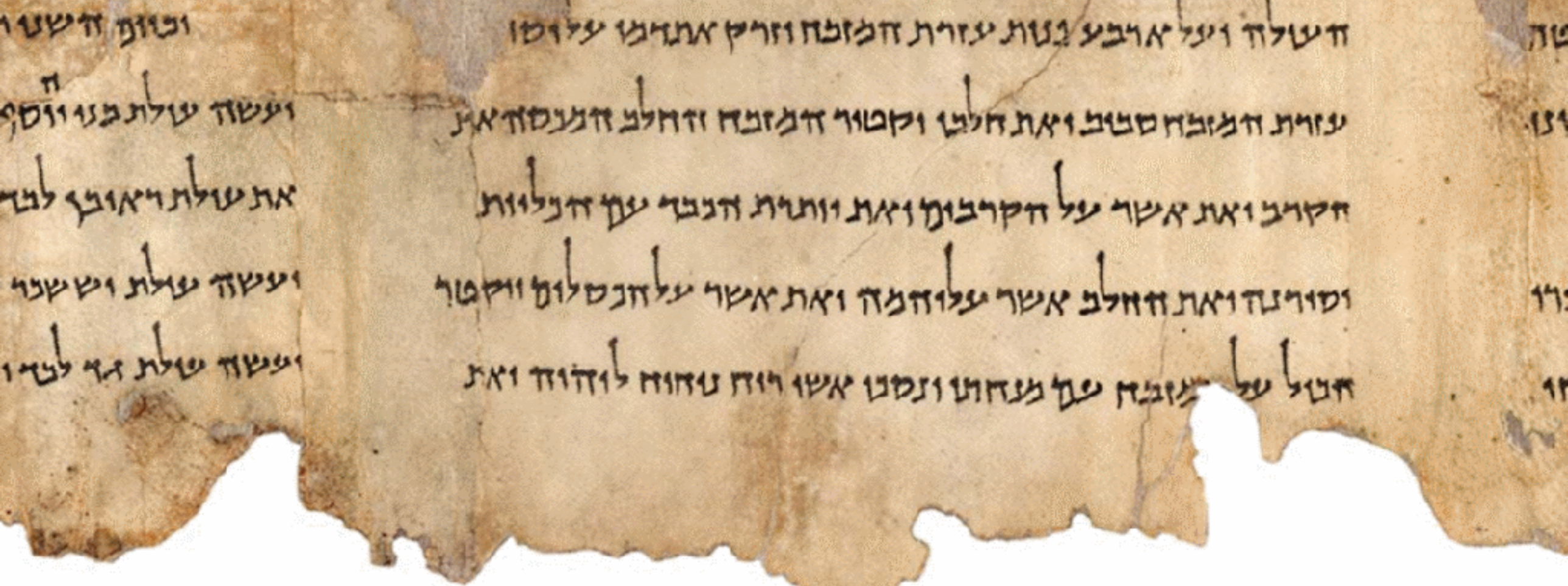

Natural Language Processing

Info 159/259

Lecture 19: WordNet, supersenses and WSD (April 2, 2020)

David Bamman, UC Berkeley

Word representation

…	…
the	0
a	0
an	0
for	0
in	0
on	0
dog	1
cat	0
…	…

dog is a point in V-dimensional space

dog

4.1
-0.9

dog is a point in 2-dimensional space

Polysemy

the movie is so bad , in fact , that it retains that ridiculous tarzan call that was so tirelessly mocked in last summer's comedy " george of the jungle .

the performances are bad .

Polysemy

	Sense 1	Sense 2
bad	Of poor quality or little worth.	slang (orig. U.S.). Formidable, good.
sick	Suffering from illness of any kind; ill, unwell, ailing.	slang (now esp. Skateboarding and Surfing). Excellent, impressive; risky.
awesome	Inspiring awe; appalling, dreadful, weird.	Expressing enthusiastic approval: great, excellent, highly impressive; fantastic.
wicked	Bad in moral character, disposition, or conduct	Excellent, splendid; remarkable. slang (orig. U.S.).

Oxford English Dictionary

Word senses

I'm going to the bank

- $bank_1$ = "financial institution"
- $bank_2$ = "sloping mound"
- $bank_3$ = "biological repository"
- $bank_4$ = "building where a $bank_1$ does its business"

Word senses

- A word sense is a representation of one aspect of a word's meaning.

Word senses

- "Serve"

S: (v) **serve**, function (serve a purpose, role, or function) *"The tree stump serves as a table"; "The female students served as a control group"; "This table would serve very well"; "His freedom served him well"; "The table functions as a desk"*
S: (v) **serve** (do duty or hold offices; serve in a specific function) *"He served as head of the department for three years"; "She served in Congress for two terms"*
S: (v) **serve** (contribute or conduce to) *"The scandal served to increase his popularity"*
S: (v) service, **serve** (be used by; as of a utility) *"The sewage plant served the neighboring communities"; "The garage served to shelter his horses"*
S: (v) **serve**, help (help to some food; help with food or drink) *"I served him three times, and after that he helped himself"*
S: (v) **serve**, serve up, dish out, dish up, dish (provide (usually but not necessarily food)) *"We serve meals for the homeless"; "She dished out the soup at 8 P.M."; "The entertainers served up a lively show"*
S: (v) **serve** (devote (part of) one's life or efforts to, as of countries, institutions, or ideas) *"She served the art of music"; "He served the church"; "serve the country"*
S: (v) **serve**, serve well (promote, benefit, or be useful or beneficial to) *"Art serves commerce"; "Their interests are served"; "The lake serves recreation"; "The President's wisdom has served the country well"*
S: (v) **serve**, do (spend time in prison or in a labor camp) *"He did six years for embezzlement"*
S: (v) **serve**, attend to, wait on, attend, assist (work for or be a servant to) *"May I serve you?"; "She attends the old lady in the wheelchair"; "Can you wait on our table, please?"; "Is a salesperson assisting you?"; "The minister served the King for many years"*
S: (v) **serve**, process, swear out (deliver a warrant or summons to someone) *"He was processed by the sheriff"*
S: (v) suffice, do, answer, **serve** (be sufficient; be adequate, either in quality or quantity) *"A few words would answer"; "This car suits my purpose well"; "Will $100 do?"; "A `B' grade doesn't suffice to get me into medical school"; "Nothing else will serve"*
S: (v) **serve** (do military service) *"She served in Vietnam"; "My sons never served, because they are short-sighted"*
S: (v) **serve**, service (mate with) *"male animals serve the females for breeding purposes"*
S: (v) **serve** (put the ball into play) *"It was Agassi's turn to serve"*

Word senses

- They rarely serve red meat
- He served as U.S. ambassador to Norway
- He might have served his time.

Jurafsky & Martin (2008)

Zeugma

- Conjunction (“yoke”) of antagonistic readings; one test for whether word senses are distinct.

- Which flights serve breakfast?
- Does Midwest Express serve Philadelphia?
- Does Midwest Express serve breakfast and Philadelphia?

Word senses

I’m going to the bank

Je vais à la _____

Word senses

I'm going to the bank

Je vais à la banque

(financial institution)

Word senses

I’m going to the bank

Je vais à la rive

(side of the river)

Relationship between senses

- Synonymy/antonymy
- Hypernymy
- Metonymy
- Meronymy

Synonym

- Two senses of different words are synonyms of each other if their meaning is nearly identical*
- Two words are never exactly the same in their meaning, distribution of use, dialect or other contexts in which they're licensed.
- Synonyms can be exchanged for each other without changing the truth conditions of a sentence.

couch	sofa
filbert	hazelnut
car	automobile
fair	impartial
fair	pale

Synonymy

Synonymy holds between word senses, not words

- How big is that plane?
- Would I be flying on a large or small plane?

- Miss Nelson, for instance, became a kind of big sister to Benjamin
- ?Miss Nelson, for instance, became a kind of large sister to Benjamin

Synonymy

love	1
loving	0.74
loves	0.73
lover	0.69
passion	0.69
affection	0.67
loved	0.66
soul	0.64
happiness	0.64
hate	0.64
sorrow	0.63
pity	0.63
yearning	0.63
lovers	0.63
tenderness	0.62
joy	0.62
longing	0.61
adore	0.61
rapture	0.61
goodness	0.6

cosine similarity to “love"

Antonymy

- Two senses of different words are antonyms of each other if their meaning is nearly opposite
- All aspects of meaning are nearly identical between antonyms, except one (very much like synonyms in this respect)

long	short	both describe length
big	little	both describe size
fast	slow	both describe speed
cold	hot	both describe temperature
dark	light	both describe luminescence

Hyponymy

hypo = “under”
(e.g., hypothermia)

- Sense A is a hyponym of sense B if A is a subclass of B
- Formally, entailment: for entity x, $A(x) \Rightarrow B(x)$

hyponym/subordinate	hypernym/superordinate
car	vehicle
mango	fruit
chair	furniture
dog	mammal
mammal	animal

Hyponymy

hypo = “under”
(e.g., hypothermia)

- Hyponymy is generally transitive

hyponym/subordinate	hypernym/superordinate
car	vehicle
mango	fruit
chair	furniture
dog	mammal
mammal	animal
dog	animal

Meronymy

- Part-whole relations. A meronym is a part of a holonym.

meronym	holonym
leg	chair
wheel	car
car	automobile

WordNet

- Lexical database for nouns, verbs and adjectives/adverbs.
- Each word sense is arranged in a synset (category of near-synonyms) and each synset is related to others in terms of their sense relations.

Relations

Relation	Also Called	Definition	Example
Hypernym	Superordinate	From concepts to superordinates	*breakfast*^{1} $\rightarrow$ *meal*^{1}
Hyponym	Subordinate	From concepts to subtypes	*meal*^{1} $\rightarrow$ *lunch*^{1}
Instance Hypernym	Instance	From instances to their concepts	*Austen*^{1} $\rightarrow$ *author*^{1}
Instance Hyponym	Has-Instance	From concepts to concept instances	*composer*^{1} $\rightarrow$ *Bach*^{1}
Member Meronym	Has-Member	From groups to their members	*faculty*^{2} $\rightarrow$ *professor*^{1}
Member Holonym	Member-Of	From members to their groups	*copilot*^{1} $\rightarrow$ *crew*^{1}
Part Meronym	Has-Part	From wholes to parts	*table*^{2} $\rightarrow$ *leg*^{3}
Part Holonym	Part-Of	From parts to wholes	*course*^{7} $\rightarrow$ *meal*^{1}
Substance Meronym		From substances to their subparts	*water*^{1} $\rightarrow$ *oxygen*^{1}
Substance Holonym		From parts of substances to wholes	*gin*^{1} $\rightarrow$ *martini*^{1}
Antonym		Semantic opposition between lemmas	*leader*^{1} $\Longleftrightarrow$ *follower*^{1}
Derivationally Related Form		Lemmas w/same morphological root	*destruction*^{1} $\Longleftrightarrow$ *destroy*^{1}

Figure 17.2 Noun relations in WordNet.

Synsets

synset	gloss
mark, grade, score	a number or letter indicating quality
scratch, scrape, scar, mark	an indication of damage
bell ringer, bull's eye, mark, home run	something that exactly succeeds in achieving its goal
chump, fool, gull, mark, patsy, fall guy, sucker, soft touch, mug	a person who is gullible and easy to take advantage of
mark, stigma, brand, stain	a symbol of disgrace or infamy

Synsets

- S: (n) victim, dupe (a person who is tricked or swindled)
  - S: (n) person, individual, someone, somebody, mortal, soul (a human being) *"there was too much for one person to do"*
    - S: (n) organism, being (a living thing that has (or can develop) the ability to act or function independently)
      - S: (n) living thing, animate thing (a living (or once living) entity)
        - S: (n) whole, unit (an assemblage of parts that is regarded as a single entity) *"how big is that part compared to the whole?"; "the team is a unit"*
          - S: (n) object, physical object (a tangible and visible entity; an entity that can cast a shadow) *"it was full of rackets, balls and other objects"*
            - S: (n) physical entity (an entity that has physical existence)
              - S: (n) entity (that which is perceived or known or inferred to have its own distinct existence (living or nonliving))

Hypernyms of {chump, fool, gull, mark, patsy, fall guy, sucker, soft touch, mug} synset

WordNet

- WordNet encodes human-judged measures of similarity. Learn distributed representations of words that respect WordNet similarities (Faruqui et al. 2015)
- By indexing word senses, we can build annotated resources on top of it for word sense disambiguation.

Semcor

- Semcor: 200K+ words from Brown corpus tagged with Wordnet senses.
  - http://web.eecs.umich.edu/~mihalcea/downloads/semcor/semcor3.0.tar.gz

original	It urged that the city take steps to remedy this problem
lemma sense	It urge^{1} that the city^{2} take^{1} step^{1} to remedy^{1} this problem^{2}
synset number	It urge$^{2:32:00}$ that the city$^{1:15:01}$ take$^{2:41:04}$ step$^{1:04:02}$ to remedy$^{2:30:00}$ this problem$^{1:10:00}$

- They rarely serve red meat
- Eisenhower served as Supreme Commander of the Allied Expeditionary Forces during WWII.
- He might have served his time.

S: (v) **serve**, function (serve a purpose, role, or function) *"The tree stump serves as a table"; "The female students served as a control group"; "This table would serve very well"; "His freedom served him well"; "The table functions as a desk"*
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“All-word” WSD

“Only$_{only1}$ a relative$_{relative1}$ handful$_{handful1}$ of such$_{such0}$ reports$_{report3}$ was received$_{receive2}$”

- For all content words in a sentence, resolve each token to its sense in an fixed sense inventory (e.g., WordNet).

WSD

- Dictionary methods (Lesk)
- Supervised (machine learning)
- Semi-supervised (Bootstrapping)

Dictionary methods

- Predict the sense a given token that has the highest overlap between the token's context and sense's dictionary gloss.

Dictionary methods

bank[1]	Gloss:	a financial institution that accepts deposits and channels the money into lending activities
	Examples:	"he cashed a check at the bank", "that bank holds the mortgage on my home"
bank[2]	Gloss:	sloping land (especially the slope beside a body of water)
	Examples:	"they pulled the canoe up on the bank", "he sat on the bank of the river and watched the currents"

"The boat washed up on the river bank."

Lesk Algorithm

```
function SIMPLIFIED LESK(word, sentence) returns best sense of word

  best-sense ← most frequent sense for word
  max-overlap ← 0
  context ← set of words in sentence
  for each sense in senses of word do
    signature ← set of words in the gloss and examples of sense
    overlap ← COMPUTEOVERLAP(signature, context)
    if overlap > max-overlap then
        max-overlap ← overlap
        best-sense ← sense
  end
  return(best-sense)
```

Figure 19.10 The Simplified Lesk algorithm. The COMPUTEOVERLAP function returns the number of words in common between two sets, ignoring function words or other words on a stop list. The original Lesk algorithm defines the *context* in a more complex way.

Lesk Algorithm

- Extension (Basile et al. 2014): measure similarity between gloss $g = \{g_1, \ldots g_G\}$ and context $c = \{c_1, \ldots, c_C\}$ as cosine similarity between sum of distributed representations

$$\cos\left(\sum_{i=1}^{G} g_i, \sum_{i=1}^{C} c_i\right)$$

Supervised WSD

- We have labeled training data; let's learn from it.
  - Decision trees (Yarowsky 1994)
  - Naive Bayes, log-linear classifiers, support vector machines (Zhong and Ng 2010)
  - Bidirectional LSTM (Raganato et al. 2017)

Supervised WSD

- Pre-processing: part of speech tagging, lemmatization, syntactic parsing (headwords, dependency relations)
- Collocations (e.g., token 1 word to the left, 1 word to the right)
- Bag of words: all words within window of n tokens

feature
w_{i-1} = fish
w_{i-2}= fish
w_{i+1} = fish
w_{i+2} = fish
word in context = fish
…

	Dev	Test Datasets				Concatenation of All Test Datasets				
	SE07	**SE2**	**SE3**	**SE13**	**SE15**	**Nouns**	**Verbs**	**Adj.**	**Adv.**	**All**
BLSTM	61.8	71.4	68.8	65.6	69.2	70.2	56.3	75.2	**84.4**	68.9
BLSTM + att.	62.4	71.4	**70.2**	66.4	70.8	71.0	**58.4**	75.2	83.5	69.7
BLSTM + att. + LEX	63.7	**72.0**	69.4	66.4	**72.4**	**71.6**	57.1	**75.6**	83.2	**69.9**
BLSTM + att. + LEX + POS	**64.8**	**72.0**	69.1	**66.9**	71.5	71.5	57.5	75.0	83.8	**69.9**
Seq2Seq	60.9	68.5	67.9	65.3	67.0	68.7	54.5	74.0	81.2	67.3
Seq2Seq + att.	62.9	69.9	69.6	65.6	67.7	69.5	57.2	74.5	81.8	68.4
Seq2Seq + att. + LEX	64.6	70.6	67.8	66.5	68.7	70.4	55.7	73.3	82.9	68.5
Seq2Seq + att. + LEX + POS	63.1	70.1	68.5	66.5	69.2	70.1	55.2	75.1	84.4	68.6
IMS	61.3	70.9	69.3	65.3	69.5	70.5	55.8	75.6	82.9	68.9
IMS+emb	**62.6**	**72.2**	**70.4**	65.9	71.5	**71.9**	56.6	**75.9**	**84.7**	**70.1**
Context2Vec	61.3	71.8	69.1	65.6	**71.9**	71.2	**57.4**	75.2	82.7	69.6
Lesk_{ext}+emb	⋆56.7	63.0	63.7	66.2	64.6	70.0	51.1	51.7	80.6	64.2
UKB_{gloss} w2w	42.9	63.5	55.4	⋆62.9	63.3	64.9	41.4	69.5	69.7	61.1
Babelfy	51.6	⋆67.0	63.5	**66.4**	70.3	68.9	50.7	73.2	79.8	66.4
MFS	54.5	65.6	⋆66.0	63.8	⋆67.1	67.7	49.8	73.1	80.5	65.5

Raganato et al. 2017

One sense per discourse

- If a word appears multiple times in a document, it's usually with the same sense. (Gale et al. 1992)
    - Articles about financial banks don't usually talk about river banks.

Supervised learning

But WSD is not POS tagging

Semi-supervised WSD

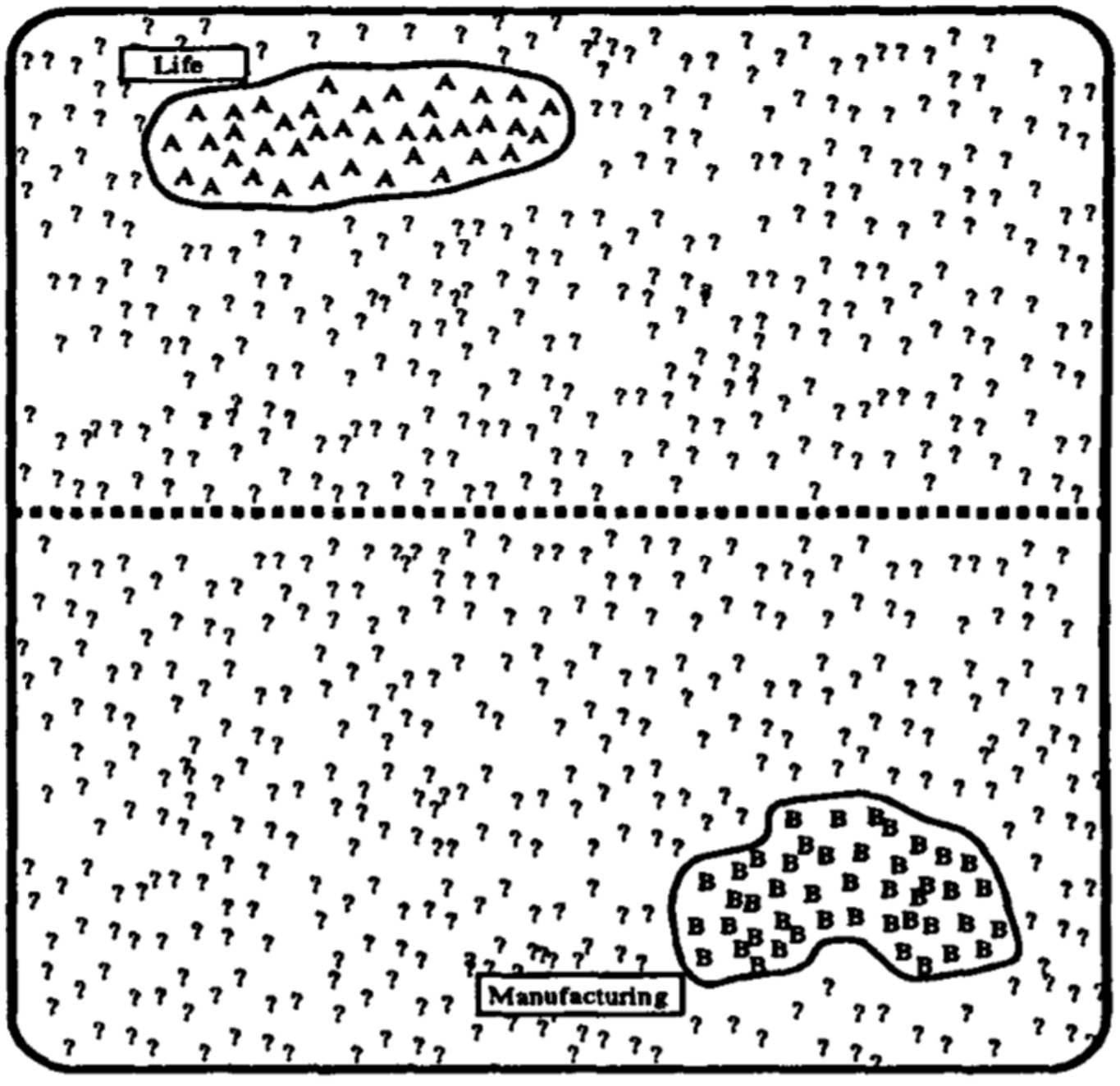
1. Produce seeds (dictionary definitions, single defining collocate, or label common collocates)

2. Repeat until convergence:

    1. Train supervised classifier on labeled examples

    2. Label all examples, and keep labels for high-confidence instances

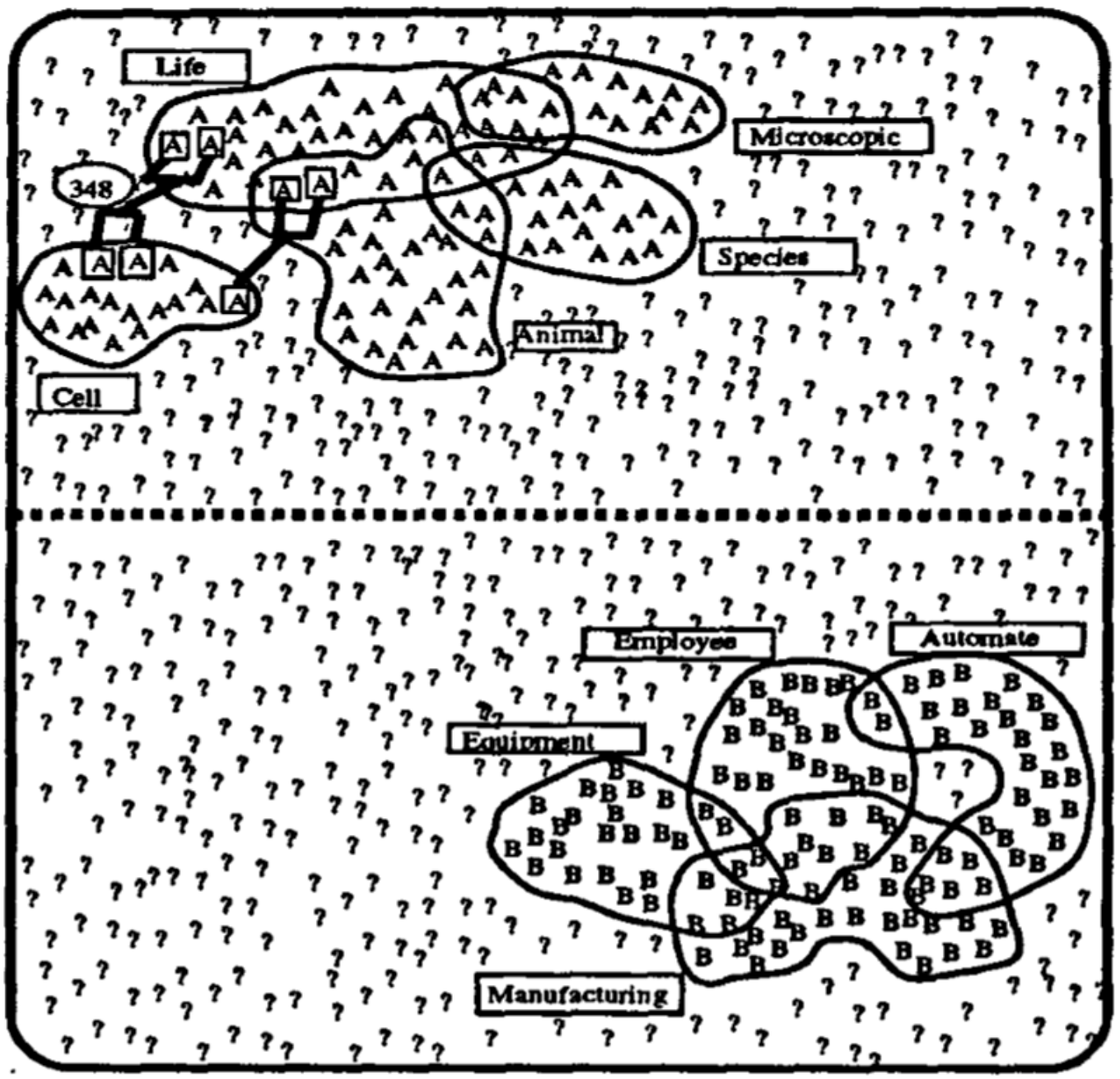
Semi-supervised WSD



"Plant"

A = SENSE-A training example
B = SENSE-B training example
? = currently unclassified training example
Life = Set of training examples containing the collocation "life".

Semi-supervised WSD



"Plant"

A = SENSE-A training example
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Evaluation

- Annotated data; cross-validation.
  - Semcor
  - Ontonotes
- Semeval/Senseval competitions

Hyponymy

… Entity	… Entity
Animal	Artifact
Vertebrate	Instrumentality
Mammal	Conveyance
Ungulate	Wheeled vehicle
Equine	Self-propelled vehicle
Horse	Motor vehicle
	Car

NOUNS			
SUPERSENSE	NOUNS DENOTING	SUPERSENSE	NOUNS DENOTING
act	acts or actions	object	natural objects (not man-made)
animal	animals	quantity	quantities and units of measure
artifact	man-made objects	phenomenon	natural phenomena
attribute	attributes of people and objects	plant	plants
body	body parts	possession	possession and transfer of possession
cognition	cognitive processes and contents	process	natural processes
communication	communicative processes and contents	person	people
event	natural events	relation	relations between people or things or ideas
feeling	feelings and emotions	shape	two and three dimensional shapes
food	foods and drinks	state	stable states of affairs
group	groupings of people or objects	substance	substances
location	spatial position	time	time and temporal relations
motive	goals	Tops	abstract terms for unique beginners
VERBS			
SUPERSENSE	VERBS OF	SUPERSENSE	VERBS OF
body	grooming, dressing and bodily care	emotion	feeling
change	size, temperature change, intensifying	motion	walking, flying, swimming
cognition	thinking, judging, analyzing, doubting	perception	seeing, hearing, feeling
communication	telling, asking, ordering, singing	possession	buying, selling, owning
competition	fighting, athletic activities	social	political and social activities and events
consumption	eating and drinking	stative	being, having, spatial relations
contact	touching, hitting, tying, digging	weather	raining, snowing, thawing, thundering
creation	sewing, baking, painting, performing		

Ciarmita and Altun 2003

Supersense tagging

B-artifact I-artifact B-motion B-time B-group

The station wagons arrived at noon, a long shining line

B-motion B-location I-location

that coursed through the west campus.

Noun supersenses (Ciarmita and Altun 2003)

Supersense tagging

- Ciarameta and Altun (2006). Trained on data from Semcor (Miller et al. 1993); Brown corpus annotated with WordNet synset labels
- Token-level predictor – each instance of a word has its own supersense tag.
- Maximum-entropy Markov Model (MEMM) trained with averaged perceptron. Features for: word token identity, part-of-speech tag, word shape, previous label + supersense for most frequent synset for word.
- In-domain accuracy: 77.1 F score (cf. 66 F MFS baseline)

Data

- Semcor: 200K+ words tagged with Wordnet senses.
  http://web.eecs.umich.edu/~mihalcea/downloads/semcor/semcor3.0.tar.gz

- WordNet
  https://wordnet.princeton.edu/wordnet/download/