Assignment 9 + Word Sense Disambiguation

(SNLP Tutorial 10)

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Assignment 9

- Exercise 1: Feature Engineering, Classification
- Bonus: Support Vector Machines

Word Sense Disambiguation

Apple is full of vitamins.
Apple was struggling last quarter.
Apple was thrown away from the meeting.

$f(w, C) = s \in S_w$
$f(\text{Apple}, * \text{ was thrown away from the meeting}) \in \{\text{fruit}, \text{company}\}$

Word Sense Disambiguation

Machine translation:

- Apfel ist voller Vitamine.
- Apple ist voller Vitamine.
- Apfel hatte im letzten Quartal Probleme.
- Apple hatte im letzten Quartal Probleme.

Information retrieval:

- Query: Apple vitamins
- Relevant document: benefits of eating apples

Dialogue systems

Spelling correction

One sense per . . .

One sense per discourse

- One meaning per word+document

One sense per collocation

- Nearby words help determine the sense

Dictionary

- Dictionary/Thesaurus: $\forall w, s \in S_w : D(s) =$ description of sense s
- Context: $\forall w, C(w) =$ context of word w in a specific occurence

Lesk's Algorithm

- Idea: Sense s_i of ambiguous word w is likely to be the correct sense if many of the words used in the dictionary definition of s_i are also used in the definitions of words in the ambiguous word's context.

$$s_{opt} = \operatorname*{argmax}_{s_k} sim\left(D(s_k), \bigcup_{v_j \in C} E(v_j)\right)$$

Similarity

$$\frac{2|X \cap Y|}{|X| + |Y|} \qquad \frac{2|X \cap Y|}{|X \cup Y|} \qquad \frac{|X \cap Y|}{\sqrt{|X| \cdot |Y|}}$$

- Advantages? Disadvantages?

Supervised Disambiguation

- Sequence Labelling / Classification

Bayes Decision

$$\hat{s} = \arg\max_s p(s|C) = \arg\max_s \frac{p(C|s) \cdot (p(s))}{p(C)}$$
$$= \arg\max_s p(C|s) \cdot (p(s))$$

Naïve Bayes

$$p(C|s) = \prod_{x \in C} p(x|s)$$

- Estimate by MLE counts (+ smoothing)
- Independence within context
- Position in context does not matter
- Advantages? Disadvantages?

Unsupervised Disambiguation

- Machine translation is able to choose the right sense
  (assuming different senses have different translations)
- MT is trained on unsupervised data
- Apple was struggling last quarter.
  Apple hatte im letzten Quartal Probleme.
- Apple is full of vitamins.
  Apfel ist voller Vitamine.
- Translations (in German): {Apfel, Äpfel, Apple}
- Indicator words: {struggling, quarter, full, vitamins} (stopwords removed)

Partition translated words ($\{Q_1, Q_2\}$) and indicator words ($\{P_1, P_2\}$) to maximize:

$$I(P;Q) = \sum_{i \in Q, t \in P} \log \frac{p(i,t)}{p(i) \cdot p(t)}$$

Flip-Flop Algorithm

1. find random partition P $= \{P_1, P_2\}$ of $t_1, ..., t_m$
2. while improving I(P;Q) do
3. - find partition Q $= \{Q_1, Q_2\}$ of $x_1, ..., x_n$ that maximises I(P;Q)
4. - find partition P $= \{P_1, P_2\}$ of $t_1, ..., t_m$ that maximises I(P;Q)
5. end

- t_i : translations of the ambiguous word
- x_i : indicator words
- I(P;Q) monotonically increases until convergence
- Disambiguation
  Determine x_i

if $x_i \in Q_1$ assign sense 1

if $x_i \in Q_2$ assign sense 2

EM Algorithm

- Idea: Random initialisation followed by parameter estimation
- Paramaters? $P(v_j|s_k)$ and $P(s_k)$
- Maximise log-likelihood $\log \prod_i \sum_k P(c_i|s_k)P(s_k)$
- E step: $h_{ik} = \frac{P(c_i|s_k)P(s_k)}{\sum_l P(c_i|s_l)P(s_l)}$
- M step: $P(v_j|s_k) = \frac{\sum_i C(v_j \in c_i) \cdot h_{ik}}{\sum_j \sum_i C(v_j \in c_i) \cdot h_{ik}}$

  $P(s_k) = \frac{\sum_i h_{ik}}{\sum_k \sum_i h_{ik}}$
- Disambiguation: $s_{opt} = argmax_{s_k}[\log P(s_k) + \sum_{v_j \in C} \log P(v_j|S_k)]$

Yarowsky Algorithm

- Utilises one sense per discourse and one sense per collocation
- Algorithm:

1. In a large corpus, identify all examples of a polysemous word, and store their contexts as an untagged training set.
   e.g.
   The company *plant* is still operational...
   The region abounts in *plant* life...
   The classification of *plant* and animal kingdoms...

2. For each sense of the word $(s_1 ... s_k)$, identify collocations representative of the sense, and tag all the sentences from (1) which contain the seed collocation with the respective label.
   e.g.
   Sense 1: The company *plant* is still operational
   Sense 2: The region abounds in *plant* life...
   Sense 2: The classification of *plant* and animal kingdoms

Yarowsky Algorithm

3. a) Train on the seed sets (Sense 1, Sense 2).
   b) Apply the obtained classifier on the entire sample set. Only retain those tags that are above a certain probability threshold. Add these examples to the seed set.
   c) Use one sense per discourse to augment and correct the available data.

      e.g.

      Sense 1: The company *plant* is still operational

      ? $\rightarrow$ Sense 1: The *plant* was shut down due to inflation.
   d) Repeat (3a) to (3c)
4. Hold training parameters constant, and the algorithm will converge on the residual set.
5. Apply the classifier to new data or original untagged data.

Resources

1. UdS SNLP Class, WSD: https://teaching.lsv.uni-saarland.de/snlp/
2. Classical Statistical WSD: https://www.aclweb.org/anthology/P91-1034.pdf
3. WSD: https://www.cs.toronto.edu/~frank/csc2501/Lectures/8%20Word%20sense%20disambiguation.pdf
4. Lesk Algorithm: https://www.c-sharpcorner.com/article/lesk-algorithm-in-python-to-remove-word-ambiguity/
5. Yarowsky Algorithm: https://www.coli.uni-saarland.de/courses/comsem-10/material/Victor_Santos_Yarowsky.pdf
6. https://www.aclweb.org/anthology/P95-1026.pdf