GloVe: Global Vectors for Word Representation

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Presented by Chris Kedzie

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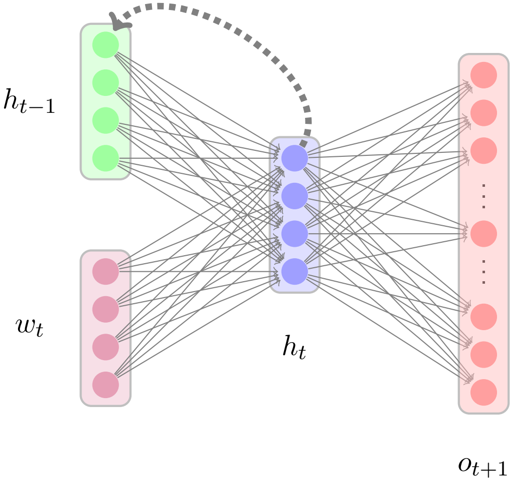
Overview

1. Introduction
2. Problem
3. GloVe Model
4. Experiments

Word Representations: A history

Neural Language Models – Recurrent NNLM



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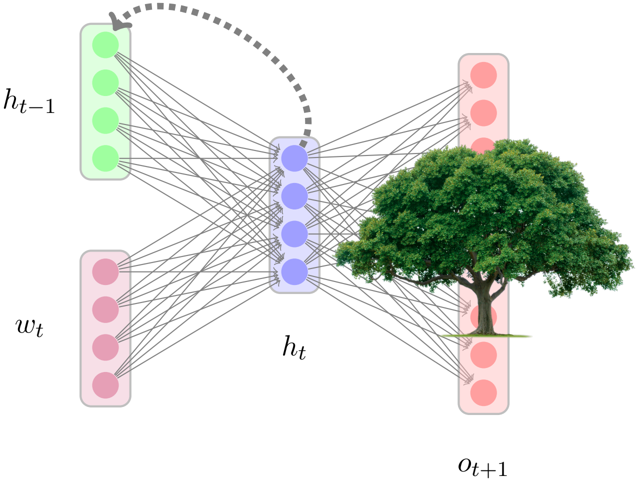

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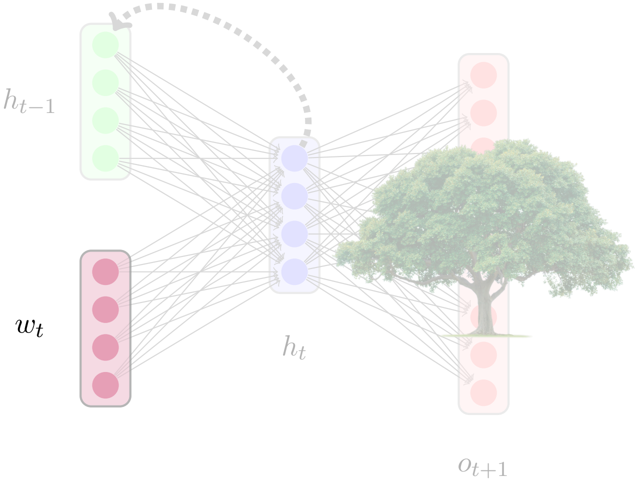
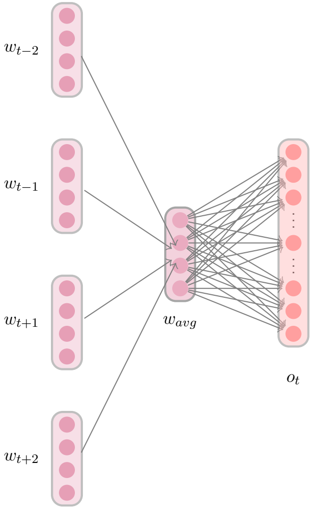


Neural Language Models – Continuous BOW



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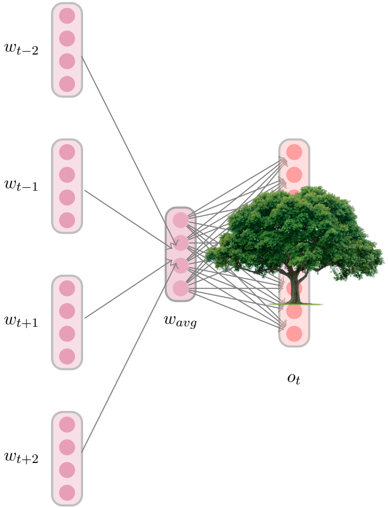


Linear Relationships

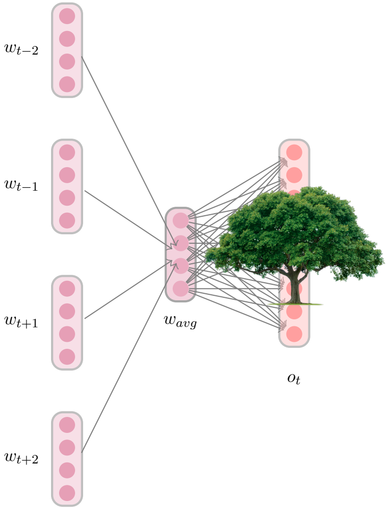
Semantic

$$w_{king} - w_{man} + w_{woman} \approx w_{queen}$$

Syntactic

$$w_{easy} - w_{easiest} + w_{luckiest} \approx w_{lucky}$$

Noise Contrastive Estimation



Scalable Embedding Learning

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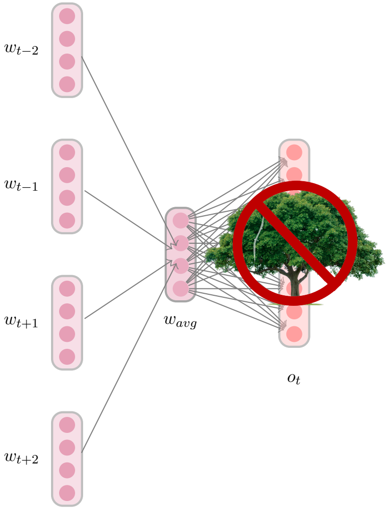

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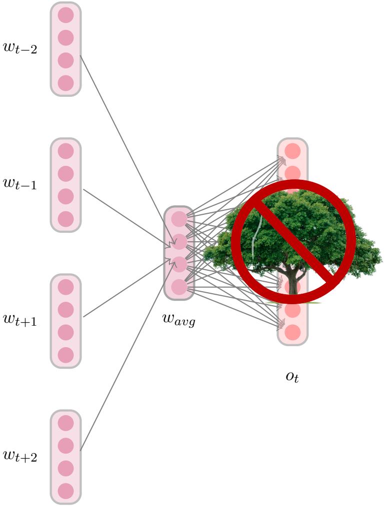

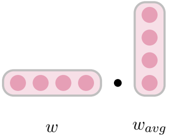

GloVe

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Lots of time spent scanning context windows to learn a distribution for

$$P(w|the)$$

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Theatre or theater is a collaborative form of fine art that uses live performers to present the experience of a real or imagined event before a live audience in a specific place. The performers may communicate this experience to the audience through combinations of gesture, speech, song, music, and dance. Elements of art and stagecraft are used to enhance the physicality, presence and immediacy of the experience. The specific place of the performance is also named by the word "theatre" as derived from the Ancient Greek (thatron, "a place for viewing"), itself from (theomai, "to see", "to watch", "to observe").
Modern Western theatre comes from large measure from ancient Greek drama, from which it borrows technical terminology, classification into genres, and many of its themes, stock characters, and plot elements. Theatre artist Patrice Pavis defines theatricality, theatrical language, stage writing, and the specificity of theatre as synonymous expressions that differentiate theatre from the other performing arts, literature, and the arts in general.
Theatre today, broadly defined, includes performances of plays and musicals, ballets, operas and various other forms.

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There's got to be a better way!

Matrix Factorization Methods

e.g. SVD, COALS, etc. directly on co-occurrence matrix.

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Main drawback: frequent words like *the* and *a* have an outsized effect on the representation learning.

GloVe

GloVe Model

$$J = \sum_{i,j=1}^{V} f\left(X_{ij}\right)\left(w_i^T \tilde{w}_j + b_i + \tilde{b}_j - \log X_{ij}\right)^2$$

Notation!

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Motivation

Prob. and Ratio	$k = solid$	$k = gas$	$k = water$	$k = fashion$
$P(k\|ice)$	1.9×10^{-4}	6.6×10^{-5}	3.0×10^{-3}	1.7×10^{-5}
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$$F(w_i, w_j, \tilde{w}_k) = \frac{P_{ik}}{P_{jk}}$$

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F should encode information in the ratio $\frac{P_{ik}}{P_{jk}}$.

Derivation

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\begin{aligned}
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w_i^T \tilde{w}_k &= \log X_{ik} - b_i - \tilde{b}_k \\
w_i^T \tilde{w}_k + b_i + \tilde{b}_k &= \log X_{ik}
\end{aligned}
$$

Derivation

This suggests a least-squares objective function,

$$J = \sum_{i,j=1}^{V} \left(w_i^T \tilde{w}_j + b_i + \tilde{b}_j - \log X_{ij} \right)^2$$

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$$\Rightarrow J = \sum_{i,j=1}^{V} f\left(X_{ij}\right) \left(w_i^T \tilde{w}_j + b_i + \tilde{b}_j - \log X_{ij} \right)^2$$

where f has the following desiderata:

1. $f(0) = 0$
2. $f(x)$ should be non-decreasing so that rare co-occurrences are not overweighted.
3. $f(x)$ should be relatively small for large values of x, so that frequent co-occurrences are not overweighted.

Derivation

This suggests a least-squares objective function, but...

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where $f(x) = \begin{cases} \left(\frac{x}{x_{\max}}\right)^{\alpha} & \text{if } x < x_{\max} \\ 1 & \text{otherwise} \end{cases}$

Weighting Function

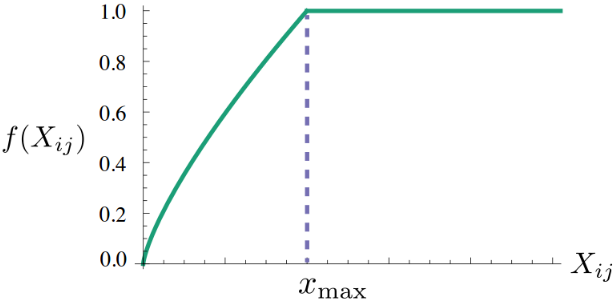

Figure 1: Weighting function f with $\alpha = 3/4$.

Optimization

$$J = \sum_{i,j=1}^{V} f\left(X_{ij}\right)\left(w_i^T \tilde{w}_j + b_i + \tilde{b}_j - \log X_{ij}\right)^2$$

where $f(x) = \begin{cases} \left(\frac{x}{x_{\max}}\right)^{\alpha} & \text{if } x < x_{\max} \\ 1 & \text{otherwise} \end{cases}$

In this paper: $\alpha = \frac{3}{4}$ and $x_{\max} = 100$.

The model is trained using AdaGrad and stochastically sampling non-zero elements from X. An initial learning rate of .05 is used.

Word Analogies

a is to b as c to ?

$$w_b - w_a + w_c$$

Word Analogies

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Paris is to *France* as *Tokyo* is to ?

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Word Analogies

a is to b as c to ?
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$$\arg\max_{w'} \text{cosine-sim}(w_b - w_a + w_c, w')$$

Word Analogies – Results

Model	Dim.	Size	Sem.	Syn.	Tot.
ivLBL	100	1.5B	55.9	50.1	53.2
HPCA	100	1.6B	4.2	16.4	10.8
GloVe	100	1.6B	<u>67.5</u>	<u>54.3</u>	<u>60.3</u>
SG	300	1B	61	61	61
CBOW	300	1.6B	16.1	52.6	36.1
vLBL	300	1.5B	54.2	<u>64.8</u>	60.0
ivLBL	300	1.5B	65.2	63.0	64.0
GloVe	300	1.6B	<u>80.8</u>	61.5	<u>70.3</u>
SVD	300	6B	6.3	8.1	7.3
SVD-S	300	6B	36.7	46.6	42.1
SVD-L	300	6B	56.6	63.0	60.1
CBOW†	300	6B	63.6	<u>67.4</u>	65.7
SG†	300	6B	73.0	66.0	69.1
GloVe	300	6B	<u>77.4</u>	67.0	<u>71.7</u>
CBOW	1000	6B	57.3	68.9	63.7
SG	1000	6B	66.1	65.1	65.6
SVD-L	300	42B	38.4	58.2	49.2
GloVe	300	42B	**<u>81.9</u>**	**<u>69.3</u>**	**<u>75.0</u>**

Word Similarities

Humans scored similarity of word pairs.

word 1	word 2	human score (mean) (1-10)	cosine-similarity (-1, 1)
king	cabbage	0.23	0.11
king	queen	8.58	0.78
king	rook	5.92	0.25

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Embeddings are evaluated by Spearman rank correlation of human scores to cosine similarity.

Word Similarities – Results

Model	Size	WS353	MC	RG	SCWS	RW
SVD	6B	35.3	35.1	42.5	38.3	25.6
SVD-S	6B	56.5	71.5	71.0	53.6	34.7
SVD-L	6B	65.7	<u>72.7</u>	75.1	56.5	37.0
CBOW†	6B	57.2	65.6	68.2	57.0	32.5
SG†	6B	62.8	65.2	69.7	<u>58.1</u>	37.2
GloVe	6B	<u>65.8</u>	<u>72.7</u>	<u>77.8</u>	53.9	<u>38.1</u>
SVD-L	42B	74.0	76.4	74.1	58.3	39.9
GloVe	42B	<u>**75.9**</u>	<u>**83.6**</u>	<u>**82.9**</u>	<u>**59.6**</u>	<u>**47.8**</u>
CBOW*	100B	68.4	79.6	75.4	59.4	45.5

Named Entity Recognition

NER is a sequence tagging task where the goal is to identify named entities:

Jim	bought	300	shares	of	Acme	Corp	.	in	2006	.
B-PER	O	O	O	O	B-ORG	I-ORG	I-ORG	O	B-TIME	O

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Combined discrete features of existing system (Stanford NER).

Word embeddings were treated as additional features in a linear-chain CRF model.

Named Entity Recognition – Results

Model	Dev	Test	ACE	MUC7
Discrete	91.0	85.4	77.4	73.4
SVD	90.8	85.7	77.3	73.7
SVD-S	91.0	85.5	77.6	74.3
SVD-L	90.5	84.8	73.6	71.5
HPCA	92.6	**88.7**	81.7	80.7
HSMN	90.5	85.7	78.7	74.7
CW	92.2	87.4	81.7	80.2
CBOW	93.1	88.2	82.2	81.1
GloVe	**93.2**	88.3	**82.9**	**82.2**

The end! Thanks!