Polysemy in verbs: systematic relations between senses and their effect on annotation

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Abstract

Sense inventories for polysemous predicates are often comprised by a number of related senses. In this paper, we examine different types of relations within sense inventories and give a qualitative analysis of the effects they have on decisions made by the annotators and annotator error. We also discuss some common traps and pitfalls in design of sense inventories. We use the data set developed specifically for the task of annotating sense distinctions dependent predominantly on semantics of the arguments and only to a lesser extent on syntactic frame.

1 Introduction

Lexical ambiguity is pervasive in natural language, and its resolution has been used to improve performance of a number of natural language processing (NLP) applications, such as statistical machine translation (Chan et al., 2007; Carpuat and Wu, 2007), cross-language information retrieval and question answering (Resnik, 2006). Sense differentiation for the predicates depends on a number of factors, including syntactic frame, semantics of the arguments and adjuncts, contextual clues from the wider context, text domain identification, etc.

Preparing sense-tagged data for training and evaluation of word sense disambiguation (WSD) systems involves two stages: (1) creating a sense inventory and (2) applying it in annotation. Creating sense inventories for polysemous words is a task that is notoriously difficult to formalize. For polysemous verbs especially, constellations of related meanings make this task even more difficult. In lexicography, “lumping and splitting” senses during dictionary construction – i.e. deciding when to describe a set of usages as a separate sense – is a well-known problem (Hanks and Pustejovsky, 2005; Kilgarriff, 1997). It is often resolved on an ad-hoc basis, resulting in numerous cases of “overlapping senses”, i.e. instances when the same occurrence may fall under more than one sense category simultaneously.

This problem has also been the subject of extensive study in lexical semantics, addressing questions such as when the context selects a distinct sense and when it merely modulates the meaning, what is the regular relationship between related senses, and what compositional processes are involved in sense selection (Pustejovsky, 1995; Cruse, 1995; Apresjan, 1973). A number of syntactic and semantic tests are traditionally applied for sense identification, such as examining synonym series, compatible syntactic environments, coordination tests such as cross-understanding or zeugma test (Cruse, 2000). None of these tests are conclusive and normally a combination of factors is used. At the recent Senseval competitions (Mihalcea et al., 2004; Snyder and Palmer, 2004; Preiss and Yarowsky, 2001), the choice of sense inventories frequently presented problems, spurring the efforts to create coarser-grained sense inventories (Hovy et al., 2006; Palmer et al., 2007;Navigli, 2006).

Part of the reason for such difficulties in establishing a set of senses available to a lexical item is that the meaning of a polysemous verb is often determined in composition and depends to the same extent on semantics of the particular arguments as it does on the base meaning of the verb itself. A number of systematic relations often holds between different senses of a polysemous verb. Depending on the kind of ambiguity involved in each case, some senses are easier to distinguish than others. Sense-tagged data (e.g. SemCor (Landes et al., 1998), PropBank (Palmer et al., 2005), OntoNotes (Hovy et al., 2006)) typically provides no way to differentiate between sense distinctions motivated by different factors. Treating different disambiguation factors separately would allow one to examine the contribution of each factor, as well as the success of a given algorithm in identifying the corresponding senses.

Within the scope of a sentence, syntactic frame and semantics of the arguments are most prominent in sense
disambiguation. The latter is often more subtle and hence complex. Our goal in the present study was to target sense distinctions motivated strongly or exclusively by differences in argument semantics. We base the present discussion on the sense-tagged data set we developed for 20 polysemous verbs. We argue below that cases which can not be reliably disambiguated by humans introduce noise into the data and therefore should be kept out, a principle adhered to in the design of this data set.

The choice of argument semantics as the target disambiguation factor was motivated by several considerations. In automatic sense detection systems, argument semantics is often represented using external resources such as thesauri or shallow ontologies. Sense induction systems using distributional information often do not take into account the possible implications of induced word clusters for sense disambiguation. Our goal was to analyze differences in argument semantics that contribute to disambiguation.

In this paper, we discuss different kinds of systematic relations observed between senses of polysemous predicates and examine the effects they have on decisions made by the annotators. We also examine sense inventories for other factors that influence inter-annotator agreement rates and lead to annotation error. In Section 2, we discuss some of the factors that influence compilation of sense inventories and the methodology involved. In Section 3, we describe briefly the data set and the annotation task. In Sections 4 and 5, we discuss the relations observed between different senses within sense inventories in our data set, their effect on decisions made by the annotators, and the related annotation errors.

2 Defining A Sense Inventory

Several current resource-oriented projects undertake to formalize the procedure of identifying a word sense. FrameNet (Ruppenhofer et al., 2006) attempts to organize lexical information in terms of script-like semantic frames, with semantic and syntactic combinatorial possibilities specified for each frame-evoking lexical unit (word/sense pairing). Semantics of the arguments is represented by Fillmore's case roles (frame elements) which are derived on ad-hoc basis for each frame.

In OntoNotes project, annotators use small-scale corpus analysis to create sense inventories derived by grouping together WordNet senses. The procedure is restricted to maintain 90% inter-annotator agreement (Hovy et al., 2006).

Corpus Pattern Analysis (CPA) (Hanks and Pustejovsky, 2005; Pustejovsky et al., 2004) attempts to catalog prototypical norms of usage for individual words, specifying them in terms of context patterns. As a corpus analysis technique, CPA has its origins in the analysis of large corpora for lexicographic purposes, of the kind that was used for compiling the Cobuild dictionary (Sinclair and Hanks, 1987). Each pattern gives a combination of surface textual clues and argument specifications. A lexicographer creates a set of patterns by sorting a concordance for the target predicate according to the context features. In the present study, we use a modification of the CPA technique in the way explained in Section 3.

In CPA, syntactic and textual clues include argument structure and minor syntactic categories such as locatives and adjuncts; collocates from wider context; subphrasal cues such as genitives, partitives, bare plural/determiner, infinitivals, negatives, etc. Semantics of the arguments is represented either through a set of shallow semantic types corresponding to basic semantic features (e.g. Person, Location, PhysObj, Abstract, Event, etc.) or extensionally through lexical sets, which are effectively collections of lexical items.¹

Several CPA patterns may correspond to a single sense. The patterns vary in syntactic structure or the encoding of semantic roles relative to the described event. For example, for the verb treat, DOCTOR treating PATIENT and DOCTOR treating DISEASE both correspond to the medical sense of treat. Knowing which semantic role is expressed by a particular argument is often useful for performing inference. For instance, treating a disease eliminates the disease, but not the patient. In the present annotation task, each pattern is viewed as sense in construction and labeled as a separate sense.

In the rest of the paper, we will use the term “sense” to refer also to such microsenses.

For the cases where sense differentiation depends strongly on differences in semantics of the arguments, several factors further complicate creating a sense inventory. Prototypicality as a general principle of category organization seems to play an important role in defining both the boundaries of senses and the corresponding argument groupings. The same sense of the predicate is often activated by a number of semantically diverse arguments. Such argument sets are frequently organized around a core of typical members that are a “good fit” with respect to semantic requirements of the corresponding sense of the target. The relevant semantic feature is prominent for them, while other, more peripheral members of the argument set, merely allow the relevant interpretation (see Rumshisky (2008) for discussion). For example, the verb absorb has a sense involving absorbing a substance, and the typical members of the corresponding argument set would be actual substances, such as oil, oxygen, water, air, salt, etc. But goodness, dirt, flavor, moisture would also activate the same sense.

Each decision to split a sense and make another category is to a certain extent an arbitrary decision. For example, for the verb absorb, one can separate absorbing a substance (oil, oxygen, water, air, salt) from absorbing energy (radiation, heat, sound, energy). The latter sense may or may not be separated from absorb-

¹See Rumshisky et al. (2006) and Pustejovsky et al. (2004) for more detail.
ing impact (blow, shock, stress). But it is a marked continuum, i.e. certain points in the continuum are more prominent, with necessity of a given concept reflected in the frequency of use.

When several senses are postulated based on argument distinctions, there are almost always boundary cases that can be seen to belong to both categories. Consider, for example, two senses defined for the verb launch and the corresponding direct objects in (1):

(1) a. Physically propel an object into the air or water
   missile, rocket, torpedo, satellite, shuttle, craft
b. Begin or initiate an endeavor
   campaign, initiative, investigation, expedition, drive, competition, crusade, attack, assault, inquiry

The senses seem to be very clearly separated, yet examples like launch a ship clearly fall on the boundary: while ships are physical objects propelled into water, launching a ship can be virtually synonymous with launching an expedition.

Similarly, for the verb conclude, two senses below which are linked to nominal complements are clearly separated:

(2) a. finish
   meeting, debate, investigation, visit, tour, discussion; letter, chapter, novel
b. reach an agreement
   treaty, agreement, deal, contract, truce, alliance, ceasefire, sale

However, conclude negotiations is clearly a boundary case where both interpretations are equally possible (negotiations may be concluded without reaching an agreement). In fact, the two annotators chose different senses for this example:

(3) We were able to operate under a lease agreement until purchase negotiations were concluded.
   annoA: finish
   annoB: reach an agreement

In many cases, postulating a separate sense for a coherent set of nominal complements is not justified, as there are regular semantic processes that allow the complements to satisfy selectional requirements of the verb. For example, the verb conclude, in the finish sense accepts EVENT complements. Therefore, nouns such as letter, chapter, novel in (2) must be coerced into events corresponding to the activity that typically brings them about, that is, re-interpreted as events of writing (their Agentive quale, cf. Pustejovsky (1995)). Similarly, the verb deny in the first sense (state or maintain that something is untrue) accepts PROPOSITION complements:

(4) a. state or maintain that something is untrue
   allegations, reports, rumour; significance, importance, difference; attack, assault, involvement
b. refuse to grant something
   access, visa, approval, funding, license

Event nouns such as attack and assault are coerced into a propositional reading, as are relational nouns such as significance and importance.

Interestingly, as we have noted before (Rumshisky et al., 2006), each predicate imposes its own gradation with respect to prototypicality of elements of the argument set. As a result, even though basic semantic types such as PHYSOBJ, ANIMATE, EVENT, are used uniformly by many predicates, argument sets, while semantically similar, typically differ between predicates. For example, fall in the subject position and cut in the direct object position select for things that can be decreased:

(5) a. cut (dobj): reduce or lessen
   price, inflation, profits, cost, emission, spending, deficit, wages overhead, production, consumption, fees, staff
b. fall (subj): decrease
   price, inflation, profits, attendance, turnover, temperature, membership, import, demand, level

While there is a clear commonality between these argument sets, the overlap is only partial. To give another example, consider INFORMATION-selecting predicates explain (subj), grasp (dobj) and know (dobj). The nouns book and note occur in the subject position of explain; answer occurs both as the subject of explain and direct object of know; however, grasp accepts neither of these nouns as direct object. Thus, the actual selectional behavior of the predicates does not seem to be well described in terms of a fixed set of types, which is what is typically assumed by many ontologies used in automatic WSD.

3 Task Description

We were interested specifically in those cases where disambiguation needs to be made without relying on syntactic frame, and the main source of disambiguation is semantics of the arguments. Such cases are harder to identify formally in the development of sense inventories and harder for the annotators to determine. For example, phrasal verbs or idiomatic constructions that help identify a particular sense were intentionally excluded from our data set. Thus, for the verb cut, one of the senses involves cutting out a shape or a form (e.g. cut a suit), but the sentences with the corresponding phrasal form cut out were thrown out.

Even so, syntactic clues that contribute to disambiguation in some cases overrule the interpretation suggested by the argument. For example, for the verb deny, in deny the attack, the direct object strongly suggests a propositional interpretation for deny (that the attack didn’t happen). However, the use of ditransitive construction (indicated in the example below by the past participle) overrules this interpretation, and we get the refuse to grant sense:

(6) Astorre, denied his attack, had stayed in camp, uneasily brooding.
In fact, during the actual annotation, one of the annotators did not recognize the use of past participle, and erroneously assigned the state or maintain something to be untrue sense to this sentence.

3.1 Data set

The data set was developed using the British National Corpus (BNC), which is more balanced than the more commonly annotated Wall Street Journal data. We selected 20 polysemous verbs with sense distinctions that were judged to depend for disambiguation on semantics of the argument in several argument positions, including direct object (dobj), subject (subj), or indirect object within a prepositional phrase governed by with (iobj, with):


doobj: absorb, acquire, admit, assume, claim, conclude, cut, deny, dictate, drive, edit, enjoy, fire, grasp, know, launch

subj: explain, fall, lead

iobj, with: meet

We used the Sketch Engine (Kilgarriff et al., 2004) both to select the verbs and to aid the creation of the sense inventories. The Sketch Engine is a lexicographic tool that lists collocates that co-occur with a given target word in the specified grammatical relation. The collocates are sorted by their association score with the target.

A set of senses was created for each verb using a modification of the CPA technique (Pustejovsky et al., 2004). A set of complements was examined in the Sketch Engine. If a clear division was observed between semantically different groups of collocates in a certain argument position, the verb was selected. For semantically distinct groups of collocates, a separate sense was added to the sense inventory for the target. For example, for the verb acquire, a separate sense was added for each of the following sets of direct objects:

(7) a. Take on certain characteristics
shape, meaning, color, form, dimension, reality, significance, identity, appearance, characteristic, flavor
b. Purchase or become the owner of property
land, stock, business, property, wealth, subsidiary, estate, stake

The sense inventory for each verb was cross-checked against several resources, including WordNet, PropBank, Merriam-Webster and Oxford English dictionaries, and existing correspondences in FrameNet (Ruppenhofer et al., 2006; Hiroaki, 2003), OntoNotes (Hovy et al., 2006),3 and CPA patterns (Hanks and Pustejovsky, 2005; Rumshisky and Pustejovsky, 2006; Pustejovsky et al., 2004). We performed test annotation on 100 instances, with the sense inventory additionally modified upon examining the results of the annotation. This sense inventory was provided to two annotators, along with 200 sentences for each verb. Each sentence was pre-parsed with RASP (Briscoe and Carroll, 2002), and the head of the target argument phrase was identified. Misparses were manually corrected in post-processing.

3.2 Defining the task for the annotators

Data set creation for a WSD task is notoriously hard (cf. Palmer et al. (2007)), as the annotators are frequently forced to perform disambiguation on sentences where no disambiguation can really be performed. This is the case, for example, for overlapping senses, where more than one sense is activated simultaneously (Rumshisky, 2008; Pustejovsky and Boguraev, 1993). The goal was to create, for each target word, a set of instances where humans had no trouble disambiguating between different senses.

Two undergraduate linguistics majors served as annotators. The annotators were instructed to mark each sentence with the most fitting sense. The annotators were allowed to mark the sentence as “N/A” and were instructed to do so if (i) the sense inventory was missing the relevant sense, (ii) more than one sense seemed to fit, or (iii) the sense was impossible to determine from the context.

With respect to metaphoric senses, instructions were to throw out cases of creative use where the interpretation was difficult or not immediately clear. The cases where the target grammatical relation was actually absent from the sentence also had to be marked as “N/A” (e.g. for fire, sentences without direct object, e.g. a stolen car was fired upon). The annotators were also instructed to mark idiomatic expressions and phrasal verbs as “N/A”, e.g. for the verb fall: fall from favor, fall through, fall in, fall back, fall silent, fall short, fall in love.

Disagreements between the annotators were resolved in adjudication by the co-authors. The average inter-annotator agreement (ITA) for our data set was computed as a macro-average of the percentage of instances that were annotated with the same sense by both annotators to the total number of instances retained in the data set for each verb. The instances that were marked as “N/A” by one of the annotators (or thrown out during the adjudication) were not included in the computation. The ITA value for our data set was 95%. However, as we will see below, the ITA values do not always reflect the actual accuracy of annotation, due to some common problems with sense inventories.

3.3 Glossing a sense

A very common problem with glossing a sense involves the situation where a sense inventory includes two senses one of which is an extension of the other. The derived sense may be related to the primary sense through metaphor, and this often results in the former taking on a semantically less specific interpretation. The problem with creating glosses in this situation is that the words used may have sense distinctions...
parallel to the ones in the target verb being described. This leaves the annotators free to choose either sense. This seems to be the case, for example, with OntoNotes sense inventory for fire, where ignite or become ignited is the gloss under which very divergent examples are grouped: oil fired the furnace (literal, primary sense) and curiosity fired my imagination (metaphoric extension). Clearly, annotators were having a problem with this sense due to the fact that the verb ignite has sense distinctions which are based on the same metaphor (fire = inspire) and therefore are very similar to those of the verb fire.

In case of semantic underspecification, annotators may be left free to choose the more generic sense, which contaminates the data set while not being reflected in the inter-annotator agreement values. For example, in our sense inventory for acquire, the gloss for acquire a new customer has to be very generic. We used the gloss “become associated with something, often newly brought into being”. However, that led the annotators to overuse this gloss and select this sense in cases where a more specific gloss was more appropriate:\(^4\)

\[ \text{(8) By this treaty, Russia acquired a Black Sea coastline.} \]

annoA: become associated with something, often newly brought into being
annoB: become associated with something, ...
correct: purchase or become the owner of property

For a more detailed analysis of this phenomenon, see Section 5.

4 Relations Between Senses

In this section, we discuss linguistic processes underlying relations between senses within a single sense inventory. We believe that a detailed analysis of these processes should help to account for the annotator’s ability to perform disambiguation. Some sense distinctions appear more striking to the annotators, depending on the type of relation involved.

In line with existing approaches to sense relations, we will look at both the linguistic structures involved in sense modification and the productive processes acting on linguistic structures. For the purposes of our present discussion, we interpret the literal (physical, direct) senses to be primary, with respect to more abstract or metaphorical senses.

4.1 Argument structure alternations

Some of the most striking differences between the senses are related to the argument structure alternations:

1. Different case roles (frame elements) may be expressed in the same argument position (in this case, direct object), corresponding to different perspectives on the same event. For example, direct object position of the verb drive may be filled by VEHICLE, DISTANCE, or PHYSOBJ giving rise to three distinct senses: (i) operate a vehicle controlling its motion, (ii) travel in a vehicle a certain distance, and (iii) transport something or someone. Similarly, for the verb fire, PROJECTILE or WEAPON in direct object position give rise to two related senses: (i) shoot, discharge a weapon, (ii) shoot, propel a projectile.

2. The distinction between propositional and non-propositional complements, as for the verbs admit and deny in (9) and (10):

\[ \text{(9) a. admit defeat, inconsistence, offense} \]
\[ \text{(acknowledge the truth or reality of)} \]
\[ \text{b. admit patients, students} \]
\[ \text{(grant entry or allow into a community)} \]

\[ \text{(10) a. deny reports, importance, allegations} \]
\[ \text{(state or maintain to be untrue)} \]
\[ \text{b. deny visa, access} \]
\[ \text{(refuse to grant)} \]

3. There is a mutual dependency between subcategorization features of the complements in different argument positions. For example, the [+animate] subject may combine with specific complements not available for [−animate], as for the two senses of acquire: (i) learn and (ii) take on certain characteristics. Compare NP\text{_{subj}} [−animate] acquire NP\text{_{dobj}} (language, manners, knowledge, skill) vs. NP\text{_{subj}} [−animate] acquire NP\text{_{dobj}} (importance, significance). Similarly, for absorb, compare NP\text{_{subj}} [±animate] absorb NP\text{_{dobj}} (substance) and NP\text{_{subj}} [±animate] absorb NP\text{_{dobj}} (skill, information). Note that, as one would expect, such dependencies are inevitable even despite the fact that our data set was developed specifically to target sense distinctions dependent on a single argument position.

4.2 Event structure modification

Event structure modifications (i.e. operations affecting aspectual properties of the predicate) are another source of sense differentiation. Two cases appear most prominent:

1. The event structure is modified along with the characteristics of the arguments. For example, for enjoy, compare enjoy skiing, vacation (DYNAMIC EVENT) with enjoying a status (STATE). Similarly, for lead, compare a person leads smb somewhere (PROCESS) vs. a road (PATH) leads somewhere (STATE); for explain, compare something or somebody explains smth (= clarifies, describes, makes comprehensible, PROCESS) vs. something [−inanimate, +abstract] explains something (= is a reason for something, STATE); for fail, compare PHYSOBJ falls (TRANSITION or ACCOMPLISHMENT) vs. a case falls into a certain category (STATE).

2. The aspectual nature of the predicate is the only semantically relevant feature that remains unchanged after consecutive sense modifications. For example, the progressive meaning of ‘beginning something’ is preserved in shifting from the physical sense of the verb launch in launch a missile to launch a campaign and launch a product.

\(^4\)We will refer to annotators A and B as annoA and annoB.
4.3 Lexical semantic features

Sense distinctions often involve deeper semantic characteristics of the verbs which could be accounted for by means of lexical semantic features such as qualia structure roles in Generative Lexicon (Pustejovsky, 1995):5

1. Consider how the meaning component ‘manner of motion’ (typically associated with the agentive role) gets transformed in the different senses of drive. It is obviously present in the physical uses of drive (such as operate a vehicle, transport something or somebody, etc.), but is completely lost in motivate the progress of (as in drive the economy, drive the market forward, etc.). The value of the agentive role of drive becomes underspecified or semantically weak, so that the overall meaning of drive is transformed to cause something to move.

2. Information about semantic type contained in qualia structure allows apparently diverse elements to activate the same sense of the verb. For instance, the verb absorb in the sense learn or incorporate skill or information occurs with direct objects such as values, atmosphere, information, idea, words, lesson, attitudes, culture. The requisite semantic component is realized differently for each of these words. Some of them are complex types6 with INFORMATION as one of the constituent types: words (ACOUSTIC/VISUAL ENTITY • INFO), lesson (EVENT • INFO). Others, such as idea, are polysemous, with one of the senses being INFORMATION. Cases like culture and values are more difficult, but since they refer to knowledge, the INFORMATION component is clearly present. Consequently, the annotators are able to identify the corresponding sense of absorb with a high degree of agreement.

4.4 Metaphor and metonymy

The processes causing the mentioned meaning transformations in our corpus often involve metaphor and metonymy. Below are some of the conventionalized extensions with metaphorical flavor:

(11) a. grasp object vs. grasp meaning
    b. launch object vs. launch an event (campaign, assault) or launch a product (newspaper, collection)
    c. meet with a person vs. meet with success, resistance
    d. lead somebody somewhere vs. lead to a consequence

Note that these metaphorical extensions involve abstract or continuous objects (meaning, assault, success, consequence), which in turn cause event structure modifications (lead as a process vs. lead as a state). Thus, the processes and structures we are dealing with are clearly interrelated.

The metonymical process can be exemplified by edit as make changes to the text and as supervise publication, which are in a clear contiguity relationship.

One of the effects of the metaphorization and progressive emptying of the primary (physical, concrete) senses is the distinction between generic and specific senses. For example, compare acquire land, business (specific sense) to acquire an infection, a boyfriend, a following, which refers to some extremely light generic association. Similar process is observed for the semantically weak sense of fall, be associated with or get assigned to a person or location or for event to fall onto a time:

(12) Birthdays, lunches, celebrations fall on a certain date or time.
    Stress or emphasis fall on a given topic or a syllable
    Responsibility, luck, suspicion fall on or to a person

The specificity often involves specialization within a certain domain:

(13) a. conclude as finish vs. conclude as reach an agreement (Law, Politics)
    b. fire as shoot a weapon or a projectile vs. fire as kick or pass an object of play in sports (Sport)

Thus, when concluding a pact or an agreement, a certain EVENT is also being finished (negotiation of that agreement), necessarily with a positive outcome.

In the following section, we will try to show how different kinds of relations between senses influence disambiguation carried out by the annotators. In particular, we look at different sources of disagreement and annotator error as determined in adjudication.

5 Analysis of Annotation Decisions

As we have seen above, in many cases disambiguation is impossible due to the nature of compositionality. Also, as there are no clear answers to a number of questions concerning sense identification, the annotators deal with sense inventories that are imperfect. Results of the disambiguation task carried out by the annotators reflect all these defects.

In cases when a specific meaning from the data set is not included into the sense inventory (e.g. due to its low frequency or extreme fine-grainedness) the annotators may use a more general meaning or pick the closest meaning available. For example, within the sense inventory for fire, there was no separate gloss for fire an engine. Annotator A in our experiment chose the closest specific meaning available, and Annotator B marked it with a more generic sense:

(14) Engineers successfully fired thrusters to boost the research satellite to an altitude of 507 km.
    annoA: shoot, propel a projectile
    annoB: apply fire to

As mentioned in Section 3.3, even when the appropriate specific sense is available, annotators frequently chose the more generic sense in its place, as in (15), (16) and (17), and also in (8).

5 We will use the terminology from Generative Lexicon (Pustejovsky, 1995; Pustejovsky, 2007) to discuss lexical semantic properties, such as qualia roles, complex and functional types, and so on.

6 Complex type is a term used for concepts that inherently refer to more than one semantic type.
(15) Several referrals fell into this category.
annoA: be associated with or get assigned to a person or location or for event to fall onto a time
annoB: be categorized as or fall into a range

(16) The terrible silence had fallen.
annoA: be associated with or get assigned to a person or location or for event to fall onto a time
annoB: for a state (such as darkness or silence) to come, to commence

(17) He acquired a taste for performing in public.
annoA: become associated with something, often newly brought into being
annoB: become associated with something, ...
correct: learn

Note that in (8) this decision was probably motivated by the annotators’ uncertainty about the semantic ascription of the relevant argument (coastline is not a prototypical owned property). The generic sense seems to be the safest option to take for the annotators, as compared to taking a chance with a specific meaning. Due to its low degree of semantic specification, the generic sense is potentially able to embrace almost every possible use. This is not a desirable outcome because the generic senses are introduced in the inventory to account only for semantically underspecified cases. For instance, become associated with something, often newly brought into being is appropriate for acquire a grandchild, but not for acquire a taste or acquire a proficiency.

Remarkable variation is also observed with respect to non-literal uses as discussed in Section 4.4. For example, in (18) and (19) abstract NPs panic and imbalance of forces are equated with energy or impact by one annotator and with substance by the other.

(18) Her panic was absorbed by his warmth.
annoA: absorb energy or impact
annoB: absorb substance

(19) Alternatively, imbalance of forces can be absorbed into the body.
annoA: absorb energy or impact
annoB: absorb substance

In some cases, the literal and the metaphoric senses are activated simultaneously resulting in ambiguity (cf. Cruse (2000)):

(20) For over 300 years this waterfall has provided the energy to drive the wheels of industry.
annoA: motivate the progress of
annoB: provide power for or physically move a mechanism

(21) But fashion changed and the short skirt fell – literally – from favour and started skimming the ankles.
annoA: lose power or suffer a defeat
annoB: N/A

(22) She was delighted when the story of Hank fell into her lap.
annoA: be associated with or get assigned to a person or location or for event to fall onto a time
annoB: physically drop; move or extend downward

Impact of subcategorization features on disambiguation (cf. Section 4.1 para 3) is illustrated in (23).

(23) The reggae tourist can easily absorb the current reggae vibe.
annoA: absorb energy or impact
annoB: learn or incorporate skill or information

Both interpretations chosen here (absorb energy or impact and learn or incorporate skill or information) were possible due to the animacy of the subject, which activates two different subcategorization frames and subsequently two different senses.

Typically, cases where semantic type of the relevant arguments (cf. Section 4.3 para 2) is not clear result in annotator disagreement:

(24) The AAA launched education programs.
annoA: begin or initiate an endeavor (EVENT
annoB: begin to produce or distribute; start a company (PRODUCT)

(25) France plans to launch a remote-sensing vehicle called Spot.
annoA: physically propel into the air, water or space (PHYSOBJ
annoB: begin to produce or distribute; start a company (PRODUCT)

The two cases above are interesting in that both program and vehicle are ambiguous and can be analyzed semantically as members of different semantic classes. This is what the annotators in fact do, and as a result, ascribe them to different senses. Program can be categorized as EVENT (‘series of steps’) or as INTELLECTUAL ACTIVITY PRODUCT (‘document or system of projects’). It is a complex type, i.e. it is an inherently polysemous word that represents at least two different semantic types. Vehicle, in turn, is a functional type: on the one hand, it represents an entity with certain formal properties (PHYSOBJ interpretation), on the other hand, it is an artifact, with a prominent practical purpose (PRODUCT interpretation).

In fact, most problems the annotators had with the task are due to the inherent semantic complexity of words such as vehicle and program in (24) and (25) and to the existence of boundary cases, where the relevant noun does not properly belong to one or another semantic category. This is the case with panic, imbalance or reggae vibe in (18), (19), and (23), and also with taste and coastline in (17) and (7).

In some of these cases, other contextual clues may come into play and tip the balance in favor of one or another sense. Note that disambiguation was influenced by a wider context even despite the intentionally restrictive task design (targeting a particular syntactic relation for each verb). For instance, in (26), domain-specific clues referring to war or military conflict (such as rebel control) could have motivated Annotator B’s decision to ascribe it to the sense lose power or suffer a defeat (even though a road is not typically an entity that can lose power), while the other annotator chose a more generic meaning:
(26) The road fell into rebel control.
annoA: be associated with or get assigned to a person or location or for event to fall onto a time
annoB: lose power or suffer a defeat

Other pragmatic and discourse-oriented clues played a role, in particular, positive and negative connotation of the senses and the relevant arguments, as well as the temporal organization of discourse. For example, in (27) and (28), positive or neutral interpretation of wave of immigrants and change could have led to the choice of take in or assimilate and learn or incorporate skill or information senses, while the negatively-colored interpretation might explain the choice of the bear the cost of sense.

(27) ...help absorb the latest wave of immigrants.
annoA: bear the cost of; take on an expense
annoB: take in or assimilate, making part of a whole or a group

(28) For senior management an important lesson was the trade unions' capacity to absorb change and to become its agents.
annoA: learn or incorporate skill or information
annoB: bear the cost of; take on an expense

Temporal organization of a broader discourse is another important factor. For example, for the verb claim, the senses claim the truth of and claim property you are entitled to have different presuppositions with respect to preexistence of the thing claimed. In (28), due to the absence of a broader context, the annotators chose two different temporal reference interpretations. For Annotator B, success was something that has happened already, while for A this was not clear (success might have been achieved or not):

(29) One area where the government can claim some success involves debt repayment.
annoA: come in possession of or claim property you are entitled to
annoB: claim the truth of

6 Conclusion

We have given a brief overview of different types of sense relations commonly found in polysemous predicates and analyzed their effect on different aspects of the annotation task, including sense inventory design and execution of the WSD annotation.

The present analysis suggests that theoretical tools must be refined and further developed in order to give an adequate account to the sense modifications found in real corpus data. To this end, broader contextual clues and discourse-oriented clues need to be included in the analysis.

Semantically annotated corpora are routinely developed for the training and testing of automatic sense detection and induction algorithms. But they do not typically provide a way to distinguish between different kinds of ambiguities. Consequently, it is difficult to perform adequate error analysis for different sense detection systems. Appropriate semantic annotation that would allow one to determine which sense distinctions can be detected better by automatic systems does not need to be highly specific and unnecessarily complex, but requires development of robust generalizations about sense relations.

One obvious conclusion is that data sets need to be explicitly restricted to the instances where humans have no trouble disambiguating between different senses. Thus, prototypical cases can be accounted for reliably, ensuring the clarity of annotated sense distinctions. At face value, imposing such restrictions may appear to negatively influence usability of the resulting data set in particular applications requiring WSD, such as machine translation or information retrieval. However, this decision impacts most strongly those boundary cases which are not reliably disambiguated by human annotators, and which rather introduce noise into the data set.

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