Polysemy in Verbs: Systematic Relations between Senses and Their Effect on Annotation

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Problem:
- Word sense disambiguation

In particular:
- Disambiguation of polysemous verbs

Subproblem:
- Senses distinguished predominantly through semantics of the arguments
Word Sense Annotation

• Semantically annotated corpora are routinely developed for the training and testing of automatic sense detection and induction systems
  - SemCor (Landes et al., 1998)
  - OntoNotes (Hovy et al., 2006)
  - PropBank (Palmer et al. 2005)
  - Framenet Corpus (Rupenhofer et al., 2006)
Task Stages

• Stage 1. Data set construction
  – sense inventory construction
  – data extraction/collection
  – data preprocessing

• Stage 2. Annotation
  – annotating examples
  – checking agreement
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Focus of Our Study

• What happens under the magnifying glass?
  - What are the sources of disagreement in annotation?
  - There are plenty of difficult cases. What do the annotators do in those cases?
• We would like to look at
  - The effects relations between senses have on decisions made by the annotators and annotation error
  - Some common traps and pitfalls in design of sense inventories
Talk Outline

- Introduction
- Motivation
- Annotation task
  - Data set
  - Annotation guidelines
- Design of sense inventories
- Relations between senses
- Annotation decisions
- Conclusions
Sense Differentiation for Verbs

Establishing a set of senses for polysemous verbs is notoriously hard, since the meaning
• is very often determined in composition
• depends to the same extent on semantics of the arguments as on the base meaning of the verb itself
• often, constellations of related meanings exist and the meanings are extended “on the fly”
Constellations of related meanings

to drive = ?
Constellations of related meanings

physically urge an animal to go in a direction
drive cattle, horses
Constellations of related meanings

- physically urge an animal to go in a direction
- drive cattle, horses
- force a vessel to move in a direction
- storms and tides driving boats ashore
Constellations of related meanings

physically urge an animal to go in a direction
drive cattle, horses

move or provide power for the motion of a mechanism
steam driving the engine

force a vessel to move in a direction
storms and tides driving boats ashore
Constellations of related meanings

- operate a vehicle, controlling its motion
- travel in a vehicle a certain distance
- transport something or someone

drive a car
drive twenty miles
drive a friend home

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- cause to enter a state or force into an activity
  drive into poverty, into despair, to commit crimes
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- push a sharp object into another object
  - drive a nail, a stake into the ground
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- force a vessel to move in a direction

  • storms and tides driving boats ashore

- force an adversary to leave competitors away, enemy off the battlefield

- push a sharp object into another object

  • drive a nail, a stake into the ground

- strike or throw an object of play

  • drive the ball into the corner

- cause to enter a state or force into an activity

  • drive into poverty, into despair, to commit crimes
Motivation

• Different ambiguities require different kinds of contextual information to be resolved

• Sense-tagged corpora typically do not address the question of what factors allow the speakers to identify a particular sense
  – impossible to evaluate contribution of different factors (different contextual cues) to sense differentiation

• Consequently, it is difficult to perform adequate error analysis for automatic sense detection (WSD/WSI) systems
Sources of Sense Differentiation

Within the scope of a sentence, there are two main sources of sense differentiation for verbs:

• syntactic frame
• semantics of the arguments
Sources of Sense Differentiation

• Syntactic frame
  The authorities **denied** the *visa* to the prime minister *(refuse to give)*
  The authorities **denied** the *attack* *(proclaim false)*

• Semantics of the arguments
  The general **fired** four *rounds* *(shoot)*
  The general **fired** four *lieutenant-colonels* *(dismiss)*

  The customer will **absorb** this *tax* *(pay)*
  The customer will **absorb** this *information* *(learn)*
Sources of Sense Differentiation

- Typically, it is easier for people to distinguish senses that are linked to specific syntactic patterns:

  Achilles, **denied** his *attack*, had to stay in camp, brooding

- ditransive construction makes sense recognition easy
Sources of Sense Differentiation

- When sense distinctions are linked to semantics of the verb's arguments, things are often less clear
  
  e.g. Security camera *footage showed* the suspect getting into a car.
  
  (pictorially represent)
  
  e.g. The *study showed* a dependency between X and Y
  
  (demonstrate by reasoning)
  
  e.g. The *diagram shows* a dependency between X and Y
  
  -- both?
Case Study: Sense Distinctions linked to Semantics of a Single Argument

• Select the verbs that have sense distinctions that can be detected looking at semantics of a single argument

• Use sense inventories that contain the relevant senses
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Annotation Task (Setup)

- Standard sense-annotation setup, similar to Senseval Lexical Sample tasks
  - the target word is disambiguated by the annotators, one sense is assigned to each occurrence
  - annotators are given a context for each occurrence (sentence)
Data Set Construction

20 (verb, grammatical relation) pairs

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

- subj: explain, fall, lead

- iobj_with: meet
Verb Selection

• British National Corpus
• Sketch Engine (Kilgarriff et al., 2004)
  – lexicographic tool that gives a ranked listing of words that co-occur with the target in the specified grammatical relation
• Sense inventory was created for each (verb, relation) pair using a modification of the CPA technique
Corpus Pattern Analysis (CPA) (P. Hanks)

- lexicographic technique that aims to capture norms of usage for individual words using full context specification
- including argument structure, minor categories (locatives, adjuncts, etc.), subphrasal cues (genitives, partitives, bare plural/determiner, infinitivals, negatives, etc.)
- semantics of the arguments specified in terms of basic semantic features (PhysObj, Abstract, Event) or lexical sets (collections of lexical items)
The customer will absorb the cost.
Mr. Clinton wanted energy producers to absorb the tax.
PATTERN 1: [[Abstract] | [Person]] absorb [[Asset]]

They quietly absorbed all this new information.
Meanwhile, I absorbed a fair amount of management skills.
PATTERN 2: [[Person]] absorb {([QUANT]) [[Abstract= Concept]]}

Water easily absorbs heat.
The SO$_2$ cloud absorbs solar radiation.
PATTERN 3: [[PhysObj] | [Substance]] absorb [[Energy]]

The villagers were far too absorbed in their own affairs.
He became completely absorbed in struggling for survival.
PATTERN 4: [[Person]] {be | become} absorbed {in [[Activity]][[Abstract]]}
# Sketch Engine

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## Sketch Engine

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Senses for *dictate, dobj*

(1) *verbalize to be recorded* (letter, passage, memoir)

(2) *determine the character of or serve as a motivation for* (terms, policy, etc.)
**Sense Inventory Construction**

- Sense inventory for each verb cross-checked against:
  - WordNet, PropBank, Merriam-Webster, Oxford English dictionary, and existing correspondences in FrameNet, OntoNotes, and CPA Patterns.

- We performed test annotations of 100 instances, with sense inventories additionally modified upon examining the results of annotation.
Sense inventory for acquire, dobj

1. *take on certain characteristics*
   - e.g. importance, meaning; also: reputation

2. *learn*
   - e.g. language, manners, knowledge, skill

3. *purchase or become the owner of property*
   - e.g. land, stocks, business

4. *become associated with something, often newly brought into being*
   - e.g. cities acquiring new jobs
Sense inventory for fall, subj

1. physically drop; move or extend downward
   e.g. physical objects falling; also: extending downward: rainbow, light, hair
2. decrease (e.g. price, inflation, profits, attendance)
3. lose power of suffer a defeat (e.g. Roman Empire, Napoleon, France)
4. for a state to come or commence (e.g. darkness, silence, night)
5. be categorized or fall into a range
   e.g. cases falling into categories, into types, into a range
6. be associated with or get assigned to a person, location, or time
   e.g. Birthdays, lunches, celebrations falling on a date
   e.g. Stress or emphasis falling on a syllable or a topic
   e.g. Responsibility, luck, suspicion falling on or to a person
Talk Outline

• Introduction
• Motivation
• Annotation task
  − Data set
  − Annotation guidelines
• Design of sense inventories
• Relations between senses
• Annotation decisions
• Conclusions
Annotation Task

Annotators are given

• a sense inventory for each verb

• a set of sentences to tag
Annotation Guidelines

Annotators were given the following instructions:

- mark each sentence with the most fitting sense
- allowed to mark sentence as “N/A” if
  • sense inventory was missing the relevant sense
  • more than one sense seemed to fit
  • the sense was impossible to determine from context
- with respect to metaphoric senses, instructions were to throw out cases where interpretation was difficult or not immediately clear
- idiomatic expressions and phrasal verbs thrown out
Inter-Annotator Agreement

- Annotators were two linguistics majors
- Inter-annotator agreement was 95%
- Disagreements were resolved in adjudication by the co-authors
- ITA was computed as macro-average of percentage of instances annotated with the same sense by both annotators
- The instances marked as “N/A” by one or both annotators or in adjudication were not included in the computation
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Sense Inventory Problems

• Parallel sense distinctions
  - Words used in the sense inventory may have sense distinctions parallel to the sense distinctions of the target word being described
    • OntoNotes sense inventory for fire has a gloss ignite or become ignited under which very divergent examples are grouped:
      - oil fired the furnace (literal, primary sense)
      - curiosity fired my imagination (metaphoric extension).

• Generic vs. specific senses
  - acquire a land, a business (purchase or become the owner of property) vs.
    acquire an infection, a boyfriend, a following (become associated with something, often newly brought into being)
  - fall (be associated or get assigned to a person, location or time)
Prototypicality in Argument Sets

- The same sense is often activated by a number of semantically diverse arguments.
- The requisite semantic component may be central to some of them, and accidental to others.

  - **absorb** oil, oxygen, water vs. dirt, flavour, moisture
    - actual SUBSTANCES vs. other words that activate the same sense
  - **take on**: “tackle an adversary” vs. “acquire a quality”
    - competition, enemy, opponent, government, world
    - shape, meaning, color, reality
      - competition vs. government
        - [+adversary] component
“Senses in Construction”

- Each decision to split a sense and make another category is to a certain extent an arbitrary decision
  - drive a nail into the ground vs. drive the ball into the corner

- Distinguishing an alternation as a separate “sense in construction” may be useful for inference
  - knowing which semantic role relative to the described event is expressed by a particular argument
  - drive a car vs. drive twenty miles
Regular Semantic Processes

- Postulating a separate sense may or may not be justified when there are regular semantic processes that allow complements to satisfy selectional requirements of the verb
  - conclude visit, tour vs. conclude letter, chapter, novel
    - the latter are coerced into events corresponding to activity that brings them about, i.e. reinterpreted as events of writing
  - deny allegations, reports vs. deny attack, involvement
    - event nouns coerced into a prepositional reading
Generative Lexicon (J. Pustejovsky)

- complex types
  - dealing with regular polysemy of complex nouns such as book (INFO • PHYSOBJ), building (PROCESS • RESULT)

- qualia structure, esp. for nouns
  - agentive (how did it come about?)
  - telic (what is it used for?)
  - formal (what is it?)
  - constitutive (what is it made of, what are its parts?)
Boundary Cases

- When verb senses are linked to distinctions in argument semantics, there are almost always boundary cases
  - The *diagram showed* the dependency between X and Y
- Other examples
  - conclude a meeting, investigation, visit ("finish an event") vs. conclude a treaty, contract, cease-fire ("reach an agreement")
  - conclude negotiations
  - launch an expedition ("begin an event") vs. launch a missile ("propel a physical object")
  - launch a ship
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Relations between Senses: 
Argument Structure Alternations

1. Different case roles (frame elements) may be expressed in the same argument position (e.g. dobj), corresponding to different perspectives on the same event.

Example 1: Direct object of *drive* may be VEHICLE, DISTANCE, or PHYSOBJ giving rise to 3 senses:

a. operate a vehicle controlling its motion
b. travel in a vehicle a certain distance
c. transport something or someone

Example 2: for *fire*, PROJECTILE or WEAPON as dobj give rise to two related senses:

a. shoot, discharge a weapon
b. shoot, propel a projectile
Relations between Senses: 
Argument Structure Alternations 2

• The distinction between propositional and non-propositional complements:
  a. admit defeat, inconsistency, offence (acknowledge the truth or reality of)
  b. admit patients, students (grant entry or allow into a community)

• Mutual dependency between subcategorization features of the complements in different argument positions.
  Example: the [+animate] subject of acquire may combine with specific complements not available for [–animate]:
  a. learn: NPsubj [+animate] acquire NPdobj (language, manners, knowledge, skill)
  b. take on certain characteristics: NPsubj [–animate] acquire NPdobj (importance, significance).
Relations between Senses: Semantic Underspecification

• The meaning component ‘manner of motion’ gets transformed in different senses of *drive*.
  - Physical senses of *drive* (“operate a vehicle”, “transport something or somebody”): PRESENT
  - Non-physical use (‘motivate the progress’: *drive the economy, drive the market forward*): LOST
  - The value of the agentive role of *drive* becomes semantically weak and the overall meaning of *drive* is transformed to ‘cause something to move’.
Relations between Senses: Lexical Semantic Features

• Information about semantic type contained in QS allows apparently diverse elements to activate the same sense of the V.
  − Example: absorb (sense ‘learn or incorporate skill or information’) gets as direct objects values, atmosphere, information, idea, words, lesson, attitudes, culture.

• Different semantic realizations of the requisite semantic component:
  − complex types with INFORMATION as one of the constituent types: words (ACOUSTIC/VISUAL ENTITY•INFO), lesson (EVENT•INFO).
  − polysemous direct objects with one of the senses being INFORMATION: idea
  − more difficult cases: culture and values refer to knowledge, and the INFORMATION component is clearly present.

• Consequently, the annotators are able to identify the corresponding sense of absorb with a high degree of agreement.
Relations between Senses: Metaphor

Some of the conventionalized extensions with metaphorical flavour:

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

The distinction between generic and specific senses is one of the effects of the metaphorization

Example: acquire land, business (specific sense) vs. acquire an infection, a boyfriend, a following (light generic association).

Specificity involving specialization within a certain domain:

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)
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Situation 1. A specific meaning is not included into the sense inventory

Annotation decisions:
• use a more general meaning (annoB)
• pick the closest meaning possible (annoA)

Engineers successfully fired thrusters to boost the research satellite to an altitude of 507 km.
annoA: shoot, propel a projectile
annoB: apply fire to
Situation 2. The appropriate specific sense is available
Annotation decision: annotators choose the more generic sense

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
correct: be categorized as or fall into a range

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

Not a desirable outcome, since generic senses are introduced in the inventory to account only for semantically underspecified cases.
Situation 3. Ambiguity of literal and non-literal uses

Annotation decisions:
• metaphoric sense chosen (annoA)
• literal sense chosen (annoB)

She was delighted when the *story* of Hank *fell* into her lap
annoA: *be associated with or get assigned to a person or location*…
annoB: *physically drop; move or extend downward*
Analysis of Annotation Decisions 4

Situation 4. Impact of subcategorization features on disambiguation: the animacy of the subject activates 2 different subcategorization frames and 2 different senses

The reggae tourist can easily absorb the current reggae vibe.
annoA: absorb energy or impact
annoB: learn or incorporate skill or information
Situation 5. Semantic type of the relevant argument is not clear

Annotation decisions depend on the interpretation of semantically complex types assumed by each annotator:

program [Event•Product], vehicle [PhysObj•Product]

**The AAA launched** education programs.
anoA: *begin or initiate an endeavour* (EVENT)
anoB: *begin to produce or distribute; start a company* (PRODUCT)

**France plans to launch** a remote-sensing **vehicle** called Spot.
anoA: *physically propel into the air, water or space* (PhysObj)
anoB: *begin to produce or distribute; start a company* (PRODUCT)
Analysis of Annotation Decisions 6

Situation 6. Influence of wider context: resort to domain-specific clues is necessary to identify the sense

The choice of annoB could be motivated by specific clues referring to military conflict: rebel control

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
Situation 7. The senses compatible with a given sentence can be interpreted as having positive or negative connotation.

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

For senior management an important lesson was the trade union’s capacity to absorb change and to become its agents.
annoA: learn or incorporate sill or information (POSITIVE)
annoB: bear the cost of; take on an expense (NEGATIVE)
Situation 8. The senses have different presuppositions with respect to pre-existence of the relevant argument.

The annotation decision depends on the temporal reference interpretations: for annoB *success* is something that has already happened.

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*
Discussion

- Our analysis suggests that theoretical tools must be refined and further developed to give an adequate account to the sense modifications found in real corpus data.
- 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.
- Data sets need to be explicitly restricted to the instances where humans have no trouble disambiguating between different senses. Prototypical cases can be accounted for reliably, ensuring the clarity of annotated sense distinctions. This decision impacts most strongly those boundary cases which are not reliably disambiguated by human annotators, and which introduce noise into the data set.
Thank you

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