AN APPROACH FOR DICTIONARY-BASED CONCEPT MINING IN TURKISH

by

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ABSTRACT

AN APPROACH FOR DICTIONARY-BASED CONCEPT MINING IN TURKISH

Concept Mining is a field of NLP, where the documents, be it simple text files, e-mails, papers, journals, or any other textual materials are scanned, and the most comprehensive concepts concerning these documents are to be shown. Here concepts can be thought of as general ideas extracted from the documents. Concepts can also be extracted from visual, or audio materials, but this thesis focuses on extracting concepts from only textual materials, in an efficient way in terms of time, quality, and accuracy. In NLP field, the difference between keyword, and concept should be noticed in that keyword has to be present in the material being scanned, whereas concepts don't have to be present in this material. This is quite a big challenge which may call for the use of NLP, or statistical methods which may be beneficiary for extracting expressive concepts. This field has been studied on especially in western languages such as English, French, German, Spanish amongst many, and quite successful results have been achieved. As for Turkish this topic is still quite immature vis-à-vis the languages mentioned above. It has to be taken into account that Turkish is an agglutinative language, hence the documents first need to be pre-processed in order to process the stems. Among these words, we take only nouns into account since concepts are generally considered nouns. This thesis makes use of statistical methods, and Turkish Dictionary. The statistical method counts the frequency of words whereas the use of dictionary may suggest some probable concept words that are not present in the documents. The success rate (precision) of this thesis concept extraction method is 63.97%.

ÖZET

TÜRKÇE İÇİN SÖZLÜK TABANLI BİR KAVRAM ÇIKARMA SİSTEMİ GELİŞTİRİLMESİ

Kavram madenciliği, basit metin dosyalarının, elektronik postaların, akademik yazıların, gazete kupürlerinin veya başka metin materyallerinin taranıp, bu dokümanlardan en kapsamlı kavramların belirlendiği, Doğal Dil İşlemenin bir alanıdır. Burada kavramlar dokümanlardan çıkarılmış genel fikirler olarak düşünülebilir. Kavramlar aynı zamanda görsel veya işitsel materyallerden de çıkarılabilir; ama bu tez, zaman, kalite ve doğruluk açısından verimliliği amaç edinerek, sadece metinsel dokümanlardan kavram çıkarma üzerine odaklanmıştır. Doğal Dil İşleme alanında anahtar kelime ile kavram arasındaki fark, anahtar kelimenin dokümanda geçebilirken, kavramların dokümanda geçme zorunluluğu olmamasıdır. Bu, anlamlı kavramlar çıkarılabilmesine olanak sağlayan Doğal Dil İşleme ve istatistiksel metotların kullanılmasını gerekli kılabilir. Bu alan, İngilizce, Fransızca, Almanca, İspanyolca ve diğer birçok Batı dillerinde üzerinde çalışılmakta ve çok başarılı sonuçlar elde edilmektedir. Türkçede ise bu konu üzerine diğer dillere kıyasla çok çalışma olmamıştır. Türkçe sondan eklemeli bir dildir, bu yüzden dokümanlar önce bazı işlemlerden geçirilmeli, sonra da kelimelerin kökleri işleme tabii tutulmalıdır. Bu kelimeler arasından sadece isimler göz önünde bulundurulmalıdır; çünkü kavramlar genelde isimler olarak düşünülmektedir. Bu tez çalışmasında istatistiksel metot ve Türkçe sözlüğünden yararlanılmıştır. İstatistiksel metot kelimelerin bulunma sıklığını hesaba katan bir yol izlerken, sözlük kullanımı da dokümanda yer almayan kelimeleri olası kavram olarak önerebilmektedir. Bu tez kavram çıkarma metodunun başarı oranı yüzde 63.97 olarak belirlenmiştir.

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LIST OF ACRONYMS/ABBREVIATIONS

AI	Artificial Intelligence
BoDis	Boun Morphological Disambiguator
BoMorP	Boun Morphological Parser
CM	Concept Mining
HMM	Hidden Markov Model
IDF	Inverse Document Frequency
IR	Information Retrieval
LDA	Latent Dirichlet Allocation
LM	Language Model
LSA	Latent Semantic Analysis
ML	Machine Learning
NLP	Natural Language Processing
POS	Part-of-Speech
SVM	Support Vector Machine
TDK	Türk Dil Kurumu
TF	Term Frequency
UTF-8	8-bit Unicode Transformation Format
XML	Extensible Markup Language

1. INTRODUCTION

As of today, there are quite a number of materials, especially in electronic format many of which are processed, and used in accordance with the need of the people. For example search engines may index the web site contents, and after processing those sites, people may benefit from those materials with regard to their interests. The most common approach, in search engine domain, to get the relevant page to the needs of the user is to make use of the queries being composed of keywords. These keywords generally have to be present in the documents if some of them are to be returned, and some specific AI algorithms may be applied to measure the relevance between the keywords typed in, and the documents. Besides search engines, one may want to get a general information about a web site, blog, e-mail, survey, video or audio file, database, or some any other material. It is the case that the users don't have to know the keywords according to which some documents are to be returned or processed, so some generalized knowledge concerning those documents may be extracted, and the users may have a general idea about them.

Concept is a term used in many contexts, but its use is especially in the domain of ontology, a field of study in philosophy. In this context, concepts can be thought of as mental representations of objects, abstract objects, and constituents of propositions which makes them mediate between language and thought, or abilities that are peculiar to agents [1]. In this aspect, concepts can be thought of as generalized representations of words, which is at a level of higher abstraction. For example the word 'organism' may be a probable concept candidate for the word 'animal' since the former word is at a higher level of abstraction of the latter one. An abstract, or concrete object representing a word may have one or many concepts, also a concept may correspond to many words.

Concept extraction can be implemented in two ways as follows:

(i) Expert-based approach,
(ii) NLP or Statistical approach.

In the expert-based approach, the documents can be examined by the humans who are experts in the domain of those documents. It has many advantages, but it may be time consuming, and financial problems may be a factor. Instead the second method, that include NLP, and statistical approaches, can be used. NLP and statistical methods implement some AI algorithms that can be applied to extract concepts, some of which are clustering, latent semantic analysis (LSA), HMM (Hidden Markov Model), support vector machines (SVM), and many more. The difference between statistical, and NLP approaches is that human intervention is possible in the latter one [2]. These approaches would be efficient in terms of time, and finance, but the accuracy may be not as high as determined by expert humans.

The majority of studies in the field of Concept Mining is made in English, and many commercial software applications are built for this purpose. Some of major such software applications are AlchemyAPI, WordStat, and SPSS PASW Text Analytics. The first one proposes concepts only in English, but it also proposes keywords, sentiment analysis results, and other categorical, and semantic attributes on the documents it processes, whereas the latter two software applications provide Concept Mining algorithms in many languages besides English such as French, German, Arabic, Spanish, and some others. When it comes to Turkish, there is no known Concept Extraction software developed for this language, whereas there are some software applications which can extract keywords or key phrases as mentioned in [3, 4]. The difference is that keywords, or key phrases have to be present in the documents being scanned whereas concepts may not be obliged to be present in the document. This thesis proposes a new method for extracting concepts in Turkish through a new method. So far, even in English the use of dictionary apart from WordNet is rarely seen, in this thesis the use of dictionary may be seen as a novel approach.

The outline of this thesis work is as follows: Chapter 2 is concerning literature survey, and related works are mentioned. Chapter 3 is concerning the algorithm that is developed for this thesis work, and this method is elaborately explained. Chapter 4 is concerning the experiments, evaluations, and results. Lastly, Chapter 5 is concerning the conclusion of the thesis.

2. LITERATURE SURVEY

Concept Mining is a field where many studies are made, and it has an importance that is increasing due to the massive amounts of electronic materials and need to process those sources. For example when searching something through a search engine, or when one looks at the document, the users may not want to read all the material, instead they may want to look at keywords, to decide whether this is relevant to what they are searching for in a short period of time. Whereas the keywords have to be present in the documents, the situation for concepts are different: A concept may be present or not in the document being processed, and a concept often represent more generalized abstract ideas. Giving concepts of a document would also make the reader decide whether the document is relevant to his/her inquisition, and have a general knowledge concerning this document before even starting to read it.

Concept Extraction is used in not only field of Information Retrieval (IR), but also many different fields of study, and sectors. Some of the use of Concept Mining applications, besides IR, are concerning fields as follows:

- Medical use as mentioned in [5, 6]. The detection of cancer areas can be an example of extraction of concept from visual material. Also detecting the most common diseases in a specific patient population can also be perceived as an another example of Concept Mining.
- Legal cases [7]. Categorizing the judiciary classes, such as adult court, appellate court, and many others are some examples of concept extraction in this case.
- Banking systems. The banks may track the profiles of creditworthy customers, and propose offers, this can also be thought of as a Concept Mining method, the privacy violation can be the matter here though. Also fraud detection is an example of this field.
- Satellite images can be arranged, and identified (such as urban, or rural areas) with Concept Mining method [5].

- Results of surveys, that are open-ended, can be evaluated thanks to the use of Concept Mining methods.

Concept Mining has a wide range of use, but most of the studies are based on extracting concepts from textual materials, whereas audio or video materials are not worked on a lot.

2.1. Some Methods Examined in Concept Mining Field

In the field of study concerning Concept Mining, generally AI algorithms as well as different dictionaries, and lexical databases are used. Some papers propose a method which makes use of statistical methods, whereas some others make use of NLP algorithms. The most widely used lexical database is WordNet in this field, because this lexical database has a unit called synset, which determines the relationship between words, taking into account relations between words may help semantic relevance, and expressive concepts be extracted. Some papers propose the use of clustering, a Machine Learning (ML) algorithm, whereas some others make use of Latent Dirichlet Allocation (LDA), HMM, and many other methods.

Initially, as this thesis is concerning Concept Mining in Turkish, the algorithm in paper by Meryem Uzun-Per [8], which is also concerning Concept Mining in the same language, is carefully examined. In this paper, k-means clustering method, which is an AI method, is used. Initially documents are parsed, and then disambiguated in order to get the word stems eliminating inflectional morphemes, especially taking into account that Turkish is an agglutinative language. Then only nouns are taken into account as concepts are generally considered noun. But this thesis work doesn't propose a thorough automatic method, it also counts on the human-specialist's contribution. First document-noun matrix is built that shows the frequencies of column representative nouns in the row representative document nouns. Then, in accordance with this matrix, clusters are created including those nouns. Those clusters afterwards are assigned to documents according to a threshold value. A ratio that takes into account the division of frequency of nouns, which are also in specific cluster, in a document by the total number of words in that cluster is tested against

that threshold value. If the ratio exceeds that ratio, then cluster would be assigned to that document. Then, through the help of human specialist, concepts are assigned to those clusters, and then indirectly those concepts are assigned to the documents. In this thesis work also key files are created for each separate document, and those are used in testing phase. The success rate obtained through this paper work is 51%.

The algorithm proposed by Elberrichi *et al.* [9] makes use of the lexical database WordNet, which has relation sets called synset. Synsets are composed of many relations such as hypernymy, hyponymy, synonymy, and many others. Here hypernymy corresponds to the relation, according to which one word is a more general form of the other one. For example the word 'animal' is a hypernym of the word 'cat', and it's not a symmetric relation. The important point here is that the selected relationship as input for algorithm is this relation, that is hypernymy in that concepts are also, like hypernyms, general forms (ideas) of other words. Initially stop words are eliminated such as 'the', and 'an', afterwards noun phrases are taken into account. This can be considered a good approach since in many studies only nouns separately are taken into account, not noun phrases. So it can be said that this work is not based on a Bag-of-Words model. According to the algorithm, frequencies is taken into account. All hypernyms of words are taken, and they are valued with frequencies of those words. Then whichever hypernym word is has the utmost value, it is declared as the probable concept of the document. For example if there are words in the document such as 'football', 'handball', and 'attorney', and their frequencies are two, one, and two respectively, the hypernyms would be 'sport', 'sport', and 'law' respectively, and the values for those hypernym words would be again two, one, and two. The hypernym word 'sport' is seen twice, so its frequencies would be summed up, that is it would be 2 + 1 = 3, whereas the hypernym 'law' would have a value of '2'. So the concept for this document would be 'sport'. Then in accordance with this paper this algorithm is combined with an another one, that is text categorization, and success rate is reported to be 71%.

An another study on this field is made by Liu, and Singh [10]. In this paper, ConceptNet, a freely available large-scale commensense knowledge base is mentioned. It is similar to the lexical database WordNet in that words in ConceptNet are connected to each other in accordance with their semantic relevances as words in the latter one are also connected to each other through the relations called synsets, but the difference is that

ConceptNet is much more comprehensive than WordNet. ConceptNet can be thought of as a concept map that links nodes, which are word phrases be it verbs, nouns, or other word groups, through semantic relationships. For example the property 'IsA' in this graph can be thought of as hypernymy relation, but the properties such as PropertyOf, MotivationOf (affect), CapableOf (agent's ability), and many others cannot be found as synset relations in WordNet, so the use of this knowledge base may be beneficiary. The relations in this graph based knowledge base can also be extended. For example if there is a relation such as (IsA 'apple' 'fruit'), and (PropertyOf 'apple' 'sweet'), then we would imply a new relation such as (PropertyOf 'fruit' 'sweet'). These new extended relations may help concept extraction results get higher accuracy results. When a document is sent as input for concept extraction, first the concept map is created. This graph can be thought of nodes representing the word phrases in the documents, and their relational properties being linked to each other. If some of the nodes in the graph have many links as input, and output, the words representing those nodes may be labeled as probable concepts. This is meaningful since this relevance between words may show the semantic relationship between them, and more links around a node shows that specific word phrase has relevance to many other nodes in the graph, which makes that word a candidate for a general word, that is concept, in the context of the document. This knowledge base is developed in English, and there is no other language support.

In the paper by Ramirez *et al*. [11], a concept extraction method is proposed for web sites. In accordance with this algorithm, first web pages are parsed due to that those pages have many tags such as '<html>', '<body>', '<title>', and others, which would not contribute to the set of concepts. Then stop word elimination is performed, and words are added to the concept set in accordance with their frequencies. If the frequency of a word exceeds a specific threshold value, it is added to the concept set. It is meaningful since general idea of a document has generally to do with the most frequent words in the document, or words relevant to that most frequent words. Then the approach used takes html tags into account, only eliminating some specific tags such as 'javascript', 'style', and some others. Now each word group between tags is given a weight score. For example the words between the tag '<title>' or '<b>' would be given higher scores. After scoring operation, if also this score exceeds the threshold value, the word groups are added to the concept set. This is meaningful since words between some tags have a higher importance

compared with the other words between another tags. Also noun phrases are taken into account in this study, which makes this method have a non Bag-of-Words approach. Accuracy results for this study are reported to be high.

Lastly, a paper examined shows a novel approach towards Concept Mining [12]. This paper is concerning topic digital library construction, and extracts concepts from documents, afterwards categorize the documents through clustering. In order to extract concepts, such a method is followed: At first an equation is created which takes into account many factors concerning a term, and the multiplication of those factors yield a result. The factors are term frequency (TF), inverse document frequency (IDF), position of the first occurrence, and distribution deviation of the keywords are taken into account. Here whichever words give the highest scores, they are selected as probable concepts for the document being examined. Then through the concepts gathered as explained above, a concept matrix for documents is built. Afterwards K-Means algorithm is implemented to cluster the documents in accordance with those concepts. The success results are reported to be high.

2.2. Some Popular Software Developed for Concept Mining

Although there have been many studies concerning Concept Mining in NLP field, there are not many software applications that are popular, and widely used. Some of the reasons of it can be that most of those applications are commercial, and Concept Mining is still an area that are not well-known by people, or people don't know how they will benefit from it. But as for companies, there are some widely used commercial software, and the most popular and widely used ones SPSS Inc., WordStat, and a relatively new software AlchemyAPI. The first software tool provides Concept Mining functions for many languages, such as English, French, German, Spanish, Arabic, and many others, whereas the second one works for English, French, Italian, and German, and the last one proposes concepts just for English. But AlchemyAPI provides other functionalities besides proposing concepts in some other languages, for example sentiment analysis in English and German, whereas entity extraction is provided in eight languages that are English, German, French, Italian, Spanish, Portuguese, Swedish, and Russian.

These software tools are used in textual Concept Mining, and offer many usage areas. Some of them are fraud detection, keyword extraction, analysis of surveys which are open-ended, document classification, extracting information from reports, and many others. These tools provide graphically advanced visualization techniques as well as tables to show the concepts, their relevance, and their relations.

3. METHODOLOGY

For this thesis, four corpora are worked on which are collected from Gazi University. These corpora are pre-processed to extract the nouns, because the concepts are generally thought of as nouns. These are made by the parser, and disambiguator tools developed by Hasim Sak, at Boğaziçi University. Afterwards the nouns are used in the method in accordance with this thesis, and expressive concepts are extracted.

In this thesis, four corpora are worked on all of which are concerning different subjects. All these corpora are collected from sources in Turkish, and those are in txt format. These corpora are as follows:

(i) Sports News Corpus: This corpus has documents that are concerning sports news collected from Turkish sources. The majority of news is concerning football. The major topic is about the results of matches between different teams. Remarks by sports team players are also encountered a lot in this corpus. This corpus has 100 documents, length of each of which is, on average, not large.

(ii) Forensic News Corpus: This corpus has documents that are concerning news in the field of forensic subject from Turkish sources. The majority of news is concerning the events that are considered crime, or abuse, and decisions made by judges. This corpus has also 100 documents, length of each of which is, on average, not large.

(iii) Forensic (Court of Appeals Decisions) Corpus: This corpus has documents that are concerning court of appeals decisions. It is similar the Forensic News Corpus, however it is more comprehensive. The documents of corpus is collected from different Turkish forensic sources, and the prevalent topic concerning the crimes, or abuses, and the decisions made by the judges. This corpus has 108 documents, which makes it the largest corpus in terms of number of documents, also the length, on average, of documents is not large.

(iv) Gazi Corpus: This corpus has documents that are concerning different fields of engineering. For example some of the documents are concerning electrical engineering information, some are concerning architectural reports, and some are concerning civil engineering amongst many. The distribution of topics over different

engineering topics is homogeneous. This corpus has 60 documents, making it the smallest among corpora in terms of number of documents. But the length of each file, on average, is large.

In this thesis, the concepts are extracted from each of files in those corpora, and it can be clearly seen that files that are in same corpora have similar concepts, with the exception of Gazi Corpus in that this corpus is more heterogeneous in terms of topics within, compared with the three others.

3.1. Pre-processing on Files in Corpora

The files to be processed are written in Turkish, so the Turkish characters needed to be taken into account. In order to process those characters, the UTF-8 format has to be used in files.

UTF-8 is a format, according to which variable-width encoding, that can represent any character in the Unicode character set, is used. It is the most widely used character encoding in World Wide Web, also its popularity as the default encoding system in operating systems, software applications, and programming languages is increasing as compared with other formats.

UTF-8 encodes Unicode characters in a way using one to four 8-bit bytes, which are called 'octets' in the Unicode Standard. It encodes the characters that have lower values, meaning that those are in earlier positions in Unicode character set and occur more frequently, are encoded in fewer bytes.

Firstly, the tokenization process should take place. In accordance with this process, the punctuation characters are separated from other characters by a blank space to right, and to left. For example, the sentence below is the definition of the word 'trough' in English dictionary:

"A long, narrow, generally shallow receptacle for holding water or feed for animals."

The output of this sentence, after tokenization process is implemented, can be as follows:

"A long , narrow , generally shallow receptacle for holding water or feed for animals ."

As can be noted, the difference is that there are some added extra blank space characters before, and after punctuation characters, which in this case are comma, and period characters, if there are no anyway blank spaces preceding or following them.

3.2. Parsing and Disambiguation Processes

The files in the corpora that are to be processed are in an unstructured form as most of the textual files in electronic format are. In order to extract concepts, nouns in the documents have to be listed, and gathered, hence stemming operations eliminating the suffixes may be beneficial. In English there are no many inflectional, or derivational suffixes, so suffix elimination would not be quite a matter, but as for Turkish the situation is different in that it is an agglutinative language, many inflectional, and derivational suffixes lead to complexity.

We process the words by parsing them into morphemes, that may be derivational or inflectional, because we want to get the stems of the words, and among those stems, we pick up only the ones being nouns. We have to eliminate other types of words, such as adjectives, verbs, or nouns.

Although, in the field of Concept Mining, the majority thinks that the concepts of a document must be nouns, some think [10] those can be verbs as well. It makes sense since a verb has a definitive effect on words in a sentence, and it indirectly affects the meaning of the whole document. For example if a document has many verbs such as 'beat', one of the probable concepts of this document would be 'win', or 'victory'. But in this thesis the majority unanimity is accepted: Concepts are to be considered nouns.

In order to extract the nouns from files in the corpora, some parsing, and disambiguation tools are needed to be used, for this purpose the Boun Morpohological Parser (BoMorP) and the Boun Morphological Disambiguator (BoDis) tools [13, 14] are used. These tools are developed at Boğaziçi University.

The parser simply parses the words in the document, separates and shows the inflectional, and derivational morphemes. In order to get correct results, the above-mentioned tokenization process needs to be implemented, because although in English, there are some words which have both punctuation, and alphabetic characters such as the word "can't", there is no known word in Turkish such that when punctuation character in this word is removed, remaining words are both nouns. If we don't eliminate the punctuation characters, there would be a lower success rate. For example a word can be as follows:

"ölümsüzleştiriveremeyebileceklerimizdenmişsinizcesine"

The above word can be broken into its morphemes by a parser as follows:

"öl + üm + süz + leş + tir + iver + e + me + yebil + ecek + ler + imiz + den + miş + siniz + ce + sin + e"

The example above shows the derivational and inflectional richness of Turkish, an agglutinative language. When we try to parse languages such as English, French, Italian, Spanish, or Portuguese, we may not encounter such morpheme richness due to that those languages family are inflectional. So developing a parser for such agglutinative languages (like Turkic languages, Finnish, Hungarian, and Estonian) requires much more effort.

This parser is a finite-state machine, which is composed of three components:

(i) A lexicon that contains the stems of words in Turkish. This is needed since the roots can only then be found, and used.
(ii) A morphotactics component (morphosyntax) that defines the ordering the morphemes.

(iii) A morphophonemics component that determines the phonetic variations when morphemes are added during the word formation.

Also there is a fact that parser may return many possible parsing suggestions, for example the word 'çekin' may be parsed, and the following example can be encountered:

çekin[Verb]+[Pos]+[Imp]+[A2sg]
çeki[Noun]+[A3sg]+Hn[P2sg]+[Nom] (3.1)
Çekin[Noun]+[Prop]+[A3sg]+[Pnon]+[Nom]

Above there are some parsed forms of the word 'çekin'. In the first one, it is simply a verb with imperative mood, in the second one, it is a noun with possessive form, whereas the last one is a proper noun. The abbreviation A3sg stands for third singular person inflection, whereas P2sg stands for second plural inflection. But one cannot be sure which one of the above forms are used in the context of the word in the document only through the parser tool. So here a scoring must be implemented and one of the parsed forms should be returned, having the highest score. We need to use disambiguator tool for this.

Disambiguator tool takes parsed files as input, and disambiguates the words, that is, it selects the most accurate parsed alternative taking into account the context. In order to disambiguate the parsed words, an averaged perceptron-based algorithm is used. In order to select the most accurate alternative, a scoring mechanism is used, and this tool gives a success rate of over 97%, which is the highest achieved in Turkish so far. Table 3.1 gives an example of the parsing output of the below sentence, present in Forensic News corpus, using BoMorP, whereas Table 3.2 gives the disambiguation results of this sentence taking the output of the parser as an input. It can be clearly seen that scores are taken into account to determine the best-matching disambiguated word. In Table 3.2 it is assumed that Part-of-Speech (POS) tags are lined up in a decreasing order in terms of score.

"Mahkeme Başkanı Alçık, sanık isimlerini tek tek okudu sanıklar ise el kaldırarak savunması yapıldı."

Table 3.1. An example of parsed output.

Mahkeme mahkeme[Noun]+[A3sg]+[Pnon]+[Nom]
Başkanı
başkan[Noun]+[A3sg]+[Pnon]+YH[Acc]
başkan[Noun]+[A3sg]+SH[P3sg]+[Nom]
Başkan[Noun]+[Prop]+[A3sg]+SH[P3sg]+[Nom]
başka[Adj]-[Noun]+[A3sg]+Hn[P2sg]+NH[Acc]

Alçık Alçık[Noun]+[Prop]+[A3sg]+[Pnon]+[Nom]

,
,[Punc]

sanık
sanık[Adj] sanık[Noun]+[A3sg]+[Pnon]+[Nom]

isimlerini
isim[Noun]+[A3sg]+lArH[P3pl]+NH[Acc]
isim[Noun]+lAr[A3pl]+SH[P3sg]+NH[Acc]
isim[Noun]+lAr[A3pl]+SH[P3pl]+NH[Acc]
isim[Noun]+lAr[A3pl]+Hn[P2sg]+NH[Acc]

tek
tek[Adj]
tek[Noun]+[A3sg]+[Pnon]+[Nom]
TEK[Noun]+[Acro]+[A3sg]+[Pnon]+[Nom]
Tek[Noun]+[Prop]+[A3sg]+[Pnon]+[Nom] tek[Adv]

tek
tek[Adj]
tek[Noun]+[A3sg]+[Pnon]+[Nom]

Table 3.1. An example of parsed output (cont.).

```
TEK[Noun]+[Acro]+[A3sg]+[Pnon]+[Nom]
Tek[Noun]+[Prop]+[A3sg]+[Pnon]+[Nom] tek[Adv]

okudu
oku[Verb]+[Pos]+DH[Past]+[A3sg]

sanıklar
sanık[Adj]-[Noun]+lAr[A3pl]+[Pnon]+[Nom]
sanık[Noun]+lAr[A3pl]+[Pnon]+[Nom]

ise
i[Verb]+[Pos]+sA[Cond]+[A3sg] is[Noun]+[A3sg]+[Pnon]+YA[Dat]

el
el[Noun]+[A3sg]+[Pnon]+[Nom]

kaldırarak
kal[Verb]-DHr[Verb+Caus]+[Pos]-YArAk[Adv+ByDoingSo]
kaldır[Verb]+[Pos]-YArAk[Adv+ByDoingSo]

savunması
savun[Verb]+[Pos]-mA[Noun+Inf2]+[A3sg]+SH[P3sg]+[Nom]

yapıldı
yap[Verb]-Hl[Verb+Pass]+[Pos]+DH[Past]+[A3sg]

.
.[Punc]
```

Output of the disambiguator program taking the above parsed file as input is as follows:

Table 3.2. An example of disambiguated output.

Mahkeme
mahkeme[Noun]+[A3sg]+[Pnon]+[Nom]

Başkanı
başkan[Noun]+[A3sg]+SH[P3sg]+[Nom]
başkan[Noun]+[A3sg]+[Pnon]+YH[Acc]
Başkan[Noun]+[Prop]+[A3sg]+SH[P3sg]+[Nom]
başka[Adj]-[Noun]+[A3sg]+Hn[P2sg]+NH[Acc]

Alçık
Alçık[Noun]+[Prop]+[A3sg]+[Pnon]+[Nom]

,
,[Punc]

sanık
sanık[Noun]+[A3sg]+[Pnon]+[Nom]
sanık[Adj]

isimlerini
isim[Noun]+lAr[A3pl]+SH[P3sg]+NH[Acc]
isim[Noun]+[A3sg]+lArH[P3pl]+NH[Acc]
isim[Noun]+lAr[A3pl]+SH[P3pl]+NH[Acc]
isim[Noun]+lAr[A3pl]+Hn[P2sg]+NH[Acc]

tek
tek[Adj] tek[Noun]+[A3sg]+[Pnon]+[Nom]

Table 3.2. An example of disambiguated output (cont.).

TEK[Noun]+[Acro]+[A3sg]+[Pnon]+[Nom]
Tek[Noun]+[Prop]+[A3sg]+[Pnon]+[Nom]
tek[Adv]

tek
tek[Adj] tek[Noun]+[A3sg]+[Pnon]+[Nom]
TEK[Noun]+[Acro]+[A3sg]+[Pnon]+[Nom]
Tek[Noun]+[Prop]+[A3sg]+[Pnon]+[Nom]
tek[Adv]

okudu
oku[Verb]+[Pos]+DH[Past]+[A3sg]

sanıklar
sanık[Noun]+lAr[A3pl]+[Pnon]+[Nom]
sanık[Adj]-[Noun]+lAr[A3pl]+[Pnon]+[Nom]

ise
i[Verb]+[Pos]+sA[Cond]+[A3sg]
is[Noun]+[A3sg]+[Pnon]+YA[Dat]

el
el[Noun]+[A3sg]+[Pnon]+[Nom]

kaldırarak
kaldır[Verb]+[Pos]-YArAk[Adv+ByDoingSo]
kal[Verb]-DHr[Verb+Caus]+[Pos]-YArAk[Adv+ByDoingSo]

savunması
savun[Verb]+[Pos]-mA[Noun+Inf2]+[A3sg]+SH[P3sg]+[Nom]

Table 3.2. An example of disambiguated output (cont.).

yapıldı yap[Verb]-Hl[Verb+Pass]+[Pos]+DH[Past]+[A3sg]   . .[Punc]

The important point to note here is that those parser, and disambiguator tools also can identify numbers, and punctuations. It is useful since those characters may be needed to use in some algorithms, and many parser, and disambiguator tools developed for many languages generally overlook those types of characters.

If we look at the words shown in Table 3.1 and Table 3.2 it can be seen that thre are also sub-types for nouns. For example a word can be a proper noun, and we have to eliminate this alternative, because a proper noun such as 'Christina' can't be an abstract, general idea of a document. We also have to eliminate the abbreviation, and acronym nouns since those can't produce expressive concepts. For example the noun 'm' may stand for the noun 'meter' as abbreviation, or 'UN' may stand for 'United Nations', those may not help us determine the general concepts of a document, so those types of nouns are also to be eliminated.

3.3. Previous Algorithms Developed that do not use Dictionary

There have initially been developed some algorithms for this thesis work, but it is seen that they could not yield meaningful results. Therefore new algorithms that make use of dictionary are developed, as will be explained in Section 3.4. The previous algorithms that were tried out are as follows:

- Sentence Co-occurrence Algorithm: In accordance with this algorithm, the sentences in corpora are thought to represent semantic relationships between words. If a couple of words co-occur in many sentences, it would mean that those words are semantically related to each other. In order to extract this relationship, a square

matrix is built that stores scores indicating in how many sentences two words co-occur. Row and column words are assumed to be same in this matrix. For example (*i, j*)th element of matrix indicate in how many sentences *i*th and *j*th words co-occur in the corpus. The diagonal elements are updated as the frequencies of those words in the corpus, since diagonal elements represent the row and columns corresponding to the same word. Then the matrix is normalized by dividing all the row elements' values by the corresponding diagonal row element to get more sensible results. At last clustering methods are implemented, which are k-means, c-means and hierarchical clustering. K-means algorithm initially determines k random points on an n-dimensional plane and through iterations those points' feature values are recalculated as the mean values of data features whichever are closest to those points, until convergence is met [17]. While in k-means algorithm, a sample can belong to only one cluster, in c-means it is also possible for a sample to belong to more than one cluster. Lastly hierarchical clustering simply puts nearest samples in one cluster, then expand this cluster's range by adding another nearest samples into itself, until all samples are assigned to a cluster. This is called agglomerative clustering which we implemented for this algorithm. But three clustering methods all we implemented gave unsuccessful results. The clusters created had words that are irrelevant to each other within, so the sentence co-occurrence method had to be dismissed.

- Window Co-occurrence Algorithm: After seeing the unsuccessful clusters created by sentence co-occurrence algorithm, an another approach is tried. In accordance with this algorithm, windows are used in order to extract semantic relationships between words. Windows are simply the word groups in which words come one after another in a specified window size. The most commonly used window sizes are 30, 50, 70, and 100, and all those sizes are taken into account for this thesis work. These windows are sliding ones, that is after one iteration the starting point of one window is shifted one word rightwards. Also each word that co-occurs in one window is not assumed to be co-occurring in the very next sliding window one more time. A square matrix, as is the case for sentence co-occurrence algorithm, is built. The values in this matrix are filled in accordance with the number of windows in which two words co-occur. Diagonal elements are updated as the corresponding row (or column) word's occurrence frequency in windows. Then again, k-means, c-means and hierarchical clustering methods were implemented. For all those clustering methods,

there were only a few clusters that had words relevant to each other within, so this algorithm had to be missed as well.

- Dictionary Clustering Algorithm: After two algorithms mentioned above gave unsuccessful results, an another approach is used taking dictionary structure into account. In dictionaries, meaning text words of word entries may show the semantic relationships between words as will be elaborately explained in Section 3.4. In accordance with this algorithm, corpus nouns are taken into account, and a matrix is built. The matrix rows represent the corpus nouns, whereas columns represent the nouns in the meaning text of corpus nouns. All the duplicate values are eliminated, and matrix has values of only one and zero. When k-means, c-means and hierarchical clustering methods are implemented, very meaningful clusters have been observed, showing that the semantic relationship between words can be seen through the use of dictionary. But there was a problem that there were many clusters that included only one word, and some clusters had disproportionately many words. Amongst hierarchical clustering alternatives, euclidean and cosine similarity metrics are tried out, and it has been seen that cosine similarity metric, to a some degree, decreased the outlier problem better than did euclidean one. It may be attributed to the fact that cosine metric measures the similarity between two nodes (words) in terms of the angle between the lines through which nodes are attached to origin applying also normalization, instead of simply measuring the distance between two nodes on geometrical plane through euclidean distance. Instead, a simpler statistical algorithm is developed eliminating algorithms that take into account clustering.

3.4. Simple Frequency Matrix and Context Analysis Algorithms using Türk Dil Kurumu (TDK) Dictionary

In Concept Mining field of NLP, one of the most resorted techniques is the one that takes frequency into account. It makes sense since the general idea of a document can be extracted through the words that are frequent in this document. If a word is found only once, or twice such as 'attorney' in a lengthy document, this word may not be a top candidate concept amongst many words. So in this thesis frequency measure is used. But taking into account only the frequent words that are present in the document may not be sufficient. For example there may be words such as 'football', 'basketball', and 'handball' in

the document being examined. Just thinking of the words in the document as concepts may be wrong, because a concept may be present, or be absent in the document. So in this thesis, taking into account that concepts may not be present in the document, the TDK Dictionary is used.

3.4.1. The Structure of the Dictionary

So far, in the Concept Mining field, although the use of many Language Models (LM) such as LDA may be beneficiary [15], the use of lexical databases with AI methods such as clustering is more prevalent [16], and gives higher success rates . The most widely used lexical source is WordNet, which provides synsets that are composed of many properties. Synsets are a set of relations through which analogies can be made between words. For example the synset relation 'synonymy' implies that two words have same meaning, such as the relation between 'attorney', and 'lawyer', another relation called 'hypernymy' implies that one word has a general meaning of the other, such as the relation between 'animal', and 'organism', 'meronymy' relation implies that one word is part of the other word such as the relation between 'eye', and 'face', and there are a few more relations.

Amongst the relations of synsets, the one that is called hypernymy is most widely used for extracting concepts due to that a general meaning of a word can give us a general idea concerning this word. Some examples of hypernymy relation is as follows:

Table 3.3. Hypernymy examples.

Words	**Hypernyms**
Chihuahua	Dog
Earth	Planet
Animal	Organism
School	Building
Engineering	Profession

So far, in the studies concerning Concept Mining, other synset relations besides hypernymy are rarely preferred, and used, due to the fact that is stated above, that is

hypernyms of words can suggest a concept set concerning this document. High levels of hypernymy relations can be used in some algorithms, taking into account only the one-level hypernymy may not suggest a general concept concerning document, so two-level or higher levels may be used. For example two-level hypernymy counterpart of the word 'Chihuahua' may be 'animal', since all 'Chihuahua's are dogs, and all dogs are animals. But this thesis approaches Concept Mining field in a novel way which is not tried a lot so far: The use of basic language dictionary. This is the case since WordNet has a poor, and incomplete structure in Turkish, also the performance of the use of dictionary may excel that of WordNet in some ways.

TDK Dictionary is the official dictionary in Turkey Turkish, that is most widely used across the world. In this thesis, this dictionary is made use of through electronic medium, in XML format. This dictionary, like any others in other languages, is composed of properties as follows:

- Word entries,
- Word categories, such as adjective, noun, etc.,
- Word meanings,
- A usage shown in examples through citation sentences,
- Possible affixes,
- Stress, indicating which syllable must be strongly pronounced,
- Language of origin for the word,
- Compound phrases in which this word entry may be used,
- Proverbs, or idioms making use of this word entry.

Sometimes, some of the properties may be absent, or may have many values, for example the word 'address' may be used in either verb, or noun categories, as for in any language, it is possible that a word may have many grammatical categories, and the specific word category can be defined by the POS tagging, looking into its context. Figure 3.1 shows an example of the word entry "jaguar" and its properties, in XML format of dictionary from which we benefited. Some tag elements are labeled "undefined" meaning that those tag properties are not used for this word entry. For example the tag "<atasozu_deyim_bilesik>" stands for "proverb, idiom, compound" in Turkish, and the

word "jaguar", as shown in Figure 3.1, is not used in any proverb, idiom or compound, that is why this tag element is defined as "undefined".

Figure 3.1. A word's properties in the XML format of dictionary from which we benefited.

Among the above properties of the dictionary, we overlooked some of them, such as the stress, affixes, origin language, proverb uses, citation sentences, compound phrases, because those would not contribute to determining the concept of a document. We make use of the words if they are nouns by looking into their word category properties, and we make use of the meaning texts.

Meaning texts can be used to extract meaningful information concerning the word itself, and be benefited from for extracting concepts. These meaning texts shows the properties of words, as it is in WordNet relations. These properties may be like hypernymy, meronymy, or synonymy relations between the word entry, and meaning text words. For example the below dictionary definition for football can be examined:

Football: "A game played by two teams of 11 players each on a rectangular, 100-yard-long field with goal lines and goal posts at either end, the object being to gain possession of the ball and advance it in running or passing plays across the opponent's goal line or kick it through the air between the opponent's goal posts."

For example, the word 'game' in the meaning has a hypernymy relation with the word entry 'football'. The word 'goal' is the aim technique of this game, and the word 'ball' is the main object that is used in this game, so there are relations between those words as well.

The most widely used relations between a word entry, and the other words that are in meaning text of this entry can be summarized as follows:

- Synonymy: It is a relation that two words have equivalent meanings. It is a symmetrical relation. For example the words 'human being', and 'person' are synonyms.
- Meronymy: It is a relation that one of the words is a constituent of the other word. It is not a symmetrical relation. For example the words 'finger', and 'hand' have this relationship.
- Location: It is a relation that shows the location of a word with respect to the other word. For example the words 'capital', and 'country' have this relationship.
- Usability: It is a relation that one word is used for an aim. For example toothbrush is used for brushing teeth.
- Effect: It is a relation that one action (word) leads to a result. For example taking medication leads to a healthy state.
- Hypernymy: As mentioned above, it is a relation that one word is a general concept of an another word. For example the words 'dog', and 'Golden Retriever' have this relation.
- Hyponymy: It is a relation that one word has a more specific concept of the other word. For example the words 'teacher', and 'profession' have this relationship. It is not to be confused with the meronymy relationship.
- Subevent: It is a relation that one action has a sub-action. For example waking up in the morning would make one yawn.
- Prerequisite relation: It is a relation that one action is a prerequisite condition for another one. For example waking up in the morning is a prerequisite condition for hitting the road for job.
- Antonymy: It is a relation that one word has the opposite meaning of the other word. For example the words expressing emotional states such as 'happy', and 'sad' have this relationship.

The above relations can be used to measure the analogy between words, and as for Turkish it can be clearly seen that using this dictionary is much more useful since this is more comprehensive as compared with the WordNet, synsets of which is poor, and

incomplete in this language. Nonetheless it should be noted that some of features stated above, such as antonymy, may not contribute to extraction of concepts.

Making analogy between words can be used in algorithms. For example if one wants to cluster the words, and afterwards want to classify the documents, this method is useful. The analogies between words, which can be seen by the existence of common words in the meaning texts of those words, can make some words in the same cluster, or an another one. The only possible relation that would be considered harmful when implementing clustering using the similarity of meaning texts is antonymy. One word may be expressed in the meaning text of its antonym word, due to this common word they would be assigned to the same cluster, which is not sensible. For example let's look at the below meaning texts of two words.

Table 3.4. Raw dictionary definitions of two words.

Cat: "A small carnivorous mammal *(Felis catus* or *F. domesticus)* domesticated since early times as a catcher of rats and mice and as a pet and existing in several distinctive breeds and varieties."
Lion: "A large carnivorous feline mammal *(Panthera leo)* of Africa and northwest India, having a short tawny coat, a tufted tail, and, in the male, a heavy mane around the neck and shoulders."

The common words in the above two sentences are 'carnivorous', and 'mammal'. This would show that those two word entries would be similar in some senses, so they would be assigned to same cluster. Also another category members can be assigned to the same cluster, for example fruits, such as apple, peach, and cherry can be grouped in one cluster, also animals, month names, profession names, electronic devices, and many other specific category members can be grouped in separate clusters.

The relations in dictionary described above may be algorithmically applied anywhere in NLP, but it is important to note that in this thesis only nouns are thought of as concepts, so the ones which have nothing to do with noun category are eliminated. For instance, sub-event relation takes only verbs into account and makes analogies between those event, hence we overlook this relation.

Since in this thesis dictionary is benefited from, it has to be parsed, and disambiguated. These processes are required since Turkish is an agglutinative language, and many inflectional morphemes have to be eliminated. For example the meaning text for the word of 'jaguar' in Turkish is as follows:

"Kedigillerden, Orta ve Güney Amerika'da yaşayan, postu iri benekli memeli türü (Felis onca)."

Here the first word should be returned as 'kedigiller', eliminating the inflectional morpheme 'den', and then this processed word must be used in the algorithm. But it is important to note that when parsing operations are successful, words cannot be disambiguated correctly at a high success rate. It is due to that meaning texts are composed of a few words, and due to this data sparseness, averaged perceptron-based algorithm cannot assign very meaningful scores to those possible POS tags.

3.4.2. Context Analysis for Disambiguation

It is possible for word entries in the dictionary to have many different meanings. We have to select the one which is meant in accordance with the corpora nouns. For instance the word 'bank' has many meanings, and we have to extract the true meaning text by looking into the corpora. In order to extract the true meaning we can do context analysis [18]. Context analysis in NLP means that we create windows surrounding a word, and make analysis in accordance with the words in these windows. The size of windows can vary, but the most widely used ones are generally 30, 50, and 70 grams. These can be called n-grams, for example if a 30-gram window is to be used, the 15 words to left of the test word, and another 15 words to right of the test word are taken into account. In this thesis 30-grams are used.

The contexts are the words surrounding a test word in corpora. All of these context words are compared with the meaning text words, and if the number of common words is high compared with that of other meaning texts, this meaning would be chosen as the true meaning. It can be formulized as follows:

$$\text{argmax}_{\text{m}} Similarity(m, c_w) = \frac{CommonCount(m,c_w)}{length(m)} \quad (3.2)$$

The above formula tries to find the highest similarity score among candidate meaning texts. w stands for the corpus noun, m stands for the meaning text, c_w stands for the context of the word w, CommonCount counts the number of common words that are found in both context, and meaning text of a word. Lastly we have to normalize the score by dividing the score by the number of nouns in the meaning text. It is sensible since a meaning text may contain many words, and if the number of common words found are not too high, then the other meaning text with a fewer words should be scored higher, and favoured. The words that are taken into account are only nouns.

This context analysis is useful especially when taking into account that many words have more than one meaning. But if the documents' sizes are small, this may be a drawback that is called data sparseness. For example if a document contains fewer than 30 words, say 10, then the algorithm may fail in performance results. If the context size is increased, more meaningful results can be achieved, but it has the drawback that performance (time, and space complexity) may be lowered. Also it should be noted that the context words don't have to be nouns, those can be adjectives, adverbs, verbs or pertain to other word categories. This is a fair approach because if we eliminate the non-noun words before making context analysis, then nouns that are in fact in a lengthy distance where there many other words between them, can be thought of as that they are close to each other, and this would be problematic. When creating n-gram contexts, words of any category, such as adjective, verb, etc. are first taken into account, but then when only nouns are selected, word categories excluding nouns are eliminated.

In this thesis there have been developed a few different algorithms and it is seen success rates for different corpora vary in accordance with those algorithms. When looking at overall results, the second algorithm (Section 3.4.4) excels the first algorithm (Section 3.4.3) in most of the corpora in terms of evaluation results.

3.4.3. Simple Frequency Algorithm (Alternative 1)

Concepts of a document generally have to do with the words that abound in that document, that is why we had to use the frequency factor. For example, if we encounter a document that abounds with the word "football", we may be inclined to think that the concept of this document would be concerning "sport". Taking frequency into account, in this a statistical method was developed, that extracts concepts favouring the words that are more frequent.

We first take all the nouns in the document(s) and label them as pre-concepts. Here we eliminate other types of words, such as adjectives and verbs. Then we can start building a matrix. This matrix has rows representing the nouns encountered in the document and columns representing the nouns encountered in the meaning text sentences of those row words. But we also have to take into account that the rows on the words are also added as column items. For example the word "football" may be very frequent in the document, so this word should be regarded as a probable concept as well.

The cells in the matrix are filled as follows: After we built the matrix, we fill the cells by one or zero depending on whether the column word appears in the row word's meaning text or not. Then we implement frequency operation: We multiply all the cell values in the matrix by the corresponding row word frequency. For instance, if the word "football" is encountered 10 times in a document and its meaning text nouns in the dictionary are "sport", and "team", then those columns' ("sport", "team" and "football") values in the correspondent row "football" would be updated as 10, whereas the other columns would be updated as zero. Then the cell values in the matrix are multiplied by the row word's scope, and first location properties. The term scope means that how a word is distributed over a document. If a word is encountered in only a paragraph or part of the document, its scope is assumed to be small, if a word is encountered in different sections of the document, say first and last paragraph, its scope is assumed to be large. First location indicates the first location of a word, if it is encountered in initial parts of the document, its value is higher, otherwise it is lower. A logarithmic function is used when taking into account those two functions of words.

Then the column values are summed up in the matrix and we take the column word that yields the highest summation as the probable concept. This is meaningful since the concept may or may not be present in the document, so the use of dictionary would be beneficial. An example showing the mapping of terms into concepts is shown in Figure 3.2.

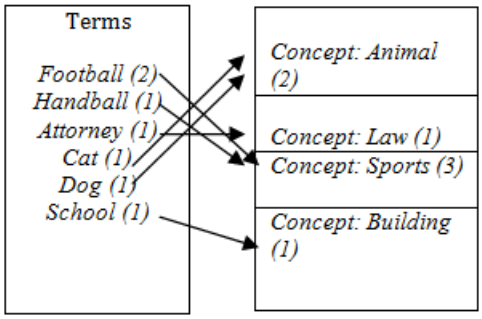

Figure 3.2. An example showing the mapping of document words into concepts.

In the Figure 3.2, the column to the left is a representative of words encountered in the document, whereas the column to the right includes the representative nouns encountered in their meaning texts. Due to that the words "football" and "handball" are frequent in the above example and the word "sports" is present in their meaning texts, its score would be three and this word would be assigned as the probable concept of the document or corpus.

As mentioned above, we benefit from dictionary to extract concepts from documents, but instead of using just meaning text nouns for this concept extraction process, also a hierarchical data structure that contains two, three and four levels is built. In accordance with this structure, the main word is atop the hierarchy, then the meaning text nouns of this word is in the lower level, whereas the respective meaning text nouns of these meaning text nouns are in the lower levels. An example of this data structure with three-levels is depicted in Figure 3.3.

This hierarchical structure may have some specific features, for example each word in different levels may be assigned a different coefficient and we may take this coefficient factor into account when building up the matrix. If we construct three-level hiearchies built through the dictionary, we may assign high values for the top levels and low values

for lower levels. This is the case because the semantic relationship between the main word and the lower level nouns weakens while going down through the hierarchy structure.

We multiplied the top-level words in the matrix by 1, the second-level words by 0.5 and the lowest-level words by 0.25. We used this geometric approach since the meaning text nouns' frequencies increase geometrically from one level to the below one. But we noticed that three-level structure gives slightly higher results compared to that of two-level structure, so we preferred three-level structure with coefficients yielding higher precision values. Also four-level structure gave worse results than did three-level one, so using a three-level structure was the best choice.

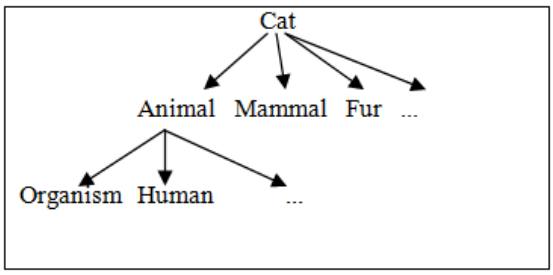

Figure 3.3. A hierarchical data structure with three-levels of the word 'cat' in the dictionary.

The matrix cells are filled, as mentioned above, without taking frequency into account and the results yielded were much less successful. That shows the importance of taking frequency into account. The pseudo-code of this algorithm is given in Figure 3.4.

We also have to take into account that some words are quite common in the dictionary, such as "situation", "thing", "person" and so on. Here the top 1% most frequent words in the meaning texts in the dictionary are determined as stop-words and then they are eliminated. Generally tf-idf is used for elimination of words, but since we make use of the dictionary as a base, top words elimination is sufficient.

Algorithm: Extracting concepts through simple frequency using dictionary

Input

F1: Documents in corpus

Output

F2: Concepts of documents

Begin

1: *L* <- Assign *F1* to the list
2: **for** each document *i* in *L*
3: *Matrix* <- Ø
4: **for** each word *j* in document *i*
5: *Meaning* <- Meaning text nouns of word *j*
6: Add word *j* to *Meaning*
7: **for** each word *k* in *Meaning*
8: $Matrix(j, k) = Freq(j) \times FirstLoc(j) \times Scope(j)$
9: **end for**
10: **end for**
11: Fill the cells in *Matrix* by value zero which have no value assigned
12: *Matrix* <- Remove Duplicate Row and Columns of *Matrix*
13: *List* <- sum(*Matrix* columns)
14: *List* <- sort(*List*)
15: Add column words, corresponding to top(*List*), to *F3*
16: **end for**

End

Figure 3.4. Pseudo-code of extraction of concepts using dictionary that takes into frequency factor.

3.4.4. Frequency and Context Algorithm (Alternative 2)

Although it is noticed the algorithm 1 developed for this thesis stated above gave meaningful concepts, drawbacks can be clearly seen. For example, let's assume there is a document containing the noun "football" and there is no other noun and its meaning text in the dictionary is as follows:

"A game played by two teams of 11 players each on a rectangular, 100-yard-long field with goal lines and goal posts at either end, the object being to gain possession of the ball and advance it in running or passing plays across the opponent's goal line or kick it through the air between the opponent's goal posts."

According to the algorithm stated above (Section 3.4.1), we take the nouns in this meaning text into account and build up a matrix containing those nouns, including the word 'football'. Since the word "football" is seen three times, the column labeled "goal" has a value of 3 as well and at the end the probable concept may be the word "goal", as well as the other concepts may be "game", "team", "line" and other nouns in the meaning text. (This is the case since the matrix would be of size 1 x *CountNoun(MeaningTextOf(Football)*), indicating that there is only one noun, that is "football", in the document.) Having a concept of "goal" through this document would be a bit nonsense (also here we can assume that properties of first location, and scope are ignored in this example), hence the algorithm is modified in the following manner:

All the dictionary meaning text nouns would not be useful in determining the general idea of the main word, so some of those nouns have to be eliminated. In order to determine which meaning text noun is relevant in the use of the main word, a corpus-based context analysis is used. There are a few corpora and for each corpus, and a 30-word window size context analysis is used, that is 15 words on the left of the test words and 15 words on the right of the test words are looked up. Hereby the context words which are not nouns are eliminated, because we think of concepts as only nouns. Then it is assumed that if a context word is also present in the meaning text of the main word in dictionary, we take this context word into account. After scanning the whole corpus, whichever context word is seen most, given that context word is also seen in the meaning text of the main word,

this word is added as a column word in the matrix corresponding to the row word. Then, similar to what we have done in (Section 3.4.1), we multiply the row elements values by the frequency, first location, and scope properties of the row representative word and sum up the columns values. Whichever column value has the maximum value, we define that column representative word as the probable concept. In this case, we take mostly two words for each word in the document: The word itself and the word in the meaning text of this word that is most widely seen in the contexts in the corpus. Firstly again, of course, the stop words present in the TDK Dictionary are eliminated.

This approach makes sense, since all meaning text nouns would not be useful in determining the general idea, that is concept, of a word. Also the corpus-based approach shows that the most relevant word in the meaning text of a test word is extracted through the context analysis. Selecting at most two words, that are the word itself and the most frequent word in the contexts of the word that is also present in the meaning text of the row word in the matrix rather than taking into account all nouns in the meaning text of a word increased the success rate for three of the corpora. Pseudo-code of this algorithm is given in Figure 3.5.

3.5. Simple Illustrations of the Methodology

Simple frequency algorithm takes into account the nouns in the document, their meaning text nouns present in the dictionary, and their frequencies. For example let's assume there are two nouns in the document, that are 'tiger' (which stands for 'kaplan' in English), and 'monkey' (which stands for 'maymun' in Turkish). The meaning texts of those words are shown in Table 3.5 as follows:

Table 3.5. Dictionary definitions for two words, that are 'kaplan', and 'monkey'.

Kaplan: Kedigillerden, enine siyah çizgili, koyu sarı postu olan, Asya'da yaşayan çevik ve yırtıcı hayvan (Felis tigris).
Maymun: Dört ayaklı, iki ayağı üzerinde de yürüyebilen, ormanda toplu olarak yaşayan, kuyruklu hayvan.

Algorithm: Extracting concepts through simple frequency using dictionary

Input

F1: Documents in corpus

Output

F2: Concepts of documents

Begin

1: *L* <- Assign *F1* to the list
2: **for** each document *i* in *L*
3: *Matrix* <- Ø
4: **for** each word *j* in document *i*
5: Add meaning word of *j* that is most frequent in the corpus to *Meaning*
6: Add word *j* to *Meaning*
7: **for** each word *k* in *Meaning*
8: $Matrix(j, k) = Freq(j) * FirstLoc(j) * Scope(j)$
9: **end for**
10: **end for**
11: Fill the cells in *Matrix* by value zero which have no value assigned
12: *Matrix* <- Remove Duplicate Row and Columns of *Matrix*
13: *List* <- sum(*Matrix* columns)
14: *List* <- sort(*List*)
15: Add column words, corresponding to top(*List*), to *F2*
16: **end for**

End

Figure 3.5. Pseudo-code of extraction of concepts using dictionary that takes into both frequency factor and context analysis.

Then we are to build the matrix, row words of which are the document words whereas the column words are the nouns found in their meaning texts. Table 3.6 shows this

matrix, it should be taken into account that duplicate nouns are removed. (In this example the first location, and scope properties are ignored to make it more comprehensible, and less complex.)

Table 3.6. Matrix constructed with the words 'tiger' and 'dog' in accordance with the simple frequency algorithm.

	Kedigiller	çizgi	post	hayvan	orman	kuyruk	kaplan	Maymun
Tiger	1	1	1	1	0	0	1	0
Monkey	0	0	0	1	1	1	0	1
Summation	1	1	1	2	1	1	1	1

Amongst the column words in Table 3.6, the noun 'hayvan' has the highest value, that is two, and this is labeled as the top concept. The words 'kaplan' and 'maymun' are also added as column words since document words can be probable concepts. But it should be taken into account that some words such as 'post' and 'çizgi' would not have to do with determining general concept of this document, so those had better be eliminated. Second alternative, that is frequency and context algorithm would yield better results counting this factor.

Second algorithm simply takes into account the document words and one meaning text noun for each document word that is most commonly found in the contexts of those document words in whole corpus. A simple example can be examined as follows:

Table 3.7. Matrix constructed with the words 'tiger' and 'dog' in accordance with the frequency and context algorithm.

	hayvan	kaplan	maymun
Tiger	1	1	0
Monkey	1	0	1
Summation	2	1	1

In accordance with the matrix shown above, the most frequent word in the contexts of both words, that are 'kaplan', and 'maymun' is 'hayvan'. Other words are eliminated for

there would be only one word that is most frequent in the corpus. Also the words 'kaplan' and 'maymun' are added as column words since they are present in document. Here again the highest score is that of word 'hayvan', so the concept of this document would be labeled 'hayvan'.

Table 3.8. Content of a document from Forensic Decisions corpus.

T.C.
YARGITAY
6. Ceza Dairesi

YARGITAY İLAMI

Esas No: 2001/10772
Karar No: 2001/14183
Tebliğname : 6/12620

ÖZET: Sanığın, staj yaptığı bankanın müşterisinin banka kartıyla şifresini ele geçirip ATM'den para çekmekten ibaret eylemi TCY.nın 525/b-2.maddesine uyan suçu oluşturur

Dolandırıcılıktan sanık H.G ve M.Ö'nin yapılan yargılanmaları sonunda: Mahkumiyetlerine ilişkin İSTANBUL 6.Ağır Ceza Mahkemesinden verilen 22.11.1999 tarihli hükmün Yargıtay'ca incelenmesi sanık Hasan müdafii ile duruşmalı olarak sanık Mehmet müdafii tarafından istenilmiş olduğundan dava evrakı C.Başsavcılığından onama isteyen 15.6.2001 tarihli tebliğname ile 28.6.2001 tarihinde daireye gönderilmekle tayin edilen günde yapılan duruşma sonunda okunarak gereği görüşülüp düşünüldü.

Sanık H.G. müdafiinin yasal süreden sonraki temyiz isteminin CMUK.nun 317.maddesine göre REDDİNE Sanık M.Ö'e ilişkin temyiz incelemesine gelince Adı geçenin, staj yaptığı bankanın müşterisi K.A nın banka kartıyla şifresini ele geçirip daha sonra ATM.den para çekmekten ibaret bulunması karşısında, eyleminin TCK.nun 525/b-2.maddesine uyan suçu oluşturacağı gözetilmeden,unsurları bulunmayan dolandırıcılıktan mahkumiyetine karar verilmesi Bozmayı gerekçe olarak BOZULMASINA ilişkin oybirliğiyle alınan karar 21.11.2001 günü Yargıtay C.Savcısı önünde, sanık müdafiinin yokluğunda açıkça ve yöntemince okunup anlatıldı.

Table 3.8 shows content of a document from Forensic Decisions corpus, whereas Table 3.9 shows the concepts that are extracted algorithmically, in a decreasing

importance, from this document as an example. It can be seen most of the concepts extracted are meaningful. Some words that are not present in the document can also be probable concept candidates. For example the word "hüküm" is not present in the document shown in Table 3.8, but algorithm defines this word as a concept as shown in Table 3.9.

Table 3.9. Top 15 Concepts extracted algorithmically from the document shown in Table 3.8.

1.	sanık
2.	suç
3.	banka
4.	faiz
5.	usul
6.	daire
7.	ceza
8.	staj
9.	hizmet
10.	müşteri
11.	hüküm
12.	telefon
13.	kart
14.	şifre
15.	eylem

4. EXPERIMENTS AND EVALUATION

4.1. Corpora

In this thesis, four corpora are processed and algorithm developed in accordance with this work tries to extract expressive concepts from those corpora. These four corpora are elaborately mentioned in Chapter 3. These corpora are processed through two algorithms, former one taking into account dictionary structure and properties of words, whereas the latter one taking into account also context analysis. On average, the second algorithm (alternative 2) is seen to yield better performance results.

4.2. Evaluation Metrics

As evaluation of results, there have been developed many metrics in the domain of science, engineering, and statistics. The most widely used ones are precision, recall and accuracy, in the domain of NLP those are also the commonly used evaluation metrics. These metrics can be formulized as follows:

$$Precision = \frac{number\ of\ true\ positives}{numer\ of\ true\ positives + false\ positives} \quad (4.\ 1)$$

$$Recall = \frac{number\ of\ true\ positives}{number\ of\ true\ positives + false\ negatives} \quad (4.\ 2)$$

$$Accuracy = \frac{number\ of\ true\ positives + number\ of\ true\ negatives}{number\ of\ true\ positives + false\ positives + false\ negatives + true\ negatives} \quad (4.\ 3)$$

Precision (also known as positive predictive value) simply is the fraction of retrieved instances which are relevant, while recall (also called sensitivity) is the fraction of relevant instances that are retrieved. For example, a search engine takes queries and if there are 10 documents which are correct for a query and amongst those documents three of them are returned, recall is 3 / 10. If search engine shows five documents as top results, then precision value would be 3 / 5. In this thesis work precision, and accuracy are used as

evaluation metrics, as in NLP domain, those are the most widely used and expressive metrics. Table 4.1 examines those metrics as shown below.

Table 4.1. Evaluation metrics.

		Condition as determined by *Gold* standard		
		True	False	
Test Outcome	Positive	True positive	False positive	Positive predictive value or Precision
	Negative	False negative	True negative	Negative predictive value
		Recall or Sensitivity	Specificity	Accuracy

4.3. Evaluation Method using Comparison Windows

In this thesis work, files were created which contain concepts for each file in corpora that are extracted through the algorithm developed. These files include the top 15 concepts that are suggested by the algorithm. The concept terms that have a higher value in accordance with the matrix algorithm than that of others are labeled as 'top concepts'. In order to evaluate the precision of those assigned concepts, totally 368 files in four corpora are examined, and concepts are manually extracted. Then the concepts that are extracted manually, and algorithmically are compared with one another. In manually extraction manner, all the files in the corpora are read by two humans, and hereafter concepts of those files are lined up in a decreasing importance. This comparison is made with windows, sizes of which are determined as three, five, seven, eight, nine, ten, and fifteen words. For different corpora, the window comparison sizes used are as follows:

- Forensic Decisions Corpus: Three, five, seven, ten and fifteen window comparison sizes are used.
- Forensic News Corpus: Three, five, seven and eight window comparison sizes are used.

- Sports News Corpus: Three, five and seven window comparison sizes are used. It has many different topics concerning sports.
- Gazi Corpus: Three, five, seven and nine window comparison sizes are used.

Also for all corpora, the top concepts found algorithmically were compared with all the concepts extracted manually, called unlimited comparison.

To illustrate this comparison Table 4.2 can be examined:

Table 4.2. An example showing the top three concepts in two documents.

Documents	**Algorithm**	**Manual**
Document 1	Sport, Game, Match	Sport, Match, Politics
Document 2	Court, Attorney, Judge	Attorney, Accused, Match

Table 4.2 shows the top three concepts for two documents, extracted both manually and algorithmically. In the first document, it can be seen that the success rate (precision) is 2 / (2 + 1) = 0.66, since there are two words in common, which are "sport" and "match" that are found both in concept clusters extracted manually and algorithmically. However the word "game" is not in the top three concept cluster yielded manually, so it decreases the success rate. In Document 2, the success rate is 0.33, since only the word "attorney" is common amongst the three top concepts. This is an example taking into account comparison window size which is three, also other comparisons can be similarly made taking into account different sizes.

The evaluation results precisions vary from one corpus to another one, showing that the concepts extracted can be corpus-biased. It is seen that higher precision results are achieved for "Forensic Decisions", and "Forensic News" corpora, whereas the precision results for corpora "Sport News", and "Gazi" are evidently lower. This may be due to that topic distribution in the former above-mentioned two corpora is not as diverse as compared with the latter two corpora. The topics in the corpus "Sport News" are mainly concerning

"football" albeit there are many other topics about sports, but in the corpus "Gazi" there is no a specific topic. The topics in this corpus are very diverse, some of them including reports concerning different engineering fields, or architecture. Since the second algorithm is corpus-based, having no common topics is seen to decrease the precision results.

The precision results, taking into account unlimited comparisons, for different corpora are depicted in figures as follows:

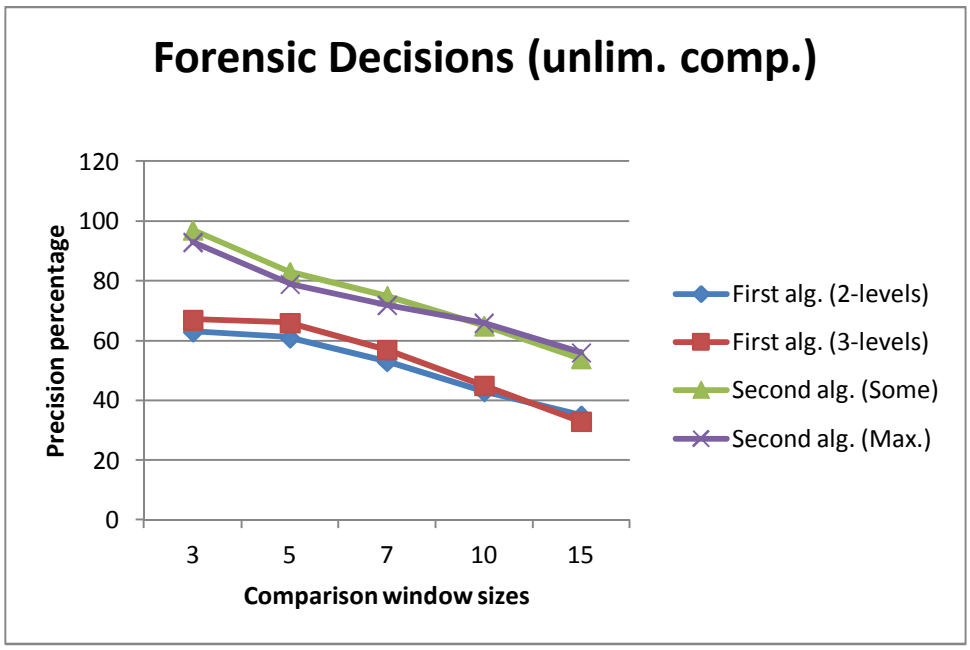

Figure 4.1. Precision percentages for Forensic Decisions corpus in accordance with unlimited comparison window sizes.

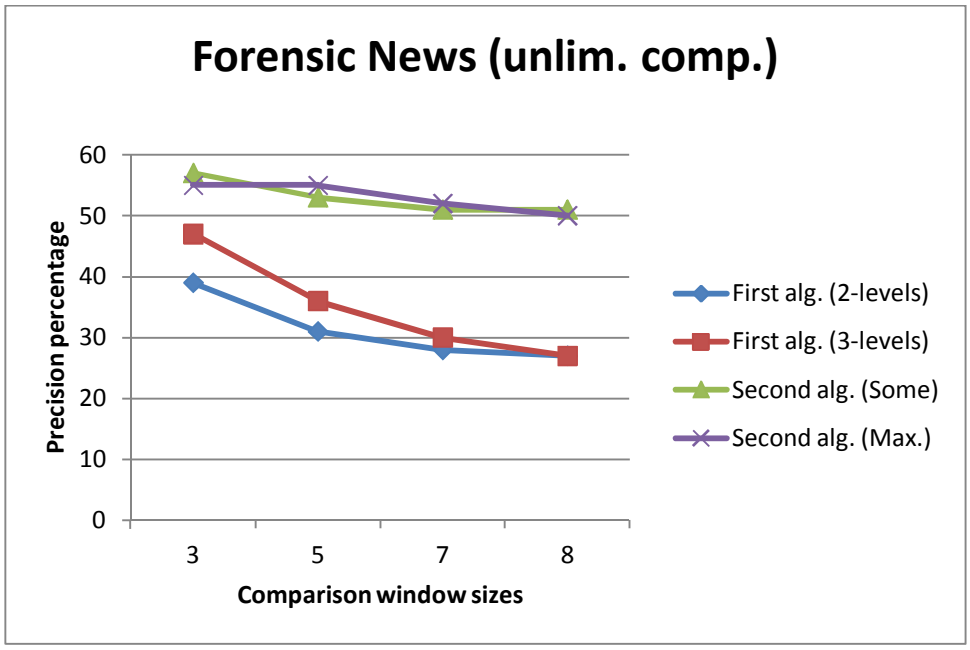

Figure 4.2. Precision percentages for Forensic News corpus in accordance with limited comparison window sizes.

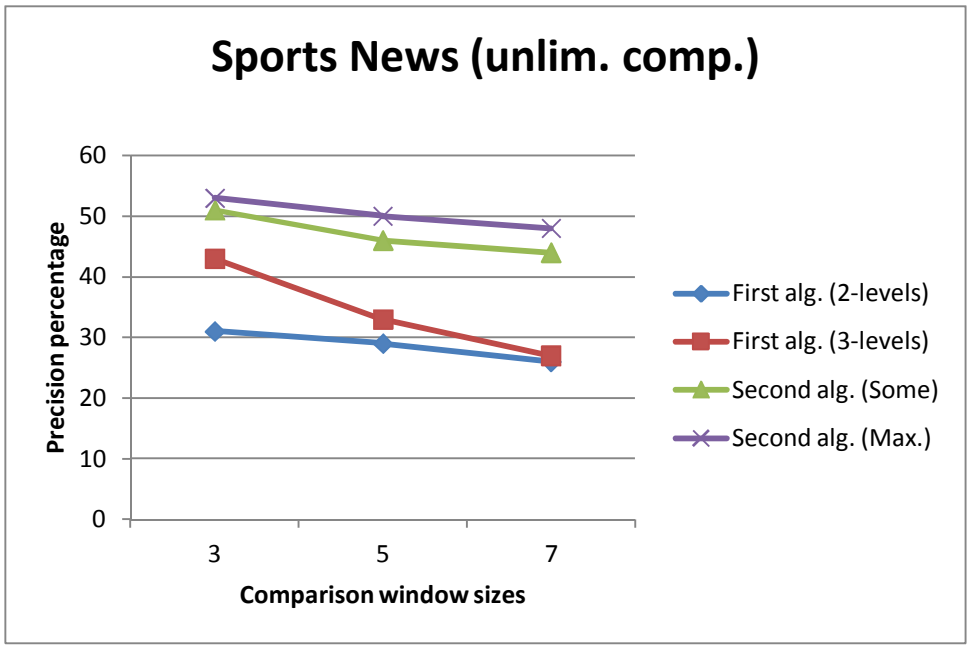

Figure 4.3. Precision percentages for Sports News corpus in accordance with unlimited comparison window sizes.

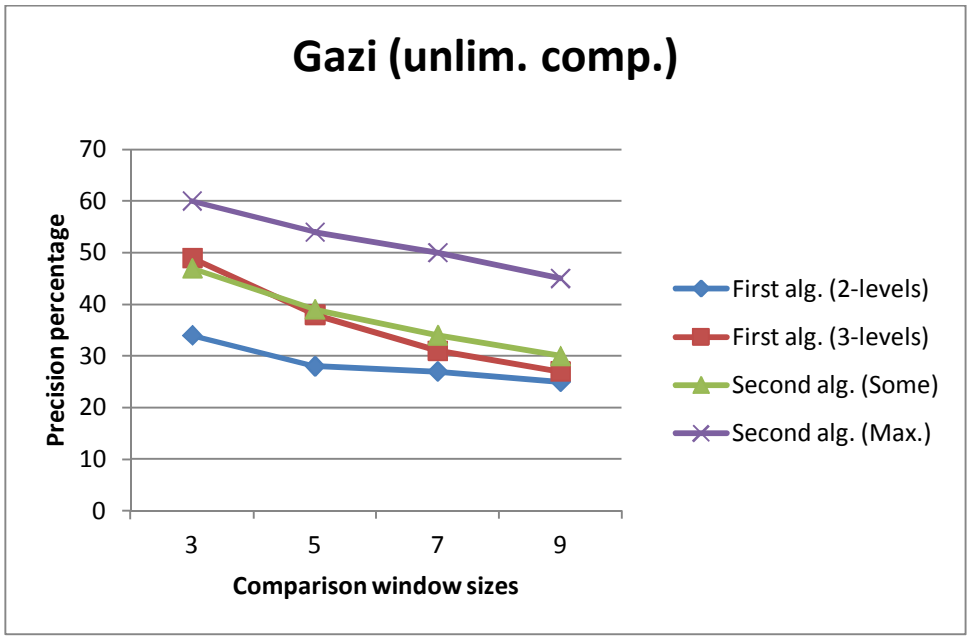

Figure 4.4. Precision percentages for Gazi corpus in accordance with unlimited comparison window sizes.

In above figures, First alg. (two-levels) stands for the first alternative algorithm according to which a matrix is built as explained in Section 3.4.3, a hierarchy with two-levels is taken into account. First alg. (three-levels) takes into three-level hierarchical structure built through dictionary, different coefficients for different levels, and frequency into account. Second alg. (Max.) is the second approach developed, according to which for each document noun, the noun itself and another noun that is both most widely found in the contexts of the document word in corpora, and present in the meaning text are taken into account, that is, at most two words for document nouns are used for each row in the matrix. Second alg. (Some) takes into account, for document words, all the nouns present in both the meaning text of document nouns, and contexts. Some meaning text nouns are eliminated due to that they are not present in the contexts of the document nouns in corpora. Also some words are assigned higher scores in that they are more widely found in the contexts of document words in corpora. As can be clearly noticed, first algorithm alternatives give unsuccessful results, because, as stated before, all meaning text nouns would not present the general meaning, that is concept, of a word, so some elimination would give amelioration in results.

For different corpora, algorithms give different precision results. The highest precision results are achieved through the second algorithm (max.) for the corpora Gazi, Sport News, and the second algorithm with two alternatives for the corpora Forensic Decisions and Forensic News. When taking into account the highest precision success rates obtained using unlimited comparison window size, precision, on average, is 52.1% for first algorithm (one of the sub-algorithms is selected whichever gives the highest accuracy results), and 63.97% for second algorithm.

An example of comparing the precision results for different corpora, selecting the window size as seven, unlimited, is shown in Figure 4.5. That is, top three concepts found algorithmically are compared with all words found manually. An important point here to note is that Forensic Decision success results excel the other ones to an extreme degree, whereas Gazi corpus success results give very weak results. It may be due to that, as stated before, a single topic that is forensic domain is encountered in all the documents of the Forensic Decisions corpus, whereas Gazi corpus has many different topics distributed over its documents, such as engineering, scientific, or architectural reports, and tutorials.

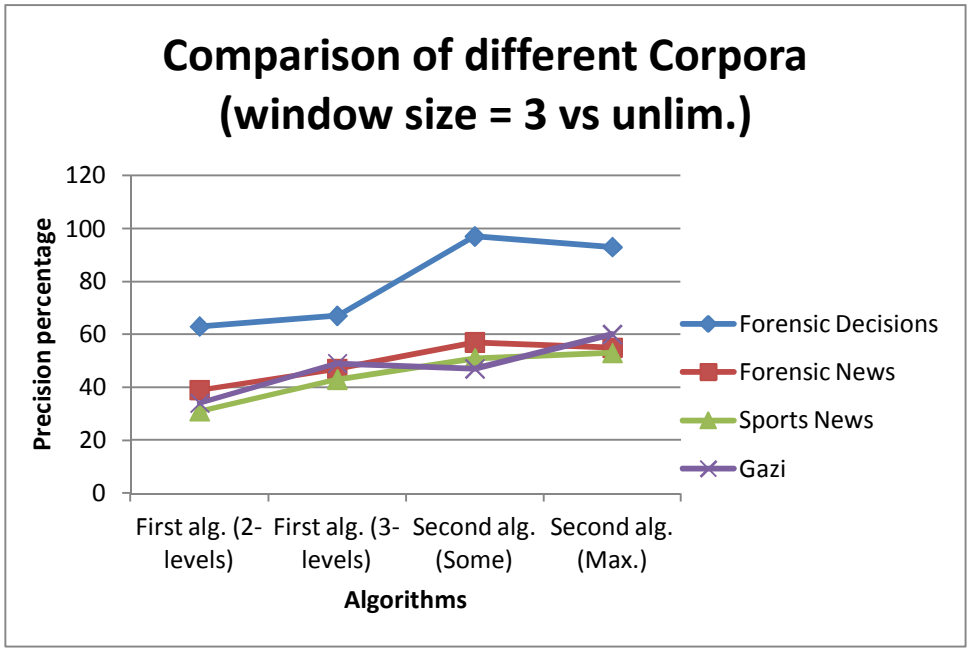

Figure 4.5. Comparison of different corpora in accordance with different algorithm, taking into account three vs. unlimited approach.

5. CONCLUSION

Concept Mining is a field of NLP that can be used in medical applications, forensic cases, financial systems such as that of banks, text categorization, search engine algorithms and many other domains. Its importance is increasing due to that the size of data and documents in electronic medium is growing to an extreme degree, and conceptual information from those electronic materials (be it textual, visual or audio) need to be extracted through computerized, automatic methods in an efficient way. Most of the data from which concepts are extracted are textual ones in this domain, whereas concept extraction from visual and audio materials are rarely used as compared with the former one. In this thesis only textual materials are processed for concept extraction.

Many algorithms have been used for extracting concepts so far, but the most commonly used ones are that of statistical and NLP methods. These methods include SVM, HMM, LSA, clustering and many more algorithms which can ease extracting the concepts. Possibility of human intervention in NLP makes it more beneficial and useful than making use of statistical methods.

Although the majority of algorithms used in extraction of concepts domain makes use of the AI methods. Also during this thesis study, machine learning methods such as clustering is implemented, but after seeing that no meaningful results could be achieved, those methods are dismissed. Instead a simple, novel statistical method benefiting from dictionary is developed. Two methods have been developed for this thesis work. The former one takes into account all the words in meaning text of a word that is present in the document when trying to extract concepts from a document, while the latter one takes into account only the words in the document itself, and an extra word that is present in the meaning texts of those words, and also that is most commonly found in the contexts of the words. The latter one makes use of 2nd approach, that is context analysis whereas the former one doesn't follow such an approach.

In accordance with this algorithm, also some features of the words are taken into account besides using dictionary. These features include the frequency, first location, and scope factors of the terms. This is a meaningful approach, since the general idea, that is concept, of a document generally has to do with the words that are most widely found in this material. Also other location properties of words may carry a lot of weight with the general idea, that is concept of the documents.

The two algorithms developed for this thesis gave meaningful results, but, on average, the second alternative gave higher precision results for four corpora. The first algorithm gave a precision result of 52.1%, whereas the second one precision rate of 63.97%. This is the case since first algorithm takes into account all the meaning text nouns of the document nouns, and all of these would not contribute to extracting general ideas concerning those words.

Many studies are carried out concerning concept mining for most widely spoken languages, such as English and Spanish, but as for Turkish it is still an immature topic and there have been only a few studies concerning this area. Taking into account that the results achieved in this thesis work are high, it may be used for extracting concepts from Turkish documents in corpora.

As a future work, there may be implemented some ameliorations on this thesis work. For example verbs can also be taken into account, because verbs also can give a general idea concerning the document. Verbs are considered to have a core importance in the sentence structure in that all other words are dependent on them, hence thinking of them as probable concepts may be beneficial. Also noun phrases can be used in this context, but since through the parser and disambiguator tools the noun phrases cannot be extracted, this approach had to be dismissed. Making use of grammatical cases, such as subject, and object cases can contribute to extracting more meaningful concepts, but for there are no Turkish grammatical case identifier tool, or program we know, we had to dismiss this approach as well.

Another future work would be that initial algorithms (Section 3.3) can be enhanced. K-means, c-means and hierarchical clustering methods yielded unsuccessful results for

sentence, and window co-occurrence algorithms, and those methods would be dismissed, but as for the algorithm making use of dictionary, clustering methods can be bettered. In this thesis, corpus-based approach is used as training data for dictionary-clustering method, but a new algorithm can be developed that approaches the whole TDK Turkish dictionary as a training data. In accordance with this algorithm, dictionary word entries can be semantically related to one another with the common words in their meaning texts. Since dictionary is much bigger than corpora, this would constitute a better training data in that after clustering, any word in documents can be assigned to a cluster for dictionary anyway includes all the words in the corpora. Clusters can also be homogeneous and their density in terms of words they contain would not differ much from one another.

REFERENCES

1. E., Zalta, "Fregean Senses, Modes of Presentation, and Concepts", *Philosophical Perspectives*, Vol. 15, pp. 335-359, 2001.

2. SPSS Inc., "Mastering New Challenges in Text Analytics", *SPSS Technical Report*, MCTWP-0109, 2009.

3. F., Kalaycılar and I., Cicekli, "TurKeyX: Turkish Keyphrase Extractor", *ISCIS '08. 23rd International Symposium,* 27-29 October, 2008.

4. N., Pala and I., Cicekli, "Turkish Keyphrase Extraction Using KEA", *Proceedings of 22nd International Symposium on Computer and Information Sciences (ISCIS 2007)*, Ankara, Turkey, 2007.

5. V., Faber, J. G., Hochberg, P. M., Kelly, T. R., Thomas and J. M., White, "Concept Extraction – A Data-Mining Technique", *Los Alamos Science*, 1994.

6. N. A., Bennett, Q., He, C. T. K., Chang and B. R., Schats, "Concept Extraction in the Interspace Prototype", Technical Report, Dept. of Computer Science, University of Illinois at Urbana-Champaign, Champaign, IL, 1999.

7. M. F., Moens and R., Angheluta, "Concept Extraction from Legal Cases: The Use of a Statistic of Coincidence", *International Conference on Artificial Intelligence and Law,* ICAIL, ACM, 2003.

8. M., Uzun, *Developing a Concept Extraction System for Turkish*, M.S. Thesis, Boğaziçi University, 2011.

9. Z., Elberrichi, A., Rahmoun and M. A., Bentaalah, "Using WordNet for Text Categorization", *The International Arab Journal of Information Technology*, Vol. 5, No. 1, 2008.

10. H., Liu and P., Singh, "ConceptNet - A Practical Commonsense Reasoning Tool-Kit", *BT Technology Journal*, Vol. 22, No. 4, 2004.

11. P. M., Ramirez and C. A., Mattmann, "ACE: Improving Search Engines via Automatic Concept Extraction", *Information Reuse and Integration*, 2004.

12. Z., Chengzhi and W., Dan, "Concept Extraction and Clustering for Topic Digital Library Construction", *IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology*, 2008.

13. H., Sak, T., Güngör and M., Saraçlar, "Turkish Language Resources: Morphological Parser, Morphological Disambiguator and Web Corpus", *GoTAL 2008*, vol. LNCS 5221, pp. 417-427, Springer, 2008.

14. H., Sak, T., Güngör and M., Saraçlar, "Morphological Disambiguation of Turkish Text with Perceptron Algorithm", *CICLing 2007*, vol. LNCS 4394, pp. 107-118, 2007.

15. L., AlSumait, D., Barbar´a and C., Domeniconi, "On-Line LDA: Adaptive Topic Models for Mining Text Streams with Applications to Topic Detection and Tracking", *ICDM '08 Proceedings of the 2008 Eighth IEEE International Conference on Data Mining*, 2008.

16. D., Pennock, K., Dave and S., Lawrence, "Mining the Peanut Gallery: Opinion Extraction and Semantic Classification of Product Reviews", *Proceedings of the Twelfth International World Wide Web Conference (WWW'2003),* ACM, 2003.

17. E., Alpaydın, *Introduction to Machine Learning, 2e,* The MIT Press, London, England, 2010.

18. K., Çelik and T., Güngör, *A Comprehensive Analysis of using Semantic Information in Text Categorization*, M.S. Thesis, Boğaziçi University, 2009.