustive and consistent linguistic knowledge, automatic methods can help alleviate problems associated with manual construction.

Term descriptions, which are usually carefully organized in encyclopedias, are valuable linguistic knowledge, but have seldom been targeted in past NLP literature. As with other types of linguistic knowledge relying on human introspection and supervision, constructing encyclopedias is quite expensive. Additionally, since existing encyclopedias are usually revised every few years, in many cases users find it difficult to obtain descriptions for newly created terms.

To cope with the above limitation of existing encyclopedias, it is possible to use a search engine on the World Wide Web as a substitute, expecting that certain Web pages will describe the submitted keyword. However, since keyword-based search engines often retrieve a surprisingly large number of Web pages, it is time-consuming to identify pages that satisfy the users' information needs.

In view of this problem, we propose a method to automatically extract term descriptions from Web pages and summarize them. In this paper, we generally use "Web pages" to refer to those pages containing textual contents, excluding those with only image/audio information. Besides this, we specifically target descriptions for technical terms, and thus "terms" generally refer to technical terms.

In brief, our method extracts fragments of Web pages, based on patterns (or templates) typically used to describe terms. Web pages are in a sense semi-structured data, because HTML (Hyper Text Markup Language) tags provide the textual information contained in a page with a certain structure. Thus, our method relies on both linguistic and structural description patterns.

We used several NLP techniques to semi-automatically produce linguistic patterns. We call this approach "NLP-based method."

We also produced several heuristics associated with the use of HTML tags, which we call "HTML-based method." While the former method is language-dependent, and currently applied only to Japanese, the latter method is theoretically language-independent.

Our research can be classified from several different perspectives. As explained in the beginning of this section, our research can be seen as linguistic knowledge extraction. Specifically, our research is related to Web mining methods (Nie et al., 1999; Resnik, 1999).

From an information retrieval point of view, our research can be seen as constructing domain-specific (or task-oriented) Web search engines and software agents (Etzioni, 1997; McCallum et al., 1999).

2 Overview

Our objective is to collect encyclopedic knowledge from the Web, for which we designed a system involving two processes. As with existing Web search systems, in the background process our system periodically updates a database consisting of term descriptions (a description database), while users can browse term descriptions anytime in the foreground process.

In the background process, depicted as in Figure 1, a search engine searches the Web for pages containing terms listed in a lexicon.

Then, fragments (such as paragraphs) of retrieved Web pages are extracted based on linguistic and structural description patterns. Note that as a preprocessing for the extraction process, we discard newline codes, redundant white spaces, and HTML tags that our extraction method does not use, in order to standardize the layout of Web pages.

However, in some cases the extraction process is unsuccessful, and thus extracted fragments are not linguistically understandable. In addition, Web pages contain some non-linguistic information, such as special characters (symbols) and e-mail addresses for contact, along with linguistic information. Consequently, those noises decrease extraction accuracy.

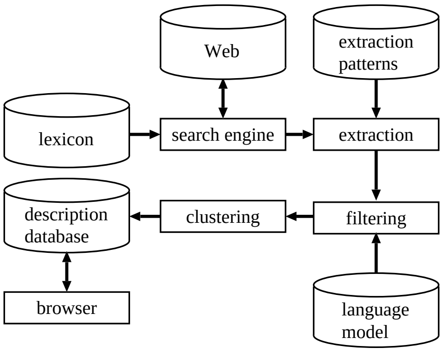


Figure 1: The control flow of our extraction system.

In view of this problem, we perform a filtering to enhance the extraction accuracy. In practice, we use a language model to measure the extent to which a given extracted fragment can be linguistic, and index only fragments judged as linguistic into the description database.

At the same time, the URLs of Web pages from which descriptions were extracted are also indexed in the database, so that users can browse the full content, in the case where descriptions extracted are not satisfactory.

In the case where a number of descriptions are extracted for a single term, the resultant description set is redundant, because it contains a number of similar descriptions. Thus, it is preferable to summarize descriptions, rather than to present all the descriptions as a list.

For this purpose, we use a clustering method to divide descriptions for a single term into a certain number of clusters, and present only descriptions that are representative for each cluster. As a result, it is expected that descriptions resembling one another will be in the same cluster, and that each cluster corresponds to different viewpoints and word senses.

Possible sources of the lexicon include existing machine readable terminology dictionaries, which often list terms, but lack descriptions. However, since new terms unlisted in existing dictionaries also have to be considered, newspaper articles and magazines distributed via the Web can be possible sources. In other words, a morphological analysis is performed periodically (e.g., weekly) to identify word tokens from those resources, in order to enhance the lexicon. However, this is not the central issue in this paper.

In the foreground process, given an input term, a browser presents one or more descriptions to a user. In the case where the database does not index descriptions for the given term, term descriptions are dynamically extracted as in the background process. The background process is optional, and thus term descriptions can always be obtained dynamically. However, this potentially decreases the time efficiency for a real-time response.

Figure 2 shows a Web browser, in which our prototype page presents several Japanese descriptions extracted for the word "*deeta-mainingu* (data mining)." For example, an English translation for the first description is as follows:

> data mining is a process that collects data for a certain task, and retrieves relations latent in the data.

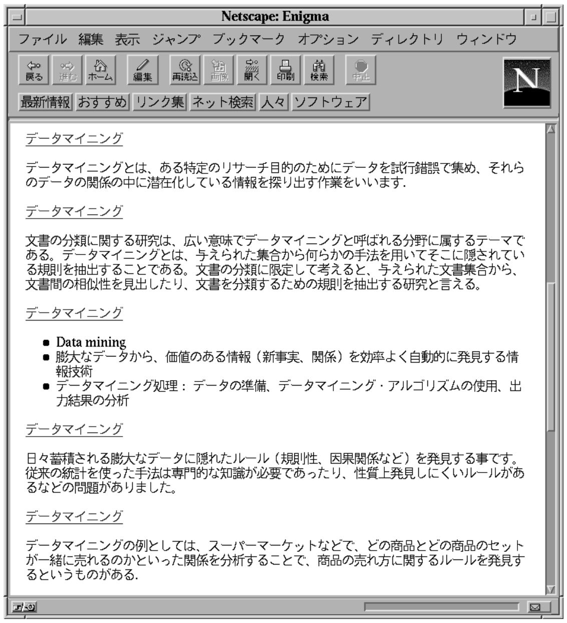
In Figure 2, each description uses various expressions, but describes the same content: data mining is a process which discovers rules latent in given databases. It is expected that users can understand what data mining is, by browsing some of those descriptions. In addition, each headword ("*deeta-mainingu*" in this case) positioned above each description is linked to the Web page from which the description was extracted.

In the following sections, we first elaborate on the NLP/HTML-based extraction methods in Section 3. We then elaborate on noise reduction and clustering methods in Sections 4 and 5, respectively. Finally, in Section 6 we investigate the effectiveness of our extraction method by way of experiments.

3 Extracting Term Descriptions

3.1 NLP-based Extraction Method

The crucial content for the NLP-based extraction method is the way to produce linguistic patterns that can be used to describe technical terms. However, human introspection is a difficult method to exhaustively enumerate possible description patterns.



データマイニング

データマイニングとは、ある特定のリサーチ目的のためにデータを試行錯誤で集め、それらのデータの関係の中に潜在化している情報を探り出す作業をいいます.

データマイニング

文書の分類に関する研究は、広い意味でデータマイニングと呼ばれる分野に属するテーマである。データマイニングとは、与えられた集合から何らかの手法を用いてそこに隠されている規則を抽出することである。文書の分類に限定して考えると、与えられた文書集合から、文書間の相似性を見出したり、文書を分類するための規則を抽出する研究と言える。

データマイニング

- **Data mining**
- 膨大なデータから、価値のある情報（新事実、関係）を効率よく自動的に発見する情報技術
- データマイニング処理： データの準備、データマイニング・アルゴリズムの使用、出力結果の分析

データマイニング

日々蓄積される膨大なデータに隠れたルール（規則性、因果関係など）を発見する事です。従来の統計を使った手法は専門的な知識が必要であったり、性質上発見しにくいルールがあるなどの問題がありました。

データマイニング

データマイニングの例としては、スーパーマーケットなどで、どの商品とどの商品のセットが一緒に売れるのかといった関係を分析することで、商品の売れ方に関するルールを発見するというものがある.

Figure 2: Example Japanese descriptions for "*deeta-mainingu* (data mining)."

Thus, we used NLP techniques to semi-automatically collect description patterns from machine readable encyclopedias, because they usually contain a significantly large number of descriptions for existing terms. In practice, we used the Japanese CD-ROM World Encyclopedia (Heibonsha, 1998), which includes approximately 80,000 entries related to various fields.

Before collecting description patterns, through a preliminary study on the encyclopedia we used, we found that term descriptions frequently contain salient patterns consisting of two Japanese "*bunsetsu*" phrases. The following sentence, which describes the term "X," contains a typical *bunsetsu* combination, that is, "X *toha*" and "*de-aru*":

X *toha* Y *de-aru* (X is Y).[1]

[1] Although "*de-aru*" itself is not a *bunsetsu* phrase, we use *bunsetsu* phrases to refer to combinations of several words.

In other words, we collected description patterns, based on the co-occurrence of two *bunsetsu* phrases, as in the following method.

First, we collected entries associated with technical terms listed in the World Encyclopedia, and replaced headwords with a variable "X." Note that the World Encyclopedia describes various types of words, including technical terms, historical people and places, and thus description patterns vary depending on the word type. For example, entries for historical people usually contain when/where the people were born and their major contributions to the society.

However, for the purposes of our extraction, it is desirable to use entries solely associated with technical terms. We then consulted the EDR machine readable technical terminology dictionary, which contains approximately 120,000 terms related to the information processing field (Japan Electronic Dictionary Research Institute, 1995), and obtained 2,259 entries associated with terms listed in the EDR dictionary.

Second, we used the ChaSen morphological analyzer (Matsumoto et al., 1997), which has commonly been used for much Japanese NLP research, to segment collected entries into words, and assign them parts-of-speech. We also developed simple heuristics to produce *bunsetsu* phrases based on the part-of-speech information.

Finally, we collected combinations of two *bunsetsu* phrases, and sorted them according to their co-occurrence frequency, in descending order. However, since the resultant *bunsetsu* co-occurrences (even with higher rankings) are extraneous, we supervised (verified, corrected or discarded) the top 100 candidates, and produced 20 description patterns. Figure 3 shows a fragment of the resultant patterns and their English glosses. In this figure, "X" and "Y" denote variables to which technical terms and sentence fragments can be unified, respectively.

Here, we are in a position to extract sentences that match with description patterns, from Web pages retrieved by the search engine (see Figure 1). In this process, we do not conduct morphological analysis on Web pages, because of computational cost. Instead, we first segment textual contents in Web pages into sentences, based on the Japanese punctuation system, and use a surface pattern matching based on regular expressions.

Japanese	English Gloss
X *toha* Y *dearu.*	X is Y.
X *ha* Y *dearu.*	X is Y.
Y *wo* X *to-iu.*	Y is called X.
X *wo* Y *to-sadameru.*	X is defined as Y.
Y *wo* X *to-yobu.*	Y is called X.

Figure 3: A fragment of linguistic description patterns we produced.

However, in most cases term descriptions consist of more than one sentence. This is especially salient in the case where anaphoric expressions and itemization are used. Thus, it is desirable to extract a larger fragment containing sentences that match with description patterns.

In view of this problem, we first use linguistic description patterns to briefly identify a zone, and sequentially search the following fragments relying partially on HTML tags, until a certain fragment is extracted:[2]

(1) paragraph tagged with `<P>...</P>` (or `<P>...<P>` in the case where `</P>` is missing),

(2) itemization tagged with `<UL>...</UL>`,

(3) N sentences identified with the Japanese punctuation system, where the sentence that matched with a description pattern is positioned as near center as possible, where we empirically set $N = 3$.

3.2 HTML-based Extraction Method

Through a preliminary study on existing Web pages, we identified two typical usages of

[2] Although we use HTML tags to identify appropriate text fragments, we call the method described in this section NLP-based method, in a comparison with the method in Section 3.2 that relies solely on HTML tags.

HTML tags associated with describing technical terms.

In the first usage, a term in question is highlighted as a heading by way of <H>...</H>, <B>...</B> or <DT> tag, and followed by its description in a short fragment. In the second usage, terms that are potentially unfamiliar to readers are tagged with the anchor <A> tag, providing hyperlinks to other pages (or a different position within the same page) where they are described.

The crucial factor here is to determine which fragment in the page is extracted as a description. For this purpose, we use the same rules described in Section 3.1. However, unlike the NLP-based method, in the HTML-based method we extract the fragment that *follows* the heading and the position linked from the anchor. However, in the case where a term in question is tagged with <DT>, we extract the following fragment tagged with <DD>. Note that <DT> and <DD> are inherently provided to describe terms.

The HTML-based method is expected to extract term descriptions that cannot be extracted by the NLP-based method, and vice versa. In fact, in Figure 2 the third and fourth descriptions were extracted with the HTML-based method, while the rest were extracted with the NLP-based method.

4 Language Modeling for Filtering

Given a set of Web page fragments extracted by the NLP/HTML-based methods, we select fragments that are linguistically understandable, and index them into the description database. For this purpose, we perform a language modeling, so as to quantify the extent to which a given text fragment is linguistically acceptable.

There are several alternative methods for language modeling. For example, grammars are relatively strict language modeling methods. However, we use a model based on N-gram, which is usually more robust than that based on grammars. In other words, text fragments with lower perplexity values are more linguistically acceptable.

In practice, we used the CMU-Cambridge toolkit (Clarkson and Rosenfeld, 1997), and produced a trigram-based language model from two years of Mainichi Shimbun Japanese newspaper articles (Mainichi Shimbun, 1994 1995), which were automatically segmented into words by the ChaSen morphological analyzer (Matsumoto et al., 1997).

In the current implementation, we empirically select as the final extraction results text fragments whose perplexity values are lower than 1,000.

5 Clustering Term Descriptions

For the purpose of clustering term descriptions extracted using methods in Sections 3 and 4, we use the Hierarchical Bayesian Clustering (HBC) method (Iwayama and Tokunaga, 1995), which has been used for clustering news articles and constructing thesauri.

As with a number of hierarchical clustering methods, the HBC method merges similar items (i.e., term descriptions in our case) in a bottom-up manner, until all the items are merged into a single cluster. That is, a certain number of clusters can be obtained by splitting the resultant hierarchy at a certain level.

At the same time, the HBC method also determines the most representative item (centroid) for each cluster. Then, we present only those centroids to users.

The similarity between items is computed based on feature vectors that characterize each item. In our case, vectors for each term description consist of frequencies of content words (e.g., nouns and verbs identified through a morphological analysis) appearing in the description.

6 Experimentation

6.1 Methodology

We investigated the effectiveness of our extraction method from a scientific point of view. However, unlike other research topics where benchmark test collections are available to the public (e.g., information retrieval), there are two major problems for the purpose of our experimentation, as follows:

- production of test terms for which descriptions are extracted,

- judgement for descriptions extracted for those test terms.

For test terms, possible sources are those listed in existing terminology dictionaries. However, since the judgement can be considerably expensive for a large number of test terms, it is preferable to selectively sample a small number of terms that potentially reflect the interest in the real world.

In view of this problem, we used as test terms those contained in queries in the NACSIS test collection (Kando et al., 1999), which consists of 60 Japanese queries and approximately 330,000 abstracts (in either a combination of English and Japanese or either of the languages individually), collected from technical papers published by 65 Japanese associations for various fields.[3]

This collection was originally produced for the evaluation of information retrieval systems, where each query is used to retrieve technical abstracts. Thus, the title field of each query usually contains one or more technical terms. Besides this, since each query was produced based partially on existing technical abstracts, they reflect the real world interest, to some extent. As a result, we extracted 53 test terms, as shown in Table 1. In this table, we romanized Japanese terms, and inserted hyphens between each morpheme for enhanced readability.

Note that unlike the case of information retrieval (e.g., a patent retrieval), where every relevant document must be retrieved, in our case even one description can potentially be sufficient. In other words, in our experiments, more weight is attached to accuracy (precision) than recall.

For the search engine in Figure 1, we used "goo,"[4] which is one of the major Japanese Web search engines. Then, for each extracted description, one of the authors judged it correct or incorrect.

6.2 Results

Out of the 53 test terms extracted from the NACSIS collection, for 44 terms goo retrieved one or more Web pages. Among those 44 test terms, our method extracted at least one term description for 27 terms, disregarding the judgement. Thus, the coverage (or applicability) of our method was 61.4%. In Table 1, the third column denotes the number of Web pages identified by goo. However, goo retrieves contents for only the top 1,000 pages.

Table 1 also shows the number descriptions judged as correct (the column "#C"), the total number of descriptions extracted (the column "#T"), and the accuracy (the column "A"), for both cases with/without the trigram-based language model.

Table 1 shows that the NLP/HTML-based methods extracted appropriate term descriptions with a 63.5% accuracy, and that the trigram-based language model further improved the accuracy from 63.5% to 67.9%. In other words, only two descriptions are sufficient for users to understand a term in question. Reading a few descriptions is not time-consuming, because they usually consist of short paragraphs.

We also investigated the effectiveness of clustering, where for each test term, we clustered descriptions into three clusters (in the case where there are less than four descriptions, individual descriptions were regarded as different clusters), and only descriptions determined as representative by the HBC method were presented as the final result. We found that 66.7% of descriptions presented were correct ones. In other words, users can obtain descriptions from different viewpoints and word senses, maintaining the extraction accuracy obtained above (i.e., 67.9%).

However, we concede that we did not investigate whether or not each cluster corresponds to different viewpoints in a rigorous manner.

For the polysemy problem, we investigated all the descriptions extracted, and found that only "*korokeishon* (collocation)" was associated with two word senses, that is, "word collocations" and "position of machinery." Among the three representative descriptions

[3] http://www.rd.nacsis.ac.jp/~ntcadm/index-en.html

[4] http://www.goo.ne.jp/

Table 1: Extraction accuracy for the 27 test terms (#C = the number of correct descriptions, #T = the total number of extracted descriptions, A = accuracy (%)).

			w/o Trigram			w Trigram		
Japanese Term	English Gloss	#Pages	#C	#T	A	#C	#T	A
Zipf-*no-housoku*	Zipf's law	15	1	1	100	1	1	100
akusesu-seigyo	access control	6,925	10	20	50.0	10	20	50.0
bunsho-gazou-rikai	document image understanding	43	1	1	100	1	1	100
chiteki-eejento	intelligent agent	323	3	5	60.0	3	5	60.0
deeta-mainingu	data mining	3,389	37	49	75.5	30	40	75.0
denshi-sukashi	digital watermark	2,124	29	32	90.6	29	32	90.6
denshi-toshokan	digital library	7,938	10	26	38.5	8	17	47.1
gazou-kensaku	image retrieval	1,694	1	4	25.0	1	3	33.3
guruupuwea	groupware	19,760	14	40	35.0	12	21	57.1
hikari-faibaa	optical fiber	10,078	17	25	68.0	14	21	66.7
ichi-keisoku	position measurement	735	0	3	0	0	3	0
identeki-arugorizumu	genetic algorithm	4,686	24	31	77.4	22	28	78.6
jinkou-chinou	artificial intelligence	18,190	10	19	52.6	9	13	69.2
jiritsu-idou-robotto	autonomous mobile robot	792	2	2	100	2	2	100
jisedai-intaanetto	next generation Internet	1,963	6	10	60.0	6	10	60.0
kiiwaado-jidou-chuushutsu	keyword automatic extraction	25	1	1	100	1	1	100
kikai-hon'yaku	machine translation	3,141	1	10	10.0	0	8	0
korokeishon	collocation	547	7	16	43.8	7	15	46.7
koshou-shindan	fault diagnosis	1,682	2	5	40.0	2	4	50.0
maruchikyasuto	multicast	5,758	18	25	72.0	15	22	68.2
media-douki	media synchronization	46	1	1	100	1	1	100
nettowaaku-toporojii	network topology	438	1	4	25.0	0	3	0
nyuuraru-nettowaaku	neural network	9,537	37	47	78.7	36	45	80.0
ringu-gata-nettowaaku	ring network	44	0	1	0	0	1	0
shisourasu	thesaurus	3,399	21	23	91.3	19	20	95.0
souraa-kaa	solar car	3,698	12	21	57.1	12	21	57.1
teromea	telomere	873	26	36	72.2	25	34	73.5
total	—	109,049	292	460	63.5	266	392	67.9

for "*korokeishon* (collocation)," two corresponded to the first sense, and one corresponded to the second sense. To sum up, the HBC clustering method correctly identified polysemy.

7 Conclusion

In this paper, we proposed a method to extract encyclopedic knowledge from the World Wide Web.

For extracting fragments of Web pages containing term descriptions, we used linguistic and HTML structural patterns typically used to describe terms. Then, we used a language model to discard irrelevant descriptions. We also used a clustering method to summarize extracted descriptions based on different viewpoints and word senses.

We evaluated our method by way of experiments, and found that the accuracy of our extraction method was practical, that is, a user can understand a term in question, by browsing two descriptions, on average. We also found that the language model and the clustering method further enhanced our framework.

Future work will include experiments using a larger number of test terms, and application of extracted descriptions to other NLP research.

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