Methods and metrics: Natural language generation metrics

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CS224u: Natural language understanding

Challenges

1. There is more than one effective way to say most things.
2. What are we measuring?
   - Fluency?
   - Truthfulness?
   - Communicative effectiveness?

Perplexity of a probability distribution

Perplexity

For a sequence $\mathbf{x} = [x_1, \ldots x_n]$ and probability distribution p:

$$\mathbf{PP}(p, \mathbf{x}) = \prod_{i=1}^{n} \left(\frac{1}{p(x_i)} \right)^{\frac{1}{n}}$$

Mean perplexity

For a corpus X of m examples:

$$\textbf{mean-PP}(p, X) = \exp\left(\frac{1}{m} \sum_{\mathbf{x} \in X} \log \mathbf{PP}(p, \mathbf{x}) \right)$$

Properties

- Bounds: $[1, \infty]$, with 1 best.
- Equivalent to the exponentiation of the cross-entropy loss.
- Value encoded: does the model assign high probability to the input sequence?
- Weaknesses:
  - Heavily dependent on the underlying vocabulary.
  - Doesn't allow comparisons between datasets.
  - Even comparisons between models are tricky.

Word-error rate

Edit distance

A measure of distance between strings. Word-error rate can be seen as a family of measures depending on the choice of distance measure.

Word-error rate

$$\mathbf{wer}(\mathbf{x}, \mathbf{pred}) = \frac{\text{distance}(\mathbf{x}, \mathbf{pred})}{\text{length}(\mathbf{x})}$$

Corpus word-error rate

For a corpus X:

$$\frac{\sum_{\mathbf{x} \in X} \text{distance}(\mathbf{x}, \mathbf{pred})}{\sum_{\mathbf{x} \in X} \text{length}(\mathbf{x})}$$

Properties

- Bounds: $[0, \infty]$, with 0 the best.
- Value encoded: how aligned is the predicted sequence with the actual sequence – similar to F scores.
- Weaknesses:
  - Just one reference text.
  - A very syntactic notion – consider *It was good* vs. *It was not good.* vs. *It was great*

BLEU scores

BLEU scores

Modified n-gram precision

Candidate:	`the the the the the the the`
Ref 1:	`the cat is on the mat`
Ref 2:	`there is a cat on the mat`
Score:	2 / 7

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Brevity penalty

- r: sum of all minimal absolute length differences between candidates and referents.
- c: total length of all candidates
- BP: 1 if $c > r$ else $e^{1-\frac{r}{c}}$

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BLEU

BP $\cdot$ the sum of weighted modified n-gram precision values for each n considered

Properties

- Bounds: $[0, 1]$, with 1 the best, though with no expectation that any system will achieve 1.
- Value encoded:
  - Appropriate balance of (modified) precision and "recall" (BP).
  - Similar to word-error rate, but seeks to accommodate the fact that there are typically multiple suitable outputs for a given input.
- Weaknesses:
  - Callison-Burch et al. (2006) argue that BLEU fails to correlate with human scoring of translations.
  - Very sensitive to n-gram order.
  - Insensitive to n-gram types (*that dog* vs. *the dog* vs. *that toaster*).
  - Liu et al. (2016) specifically argue against BLEU as a metric for assessing dialogue systems.

Other n-gram-based metrics

Word-error rate	Edit-distance from a single reference text
BLEU	Modified precision and brevity penalty, against many reference texts
ROUGE	Recall-focused variant of BLEU, focused on assessing summarization systems
METEOR	Unigram-based alignments using exact match, stemming, synonyms
CIDEr	Weighted cosine similarity between TF-IDF vectors

Communication-based metrics

For NLU, it's worth asking whether you can evaluate your system based on how well it actually communicates in the context of a real-world goal.

Context	Utterance
	The darker blue one
	dull pink not the super bright one
	not any of the regular greens

Newman et al. 2020

References I

Chris Callison-Burch, Miles Osborne, and Philipp Koehn. 2006. Re-evaluating the role of Bleu in machine translation research. In *11th Conference of the European Chapter of the Association for Computational Linguistics*, Trento, Italy. Association for Computational Linguistics.

Chia-Wei Liu, Ryan Lowe, Iulian Serban, Mike Noseworthy, Laurent Charlin, and Joelle Pineau. 2016. How NOT to evaluate your dialogue system: An empirical study of unsupervised evaluation metrics for dialogue response generation. In *Proceedings of the 2016 Conference on Empirical Methods in Natural Language Processing*, pages 2122–2132, Austin, Texas. Association for Computational Linguistics.

Benjamin Newman, Reuben Cohn-Gordon, and Christopher Potts. 2020. Communication-based evaluation for natural language generation. In *Proceedings of the Society for Computation in Linguistics*, pages 234–244, Washington, D.C. Linguistic Society of America.