Modeling with Machine Learning: RNN (part 2)

Recall: learning to encode/decode

- Language modeling

  This course has been a

  success (?)

- Sentiment classification

  I have seen better lectures

  -1

- Machine translation

  I have seen better lectures

  Olen nähnyt parempia luentoja

encoding **decoding**

Outline (part 2)

- Modeling sequences: language models
  - Markov models
  - as neural networks
  - hidden state, Recurrent Neural Networks (RNNs)
- Example: decoding images into sentences

Markov Models

- Next word in a sentence depends on previous symbols already written (history = one, two, or more words)

  The lecture leaves me bumfuzzled

- Similar, next character in a word depends on previous characters already written

  bumfuzzled

- We can model such kth order dependences between symbols with Markov Models

Markov Language Models

- Let $w \in V$ denote the set of possible words/symbols that includes
  - an UNK symbol for any unknown word (out of vocabulary)
  - <beg> symbol for specifying the start of a sentence
  - <end> symbol for specifying the end of the sentence

<beg>	The	lecture	leaves	me	UNK	<end>
w_0	w_1	w_2	w_3	w_4	w_5	w_6

- In a first order Markov model (bigram model), the next symbol only depends on the previous one

A first order Markov model

- Each symbol (except <beg>) in the sequence is predicted using the same conditional probability table until an <end> symbol is seen

				w_i		
		ML	course	is	UNK	<end>
w_{i-1}	<beg>	0.7	0.1	0.1	0.1	0.0
	ML	0.1	0.5	0.2	0.1	0.1
	course	0.0	0.0	0.7	0.1	0.2
	is	0.1	0.3	0.0	0.6	0.0
	UNK	0.1	0.2	0.2	0.3	0.2

Sampling from a Markov model

				w_i		
		ML	course	is	UNK	<end>
w_{i-1}	<beg>	0.7	0.1	0.1	0.1	0.0
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	course	0.0	0.0	0.7	0.1	0.2
	is	0.1	0.3	0.0	0.6	0.0
	UNK	0.1	0.2	0.2	0.3	0.2

Maximum likelihood estimation

- The goal is to maximize the probability that the model can generate all the observed sentences (corpus S)

$$s \in S, \quad s = \{w_1^s, w_2^s, \ldots, w_{|s|}^s\}$$

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- The ML estimate is obtained as normalized counts of successive word occurrences (matching statistics)

Feature based Markov Model

- We can also represent the Markov model as a feed-forward neural network (very extendable)

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Temporal/sequence problems

- Language modeling: what comes next?

This course has been a tremendous ...

tremendous $\begin{bmatrix} 0 \\ \vdots \\ 1 \\ 0 \end{bmatrix}$

?

a $\begin{bmatrix} 1 \\ 0 \\ \vdots \\ 0 \end{bmatrix}$

$x^{(t)}$ $y^{(t)}$

Temporal/sequence problems

- A trigram language model

tremendous $\begin{bmatrix}0\\ \vdots\\ 1\\ 0\end{bmatrix}$

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$x^{(t)}$

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RNNs for sequences

- Language modeling: what comes next?

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RNNs for sequences

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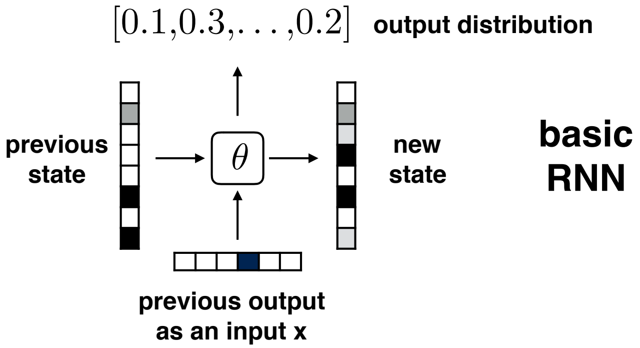
$$s_t = \tanh(W^{s,s}s_{t-1} + W^{s,x}x_t)$$ state

$$p_t = \mathrm{softmax}(W^o s_t)$$ output distribution

Decoding, RNNs

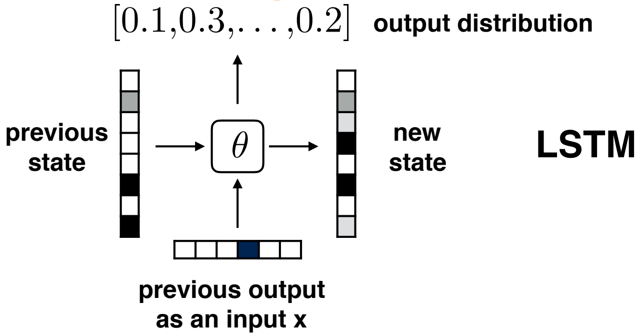
- Our RNN now also produces an output (e.g., a word) as well as update its state



$$s_t = \tanh(W^{s,s}s_{t-1} + W^{s,x}x_t)$$ state

→ $$p_t = \mathrm{softmax}(W^o s_t)$$ output distribution

Decoding, LSTM



$$f_t = \mathrm{sigmoid}(W^{f,h}h_{t-1} + W^{f,x}x_t)$$ forget gate

$$i_t = \mathrm{sigmoid}(W^{i,h}h_{t-1} + W^{i,x}x_t)$$ input gate

$$o_t = \mathrm{sigmoid}(W^{o,h}h_{t-1} + W^{o,x}x_t)$$ output gate

$$c_t = f_t \odot c_{t-1} + i_t \odot \tanh(W^{c,h}h_{t-1} + W^{c,x}x_t)$$ memory cell

$$h_t = o_t \odot \tanh(c_t)$$ visible state

→ $$p_t = \mathrm{softmax}(W^o h_t)$$ output distribution

Decoding (into a sentence)

- Our RNN now needs to also produce an output (e.g., a word) as well as update its state

vector encoding
of a sentence
“I have seen better
lectures”

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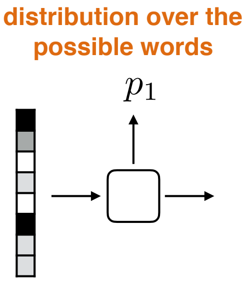

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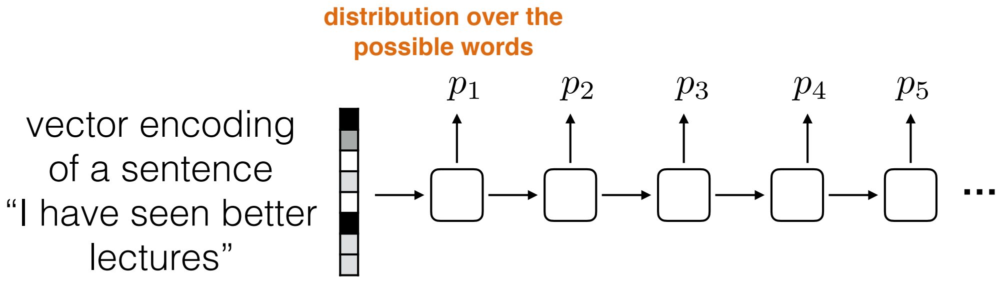


distribution over the possible words

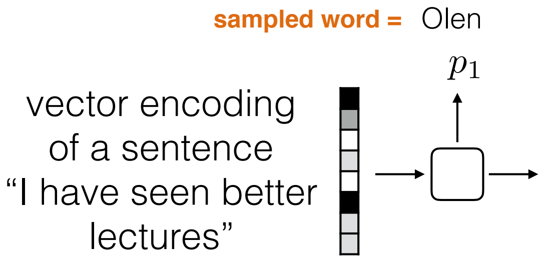
p_1 p_2 p_3 p_4 p_5

vector encoding of a sentence "I have seen better lectures"

…

Decoding (into a sentence)

- Our RNN now needs to also produce an output (e.g., a word) as well as update its state



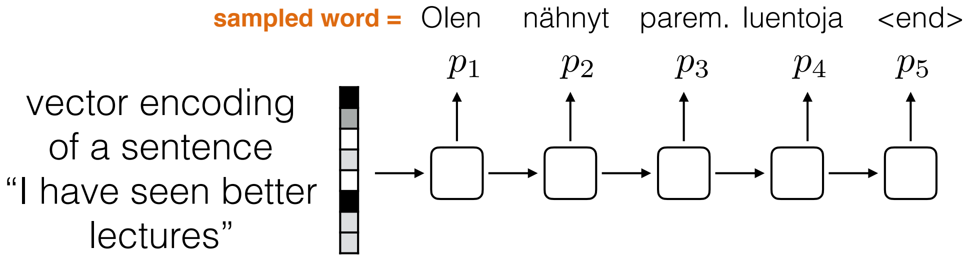
sampled word = Olen

p_1

vector encoding of a sentence "I have seen better lectures"

Decoding (into a sentence)

- Our RNN now needs to also produce an output (e.g., a word) as well as update its state



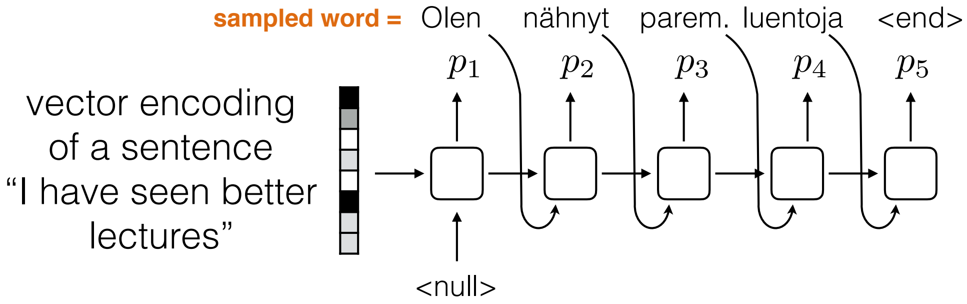
sampled word = Olen nähnyt parem. luentoja <end>

p_1 p_2 p_3 p_4 p_5

vector encoding of a sentence "I have seen better lectures"

Decoding (into a sentence)

- Our RNN now needs to also produce an output (e.g., a word) as well as update its state
- The output is fed in as an input (to gauge what's left)



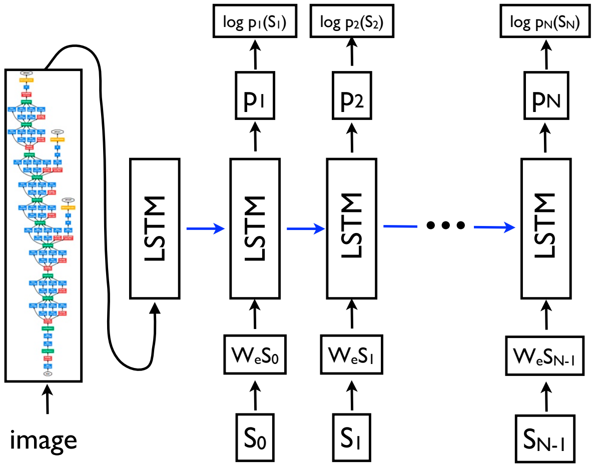
sampled word = Olen nähnyt parem. luentoja <end>

p_1 p_2 p_3 p_4 p_5

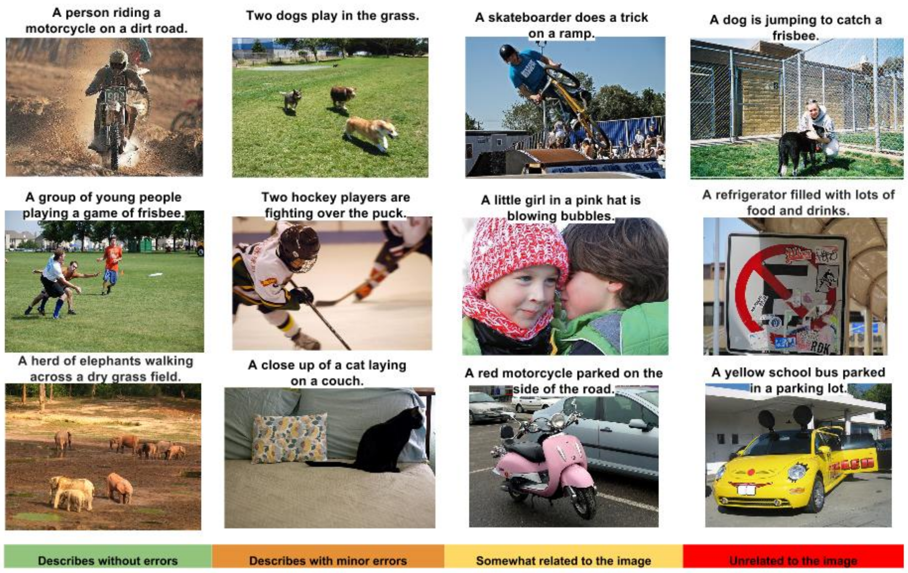
vector encoding of a sentence "I have seen better lectures"

<null>

Mapping images to text



Examples


A person riding a motorcycle on a dirt road.

Two dogs play in the grass.

A skateboarder does a trick on a ramp.

A dog is jumping to catch a frisbee.

A group of young people playing a game of frisbee.

Two hockey players are fighting over the puck.

A little girl in a pink hat is blowing bubbles.

A refrigerator filled with lots of food and drinks.

A herd of elephants walking across a dry grass field.

A close up of a cat laying on a couch.

A red motorcycle parked on the side of the road.

A yellow school bus parked in a parking lot.

Describes without errors | Describes with minor errors | Somewhat related to the image | Unrelated to the image

Key things

- Markov models for sequences
  - how to formulate, estimate, sample sequences from
- RNNs for generating (decoding) sequences
  - relation to Markov models
  - evolving hidden state
  - sampling from
- Decoding vectors into sequences