Evaluating vector-space models of analogy

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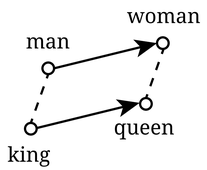
MOTIVATION

Recent vector-space word representations (`word2vec`, `GloVe`) seem to capture verbal analogies, mirroring the parallelogram model of analogy (Rumelhart & Abrahamson, 1973).



QUESTIONS:

- How well do these methods capture a wide variety of semantic relations?
- Do the limitations of using vector spaces to evaluate word similarity also apply to relational simlarity?

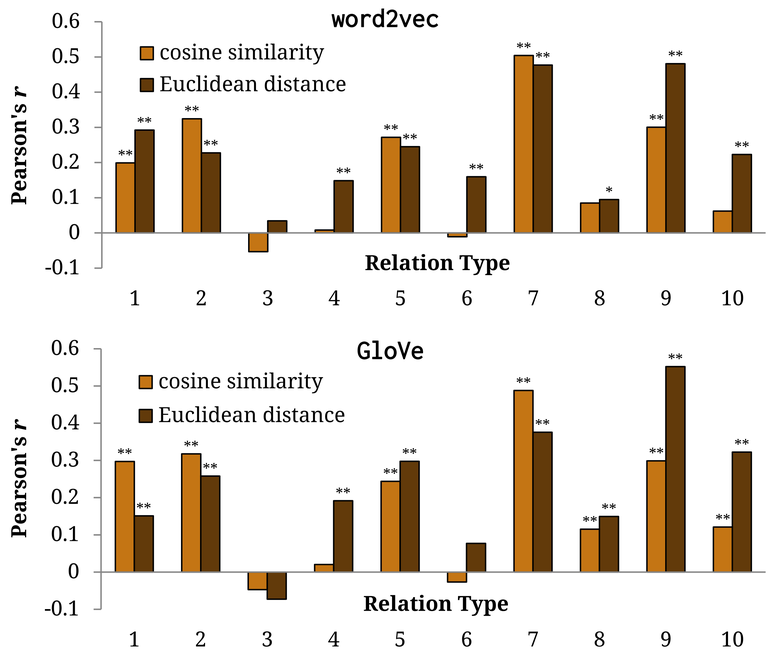
SEMANTIC RELATIONS DATASET

Selected relational subtypes from the SemEval-2012 Task 2 dataset (Jurgens et al., 2012), example word pairs, and visualizations of difference vectors using 2D PCA projections of `word2vec` vectors

CLASS-INCLUSION *Taxonomic* e.g., *flower : tulip*	CLASS-INCLUSION *Class:Individual* e.g., *river : Nile*	PART-WHOLE *Object:Component* e.g., *car : engine*	PART-WHOLE *Collection:Member* e.g., *forest : tree*
SIMILAR *Synonymity* e.g., *car : auto*	SIMILAR *Dimensional Similarity* e.g., *simmer : boil*	CONTRAST *Contrary* e.g., *old : young*	CONTRAST *Reverse* e.g., *buy : sell*
ATTRIBUTE *Item:Attribute* e.g., *beggar : poor*	ATTRIBUTE *Object:State* e.g., *coward : fear*	NON-ATTRIBUTE *Item:Nonattribute* e.g., *fire : cold*	NON-ATTRIBUTE *Object:Nonstate* e.g., *corpse : life*
CASE RELATIONS *Agent:Instrument* e.g., *soldier : gun*	CASE RELATIONS *Action:Object* e.g., *plow : earth*	CAUSE-PURPOSE *Cause:Effect* e.g., *joke : laughter*	CAUSE-PURPOSE *Cause:Compensatory Action* e.g., *hunger : eat*
SPACE-TIME *Location:Item* e.g., *library : book*	SPACE-TIME *Time:Associated Item* e.g., *winter : snow*	REFERENCE *Sign:Significant* e.g., *siren : danger*	REFERENCE *Representation* e.g., *diary : person*

EXP 1: RELATIONAL SIMILARITY

Turkers rated the relational similarity between word pairs from the SemEval dataset. A total of 6,194 comparisons were rated, each with at least 10 ratings. Predictions of relational similarity were obtained from `word2vec` and `GloVe` by calculating the cosine similarity and Euclidean distance beween difference vectors.



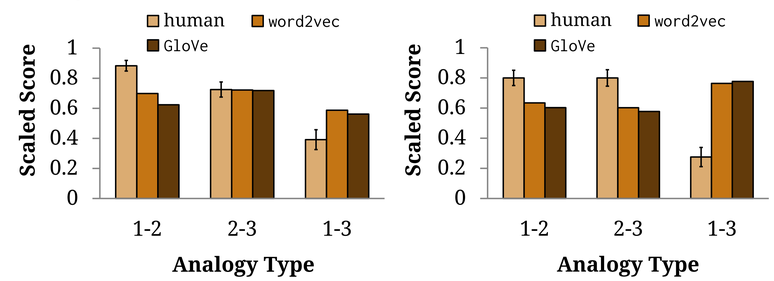
EXP 2: SYMMETRY

Human ratings of word similarity violate the metric axiom of symmetry, which vector-space models cannot explain (Tversky, 1977). Do human ratings of *relational* similarity also violate symmetry? Turkers rated 500 comparisons created from the SemEval dataset in one of two presentation orders. The two orders produced significantly different relational similarity ratings for 77 of these comparisons ($p < .05$), which is significantly more than expected if order did not matter ($p < .001$).

Comparison	Forward rating	Backward rating
angry : smile – exhausted : run	4.76	2.36
hairdresser : comb – pitcher : baseball	6.10	4.84
narrative : epilogue – animal : pig	2.80	3.84

EXP 3: TRIANGLE INEQUALITY

Do psychological representations of relational similarity also violate the triangle inequality axiom? We created 12 triads such as ***person : clothes, bird : feathers,* and *cat : whiskers***, for which the 1-2 and 2-3 pairs are good analogies (both relationally similar), whereas the 1-3 pair is a bad analogy (relationally dissimilar). Turkers' ratings of the quality of these analogies indeed violated the triangle inequality, with type 1-2 and 2-3 analogies receiving significantly higher ratings ($M = 5.44$ and $M = 5.43$, respectively) than type 1-3 analogies ($M = 2.99$), $p < .001$. On the other hand, predictions obtained using `word2vec` and `GloVe` showed no effect of analogy type ($p = .31$ and $p = .79$, respectively).



CONCLUSIONS

- The parallelogram model of analogy captures some semantic relations rather well, but completely fails on other relations.
- Human ratings of relational similarity violate the metric axioms of symmetry and triangle inequality, which poses a challenge for any vector-space model of analogy.

REFERENCES

Jurgens, D. A., Turney, P. D., Mohammad, S. M., & Holyoak, K. J. (2012). SemEval-2012 Task 2: Measuring Degrees of Relational Similarity. In *Proceedings of the First Joint Conference on Lexical and Computational Semantics - Volume 1* (pp. 356–364).

Rumelhart, D. E., & Abrahamson, A. A. (1973). A model for analogical reasoning. *Cognitive Psychology*, *5*(1), 1–28.

Tversky, A. (1977). Features of similarity. *Psychological Review*, *84*(4), 327.