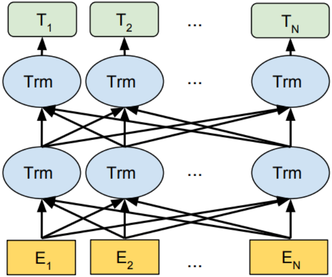
# Deep Learning for NLP

## BERT

## ARLMs vs. MLM



**Learning goals**

- Understand the concept of self-supervision
- Gain ability to distinguish different types of language models

# AGAIN: WHAT IS A LANGUAGE MODEL?

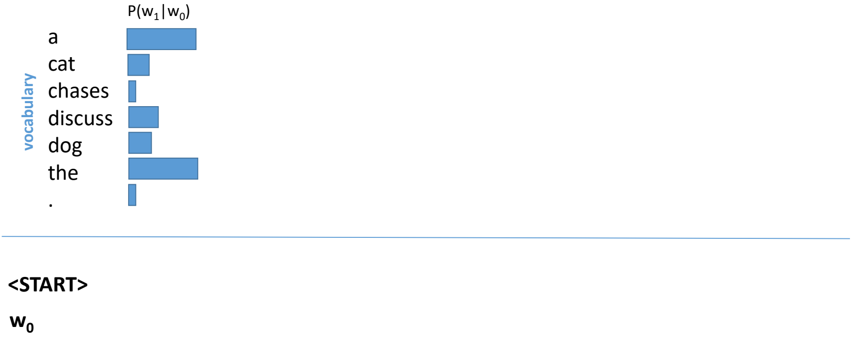
- Statistical model that predicts text that fits well for a given context (typically also text)
- Auto-regressive LMs (ARLMs)
    - Predict one word that is highly likely given a prompt (previous words)
    - For predicting an entire text, repeat the process (i.e., extend the prompt with previously predicted words)
    - To predict a text from scratch, use an extra symbol `<START>` as the initial prompt

# ARLM: TOY EXAMPLE

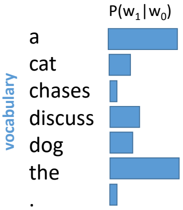
**<START>**

$\mathbf{w_0}$

# ARLM: TOY EXAMPLE



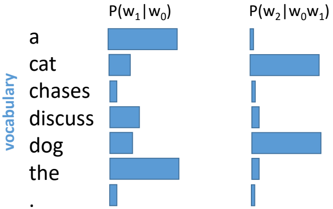
# ARLM: TOY EXAMPLE



**<START>** **the**

$\mathbf{w_0}$ $\mathbf{w_1}$

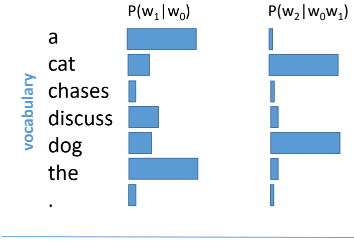
# ARLM: TOY EXAMPLE



**<START>** **the**

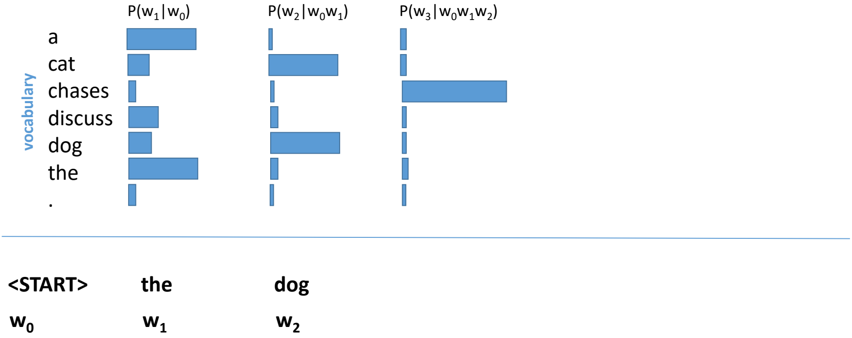
$\mathbf{w_0}$ $\mathbf{w_1}$

# ARLM: TOY EXAMPLE

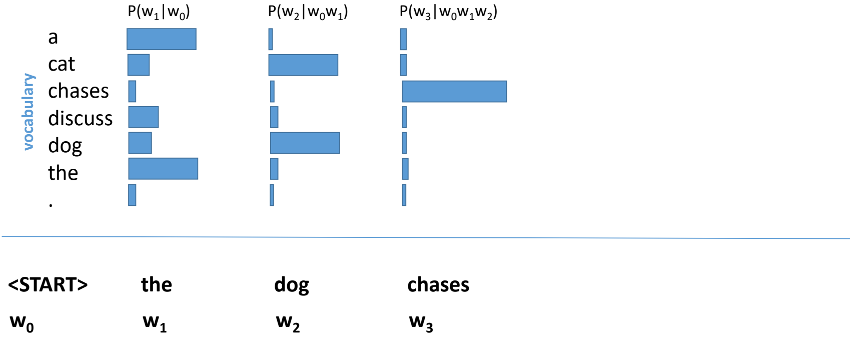


| <START> | the | dog |
|---|---|---|
| $w_0$ | $w_1$ | $w_2$ |

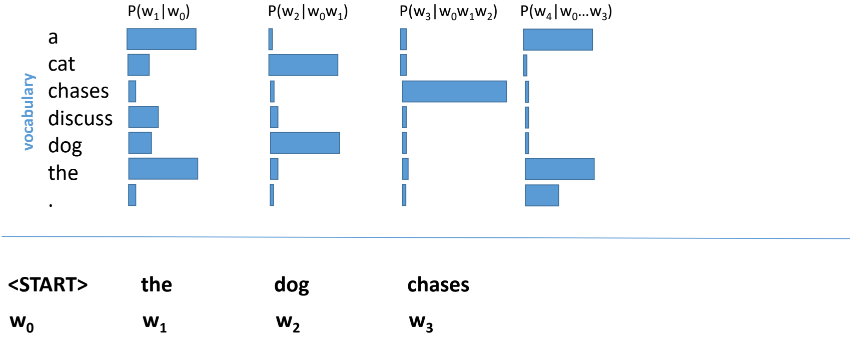
# ARLM: TOY EXAMPLE



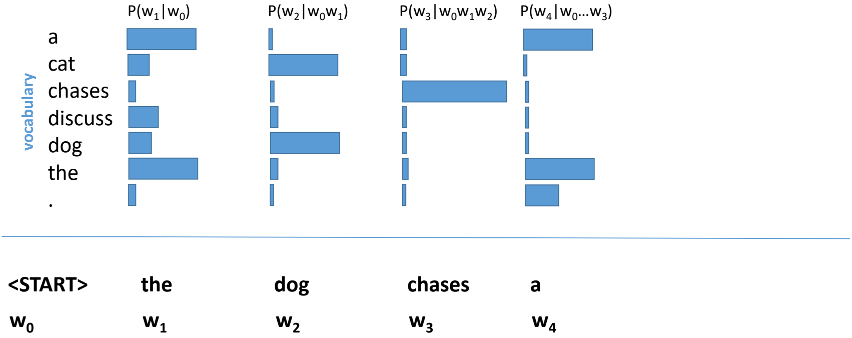
# ARLM: TOY EXAMPLE



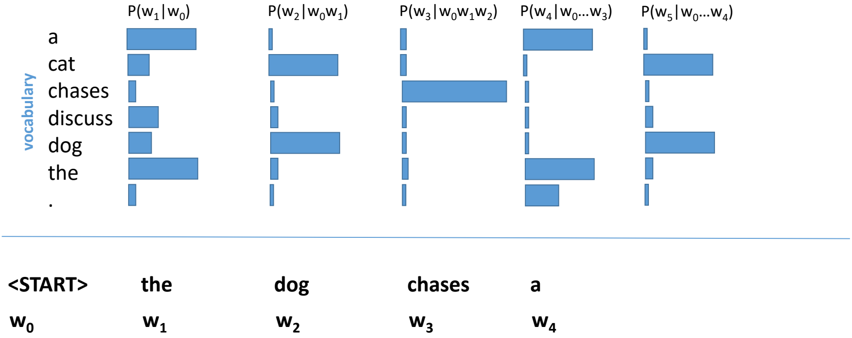
# ARLM: TOY EXAMPLE



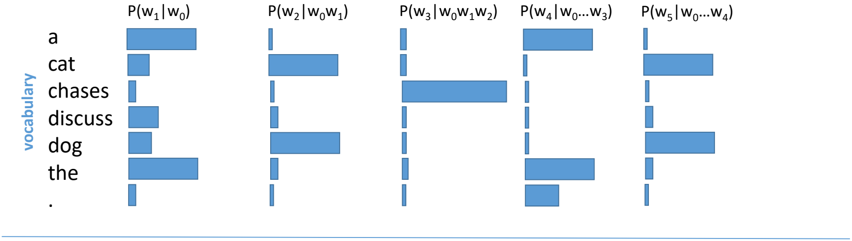
# ARLM: TOY EXAMPLE



# ARLM: TOY EXAMPLE

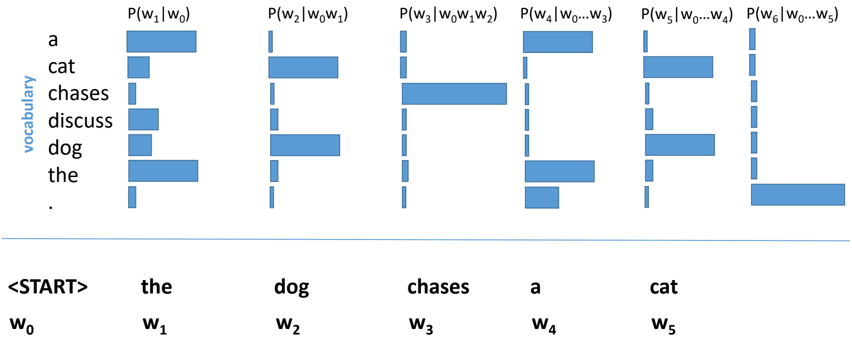


# ARLM: TOY EXAMPLE

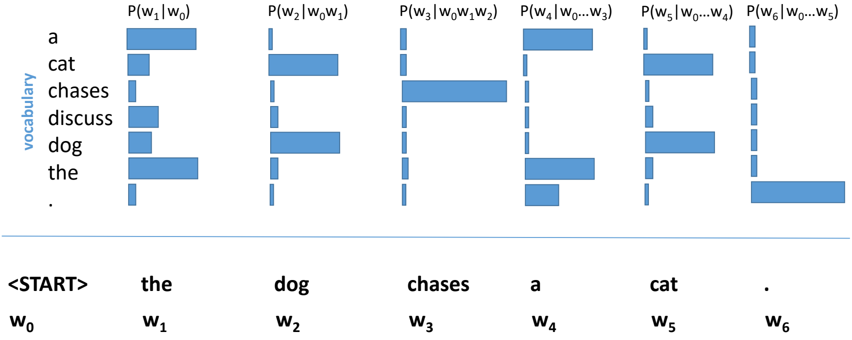


| | | | | | |
|---|---|---|---|---|---|
| **<START>** | **the** | **dog** | **chases** | **a** | **cat** |
| $\mathbf{w_0}$ | $\mathbf{w_1}$ | $\mathbf{w_2}$ | $\mathbf{w_3}$ | $\mathbf{w_4}$ | $\mathbf{w_5}$ |

# ARLM: TOY EXAMPLE



# ARLM: TOY EXAMPLE



# ARLM: PROBABILISTIC INTERPRETATION I

- Gives an estimate for the probability of a sentence using conditional probabilities
- In general:

$$P(A \cap B) = P(B) \cdot P(A|B)$$

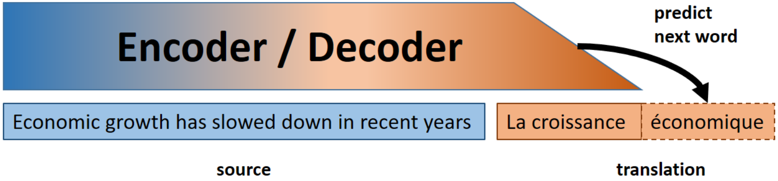
- For $P(\mathit{sentence})$:

$$P(w_1, w_2, \ldots, w_n | w_0)$$

$$= P(w_1|w_0) \cdot P(w_2|w_0, w_1) \cdot \ldots \cdot P(w_n|w_0, \ldots, w_{n-1})$$

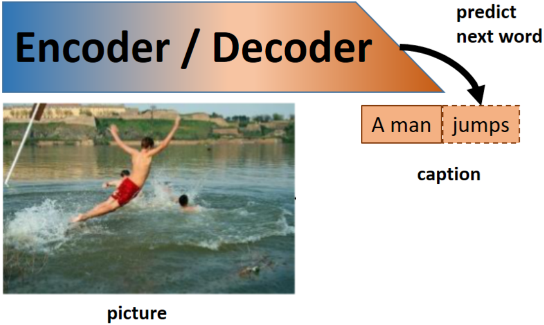
# EXAMPLES OF ARLMS (1) I

## Neural Machine Translation:



# EXAMPLES OF ARLMS (1) I

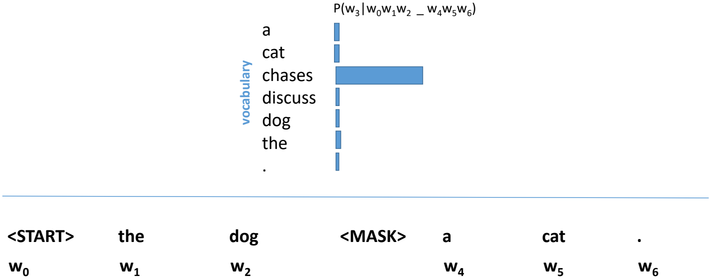
## Image Captioning:



# MASKED LANGUAGE MODELS (MLM) I

- We have seen auto-regressive LMs
  - context: previous words
  - predict: next word
- Another type: *Masked* LMs (MLMs)
  - context: surrounding words
  - predict: masked word

# MLM: TOY EXAMPLE I



# MLM: PROBABILISTIC INTERPRETATION I

- Estimates $P(w_i|w_0, w_1, w_{i-1}, \ldots, w_{i+1}, w_n)$
- No “clean“ estimate for $P(\mathit{sentence})$, as

$$P(w_1, w_2, \ldots, w_n|w_0)$$

$$\neq P(w_1|w_0, w_2, \ldots, w_n) \cdot P(w_2|w_0, w_1, w_3, \ldots, w_n)$$

- ARLMs are better than MLMs for generating texts
- Advantage of MLMs: Learning contextualized representations

# SELF-SUPERVISION I

# DEFINITION

*Unsupervised Learning:*

- No labels attached to the data
- Learn patterns / clusters from the features only

*Supervised Learning:*

- (Gold) Labels attached to the data
- Learn from the association between features and labels

**Self-Supervised Learning:**

- No *external* labels attached to the data
  $\rightarrow$ Samples with suitable labels can be generated from the known structure of the data itself
- *Technically* supervised learning, but *no labeling effort* $+$ simultaneous ability to generate massive amounts of labeled data points

# SELF-SUPERVISED OBJECTIVES I

**Self-supervised objectives:**

- Skip-gram objective (cf. word2vec)
- Language modeling objective
- *Masked language modeling (MLM)* objective
- ... and many more possibilities for text data