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A Thematic-Role-Based Approach for Word Sense Disambiguation

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ABSTRACT

The present paper investigates the thematic roles that can be developed for the purpose of Word Sense Disambiguation. In MT systems and electronic word databases, thematic role relations are not clearly included among other semantic relations. Identifying thematic roles of predicates helps in disambiguating word senses and hence producing more accurate translation. For instance, the meaning of the verb 'eat' differs depending on the thematic roles it assigns for its Subject and Object. When it assigns an animate Agent for its Subject and food Patient for its Object, it means 'take in solid food'. However, when it assigns Force for its Subject and metal Theme for its Object, it means 'cause to deteriorate due to the action of water, air or an acid'. Accordingly, different translations are produced in each context. Selectional restrictions are also tackled in the analysis of the sample verbs. The implementation is made on three MT systems: Al Wafi, Sakhr and Google. They all produce incorrect translations of the sample verbs. A suggested translation is proposed for each verb after analyzing its thematic roles and selectional restrictions. In this way, the present paper is significant since it helps in improving the performance of MT systems. The present paper will focus only on a group of English verbs that convey a variety of meanings. It will show a number of problematic cases in translation that occur due to the lack of thematic roles in the core of the system. After developing thematic roles, it is expected that such cases will be disambiguated.

1. Introduction

1.1 Statement of the problem

The problem is that although Wordnet (taken as an example of electronic semantic database) is structured to expose semantic relations among the synsets, thematic role relations are not clearly included. For example, the synset of a verb like 'die' (with the meaning of 'perish' or 'pass away') is presented in Wordnet 2.1 via certain semantic relations such as its antonym (be born) or its hypernym (change state). However, there is no mention to the relations that hold between 'die' and its nominal arguments. In other words, it is not clear whether 'die' assigns an agent or an Experiencer, whether it entails a patient or not, or whether it has temporal and locational roles or not (e.g. source/goal/ duration). Such relations are called thematic role relations and they are lacking in Wordnet. Thus, developing an inventory of thematic roles adds a new semantic relation to WordNet.

1.2 Research Questions

The present paper seeks answers to the following questions:

1- What are the thematic role candidates that can be integrated into WordNet for the purpose of word sense disambiguation?

2- How can these thematic roles disambiguate the meanings of selected verbs?

1.3 Scope and Limitations

The research scope focuses not only on the English verbs that have two or more different meanings but also that their meanings differ depending of the difference in their thematic roles and selectional restrictions. The sample verbs are exposed to translation by three MT systems: Al Wafi, Google and Sakhr. The three systems fail to disambiguate the verb meanings. A suggested thematic-role-based translation is presented for each verb in each context. In this way, the hypothesis of the research is tested and the results show how thematic roles can help in word sense disambiguation in MT systems.

2. Review of literature

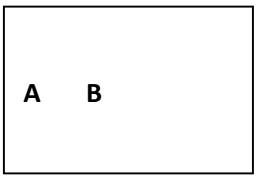
2.1 What is WordNet

WordNet was first developed by Professor George A. Miller in 1990 (Miller, 1990). It is an electronic lexical database whose building blocks are word forms and word meanings. Only content words such as nouns, verbs, adjectives and adverbs are represented in their familiar orthographic forms and grouped into synonym sets called synsets to represent their meanings. The synsets, in their turns, are interlinked by means of different semantic relations. A synset, then, is linked to a set of antonyms, a set of meronyms, a set of hyponyms and other semantic sets. Each synset, however, represents a certain lexical concept. For instance, flower (n) has three synsets representing three lexical concepts. The first has the sense 'a plant cultivated for its blooms or blossoms'. The second provides a group of synonyms sharing the sense of a 'reproductive organ of angiosperm plants especially one having showy or colorful parts', namely 'blossom' and 'bloom'. The third sense is 'the period of greatest prosperity or productivity'. The synonyms are 'prime, peak, heyday, bloom, blossom, efflorescence, flush....' Different semantic relations link the synsets of flower(n) with other synsets: hyperonymy (flower is a kind of X), hyponymy (X is a kind of flower), holonymy (flower is a part of X) and meronymy (X is a part of flower) (Miller, 1990).

2.2 Semantic relations in Euro WordNet

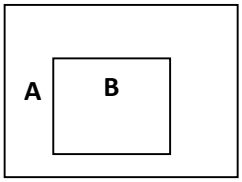
Each lexical unit has "an indefinite number of contextual relations but at the same time constitutes a unified whole" (Cruse 1986:84). The meaning of a lexical unit then is revealed via such contextual relations. Lexical relations comprise paradigmatic conceptual relations among lexemes. Cruse refers to the basic lexical relations as “congruence relations”. He suggests four relations between classes as follows:

i. **Identity**: where class A and class B have the same members



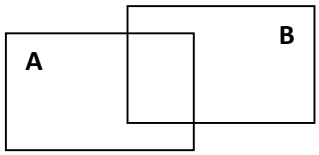
It is practically difficult to find two lexical items that are identical.

ii. **Inclusion**: where class B is wholly included in class A



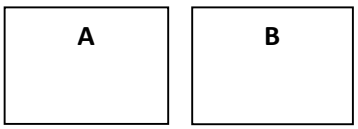
As in *mammal* and *animal* (a mammal includes animal)

iii. **Overlap**: where class A and class B have members in common but each has members not found in the other.



As in *violin* and *fiddle* (they have properties in common but still differ in terms of other properties)

iv. **Disjunction:** where class A and class B have no members in common.



As in *dead* and *alive*

The synsets are connected to each other via semantic relations that vary according to the type of the lexeme (Noun, Verb, Adjective or Adverb).The four basic relations suggested by Cruse can be applied to the majority of EWN semantic relations as follows:

1- **Synonym**s: holding the relation of identity. A is synonym to B if A and B have identical senses.

2- **Hypernyms**: holding the relation of inclusion. *Y* is a hypernym of *X* if every *X* is a (kind of) *Y*; if every *X* is included in *Y*

3- **Hyponyms**: holding the relation of inclusion. *Y* is a hyponym of *X* if every *Y* is a (kind of) *X*; if every *Y* is included in *X.*

4- **Antonyms**: holding the relation of disjunction. *X* is an antonym of *Y* if *X* is opposite in meaning to *Y*. The two classes do not share any members. They are disjunctive.

2.3 Thematic Roles

A catchall definition of thematic roles can be set as the semantic relations that hold between the verb and the different arguments that can be assigned to this verb. However, they cannot be described in semantic terms only, as Dowty assumes they are “creatures of syntax-semantics interface, and thus require a sound semantic theoretical basis as well as a syntactic one …” (Dowty1991:548). Thematic roles have developed through different linguistic stages starting from Gruber (1965), who introduced the concept using the term thematic relations, and Government and Binding theory (GB) in which thematic relations were introduced in a pure syntactic form as Theta Roles. Then the term was developed into a different semantic concept by Jackendoff (1972) who called these semantic relations 'Thematic Relations'. However, thematic relations can be described as corresponding to Fillmore's Deep Cases that were introduced in the structure of his Case Grammar (Fillmore, 1968). The present research deals with the concept using the term Thematic Roles. It also avails of what Dowty calls Thematic Proto Roles (Dowty, 1991).

2.4 Selectional Restrictions

The concept of selectional restriction was first introduced during the 1960s by Chomsky in the course of transformational grammar (Chomsky, 1965). Similar to most of the notions that emerged in this course, selectional restrictions were dealt with on the syntactical level. They are the limitations imposed on the selection of NPs by a given verb in the sentence. NPs are syntactically described as subjects or objects of the verb. However, without considering selectional restrictions, the sentences in the following examples are semantically odd

2.5 Word Sense Disambiguation

Word sense disambiguation (WSD) is the task of determining the proper meaning of a word in a given context (Dang, 2004). The process of disambiguating words is significantly required for improving natural language processing (NLP) systems including MT systems.

Verb sense disambiguation (VSD) is a subtask or a classification task of WSD. It is a classification task in the sense that it classifies a list of verb senses given in an inventory to select the proper meaning for a given context (Yarowsky, 2000).Verbs that convey more than one meaning are problematic for NLP applications. They pose the greatest obstacle for word sense disambiguation (WSD) since there is always a debate among even humans about what constitutes a different sense for polysemous word (Dang, 2004). Unlike WSD, verb sense disambiguation has not received much intention by researchers until recently.Verbs are treated by most systems the same way as nouns based mainly on examining collocation features for the purpose of disambiguation.(Ye & Baldwin, 2006). However, the verb-argument structure is traditionally ignored in the information required for disambiguation. The present research deals with verb-argument structures in terms of thematic roles and selectional preferences made by the verb. Information about such roles and preferences can help MT systems produce more accurate translation of verbs.

Early works were made to develop automatic WSD systems and were useful to solve problematic homonyms like bank. Yet, polysemous verbs like run (with related but distinct meanings) are still undistinguishable for NLP applications.

3. Methodology

3.1 Attempted analysis of successful sample verbs:

The analysis presented in this section is made to eleven successful sample verbs where each verb assigns more than one thematic role depending on the context in which it occurs. The thematic roles are mapped to the syntactic representations made by each verb (mainly Subject and Object or Complement in case of intransitive verbs). Selectional restrictions imposed by each verb on its nominal arguments are also mapped to its syntactic representations.

The analysis is presented into four tables standing for four main categories. The first category (as shown in Table 1) includes transitive verbs that share the same pattern of the assigned thematic roles as mapped to their Subject and Object. Thus, in the first context each verb assigns Agent for its Subject and Patient for its Object, whereas in the second context the verb assigns Agent for its Subject and Theme for its Object. In addition, a variety of different selectional restrictions are also presented as imposed by the verb on its Subject and Object in each context.

The second category (as shown in Table 2) includes transitive verbs that share the same thematic roles for its Subjects and Objects, whereas they impose different selectional restrictions on these syntactic representations. The verbs in this category illustrate for the significance of selectional restrictions to be considered along with thematic role relations for WSD. In this pattern the disambiguation of the verb meaning is made by investigating the selectional restrictions rather than the thematic role relations merely.

The third category (as shown in Table 3) includes transitive verbs that assign different thematic roles, and impose different selectional restrictions on their Subject and Object in different contexts. The disambiguation of the meanings of the verbs can be easily made by investigating thematic roles or selectional restrictions.

The fourth category (as shown in Table 4) includes intransitive verbs that have only one grammatical role; i.e. Subject. The sample verbs here show different patterns of both thematic roles and selectional restrictions they impose on these roles.

Sample Verb	Sentence	Thematic Roles	Selectional Restrictions	Meaning
1. Break	1.1 "He broke the glass plate" The ball broke the window	Agent / Instrument Subject	<Animate> <inanimate>	Cause to separate or divide into pieces
		Patient Object	Physical entity	
	1.2 "Break a law" She broke a law.	Agent Subject	Animate	Breach or violate
		Theme Object	Legal agreements or rules	
2. Clap	2.1 "The big bird clapped its wings."	Agent Subject	bird	Flap
		Theme Object	wings	
	2.2 The children clapped their hands.	Agent Subject	human	Applaud
		Patient Object	hands	
3. Cure	3.1 'cure a cold' "The treatment cured the boy's acne"	Agent / Force Subject	Animate / Inanimate	'heal'
		Theme Object	Disease	
	3.2 "cure meats" "cure pickles"	Agent Subject	Animate	'preserve'
		Patient Object	Food	

Table 1: The Analysis of the first category of sample verbs

The verb break as a transitive verb has several meanings. However, only two meanings are presented here since they are the most significant for the purpose of the present research. These two meanings strongly manifest how the meaning of the verb is identified depending on the thematic roles assigned for its Subject and Object. In 1.1 He broke the glass plate the Subject is an Agent <Animate>. It can also be an Instrument <Inanimate> as in The ball broke the window. The ball is the instrument with which the window was broken. Whether the Subject is an Agent or Instrument, whether it is <Animate> or <Inanimate> does not affect the meaning. The significant factor in this context is the thematic role assigned for the Object as well as the selectional restrictions imposed on it. The object (the glass plate or the window) is Patient and it must be <Physical entity>. As such, where break as a transitive verb assigns Agent <Animate> (or Instrument <Inanimate>) for its Subject along with a Patient <Physical entity> for its Object, it has the meaning of Cause to separate or divide into pieces. On the other hand, when break changes the thematic roles assigned for its Subject and Object it has a different meaning. In 1.2 Break a law the Subject must be Agent <Animate> (She, John, The doctor broke a law). In this context the Subject cannot be Instrument (The ball, the keys broke a law). The Object is a Theme not Patient and it must be <a kind of legal agreement or promise> (You broke our promise, They broke the contract). The verb break in such contexts has the meaning of violate or breach but not separate into pieces.

In example 2.1 The big bird clapped its wings the verb clap assigns an Agent role for its Subject and a Theme role for its Object. The verb places a kind of selectional restriction on its Agent and Theme. Such restrictions are crucial in disambiguating its meaning. The Agent here is <Bird> and the Theme is <Wings>. Accordingly, in any context where clap assigns an Agent <Bird> and a Theme <Wings>, it has the meaning of Flap. However, when it assigns an Agent <Human> for its Subject and a Patient<Hands> for its Object, it has the meaning of applaud as shown in example 2.2 the children clapped their hands. It is obvious that selectional restrictions play a significant role in disambiguating the meaning of the verb in each context. The verb assigns an Agent for its Subject in both contexts. However, the selectional restriction it imposes on each Agent differentiates the meaning in each context. Thus, in the first context the Agent must be <Bird> (eagle, owl, lark, falcon and so on) to produce the meaning of flap, whereas in the second context the Agent must be <Human> to produce the meaning of applaud. Additionally, the verb assigns different thematic roles for its Object in each context (Theme and Patient). However, the selectional restrictions incrementally help disambiguate the meaning. The Theme must be <Wings> to mean flap and the Patient must be <Hands> to mean applaud.

In example 3.1 and 3.2, it is obvious that the transitive verb cure has two different meanings. The disambiguation factor here lies in the thematic roles and selectional restrictions imposed by the verb mainly on its Object rather than its Subject. In 3.1 cure a cold, the subject can be an Agent <Animate> (The doctor, My uncle, Mary can cure a cold). It can also be a Force which is necessarily <Inanimate> as in The treatment cured the boy's acne where treatment cannot be Agent or <Animate>. It is simply the natural actor of the verb or the Force that instigates the action. For its Object, cure assigns a Theme that must be <Disease> (a cold, an acne, fever, etc.). In the context where cure assigns a Theme <Disease> for its Object (whether it assigns an Agent <Animate> or a Force <Inanimate> for its Subject) it means to heal. On the other hand, in 3.2cure meats or cure pickles, it is obvious that the verb changes its roles assigned for its Object. Accordingly, it has a different meaning. In this context cure assigns a Patient for its Object. It is the Patient that internally changed by the action. The verb also imposes that its Patient Object must be <Food>. Similar to the example in 3.1, cure may assign an Agent <Animate> for its Subject (Adam, She, The workers cure meats) or a Force <Inanimate> (These chemicals, devices are used to cure pickles). The meaning of cure is changed to be preserve. Such a change in meaning is due to the change in the roles assigned by the verb for its Object.

Table 2 presents the analysis of three verbs. They are all transitive verbs: Land, Play and See. They share the same thematic roles for their syntactic representations. In other words, each verb assigns Agent for its Subject and Theme for its Object in the two sentences expressing its two different contexts. The disambiguation of the verb sense lies here in the difference of the selectional restrictions rather than the thematic roles.

Sample Verb	Sentence	Thematic Roles	Selectional Restrictions	Meaning
4. Land	4.1 "The pilot managed to land the airplane safely" "land a seaplane on a lake"	Agent Subject	Animate	'to bring down' 'put down' 'set down'
		Theme Object	Vehicle	
	4.2 "landed a big catfish"	Agent Subject	Animate	'catch' 'pull in'
		Theme Object	Fish	
5. Play	5.1 'We played hockey all afternoon'	Agent Subject	Animate	Engage or participate in games or sport.
		Theme Object	Game	

	5.2 Mary played her favourite CD He played the CD, stereo, cassette, phonograph etc.	Agent Subject	Animate	Run or cause to emit recorded sound
		Theme Object	Sound recording	
6 See	6.1 "Can you see the bird in that tree?"	Experiencer Subject	Animate	Perceive by eye
		Theme Object	Visible entity	
	6.2 "I see your point"	Experiencer Subject	Human	Understand
		Theme Object	Cognition	

Table 2: The Analysis of the second category of sample verbs

In 4.1 and 4.2, the transitive verb land seems to assign the same thematic roles for its Subject and Object. It assigns an Agent for its Subject (the pilot, He, Mary, the sailor, My sister land the airplane or landed a catfish), and a Theme for its Object (land airplane, a seaplane, a catfish). It also imposes that the Agent must be an <Animate>. However, the verb sense disambiguation can be achieved by examining the selectional restrictions imposed by land on its Theme Object. In 4.1, the Theme Object must be <Vehicle>, whereas in 4.2, the same Theme must be <Fish>. The change in the selectional restrictions imposed by the verb land on its Theme Object leads to a change in the meaning of the verb. In the context where land assigns a Theme <Vehicle> for its Object, it means to bring down, put down, set down. In the context where land assigns a Theme <Fish> for its Object, it means to catch. Thus, the transitive verb land reflects the importance of acquiring selectional restrictions along with thematic roles for word sense disambiguation.

The verb play as a transitive verb usually assigns an Agent for its grammatical Subject and imposes that this Agent should be <Animate> regardless of its meaning. In 5.1 We played hockey all afternoon, the verb assigns an Agent <Animate>we. Similarly, in 5.2 Mary played her favorite CD, it assigns an Agent <Animate> for its Subejct Mary. Obviously, the verb has a different meaning in each context, but the disambiguation of the meaning depends mainly on the difference in the thematic roles and, more precisely, the selectional restrictions it assigns for its Object rather than its Subejct. Although play assigns Theme for its Object in both 5.1 and 5.2, it imposes different restrictions for each Theme. In 5.1, play imposes that its Theme should be <Game>, whereas in 5.2 it imposes that its Theme should be <Sound Recording>. This difference in the selectional restriction leads to a difference in the meaning of the verb play. In 5.1 where play assigns a Theme <Game> for its Object, it means engage or participate in games or sports. In 5.2 where play assigns a Theme <Sound Recording> for its Object, it has the meaning Run or cause to emit recorded sound.

The significance of selectional restrictions to be mapped to the thematic roles for word sense disambiguation is highly manifested in sentence 6.1 and 6.2. The verb see assigns the same roles for its Subject and Object in the two types of sentences. It assigns Experiencer for the Subject and Theme for the Object. However, see has different meaning in each sentence. In 6.1

Can you see the bird in that tree, it has the meaning of perceive by eye, but in 6.2 I see your point, it means understand. This difference in meaning is achieved due to the difference in the selectional restrictions imposed by the verb on its thematic roles. In 6.1, see assigns Experiencer <Animate> and Theme <Visible Entity> whereas in 6.2, it assigns Experiencer <Human> and Theme <Cognition>. This reflects Wagner's proposition that "the task of acquiring thematic role relations is intrinsically related to the task of acquiring selectional restrictions." (Wagner, 2005: iii).

Table 3 presents the analysis of the third category of the sample verbs. It includes the analysis of two transitive verbs: Eat and Gain. They assign different thematic roles for each of their syntactic representation (Subject / Object) in each context. They also impose different selectional restrictions on each thematic role.

Sample Verb	**Sentence**	**Thematic Roles**	**Selectional Restrictions**	**Meaning**
7. Eat	7.1 "She was eating a banana"	Agent Subject	Animate	Take in solid food
		Patient Object	Food	
	7.2 "an acid that eats the surface of a machine part"	Force Subject	water, air, chemicals	Corrode
		Patient Object	Inanimate	
8. Gain	8.1 "gained a small fortune in real estate" "gain an understanding of international finance"	Benefactive Subject	Animate	Acquire or win
		Theme Object	Abstract or physical entity	
	8.2 "The swimmer gained the shore" "…gained the top of the mountain"	Agent Subject	Animate	Reach
		Goal Object	Destination or Location	
		Patient Object	Object	
	8.3 'We hit Detroit by noon'	Theme Subject	Animate	To reach
		Goal Object	Place	

Table 3: The Analysis of the third category of sample verbs

The verb eat usually has the meaning of Take in solid food as shown in sentence 7.1 She was eating a banana. In this context, it assigns an Agent for its Subject. It imposes that this Agent must be <Animate>. It assigns a Patient for its Object which must be <Food>. The meaning of eat may change by changing the thematic roles it assigns for its Subject and Object and the selectional restrictions it imposes. In example 7.2 an acid that eats the surface of a machine part, it has the meaning of corrode as it assigns Force role (and imposes that it should be <Water, Air or Chemical>) for its Subject and a Patient<Inanimate> for its Object.

The thematic role that really disambiguates the meaning of the verb gain is the role assigned by the verb for its Object. In sentence 8.1, the verb assigns Benefactive <Animate>for its Subject. In 8.2, it assigns an Agent <Animate> for its Subject. For humans, it is possible to disambiguate the meaning depending on the difference between Benefactive and Agent. However, it is not a possible process for MT systems, especially that both thematic roles (Agent and Benefactive) have the same selectional restrictions <Animate>. As such, machines cannot recognize this difference, and hence, the roles assigned for the Subject (though different) are not sufficient for the process of disambiguation. Yet, considering the thematic roles along with the selectional restrictions imposed by the verb on the Object is the core for disambiguating the meaning of the verb in each context. In 8.1, the verb assigns Benefactive <Animate> for its Subject and Theme <Physical or Abstract entity> for its Object. In this context and with these roles combining altogether, the verb gain has the meaning acquire or win. On the other hand, in sentence 8.2, gain assigns Agent <Animate> for its Subject and Theme <Location or Destination> for its Object. With these roles and restrictions the verb gain has the meaning reach.

Table 4 presents the analysis of the fourth category of the sample verbs. It analyzes three sample verbs. They are all intransitive verbs that have only one grammatical role; i.e. Subject. They do not have Object, but rather a complement (if any). The three verbs, Die, Draw and Read, assign different thematic roles for their Subject roles. The difference in such a thematic role leads to the difference of the meaning of each verb in each sentence.

Sample Verb	**Sentence**	**Thematic Roles**	**Selectional Restrictions**	**Meaning**
9. Die	9.1 "She died from cancer"	Experiencer Subject	Animate	Perish or pass away
	9.2 "The car died on the road"	Patient Subject	Inanimate	Stop or break down
10. Draw	10.1She is drawing	Agent Subject	Human	Make drawings or create images
	10.2 "The patient's veins don't draw easily"	Theme Subject	Vessel	To cause to flow a liquid
11 Read	11.1 She reads well. John is reading.	Agent Subject	Animate	Interpret something that is written or printed
	11.2 "Her play reads better than it acts" "How does your new watch read?"	Experiencer Subject	Inanimate	Indicate or show a figure.

Table 4: The Analysis of the fourth category of sample verbs

In examples 9.1 and 9.2, the meaning of die is identified according to what role is assigned for its Subject. It is an intransitive verb that has no Object. Thus, the thematic role and the selectional restrictions imposed on its Subject form the base for disambiguating its meaning. In 9.1, she died from cancer the verb die has the meaning of perish or pass away since it assigns an Experiencer <Animate> for its Subject. In this way, other sentences can be created with the same meaning of the verb keeping the Experiencer role (John, My grandfather, My cat, Our neighbor died). However, in 9.2 the car died on the road, it assigns a

Patient <Inanimate>. Consequently, it has the meaning of 'break down'. Similarly, the Patient <Inanimate> can be the machine, my computer, the taxi, etc. With such Patients, die keeps the same meaning of stop or break down.

Examining the verb draw, as an intransitive verb, reveals that it has two different meanings. In 10.1 She is drawing, The verb assigns Agent for its Subject and restricts such Agent for <Human> only. Thus, Mary, The students, I, My brother can draw but <Inanimate> (The glass plate, My car), Location (London, The garden) or Instrument (The key, The knife) cannot draw. In this context where the intransitive verb draw assigns an Agent <Human> for its Subject, it has the meaning make drawings or create images. On the other hand, in 10.2 The patient's veins don't draw easily, the same intransitive verb draw assigns Theme for its Subject and imposes that it should be <Vessel> (vein, artery, capillary). In this case, draw does not mean create images. It has a different meaning due to the change in the thematic roles and selectional restrictions assigned for its Subject. In 10.2, the intransitive verb draw has the meaning to cause to flaw a liquid. The disambiguation of the verb sense depends on recognizing its thematic roles and selectional restrictions.

In 11.1, the verb read is an intransitive verb that assigns an Agent <Animate> for its Subject. It has the meaning of Interpret something that is written or printed. The thematic role and the selectional restrictions imposed on the Subject of read change in 11.2Her play reads better than it acts and How does your new watch read? In this context, read assigns Experiencer for its Subject and imposes that it must be <Inanimate>. The change in thematic roles and selectional restrictions leads to the change in the meaning of read. With Experiencer <Inanimate> Subject, read means Indicate or show a figure.

Thus, the analysis of the successful sample verbs shows that there is some sort of ambiguity in the meaning of such verbs. Some verbs have two meanings whereas others have three or more. In order to disambiguate the meaning of these verbs the thematic roles they assign should be tested. It is necessary to examine the selectional restrictions imposed by the verb on its thematic roles as well. The analysis reveals that the meaning is identified depending on what thematic roles each verb assigns and what selectional restrictions each verb imposes.

3.3 Thematic- roles- based translation

The significance of developing thematic roles for WordNet lies in the fact that thematic roles are not merely semantic but rather conceptual relations that hold between the predicate and its arguments (Wagner, 2005). They are conceptual in the sense that they are generally non language – specific. In this way, they match the Basic Concepts (BCs) and can be mapped to them in the ontology of WordNet to facilitate the process of word sense disambiguation. In addition, after adding thematic roles to its ontology and when linked to other electronic nets or MT systems, WordNet can help facilitate the process of translation. MT systems generally fail to produce proper translation in such cases that need thematic- role- based disambiguation. The following part is dedicated to presenting the successful sample verbs in different sentences. Each sentence will be submitted to translation into Arabic via three MT systems; Al Wafi, Google and Sakhr. The outcome translations show mistranslated parts. A suggested successful translation is proposed for each verb in each sentence. It is, simply, a presentation of how each sample verb would be correctly translated if the thematic roles (along with the selectional restrictions) were added.

1- Break

The following examples present the transitive verb break with two meanings: to cause to separate or divide into pieces and to breach or violate. However, the translation of each sentence produced by the three MT systems does not differentiate between these two distinct meanings.

1.1 He broke the glass plate

Al Wafi translation: كسر الصحن الزجاجي

Google Translation: حطم اللوحةالزجاجية

Sakhr Translation: كسر طبق الزجاج

1.2 The ball broke the window
Al Wafi translation: كسرت الكرة النافذة
Google Translation: كسرت النافذة الكرة
Sakhr Translation: كسرت الكرة النافذة

1.3 She broke the law
Al Wafi translation: كسرت القانون
Google Translation: كسرت القانون
Sakhr Translation: خرقت القانون
Proposed translation: خرقت القانون

1.4 They broke the contract
Al Wafi translation: كسروا العقد
Google Trasnlation: كسروا العقد
Sakhr Translation: كسروا العقد
Proposed translation: خرقوا العقد

It seems that the MT system may recognize only one meaning of the transitive form of the verb break: to cause to separate or divide into pieces. In 1.1 He broke the glass plate and 1.2 The ball broke the window, the three systems deal with the verb break as having the meaning to cause to separate or divide into pieces. In this context, the verb assigns an Agent <Animate> for its Subject and a Patient<Physical entity> for its Object. As such, it has the meaning to cause to separate or divide into pieces. The successful translation of break in such a context is 'كسر'. This successful translation is produced by the three MT systems. However, the same translation 'كسر' cannot be adopted for the same verb break in contexts where it assigns Agent <Animate> for its Subject but Theme <Legal Agreement> for its Object. The change in the thematic roles turns break to mean breach or violate. As such, it should be translated into 'خرق' not 'كسر'. In 1.3 She broke the law, both Al Wafi and Google keep the same understanding of the verb and produce the same translation which is mistranslation in this context. On the other hand, Sakhr succeeds in producing the proper translation 'خرق'. It cannot be assumed that Sakhr is fed with the right logic that produces the proper translation for break and other similar verbs. In 1.4 They broke the contract, Sakhr fails in producing the proper translation of break in a similar context where the verb assigns Agent <Animate> for its Subject but Theme <Legal Agreement> for its Object. This means that the system lacks the right logic to produce the right translation. It is proposed here that the thematic roles and selectional restrictions are the most fundamental base for successful translation of ambiguous verbs.

2- Clap
2.1 The big bird clapped its wings
Al Wafi translation: صفق الطير الكبير اجنحته
Google translation صفق الطائر بجناحيه كبيرة
Sakhr Translation: الطّائر الكبير صفّق أجنحته
Proposed translation: رفرف الطير الكبير اجنحته

2.2 The children clapped their hands

Al Wafi translation: الأطفال صفقوا

Google Translation: صفق الأطفال أيديهم

Sakhr Translation: صفّق الأطفال أيديهم

The transitive verb clap in 2.1 assigns an Agent for its Subject. It imposes that such Agent should be <Bird>. For its Object, it assigns Theme <Wings>. In this context, clap means to flap. This meaning is not recognized by any of the three systems. They all mistranslate the verb in 2.1 into 'صفق' or applaud, whereas the proper translation in such context is to flap or 'رفرف' as it is presented in the proposed translation. In 2.2, the same verb clap assigns an Agent <Human> for its Subject and a Patient <Hands> for its Object. In this context clap means to applaud. It seems that only such context is recognized by the three MT systems.

3- Cure

3.1 The doctor cured the acne

Al Wafi translation: عالج الطبيب حب الشباب

Google Translation: الطبيب الشفاء من حب الشباب

Sakhr Translation: عالج الدّكتور حبّ الشّباب

3.2 These tablets cure the fever

Al Wafi translation: تعالج هذه الأقراص الحمى

Google Translation: هذه الأقراص علاج الحمى

Sakhr Translation: تعالج هذه الأقراص الحمّى

3.3 They can cure meats

Al Wafi translation: هم يمكن أن يعالجوا اللحوم

Google Translation: يمكن أن علاج اللحوم

Sakhr Translation: يمكن أن يعالجوا اللّحوم

Proposed translation: هم يمكن أن يحفظوا اللحوم

3.4 These chemicals can cure pickles

Al Wafi translation: هذه المواد الكيمياوية يمكن أن تعالج المخللات

Google Translation: يمكن علاج هذه المواد الكيميائية المخللات

Sakhr Translation: يمكن أن تعالج هذه الموادّ الكيميائيّة المخلّلات

Proposed translation: هذه المواد الكيمياوية يمكن أن تحفظ المخللات

In 3.1 and 3.2, the verb cure has the meaning heal. It assigns the same Theme and imposes the same selectional restrictions on its Object <Disease>. Although the Subject is Agent <Animate> in 3.1 the doctor and a Force <Inanimate> in 3.2 tablets, this does not affect the meaning of the verb. In this context cure is successfully translated into 'عالج' by Al Wafi and Sakhr. For Google, it also produces a proper translation 'يشف' despite the weak translation of the whole sentence. However, this does not mean that the three systems can keep the successful translation of the same verb in other contexts where the verb changes the thematic roles and selectional restrictions. In3.3 and 3.4,cure assigns Theme for its Object. However, it imposes that this

Theme must be <Food> not <Disease>. In such a context cure means preserve rather than heal. Accordingly, it should be translated into 'حفظ'. Yet, the MT systems fail to produce this proper translation due to their inability to recognize the change in the selectional restrictions imposed on the Object.

4- Die

4.1 She died from cancer.

Al Wafi translation: ماتت من السرطان

Google Translation: توفيت من مرض السرطان

Sakhr Translation:ماتت من السّرطان

4.2 My father died last year.

Al Wafi translation: أبي مات السنة الماضية

Google Translation: توفي والدي العام الماضي

Sakhr Translation:مات أبي العام الماضي

4.3 The car died on the road.

Al Wafi translation: السيارة ماتت على الطريق

Google Translationتوفى السياره على الطريق

Sakhr Translation: ماتت السّيّارة على الطّريق

Proposed translation: السيارة تعطلت على الطريق

4.4 My only computer died.

Al Wafi translation: حاسوبي الوحيد مات

Google Translation: توفى جهاز الكمبيوتر الخاص بي فقط

Sakhr Translation: كمبيوتري الوحيد مات

Proposed translation: حاسوبي الوحيد تعطل

In 4.1 and 4.2, the verb die assigns Experiencer <Animate> for its Subject. Since it is an intransitive verb it has no Object. Thus, the disambiguation of the meaning of die depends on the thematic roles and restrictions it imposes on its Subject. In the context where it assigns an Experiencer <Aniamte> for its Subject, die means perish or pass away. Al Wafi and Sakhr successfully translate it into 'مات' and Google suggests more than one successful translation 'مات' or 'توفى'. However, in 4.3 and 4.4 where die assigns a Patient <Inanimate> for its Subject, it has the meaning of stop or breakdown. In this context the verb is mistranslated by the three systems which keep the same meaning of the verb die as in 4.1 and 4.2 perish or pass away. The proper translation is proposed and die should be translated into breakdown or 'تعطل' rather than 'مات'.

5- Draw

5.1 She is drawing.

Al Wafi translation: هي ترسم

Google Translation:فهي رسم

Sakhr Translation:تقترب

5.2 The patient's veins don't draw easily.

Al Wafi translation:عروق المريض لا تسحب بسهوله

Google Translation: أوردة المريض لا توجه بسهوله

Sakhr Translation:أورده المريض لا تقترب بسهولة

Proposed Translation: أوردة المريض لا تنساب بسهولة

The intransitive form of the verb draw may have two different meanings depending on the thematic roles it assigns for its Subject. In 5.1 She is drawing, the verb assigns an Agent and restricts it to <Human> only. In this context, draw means to make drawings or create images. Al Wafi provides the successful translation of the verb among other alternatives ' ترسم، تجتذب، تسحب، تلفت، تثير'. Google also can produce the successful translation of the verb draw in this context; 'رسم'. However, only Sakhr fails to provide the right translation. It translates draw into 'تقترب'. In 5.2 the patient's veins don't draw easily, the same intransitive form of the verb draw has a different meaning. It does not mean make drawings or create images. The verb assigns different thematic roles for its Subejct and hence its meaning is changed. In 5.2, the verb draw assigns a Theme for its Subject which is restricted to <Vessel> only. Thus, draw here does not mean making drawings. Vessels cannot make drawings or create images. In this context, draw means to cause to flow a liquid. However, the three MT systems fail to produce any successful translation of draw in this context. Al Wafi translates it into 'تسحب' and Google provides some alternatives such as ' توجة، تجتذب، تنسحب'. Sakhr keeps the same translation'تقترب' as in 5.1. However, it is proposed that the successful translation of draw where it assigns a Theme <Vessel> for its Subject should be 'تسيل' or 'تنساب'.

6- Eat

6.1 She was eating a banana.

Al Wafi translation: هي كانت تاكل موزة

Google Translation: وكانت يأكل موزة

Sakhr Translation: كانت تأكل موزة

6.2 The acid eats the surface of the machine.

Al Wafi translation: ياكل الحامض سطح الماكينة

Google Translation: حمض يأكل سطح الجهاز

Sakhr Translation: يأكل الحمض سطح الماكينة

Proposed translation: يصديء الحامض سطح الماكينة

6.3 The wind eats the metals.

Al Wafi translation: تاكل الريح المعادن

Google Translation: الريح يأكل المعادن

Sakhr Translation: تأكل الرّيح المعادن

Proposed translation: تصديء الريح المعادن

In 6.1, the transitive verb eat is recognized by AL Wafi, Google and Sakhr as take in solid food and hence properly translated into 'اكل'. In this context, eat assigns an Agent <Animate> for its Subject and Patient <Food> for its Object. However, by changing the thematic roles,eat changes its meaning. In 6.2 and 6.3, the verb assigns Force <Chemical> or <Air> for its Subject and Patient <Inanimate> for its Object. Accordingly, the meaning is changed to be corrode, and the three MT systems

cannot produce the successful translation. The systems still deal with the verb eat as having the meaning of take in solid food. Al Wafi and Sakhr translate eat into 'اكل' and Google suggests the same translation as well as 'تناول' which has the same meaning. However, the successful translation of eat in this context should be 'يصديء' rather than 'ياكل'.

7- Gain

7.1 John gained a small fortune.

Al Wafi translation: جون كسب ثروة لا بأس بها

Google Translation: اكتسب جون ثروة صغيرة

Sakhr Translation: كسب جون ثروةً

7.2 She gained an understanding of international finance.

Al Wafi translation: كسبت فهم المالية الدولية

Google Translation: اكتسبت فهم التمويل الدولي

Sakhr Translation: كسبت تفاهمًا ماليّة دوليّة

7.3 The swimmer gained the shore.

Al Wafi translation: كسب السباح الشاطيء

Google Translation: حصل على السباح الشاطيء

Sakhr Translation: كسب السّبّاح الشّاطئ

Proposed translation: وصل السباح إلى الشاطيء

7.4 The climber gained the top of the mountain.

Al Wafi translation: كسب المتسلق قمة الجبل

Google Translation: اكتسب المتسلق قمة الجبل

Sakhr Translation: كسب المتسلّق أعلى الجبل

Proposed translation: وصل المتسلق إلى قمة الجبل

It is clear in 7.1 and 7.2 that the three MT systems produce the proper translation of the verb gain in such a context where the verb assigns Benefactive <Animate> for its Subject and a Theme <Abstract or Physical Entity> for its Object. The meaning of gain in this context is acquire or win and the proper translation is 'كسب' or 'اكتسب'. However, the systems keep the same translation for the same verb in 7.3 and 7.4 though they deal with the verb in a different context. In that context, the verb assigns an Agent <Animate> for its Subject, and Goal <Destination> or <Location>for its Object. The meaning of gain here is reach rather than acquire and the proper translation should be 'وصل' as shown in the proposed translation for 7.3 and 7.4.

8- Land

8.1 The pilot landed the airplane.

Al Wafi translation:أنزل الطيار الطائرة

Google Translation: هبطت الطائرة الطيار

Sakhr Translation: أنزل الطّيّار الطّائرة

8.2 She landed a big fish.

Al Wafi translation: هبطت سمك كبير
Google Translation: هبطت هي سمكة كبيرة
Sakhr Translation: أنزلت سمكًا كبيرًا
Proposed translation: اصطادت سمكة كبيرة

In 8.1, the verb land has the meaning bring down as it assigns Agent <Animate> for its Subject and Theme <Vehicle> for its Object. The three MT systems can successfully produce the right Arabic translation. Al Wafi and Sakhr translate it as 'أنزل', whereas Google uses a number of alternatives: 'حطت', 'هبطت", and 'سقطت'. However, by changing its roles, the verb land changes its meaning. In 8.2, land assigns the same Agent <Animate> for its Subject but it assigns a different Theme for its Object. The verb land imposes that its Theme must be <Fish>. In such context, where the Theme is <Fish> Object, land means catch. However, the systems fail this time to produce the right translation. Al Wafi, Google and Sakhr recognize land as bring down in both sentences. So, in 8.2, they mistranslate land as 'هبط' and 'انزل' though it should be translated into 'اصطاد' as it is proposed in the example. Such mistranslation of the verb is due to the inability of the MT system to recognize the change in the verb sense caused by the change in the selectional restrictions imposed on its Object.

9- Play
9.1 We played hockey all afternoon.
Al Wafi Translation:لعبنا هوكياً كل العصر
Google Translation: لعبنا هوكي جميع بعد ظهر اليوم
Sakhr Translation: لعبنا هوكي جميعا بعد الظهر

9.2 Mary played her favourite CD.
Al Wafi translation:لعب ماري قرصها المدمج المفضل
Google Translation:المفضلة لديها لعبت مريم CD
Sakhr Translation:لعبت ماري قرصها المدمج المفضل
Proposed Translation: شغلت ماري قرصها المدمج المفضل

In 9.1, the transitive form of play assigns an Agent <Animate> for its Subject and a Theme <Game> for its Object. In this context, play means participate in games or sports. The right translation of play here is 'لعب'. The MT systems succeed in producing the correct translation of playin this context. However, play changes its meaning in 9.2 due to a change in the thematic roles and selectional restrictions it imposes on its nominal arguments. In this context, although play assigns the same Agent <Animate> for its Subejct and a Theme role for its Object, it restricts the Theme to <Sound Recording> only. The change in the selectional restriction imposed by the verb on its Theme leads to a change in the meaning of the verb. As such, in this context where the Object is a Theme <Sound Recording>, play means run or causeto emit recorded sound. The successful translation, then, should be 'شغل' as proposed above. However, the three MT systems fail to provide such a successful translation. They all translate playas 'لعب' as they cannot recognize the change in the thematic roles or the selectional restrictions that leads to the change in the meaning.

10- Read
10.1 She reads well
Al Wafi translation:تقرأ حسناً

Google Translation: تقرأ جيداً
Sakhr Translation: تقرأ جيّدًا

10.2 He is reading
Al Wafi translation:هو يقرأ
Google Translation: إنه يقرأ
Sakhr Translation: يقرأ

10.3 Her play reads better than it acts.
Al Wafi translation: تقرأ مسرحيتها أفضل من تتصرف
Google Translation: مسرحيتها أفضل من يقرأ وهو يعمل
Sakhr Translation: تقرأ مسرحيّتها أفضل ممّا يمثّل
Proposed translation: تبدو مسرحيتها أفضل مما تمثل

10.4 How does your new watch read?
Al Wafi translation: كيف ساعتك الجديدة تقرأ؟
Google Translation: كيف تقرأ ساعتك الجديده؟
Sakhr Translation: ؟ كيف تقرأ ساعتك الجديدة
Proposed translation: كيف تبدو ساعتك الجديدة؟

In 10.1 and 10.2, the three MT systems are able to produce the correct translation of the verb read. The systems deal with the verb in its usual sense to interpret something that is written. As such, 'read' is translated as 'يقرأ' in the context where it assigns an Agent <Animate> for its Subject. However, in 10.3 and 10.4, the same verb is mistranslated by the three MT systems. Al Wafi and Sakhr translate read as 'تقرأ', whereas Google provides more translations 'تقرأ' and 'تنص'. This can be due to the change in the thematic roles and selectional restrictions the verb assigns for its Subject in this context. In 10.3 and 10.4, the verb read assigns an Experiencer <Inanimate> for its Subject (play and watch). In this context, read means to indicate or to show. However, the systems produce the same translation 'يقرأ' which is a mistranslation. The proper translation as proposed should be 'يبدو'.

11- See
11.1 Can you see the bird?
Al Wafi translation: هل بالامكان ان ترى الطير؟
Google Translation: هل تستطيع رؤية هذا الطائر
Sakhr Translation: ؟ هل يمكن أن ترى الطّائر

11.2 I can see your viewpoint
Al Wafi translation: أنا يمكن أن ارى وجهة نظرك
Google Translation: أستطيع أن أرى وجهة نظرك
Sakhr Translation: يمكن أن أرى رأيك
Proposed translation: أنا يمكن ان افهم وجهة نظرك

In 11.1, the verb see assigns an Experiencer <Animate> for its Subject and a Theme <Visible Entity> for its Object. In this context, see means to perceive by eye. It is properly translated into Arabic using the equivalent 'أرى' by the three MT systems. However, in 11.2, the verb changes the roles it assigns for its Subject and Object and, hence, changes its meaning. When see assigns an Experiencer that should be <Human> in particular (not <Animate> in general) for its Subject and Theme <Cognition> for its Object, it means to understand not to perceive by eye. As such, it should be translated as 'أفهم' not 'أري'. However, the MT systems cannot recognize such change in roles that leads to the change in the meaning of the verb. For this reason, the three systems keep the translation 'أري' in 18.2 which is a mistranslation of see in such a context.

In this way, the meaning of the same verb may differ according to the difference in the thematic roles it assigns for its Subject and Object. The analysis of these thematic roles leads to the word sense disambiguation of the verb and hence of the whole sentence or statement. The problem of ambiguity may have little effect in case of human translators. However, it is highly influential with MT systems. Consequently, adding thematic roles to the semantic relations among the synsets in WordNet and relating WordNet to MT systems will solve the problem of word sense ambiguity. Thus, the significance of the present research is twofold in the sense that it helps in improving wordnets as well as MT systems.

4. Results

The main results showed that the analysis was made on 11 verbs. The majority of verbs showed a change in their meanings due to a change in their thematic roles as well as their selectional restrictions. Only three verbs changed their meanings due to a change in their selectional restrictions rather than thematic roles. Moreover, the analysis revealed that the eleven sample verbs reflected all the thematic roles that were previously selected to form the inventory to be developed for WordNet. Only two roles were not assigned by any of the sample verbs: Source and Location. This means that the majority of the thematic roles candidates proved that they affect the meaning of the verb. As such, they should be considered for the verb sense disambiguation.

The following flowchart shows a simple representation of the logic steps the MT system would follow for the purpose of word sense disambiguation.

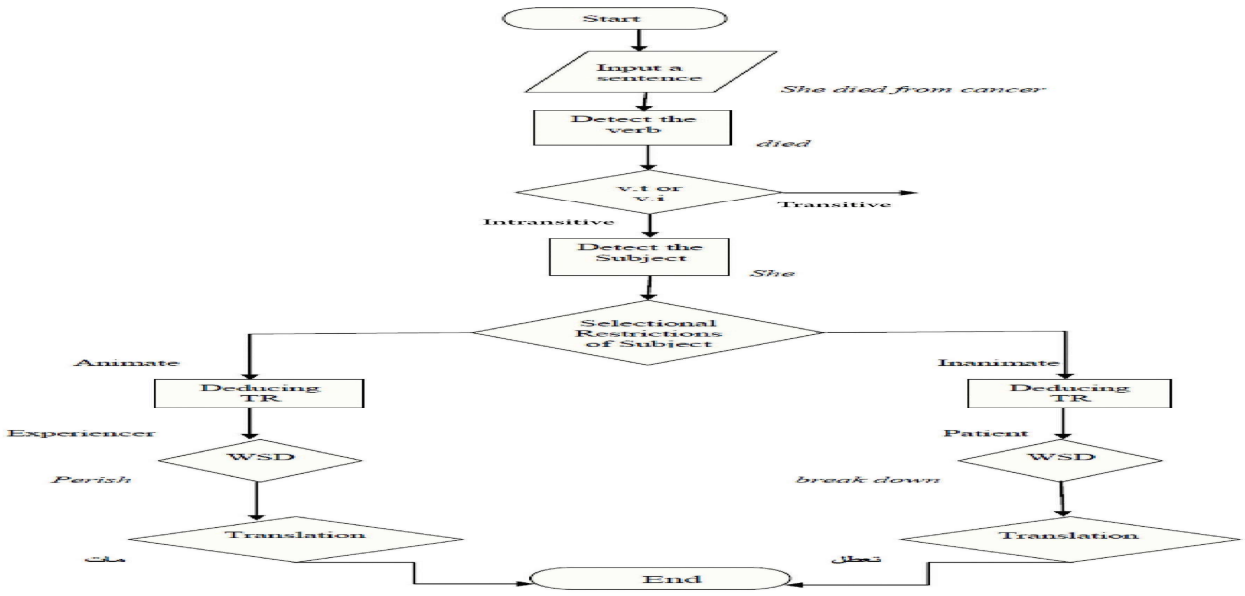


Figure 1: WSD Flow Chart. This figure illustrates the process of WSD and Translation of a verb.

First, the sentence is entered for translation, e.g. She died from cancer. The first process to be made is detecting the verb of the sentence: died. Reviewing the knowledge base, a choice has to be made as for whether the verb is transitive or intransitive. Some verbs have both forms. In such cases the machine has to detect whether there is an object (transitive) or not (intransitive). In the given example, 'died' is an intransitive verb. If the verb is intransitive, then the machine has to identify the subject only (she). The following decision is to review what selectional restriction is imposed on this subject. If it is <Animate>, then it is Experiencer thematic role. If it is <Inanimate>, then it is Patient thematic role. In the example, she is animate and, hence, it is Experiencer. After that the decision of word sense disambiguation is made. Since the verb die assigns an <Animate> Experiencer for its Subject, it means perish. However, if it assigns an <Inanimate> Patient for its Subject, it means break down. The final process to be made is translating the verb. The verb die in the sense of perish is translated into the Arabic verb 'مات'.

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