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Second-order Co-occurrence Sensitivity of Skip-Gram with Negative Sampling

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Second-order Co-occurrence

first order

(1a) As far as the Soviet Communist **Party** was concerned . . .

second order

(1b) It is well-known that Communist authorities hated rock culture . . .

(2a) . . . this is the approach taken by the British **Government**.

(2b) . . . rather than risking deportation to British authorities.

[Schütze 1998]

Research Question

- **Does SGNS capture second-order co-occurrence information?**

→ Yes – it is more sensitive to second- than first-order context overlap

- SGNS is similar to Truncated SVD in terms of capturing second-order co-occurrence structure [cf. Levy & Goldberg 2014]
- Capturing higher-order co-occurrence structure may explain superior performance of SGNS and SVD over PPMI

Exp. 1: Simulating Context Overlap

order	1ST	2ND	NONE
C1	a **c**	a c	a c
	a **d**	a d	a d
	b **c**	b e	b e
	b **d**	b f	b f
C2	c u	c **u**	c u
	c v	c **v**	c v
	d w	d **u**	d w
	d x	d **v**	d x

Table: Artificial co-occurrence pairs with context overlap in different orders of co-occurrence.

Hypothesis: SGNS makes vectors of words from the 2ND group more similar than vectors of words from the NONE group (although both groups have no first-order context overlap)

Side Hypothesis: SVD shows similar behavior as SGNS

Exp. 1: Results

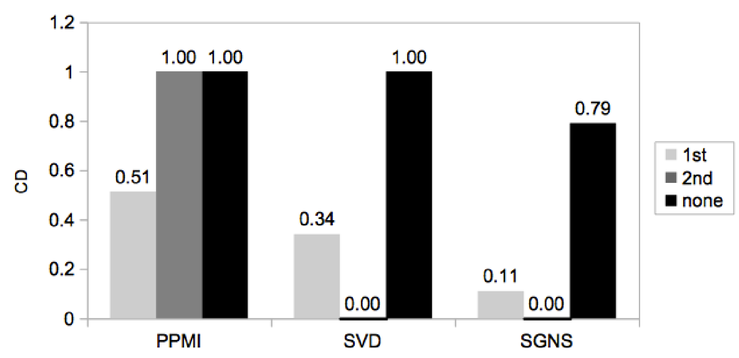

Figure: Results of simulation experiment. Values give average cosine distances across target words with different levels of context overlap.

Exp. 2: Propagating Second-order Context

- create very small corpus (10M tokens from ukWaC)

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- extract first-and second-order word-context pairs

⇓

- add second- to first-order pairs for low-frequency words

⇓

- compare performance (WordSim353) on first-order vs. mixed training pairs

Hypothesis: Additional second-order information impacts PPMI representations positively and stronger than SVD and SGNS (because the latter already capture second-order information)

Exp. 2: Results

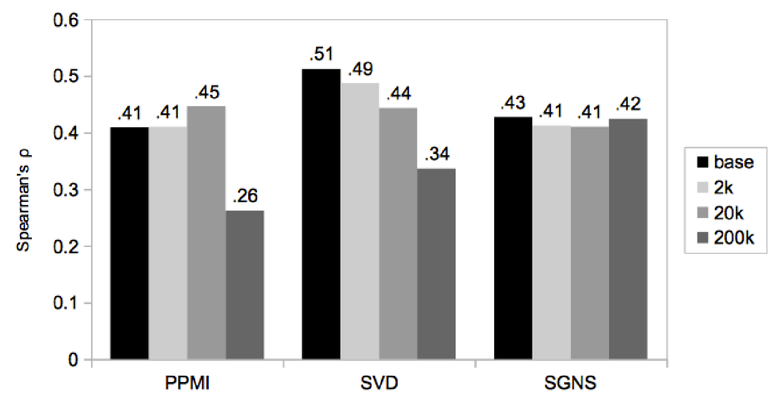
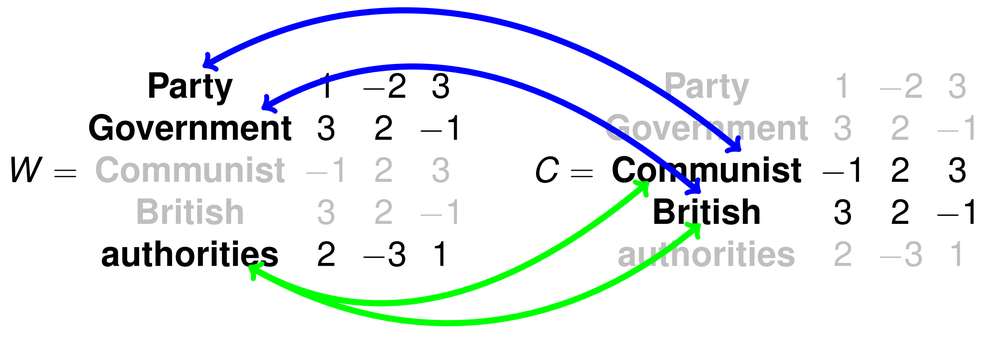


Figure: Results of experiment 2. Values give correlation (Spearman's ρ) of model predictions with human similarity judgments.

Explanation: Transitivity of SGNS



Transitivity of SGNS: The representation of context words as continuous objects (vectors) establishes transitivity of the similarity relation between word and context vectors. This enables SGNS to capture second-order co-occurrence information.

Open Questions

- Do other modern embeddings (GloVe, ELMo, BERT) capture second-order co-occurrence?

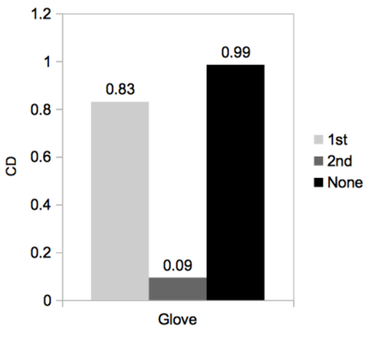


Figure: Results of simulation experiment with GloVe embeddings. [Pennington et al. 2014]

- How does second-order information relate to performance?

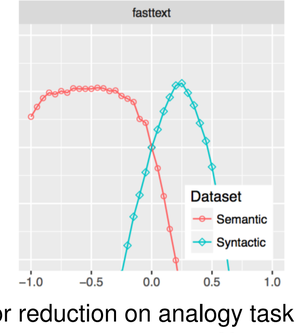


Figure: Error reduction on analogy task for levels of higher-order co-occurrence [Artetxe et al. 2018]

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