Sequence Models

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University of Maryland

Backpack Models (Attention)

Slides adapted from Joshua Wagner, Matthias Assenmacher, Jay Alammar

History of attention

NEURAL MACHINE TRANSLATION
BY JOINTLY LEARNING TO ALIGN AND TRANSLATE

Dzmitry Bahdanau
Jacobs University Bremen, Germany

KyungHyun Cho **Yoshua Bengio***
Université de Montréal

How to represent final state given previous words:

$$c = q(\{h_1, \dots, h_T\}) \tag{1}$$

New context vector is weighted sum of the hidden states:

$$c_t = \sum_{i=1}^{T_x} \alpha_{t,i} h_i. \tag{2}$$

Where the coefficients are

$$\alpha_{t,i} = align(y_t, x_i) = \frac{exp(score(s_{t-1}, h_i))}{\sum_{i'=1}^{n} exp(score(s_{t-1}, h_{i'}))} \tag{3}$$

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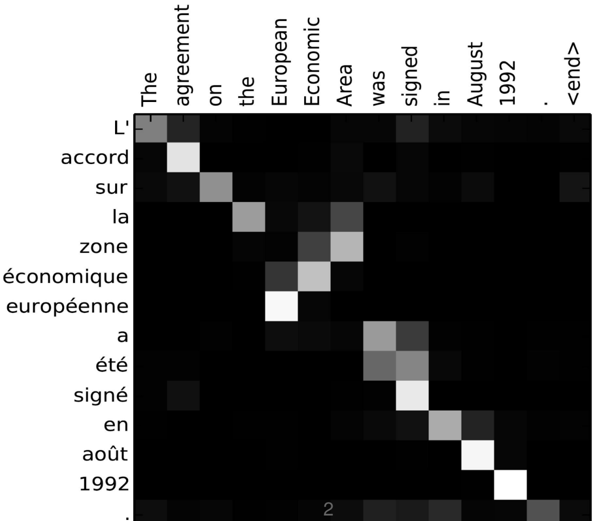
How to

New cc

Where



(1)

(2)

(3)

Key-Value Attention

Attention Is All You Need

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$$\text{Attention}(Q, K, V) = \text{softmax}\left(\frac{QK^\top}{\sqrt{d_k}}\right)V \tag{4}$$

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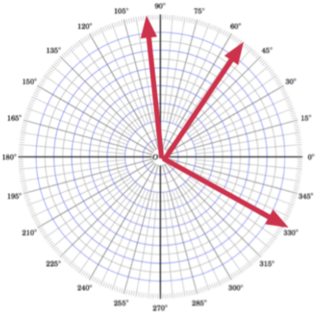

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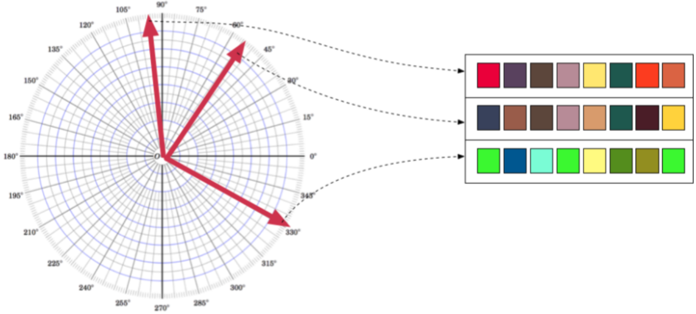

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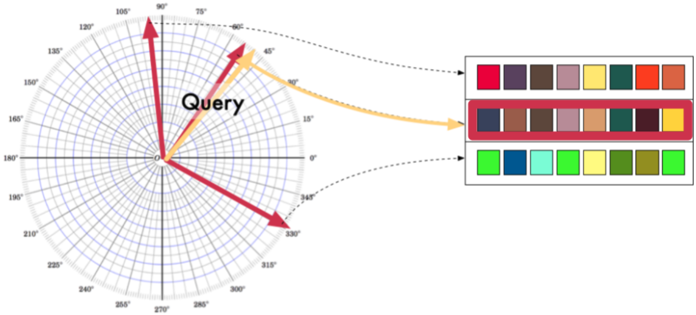

Returning to Backpack Language Model Example: "That trick was sick"

Sentence: "That trick was sick"

that	**trick**	**was**	**sick**
$C(\text{that})_0$	$C(\text{trick})_0$	$C(\text{was})_0$	$C(\text{sick})_0$
$\begin{pmatrix}0 & 0 & 0 & 0\end{pmatrix}$	$\begin{pmatrix}0 & 0 & 1 & 0\end{pmatrix}$	$\begin{pmatrix}0 & 0 & 0 & 0\end{pmatrix}$	$\begin{pmatrix}1 & 0 & 1 & 0\end{pmatrix}$
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Explanation:

- Each word has two sense vectors: $C(x_i)_1$ and $C(x_i)_2$.
- "that" and "was" have zero vectors for both senses.
- "trick" has a non-zero vector for $C(\text{trick})_1$ at the third position (evokes scateboarding), while the second vector is zero.
- "sick" has two non-zero vectors: $C(\text{sick})_1$ and $C(\text{sick})_2$: positive for skateboard, negative for health.

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Selecting the sense

Recap: Definition of $\alpha_{\ell,i,j}$:

$$\alpha_{\ell,i,j} = \begin{cases} 0 & \text{if } j \neq i \\ \sum_{r \neq i} \frac{C(\mathbf{x}_r)_{\ell+2}}{C(\mathbf{x}_r)_2 + C(\mathbf{x}_r)_3} & \text{if } j = i \end{cases} \tag{5}$$

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How can you make this happen with attention?

Doing this with attention

What are the values?

What are the keys?

Doing this with attention

What are the values?

$$V = \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix}$$

What are the keys?

Doing this with attention

What are the values?

What are the keys?

$$K = \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

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$$Q = \begin{pmatrix} 0 & 0 & \frac{2}{3} & \frac{1}{3} \\ 0 & 0 & \frac{2}{3} & \frac{1}{3} \\ 0 & 0 & \frac{2}{3} & \frac{1}{3} \\ 0 & 0 & \frac{2}{3} & \frac{1}{3} \\ 0 & 0 & \frac{2}{3} & \frac{1}{3} \\ 0 & 0 & \frac{2}{3} & \frac{1}{3} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 \end{pmatrix}$$

Putting it all together

$$\text{softmax}\left(\frac{QK^\top}{\sqrt{d}}\right) = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \tag{7}$$

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So summing over all senses, we get the sentiment 1000 (Only contributing from skateboard sense of “sick”.