Copyright Notice

NLP and Word Embeddings

deeplearning.ai

Word representation

Word representation

V = [a, aaron, …, zulu, <UNK>]

$|V| = 10,000$

1-hot representation

$$\begin{array}{cccccc}
\text{Man} & \text{Woman} & \text{King} & \text{Queen} & \text{Apple} & \text{Orange} \\
(5391) & (9853) & (4914) & (7157) & (456) & (6257) \\
\begin{bmatrix}0\\0\\0\\0\\\vdots\\1\\\vdots\\0\\0\end{bmatrix} & \begin{bmatrix}0\\0\\0\\0\\0\\\vdots\\1\\\vdots\\0\end{bmatrix} & \begin{bmatrix}0\\0\\0\\\vdots\\1\\\vdots\\0\\0\\0\end{bmatrix} & \begin{bmatrix}0\\0\\0\\0\\0\\\vdots\\1\\\vdots\\0\end{bmatrix} & \begin{bmatrix}0\\\vdots\\1\\\vdots\\0\\0\\0\\0\\0\end{bmatrix} & \begin{bmatrix}0\\0\\0\\0\\0\\\vdots\\1\\\vdots\\0\end{bmatrix} \\
O_{5391} & O_{9853} & \uparrow & \uparrow & \uparrow & \uparrow
\end{array}$$

I want a glass of orange juice.

I want a glass of apple ?.

Featurized representation: word embedding

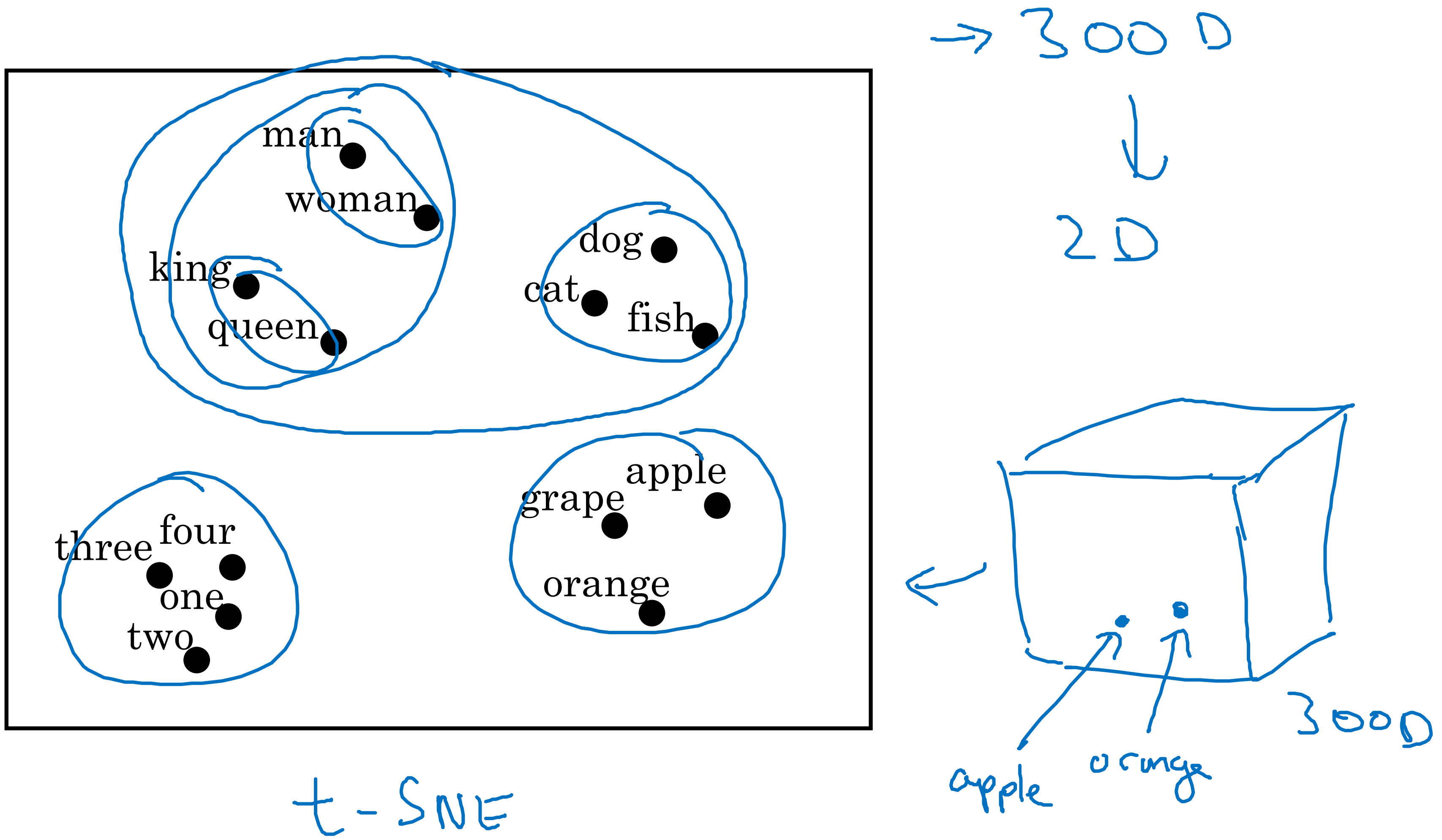
	Man (5391)	Woman (9853)	King (4914)	Queen (7157)	Apple (456)	Orange (6257)
Gender	-1	1	-0.95	0.97	0.00	0.01
Royal	0.01	0.02	0.93	0.95	-0.01	0.00
Age	0.03	0.02	0.7	0.69	0.03	-0.02
Food	0.04	0.01	0.02	0.01	0.95	0.97
⋮	⋮	⋮				
size cost alive verb	e_{5391}	e_{9853}				

300

I want a glass of orange juice.

I want a glass of apple juice.

Visualizing word embeddings



[van der Maaten and Hinton., 2008. Visualizing data using t-SNE]

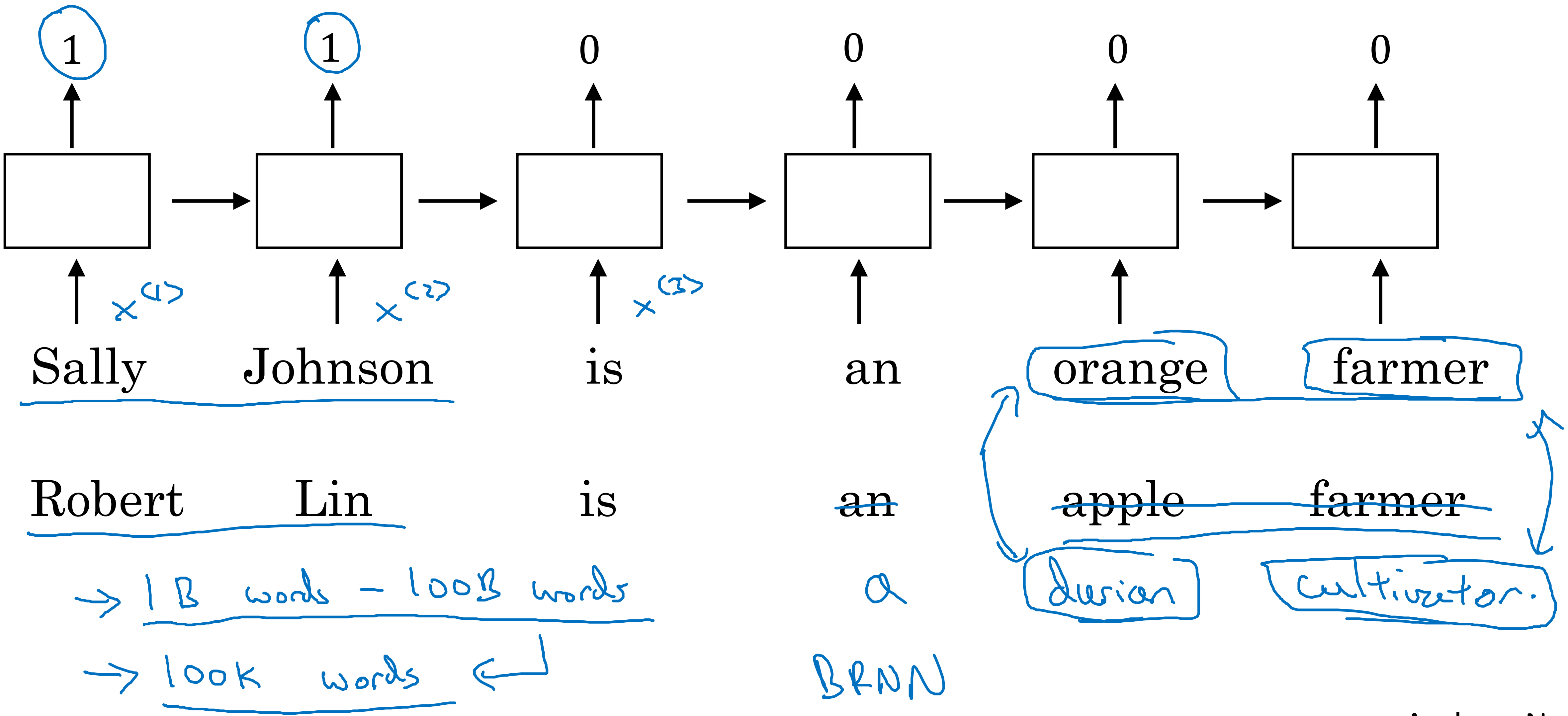
Andrew Ng

deeplearning.ai

NLP and Word Embeddings

Using word embeddings

Named entity recognition example



Sally Johnson is an orange farmer

Robert Lin is ~~an~~ ~~apple farmer~~

a durian cultivator.

→ 1B words – 100B words

→ 100k words

BRNN

Andrew Ng

Transfer learning and word embeddings

Ⓐ

1. Learn word embeddings from large text corpus. (1-100B words)

   (Or download pre-trained embedding online.)

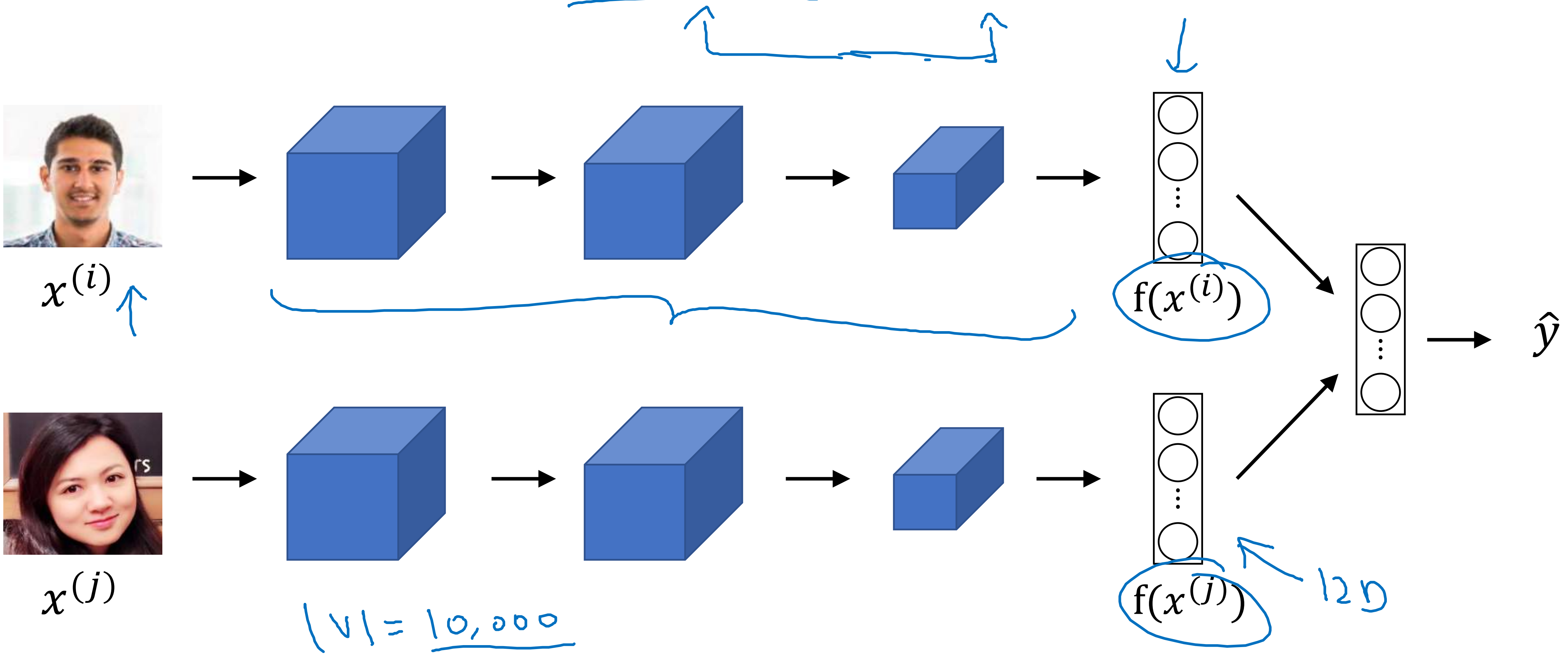
Ⓑ

2. Transfer embedding to new task with smaller training set. (say, 100k words)

   →10,000 →300

3. Optional: Continue to finetune the word embeddings with new data.

Relation to face encoding (embedding)



$|V| = 10{,}000$

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

[Taigman et. al., 2014. DeepFace: Closing the gap to human level performance]

Andrew Ng

deeplearning.ai

NLP and Word Embeddings

Properties of word embeddings

Analogies

	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

e_{5391}

e_{man} $\quad e_{woman}$

Man → Woman as King →? Queen

$$e_{man} - e_{woman} \approx e_{king} - e_{?}$$

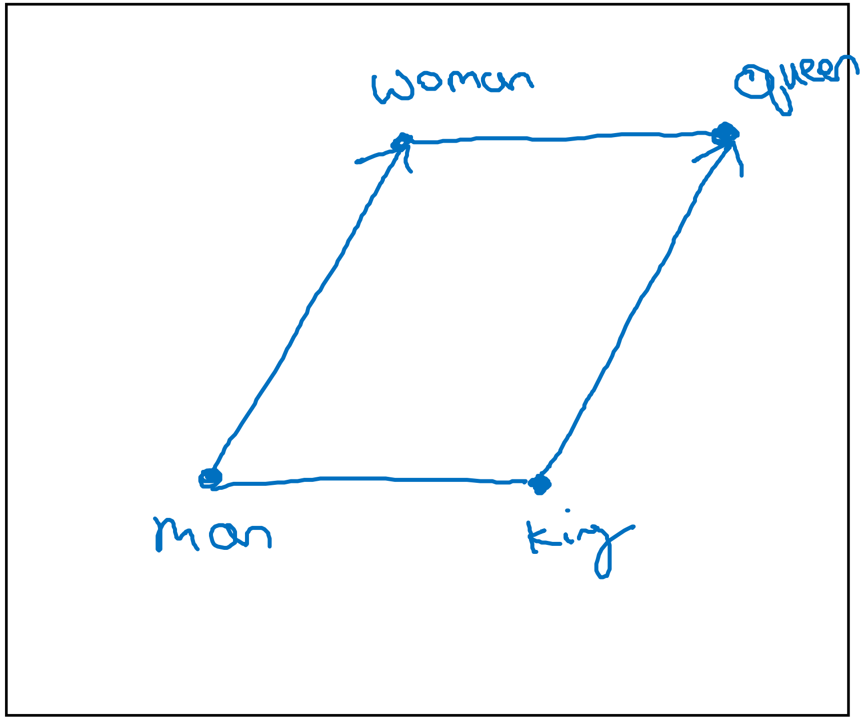
↖ queen

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

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

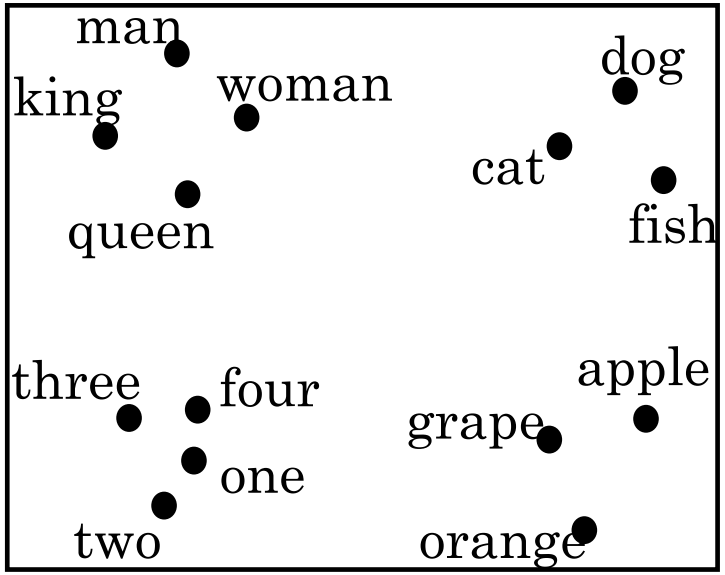
[Mikolov et. al., 2013, Linguistic regularities in continuous space word representations]

Analogies using word vectors



300 D

300D → 2D



t-SNE

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

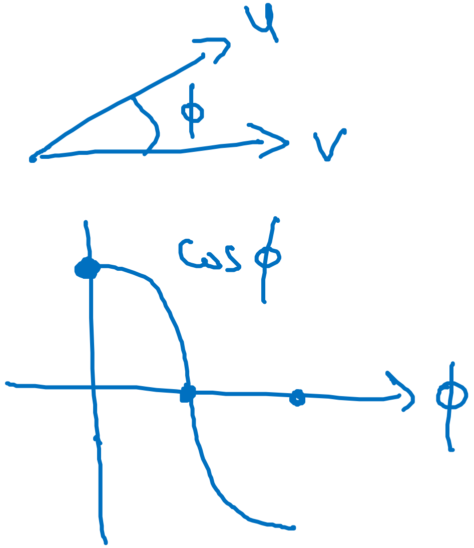
Find word w: $\arg\max_{w} \boxed{sim(e_w, e_{king} - e_{man} + e_{woman})}$

30 - 75%

Cosine similarity

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

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



$$\|u - v\|^2$$

Man:Woman as Boy:Girl

Ottawa:Canada as Nairobi:Kenya

Big:Bigger as Tall:Taller

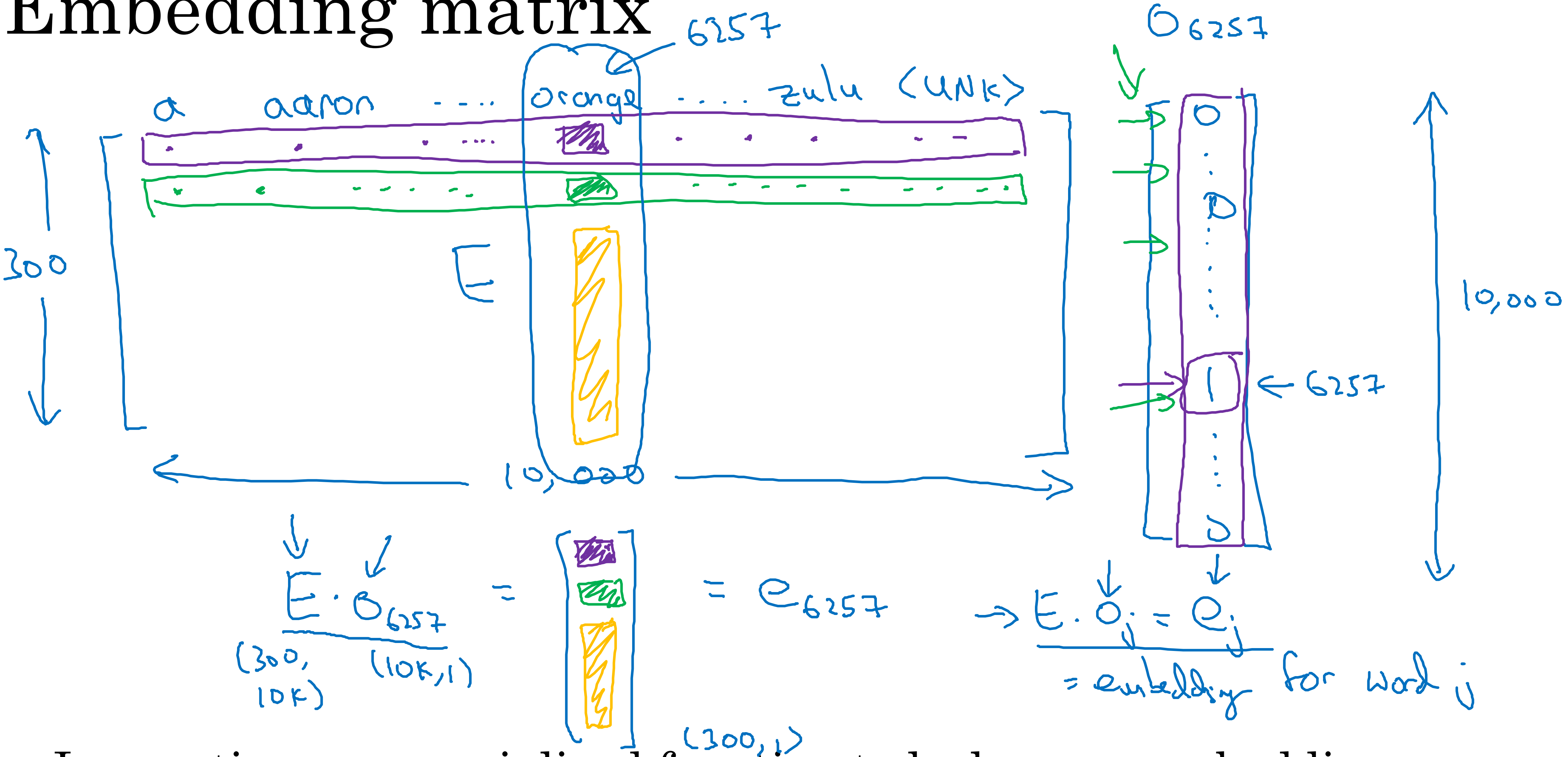
Yen:Japan as Ruble:Russia

NLP and Word Embeddings

Embedding matrix

deeplearning.ai

Embedding matrix



$E \cdot O_{6257} =$ $=e_{6257}$

$\rightarrow E \cdot O_j = e_j$

= embedding for word j

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

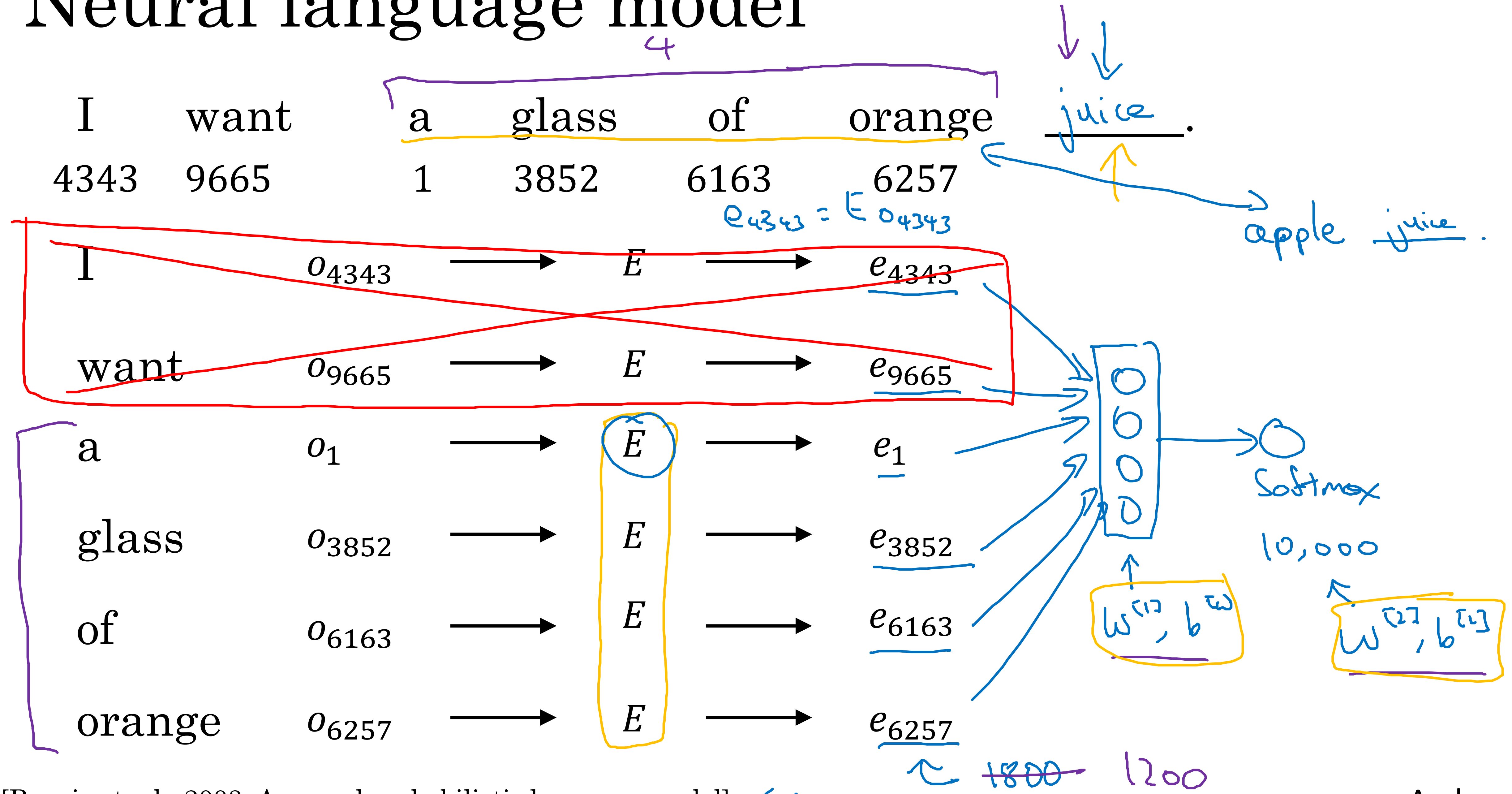
→Embedding

deeplearning.ai

NLP and Word Embeddings

Learning word embeddings

Neural language model



4

I want a glass of orange juice.

4343 9665 1 3852 6163 6257

$e_{4343} = E\, o_{4343}$

apple juice.

I $o_{4343} \longrightarrow E \longrightarrow e_{4343}$

want $o_{9665} \longrightarrow E \longrightarrow e_{9665}$

a $o_{1} \longrightarrow E \longrightarrow e_{1}$

glass $o_{3852} \longrightarrow E \longrightarrow e_{3852}$

of $o_{6163} \longrightarrow E \longrightarrow e_{6163}$

orange $o_{6257} \longrightarrow E \longrightarrow e_{6257}$

[Bengio et. al., 2003, A neural probabilistic language model]

Other context/target pairs

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

context

target

Context: Last 4 words.

4 words on left & right

a glass of orange ? to go alg wth

Last 1 word

orange ?

Nearby 1 word

glass ?

skip gram

deeplearning.ai

NLP and Word Embeddings

Word2Vec

Skip-grams

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

Context	Target
orange	juice
orange	glass
orange	my

[Mikolov et. al., 2013. Efficient estimation of word representations in vector space.]

Model

Vocab size = 10,000k

$$x \longrightarrow y$$

Context c ("orange") 6257 ⟶ Target t ("juice") 4834

$$o_c \rightarrow \boxed{E} \rightarrow e_c \rightarrow \underset{\text{softmax}}{\bigcirc} \rightarrow \hat{y}$$

$$e_c = E\, o_c$$

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

θ_t = parameter associated with output t

$$\rightarrow \mathcal{L}(\hat{y}, y) = - \sum_{i=1}^{10,000} y_i \log \hat{y}_i \leftarrow$$

$$y = \begin{bmatrix} 0 \\ \vdots \\ 1 \\ \vdots \\ 0 \end{bmatrix} \leftarrow 4834$$

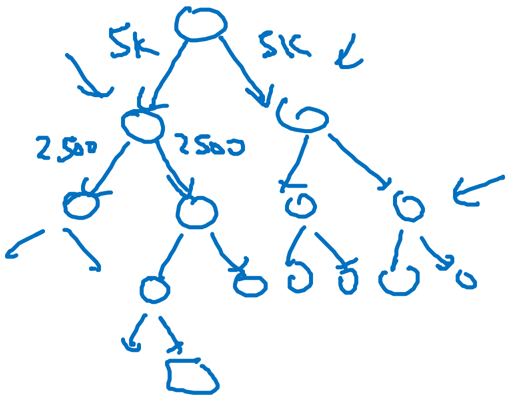
Problems with softmax classification

computational speed -> slow -> solution

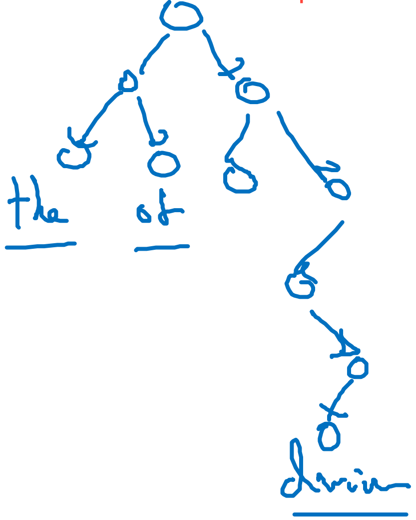
$$\underline{p(t|c)} = \frac{e^{\theta_t^T e_c}}{\boxed{\sum_{j=1}^{10,000} e^{\theta_j^T e_c}}}$$

Hierarchical softmax.

log |V|



common words on top



rare words is deeper

How to sample the context c?

→ the, of, a, and, to, ...

→ orange, apple, durian

Q durian

t

c → t

P(c)

Andrew Ng

deeplearning.ai

NLP and Word Embeddings

Negative sampling

Defining a new learning problem

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

$x \longrightarrow y$

Context	word	target?
orange	juice	1
orange	king	0
orange	book	0
orange	the	0
orange	of	0

k

k = 5-20 smaller. datasets

k = 2-5 larger dataset

[Mikolov et. al., 2013. Distributed representation of words and phrases and their compositionality]

Model

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

10,000-way softmax

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

x y

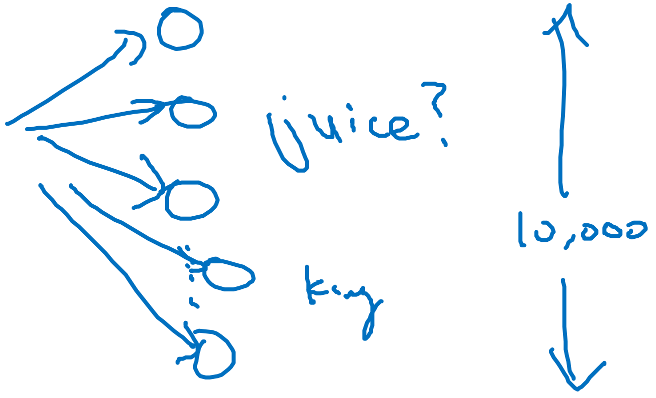
context	word	target?
orange	juice	1
orange	king	0
orange	book	0
orange	the	0
orange	of	0

k

c t y

Orange
6257

$$o_{6257} \rightarrow E \rightarrow e_{6257}$$



10,000 binary classification problem

k+1

only train k+1 of them for every iteration instead

Selecting negative examples

x		y
context	word	target?
orange	juice	1
orange	king	0
orange	book	0
orange	the	0
orange	of	0

↑

k

the, of, and, ...

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

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

↑

NLP and Word Embeddings

GloVe word vectors

deeplearning.ai

GloVe (global vectors for word representation)

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

c, t

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

$$\underbrace{X_{ij}} = X_{ji} \leftarrow$$

[Pennington et. al., 2014. GloVe: Global vectors for word representation] ↙

Model

$$\text{minimize} \sum_{i=1}^{10,000} \sum_{j=1}^{10,000} \underbrace{f(X_{ij})}_{\text{weighting term}} \left(\theta_i^T e_j + \overset{t}{b_i} + \overset{c}{b_j'} - \overset{\to 0?}{\log \underline{X_{ij}}} \right)^2$$

$$\text{"}\overset{t}{\theta_t^T} \overset{c}{e_c}\text{"}$$

$f(X_{ij}) = 0$ if $X_{ij} = 0$.

"$0 \log 0$" $= 0$

this, is, of, a, ...

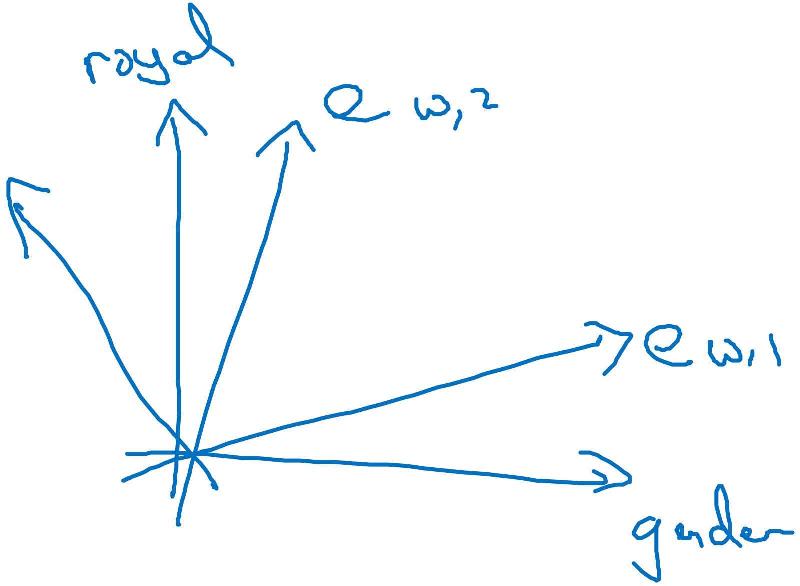
durion

θ_i, e_j are symmetric

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

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



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

$$(A\theta_i)^T(A^{-T}e_j) = \underline{\theta_i^T}\,\cancel{A^T}\cancel{A^{-T}}\,\underline{e_j}$$

deeplearning.ai

NLP and Word Embeddings

Sentiment classification

Sentiment classification problem

$\underline{x}$ → y

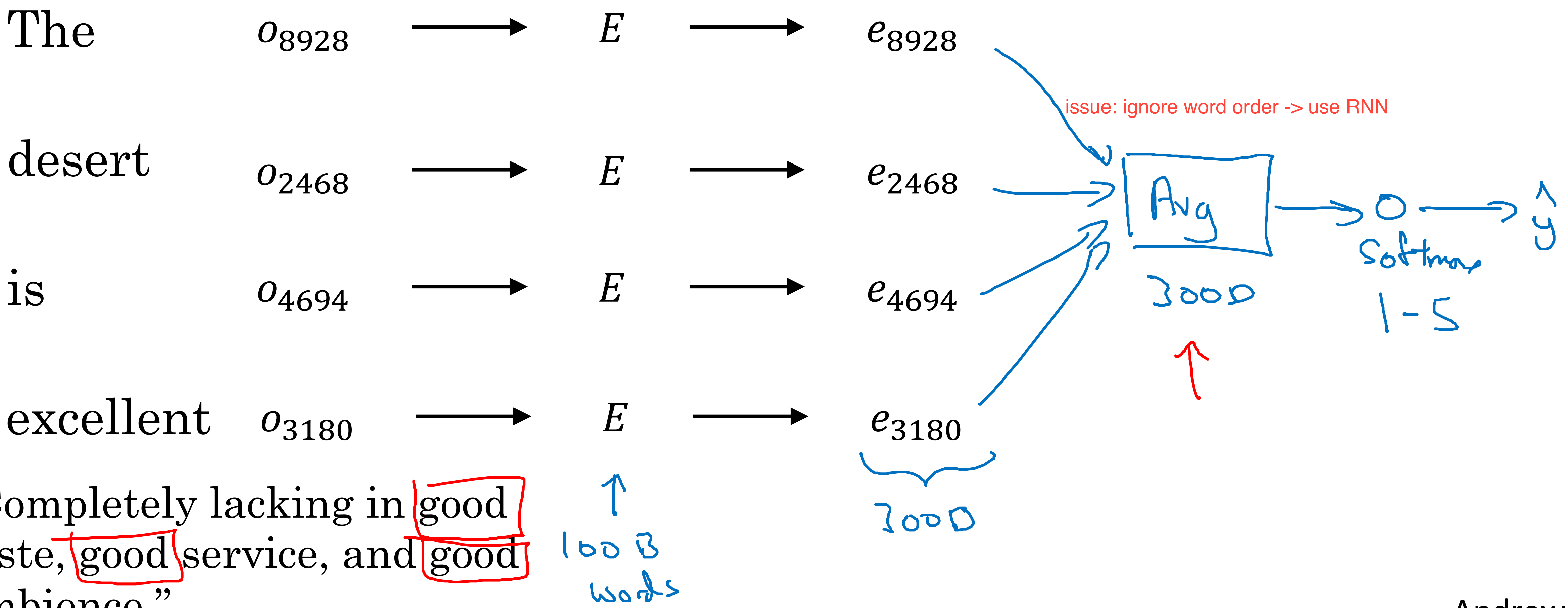
The dessert is excellent.	★★★★☆
Service was quite slow.	★★☆☆☆
Good for a quick meal, but nothing special.	★★★☆☆
Completely lacking in good taste, good service, and good ambience.	★☆☆☆☆

$\underline{10{,}000}$ → 100,000 words

Simple sentiment classification model

★★★★☆

The	dessert	is	excellent
8928	2468	4694	3180



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

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

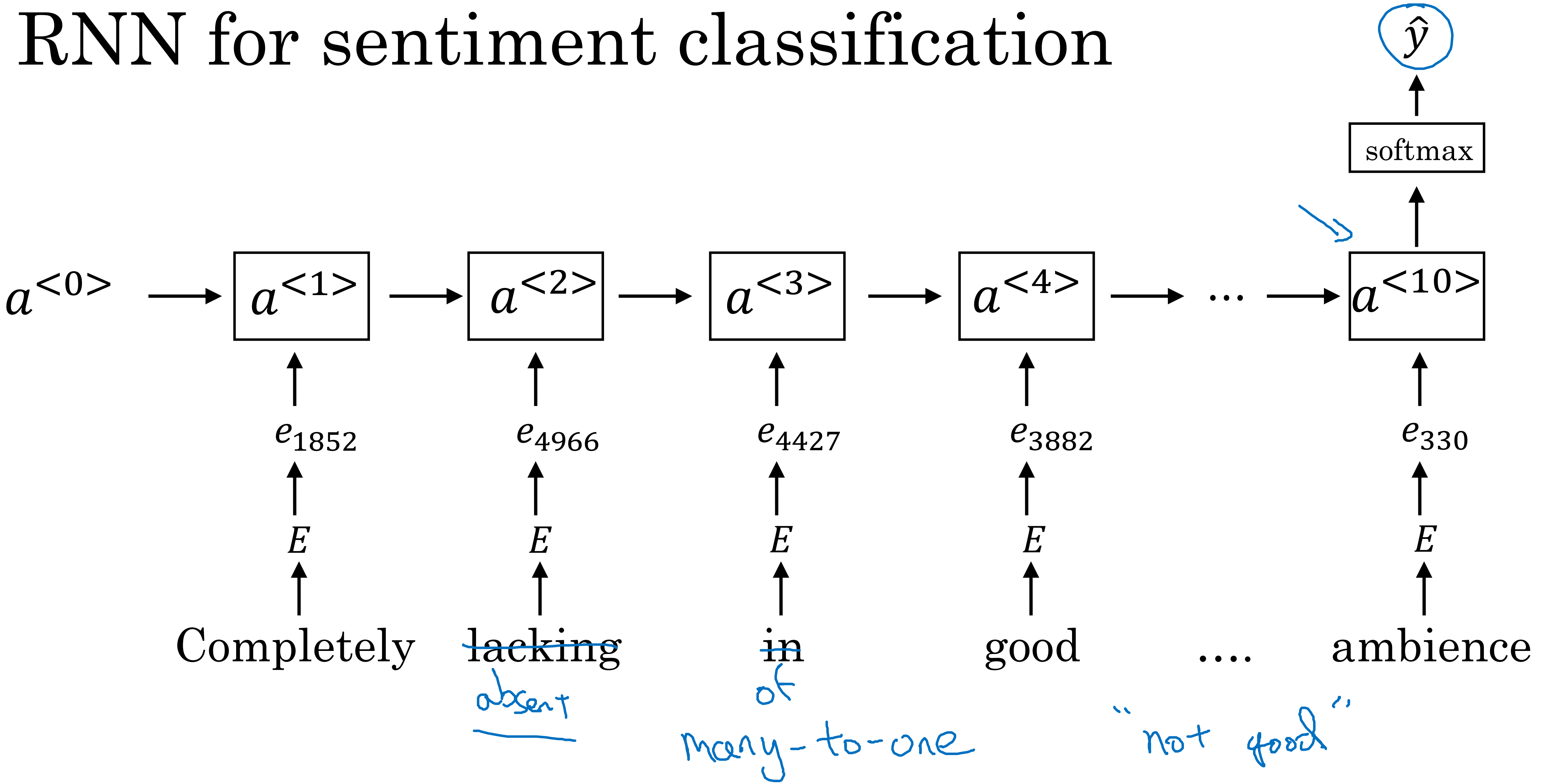
is $o_{4694} \longrightarrow E \longrightarrow e_{4694}$

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

issue: ignore word order -> use RNN

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

RNN for sentiment classification



$\hat{y}$

softmax

$a^{<0>} \rightarrow a^{<1>} \rightarrow a^{<2>} \rightarrow a^{<3>} \rightarrow a^{<4>} \rightarrow \cdots \rightarrow a^{<10>}$

e_{1852} e_{4966} e_{4427} e_{3882} e_{330}

E E E E E

Completely ~~lacking~~ ~~in~~ good …. ambience

absent

of

many-to-one

"not good"

Andrew Ng

NLP and Word Embeddings

deeplearning.ai

Debiasing word embeddings

The problem of bias in word embeddings

Man:Woman as King:Queen

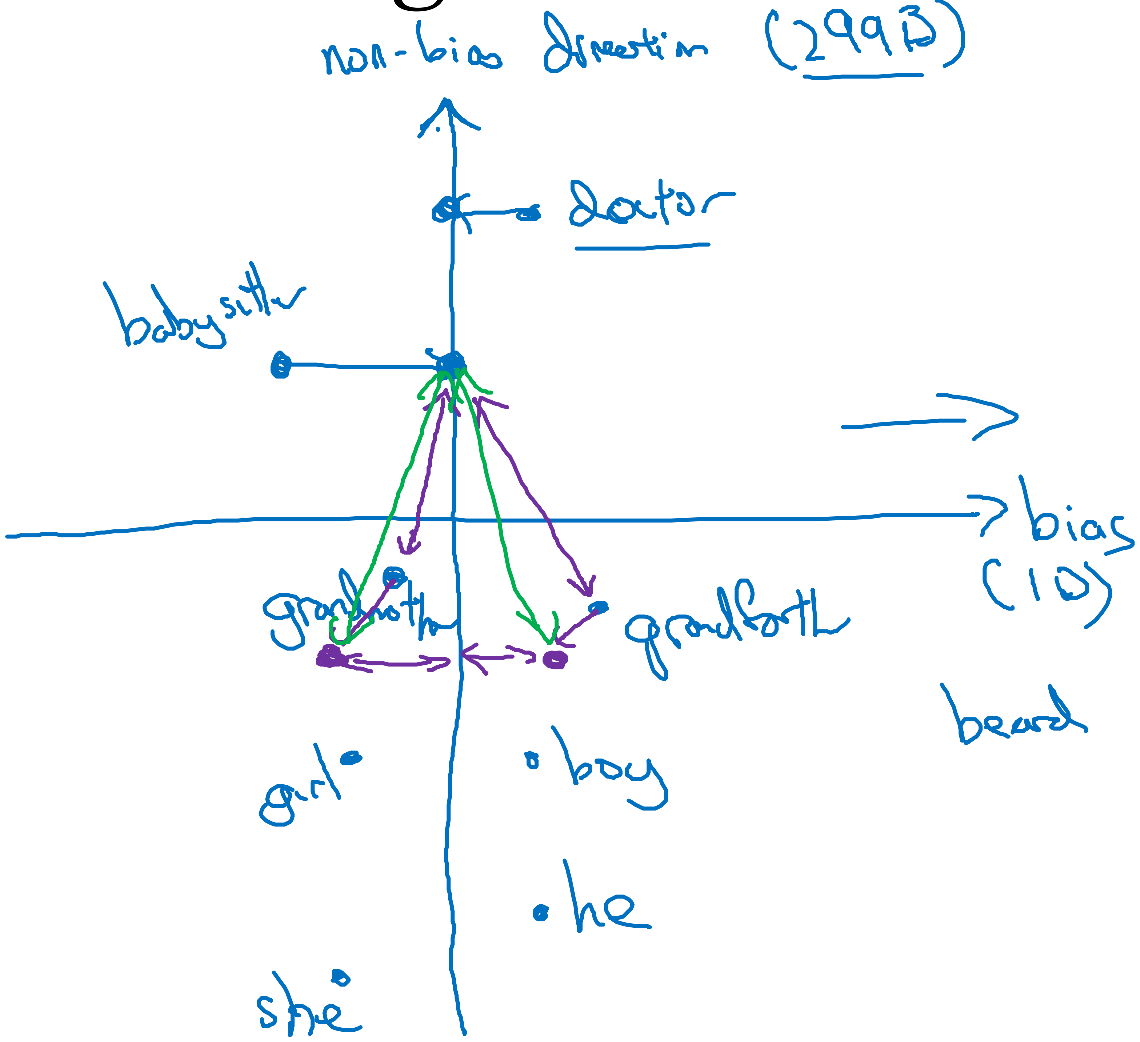
Man:Computer_Programmer as Woman: Homemaker ✗

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.

[Bolukbasi et. al., 2016. Man is to computer programmer as woman is to homemaker? Debiasing word embeddings] ↙

Addressing bias in word embeddings



1. Identify bias direction.

$e_{he} - e_{she}$

$e_{male} - e_{female}$

$\vdots$

→ average

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

3. Equalize pairs.

→ grandmother – grandfather

girl – boy

[Bolukbasi et. al., 2016. Man is to computer programmer as woman is to homemaker? Debiasing word embeddings]