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NLP and Word Embeddings

Word representation

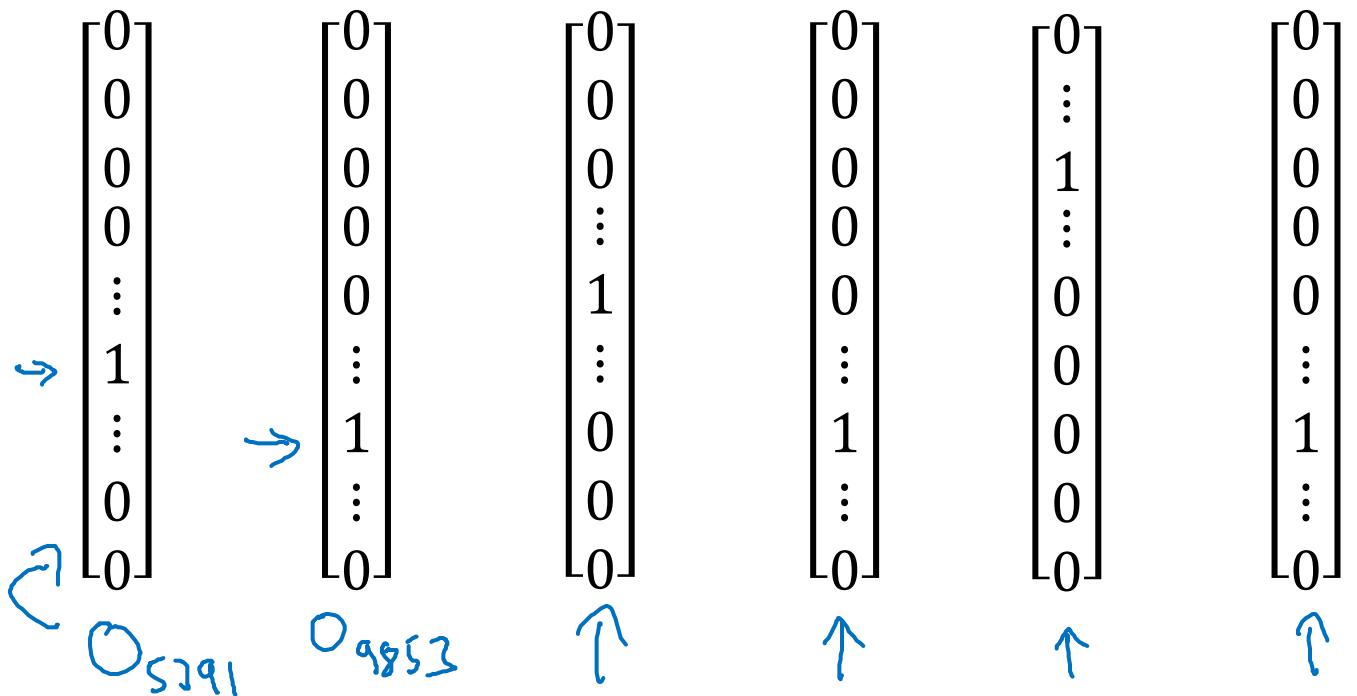
Word representation

$$V = [a, \text{aaron}, \dots, \text{zulu}, \text{<UNK>}]$$

$$|V| = 10,000$$

1-hot representation

Man (5391)	Woman (9853)	King (4914)	Queen (7157)	Apple (456)	Orange (6257)
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I want a glass of orange juice.
I want a glass of apple ____.

Featurized representation: word embedding

	Man (5391)	Woman (9853)	King (4914)	Queen (7157)	Apple (456)	Orange (6257)
Gender	-1	1	-0.95	0.97	0.00	0.01
Royal	0.01	0.02	0.93	0.95	-0.01	0.00
Age	0.03	0.02	0.7	0.69	0.03	-0.02
Food	0.04	0.01	0.02	0.01	0.95	0.97
Size	:	:				
Cost						
Color						
Verb						

Handwritten annotations:

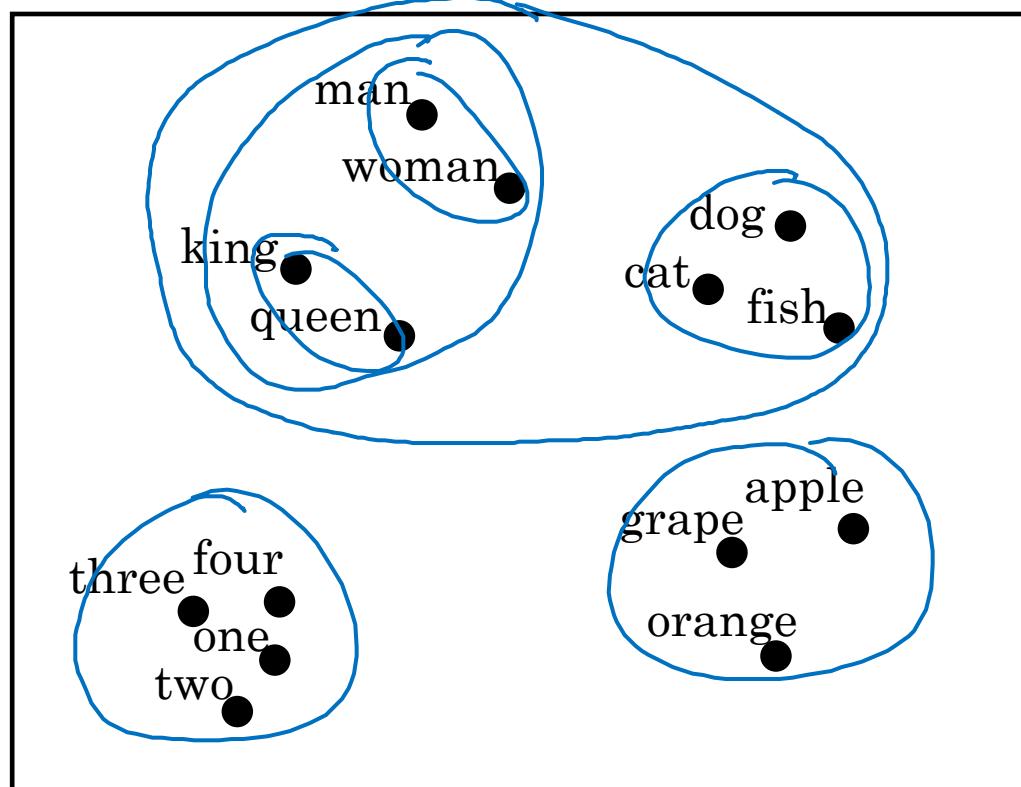
- Column 1 (Man) has values: -1, 0.01, 0.03, 0.04, :.
- Column 2 (Woman) has values: 1, 0.02, 0.02, 0.01, :.
- Row 1 (Gender) has values: -1, 1, -0.95, 0.97, 0.00, 0.01.
- Row 2 (Royal) has values: 0.01, 0.02, 0.93, 0.95, -0.01, 0.00.
- Row 3 (Age) has values: 0.03, 0.02, 0.7, 0.69, 0.03, -0.02.
- Row 4 (Food) has values: 0.04, 0.01, 0.02, 0.01, 0.95, 0.97.

Text at bottom right:

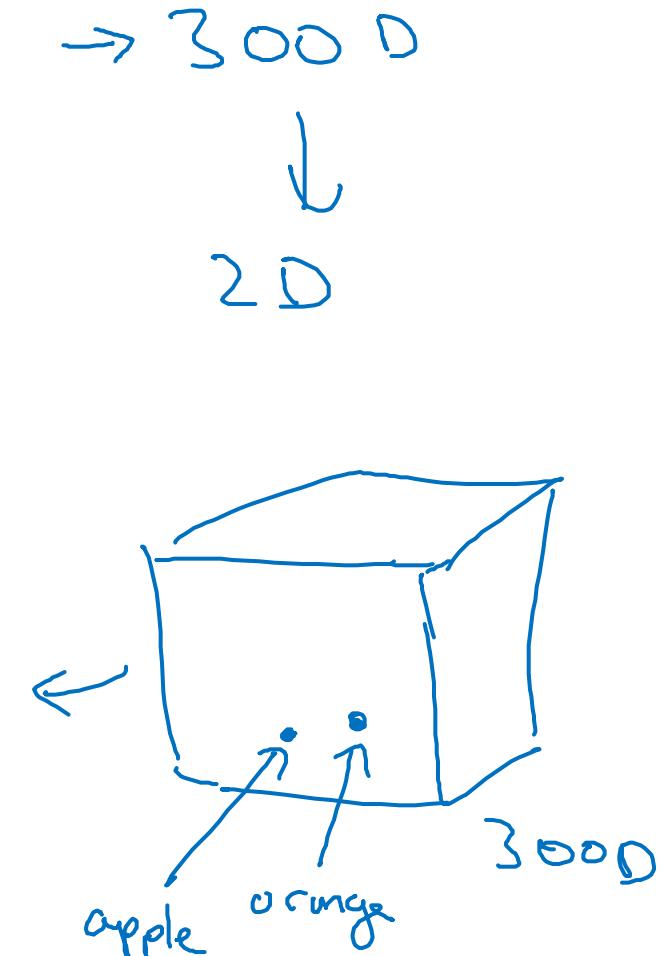
I want a glass of orange juice.
I want a glass of apple juice.

Andrew Ng

Visualizing word embeddings



t-SNE



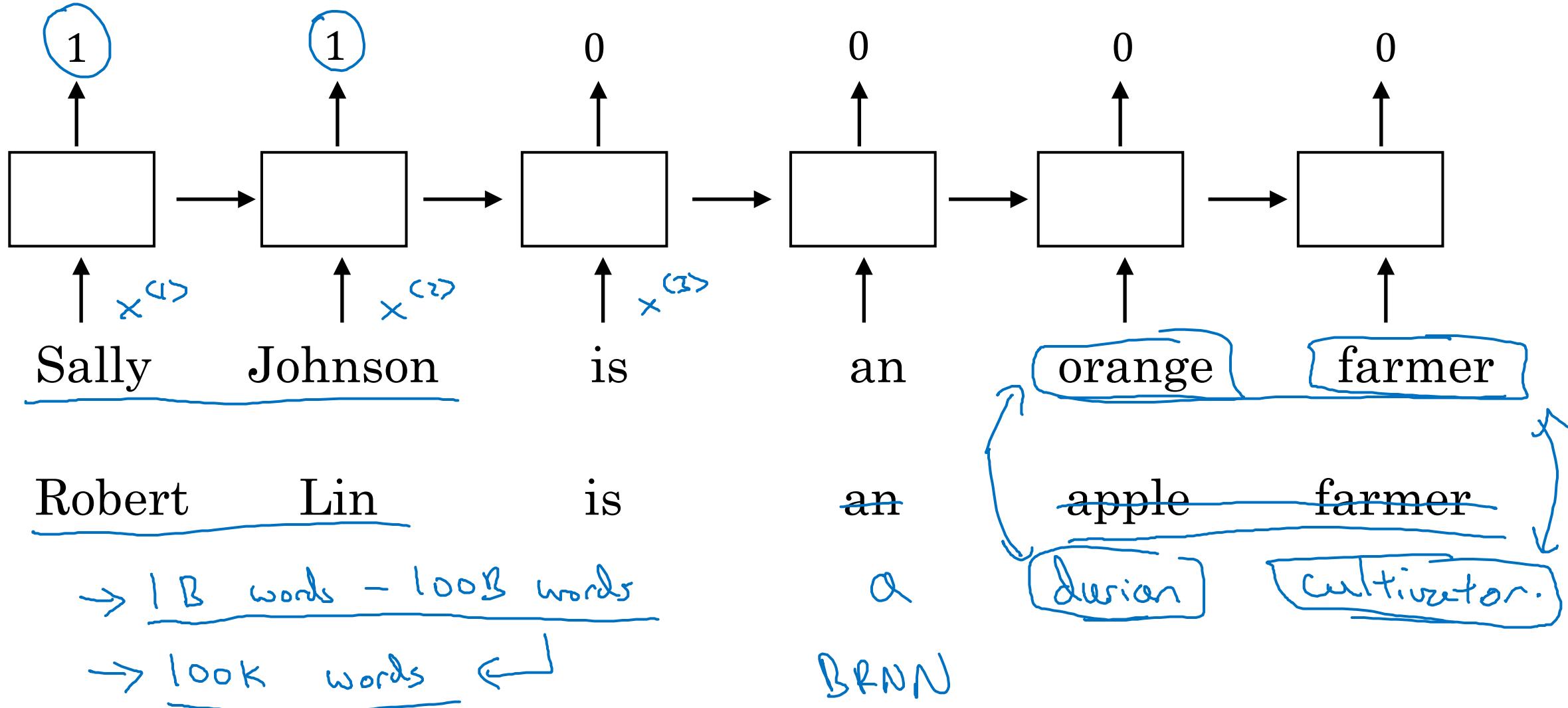


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NLP and Word Embeddings

Using word embeddings

Named entity recognition example



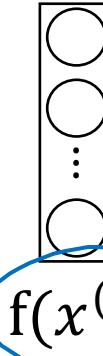
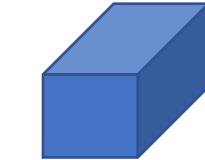
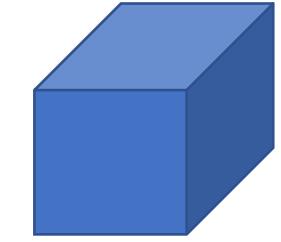
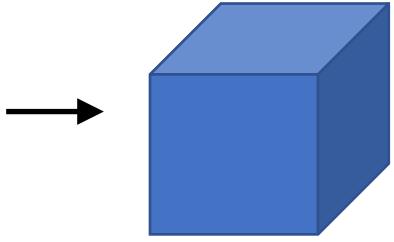
Transfer learning and word embeddings

-
- The diagram consists of two blue-outlined brackets. The top bracket, labeled 'A' in a circle, encloses the first two steps. The bottom bracket, labeled 'B' in a circle, encloses the third step. A vertical blue arrow points downwards from the end of the 'A' bracket to the start of the 'B' bracket.
1. Learn word embeddings from large text corpus. (1-100B words)
(Or download pre-trained embedding online.)
 2. Transfer embedding to new task with smaller training set.
(say, 100k words) $\rightarrow 10,000 \quad \rightarrow 300$
 3. Optional: Continue to finetune the word embeddings with new data.

Relation to face encoding (embedding) 128D



$x^{(i)}$



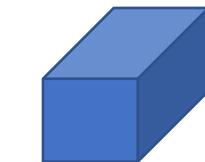
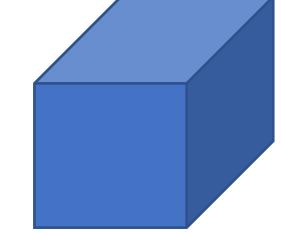
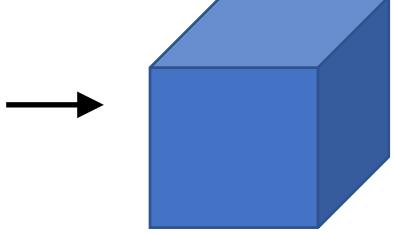
$f(x^{(i)})$

128D

\hat{y}



$x^{(j)}$



$f(x^{(j)})$

12D

$|V|=10,000$

$e_1, \dots, e_{10,000}$



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NLP and Word Embeddings

Properties of word embeddings

Analogy

	Man (5391)	Woman (9853)	King (4914)	Queen (7157)	Apple (456)	Orange (6257)
Gender	-1	1	-0.95	0.97	0.00	0.01
Royal	0.01	0.02	0.93	0.95	-0.01	0.00
Age	0.03	0.02	0.70	0.69	0.03	-0.02
Food	0.09	0.01	0.02	0.01	0.95	0.97

$$\begin{matrix} e_{5391} \\ e_{\text{man}} \end{matrix}$$

$$\underline{\text{Man} \rightarrow \text{Woman}}$$

$$e_{\text{man}} - e_{\text{woman}}$$

$$e_{\text{woman}}$$

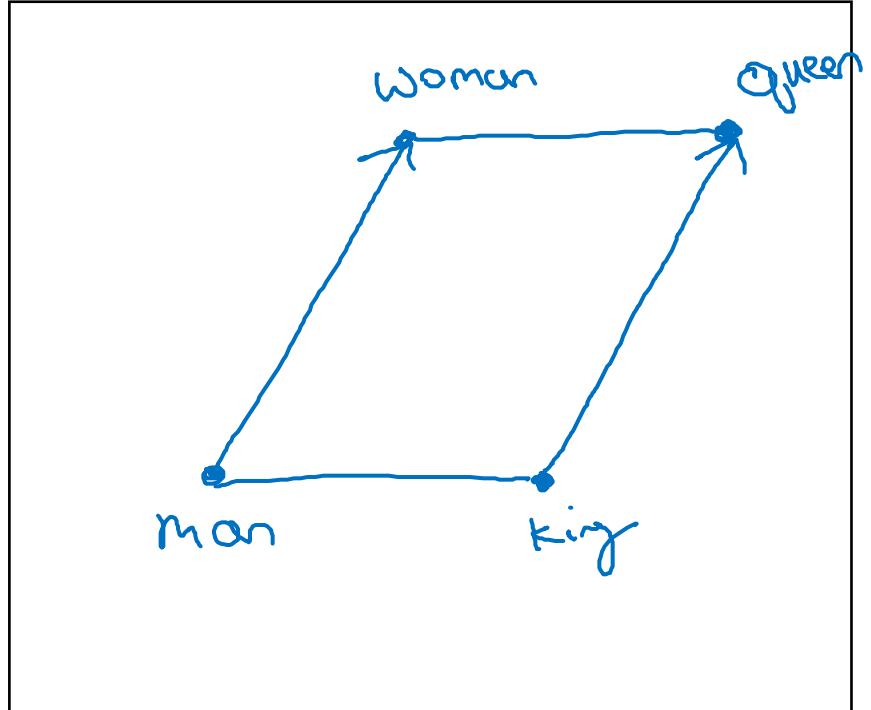
$$\underline{\text{King} \rightarrow ? \text{ Queen}}$$

$$e_{\text{king}} - e_{? \text{ Queen}}$$

$$\underline{e_{\text{man}} - e_{\text{woman}}} \approx \begin{bmatrix} -2 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$\underline{e_{\text{king}} - e_{\text{queen}}} \approx \begin{bmatrix} -2 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

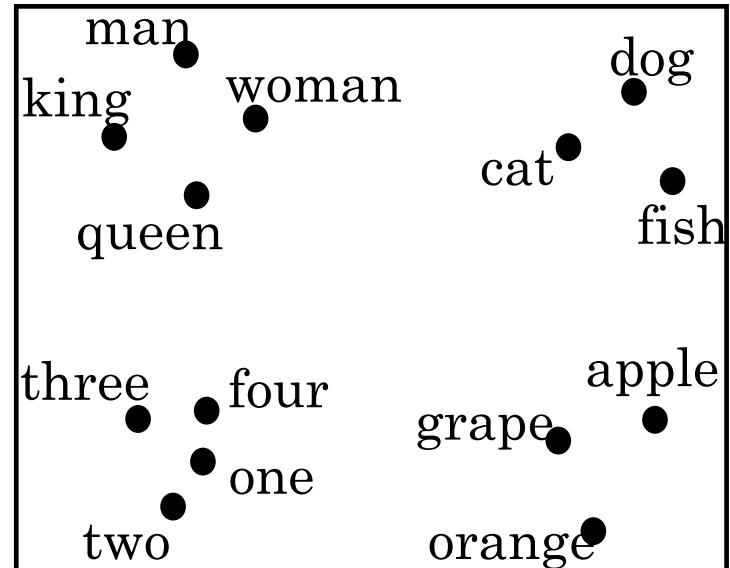
Analogies using word vectors



300 D

Find word $w_i : \arg \max_w$

$300D \rightarrow 2D$



t-SNE

$$e_{\text{man}} - e_{\text{woman}} \approx e_{\text{king}} - e_{\underline{\text{?}}} e_w$$

$\underbrace{\hspace{10cm}}$

\downarrow

$\text{Sim}(e_w, e_{\text{king}} - e_{\text{man}} + e_{\text{woman}})$

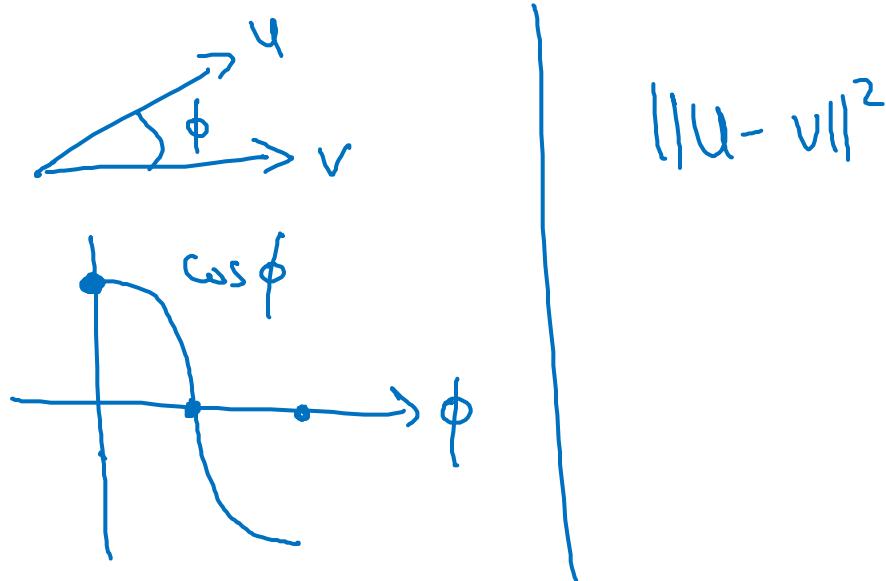
\uparrow

30 - 75%

Cosine similarity

$$\rightarrow \boxed{\text{sim}(e_w, e_{king} - e_{man} + e_{woman})}$$

$$\text{sim}(u, v) = \frac{u^T v}{\|u\|_2 \|v\|_2}$$



Man:Woman as Boy:Girl

Ottawa:Canada as Nairobi:Kenya

Big:Bigger as Tall:Taller

Yen:Japan as Ruble:Russia

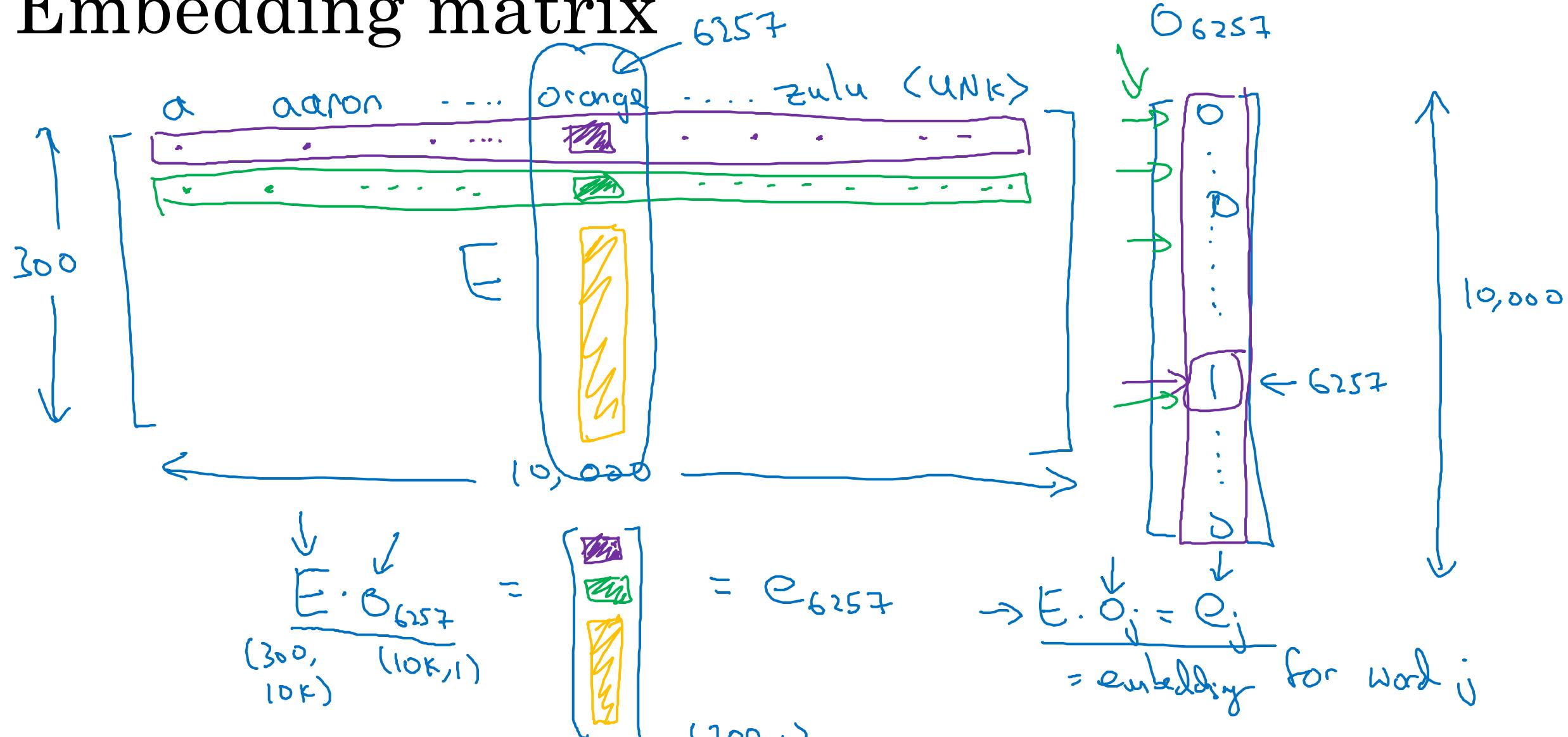


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NLP and Word Embeddings

Embedding matrix

Embedding matrix



In practice, use specialized function to look up an embedding.
→ Embedding

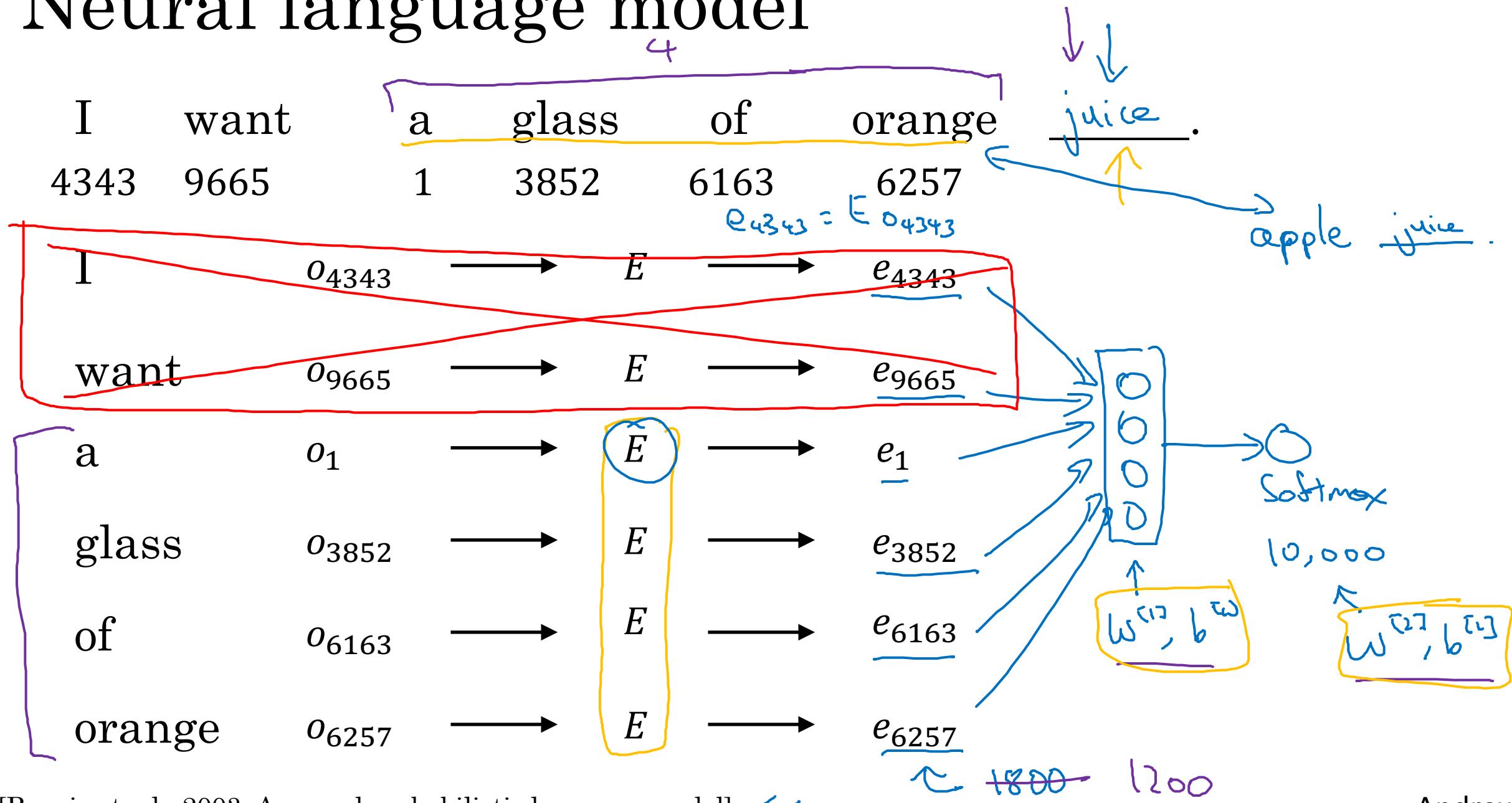


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NLP and Word Embeddings

Learning word embeddings

Neural language model



Other context/target pairs

I want a **glass** of **orange** juice to go along with my cereal.

Context: Last 4 words.

4 words on left & right

Last 1 word

Nearby 1 word

skip gram

a glass of orange ? to go along with

orange ?

glass . ?



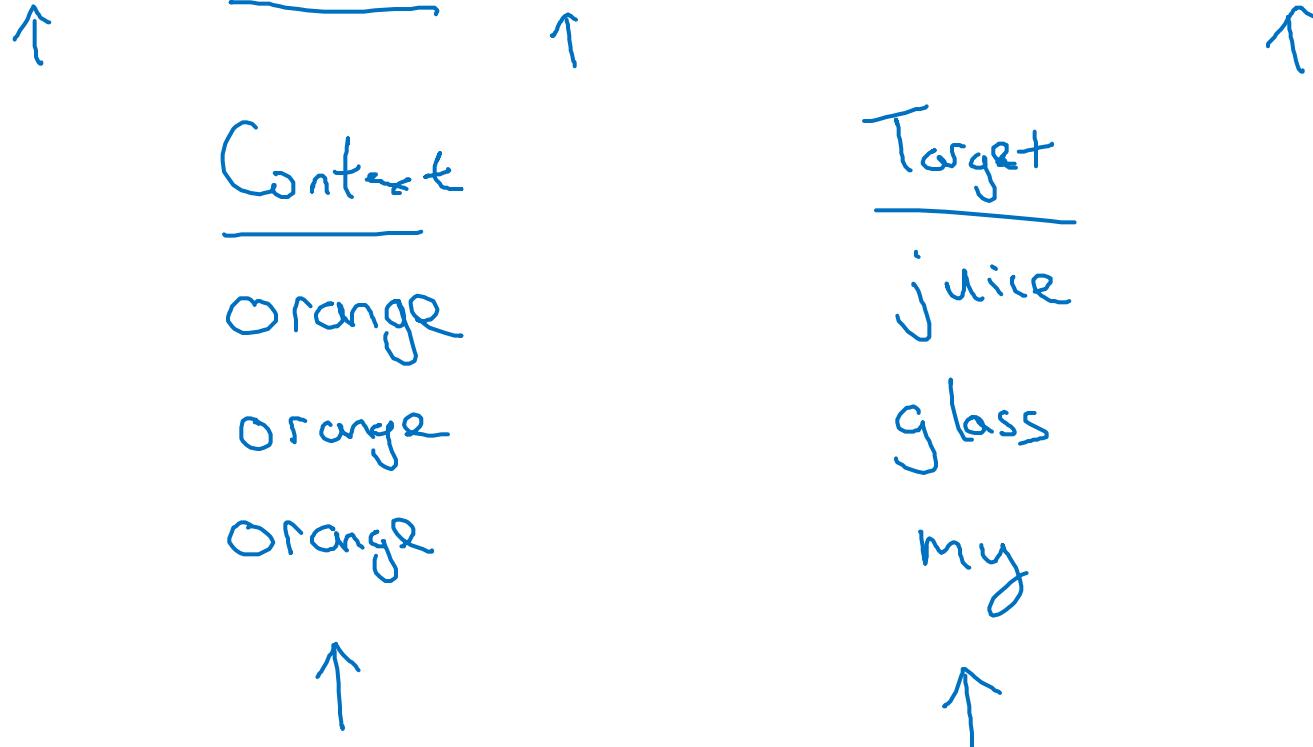
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NLP and Word Embeddings

Word2Vec

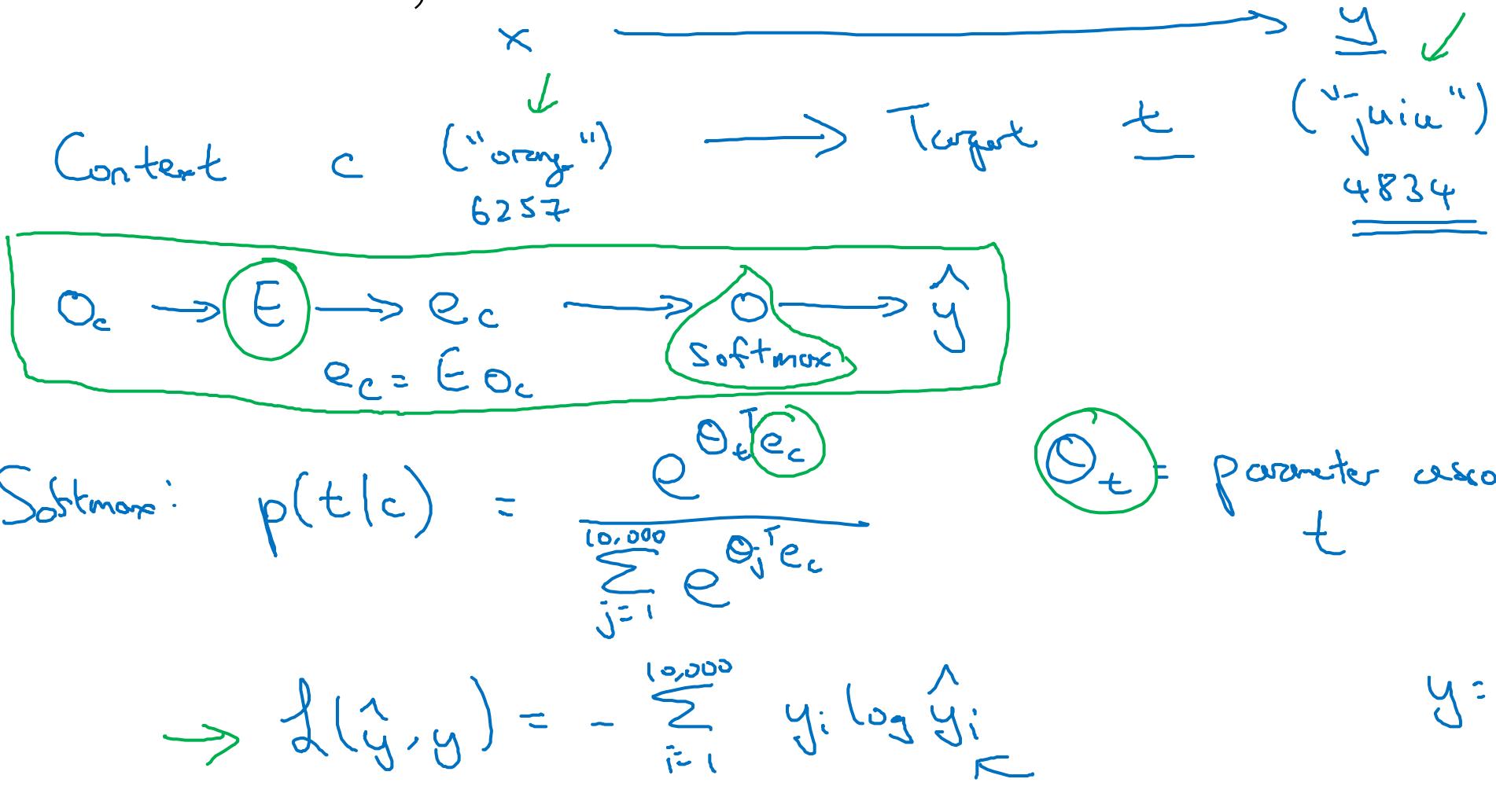
Skip-grams

I want a glass of orange juice to go along with my cereal.



Model

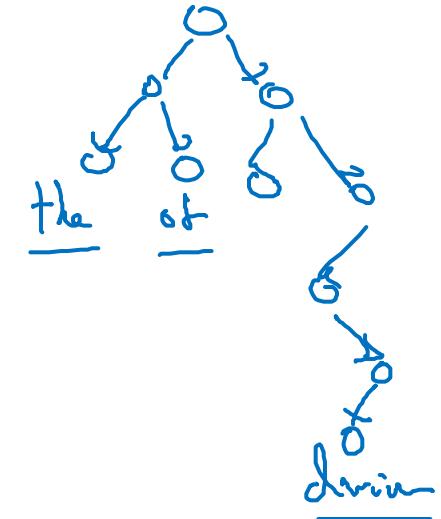
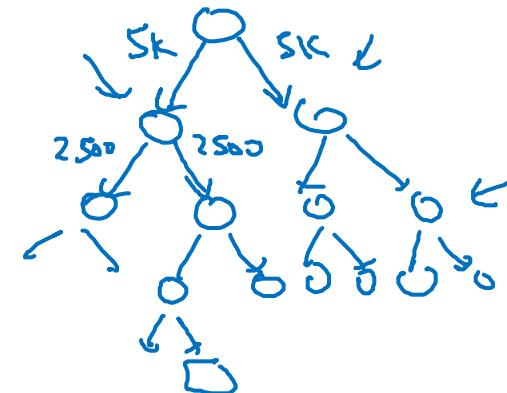
Vocab size = 10,000k



Problems with softmax classification

$$p(t|c) = \frac{e^{\theta_t^T e_c}}{\sum_{j=1}^{10,000} e^{\theta_j^T e_c}}$$

Hierarchical softmax.



How to sample the context c ?

→ the, of, a, and, to, ...

→ orange, apple, durian

P_{durian}

t
 $c \rightarrow t$
 $P(c)$



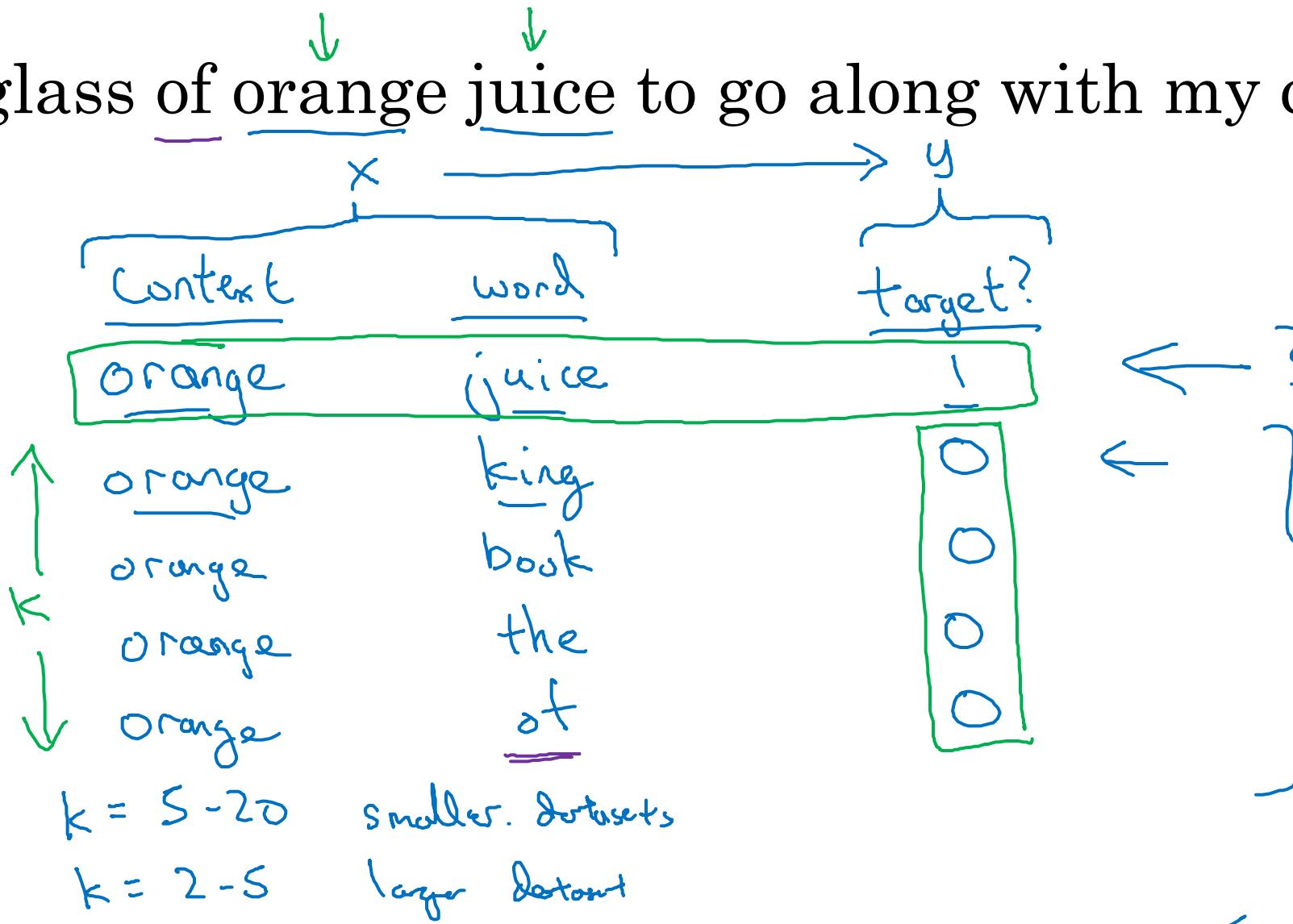
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NLP and Word Embeddings

Negative sampling

Defining a new learning problem

I want a glass of orange juice to go along with my cereal.



Model

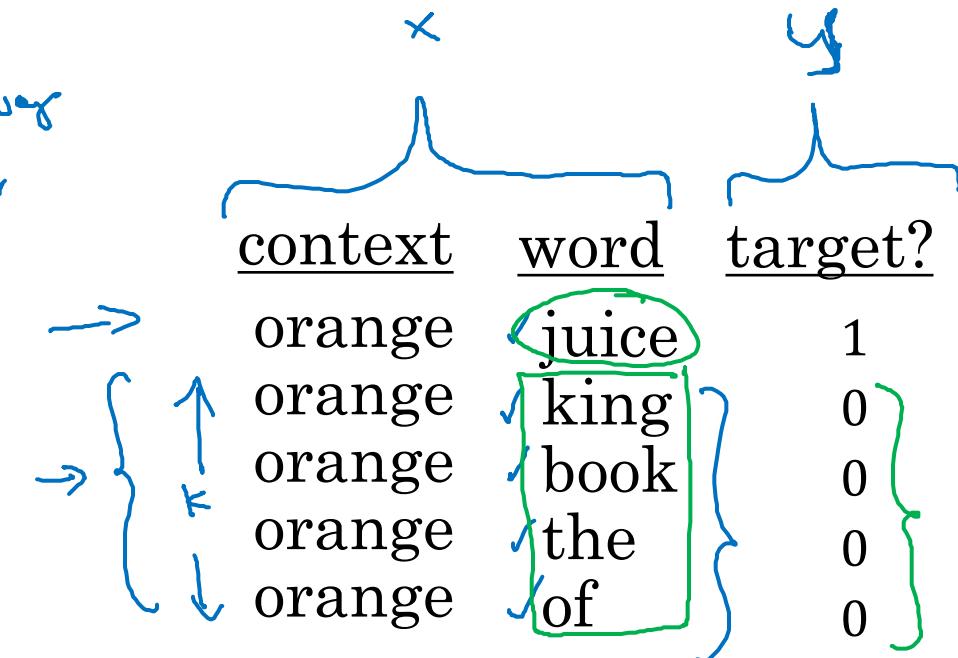
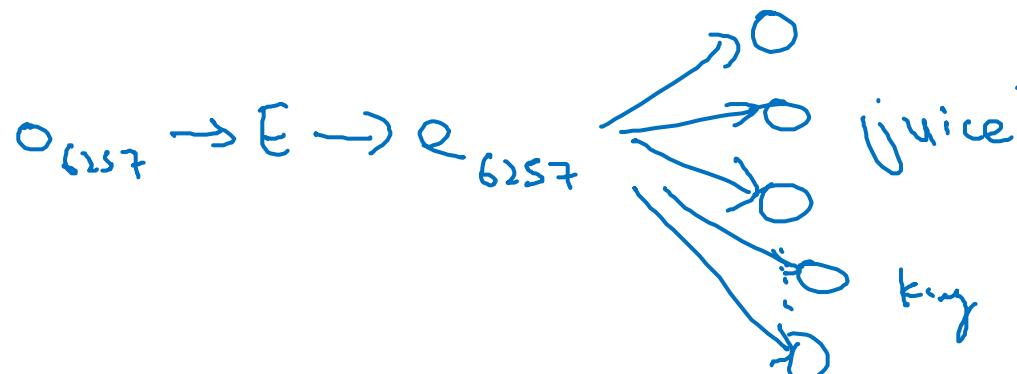
Softmax:

$$p(t|c) = \frac{e^{\theta_t^T e_c}}{\sum_{j=1}^{10,000} e^{\theta_j^T e_c}}$$

10,000-way softmax

$$P(y=1 | c, t) = \sigma(\theta_t^T e_c)$$

Orange
6257



10,000
↓

10,000 binary
classification
problem
 $k+1$

Andrew Ng

Selecting negative examples

<u>context</u>	<u>word</u>	<u>target?</u>
orange	juice	1
orange	king	0
orange	book	0
orange	the	0
orange	of	0

the , of, and, ...

$$P(w_i) = \frac{f(w_i)^{3/4}}{\sum_{j=1}^{10,000} f(w_j)^{3/4}}$$

$$\frac{1}{|V|}$$



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NLP and Word Embeddings

GloVe word vectors

GloVe (global vectors for word representation)

I want a glass of orange juice to go along with my cereal.

c, t

$$x_{ij} = \# \text{ times } \underset{\substack{\uparrow \\ c}}{j} \underset{\substack{\uparrow \\ t}}{i} \underset{\substack{\uparrow \\ t}}{j} \text{ appears in context of } \underset{\substack{\uparrow \\ c}}{i}.$$

$$x_{ij} = x_{ji} \leftarrow$$



Model

Minimize

$$\sum_{i=1}^{10,000} \sum_{j=1}^{100,000} f(x_{ij}) (\theta_i^T e_j + b_i + b_j' - \log \frac{x_{ij}}{t_c})$$

" $\theta_i^T e_c$ "

weight_{ij}
term

$f(x_{ij}) = 0$ or $x_{ij} = 0$. "0 log 0" = 0

this, is, of, a, ...
derian

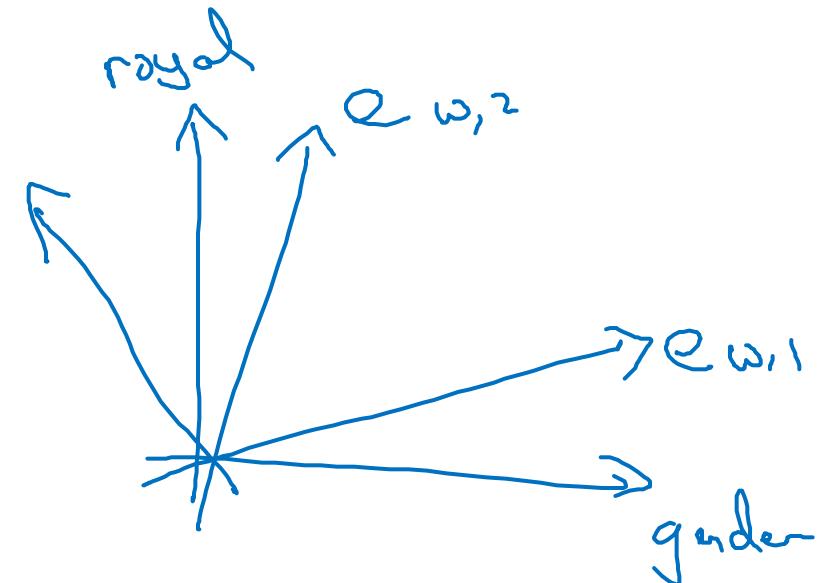
θ_i, e_j are symmetric

$\theta_w^{(\text{final})} = \frac{\theta_w + \theta_w}{2}$

Andrew Ng

A note on the featurization view of word embeddings

	Man (5391)	Woman (9853)	King (4914)	Queen (7157)
Gender	-1	1	-0.95	0.97
Royal	0.01	0.02	0.93	0.95
Age	0.03	0.02	0.70	0.69
Food	0.09	0.01	0.02	0.01



$$\text{minimize } \sum_{i=1}^{10,000} \sum_{j=1}^{10,000} f(X_{ij}) (\underbrace{\theta_i^T e_j + b_i + b'_j - \log X_{ij}}_{})^2$$

$$\left\langle (A\theta_i)^T (A^T e_j) \right\rangle = \cancel{\theta_i^T A^T A} \cancel{\theta_i^T} e_j$$



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NLP and Word Embeddings

Sentiment classification

Sentiment classification problem



The dessert is excellent.



Service was quite slow.



Good for a quick meal, but nothing special.



Completely lacking in good taste, good service, and good ambience.



10,000 \rightarrow 100,000 words

Simple sentiment classification model

The dessert is excellent
8928 2468 4694 3180



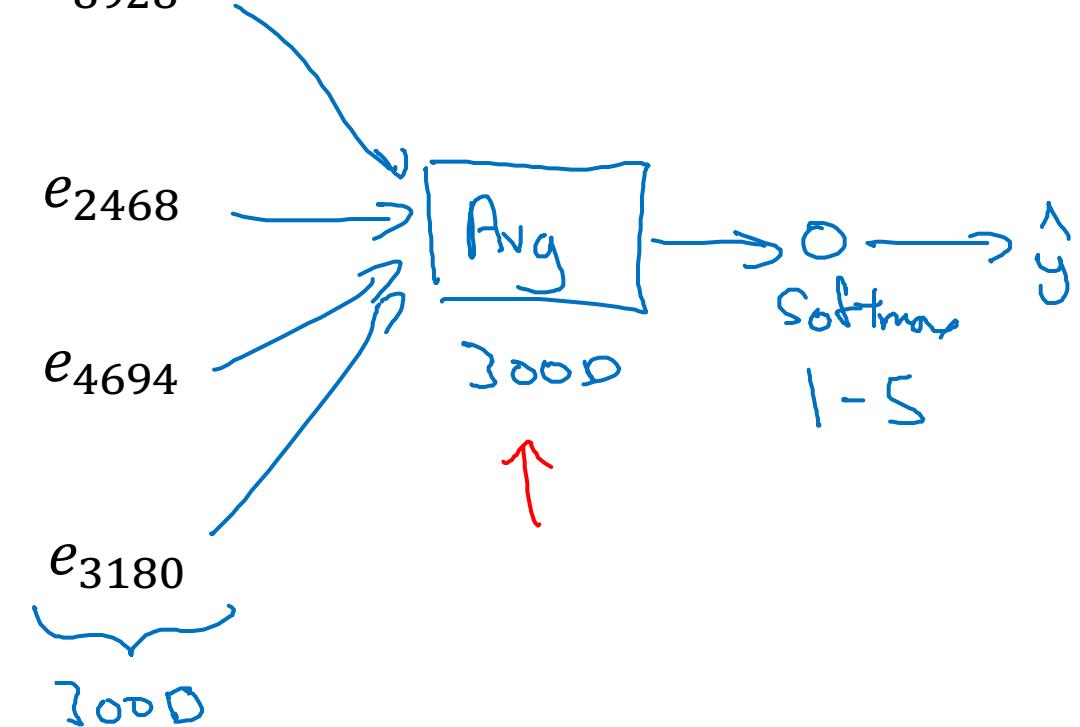
The o_{8928} $\rightarrow E \rightarrow e_{8928}$

desert $o_{2468} \rightarrow E \rightarrow e_{2468}$

is $o_{4694} \rightarrow E \rightarrow e_{4694}$

excellent $o_{3180} \rightarrow E \rightarrow e_{3180}$

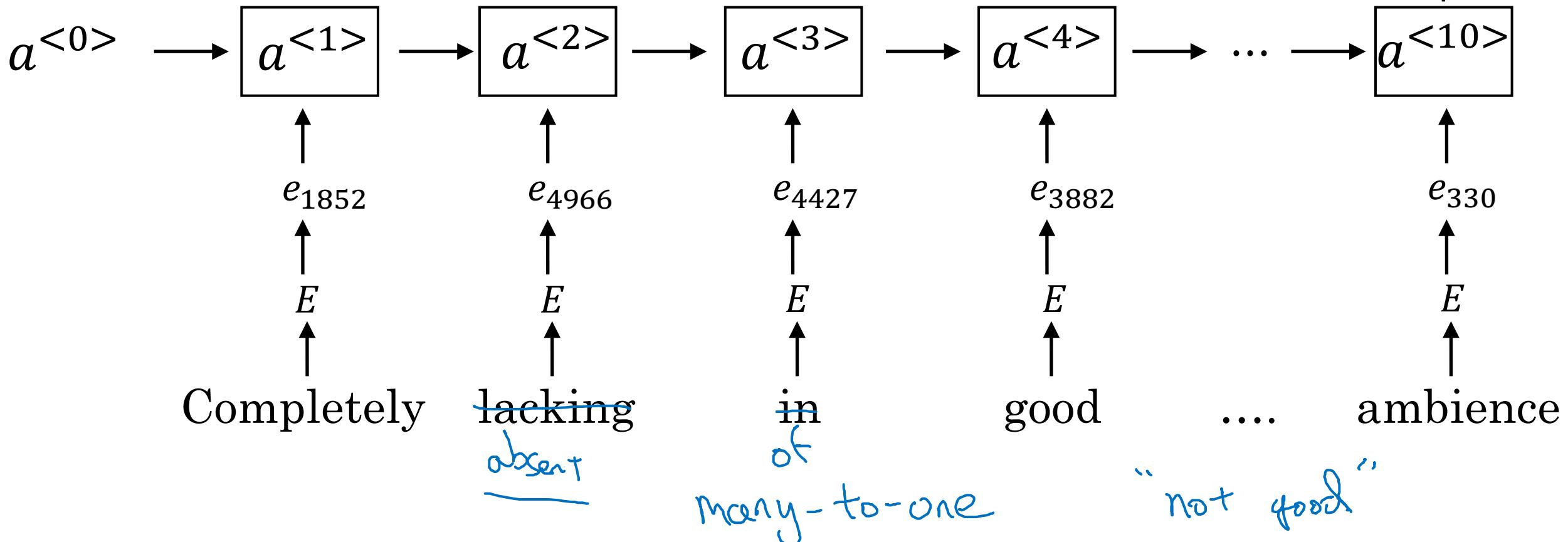
“Completely lacking in good taste, good service, and good ambience.”
↑
100 B words



RNN for sentiment classification

\hat{y}

softmax





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NLP and Word Embeddings

Debiasing word embeddings

The problem of bias in word embeddings

Man:Woman as King:Queen

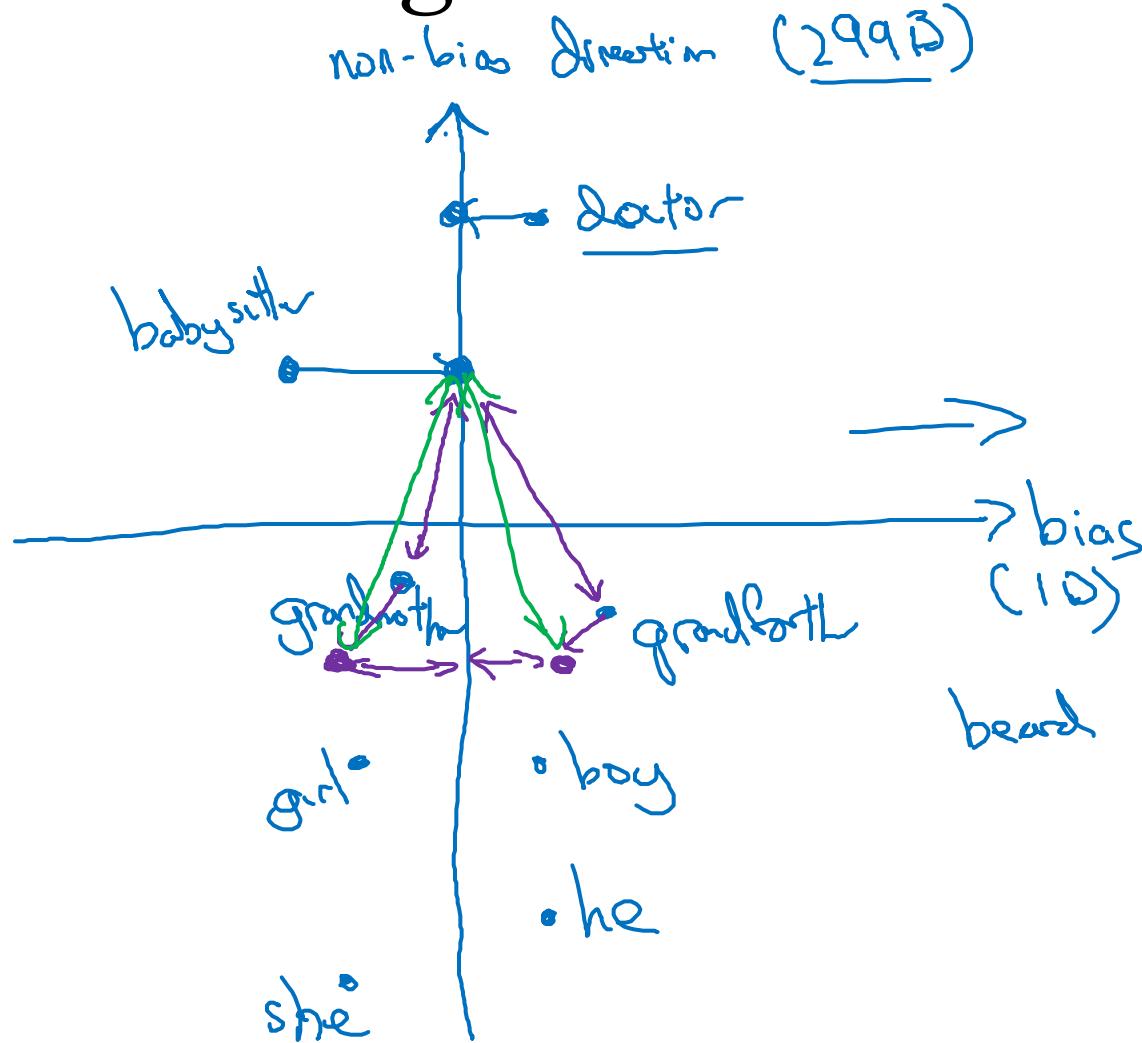
Man:Computer_Programmer as Woman:Homemaker 

Father:Doctor as Mother:Nurse 

Word embeddings can reflect gender, ethnicity, age, sexual orientation, and other biases of the text used to train the model.



Addressing bias in word embeddings



1. Identify bias direction.

$$\left\{ \begin{array}{l} e_{\text{he}} - e_{\text{she}} \\ e_{\text{male}} - e_{\text{female}} \\ \vdots \\ \text{average} \end{array} \right.$$

2. Neutralize: For every word that is not definitional, project to get rid of bias.

3. Equalize pairs.

$$\left\{ \begin{array}{l} \rightarrow \text{grandmother} - \text{grandfather} \\ \text{girl} \qquad \qquad \qquad \text{boy} \end{array} \right.$$