A Relational Framework for Interpreting Anaphora

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***Abstract*—In this paper we present a novel way to resolve indirect or bridging anaphora which gives us a richer interpretation then the current frameworks. The new framework uses the core set of relations that have been used to describe compound noun generation. We firstly argue that the linguistic processes of compound noun generation and the use of NP anaphora are based on a common relational framework. In order to validate this theory we used human annotators to interpret indirect anaphora from naturally occurring discourses. The annotators were asked to classify the relation between an anaphor and the antecedent into relation types that have been previously used to describe the relation between the modifier and the head noun of a compound noun. We obtained very encouraging results with a Fleiss's κ value of 0.66 for inter-annotation agreement. This compares well with other similar annotation experiments for relation interpretation in compound nouns. The annotation results strongly indicate that anaphora and noun compounds are based on very similar relational framework, hence should treated the same.**

***Index Terms*—naphora resolution, noun phrase anaphora, discourse structure, noun compounds, noun phrasenaphora resolution, noun phrase anaphora, discourse structure, noun compounds, noun phrasea**

I. Introduction

The term **anaphora resolution** refers to identification of the real world entity that an anaphor co-refers to. This is true in the case of pronouns where the pronoun has a one-to-one relation with the antecedent. It is also true in the case of some NPs where the anaphoric NP directly co-refers to the antecedent (eg. James Smith/Mr Smith), however in a case such as window/house, table/tablecloth or even car/vehicle, there is an indirect relation, different to a one-to-one co-reference type relation between the anaphor and the antecedent. NP anaphora resolution studies (e.g. [1], [2], [3]) treat these indirect relations as a single category and refer to them as *associative* or *bridging* anaphora, however they are still interpreted as a form co-reference. In this study we propose a relational framework that distinguishes between the different types of semantic relations that can exist between two nouns, one of which is *used anaphorically* in a discourse. Hence anaphora interpretation involves identifying the antecedent as well as the **type** of relation to the antecedent noun. Since we are now identifying the type of relation, it is now possible for an anaphor to have multiple antecedents, related by the same or a different relation. This is a significant departure from the conventional notion of anaphora resolution where an anaphor is resolved to a single previously mentioned entity, and in the case in which it is also an anaphor, it is assumed to be already resolved forming a chain of relations. For some NP anaphora this is inadequate. As an illustration, consider the excerpt below:

The robber jumped out of the ***window***$_1$.
The ***house***$_2$ *belonged to Mr Smith.*
The ***window***$_3$ *is thought to have been unlocked.*

If we allow a single resolution relation for an anaphoric NP, then *window*$_3$ would have to be resolved to either *house*$_2$ or *window*$_1$. In either case, a part of the information would not be captured. A common strategy in most studies (eg. [1], [2]) is to resolve to the most recent antecedent. In the case of the above excerpt, this would mean that we resolve *window*$_3$ to *house*$_2$ which can be assumed to be already resolved to *window*$_1$. There are two inadequacies in this strategy; firstly the semantic difference between the relation of *window*$_3$ to window$_1$ and *window*$_3$ to *house*$_2$ is approximated by a single co-reference relation, and secondly as a consequence, the direct relation between *window*$_3$ to *window*$_1$ is not captured. In the proposed framework, we will identify both *house*$_2$ and *window*$_1$ as antecedents and interpret each of them with a different relation. It can be argued that this can be overwhelming since we can form a relation between even a pair of very remote entities. However the constraint in our case is that we are only interested in **relations that give rise to anaphoric use of NPs**. The interpretation framework involves **specifying a relation** between an anaphor and the antecedent hence a consequence of this is that an NP can form relations with **more than one antecedent**. This allows us to interpret and represent the multiple relations between a simple anaphoric noun such as *window* to *house* **and** another occurrence of *window*. However, more importantly, it allows us to a richer interpretation of compound nouns by interpreting the modifier/s in addition to the head noun. As a simple example, the compound noun *battle fatigue*, appearing after the clause "*The battle caused fatigue*" has a co-referential relation to the noun *fatigue*, but in addition it also has some interpretation relation (identified later as CAUSE) to the noun *battle*.

Hence, there are two novel aspects to this framework for interpreting anaphora; firstly it identifies a specific relation between the anaphor and its antecedent. Secondly, it also interprets modifiers beyond using them to merely identify the antecedent for the head noun, ie. interprets them in the same way as the head noun. A consequential effect of this is that an NP can have more then one antecedent. Thus this framework enables us to determine the relational dependence of an anaphoric NP to **all** other NPs in the discourse.

II. Related Works

NP anaphora resolution has received considerably less attention from computational linguists compared to pronominal anaphora even though the proportion of NP anaphora in natural discourses is either comparable or more then the proportion of pronominal anaphora. The reason for this seems to be because the problem of pronoun resolution much better defined compared to NP anaphora. This complexity of the problem also explains why whatever published work is available on NP anaphora resolution, is predominantly focussed on NPs that are definite descriptions (eg. [1], [2], [4], [5]) with the accompanying task of identifying whether a definite NP is anaphoric or not. NP resolution in these studies involves identifying a single previously mentioned noun that the anaphoric NP refers to. There are two categories of anaphora; **direct** and **associative**. The direct category includes cases in which an NP directly co-refers to another entity such as the case of *he/John*. The associative category includes cases such as *window/house*. Some of the studies such as [1] have gone a step further to specify the actual associative relation in terms of synonymy[1], hyponymy[2] and meronymy[3]. The motivation for these relations seems to have risen from organization of the lexicon, WordNet [6] which is used to bridge the meanings between the anaphor and the antecedent.

This paper argues that the noun compound generation process and the anaphoric use of NPs are similar linguistic processes, hence they have to be based on a common relational framework.

A compound NP of the form *noun* + *noun* (N + N) consists of two nouns which have some underlying semantic relation ([7], [8], [9]). According to these studies use of compound NPs is highly *productive* rather then *lexical*. In this productive process, compound NPs are formed by a producer on the fly as a discourse is being produced rather then recalled and used from a lexicon. This formation of NPs is not totally unconstrained, in other words, a compound NP cannot be formed with any two random nouns. For example, *war man* can not be formed on the basis of the relation "man who hates war" or similarly *house tree* can not be formed from "tree between two houses" [10]. In both the examples there does exist a relation between the nouns, however it is of the type that can be used to form a compound NP. With the exception of [10], the other mentioned studies on compound NPs have assumed that the set of generic relations are finite and characterizable, although the set is not necessarily common among all the studies. Studies such as [7] and [8] have attempted to identify these relations, and even though the exact set of relations proposed by the different studies are slightly different, a core set is very similar. An additional aspect highlighted in [8] is that compound nouns can also be formed from "temporary or fortuitous" relations, hence it presents a case for an existence of unbounded number of relations although the vast majority of noun compounds fit into a relatively small set of categories [11].

The relational frameworks used in computational linguistics vary along similar lines as those proposed by linguists. Some works in the computational linguistics (eg. [12], [13]) assume the existence an unbounded number of relations while others (eg. [14], [15]) use categories similar to Levi's finite set. Yet others (eg. [16], [17]) are somewhat similar to [18]. Most of the research to date has been domain independent done on generic corpus such as Penn Tree Bank, British National Corpus or the web.

The later works on noun compounds have followed on from either [19] or [18] with some of them coming up with a slightly different variation while others have defined a finer grained set of relations dictated by the data sets used for the study. For example, [11] reports a set of 43 relations grouped into 10 upper level categories. Most of the relations from different studies can be mapped to an equivalent relation in other studies.

For this study we chose the set of relations proposed by in [19] for two reasons. Firstly, our analysis of corpus for anaphor-antecedent relations seemed to map better to Levi's set of nine relations for noun compounds and secondly more of these relations can be computationally determined from existing lexicons such as WordNet and the Web. In terms of natural language processing, a linguistic theory is only useful if it can be reasonable implemented in a computational system.

[19] proposes that compound NPs are derived from underlying clause or complement structures by the two processes of *predicate deletion* and *normalization*. Her work is based on similar framework as [20] except Less' transformational process is based on verb classifications. Levi proposes that, in the case of normalization, 'the underlying predicate survives overtly in the head noun, with the modifier deriving from either the subject or the object of the underlying S', giving rise to subjective (eg. industrial production) or objective (eg. heart massage) normalization. For the case of predicate deletion, Levi maintains that the number or deletable predicates is limited to only nine primitive relations. They are CAUSE, HAVE, MAKE, USE, BE, IN, FROM, ABOUT and FOR. In the next section we argue that these relations also describe anaphoric use of NPs.

III. Anaphora Resolution Framework

In the Introduction we stated that anaphora interpretation and noun compound generation are two indicants of the same underlying relational framework between entities. Hence, a framework describing compound noun generation has to apply to anaphora usage as well. In the proposed framework we extend the relations proposed for compound noun generation

[1] same meaning relation

[2] same subset/superset relation

[3] part/whole relation

by predicate deletion from [19] for interpretation of NP as well as pronominal anaphora.

An indirect reference such as *window* referring to *house* and *diesel* referring to *truck* is based on the predicates "house **has** windows" and "a truck **uses** diesel". In the case of noun compound generation, the predicate is deleted and the two entities are juxtaposed to form the noun compounds *house window* and *diesel truck*. For interpretation of the compound noun the consumer is expected to reconstruct the relation between the modifier and the head noun ([8], [19]). We propose that the compound noun generation process is very similar to NP anaphora, except in the latter case the modifier is not necessarily bound to the head noun as part of a noun compound. That is, it may exist in another clause, however the same relation is still expected to be reconstructed for a full interpretation of the anaphor. Hence, for the example for the predicate "house has window", we could have the full NP, *house window* produced by predicate deletion. However in addition, the same predicate coulc also be expressed anaphorically as in the following example:

John bought a house in Glen Eden.
The windows are wooden.

In the example above the related entities from the predicate "house has windows" are separated into two different sentences, however the consumer is still expected to reconstruct the semantic relation as in the case of noun compound generation. Hence, with the proposed anaphora interpretation framework, the only difference between noun compound generation and anaphoric use of NPs is that in the former the two nouns are used together as a compound noun while in the latter the nouns are used separately as anaphor-antecedent pairs, however they are both governed by the same semantic framework.

Semantic relations between certain entities exit by default and can be assumed as part of the lexical knowledge by a producer. For example, the HAVE relation between *car* and *tyre* is part of lexicon so the noun compound *car tyre* and the noun *tyre* used anaphorically to refer to *car* is readily understood. However, in addition, a semantic relation can also be formed between two between two entities which are not usually related by the relation. In this case the relation is explicitly expressed by a predicate as context before the predicate is deleted to form a noun compound or used anaphorically. For example, after specifying the relation "the box has tyres", the noun *tyres* can be used to indirectly refer to *box* in the same way as the reference of *tyres* to *car*. However, the former can only be used in the context of the discourse in which the relation was expressed. This corresponds to Downing's [8] fortuitous relations. We distinguish between these two type of relations as **persistent** or **contextual**. Persistent relations are those that form part of the lexical knowledge which are valid within the context of an individual discourse as well as all other discourses. On the other hand contextual relations are transient and may be valid only for the duration of a single discourse, for example, "a cup on a table" or "John has a knife". The contextual relations can be expressed as either a verb or a preposition relating two entities in the discourse being processed.

As argued earlier, the semantic relations used by NP anaphora are same as those used for noun compound generation, hence for this study we adopted the set proposed in [19] consisting of the relations CAUSE, HAVE, MAKE, USE, BE, IN, FOR, FROM and ABOUT. In order to define a complete framework for anaphora interpretation, we needed to do two modifications to the nine relations from [19]. Both of these modifications were done in order to be able to better interpret and represent plural anaphoric NPs. This was done by introducing a new relation named ACTION, and by splitting the existing BE relation into BE-INST and BE-OCCR. These are explained next.

When two or more entities in a discourse are participating in the same or similar event, they can be referred to as a unit by a collective NP in the context of the discourse. Two entities in the same or similar action can be expressed by the conjunction *and* or described by two different clauses. For instance in the sentence "The coastguard and Lion Foundation Rescue helicopter were called out.", the entities *coastguard* and *Lion Foundation Rescue helicopter* are related to each other by the virtue of participating in the same action. Similarly, the clauses "the truck rolled down the hill" and "the ball rolled down the hill" would enforce the same relation between *truck* and *ball* since they are both engaged in the same action (roll). This relation between truck and ball is only valid for the context of the discourse, hence the relation is contextual. We describe this contextual relation as the ACTION relation which relates entities participating in events which are identified to be same or similar. The ACTION is used to describe an NP such as *runners* used to refer to *fox* and *Peter* from the context clause "The fox and Peter were running".

The second modification involved defining a finer grained BE relation in order to interpret existence of plurals in a different form. We split Levi's BE relation into BE-OCCR and BE-INST to distinguish between direct co-reference or identity relation and an instance relation. In a BE-OCCR relation an NP directly forms a one-to-one co-reference to another NP, eg. *John/he* and *John/the driver*. The BE-INST relation represents cases where an anaphor refers to a plural antecedent, in a partial capacity, for example, *both trucks/northbound truck*. In this case the NP *northbound truck* is an instance of *both trucks* which is distinct from a co-reference relation. It can be argued that all subset/ superset relations such as *John/driver*(John is an instance of driver) and *car/vehicle* (car is and instance of vehicle) is an instance relation. However we consider these as BE-OCCR relation since they **function** to identify the entity. Hence in the framework, the BE-INST relation only relates a plural NP and an NP representing a subset of the plural NP.

With this discussion we can now define and exemplify the eleven relation types was used for the purpose of anaphora interpretation. They are:

CAUSE - Includes all causal relations. For example,

battle/fatigue, *earthquake/tsunami*
HAVE - Includes notions of possession. This includes diverse examples such as *snake/poison*, *house/window* and *cake/apple*.
MAKE - Includes examples such as *concrete house*, *tar/road* and *lead/pencil*.
USE - Some examples are *drill/electricity* and *steam/ship*.
BE-INST - Includes plural cases such as *both trucks/southbound truck*, *John/teachers*.
BE-OCCR - Describes the same instance participating in multiple events. For example *John Smith/Mr Smith/he* and *John Smith/the driver*.
IN - This relation captures grouping of things that share physical or temporal properties. For example *lamp/table* and *Auckland/New Zealand*.
FOR - This includes purpose of one entity for another. For example *pen/writing* and *soccer ball/play*.
FROM - This includes cases where one entity is derived from another. For example *olive/oil* and *wheat/flour*.
ABOUT - Describes cases where one entity is a topic of the other. For example *travel/story* and *loan/terms*.
ACTION - This is only a contextual relation meant to capture entities engaged in same or similar action either with the same object/s or a null object.

The next section describes the annotation experiment done in order to validate the that anaphora usage is based on the above relation types.

IV. Annotation Experiment

A. Annotators

For the purpose of human validation of all relations in the framework we used second and third year students enrolled in computer related degrees. The annotation experiments were done over a period of 4 weeks at the beginning of their usual classes. Four different streams were used each consisting of approximately 30 students. The students in each stream were given a basic training on the requirements of the annotation and they were given a single annotation task at the beginning of their class over a 4 week period. The whole annotation experiment was broken down into session based tasks involving 25 anaphoric NPs per task. This was done to ensure that each task was completed in about 10 minutes with minimal impact on the students class time. In addition, the annotators were not identified in any of the tasks. We only ensured that an annotator did not annotate the same task twice.

B. Annotation Data

Our base input data used for content analysis for all aspects of NP usage consisted of 120 articles (of mixed genre) from *The New Zealand Herald*, *The Dominion Post* and *The Press* which are three major online newspapers from three different cities in New Zealand. The choice of the articles were not completely random. This corpora was developed to serve as the input data for the anaphora resolution system which is the parent project of this study. Hence, the corpora was developed from the articles which were not too short (had more then 20 sentences), exhibited use of a variety of anaphoric uses (including pronominal anaphora) and had been written by different writers.

An inherent challenge in most NLP tasks is what is referred to as *data sparseness*. The term is used to describe a characteristic when a single chosen corpus cannot be used for consistent empirical validation of **all** aspects of a theory. This is because the prevalence of the different characteristics of an NLP theory can be unevenly distributed in a fixed corpus. Hence, we searched an extended corpus in order to make the lower threshold of 15 relations from each category. For this we used The Corpus of Contemporary American English [21]. This freely available corpora consisting of some 410 million words from a variety of genre and has an online web interface which can be used to do fairly complex searches for words and phrases hence forms an excellent resource for manual content analysis for NLP tasks.

We excluded validating the BE-OCCR relation since this is a non-ambiguous co-reference relation.

For the annotation experiment we used 3 streams of approximately 30 students giving us a total of 90 different annotators. Each annotator took 4 different tasks, one per week for a period of 4 weeks. Each task consisted of 25 antecedent-anaphor pairs and was annotated by 2 streams, ie. approx. 60 annotators. We randomly discarded some annotation task sheets in order to have a consistent number of annotations for each pair resulting in 25 annotators for each task. Each relation type from (CAUSE, HAVE, MAKE, USE, BE-INST, IN, FOR, FROM, ABOUT, ACTION) as classified by the author was represented by 15 anaphor-antecedent pairs. The pairs from each of the 10 relation types were randomly selected to make up 6 task sheets, each consisting of 25 pairs. The total number of classifications for all relations amounted to 3750 with 375 classifications for each relation type consisting of 15 different anaphor-antecedent pairs.

Each of the streams were given a basic training on on semantic interpretation of the relation types using the examples in section section III. These examples were also given as a separate sheet with each annotation task. Each task sheet consisted of anaphor-antecedent pairs and a tick box for each of the relations. The annotators were asked to choose the relation which best describes the anaphor-antecedent pair. Two additional options, OTHER and NONE were also given. The OTHER was to be used if the annotator thought that a relation does exist but is not present in the given list and option NONE to be used if the annotator thought that the pair were not related at all.

Table I shows the confusion matrix of the relation types as identified by the annotators against the author's classification. Table II shows the corresponding confusion indices between the relation types. The confusion indices indicate the likelihood of a relation type to be interpreted as another type.

	CAUSE	HAVE	MAKE	USE	BE-INST	IN	FOR	FROM	ABOUT	ACTION	OTHER	NONE
CAUSE	**208**		45	87				4	14		15	2
HAVE		**196**	113	7		13		46				
MAKE		45	**206**	120				4				
USE		45	26	**242**			59	3				
BE-INST					**347**			19			9	
IN		64	37			**241**		33				
FOR		18	5	132			**216**	4				
FROM		9	17			35	87	**227**				
ABOUT	48	11		56				7	**253**			
ACTION									5	**351**	19	

TABLE I
CONFUSION MATRIX FOR THE NON-NORMALIZED NPS. THE COLUMNS GIVE THE ANNOTATIONS BY ANNOTATORS AGAINST THE AUTHOR'S ANNOTATIONS ON THE ROWS. EACH RELATION CATEGORY HAD A TOTAL OF 375 ANNOTATIONS DONE BY 50 DIFFERENT ANNOTATORS. THE BOLDED ENTRIES INDICATE NUMBER OF ANNOTATIONS AGREEING WITH AUTHOR'S ANNOTATIONS

	CAUSE	HAVE	MAKE	USE	BE-INST	IN	FOR	FROM	ABOUT	ACTION	OTHER	NONE
CAUSE	**0.55**		0.12	0.23				0.01	0.04		0.04	0.01
HAVE		**0.52**	0.30	0.02		0.03		0.12				
MAKE		0.12	**0.55**	0.32				0.01				
USE		0.12	0.07	**0.65**			0.16	0.01				
BE-INST					**0.93**			0.05			0.02	
IN		0.17	0.10			**0.64**		0.09				
FOR		0.05	0.01	0.35			**0.58**	0.01				
FROM		0.02	0.05			0.09	0.23	**0.61**				
ABOUT	0.13	0.03		0.15				0.02	**0.67**			
ACTION								0.00	0.01	**0.94**	0.05	

TABLE II
CONFUSION INDEX MATRIX BETWEEN THE RELATION TYPES CORRESPONDING TO TABLE I. THE BOLDED ENTRIES INDICATE THE INDEX OF ANNOTATIONS WHICH WERE THE SAME AS THAT OF THE AUTHOR'S.

V. RESULTS

The first observation of the annotation results from table I is that only 2 annotations out of a total of 3750 were classified as NONE indicating that the annotators by and large thought that the pairs given had **some** relation. In addition a total of 43 (approx. 1.1%) annotations were classified as OTHER, indicating the relations were described by a relation not in the list of 10 that were given. The main categories that were interpreted as having some other relation were CAUSE and ACTION, however these were still a very small percentage with indices of 0.04 and 0.05 respectively. The bolded entries in table II give the percentage agreement of the relation types agreeing with that of the author. The relation types BE-INST and ACTION have the highest conformance indicating they are the least ambiguous. The other types vary from a low figure of 0.52 for HAVE to 0.67 for ABOUT with an overall agreement value of 0.66. The relation types that were easily confused and hence can be interpreted as semantically close were HAVE and MAKE USE. Conflating these 3 categories gives us an agreement index of 0.89. Another crucial observation is for the FROM relation. Although not by large amounts, this relation type seems to be confused with all other categories. This prompted us to closely examine the task sheets to see if there were consistent misclassifications by the author, however no such patterns were found. Some of the classifications seemed to use the FROM type as a "fall back" category.

In order to compare the inter-annotator agreement with other similar studies we also computed the Fleiss' κ measure. The κ index for the overall annotation tasks was computed to be 0.64 and the value with HAVE, MAKE and USE conflated was 0.86. The overall κ value 0.64 compares well the inter-annotator figures from other annotation experiments dealing with identification of relations. For comparison some of the results are summarized in table III.

Study	Agreement Index	No. of Relations
[11]	0.57 - 0.67 κ	43
[22]	0.61 κ	22
[23]	0.68 κ	6
[17]	52.31 %	20
[24]	0.58 κ	21

TABLE III
INTER-ANNOTATOR AGREEMENT COMPARISON BETWEEN STUDIES DEALING WITH RELATIONS BETWEEN COMPOSITE NOUNS OF NOUN COMPOUNDS.

VI. DISCUSSION

The annotation experiment results strongly indicates that the the two natural language usage phenomena of compound noun generation and anaphoric use of nouns are based on the same underlying semantic structure. Since they are two different processes they have been studied as two separate nlp research areas as well. The proposed framework for anaphora resolution allows us to marry the two nlp areas so that we can better share computational advances in the two research areas. Recently there has been an increased momentum [15], [11], [13], [12], [25], [26], [27], [28] towards automatic derivation of relations between composite nouns in noun compounds, most of them based on relations from [19]. This will result in an increasing amount of ontology describing the semantic relations between compound nouns which will also become useful for anaphora interpretation if there is an existence of a common framework. The anaphora interpretation framework proposed in this study is a step towards this.

Another significant advantage of a common framework is that it will be easier to integrate the full meaning of a compound noun and the meaning associated with it being used anaphorically. Currently, anaphora is described using a different set of relations (eg. synonymy, hypernomy, hyponomy etc.) and compound nouns with a different set. Hence, when interpreting a compound noun which is also anaphoric, it becomes difficult to merge the two meanings. The interpretative power of using this common framework is being investigated and will be reported in future publications.

VII. Concluding Remarks

In this paper we presented a relational framework for interpreting anaphoric NPs which goes beyond the conventional co-reference relations. We argued that anaphora usage and compound noun generation are based on a common relational framework. To support this we used an existing NP production framework and validated it for anaphora usage using real world discourses. We also argued that using this framework, a more accurate level of discourse interpretation can be achieved, both directly, as well as using it as a building block for a higher level discourse structure such as the coherence structure. We are in the process of enthusiastically implementing the framework and will reporting the results in near future. It is anticipated that successful computation of this framework will make it useful in numerous NLP tasks such as document visualization, summarization, archieving/retrieval and search engine applications.

References

[1] M. Poesio, R. Vieira, and S. Teufel, "Resolving bridging references in unrestricted text," in *Proceedings of a Workshop on Operational Factors in Practical, Robust Anaphora Resolution for Unrestricted Texts*. Morristown, NJ, USA: Association for Computational Linguistics, 1997, pp. 1–6.

[2] K. Fraurud, "Definiteness and the processing of noun phrases in natural discourse," *Journal of Semantics*, vol. 7, no. 4, pp. 395–433, 1990.

[3] R. Vieira and M. Poesio, "An empirically based system for processing definite descriptions," *Computational Linguistics*, vol. 26, no. 4, pp. 539–593, 2000. [Online]. Available: http://www.mitpressjournals.org/doi/abs/10.1162/089120100750105948

[4] D. Bean and E. Riloff, "Corpus-based identification of non-anaphoric noun phrases," in *Proceedings of the 37th annual meeting of the Association for Computational Linguistics on Computational Linguistics*. Association for Computational Linguistics Morristown, NJ, USA, 1999, pp. 373–380.

[5] R. Bunescu, "Associative anaphora resolution: A web-based approach," in *In Proceedings of the EACL2003 Workshop on the Computational Treatment of Anaphora*, 2003, pp. 47–52.

[6] C. Fellbaum, *WordNet: An Electronic Lexical Database*. Bradford Books, 1998.

[7] J. Levi, "Where do all those other adjectives come from," in *Chicago Linguistic Society*, vol. 9, 1973, pp. 332–354.

[8] P. Downing, "On the creation and use of english compound nouns," *Language*, vol. 53, no. 4, pp. 810–842, 1977. [Online]. Available: http://www.jstor.org/stable/412913

[9] C. N. Li, "Semantics and the structure of compounds in chinese." Ph.D. dissertation, University of Carlifornia dissertation., 1971.

[10] K. E. Zimmer, "Some general observations about nominal compounds." *Working Papers on Language Universals*, pp. C1–21, 1971.

[11] S. Tratz and E. Hovy, "A taxonomy, dataset, and classifier for automatic noun compound interpretation," in *Proceedings of the 48th Annual Meeting of the Association for Computational Linguistics*, ser. ACL '10. Stroudsburg, PA, USA: Association for Computational Linguistics, 2010, pp. 678–687. [Online]. Available: http://portal.acm.org/citation.cfm?id=1858681.1858751

[12] C. Butnariu and T. Veale, "A concept-centered approach to noun-compound interpretation," in *Proceedings of the 22nd International Conference on Computational Linguistics - Volume 1*, ser. COLING '08. Stroudsburg, PA, USA: Association for Computational Linguistics, 2008, pp. 81–88. [Online]. Available: http://portal.acm.org/citation.cfm?id=1599081.1599092

[13] P. Nakov, "Noun compound interpretation using paraphrasing verbs: Feasibility study," 2008. [Online]. Available: http://www.cs.berkeley.edu/˜nakov/selected_papers_list/aimsa2008.pdf

[14] M. Lauer, "Corpus statistics meet the noun compound: some empirical results," in *Proceedings of the 33rd annual meeting on Association for Computational Linguistics*, ser. ACL '95. Stroudsburg, PA, USA: Association for Computational Linguistics, 1995, pp. 47–54. [Online]. Available: http://dx.doi.org/10.3115/981658.981665

[15] S. N. Kim and P. Nakov, "Large-scale noun compound interpretation using bootstrapping and the web as a corpus." in *The Proceeding of Conference on Empirical Methods in Natural Language Processing, EMNLP.*, Edinburgh, UK, 2011.

[16] V. Nastase and S. Szpakowicz, "Exploring noun-modifier semantic relations," in *Proceedings of the 5th International Workshop on Computational Semantics*, 2003.

[17] S. N. Kim and T. Baldwin, "Automatic interpretation of noun compounds using wordnet similarity," in *In Proceedings of the 2nd International Joint Conference on Natural Language Processing, Jeju Island, South Korea, 1113*, 2005, pp. 945–956.

[18] B. Warren, *Semantic patterns of noun-noun compounds*, ser. Gothenburg studies in English. Acta Universitatis thoburgensis, 1978.

[19] J. N. Levi, *The syntax and semantics of complex nominals / Judith N. Levi*. Academic Press, New York :, 1978.

[20] B. Lees, Robert, "On a transformational analysis of compounds: A reply to hans marchand," *Indogermanische Forschungen*, pp. 1–13, 1966.

[21] M. Davies, "Corpus of contemporary american english," http://www.americancorpus.org/, 2010.

[22] R. Girju, "Improving the interpretation of noun phrases with crosslinguistic information," in *in Proceedings of the 45th Annual Meeting of the Association of Computational Linguistics*, 2007, pp. 568–575.

[23] D. Ó Séaghdha, "Annotating and learning compound noun semantics," in *Proceedings of the 45th Annual Meeting of the ACL: Student Research Workshop*, ser. ACL '07. Stroudsburg, PA, USA: Association for Computational Linguistics, 2007, pp. 73–78. [Online]. Available: http://portal.acm.org/citation.cfm?id=1557835.1557852

[24] R. Girju, D. Moldovan, M. Tatu, and D. Antohe, "On the semantics of noun compounds," *Computer Speech and Language*, vol. 19, no. 4, pp. 479–496, 2005.

[25] S. N. Kim and T. Baldwin, "Interpreting semantic relations in noun compounds via verb semantics," in *Proceedings of the COLING/ACL on Main conference poster sessions*, ser. COLING-ACL '06. Stroudsburg, PA, USA: Association for Computational Linguistics, 2006, pp. 491–498. [Online]. Available: http://portal.acm.org/citation.cfm?id=1273073.1273137

[26] V. S.-S. Nastase, J. Sokolova, and S. M. Szpakowicz, "Learning noun-modifier semantic relations with corpus-based and wordnet-based features," *Proceedings of the National Conference on Aritficial Intelligence.*, vol. 21, no. Part 1, pp. 781–787, 2006.

[27] K. Barker and S. Szpakowicz, "Semi-automatic recognition of noun modifier relationships," 1998.

[28] I. Hendrickx, S. N. Kim, Z. Kozareva, P. Nakov, D. O. Séaghdha, S. Padó, M. Pennacchiotti, L. Romano, and S. Szpakowicz, "Semeval-2010 task 8: Multi-way classification of semantic relations between pairs of nominals," in *Proceedings of the 5th International Workshop on Semantic Evaluation*, ser. SemEval '10. Stroudsburg, PA, USA: Association for Computational Linguistics, 2010, pp. 33–38. [Online]. Available: http://portal.acm.org/citation.cfm?id=1859664.1859670