Introduction to Human Language Technologies

5. Lexical semantics
Outline

1. Semantics
   - Motivation of lexical semantics
   - Resources

2. WordNet
   - Definition
   - Similarities

3. SentiWordNet

4. Sentiment analysis
   - Definition
   - Examples of methods
Semantics

Semantics deals with the meaning:

- Lexical semantics: deals with the meaning of individual words
- Compositional semantics: deals with the construction of meaning usually in high concordance with syntax

This session focuses on lexical semantics
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Motivation of lexical semantics

Some examples of usefulness:

- Discovery of semantic patterns
  
  Ex: USA *bombed* Hiroshima
  Then began to *bombard* the defenses
  → A sense_12533 B

- Determine discourse relations
  
  Ex: [Anna will show up *later.*] [She has *missed the train.*] → explanation
  
  Ex: [Mathew is good cooking.] [Albert fails making every dish] → contrast

- Twitter sentiment analysis
  
  Ex: @vooda1: CNN Declines to Air White House Press Conference
  Live YES! THANK YOU @CNN FOR NOT LEGITIMI... positive
  
  Ex: @Slate: Donald Trump’s administration: “Government by the worst men.”
  negative
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Resources of lexical semantics

- Knowledge-based resources: represented as graphs
  - **Ex:** WordNet (English lexical ontology)
    - SentiWordNet (sentiment polarity into WordNet)
    - BabelNet (Wikipedia + WordNet)
    - VerbNet (syntactic/semantic verbal behaviour)
    - FrameNet (conceptual behaviour – fine-grained event representation –)
    - ConceptNet (common sense knowledge)

- Corpus-based resources: contextual usage of words
  - **Ex:** Latent Semantic Analysis (LSA)
    - Word embeddings
  
  *We will study them in AHLT*
## Resources of lexical semantics

<table>
<thead>
<tr>
<th>Resource</th>
<th>URL</th>
</tr>
</thead>
<tbody>
<tr>
<td>WordNet</td>
<td><a href="https://wordnet.princeton.edu/">https://wordnet.princeton.edu/</a></td>
</tr>
<tr>
<td>SentiWordNet</td>
<td><a href="https://github.com/aesuli/SentiWordNet">https://github.com/aesuli/SentiWordNet</a></td>
</tr>
<tr>
<td>BabelNet</td>
<td><a href="https://babelnet.org/">https://babelnet.org/</a></td>
</tr>
<tr>
<td>VerbNet</td>
<td><a href="https://verbs.colorado.edu/verbnet/">https://verbs.colorado.edu/verbnet/</a></td>
</tr>
<tr>
<td>FrameNet</td>
<td><a href="https://framenet.icsi.berkeley.edu/fndrupal/">https://framenet.icsi.berkeley.edu/fndrupal/</a></td>
</tr>
<tr>
<td>LSA</td>
<td>accessible from</td>
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<tr>
<td>Word embeddings</td>
<td><a href="https://radimrehurek.com/gensim/">https://radimrehurek.com/gensim/</a></td>
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WordNet

- Free large lexical database of English
- Contains only nouns, verbs, adjectives and adverbs
- Words are grouped into synonyms sets (synsets)
- Each synset has an associated gloss and some examples
- Synsets are interlinked by means of lexical relations

http://wordnetweb.princeton.edu/perl/webwn

**Noun**

- **S:** (n) age (how long something has existed) "it was replaced because of its age"
- **S:** (n) historic period, age (an era of history having some distinctive feature) "we live in a litigious age"
Lexical relations

Example of Lexical Relation Net

{conveyance; transport}

{vehicle}

{motor vehicle; automotive vehicle}

{car; auto; automobile; machine; motorcar}

{cruiser; squad car; patrol car; police car; prowl car}

{cab; taxi; hack; taxicab;}

{hinge; flexible joint}

{bumper}

{car door}

{car window}

{car mirror}

{doorlock}

{armrest}

hyperonym

hyperonym

meronym

meronym

meronym

meronym
Lexical relations

- **Synonym**: same meaning. Ex: age - historic_period
- **Antonym**: opposite meaning. Ex: dark - light
- **Homophone**: same sound. Ex: son - sun
- **Homograph**: same written form. Ex: lead (noun - verb)
- **Polysemy**: different related meaning. Ex: newspaper (paper - firm)
- **Homonymy**: different unrelated meaning. Ex: position (place - status)
- **Hypernymy**: parent. Ex: cat - feline
- **Hyponymy**: child. Ex: feline - cat
- **Holonymy**: group, whole. Ex: class - student
- **Meronymy**: member, part. Ex: student - class
- **Metonymy**: substitution of entity. Ex: We ordered many delicious dishes at the restaurant.
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Similarities in WordNet

- Shortest Path Length: \(\text{Sim}(s_1, s_2) = \frac{1}{1 + SPL(s_1, s_2)}\)
  where \(SPL(s_1, s_2) = \text{Shortest Path Length from } s_1 \text{ to } s_2 \text{ as edge-countings}\)

- Leacock & Chodorow: \(\text{Sim}(s_1, s_2) = -\log_2 \frac{1 + SPL(s_1, s_2)}{2 \cdot \text{MaxDepth}}\)
  where \(\text{depth}(s) = SPL(\text{TopSynset}, s)\)
  \(\text{MaxDepth} = \max_{s \in \text{WN}} \text{depth}(s)\)

- Wu & Palmer:
  \(\text{Sim}(s_1, s_2) = \frac{2 \cdot \text{depth}(\text{LCS}(s_1, s_2))}{\text{depth}_{\text{LCS}(s_1, s_2)}(s_1) + \text{depth}_{\text{LCS}(s_1, s_2)}(s_2)}\)
  where \(\text{LCS}(s_1, s_2) = \text{Lowest Common Subsumer of } s_1 \text{ and } s_2\)
  \(\text{depth}_{s'}(s) = SPL(\text{TopSynset}, s) \text{ throw } s'\)

- Lin: \(\text{Sim}(s_1, s_2) = \frac{2 \cdot IC(\text{LCS}(s_1, s_2))}{IC(s_1) + IC(s_2)}\)
  where \(IC(s) = -\log_2 P(s) = \text{information content of } s \text{ (from frequencies in a corpus)}\)
Example / exercise

\[ \text{spl}(\text{beer}, \text{milk}) = 4 \]
\[ \text{Sim}_{\text{spl}}(\text{beer}, \text{milk}) = 0.2 \]
\[ \text{Sim}_{\text{wp}}(\text{beer}, \text{milk}) = 0.71 \]

\[ \text{Sim}_{\text{spl}}(\text{drug}, \text{milk})? \]
\[ \text{Sim}_{\text{wp}}(\text{drug}, \text{milk})? \]
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Definition

Extension of wordnet that adds for each synset 3 measures:

- positive_score
- negative_score
- objective_score = 1 - positive_score - negative_score

<table>
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<tr>
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<th>Gloss</th>
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<th>SentiWordnet</th>
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<td>bad.a.01</td>
<td>having undesirable or negative qualities</td>
<td>obj: 0.375</td>
<td>pos: 0.0</td>
</tr>
<tr>
<td>good.a.01</td>
<td>having desirable or positive qualities</td>
<td>pos: 0.25</td>
<td>neg: 0.0</td>
</tr>
<tr>
<td>bad.n.01</td>
<td>that which is below standard or expectations as of ethics or decency</td>
<td>obj: 0.125</td>
<td>pos: 0.0</td>
</tr>
<tr>
<td>good.n.03</td>
<td>that which is pleasing, valuable, useful</td>
<td>pos: 0.375</td>
<td>neg: 0.0</td>
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Sentiment analysis

Different subtasks:

- **Opinion detection**: given a piece of text (document or sentence), is it an objective text or a subjective one?
- **Polarity classification**: given a subjective piece of text, is it a positive opinion or a negative one?
- Opinion extraction: given a subjective piece of text, recognise the focuses of the opinion (templates \(<\text{entity}, \text{aspect}, \text{polarity}>\)).
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Unsupervised sentiment analysis

Possible solution:

$$h(D) = \sum_{s \in \hat{D}} \text{score}(s)$$

\(\hat{D}\) is usually the set of synsets related to adjectives, or to nouns and adjectives, or to nouns, verbs, adjectives and adverbs.

- **Opinion detection:**
  $$\text{score}(s) = 1 - \text{obj}_s \quad \text{or} \quad \text{score}(s) = \text{obj}_s$$

- **Polarity classification:**
  $$\text{score}(s) = \text{pos}_s - \text{neg}_s$$

**Pros:**
- no need for training corpora

**Cons:**
- low results
- need for POS and WSD taggers
Supervised sentiment analysis

Possible solution:

Bag of words with Naïve Bayes

\[ h(D) = h(w_1, \ldots, w_n) = \arg\max_y P(y) \prod_{i=1}^{n} P(w_i|y) \]

where \( y \) is the category (positive/negative, subjective/objective), and \( w_1, \ldots, w_n \) is the bag of words related to \( D \)

- Given a training corpus \( C = \{d_i\} \) partitioned into subsets \( Y_1 \) and \( Y_2 \)
  - \( P(y) \approx P_{MLE}(y) = \frac{|Y_i|}{|C|} \)
  - \( P(w_i|y) \approx P_{MLE}(w_i|Y_j) = \frac{c(w_i, Y_j)}{\sum_{w_i \in Y_j} c(w_i, Y_j)} \)

Pros:
- higher results
- no need for POS and WSD taggers

Cons:
- need for training corpora
Hybrid approach for sentiment analysis

Possible solution:

- Combine two supervised methods with SentiWordnet method
- I.e., consensuate the output of the three methods, using *voting*, for instance:
  
  if at least 2 of the methods answer *y* then output *y*
  else output the answer of the method with better accuracy in the training corpus

The combination improves the results of the isolated methods
Annex

- Base on the Bayes’ theorem:
  \[ P(y|x_1, \ldots, x_n) = \frac{P(y)P(x_1, \ldots, x_n|y)}{P(x_1, \ldots, x_n)} \]

- Naïve assumption of independence between features:
  \[ P(y|x_1, \ldots, x_n) \approx P(y)\prod_{i=1}^{n} P(x_i|y) \]

- Maximum likelihood estimation of \( P(y) \) and \( P(x_i|y) \) as training model

- Test prediction as:
  \[ h(x_1, \ldots, x_n) = \arg\max_y P(y)\prod_{i=1}^{n} P(x_i|y) \]

- Need a smoothing technique to avoid zero counts: in NLTK never seen features are discarded