ITCS 6156/8156 Fall 2023
Machine Learning

Attention & Transformers

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Class Meeting: Mon & Wed, 4:00 PM – 5:15 PM, CHHS 376

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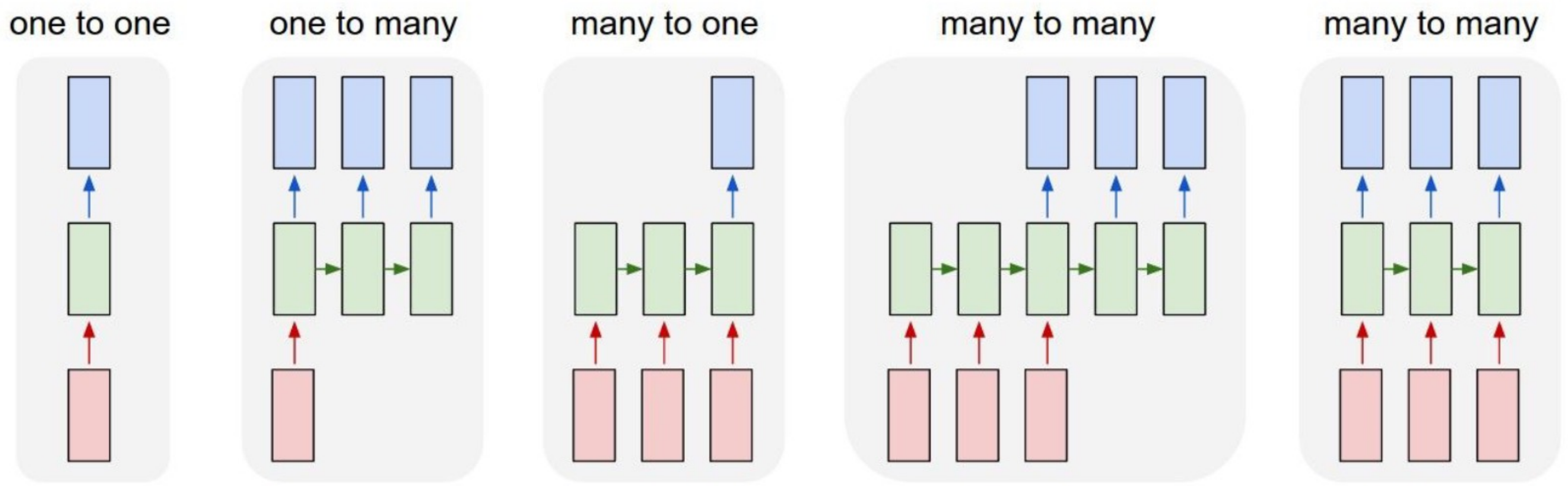
Some content in the slides is based on Dr. Ruohan Gao's lectures

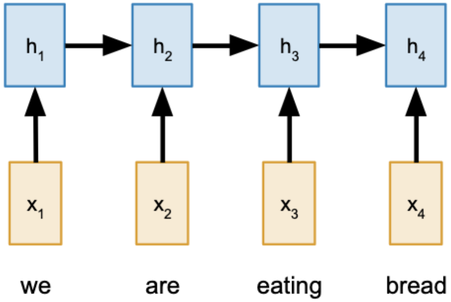
Recurrent Neural Networks



Sequence to Sequence with RNNs

Input: Sequence x_1, … x_T
Output: Sequence y_1, …, $y_{T'}$

Encoder: $h_t = f_W(x_t, h_{t-1})$



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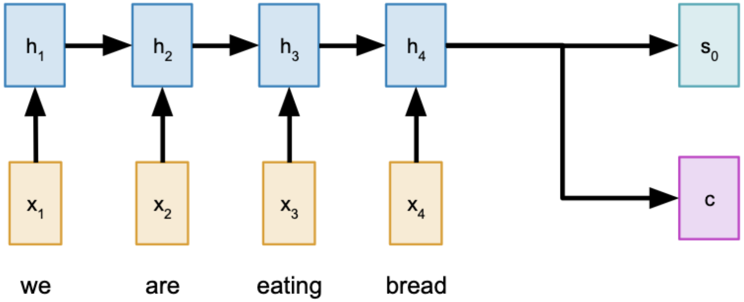
From final hidden state predict:
Initial decoder state s_0
Context vector c (often $c=h_T$)



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Sequence to Sequence with RNNs

Input: Sequence $x_1, \ldots x_T$
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Decoder: $s_t = g_U(y_{t-1}, s_{t-1}, c)$

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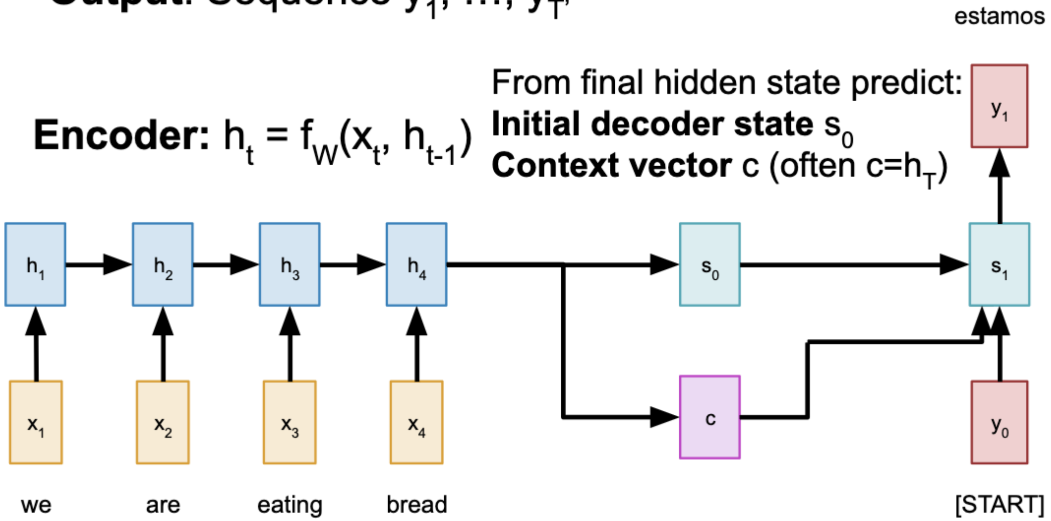

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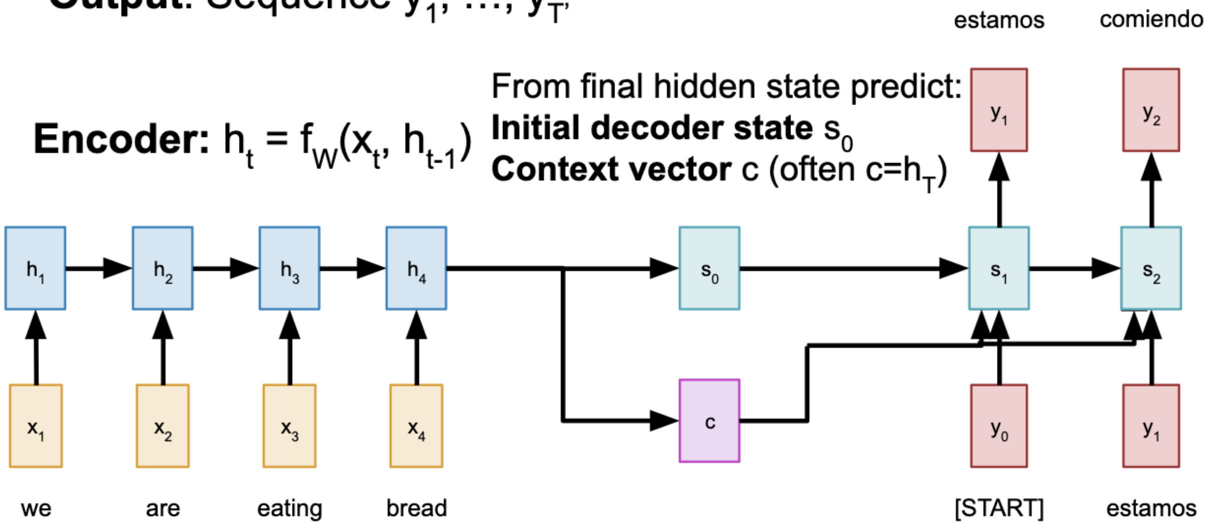

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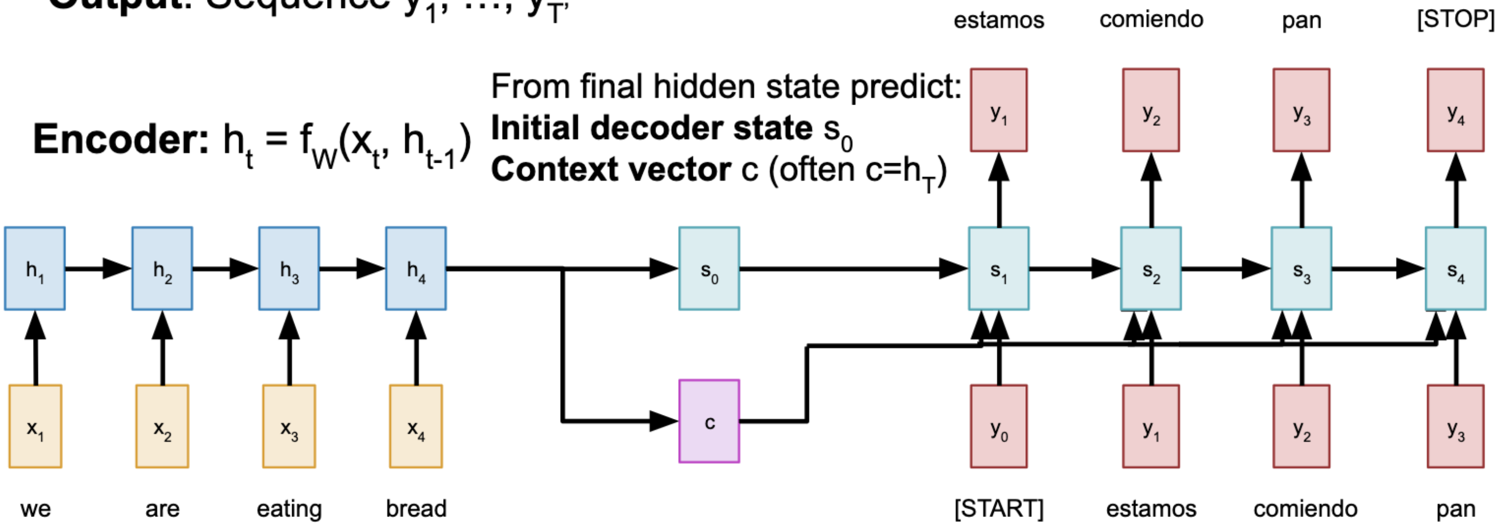

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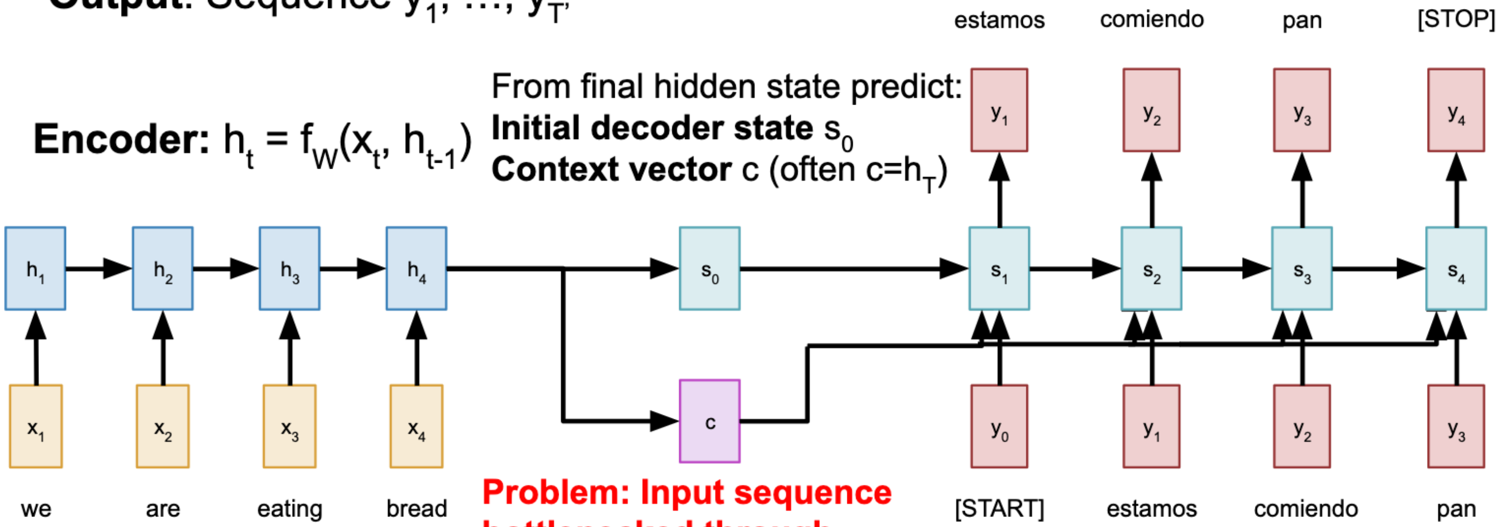

Problem: Input sequence bottlenecked through fixed-sized vector. What if T=1000 ?

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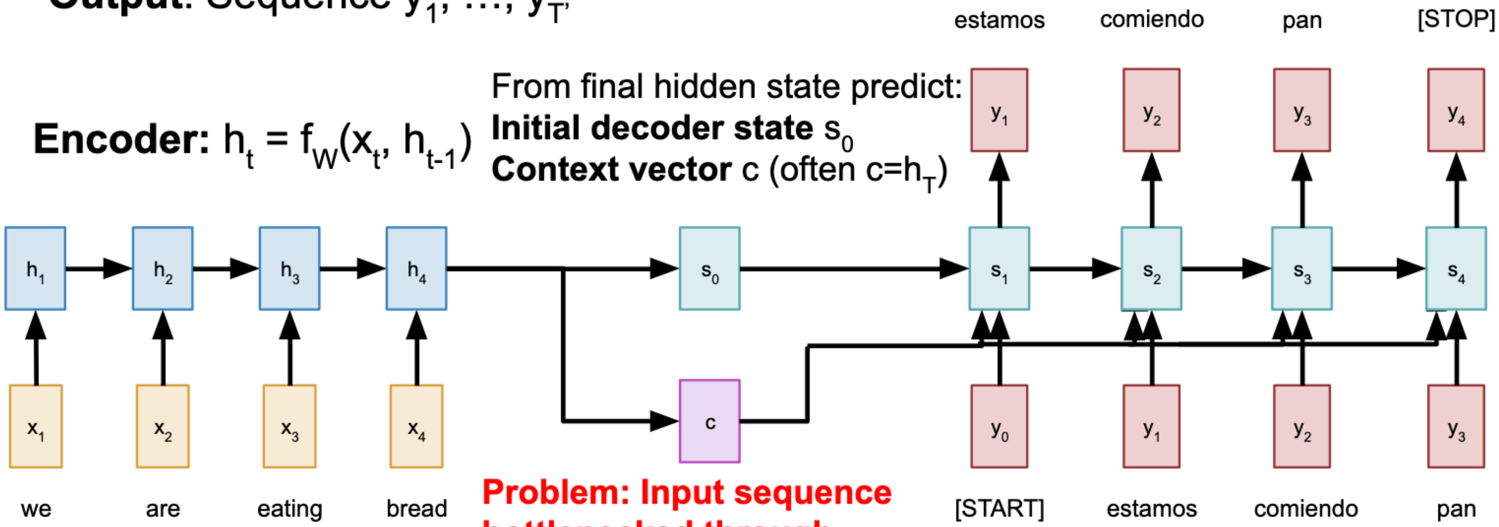

Problem: Input sequence bottlenecked through fixed-sized vector. What if T=1000 ?

Idea: use new context vector at each step of decoder!

Sequence to Sequence with RNNs and Attention

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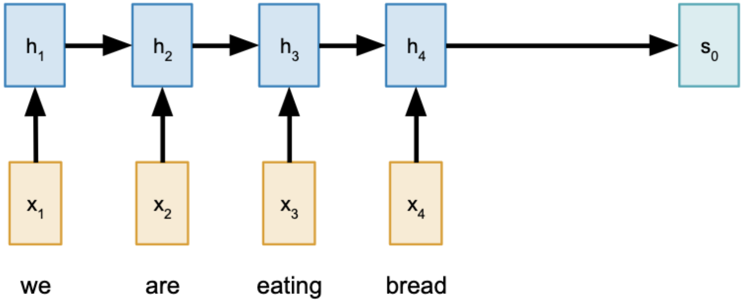
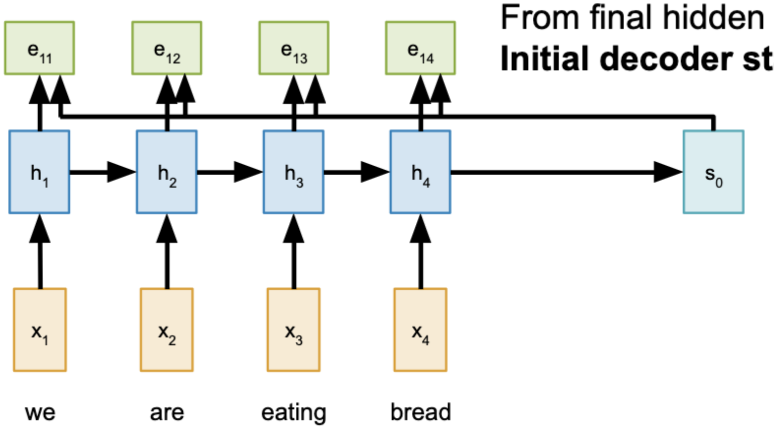


Bahdanau et al, “Neural machine translation by jointly learning to align and translate”, ICLR 2015

Sequence to Sequence with RNNs and Attention

Compute (scalar) **alignment scores**

$e_{t,i} = f_{att}(s_{t-1}, h_i)$ (f_{att} is an MLP)



From final hidden state: **Initial decoder state** s_0

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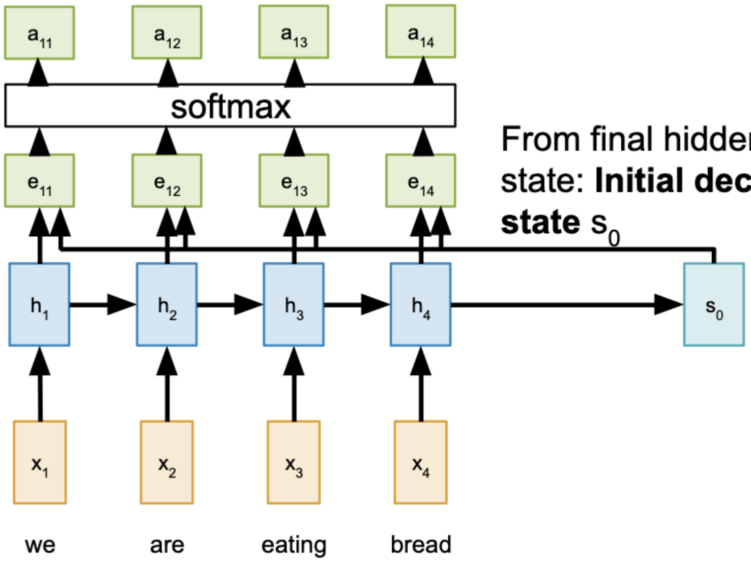
Sequence to Sequence with RNNs and Attention



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Normalize alignment scores to get **attention weights**
$0 < a_{t,i} < 1$ $\sum_i a_{t,i} = 1$

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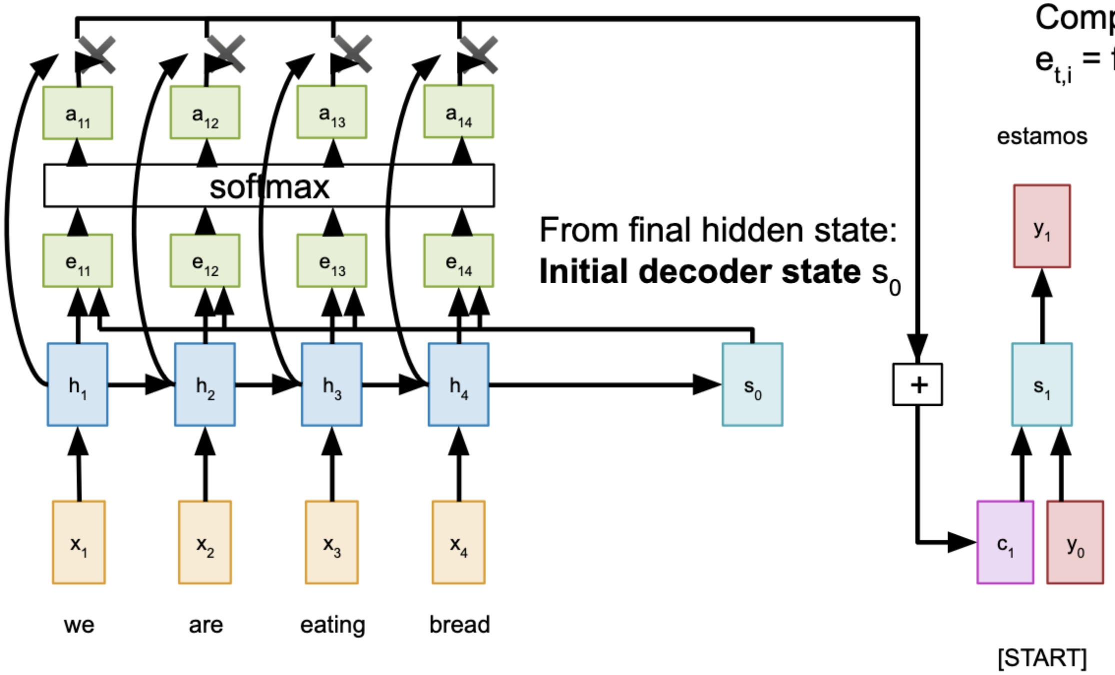

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Compute context vector as linear combination of hidden states
$c_t = \sum_i a_{t,i} h_i$

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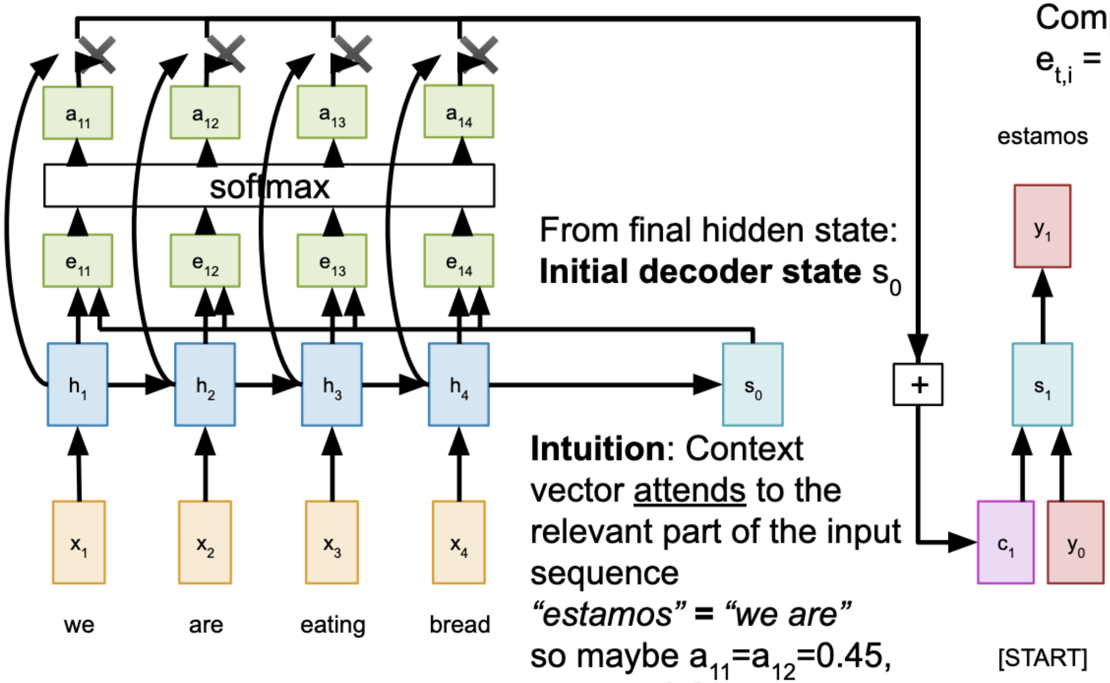
Sequence to Sequence with RNNs and Attention



From final hidden state: **Initial decoder state s_0**

Intuition: Context vector attends to the relevant part of the input sequence *"estamos" = "we are"* so maybe $a_{11}=a_{12}=0.45$, $a_{13}=a_{14}=0.05$

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Use context vector in decoder: $s_t = g_U(y_{t-1}, s_{t-1}, c_t)$

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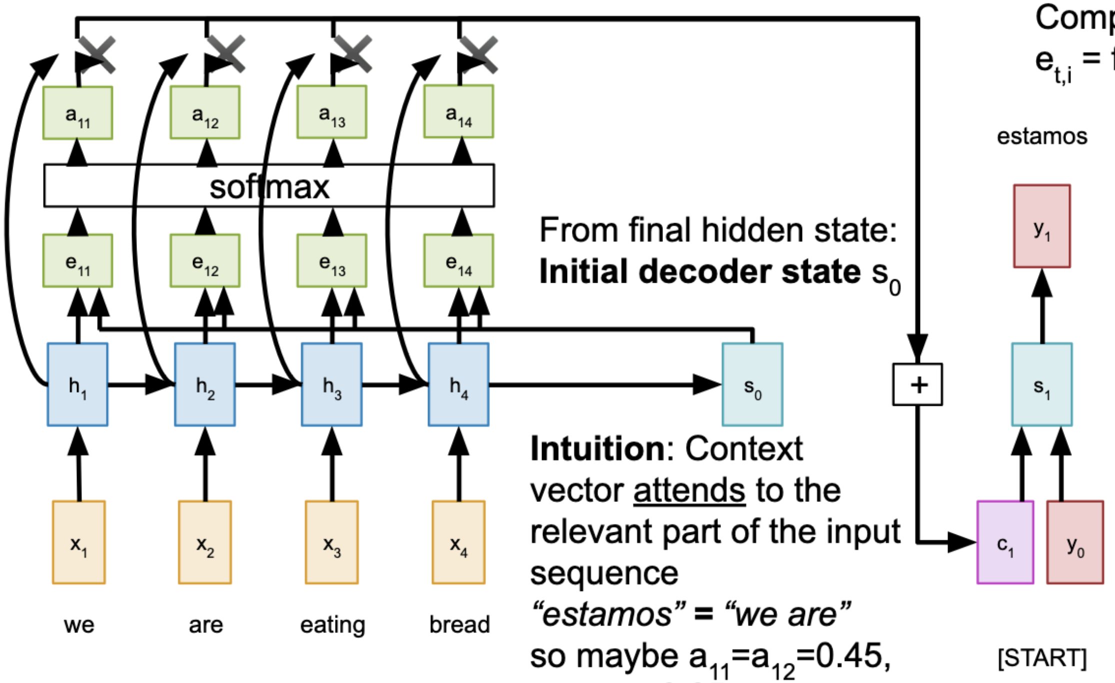
Sequence to Sequence with RNNs and Attention



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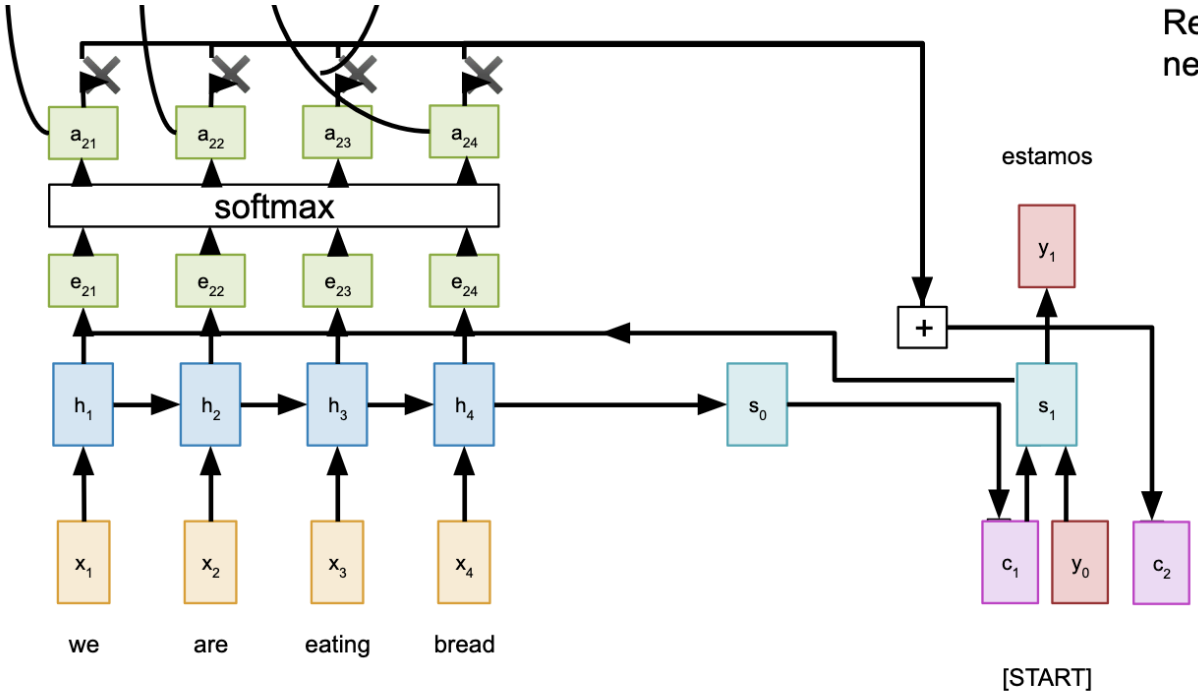
This is all differentiable! No supervision on attention weights – backprop through everything

Bahdanau et al, "Neural machine translation by jointly learning to align and translate", ICLR 2015

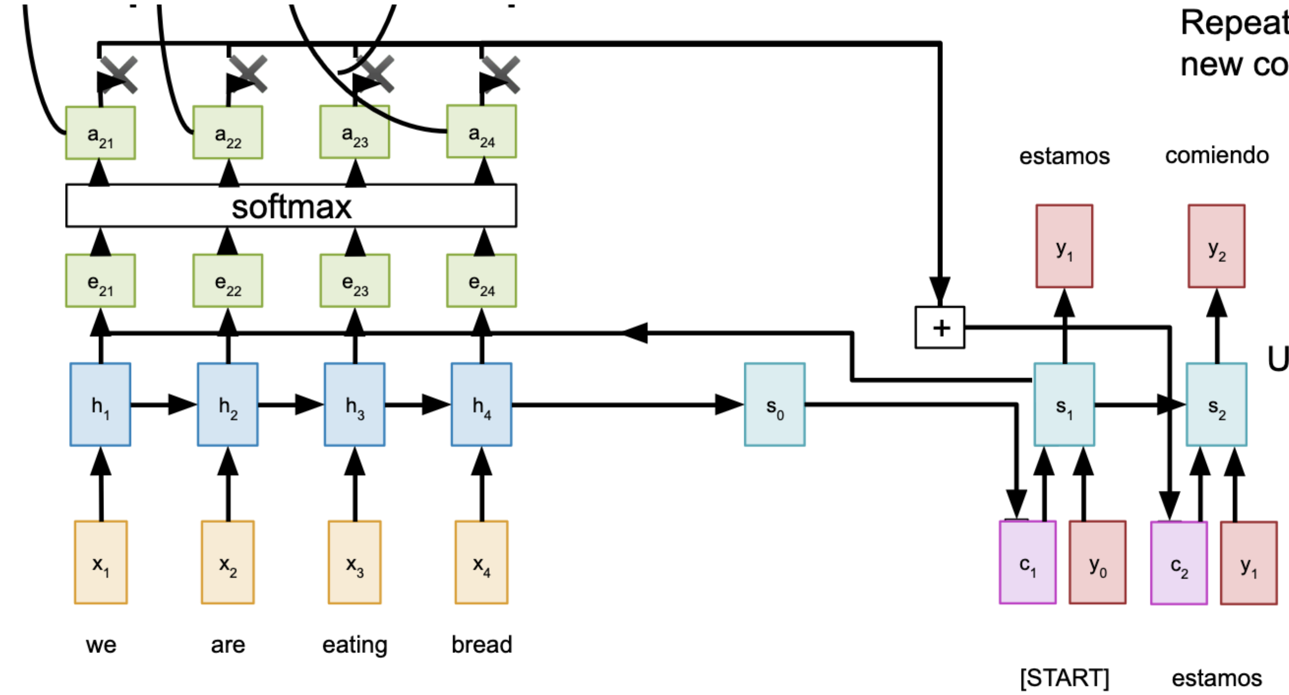
Sequence to Sequence with RNNs and Attention



Repeat: Use s_1 to compute new context vector c_2

Bahdanau et al, “Neural machine translation by jointly learning to align and translate”, ICLR 2015

Sequence to Sequence with RNNs and Attention



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Use c_2 to compute s_2, y_2

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Sequence to Sequence with RNNs and Attention

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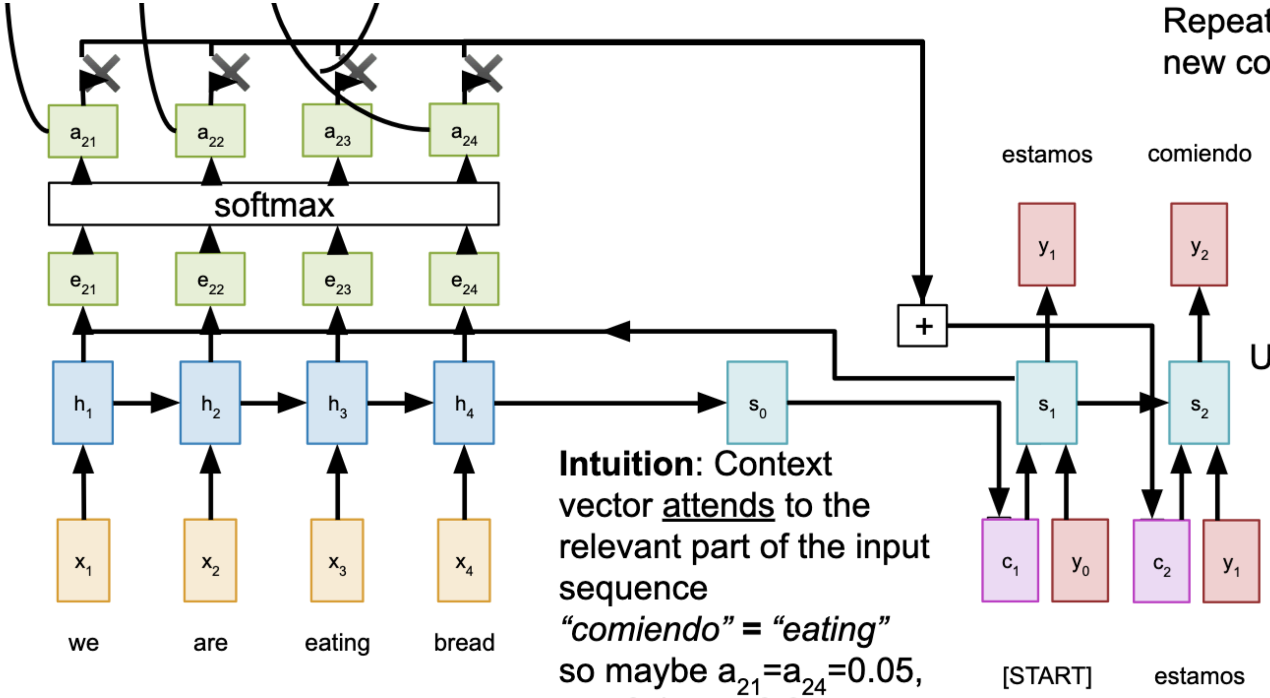


Use c_2 to compute s_2, y_2

Intuition: Context vector attends to the relevant part of the input sequence

"comiendo" = *"eating"*

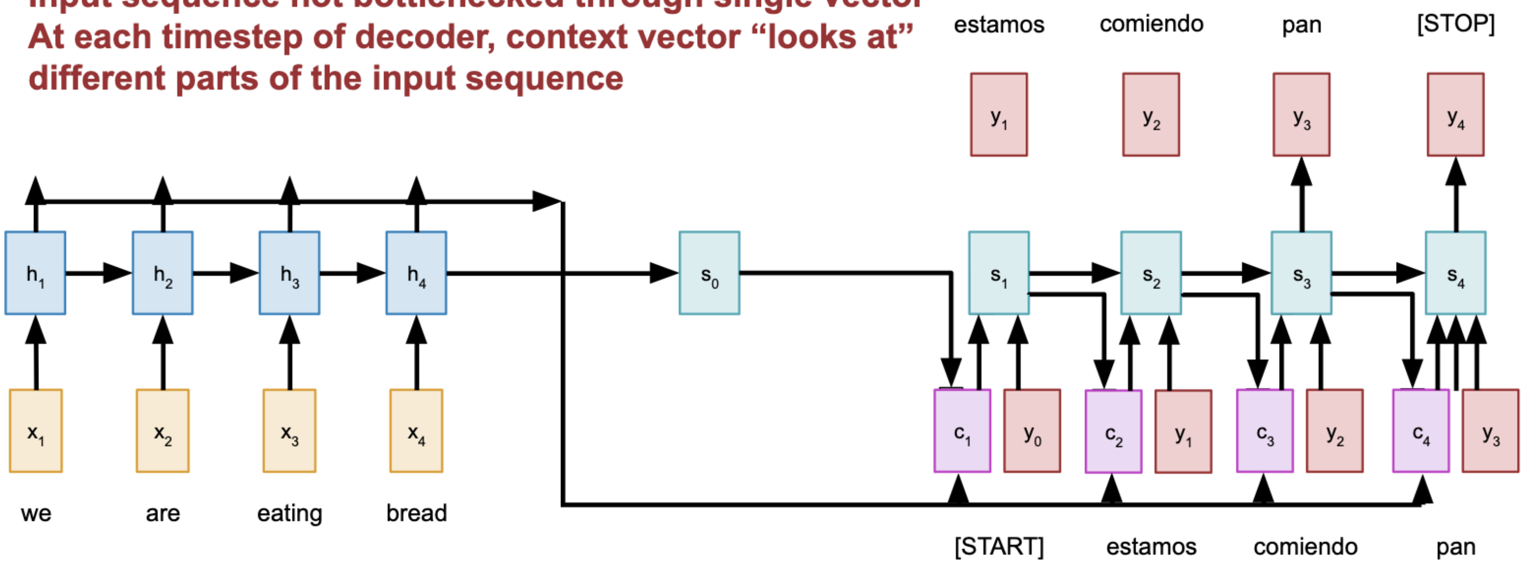
so maybe a_{21}=a_{24}=0.05, a_{22}=0.1, a_{23}=0.8

Bahdanau et al, "Neural machine translation by jointly learning to align and translate", ICLR 2015

Sequence to Sequence with RNNs and Attention

Use a different context vector in each timestep of decoder

- **Input sequence not bottlenecked through single vector**
- **At each timestep of decoder, context vector "looks at" different parts of the input sequence**



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Sequence to Sequence with RNNs and Attention

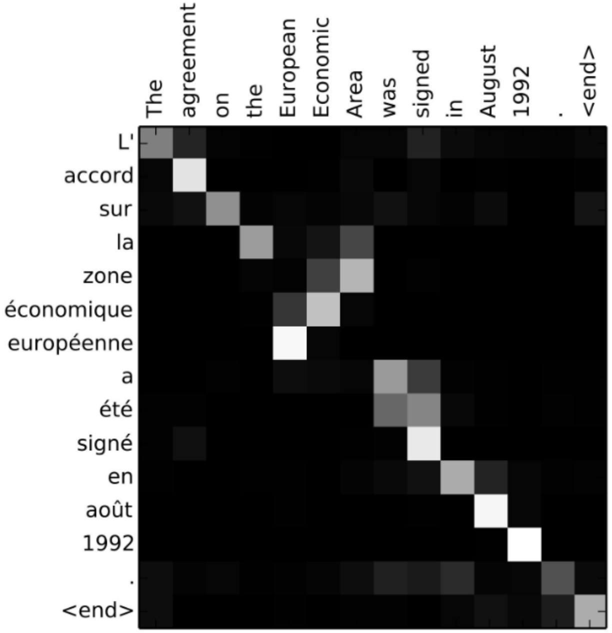
Example: English to French translation

Input: “The agreement on the European Economic Area was signed in August 1992.”

Output: “L’accord sur la zone économique européenne a été signé en août 1992.”

Bahdanau et al, “Neural machine translation by jointly learning to align and translate”, ICLR 2015

Visualize attention weights $a_{t,i}$



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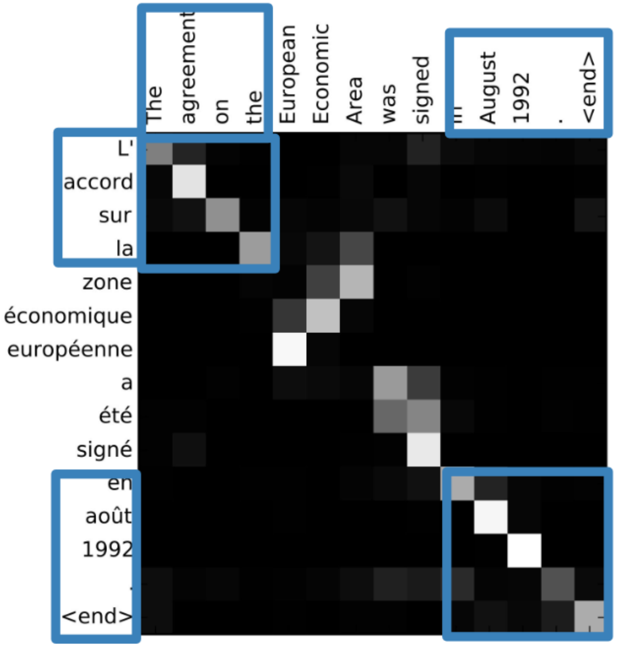

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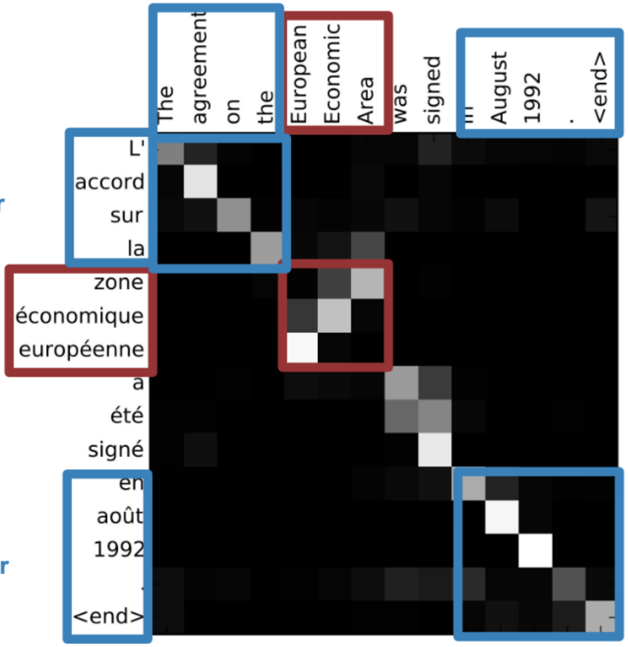
Attention figures out different word orders

Diagonal attention means words correspond in order



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Questions?

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