Choosing the Right Words: Characterizing and Reducing Error of the Word Count Approach

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Abstract

Social scientists are increasingly using the vast amount of text available on social media to measure variation in happiness and other psychological states. Such studies count words deemed to be indicators of happiness and track how the word frequencies change across locations or time. This word count approach is simple and scalable, yet often picks up false signals, as words can appear in different contexts and take on different meanings. We characterize the types of errors that occur using the word count approach, and find lexical ambiguity to be the most prevalent. We then show that one can reduce error with a simple refinement to such lexica by automatically eliminating highly ambiguous words. The resulting refined lexica improve precision as measured by human judgments of word occurrences in Facebook posts.

1 Introduction

Massive social media corpora, such as blogs, tweets, and Facebook statuses have recently peaked the interest of social scientists. Compared to traditional samples in tens or hundreds, social media sample sizes are orders of magnitude larger, often containing millions or billions of posts or queries. Such text provides potential for unobtrusive, inexpensive, and real-time measurement of psychological states (such as positive or negative affect) and aspects of subjective well-being (such as happiness and engagement). Social scientists have recently begun to use social media text in a variety of studies (Cohn et al., 2004; Kramer, 2010; Tausczik and Pennebaker, 2010; Kamvar and Harris, 2011; Dodds et al., 2011; Golder and Macy, 2011).

One of the most popular approaches to estimate psychological states is by using the word count method (Pennebaker et al., 2007), where one tracks the frequency of words that have been judged to be associated with a given state. Greater use of such words is taken to index the prevalence of the corresponding state. For example, the use of the word ‘happy’ is taken to index positive emotion, and ‘angry’ to index negative emotion. The most widely used tool to carry out such analysis, and the one we investigate in this paper, is Pennebaker’s Linguistic Inquiry and Word Count, (LIWC) (Pennebaker et al., 2001; Pennebaker et al., 2007). LIWC, originally developed to analyze writing samples for emotion and control, has grown to include a variety of lexica for linguistic and psychosocial topics including positive and negative emotions, pronouns, money, work, and religion. The word count approach has high appeal to social scientists in need of a tool to approach social media, and although others have been used (see, for example (Gottschalk and Bechtel, 1998; Bollen et al., 2010), LIWC’s lexica are generally perceived as a “tried-and-tested” list of words (Miller, 2011).

Unfortunately, the word count approach has some drawbacks when used as indicators for psychological states. Words are the unit of measurement, but words can carry many different meanings depending on context. Consider the Facebook posts below containing instances of ‘play’, a word associated with positive emotion in LIWC.
1. so everyone should come to the **play** tomorrow...

2. Does anyone what type of file i need to convert youtube videos to **play** on PS3???

3. Time to go **play** with Chalk from the Easter Bunny!

Out of the three instances, only (3) seems to communicate positive emotion. In (1), ‘play’ is used as a noun rather than the expected verb, while in (2), ‘play’ is a verb but it is used in a sense that is not directly associated with positive emotion. (1) and (2) demonstrate how *lexical ambiguities* (i.e. multiple parts-of-speech or word senses) can affect accuracy of words in a lexicon. Additionally, even when appearing as the expected part of speech and word sense, signal from a word may change due to its context, such as being within the scope of a negation as in (4), or describing something desired as in (5).

4. ...all work no **play** :-(

5. i sure wish i had about 50 hours a day to **play** cod

Our goal is to characterize the errors of the widely used *word count* approach, and show that such lexica can be significantly improved by employing an ambiguity metric to refine such lexica. Rather than work on a new method of measuring psychological states, we work within the bounds of *word count* and ask how accurate it is and whether we can improve it without sacrificing its simplicity and scalability.

We attempt to reduce the erroneous signal of the *word count* approach while maintaining legitimate signal simply by refining the lexicon. In other words, we would like to move closer to the goal in Figure 1, by eliminating words that often carry erroneous signal such as ’play’, and keeping words which often carry the sought-after signal, such as ’cheerful’. The difficulty in doing this is that we do not have the data to tell us which words are most likely to carry signal (even if we had such data we would like to develop a method that could be applied to any newly created lexica). Instead we leverage part-of-speech and word sense data to help us determine which words are lexically ambiguous.

![Figure 1: The relationship between text expressing positive emotion (POSEMO) and text containing LIWC terms for POSEMO.](image-url)

Our approach of eliminating ambiguous words increases the precision at the expense of recall, a reasonable trade-off in social media where we are working with millions or even billions of word instances. Additionally, it is minimally-supervised, in that we do not require training data on human-state; instead we use existing hand-labeled corpora, such as SemCor (Miller et al., 1993), for word sense information. Not requiring training data also means our refinement is flexible; it can be applied to multiple domains and lexica, it makes few assumptions that might introduce problems of over-fitting, and it is parsimonious in that it merely improves an established approach.

This paper makes two primary contributions: (1) an analysis of the types of errors common for the *word count* approach (Section 3), and (2) a general method for refining psychosocial lexica based on the ambiguity of words (Section 4). Before describing these contributions, we discuss related work, making the case for using social media in social science and surveying some work in computational linguistics. We then evaluate both the original *LIWC* lexicon and our refinement of it against human judgments of expression of positive and negative emotions on hand-annotated Facebook posts, and show the benefit of lexicon refinement for estimating well-being over time for large aggregates of posts. Finally, we discuss the implications of our work and possible future directions.
2 Background

Compared to traditional approaches in the social sciences, large scale analysis of social media is cheap, near real-time, unobtrusive, and gives high coverage. We outline these advantages below.

Inexpensive  Extracting information from sources such Facebook and Twitter is vastly cheaper than the more conventional polling done by companies such as Gallup – and by many social science researchers. Social media data does not require phone calls to be made or doors to be knocked on. For example, a representative survey asking 1,000 people by a leading polling company costs to the order of $10,000\(^1\). In contrast, once the software exists, social media data from tens of millions of users can be obtained and analyzed at a fraction of the cost.

Temporal Resolution  Much of the attraction of social media stems from the fact that it captures a written live stream of collective thought. When Google relied on search queries to monitor health-seeking behavior to predict influenza epidemics, the reporting lag was a mere day, whereas traditional CDC surveillance systems take 1-2 weeks to publish their data (Ginsberg et al., 2009). Infrastructure based on social media and Internet use data allows reporting and analysis systems with little to no reporting lag. Additionally, traditional survey designs are typically only designed to assess psychological states at a given point in time.

Unobtrusive Estimation  Traditional self-report survey approaches, even those implemented on the web, suffer from social desirability, priming, and other biases. For example, Kahneman et al. (Kahneman et al., 2006) found that the order in which questions are asked on questionnaires can determine how they are answered. By looking directly into the social worlds, many of these self-report biases can be avoided. The traces of human interactions in social media represent the goings-on in their original ecologies of meaning and signification. This approach diminishes the inferential distance between the context of the phenomena and the context of measurement – and thus decreases the room for systematic distortion of signal.

2.1 The Word Count Approach

As previously noted, the word count approach is most often used by social scientists through the tool known as Linguistic Inquiry and Word Count or LIWC (Pennebaker et al., 2007). The LIWC2007 dictionary is composed of almost 4,500 words and word stems organized across one or more word categories, including 406 positive emotion words and 499 negative emotion words. When long form texts are analyzed with LIWC, the program simply returns the percentages of words belonging to the different analytical categories – the simplicity of this approach makes it popular with non-technical social scientists.

LIWC’s positive and negative emotion lexica have recently begun to be used on “short form” writing in social media. For example, Golder and Macy (2011) used LIWC to study diurnal and seasonal variation in mood in a collection of 400 million Twitter messages. Kramer (2010) proposed the “Gross National Happiness” index and Kivran-Swaine and Naaman (2011) examined associations between user expressions of positive and negative emotions and the size and density of social networks. A comprehensive review can be found in Tausczik and Pennebaker (2010).

To our knowledge there is only one work which has evaluated LIWC’s accuracy over social media. Bantum and Owen (2009) evaluated LIWC on a set of posts to an Internet-based breast cancer support group. By annotating expression of emotion within this text, they were able to produce accuracy figures of sensitivity (much like recall) and predictive validity (precision). Sensitivity measured how often a word (in context) expressing positive or negative emotion was captured by LIWC. Predictive validity measured how often a word (in context) captured by LIWC as measuring positive or negative emotion was indeed expressing positive or negative emotion. While they found a recall of 0.88, the precision was only 0.31 – that is, only 31% of instances containing words indexed by LIWC actually conveyed the associated emotion. We contend that this is a major drawback for applying LIWC to social media, because while it is not important to catch every expression of emotion out of a million Tweets, it is important that when something is captured it is an accurate

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2.2 Related Work in Computational Linguistics

Researchers have been exploring the use of lexica that define the subjective orientation of words for tasks such as sentiment or subjectivity analysis. A common weakly-supervised approach starts with a small set of sentiment knowledge (seed words associated with a given sentiment) and expands the words into a large lexicon (Hatzivassiloglou and McKeown, 1997; Kamps and Marx, 2002; Kim and Hovy, 2004; Kanayama and Nasukawa, 2006; Bacicianella et al., 2010). We take a different approach. Rather than expanding lexica, we start with a large set of words and refine the set. The refinement increases precision at the cost of recall, which is a reasonable exchange when we are looking at millions or even billions of word instances. Standard applications of sentiment analysis, such as annotating movie reviews, may not be as inclined to skip instances, since they want to make predictions for items which have very few reviews.

Another line of work in sentiment analysis has created lexicons using supervised learning. One of the first works to do so was by Pang and colleagues (2002), who used data including author ratings of reviews, such as IMDB movie reviews. The author ratings become training data for sentiment classification. Pang et al. showed that human-created lexicons did not perform as well as lexicons based on simple word statistics over the training data. Interestingly, they found that words like ‘still’ were most predictive of positive movie reviews, and that punctuation marks of ‘!’ and ‘?’ were strong signs of negative movie reviews. Unfortunately, training data for subjective well-being or happiness is not yet available, preventing the use of such supervised learning methods. Additionally, this work seeks to experiment within the bounds of what social scientists are in fact using (with publications in high-impact venues such as Science). We thus take a different approach, and automatically improve human created lexicons.

Wiebe and Cardie (2005) generalized the task of sentiment analysis to that of discovering subjectivity such as “opinions, emotions, sentiments, speculations, evaluations, etc.”. More recently, Wilson et al. (2009) contended that the context may neutralize or change the polarity of the subjective orientation of a word. It is difficult to determine where concepts of happiness such as quality of relationships or degree of achievement in life fit in with subjectivity. Thus, we do not claim to be measuring subjectivity and instead we use the general term of ‘psychological state’, referring to “the way something [a person] is with respect to its main attributes” (Miller, 1993).

To the best of our knowledge, while part-of-speech tagging and word sense disambiguation are staple tasks in the computational linguistics community, the utility of a lexical ambiguity metric has yet to be explored.

3 Annotation and Analysis of Errors from the Word Count Method

One objective of our work is to document and describe how often different types of errors occur when using the word count approach on social media. To do this, we first judged a sample of 1,000 instances of LIWC terms occurring in Facebook posts to indicate whether they contribute signal towards the associated LIWC category (i.e. positive emotion). We then took instances that were deemed to carry erroneous signal and annotated them with a label for the

| POSEMO term | frequency | NEGEMO term | frequency |
|-------------|-----------|-------------|-----------|
| like        | 774,663   | hate        | 167,109   |
| love        | 797,833   | miss        | 158,274   |
| good        | 571,687   | bad         | 151,496   |
| friend*     | 406,568   | bore*       | 140,684   |
| happy       | 384,797   | shit*       | 114,923   |
| LOL         | 370,613   | hurt*       | 98,291    |
| well*       | 284,002   | craz*       | 94,518    |
| great       | 263,113   | lost        | 94,059    |
| haha*       | 240,587   | damn*       | 93,666    |
| best        | 227,381   | fuck        | 90,212    |
| better      | 212,547   | stupid*     | 85,587    |
| fun         | 216,432   | kill*       | 83,593    |
| please*     | 174,597   | hell        | 80,046    |
| hope        | 170,998   | fuckin*     | 79,959    |
| thank       | 161,827   | wrong*      | 70,714    |

Table 1: Most frequent POSEMO and NEGEMO terms in LIWC in the 12.7 million Facebook posts. “*” indicates a wildcard, so that “well*” matches “wellness”.
Table 2: Inter-annotator agreement over 1,000 instances of LIWC terms in Facebook posts. Base rate is the average of how often an annotator answered true.

| Category | Agreement | Instances | Base Rate |
|----------|-----------|-----------|-----------|
| POSEMO   | 0.742     | 500       | .654      |
| NEGEMO   | 0.746     | 500       | .697      |
| TOTAL    | 0.744     | 1,000     | .676      |
| Random   | 0.343     | -         | -         |

3.1 Annotation Process

Annotating social media instances of lexica terms provides insight into how well the word count approach works, and also yields a “ground truth” for evaluating our lexicon refinement methods. We randomly selected for labeling a sample of 1,000 status updates containing words from a given lexicon drawn from a collection of 12.7 million Facebook status updates provided by the Cambridge myPersonality project (Kosinski and Stillwell, 2012).

We used terms from the LIWC positive emotion (POSEMO) and negative emotion (NEGEMO) lexica, which are the same lexica used by the works of Kramer (2010), Kivran-Swaine and Naaman (2011), and Golder and Macy (2011). Table 1 lists the most frequent POSEMO and NEGEMO terms in our Facebook sample.

As mentioned above, we did two types of annotations. First, we judged whether each given instance of a word conveyed the correct associated type of emotion. The second task took a sample of instances judged to have incorrect signal and labeled them with a reason for the error; We refer to this as signal error type.

For the first task, we had three human judges independently evaluate the 1,000 status update instances as to whether they were indeed correct signal. The question the judges were told to answer was “Does the word contribute to the associated psychological-state (POSEMO or NEGEMO) within the sentence it appears?” In other words, “would the sentence convey less [positive emotion or negative emotion] without this word?”. Subjective feedback from the judges indicated that it was often difficult to make a decision, so we used three judges per instance. In the case of conflict between judges, the “correct” label for validation of the refined lexicon was defined to be the majority vote. A sampling of Facebook statuses demonstrates a mixed picture of relevance for the unrefined LIWC dictionaries:

1. *has had a very good day* (*good* - POSEMO)
2. *is so very bored.* (*bore* - NEGEMO)
3. *damn, that octopus is good,* lol (*damn* - NEGEMO)
4. *thank you for his number* (*numb* - NEGEMO)
5. *I got pranked sooooo bad* (*bad* - NEGEMO)
6. *don’t be afraid to fail* (*afraid* - NEGEMO)
7. *I wish I could . . . and we could all just be happy* (*happy* - POSEMO)

Some posts clearly use positive or negative lexicon words such as (1) and (2). Curse words can signify negative emotion or emphasize the opposite state as in (3), which is clearly emphasizing positive emotion here. Example (5) demonstrates the word sense issue we discussed previously. Words with wildcards that expand into other words with different meanings can be particularly problematic, as the expanded word can be far more frequent – and very different in meaning – from the original word. For example, ‘numb*’ matches ‘number’ in 4.

A different problem occurs when the context of the word changes its implication for the emotional state of the writer. This can either occur through negation such as in (6) where ‘afraid’ signals NEGEMO, but is negated with ‘don’t’ or the signal can be changed indirectly through a variety of words indicating that the writer desires (and hence lacks) the state, as in (7) where someone is wishing to be ‘happy’.

Table 2 shows the agreement between annotators calculated as $\sum_{i=1}^{3} agree(A_1^{(i)}, A_2^{(i)}, A_3^{(i)})$, where $agree(A_1, A_2, A_3)$ was 1 when all three annotations matched and 0 otherwise. Given the average positive base rate across annotators was 0.676 the chance that all three reviewers agree according to chance (random agreement) is calculated as
0.676³ + (1 – 0.676)³ = 0.343, the probability of all three answering yes plus the probability of all three answering no.

For the second task, we selected 100 instances judged to be incorrect signal from the first task, and labeled them according to the best reason for the mistake. This task required more linguistic expertise and was performed by a single annotator. Labels and descriptions are given in Table 3, which breaks down the cases into lexical ambiguity, direct or indirect negation, and other reasons such as the stemming issue (stem plus wildcard expanding into words indicating a different (or no) emotional state).

### 3.2 Analysis of Errors

Before discussing the types of errors we found when using the word count approach, we examine LIWC’s overall accuracy on our dataset. Table 4 shows the precision broken down for both the positive emotion (POSEMO) and the negative emotion (NEGEMO) lexica. We see that the precision for NEGEMO is slightly higher than POSEMO, indicating the terms in that category may be more likely to indicate their associated state.

Although the overall accuracy seems decent, one should keep in mind our subjective judgement criteria were quite tolerant, allowing any amount of contribution of the corresponding signal to be considered accurate. For example, a salutation like “Happy New Year” was judged to be a correct use of “happy” to signal POSEMO, even though it clearly does not have as strong a signal as someone saying “I feel deliriously happy”.

Frequencies of signal errors are given in Table 5. The most common signal error was wrong word sense, where the word did not signal emotional state and some other sense or definition of the word was intended (e.g. “u feel like ur living in a music video”); corresponding to the sense “to inhabit” rather than the intended sense, “to have life; be alive” (Miller, 1993)). Other common signal errors include strict negation where the word is canceled out by a clear negative quantifier (e.g. “Don’t be afraid to fail”) and wrong part of speech where the word is signaling a different part of speech than the emotion (e.g. “well, we cant afford to go to NYC”). There were also various other signal error types that include stem issues where the stem matched clearly unintended words, desiring statuses where the status is commenting on wanting the emotion instead of experiencing it and other less prevalent issues such as non-English language post, memes, or clear sarcasm.

### 4 Method for Refining Lexica

The idea behind our refinement method is to remove words that are likely to carry erroneous signal about the underlying state or emotion of the person writing the tweet or Facebook post.² We do so in an indirect fashion, without actually using training data of which posts are, in fact indicative of positive or negative emotion. Instead, we focus on reducing errors that are due to lexical ambiguity. By removing words that are often used with multiple parts of speech or multiple senses, we can tilt the balance toward precision at some cost in recall (losing some signal from the ambiguous words). This makes the word count approach more suitable for use in the massive corpora afforded by social media.

#### 4.1 Lexical Ambiguity

We address lexical ambiguity at the levels of both part of speech (POS) and word sense. As a metric of inverse-ambiguity, we determine the probability that a random instance is the most frequent sense (mfs) of the most frequent part of speech (mfp) of

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²Refinement tool is available at wwpdb.org.
Table 3: Signal error types.

| category          | label          | description                                                      | examples                                                                 |
|-------------------|----------------|------------------------------------------------------------------|--------------------------------------------------------------------------|
| Lexical Ambiguity | Wrong POS      | Not a valid signal because it is the wrong POS                   | so everyone should come to the play tomorrow...                           |
|                   | Wrong WS       | Not a valid signal because it is the wrong word sense (includes metaphorical senses) | Does anyone what type of file i need to convert youtube videos to play on PS3??? |
| Signal Negation   | Strict Negation| Within the scope of a negation, where there is a clear negative quantifier | ...all work no play :-(                                                  |
|                   | Desiring       | Within the scope of a desire / wishing for something             | i sure wish i had about 50 hours a day to play cod                       |
| Other             | Stem Issue     | Clearly not intended to be matched with the given stem           | numb* for NEGEMO matching number                                          |
|                   | Other          | Any other issue or difficult to classify                         |                                                                          |

the word, denoted $TSP$ (for top sense probability). Given a word $w$, we consider all parts of speech of $w$ ($POS(w)$) and all senses for the most frequent part of speech ($senses(mfp(w))$):

$$
p_{mfp}(w) = \frac{\max_{w_{pos} \in POS(w)} f_p(w_{pos})}{\sum_{w_{pos} \in POS(w)} f_p(w_{pos})}
$$

$$
p_{mfs}(w) = \frac{\max_{w_{sense} \in senses(mfp(w))} f_s(w_{sense})}{\sum_{w_{sense} \in senses(mfp(w))} f_s(w_{sense})}
$$

$$
TSP(w) = (p_{mfp}(w) \times p_{mfs}(w))^2
$$

Here, $f_p$ and $f_s$ represent the frequencies of a certain part-of-speech and a certain sense of a word, respectively. This is the squared-probability that an instance of $w$ is the top sense – the most-frequent part-of-speech and the most-frequency sense of that part-of-speech. The probability is squared because both the word in the lexicon and the word occurring in context should be the top sense (two independent probabilities: given an instance of a word in a corpus, and another instance of the word in the lexicon, what is the probability that both are the top POS and sense?). Frequency data is provided for parts-of-speech from the Google N-Grams 2.0 (Lin et al., 2010) and for word senses from SemCor (Miller et al., 1993). This aspect of the refinement is inspired by the most frequent sense heuristic for word sense disambiguation (McCarthy et al., 2004; Yarowsky, 1993), in which the sense of a word is chosen without regard to the context, but rather is simply based on the frequencies of senses in corpora. In our case, we restrict ourselves this way in order for the application of the lexicon to remain unchanged.

For some words, we were unable to find sense frequency data. We decided to keep such terms, on the assumption that a lack in available frequency information implies that the word is not very ambiguous. Many of these terms include Web speak such as ‘haha’ or ‘lol’, which we believe can carry a strong signal for positive and negative emotion.

Lastly, since $TSP$ is only a metric for the inverse ambiguity of a word, we must apply a threshold to determine which words to keep. We denote this threshold as $\theta$, and the description of the refined lexicon for a category, $cat$, is below.

$$lex_\theta(cat) = \{w | w \in cat \land TSP(w) > \theta\}$$

4.2 Handling Stems

Some lexica, such as the LIWC dictionary, include word stems that are intended to match multiple forms of a word. Stems are marked by the suffix ‘*’. LIWC describes the application of stems as follows: “the asterisk, then, denotes the acceptance of all letters, hyphens, or numbers following its ap-
Table 6: Precision (prec) and instance subset size (size) of refinements to the LIWC POSEMO and NEGEMO lexica with various $\theta$ thresholds (0.10, 0.50, 0.90)

| lex | cat   | prec | size |
|-----|-------|------|------|
| full| POSEMO| 67.9%| 500  |
|     | NEGEMO| 72.8%| 500  |
|     | both  | 70.4%| 1,000|
| lex0.10| POSEMO| 70.9%| 392  |
|      | NEGEMO| 71.6%| 423  |
|      | both  | 71.3%| 815  |
| lex0.50| POSEMO| 75.7%| 239  |
|      | NEGEMO| 78.9%| 232  |
|      | both  | 77.3%| 471  |
| lex0.90| POSEMO| 72.5%| 109  |
|      | NEGEMO| 78.1%| 128  |
|      | both  | 75.5%| 237  |

Figure 2: The relationship between precision and size when increasing the TSP threshold ($\theta$).

5 Evaluation

We evaluate our refinement by comparing against human judgements of the emotion conveyed by words in individual posts. In the case of human judgements, we find that the subset of human-annotated instances matching the refined lexica are more accurate than the complete set.

In section 3 we discussed the method we used to judge instances of LIWC POSEMO and NEGEMO words as to whether they contributed the associated affect. Each of the 1,000 instances in our evaluation corpus were judged three times such that the majority was taken as truth. In order to validate our refined lexica, we find the accuracy (precision) of the subset of instances which contain the refined lexica terms.

Table 6 shows the change in precision when using the refined lexica. size represents the number of instances from the full evaluation corpus matching words in the refined lexica. One can see that initially precision increase as the size becomes smaller. This is more clearly seen in Figure 2. As discussed in the method section, our goal with the refinement is improving precision, making lexica more suitable to applications over massive social media where one can more readily afford to skip instances (i.e. smaller size) in order to achieve more accuracy. Still, removing more ambiguous words does

3“How it works”: http://www.liwc.net/howliwcworks.php
not guarantee improved precision at capturing the intended psychological state; it is possible that that all senses of an ambiguous word do in fact carry intended signal or that the intended sense a low ambiguity word is not the most frequent.

Our maximum precision occurs with a threshold of 0.50, where things somewhat level-out. This represents approximately a 23% reduction in error, and verifies that we can increase precision through the automatic lexicon refinement based on lexical ambiguity.

6 Conclusions

Social scientists and other researchers are starting to measure psychological states such as happiness through text in Facebook and Twitter. We have shown that the widely used word count method, where one simply counts occurrences of positive or negative words, can often produce noisy and inaccurate estimates of expressions of psychological states. We characterized and measured the frequency of different types of errors that occur using this approach, and found that when counting words without considering context, it is lexical ambiguities (unintended parts-of-speech or word senses) which cause the most errors. We proposed a method for refining lexica by removing those words most likely to be ambiguous, and showed that we can significantly reduce error as measured by human judgements.

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