

Lecture 7: Tricks + Word Embeddings

Alan Ritter

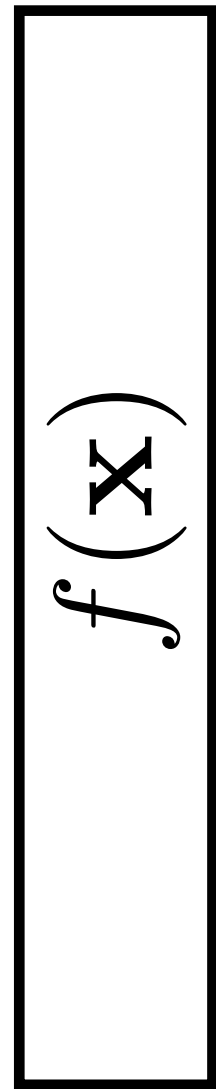
(many slides from Greg Durrett)

Recall: Feedforward NNs

$$P(\mathbf{y}|\mathbf{x}) = \text{softmax}(Wg(Vf(\mathbf{x})))$$

Recall: Feedforward NNs

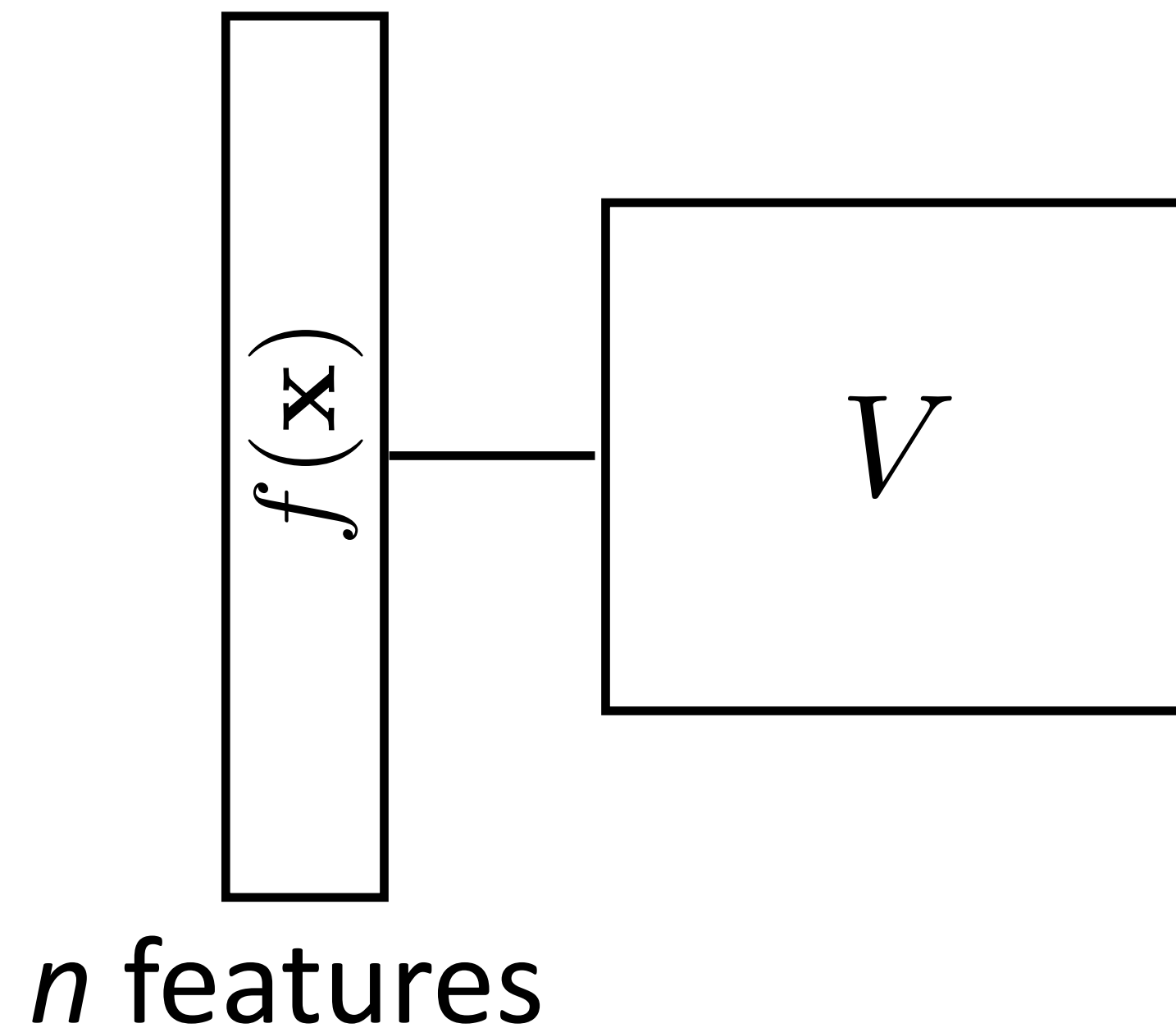
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n features

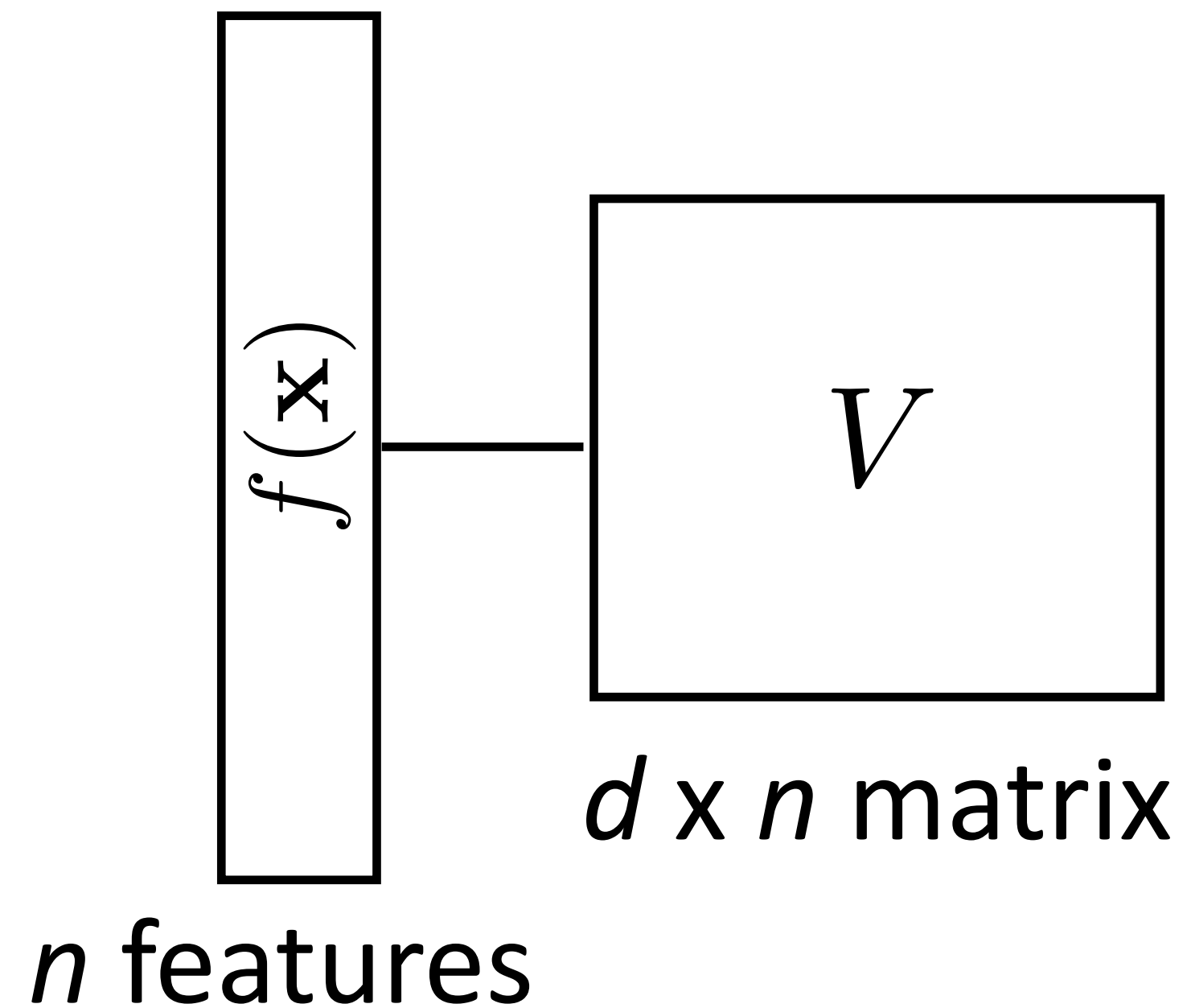
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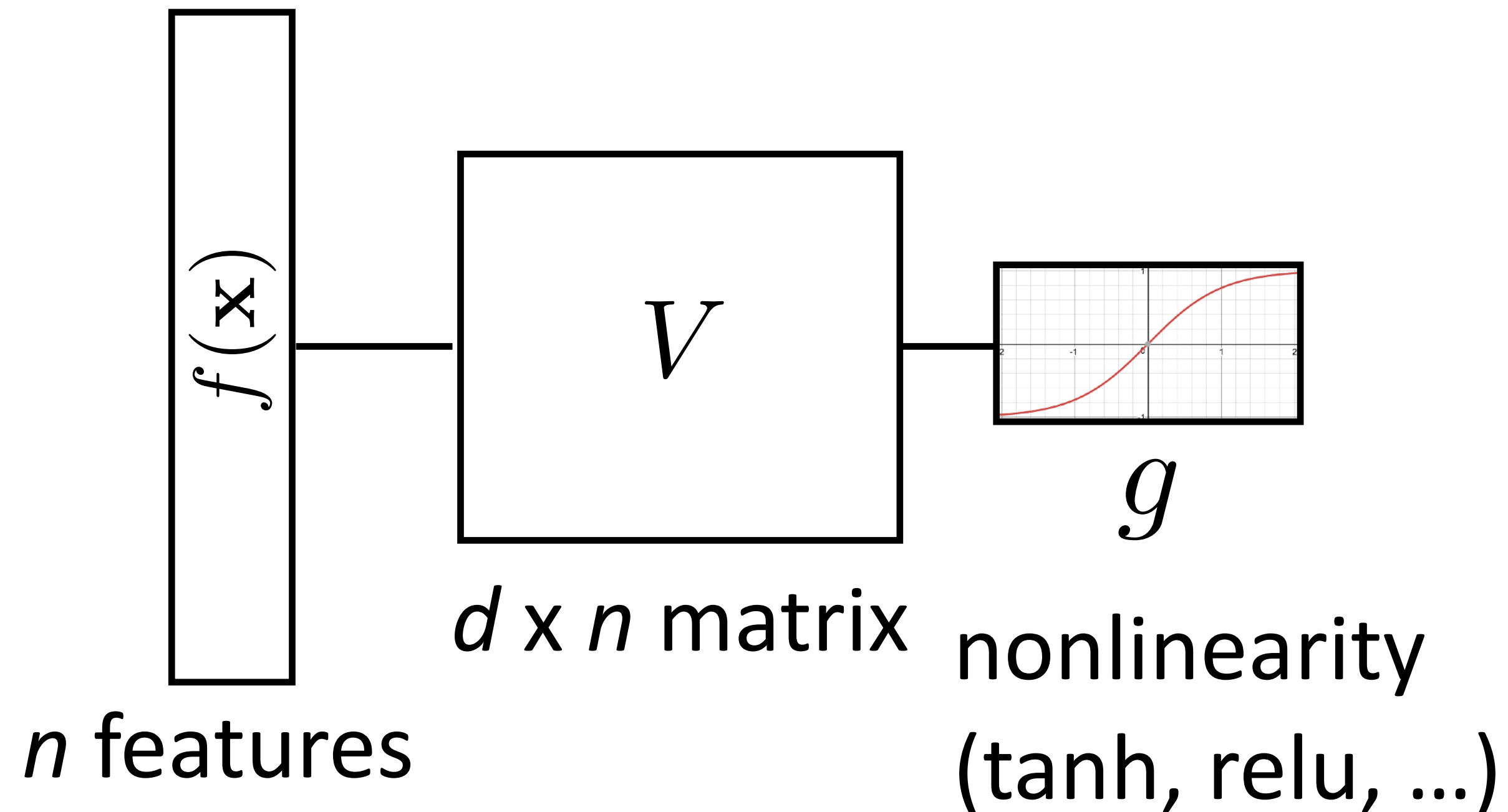
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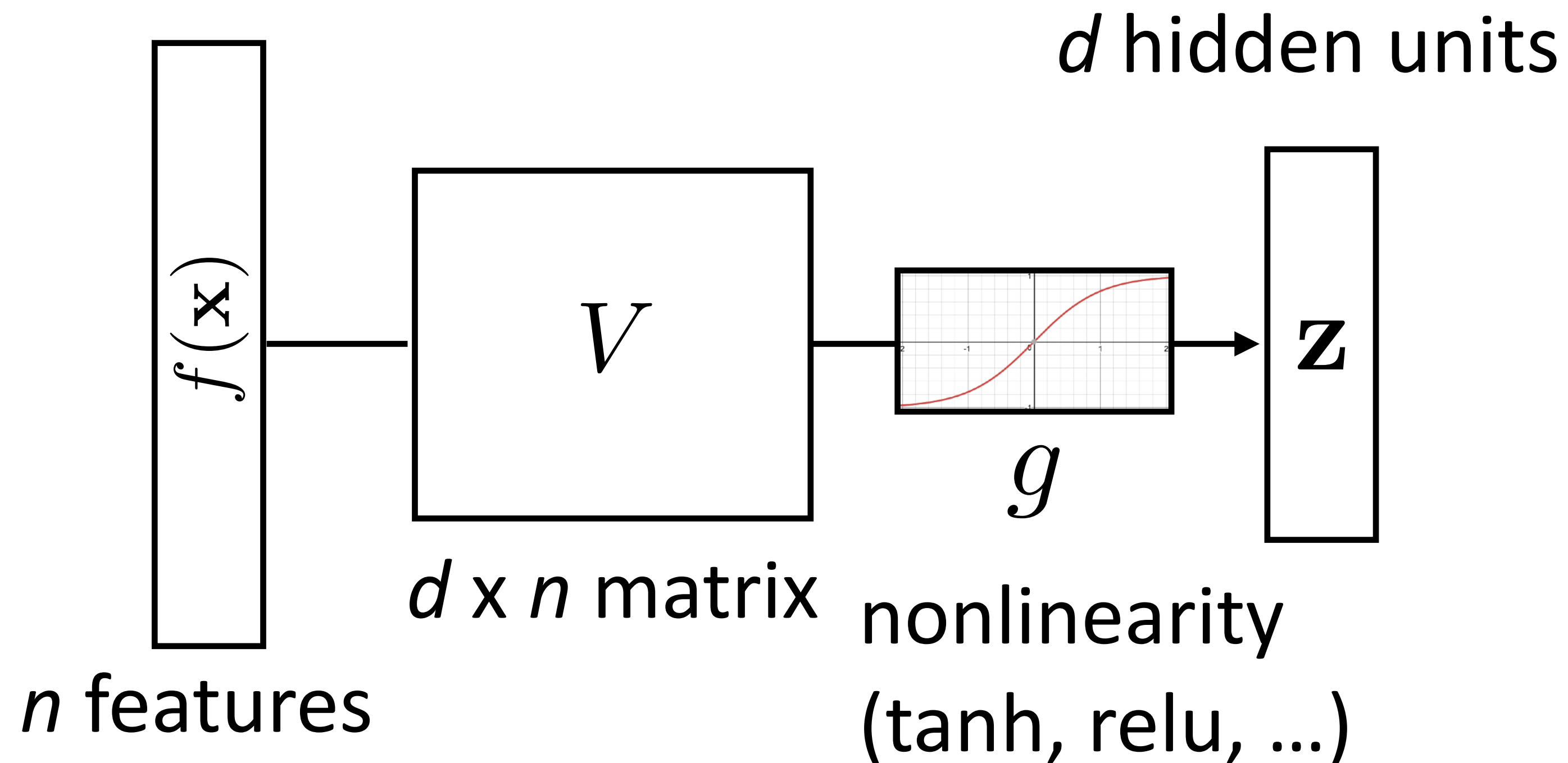
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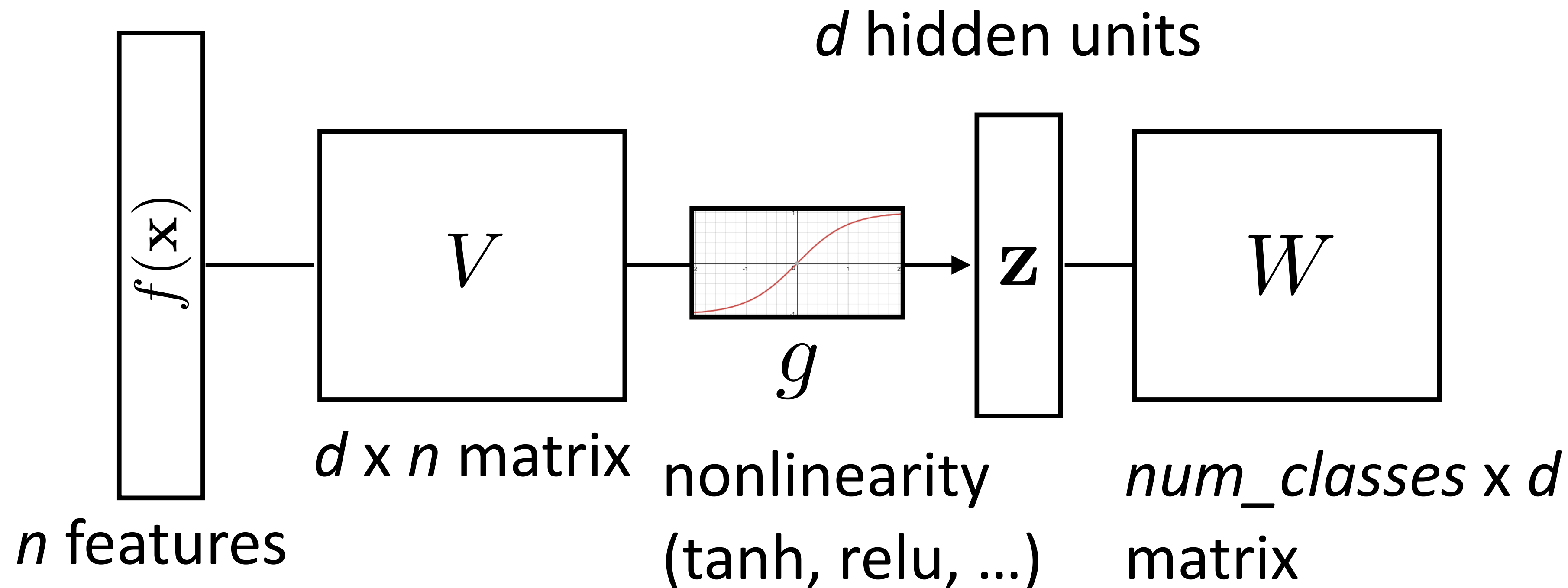
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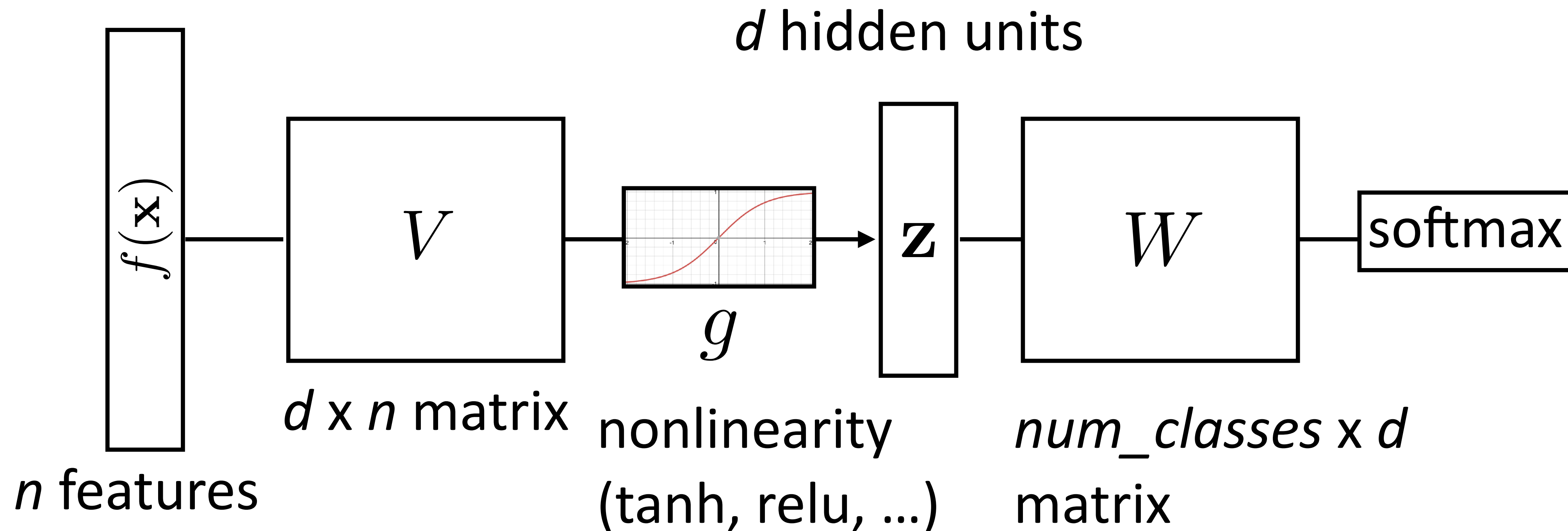
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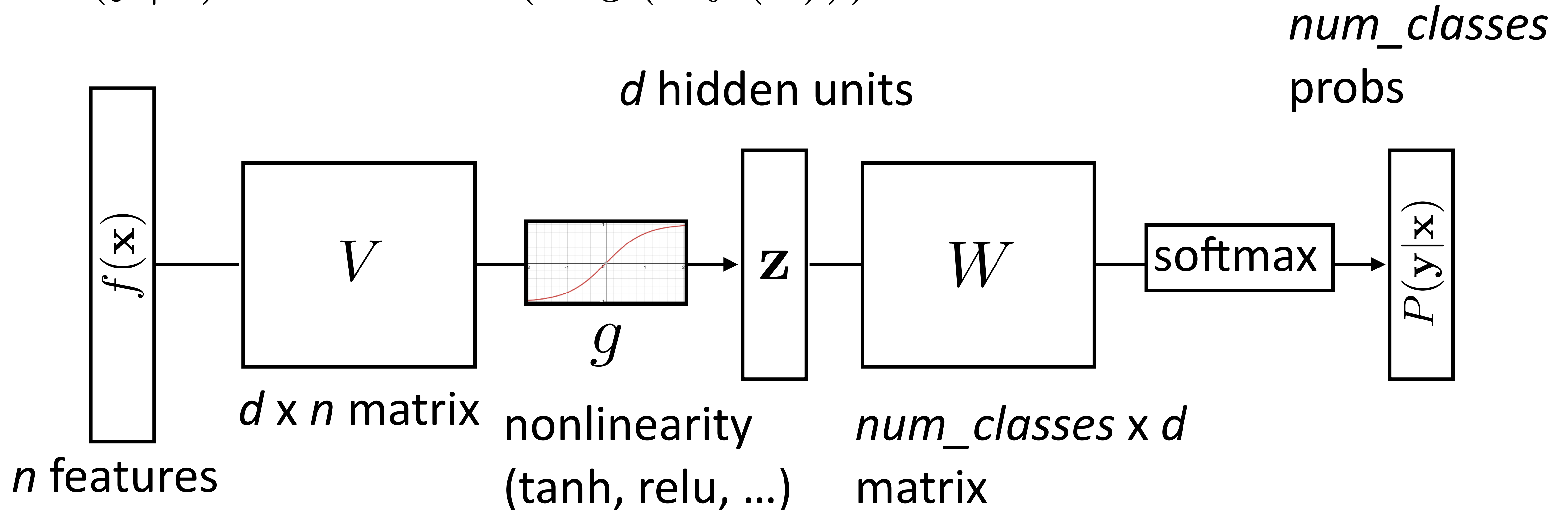
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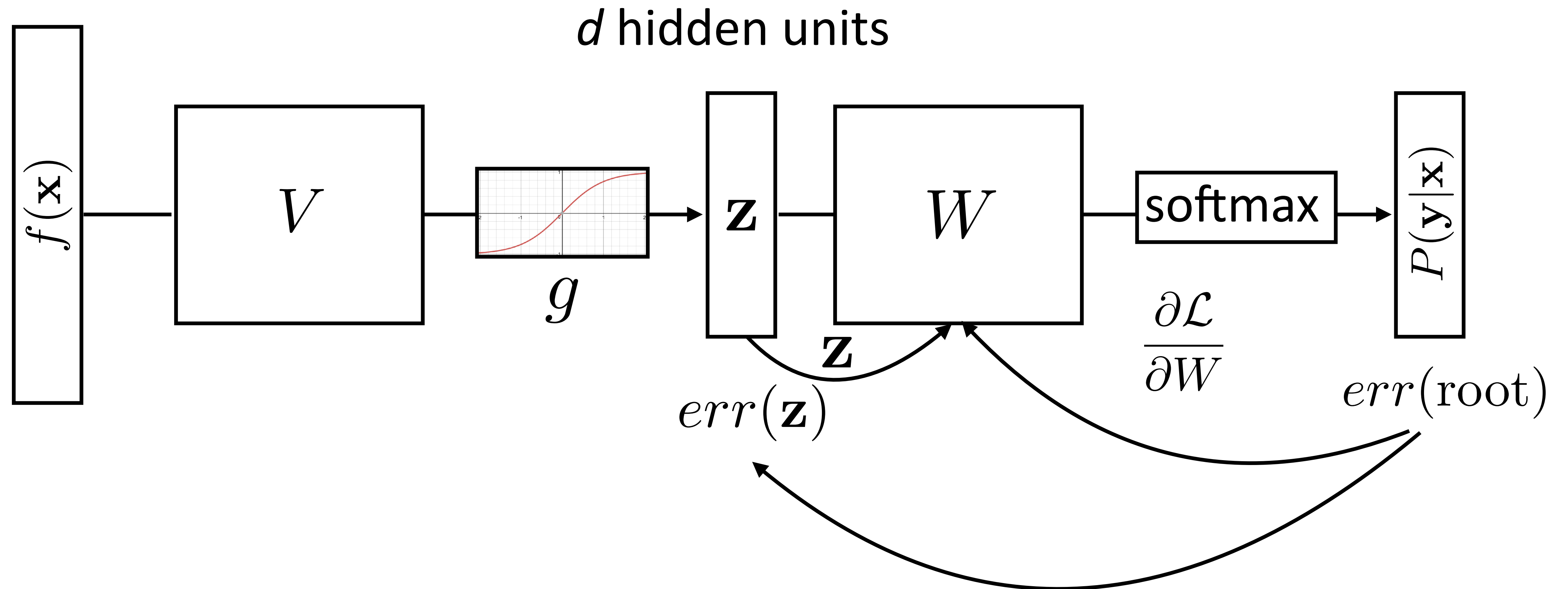
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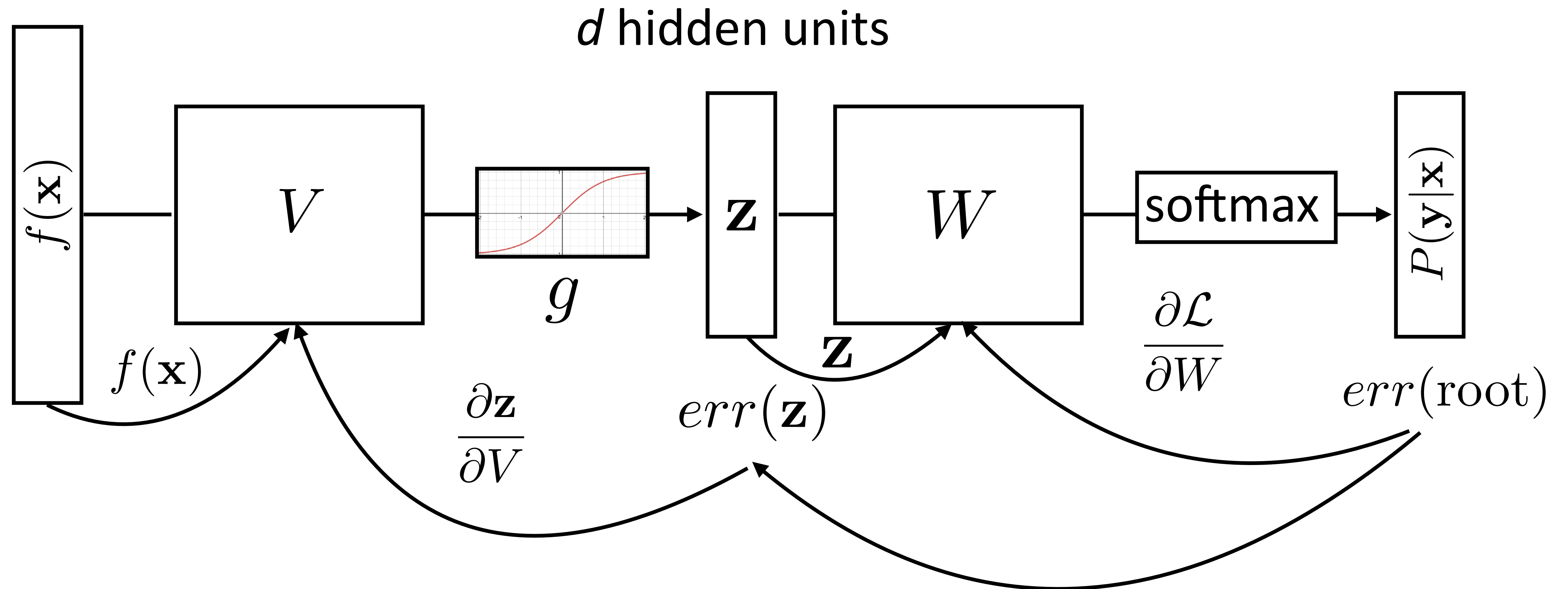
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This Lecture

- ▶ Training
- ▶ Word representations
- ▶ word2vec/GloVe
- ▶ Evaluating word embeddings

Training Tips

Training Basics

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- ▶ Basic formula: compute gradients on batch, use first-order opt. method

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- ▶ How to initialize? How to regularize? What optimizer to use?



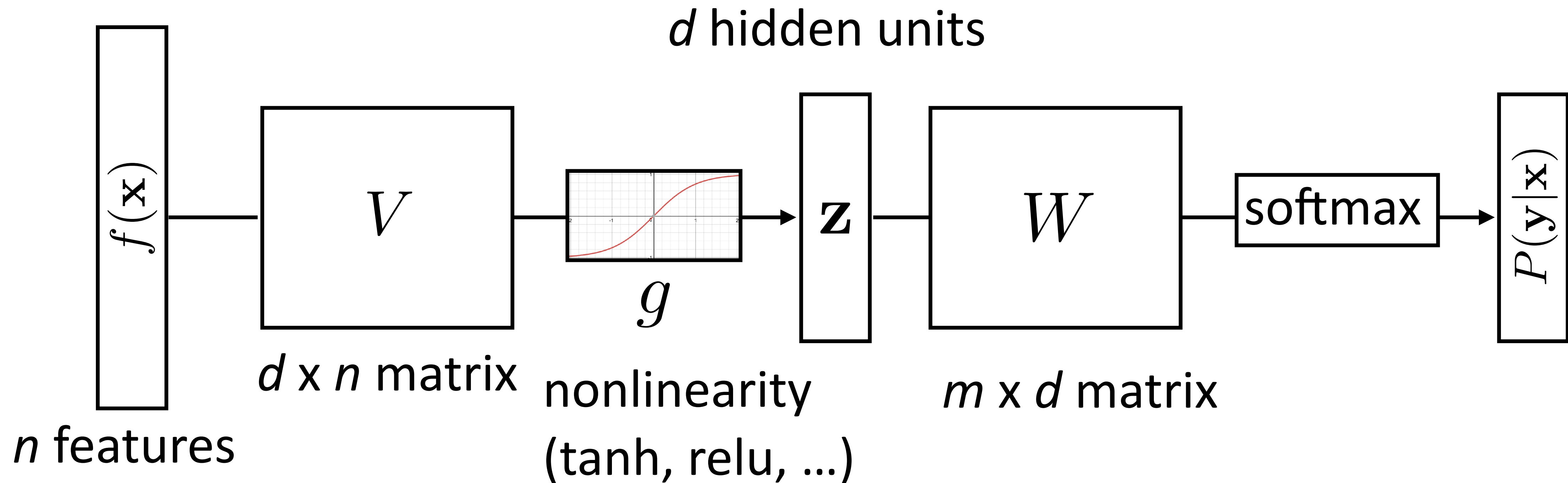
Training Basics

- ▶ Basic formula: compute gradients on batch, use first-order opt. method
- ▶ How to initialize? How to regularize? What optimizer to use?
- ▶ This lecture: some practical tricks. Take deep learning or optimization courses to understand this further



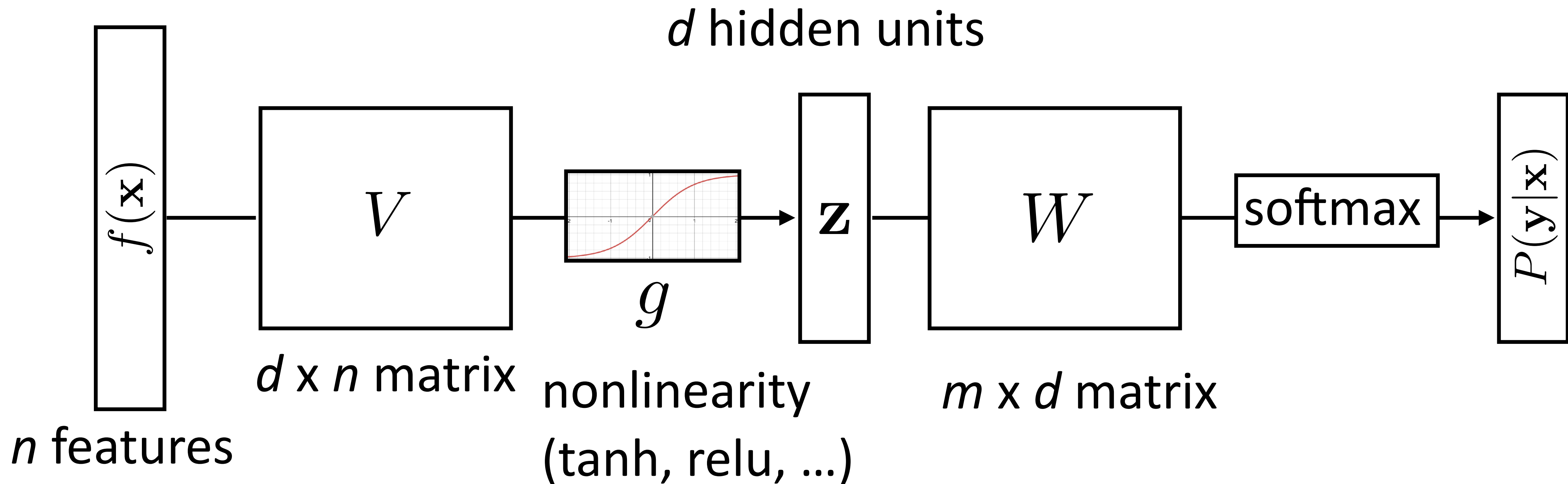
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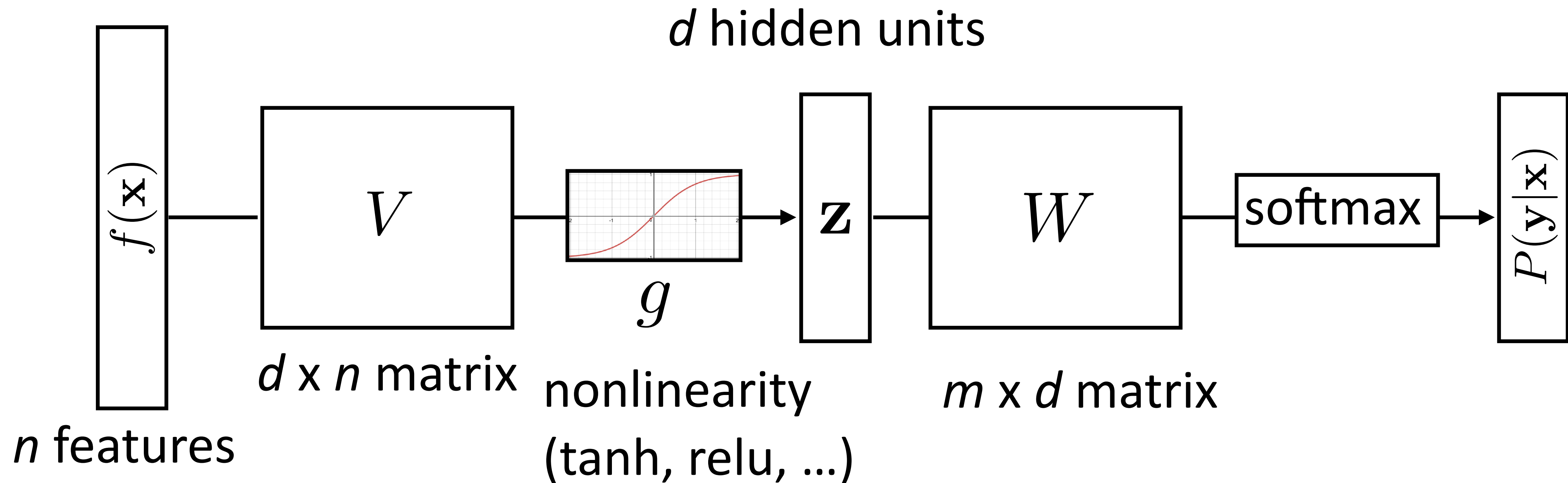
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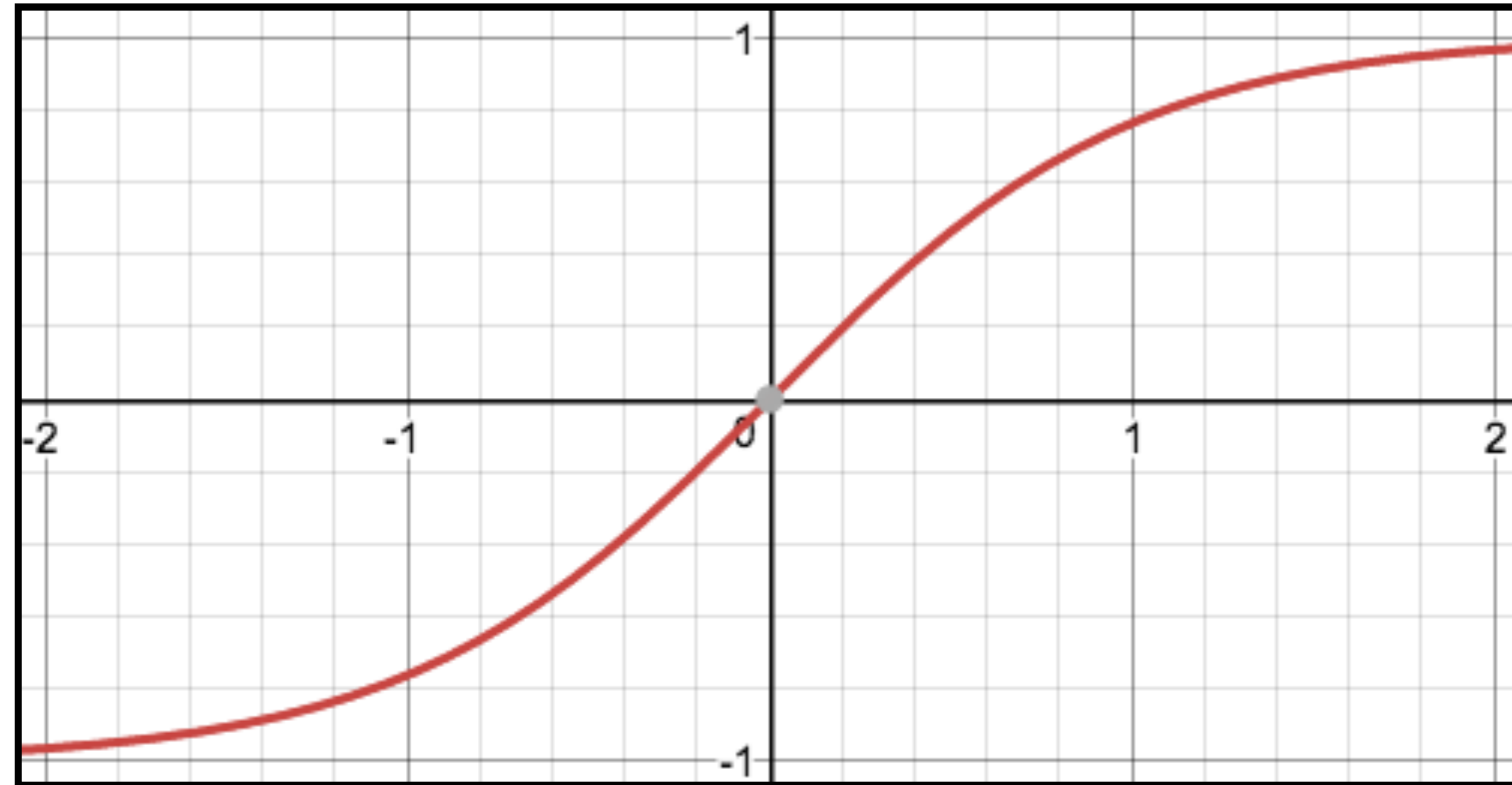
- ▶ How do we initialize V and W ? What consequences does this have?
- ▶ *Nonconvex* problem, so initialization matters!

How does initialization affect learning?

- ▶ Nonlinear model...how does this affect things?

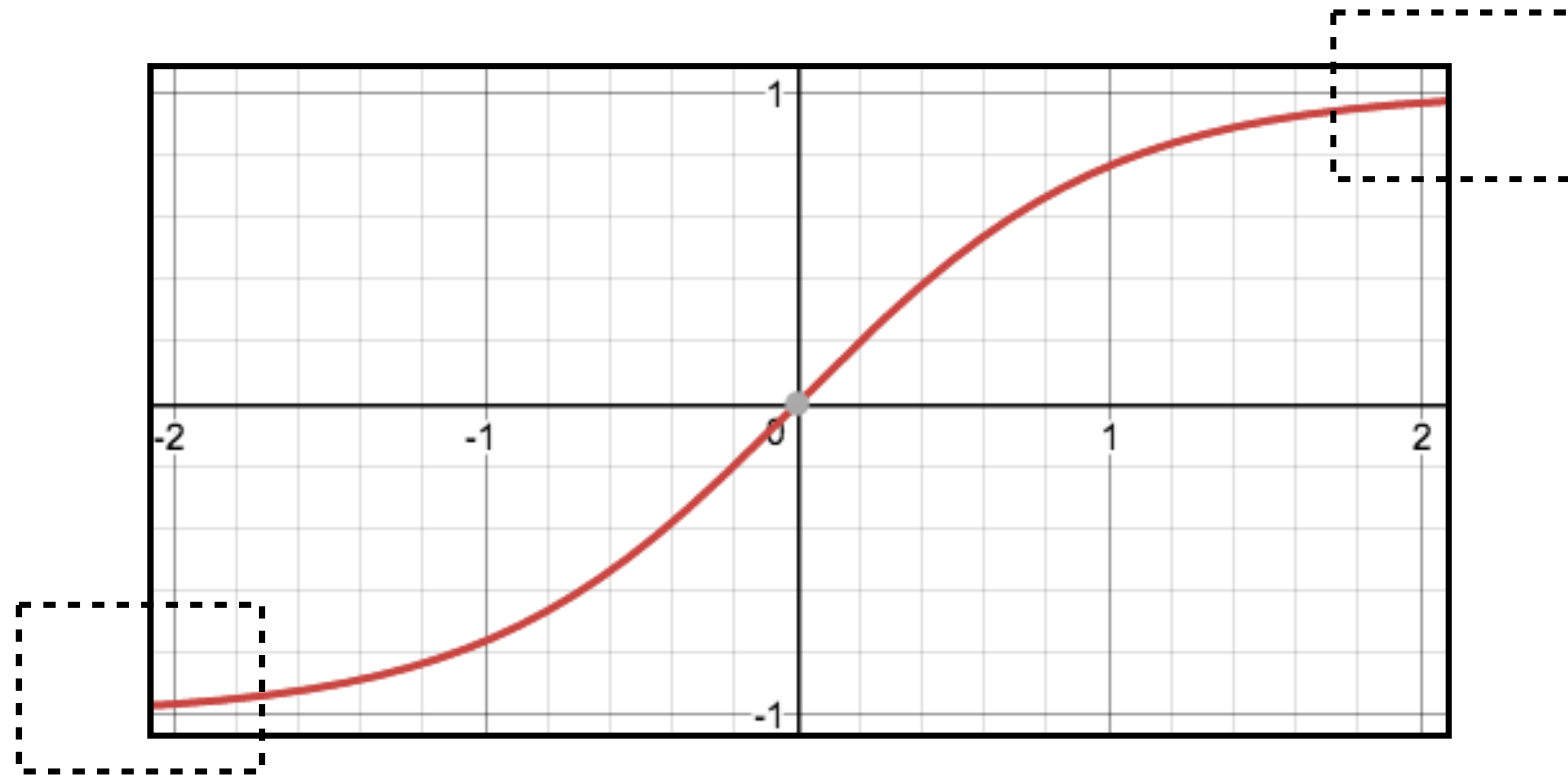
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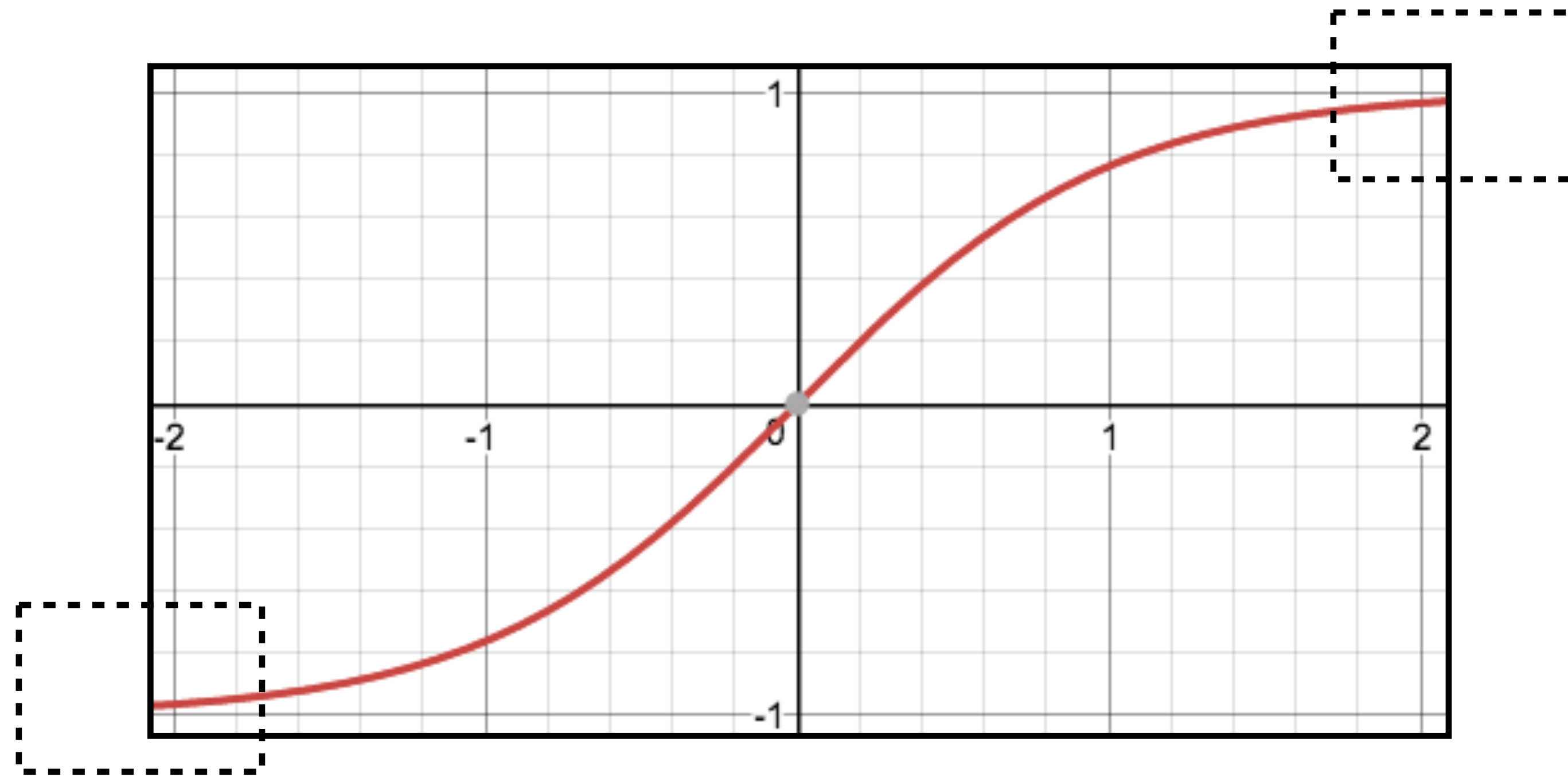
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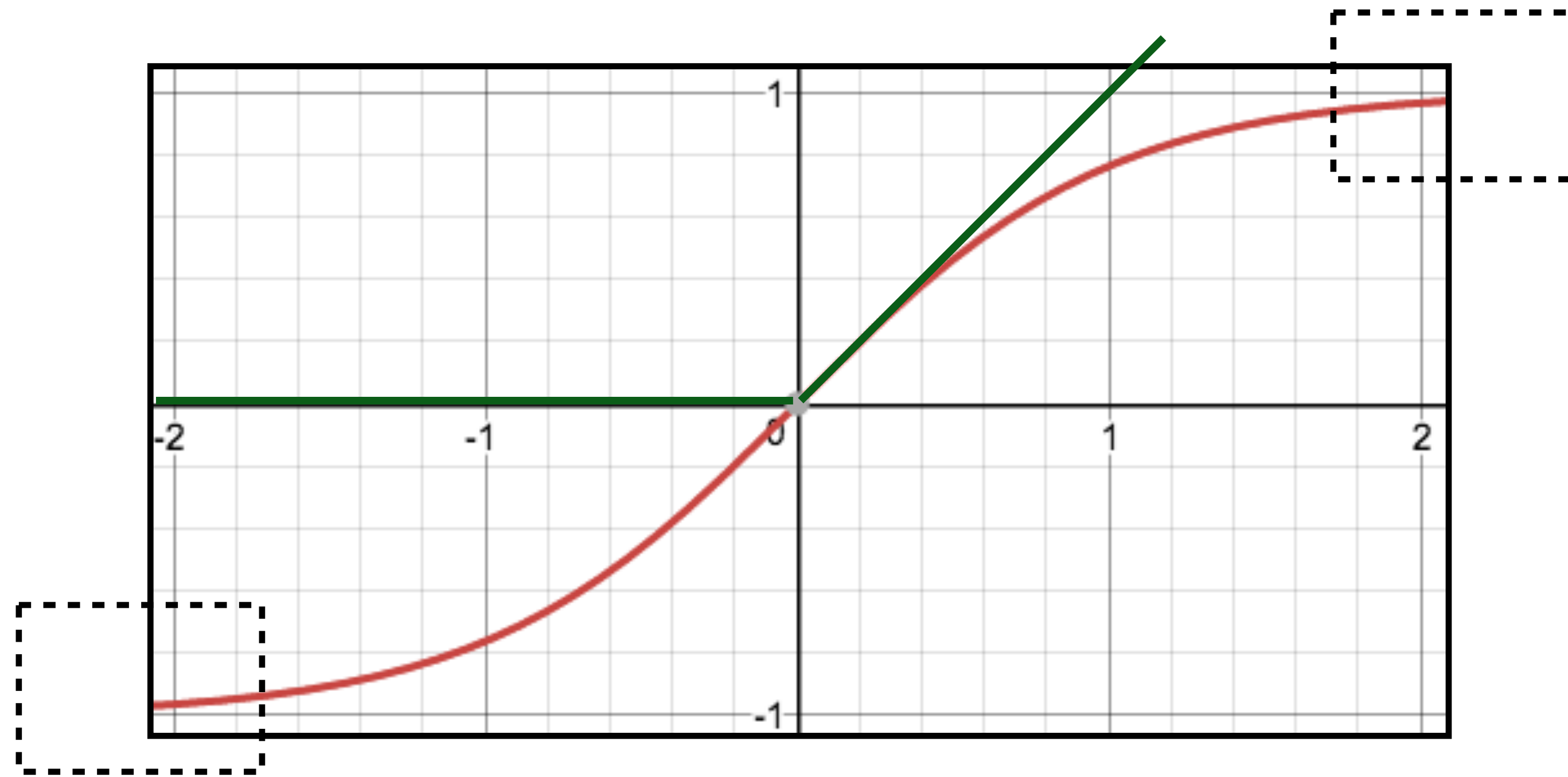
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- ▶ If cell activations are too large in absolute value, gradients are small

How does initialization affect learning?

- ▶ Nonlinear model...how does this affect things?



- ▶ If cell activations are too large in absolute value, gradients are small
- ▶ **ReLU**: larger dynamic range (all positive numbers), but can produce big values, can break down if everything is too negative

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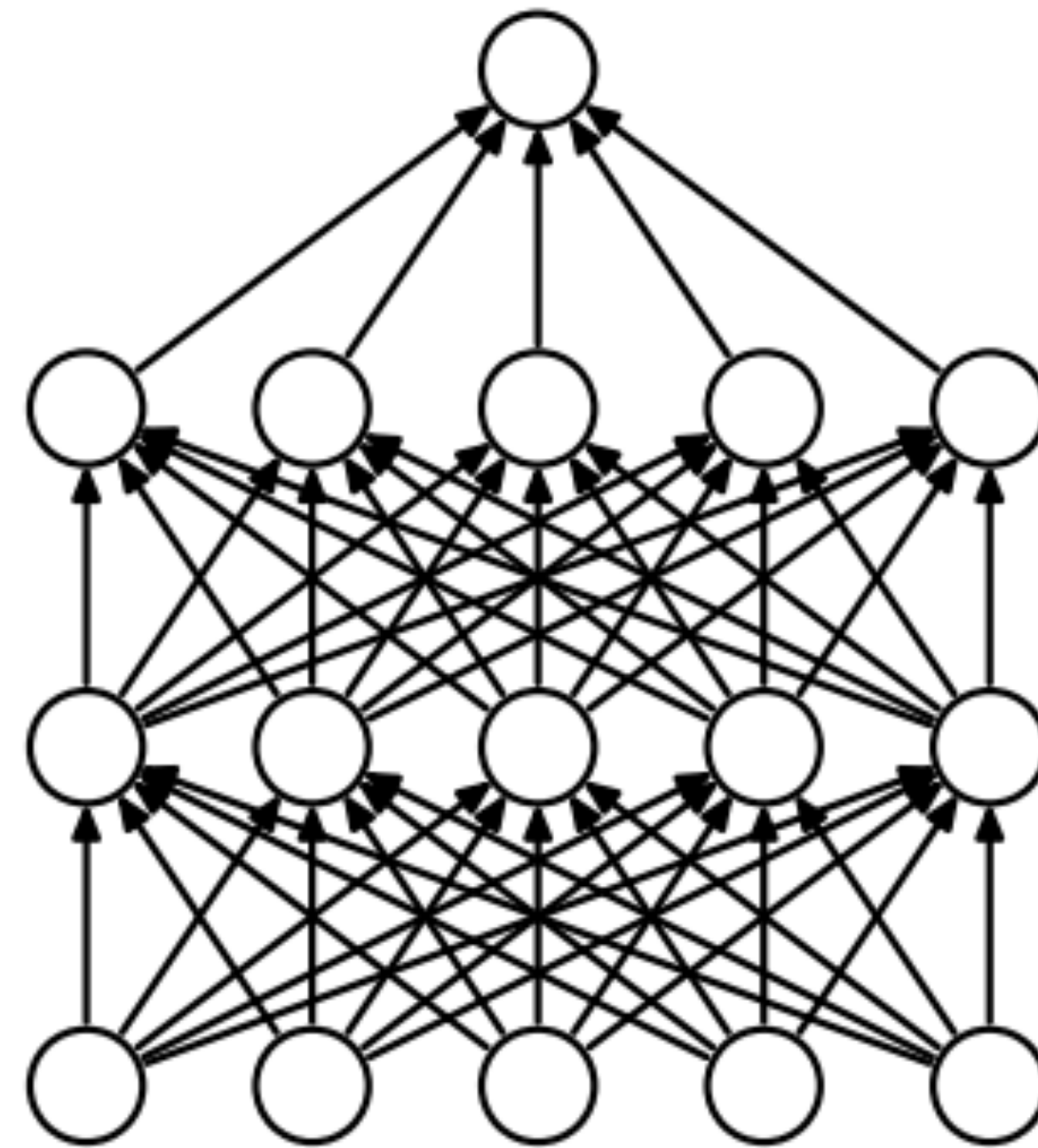
- ▶ Xavier initializer: $U \left[-\sqrt{\frac{6}{\text{fan-in} + \text{fan-out}}}, +\sqrt{\frac{6}{\text{fan-in} + \text{fan-out}}} \right]$

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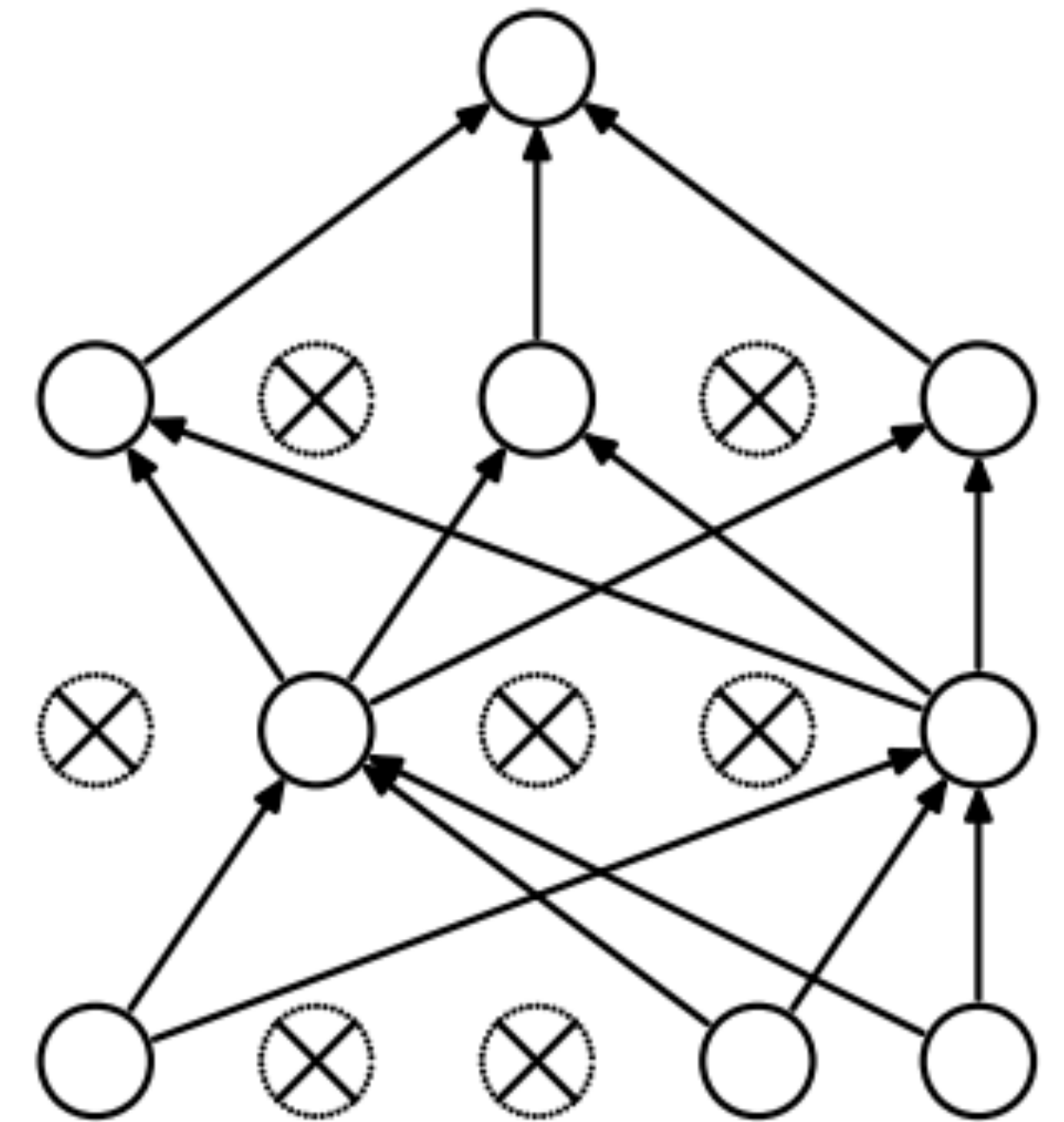
- ▶ Batch normalization (Ioffe and Szegedy, 2015): periodically shift+rescale each layer to have mean 0 and variance 1 over a batch (useful if net is deep)

Dropout

- Probabilistically zero out parts of the network during training to prevent overfitting, use whole network at test time



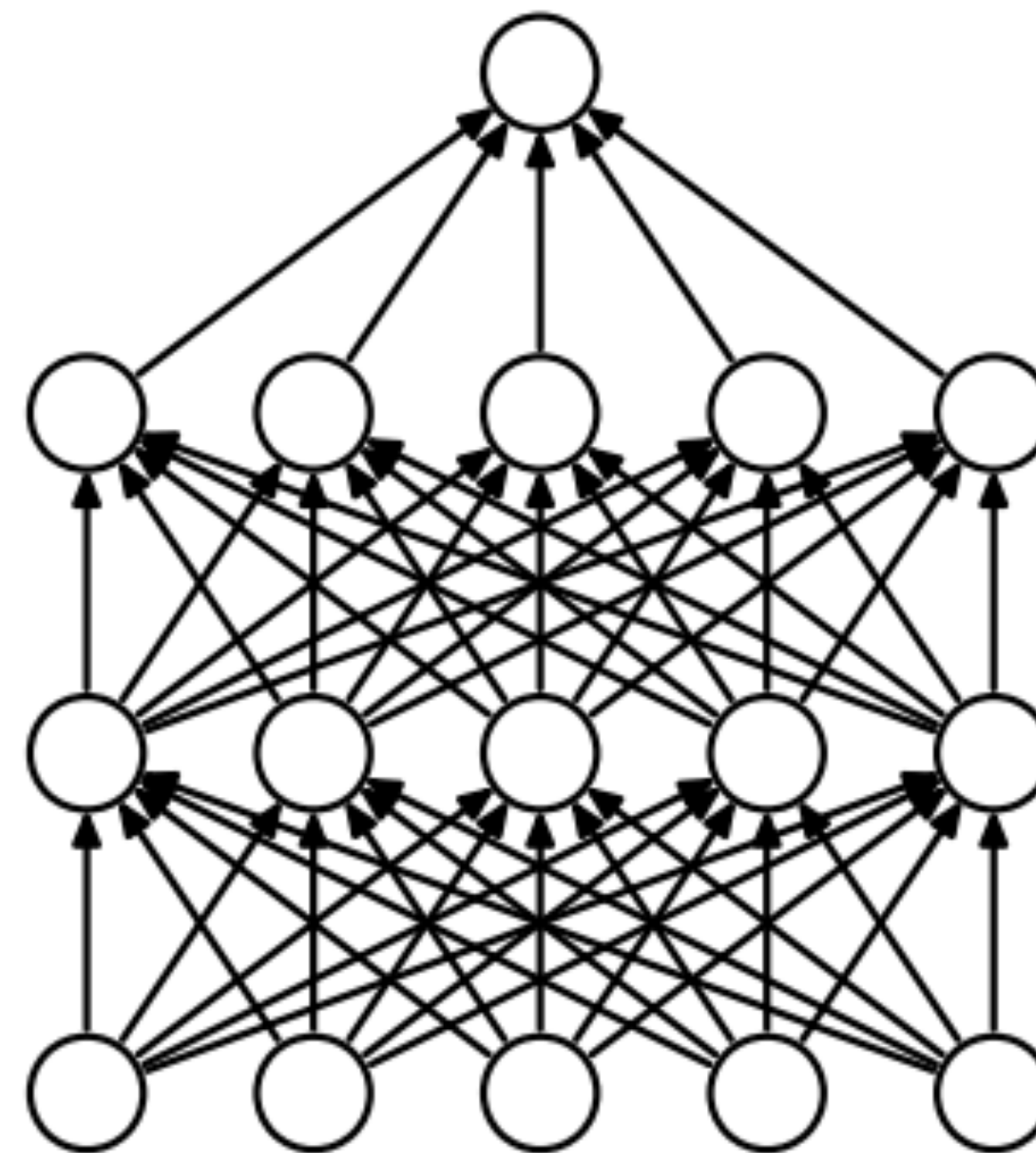
(a) Standard Neural Net



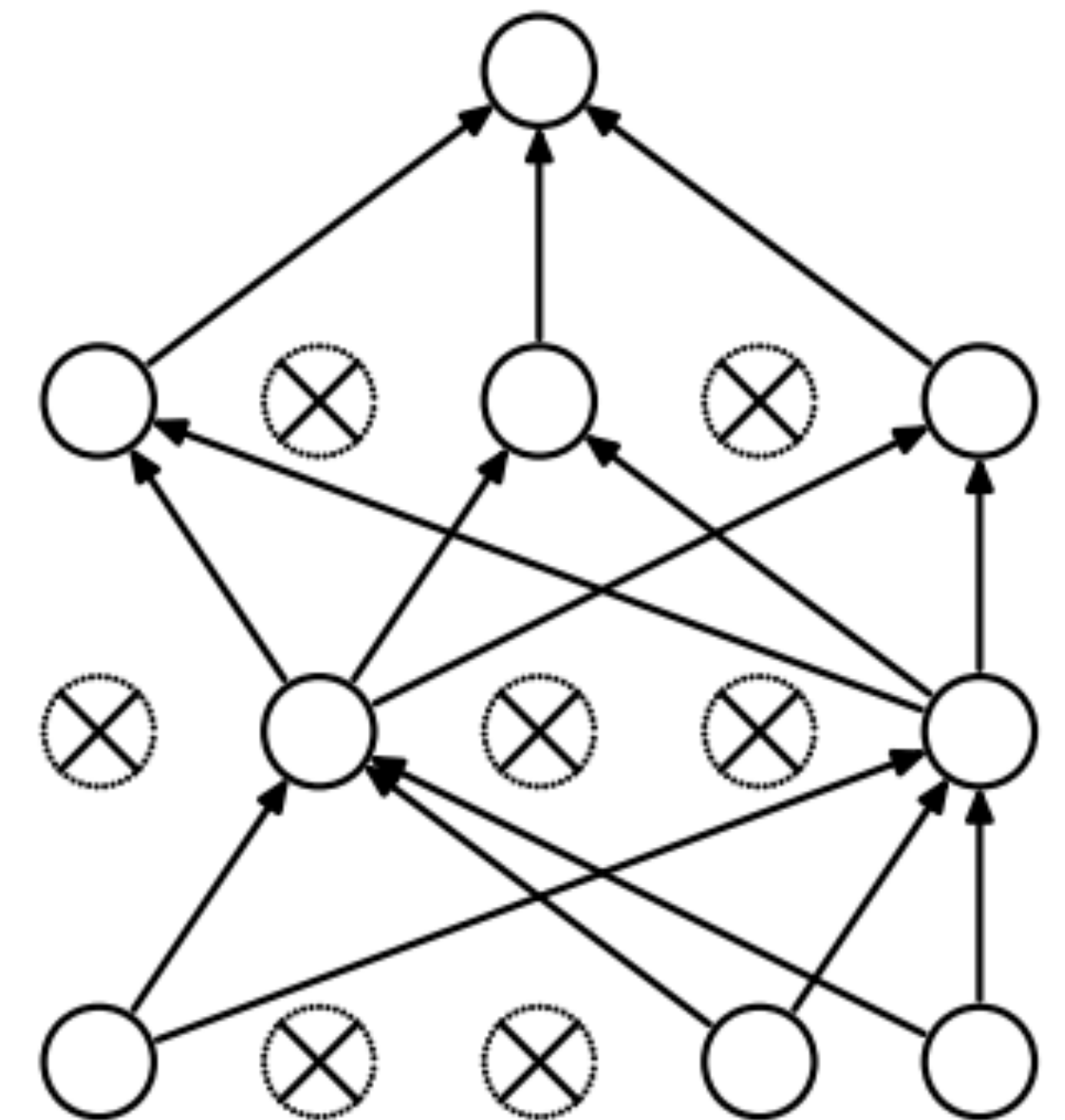
(b) After applying dropout.

Dropout

- ▶ Probabilistically zero out parts of the network during training to prevent overfitting, use whole network at test time
- ▶ Form of stochastic regularization



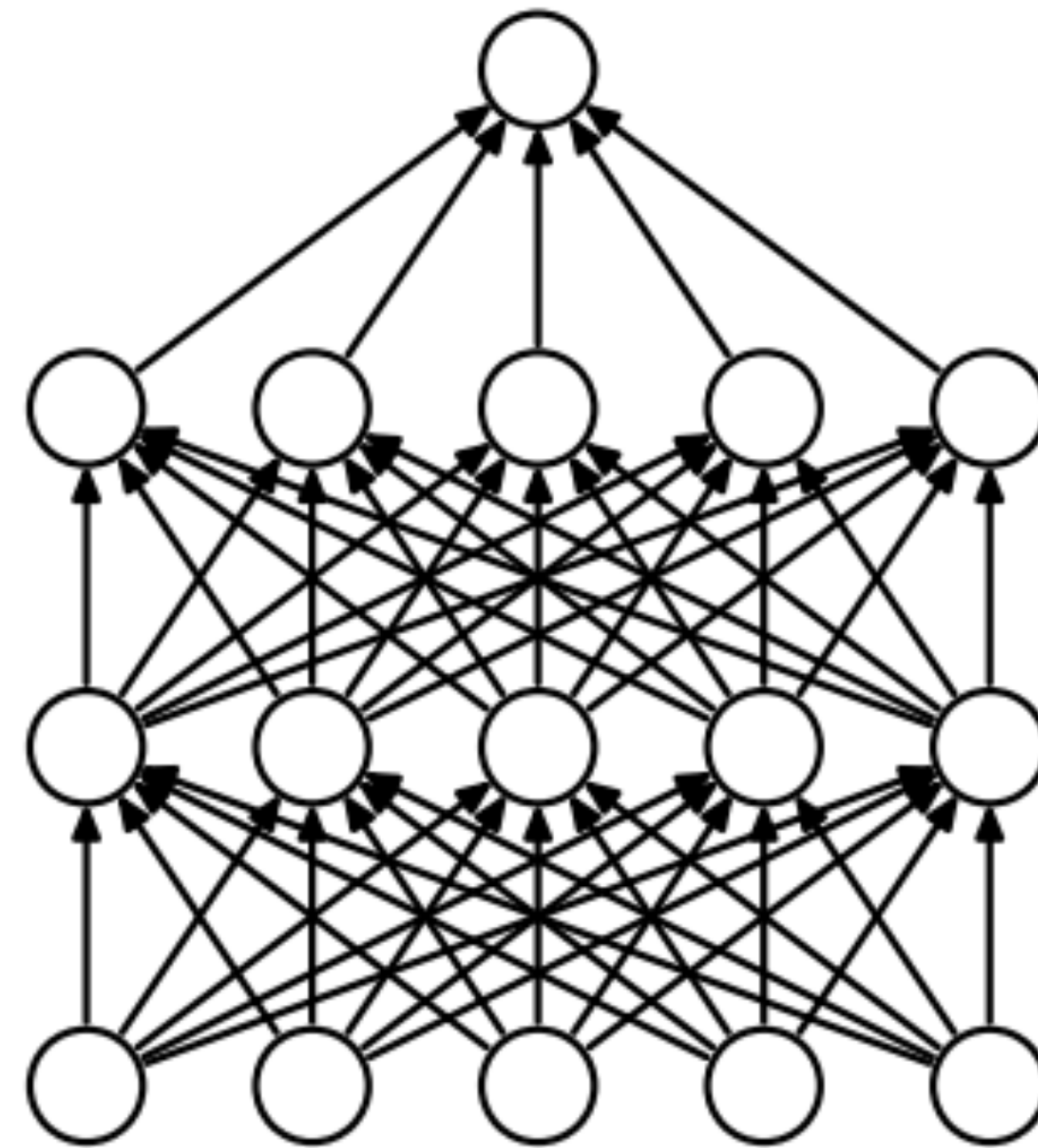
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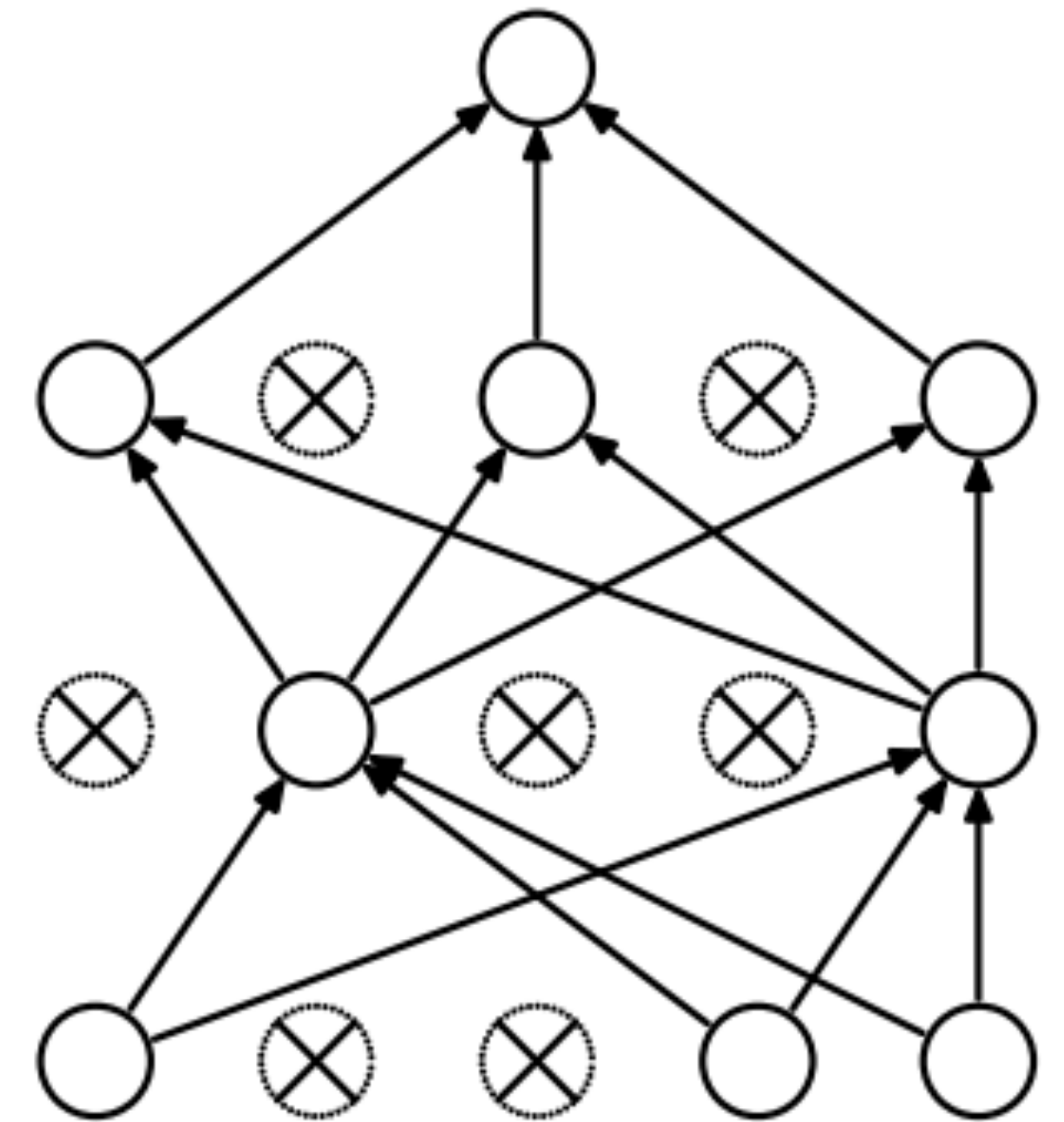
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Dropout

- ▶ Probabilistically zero out parts of the network during training to prevent overfitting, use whole network at test time
- ▶ Form of stochastic regularization
- ▶ Similar to benefits of ensembling: network needs to be robust to missing signals, so it has redundancy



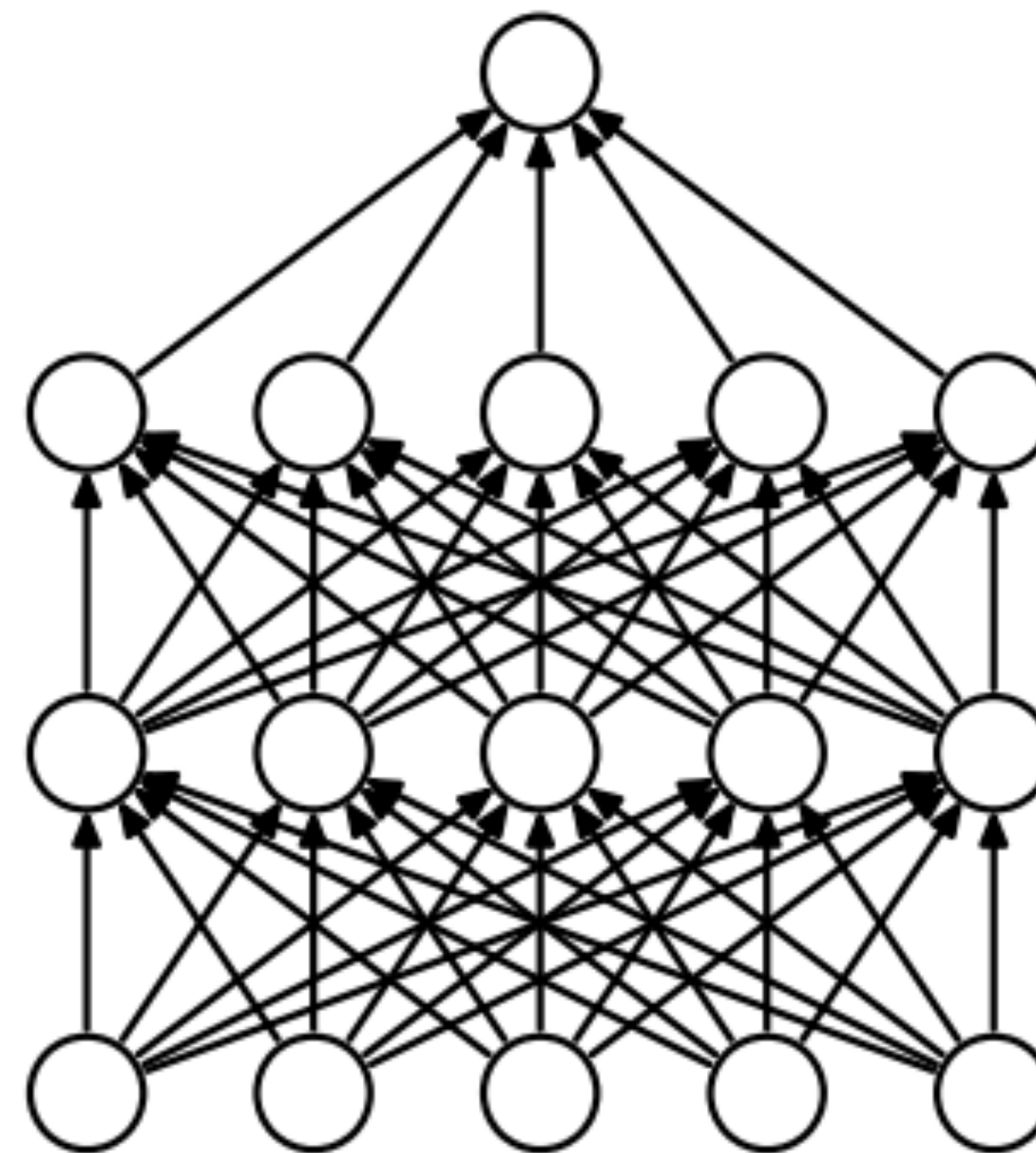
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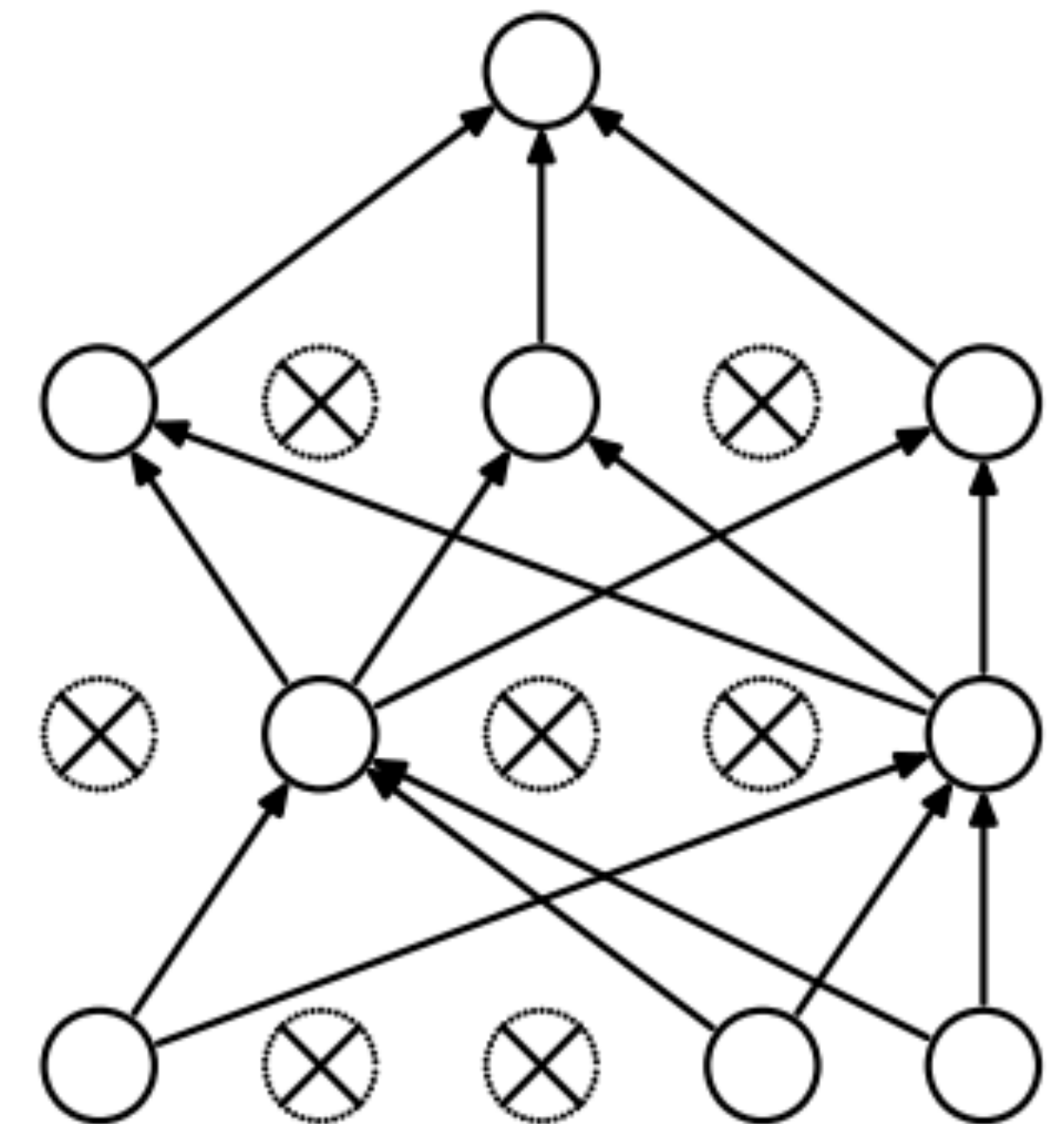
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Dropout

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- ▶ One line in Pytorch/Tensorflow



(a) Standard Neural Net



(b) After applying dropout.

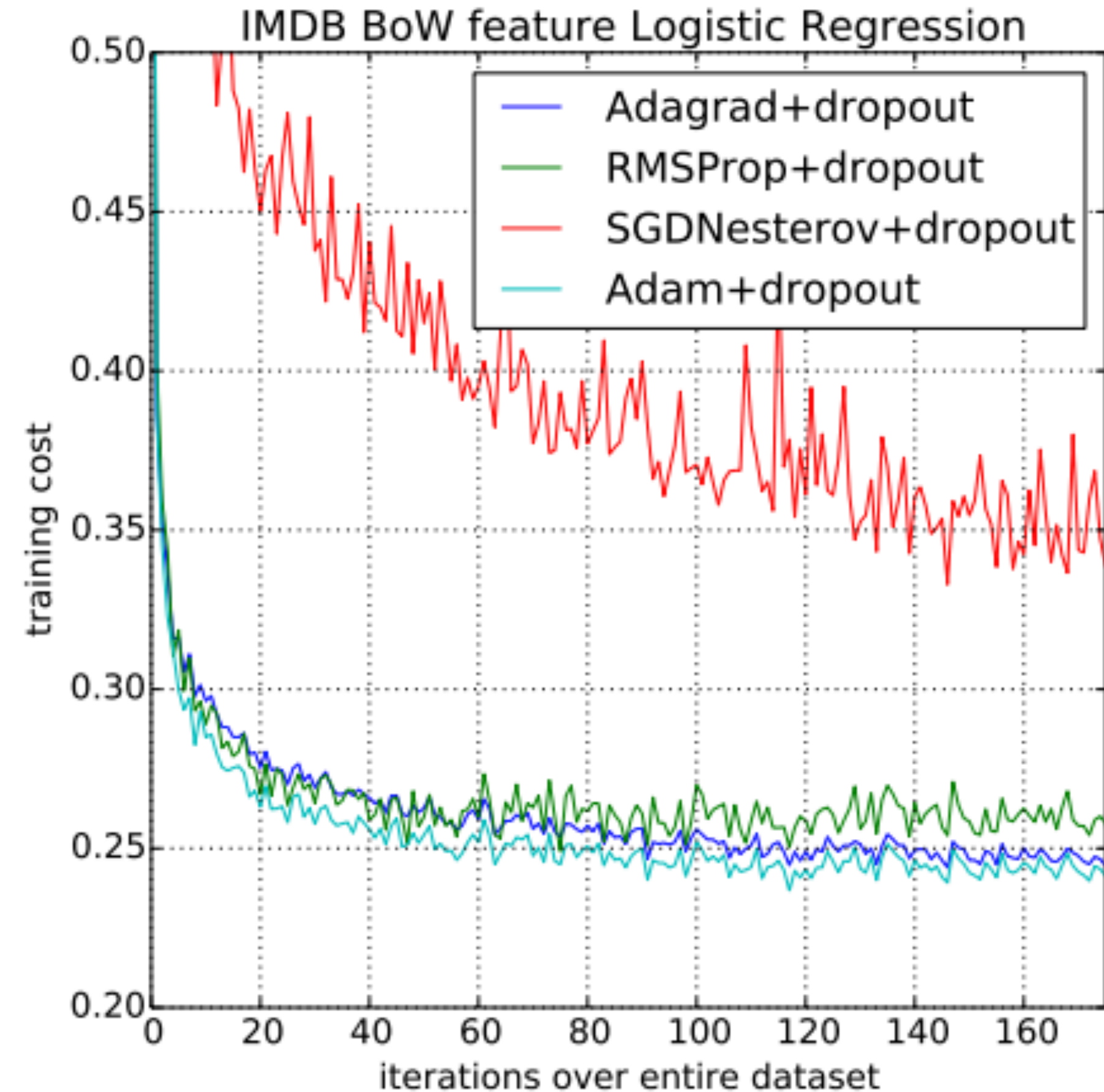
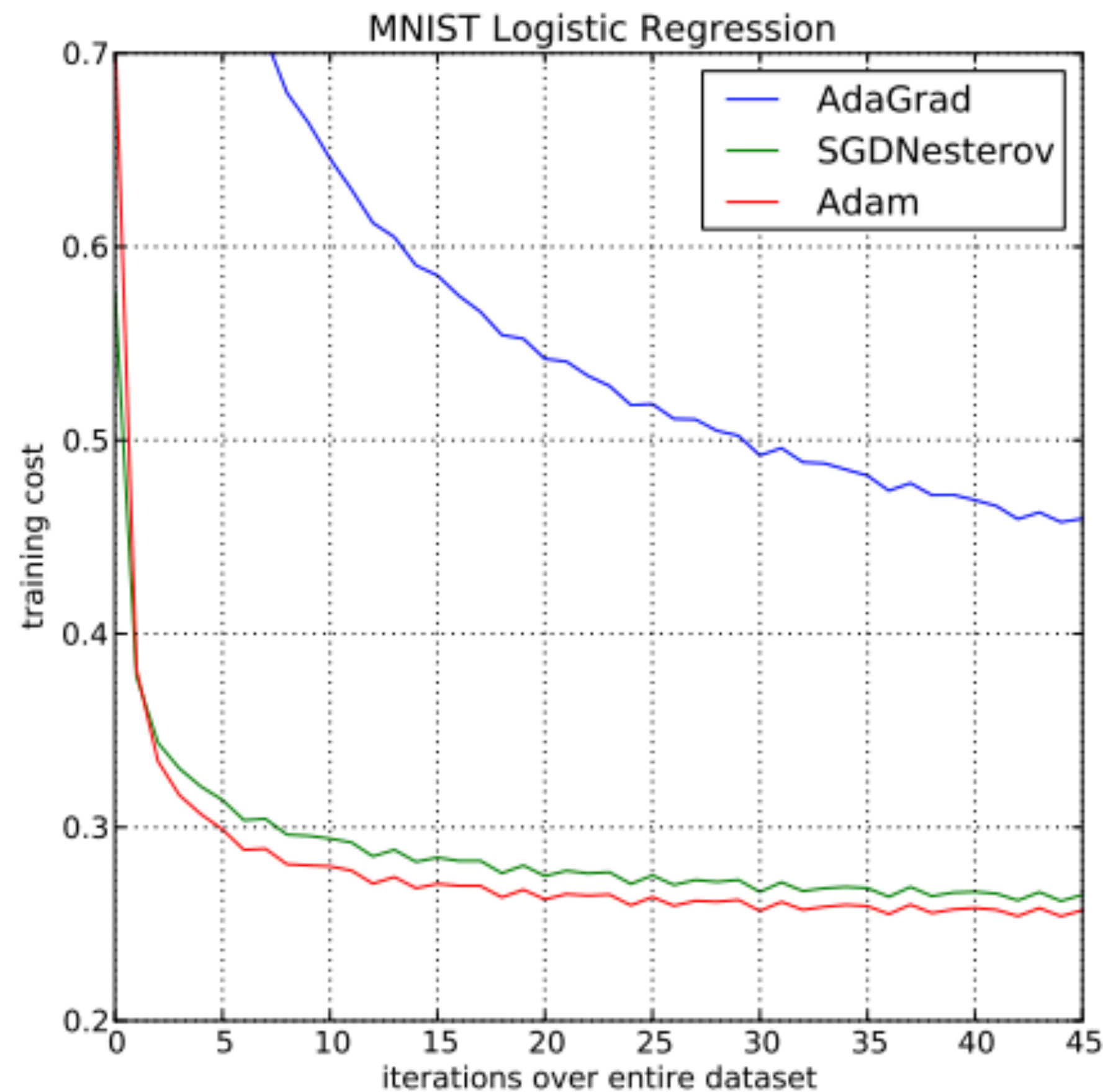
Srivastava et al. (2014)

Optimizer

- ▶ Adam (Kingma and Ba, ICLR 2015) is very widely used
- ▶ Adaptive step size like Adagrad, incorporates momentum

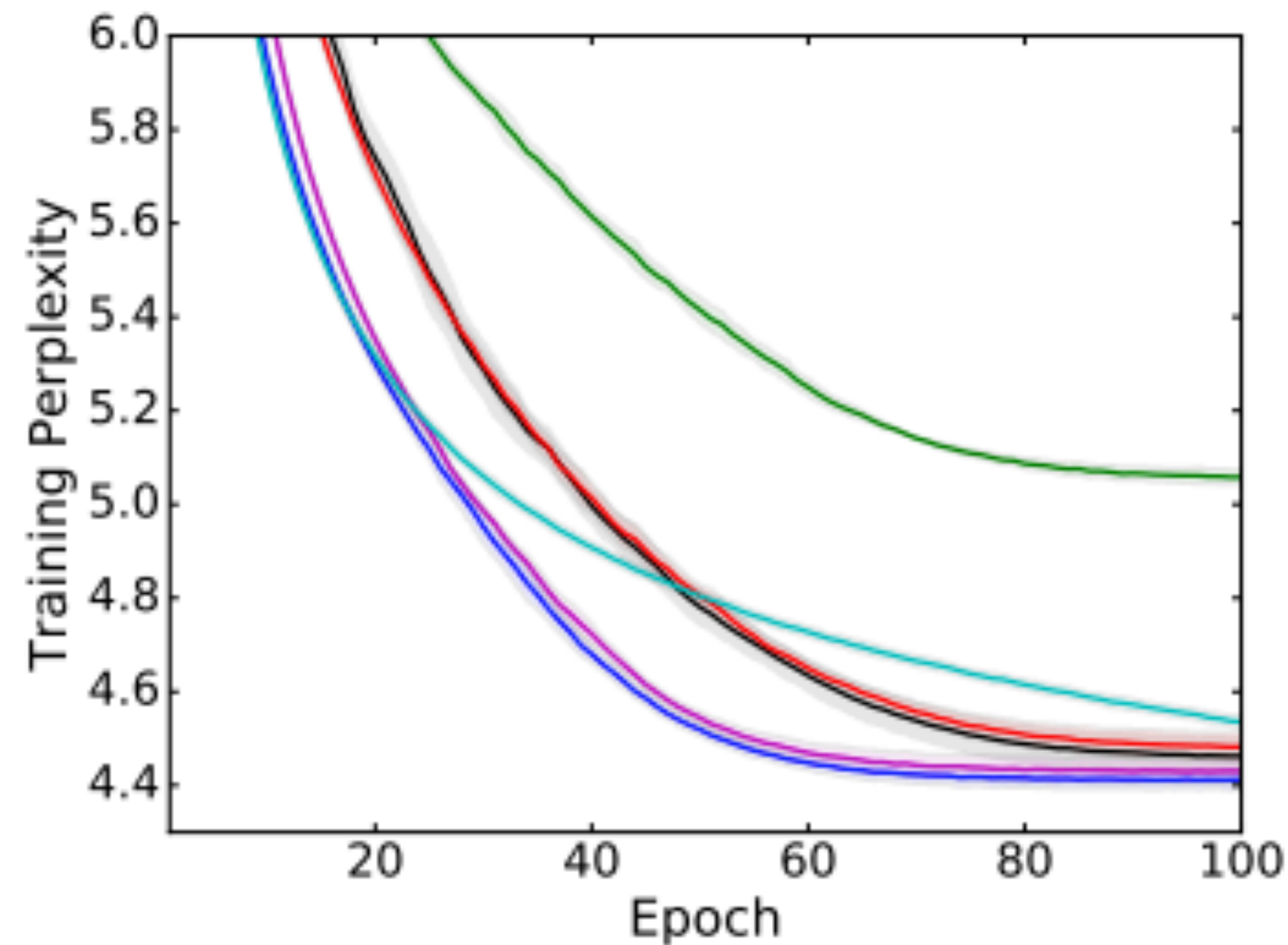
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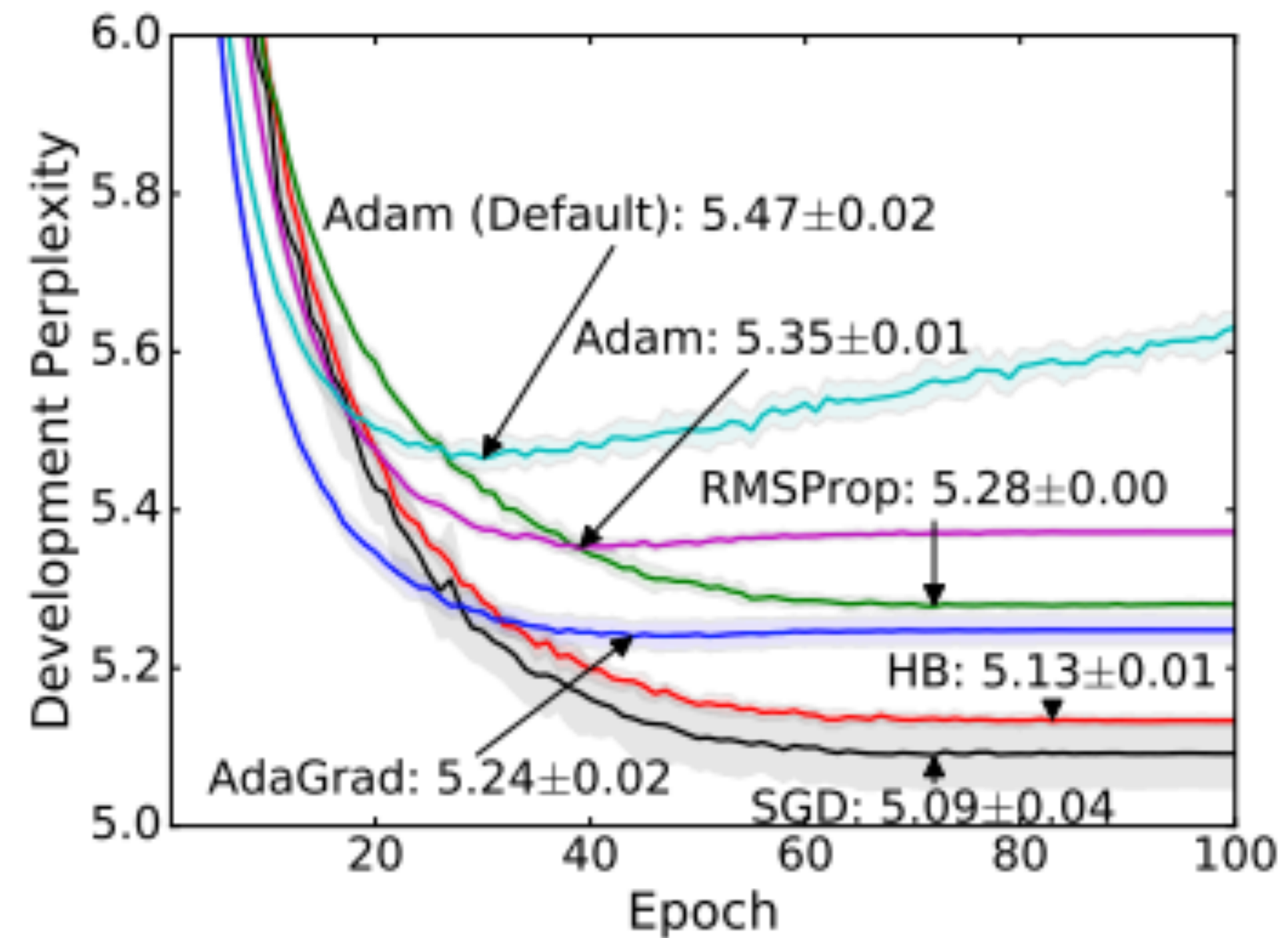


Optimizer

- Wilson et al. NIPS 2017: adaptive methods can actually perform badly at test time (Adam is in pink, SGD in black)



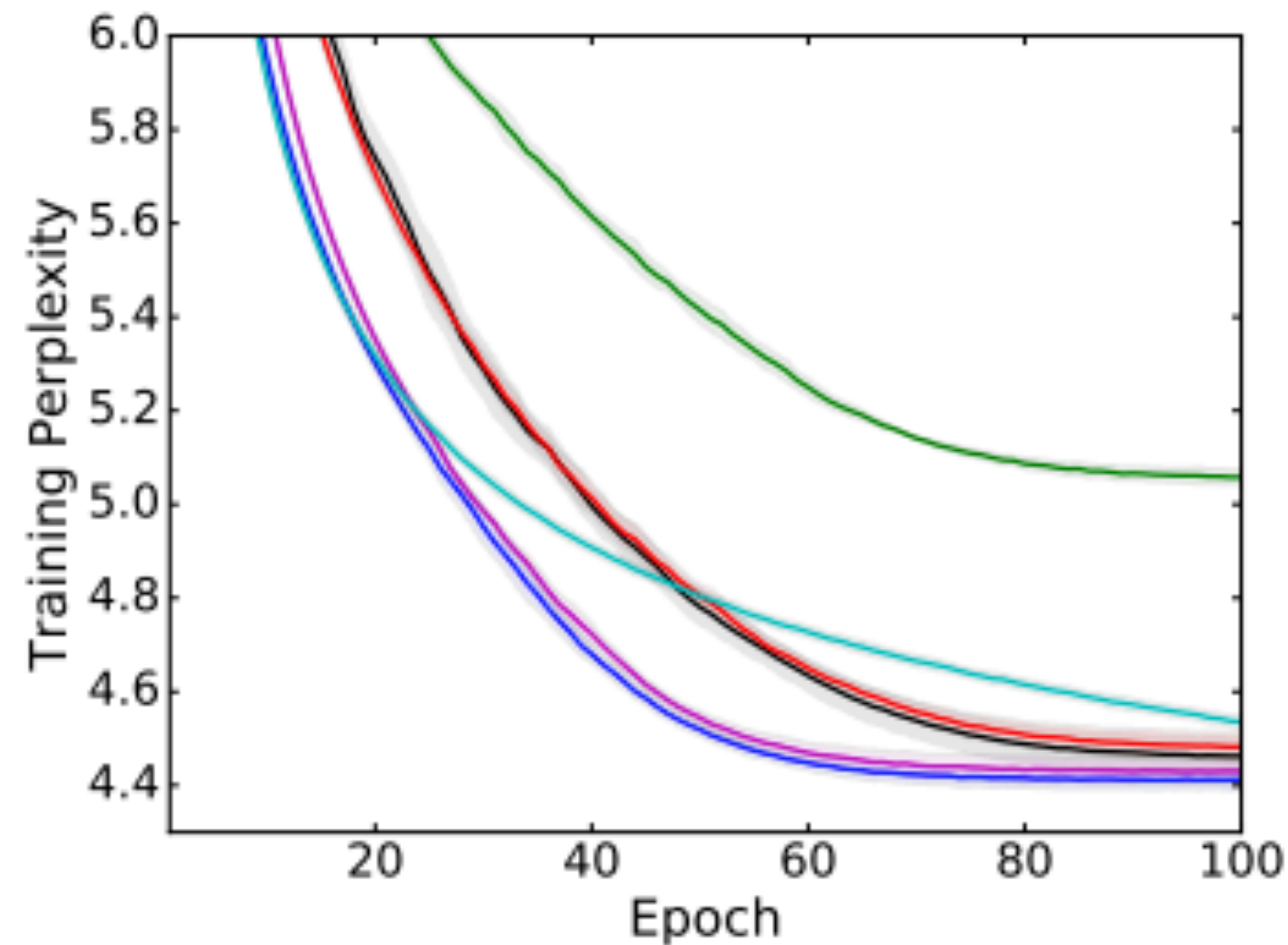
(e) Generative Parsing (Training Set)



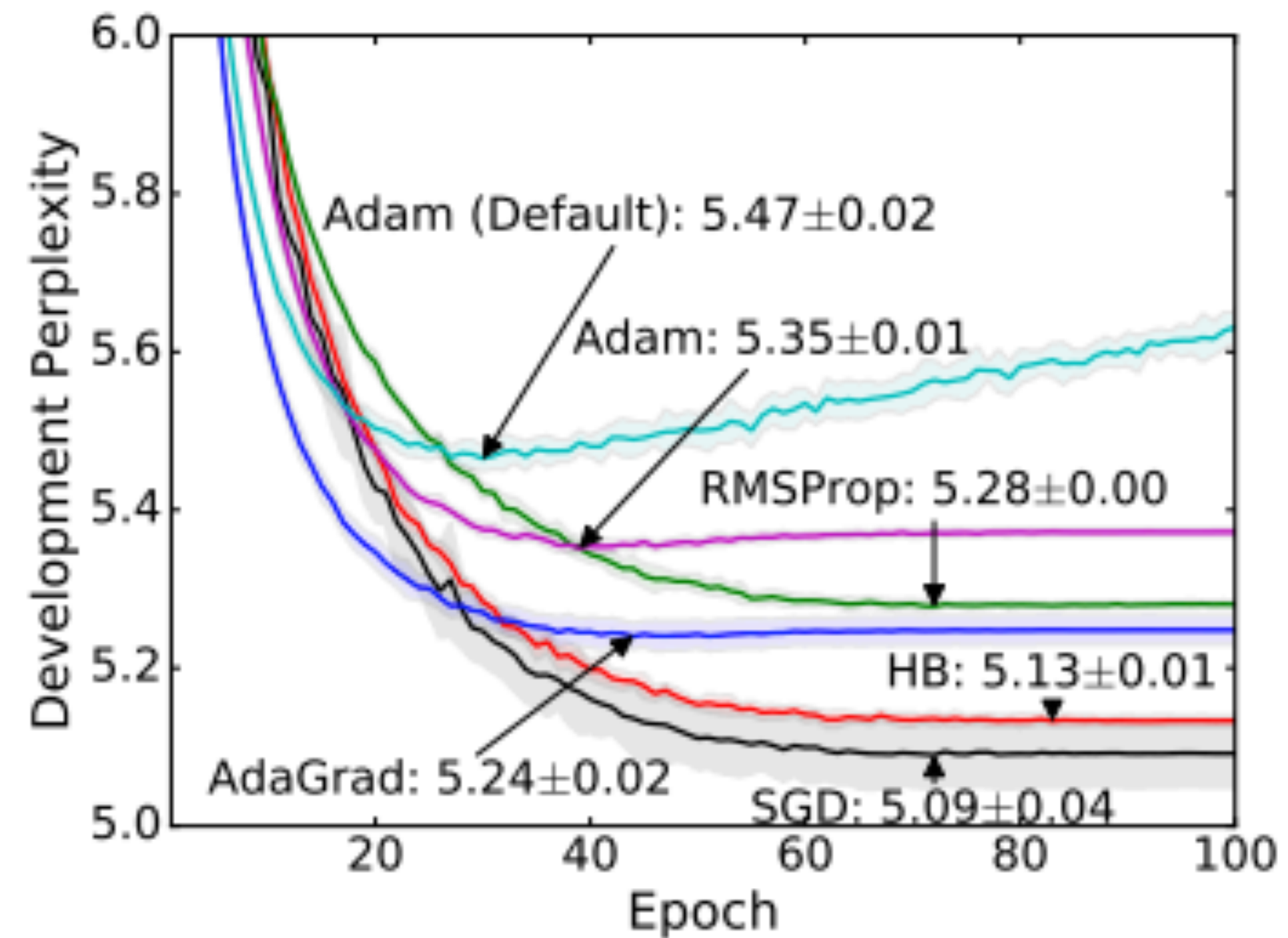
(f) Generative Parsing (Development Set)

Optimizer

- ▶ Wilson et al. NIPS 2017: adaptive methods can actually perform badly at test time (Adam is in pink, SGD in black)
- ▶ Check dev set periodically, decrease learning rate if not making progress



(e) Generative Parsing (Training Set)



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Elements of Machine Learning

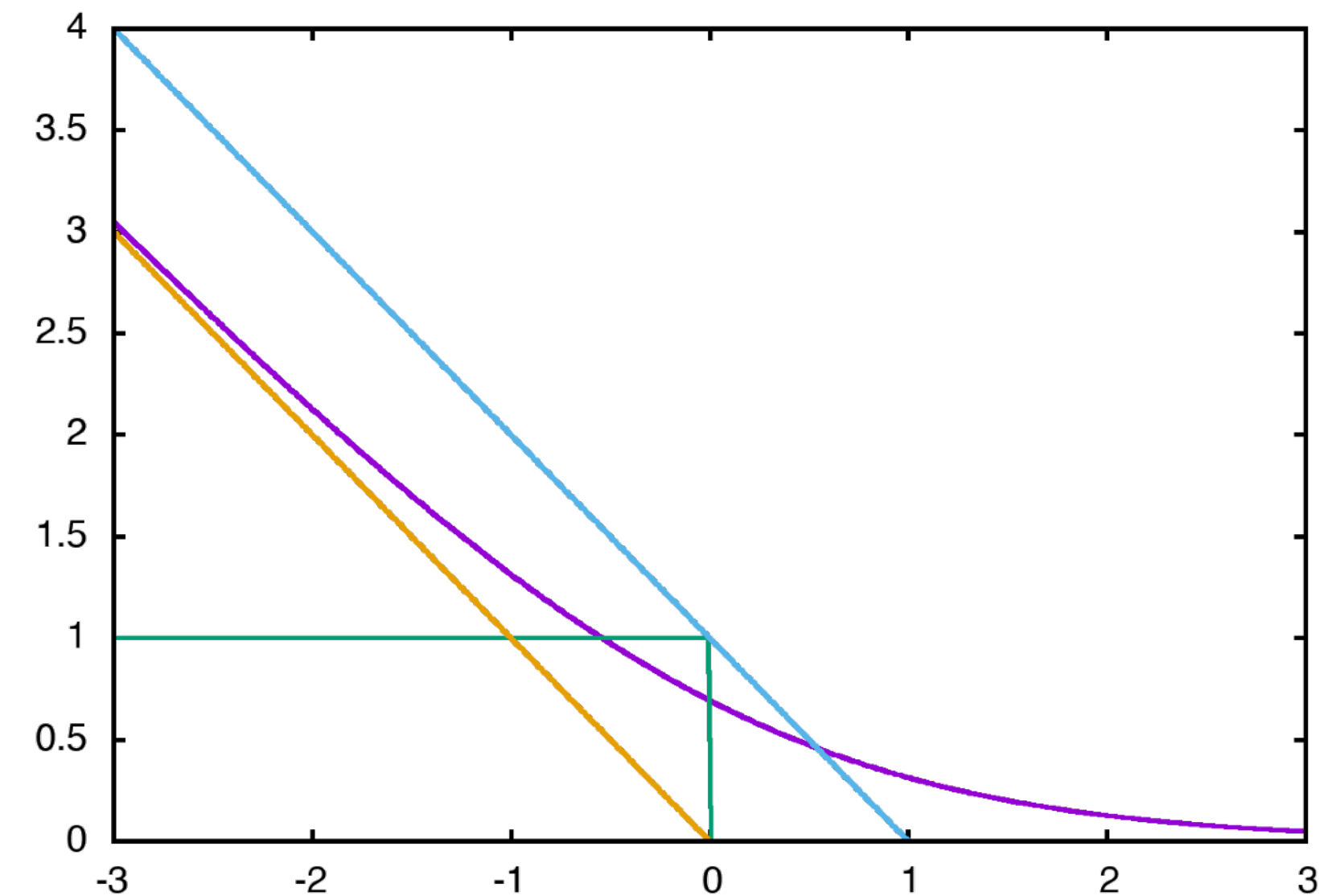
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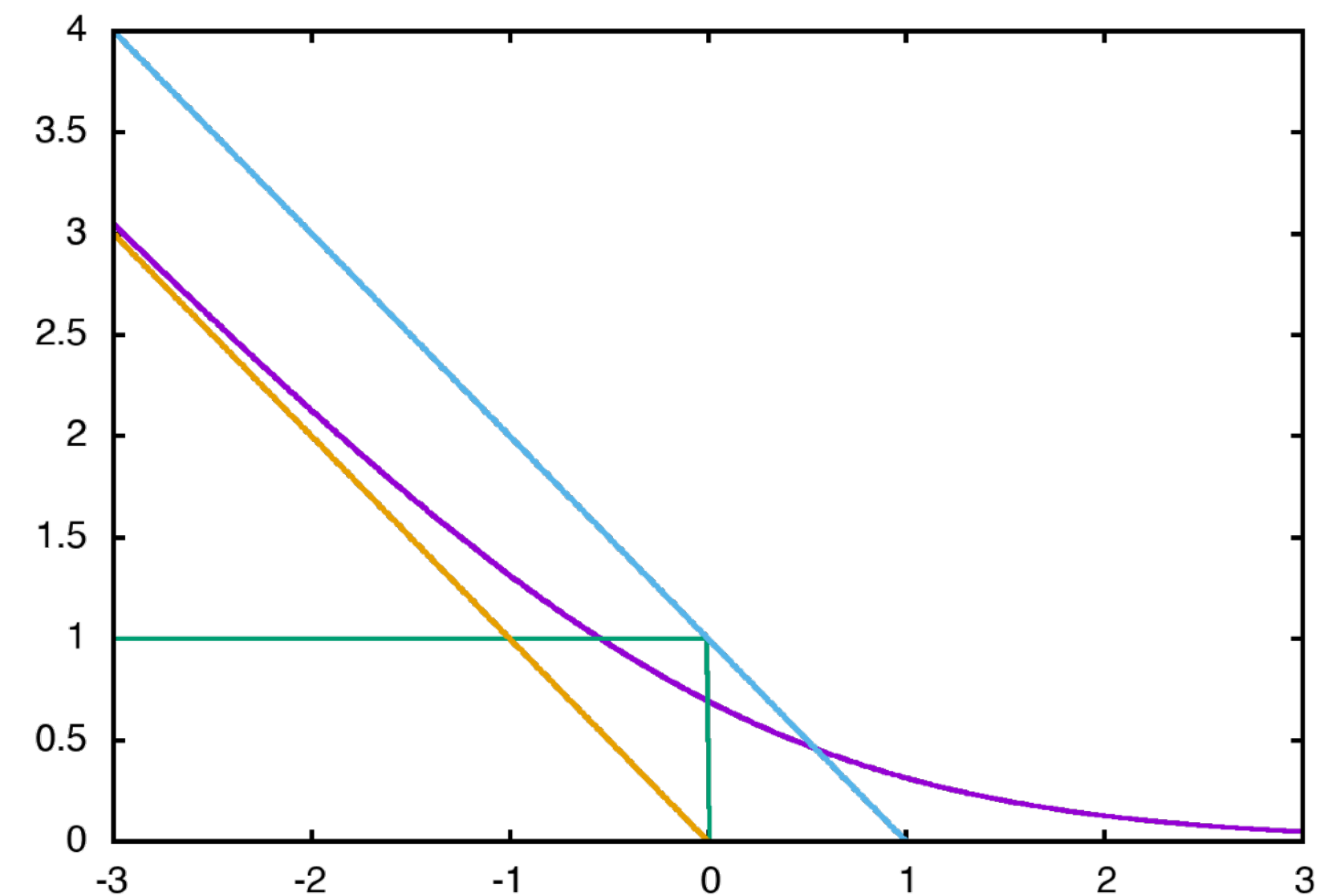
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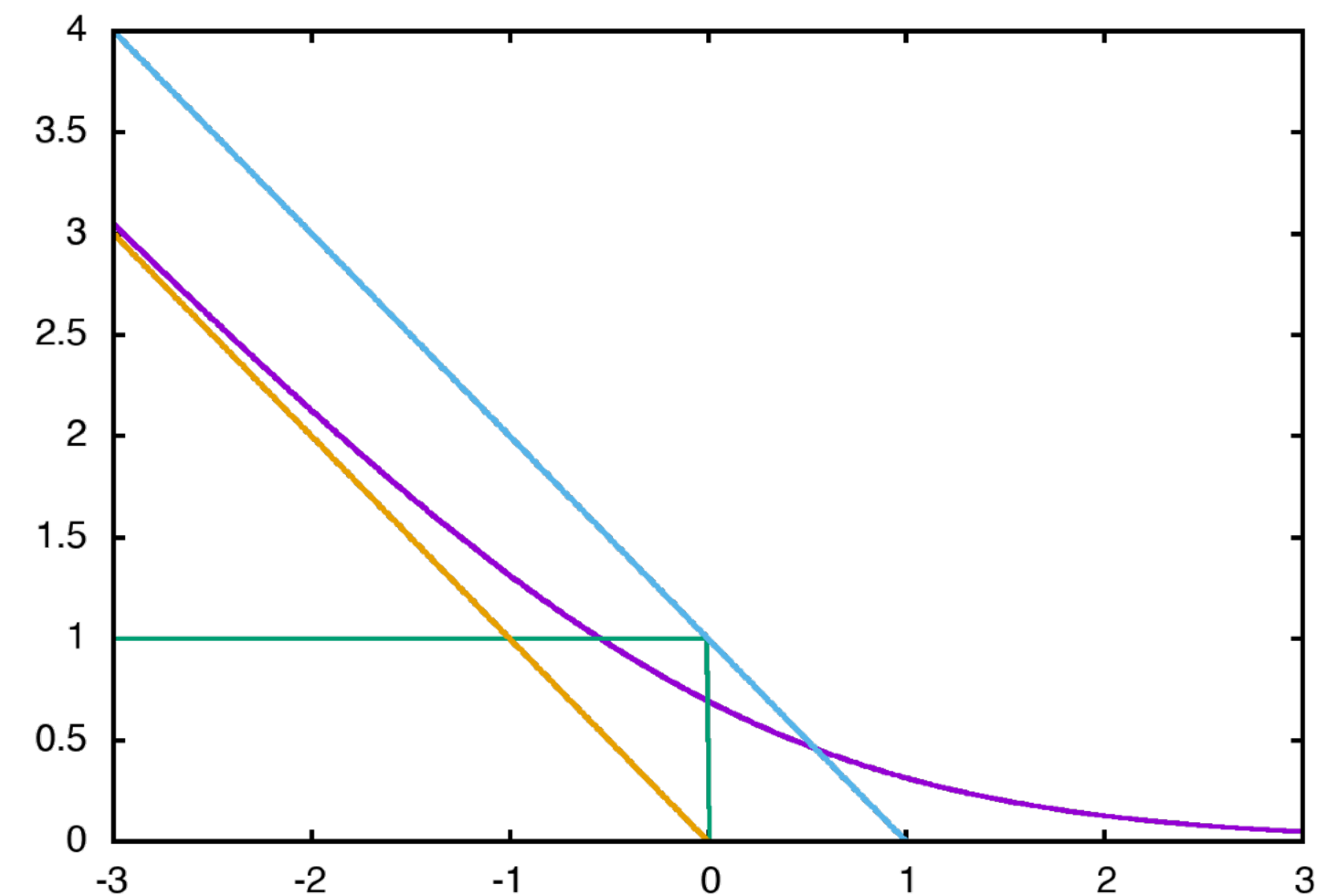
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- ▶ Training: lots of choices for optimization/hyperparameters



Word Representations

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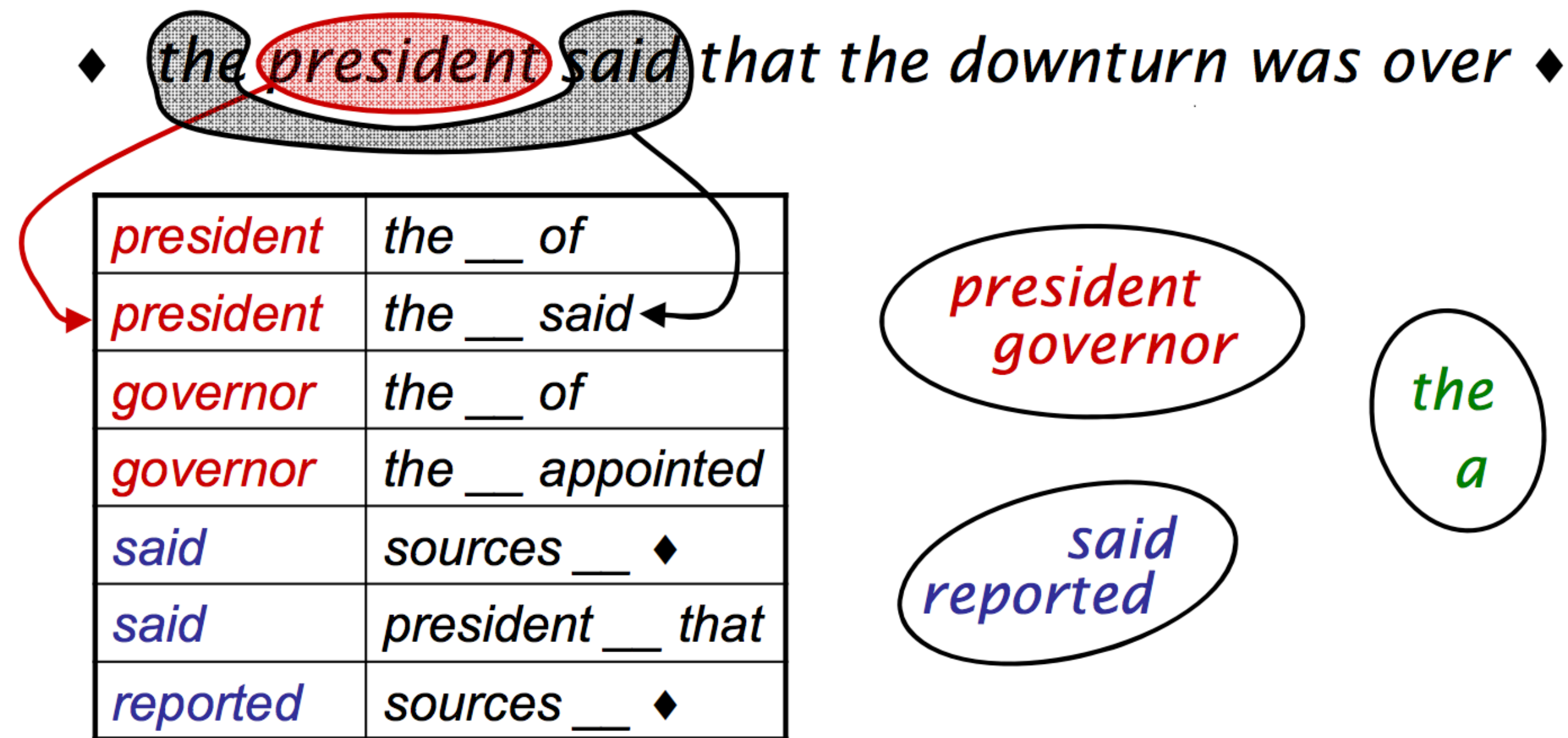
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- ▶ Continuous model \leftrightarrow expects continuous semantics from input
- ▶ “You shall know a word by the company it keeps” Firth (1957)



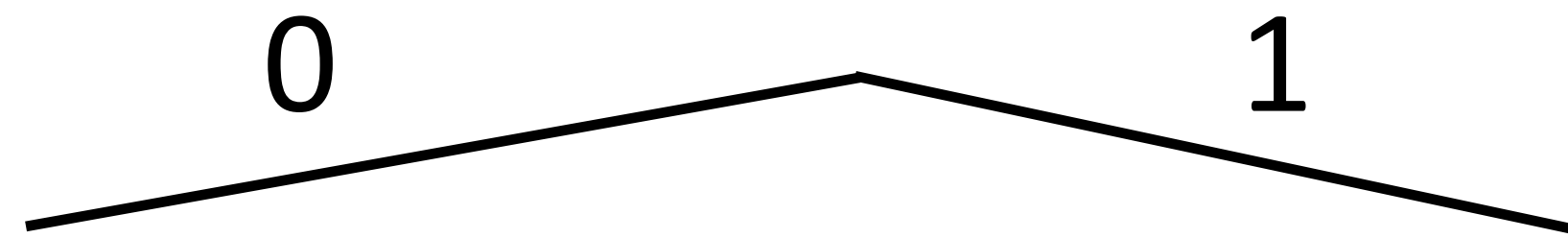
Discrete Word Representations

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- ▶ Brown clusters: hierarchical agglomerative *hard* clustering (each word has one cluster, not some posterior distribution like in mixture models)

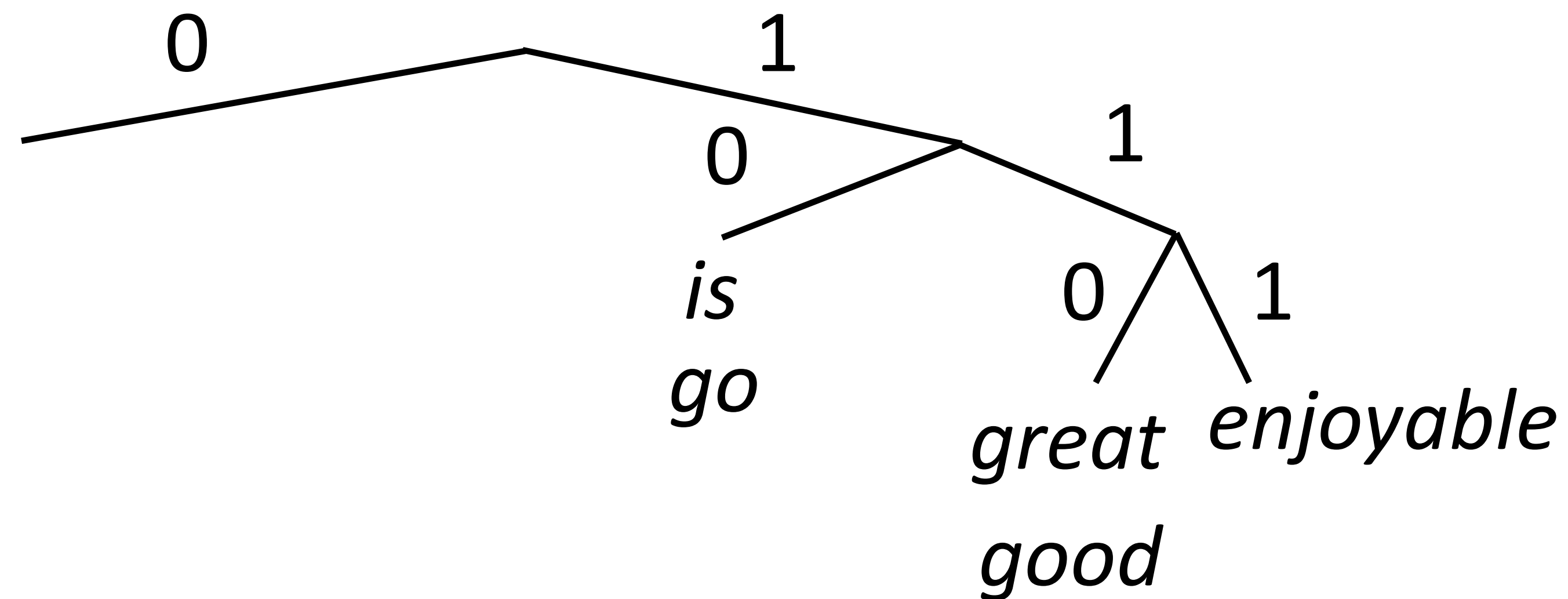
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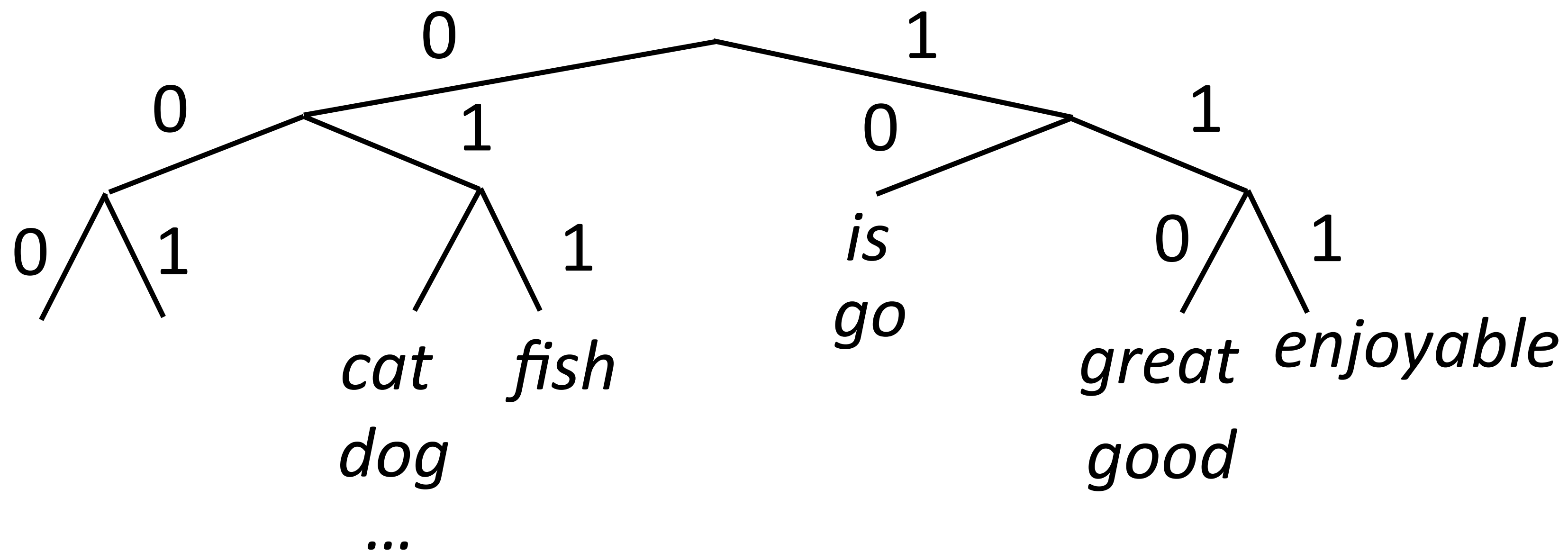
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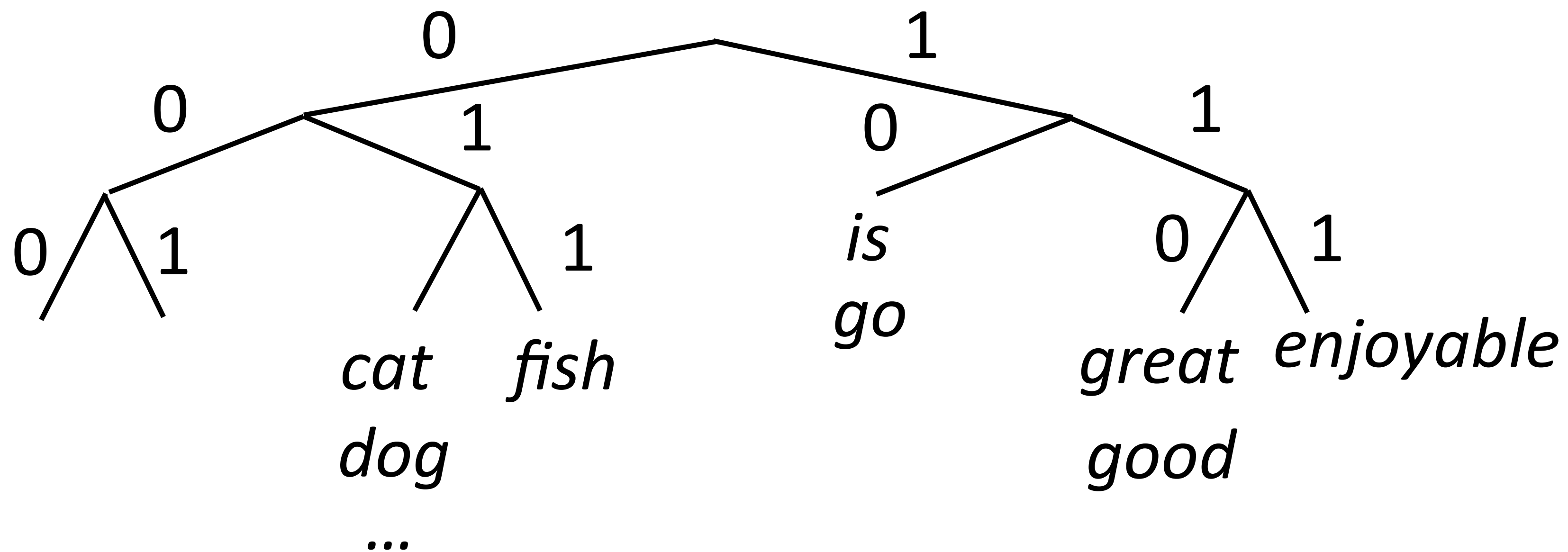
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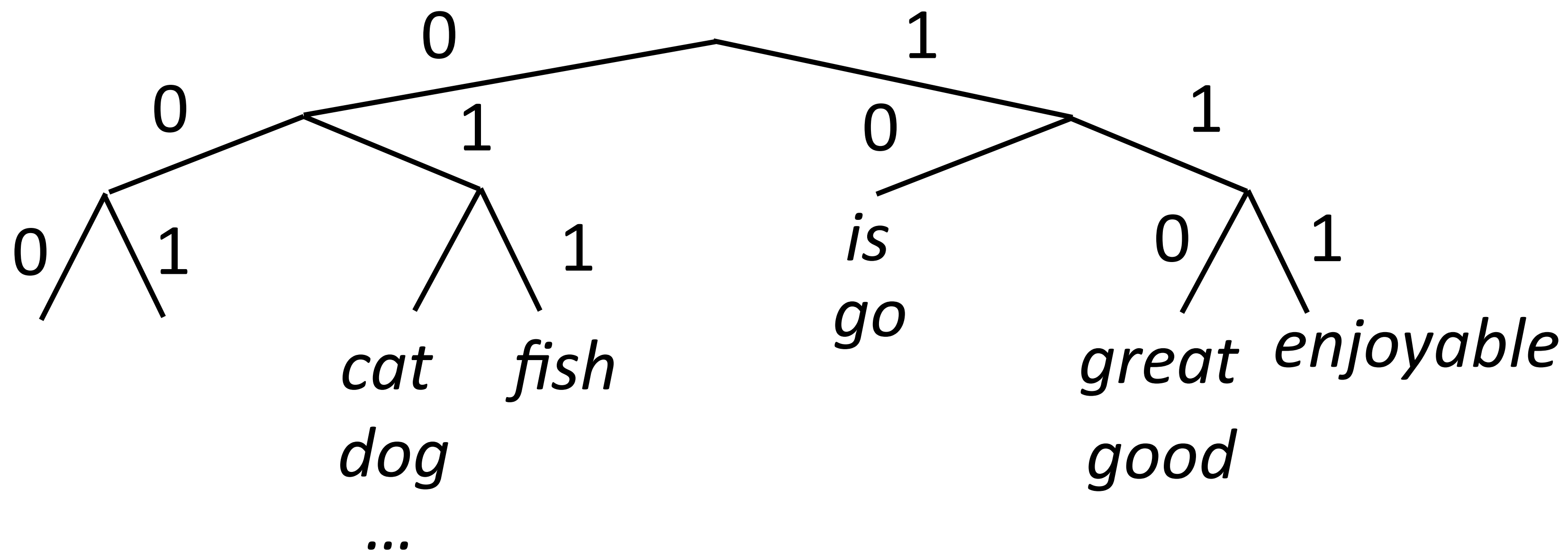
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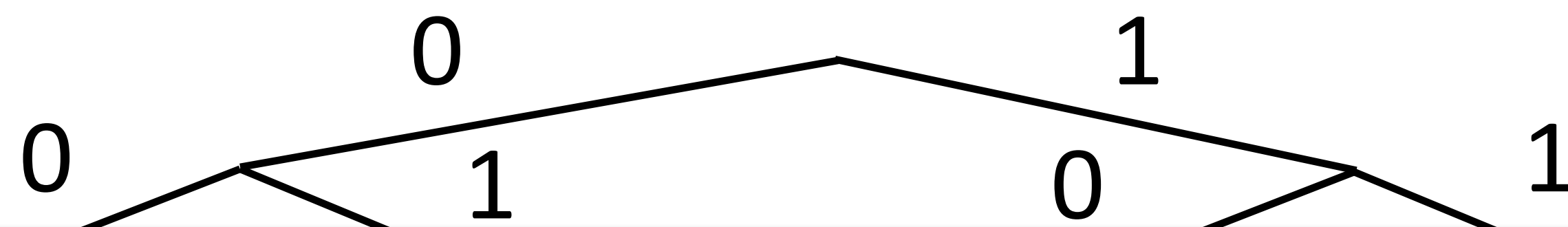
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- Brown et al. (1992)

Discrete Word Representations

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Sample Brown Clusters:

- https://raw.githubusercontent.com/aritter/5525_perceptron_tagger/master/60K_clusters.bits.txt

cat fish good great enjoyable
dog
good
...

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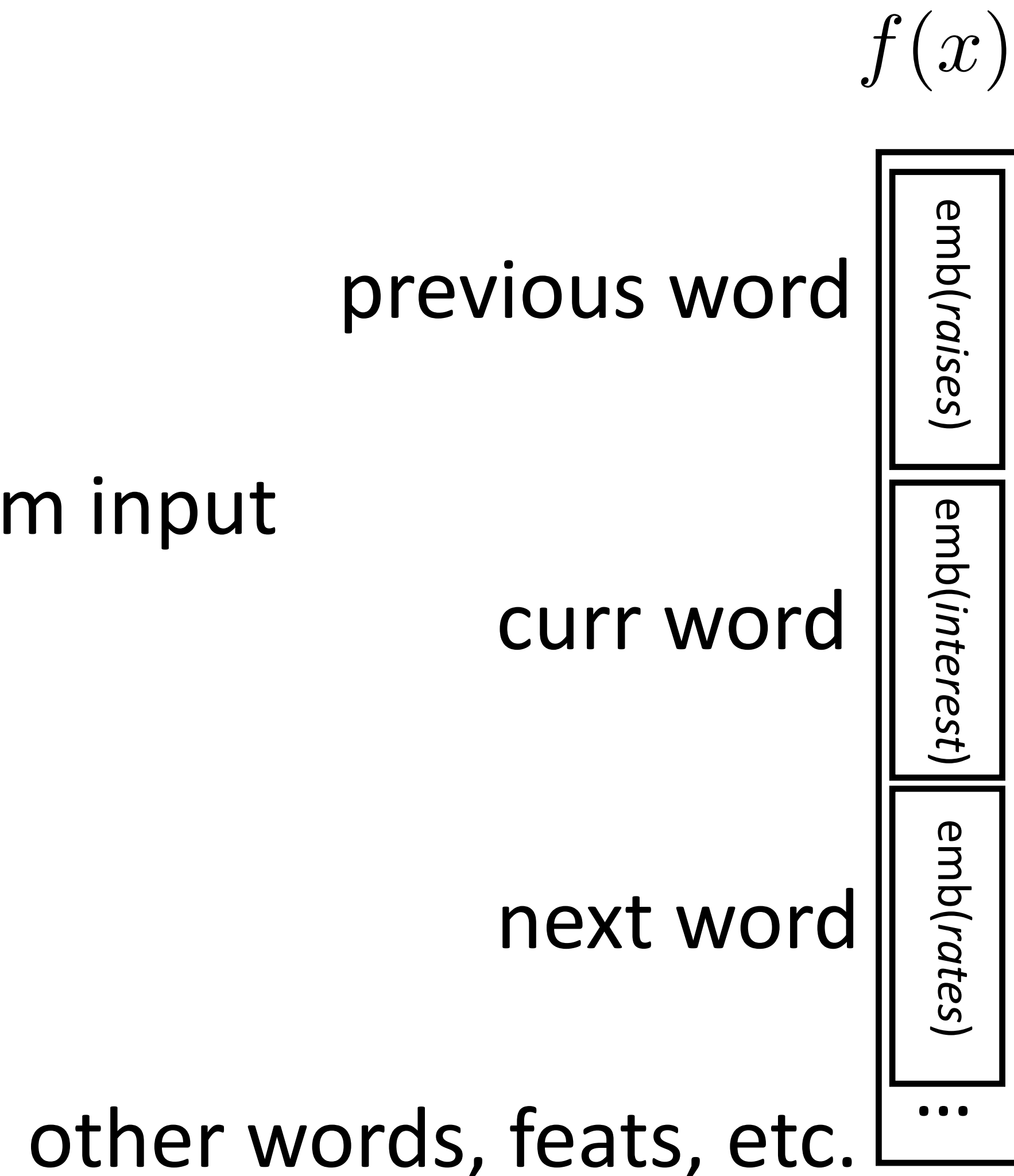
Word Embeddings

- Part-of-speech tagging with FFNNs

??

*Fed raises **interest** rates in order to ...*

- Word embeddings for each word form input



Botha et al. (2017)

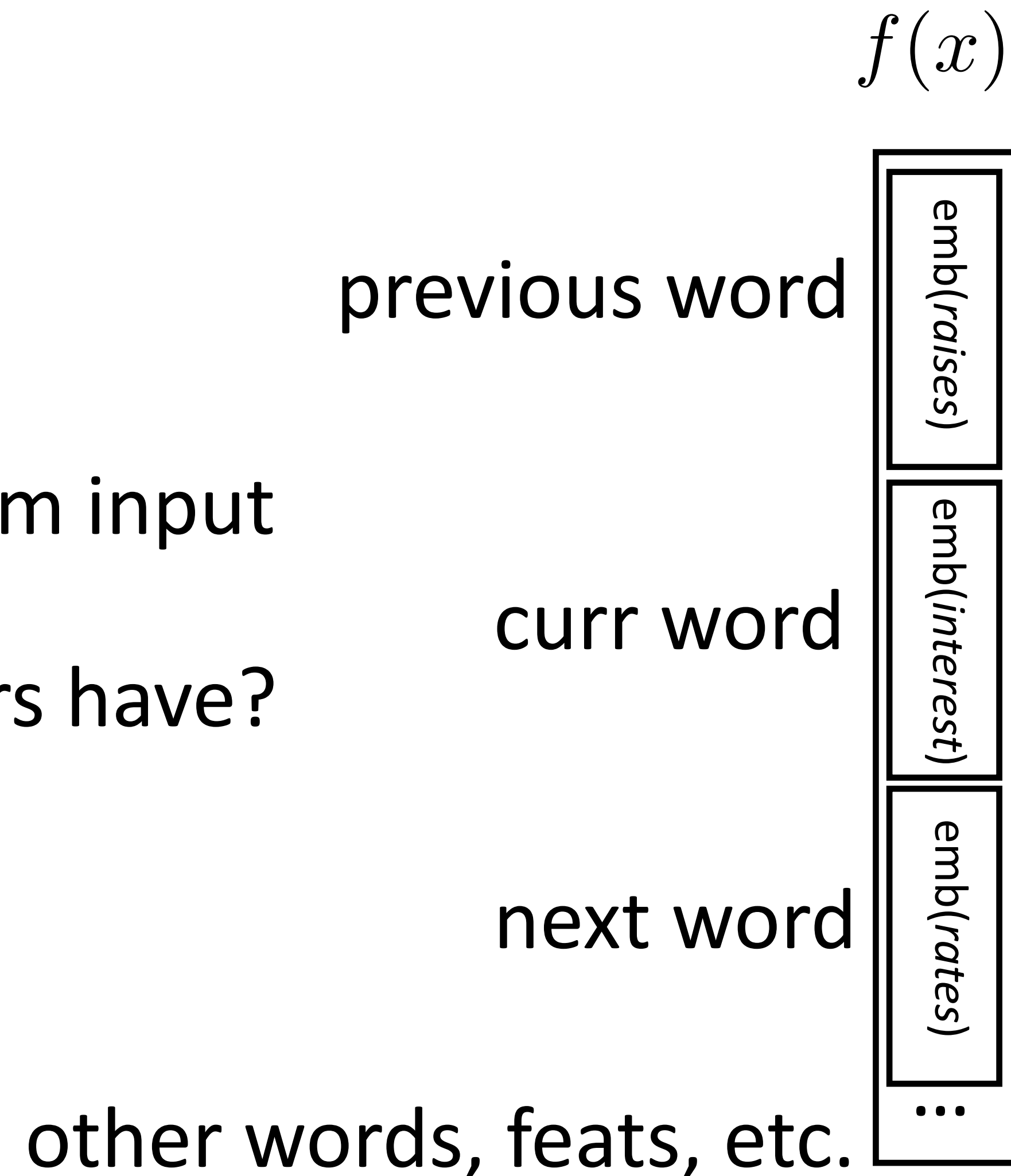
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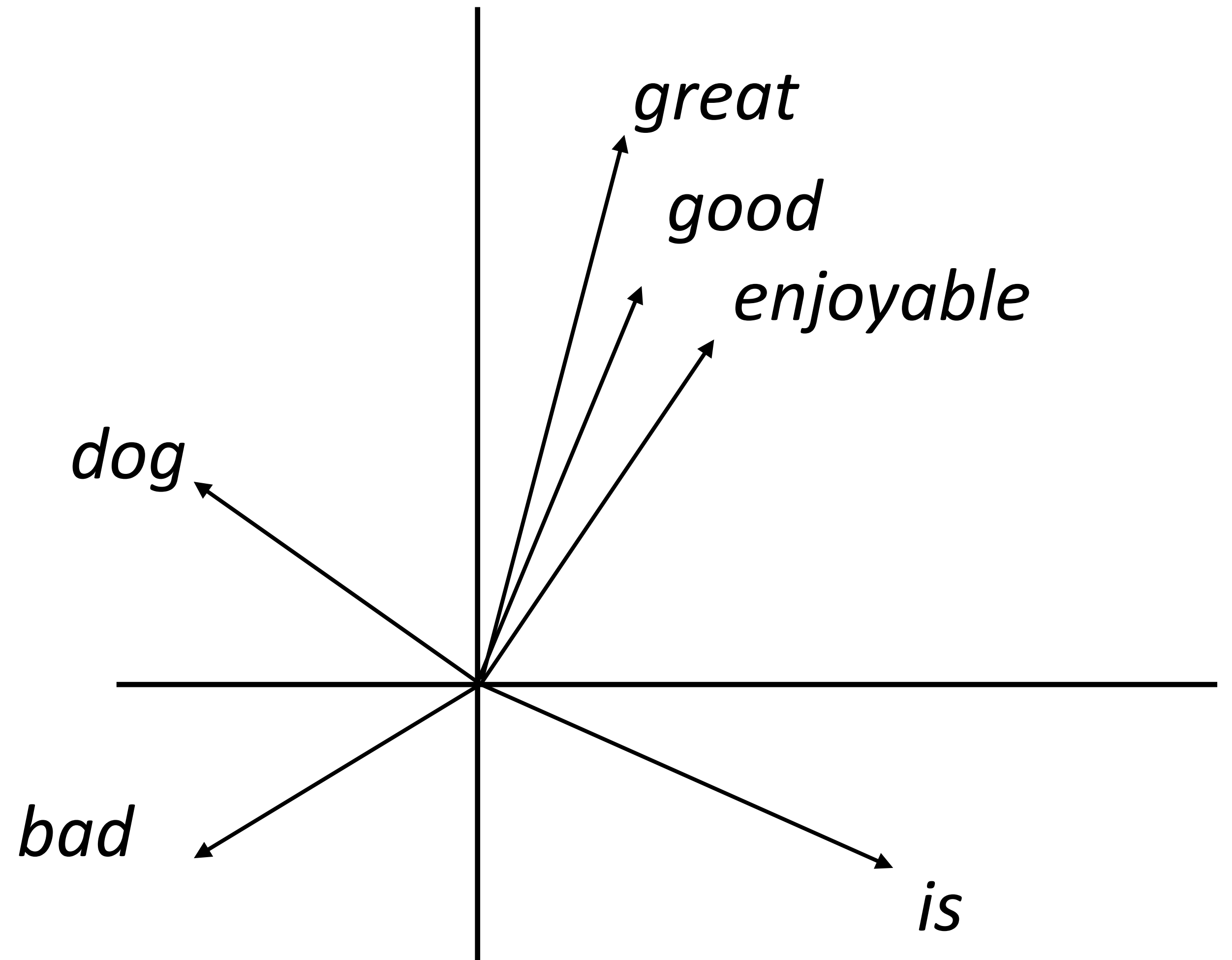
- ▶ Word embeddings for each word form input
- ▶ What properties should these vectors have?



Botha et al. (2017)

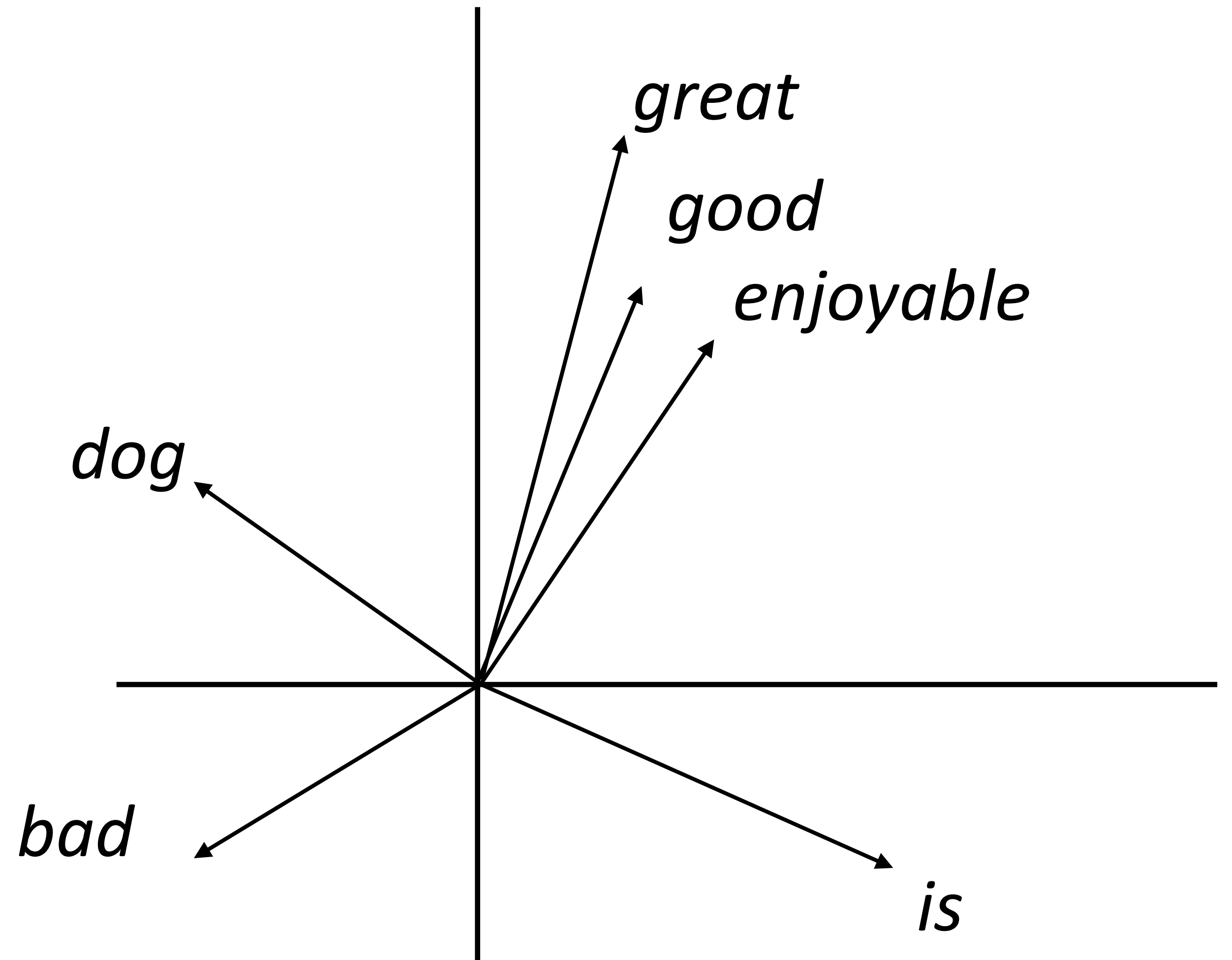
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Word Embeddings

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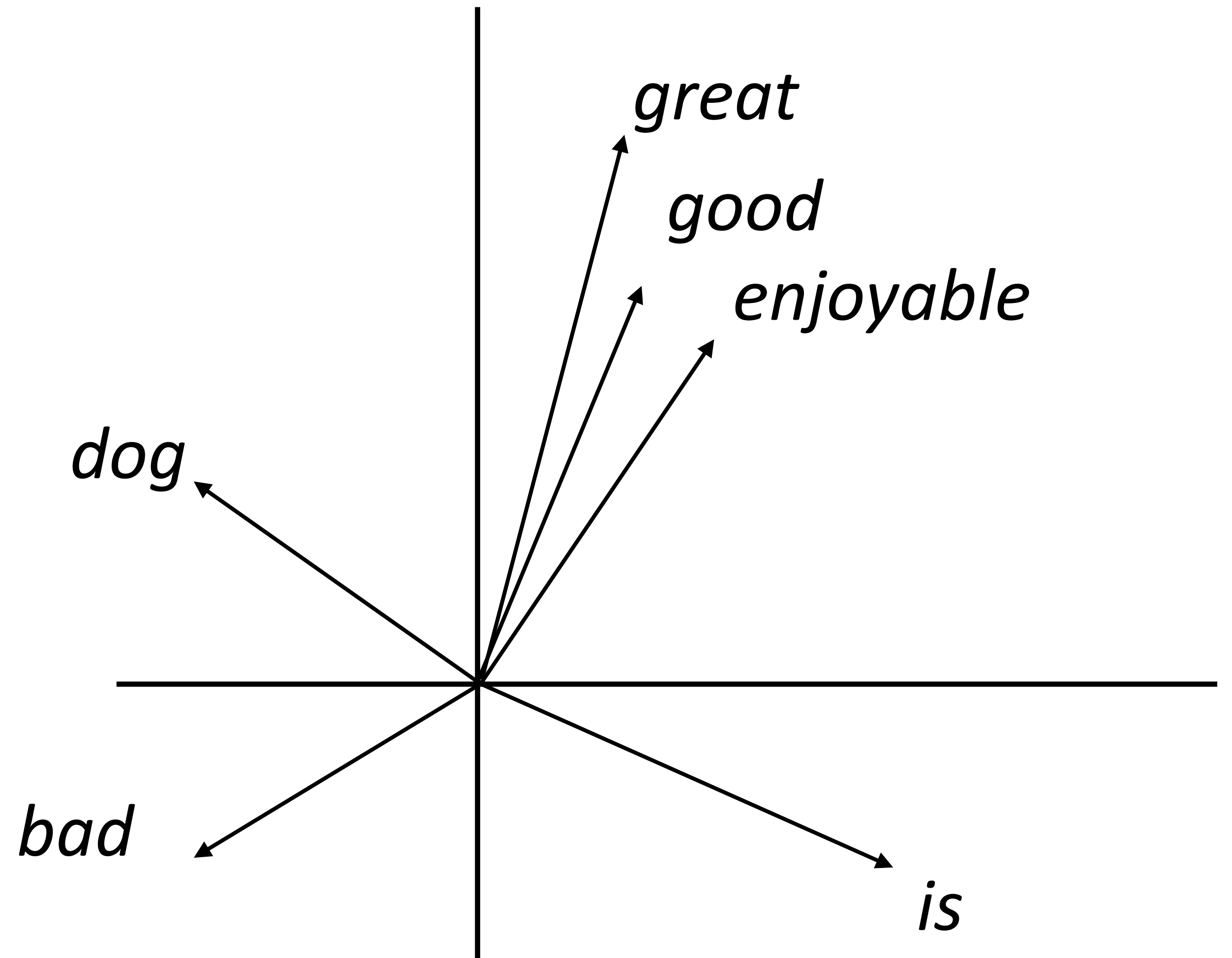
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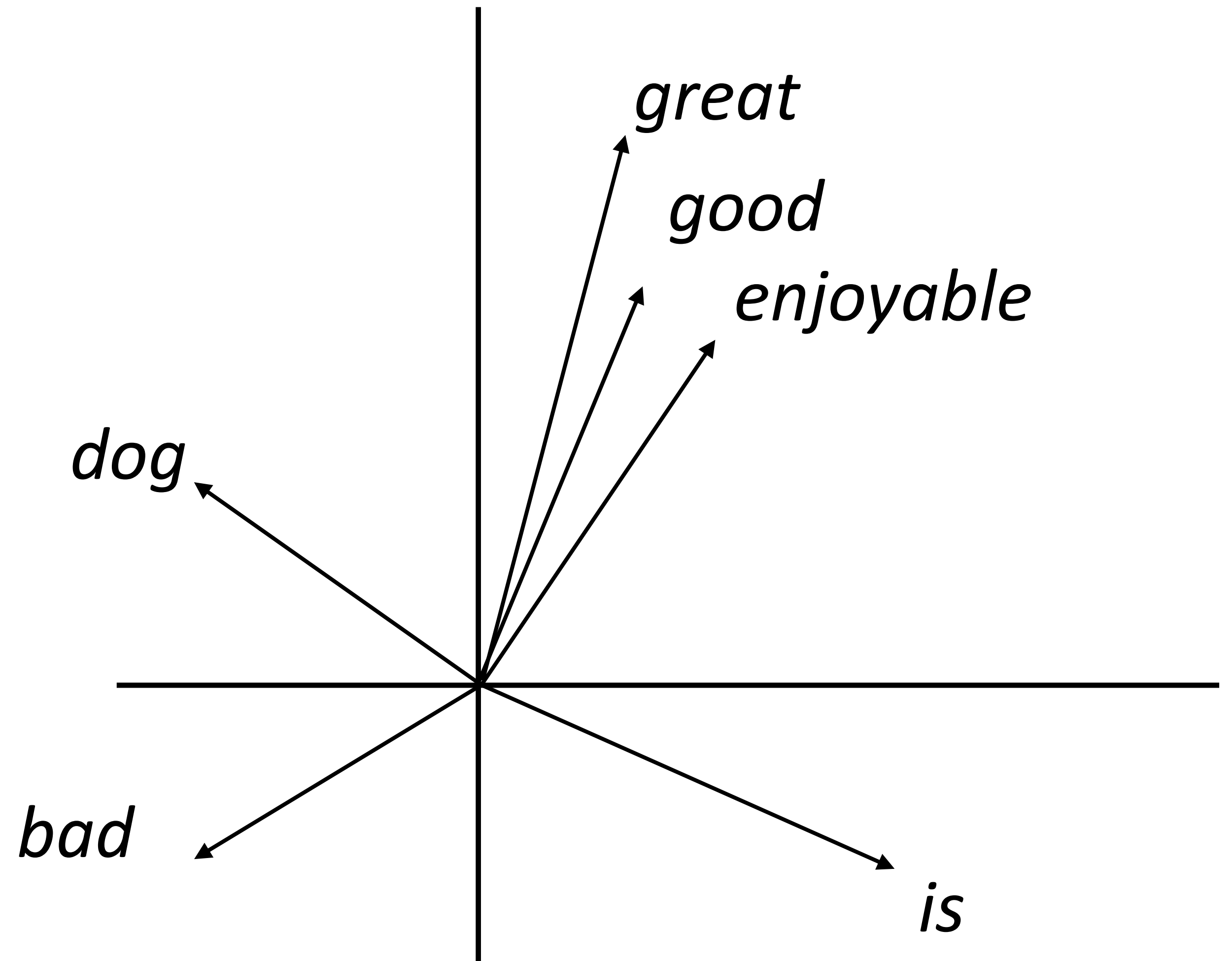
- ▶ Want a vector space where similar words have similar embeddings

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- ▶ Goal: come up with a way to produce these embeddings



word2vec/GloVe

Continuous Bag-of-Words

- ▶ Predict word from context

the dog bit the man





Continuous Bag-of-Words

- Predict word from context

the dog bit the man

The sentence "the dog bit the man" is shown in an italicized font. The word "bit" is highlighted with a solid blue square. A dashed black rectangle encloses the words "the dog bit the", indicating the context used for prediction.

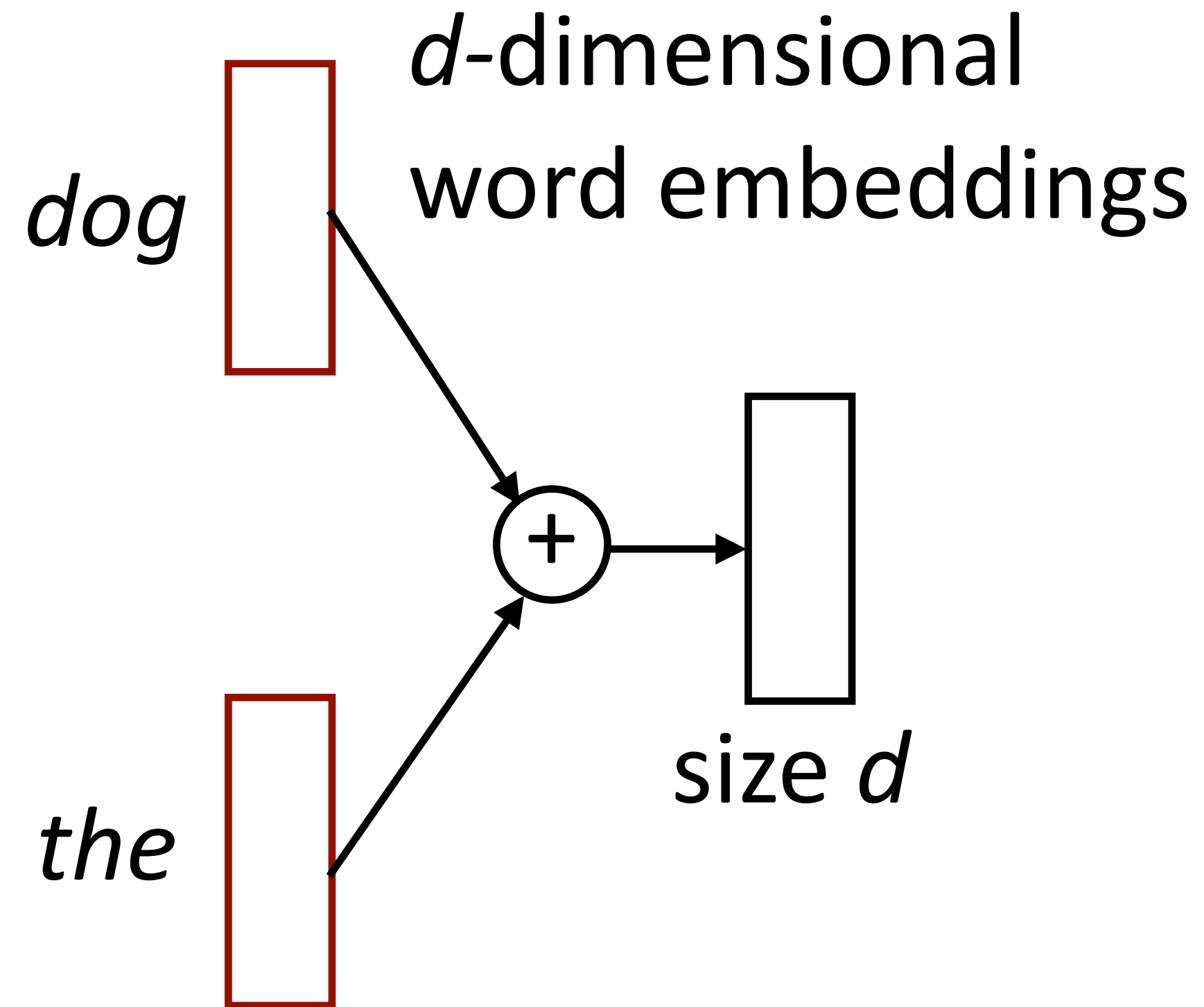
dog  d -dimensional
word embeddings

the 

Continuous Bag-of-Words

- Predict word from context

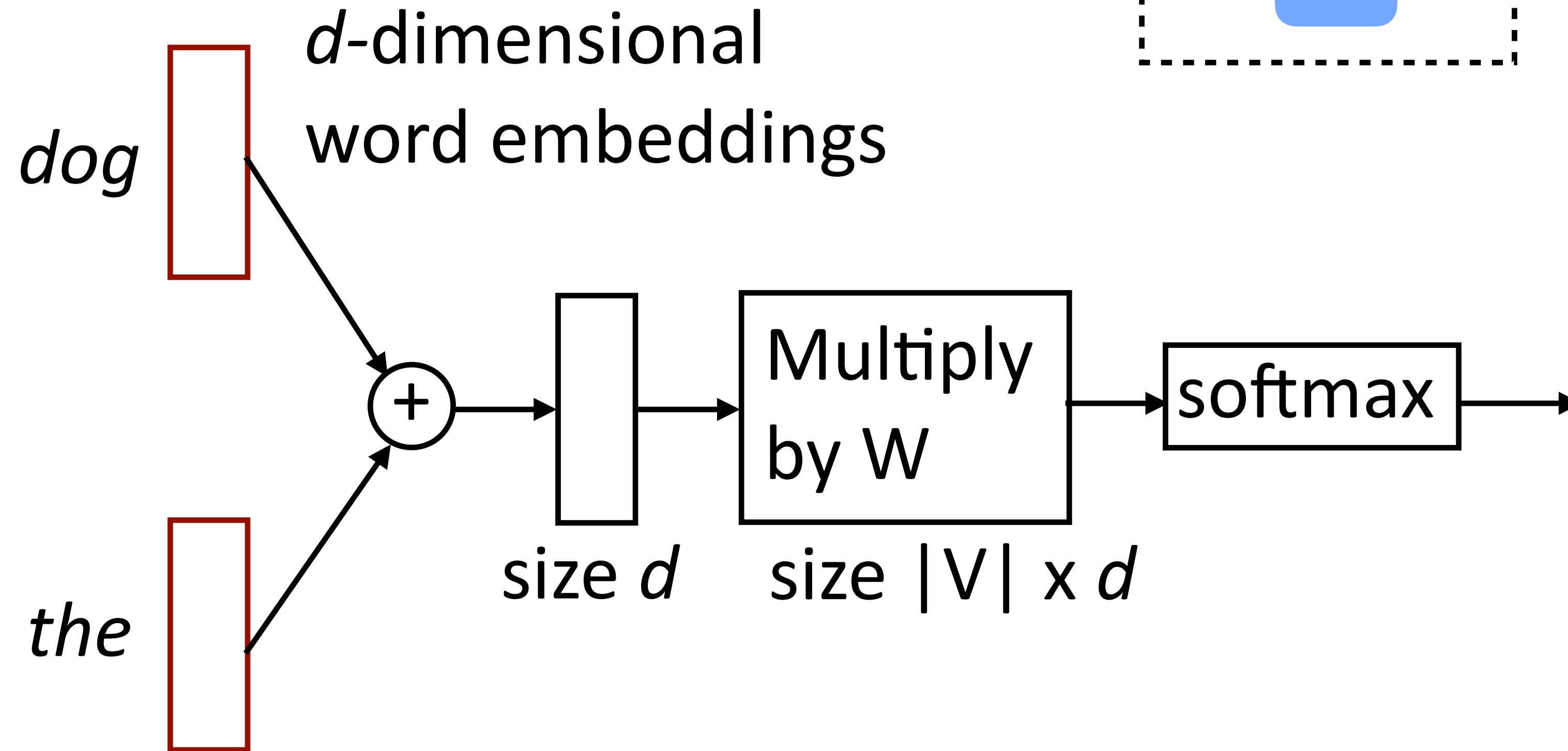
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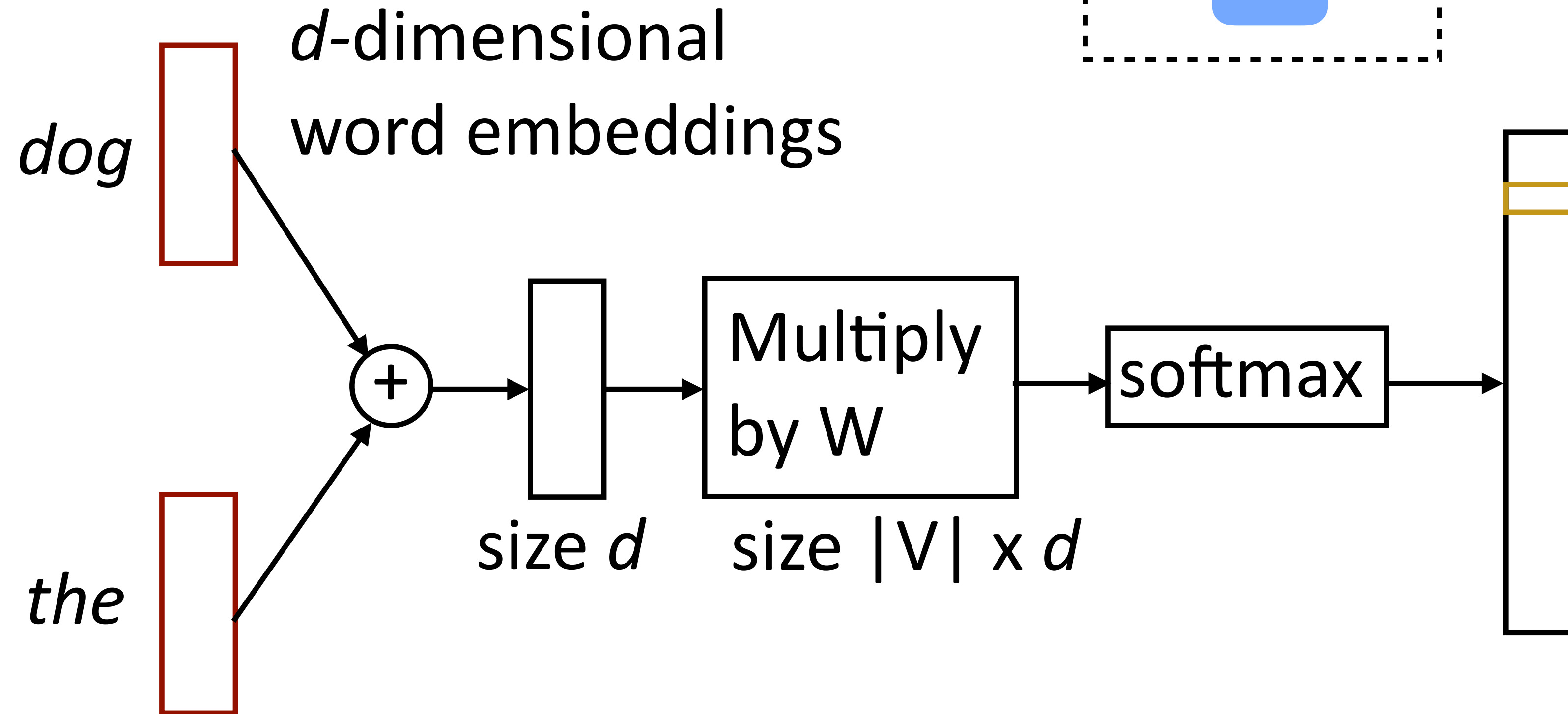
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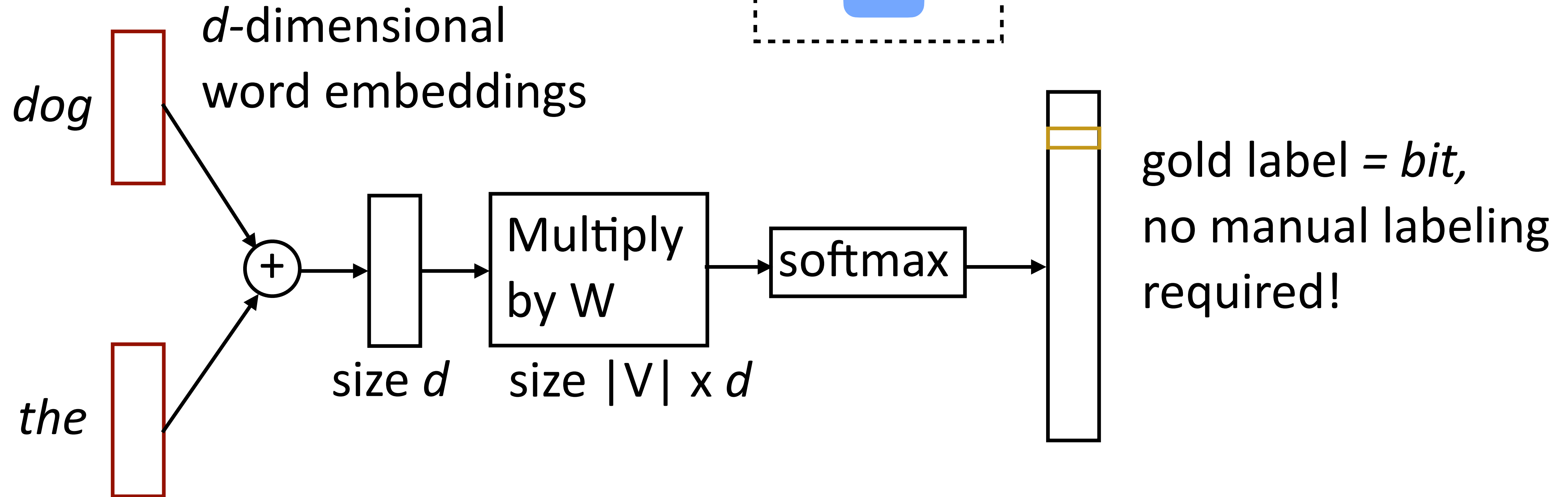
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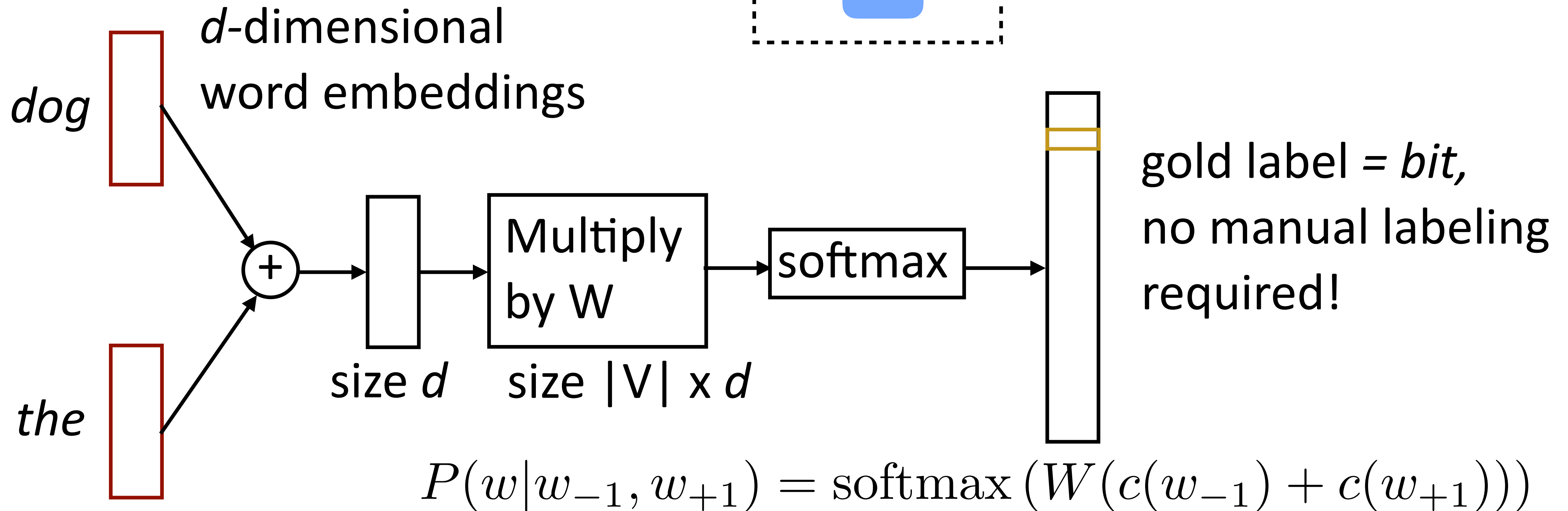
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Continuous Bag-of-Words

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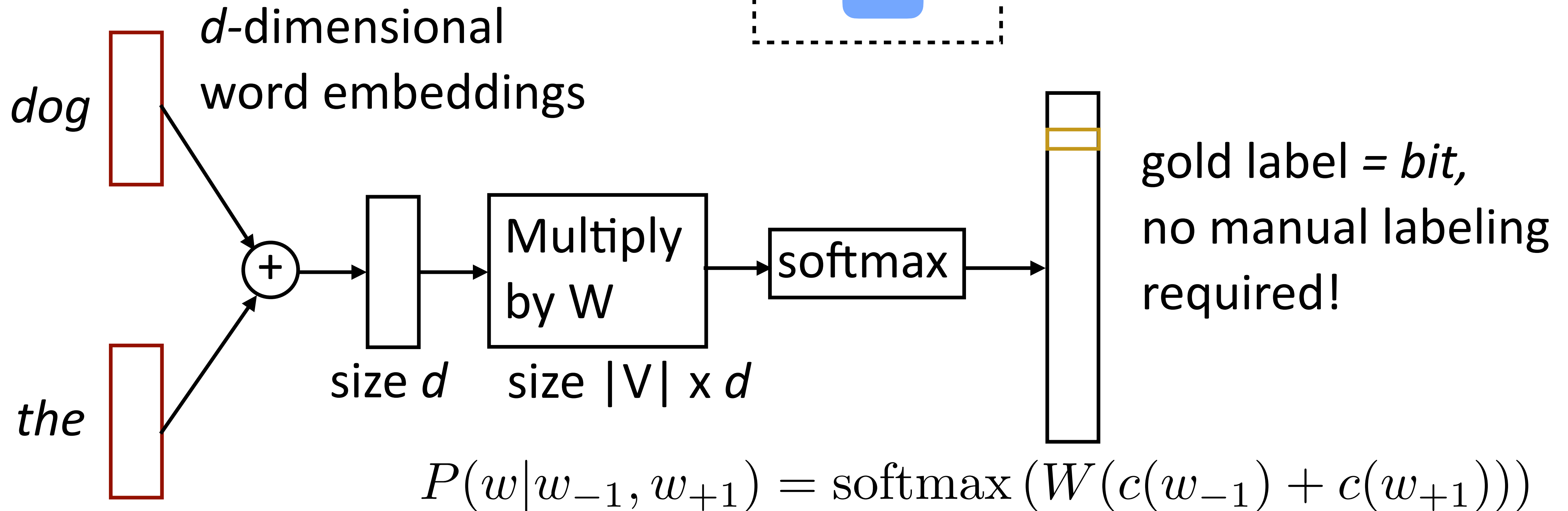
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Continuous Bag-of-Words

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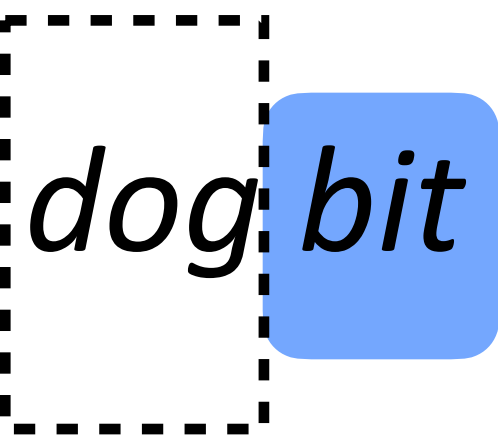
- Parameters: $d \times |V|$ (one d -length **vector per voc word**),
 $|V| \times d$ output parameters (W)

Mikolov et al. (2013)

Skip-Gram

- Predict one word of context from word

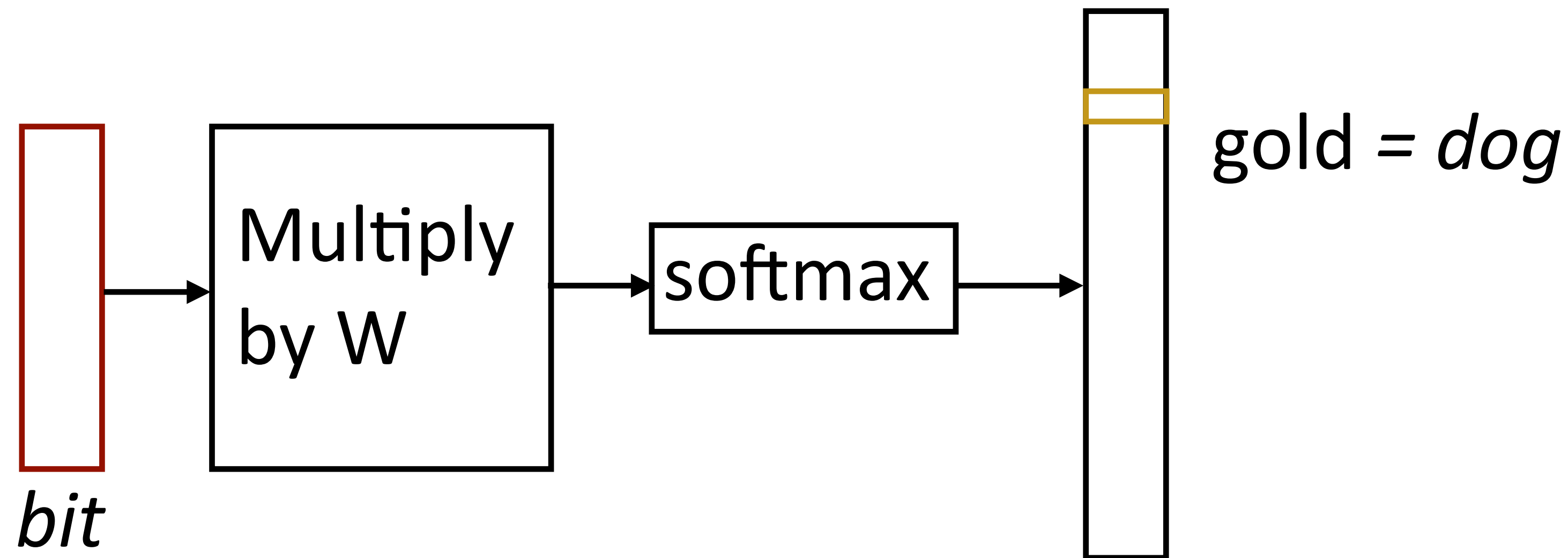
the dog bit the man



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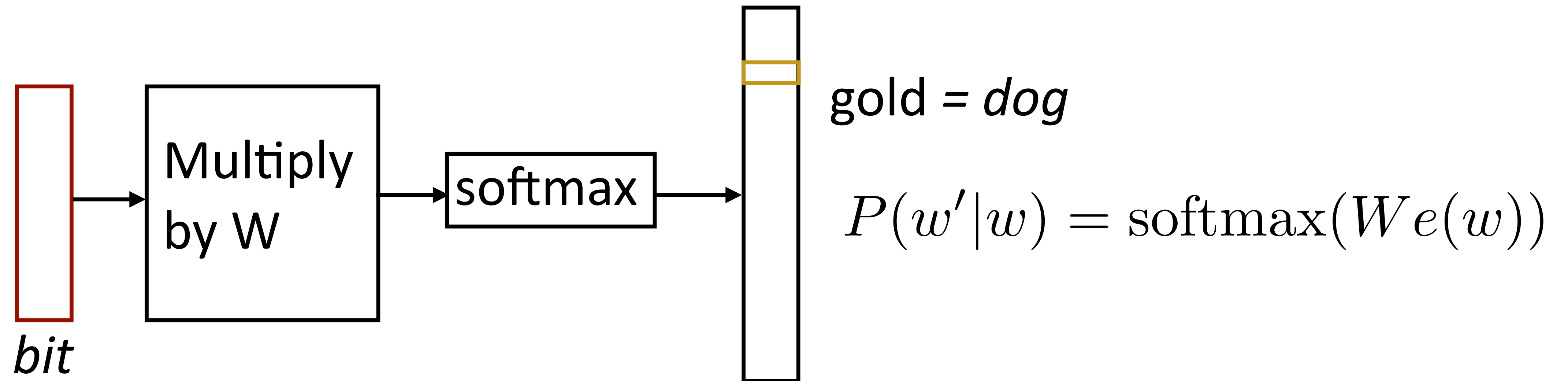
the *dog* *bit* *the* *man*



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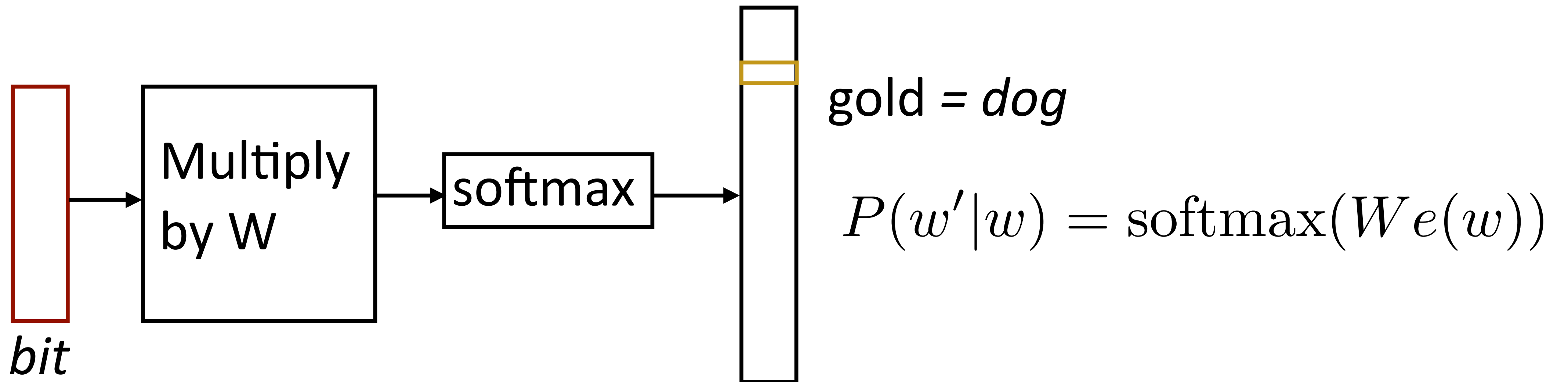
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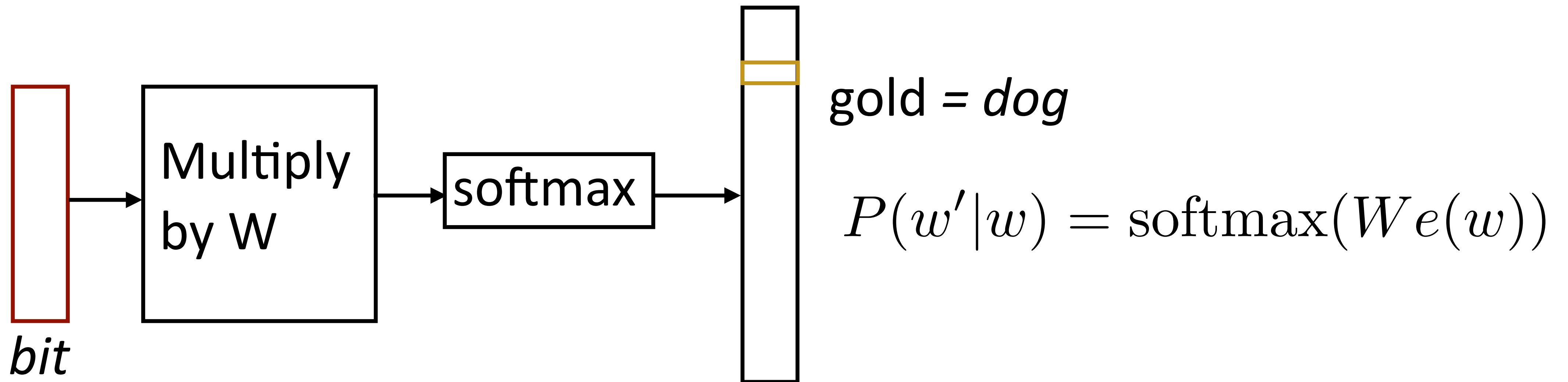


- Another training example: *bit* -> *the*

Skip-Gram

- Predict one word of context from word

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- Another training example: *bit* -> *the*
- Parameters: $d \times |V|$ **vectors**, $|V| \times d$ output parameters (W) (also usable as vectors!)

Hierarchical Softmax

$$P(w|w_{-1}, w_{+1}) = \text{softmax}(W(c(w_{-1}) + c(w_{+1}))) \quad P(w'|w) = \text{softmax}(We(w))$$

Hierarchical Softmax

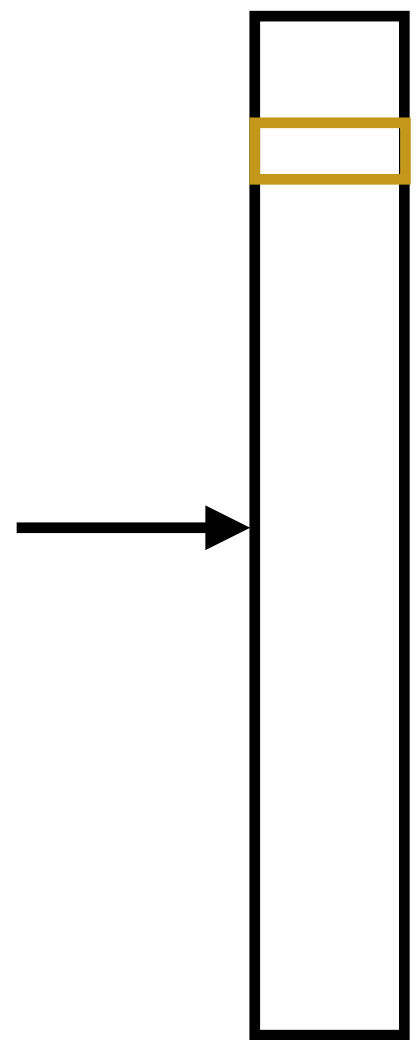
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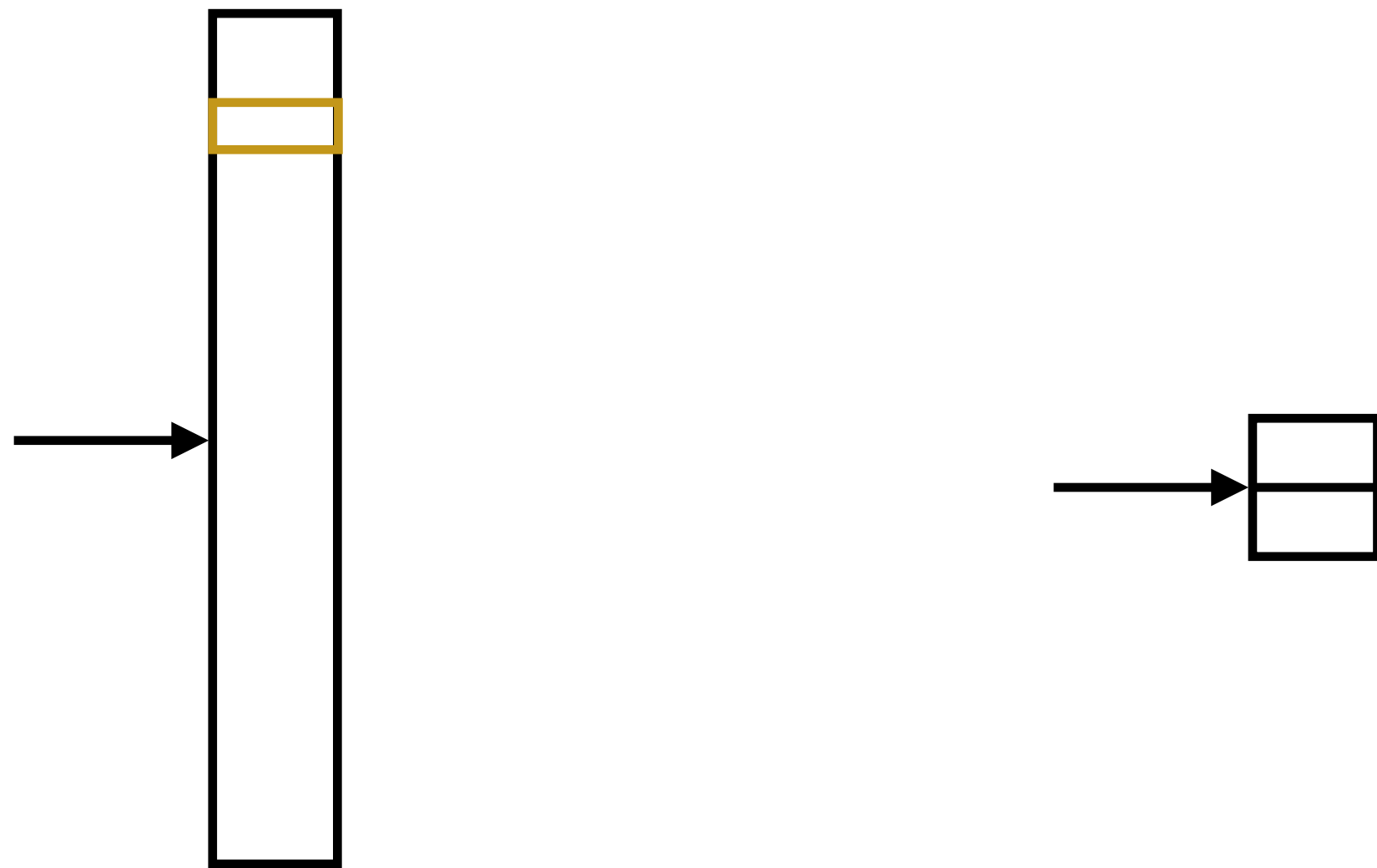


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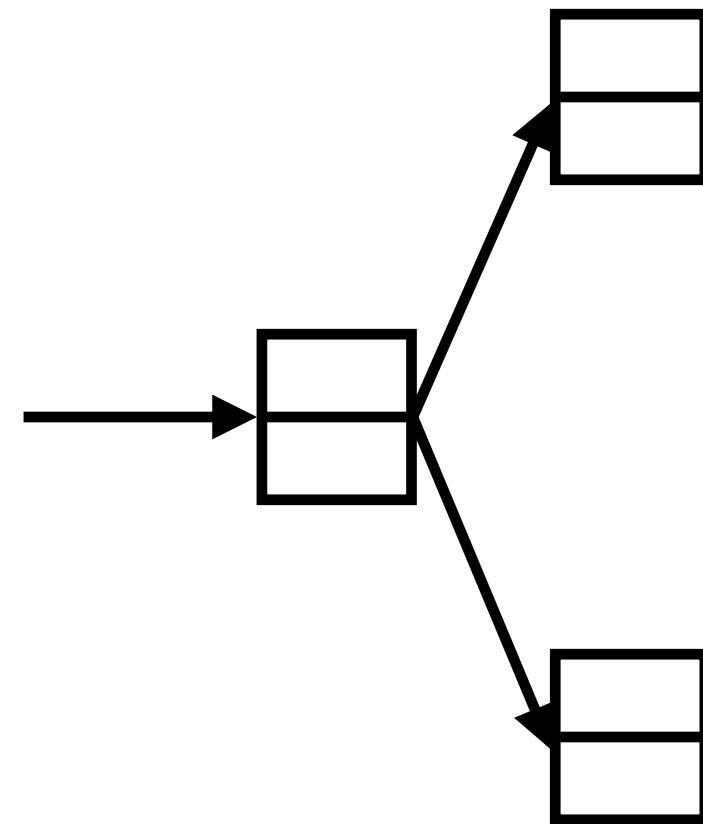
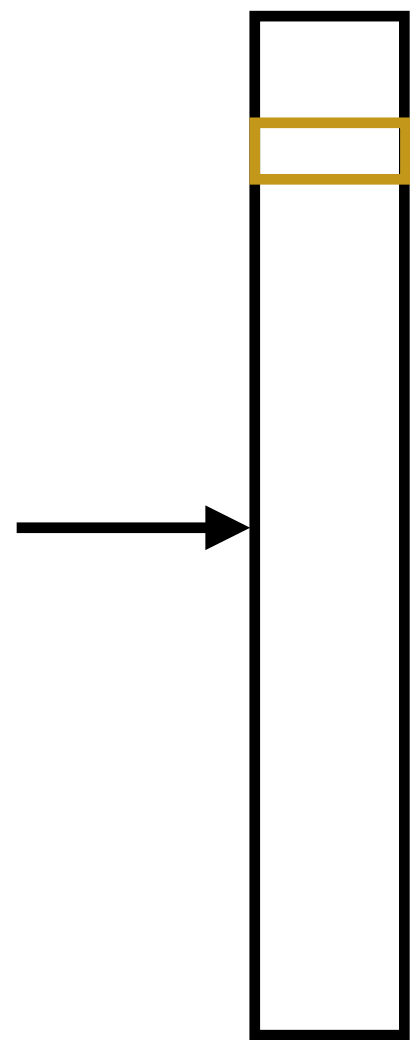


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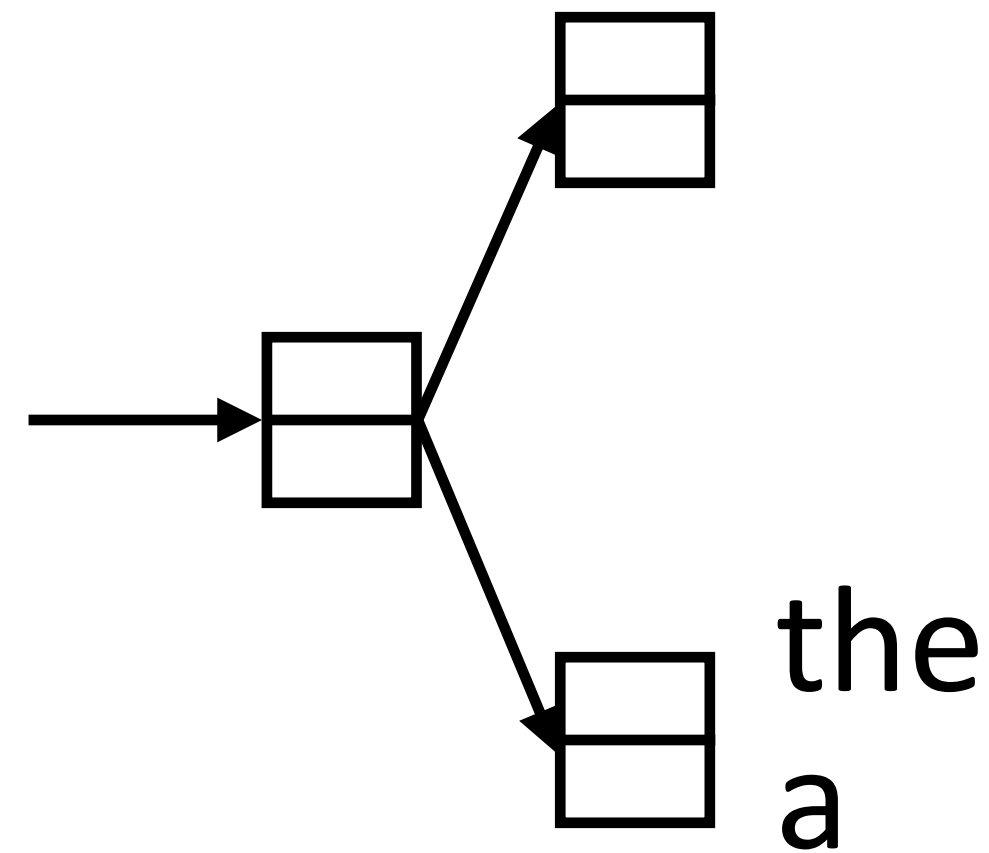
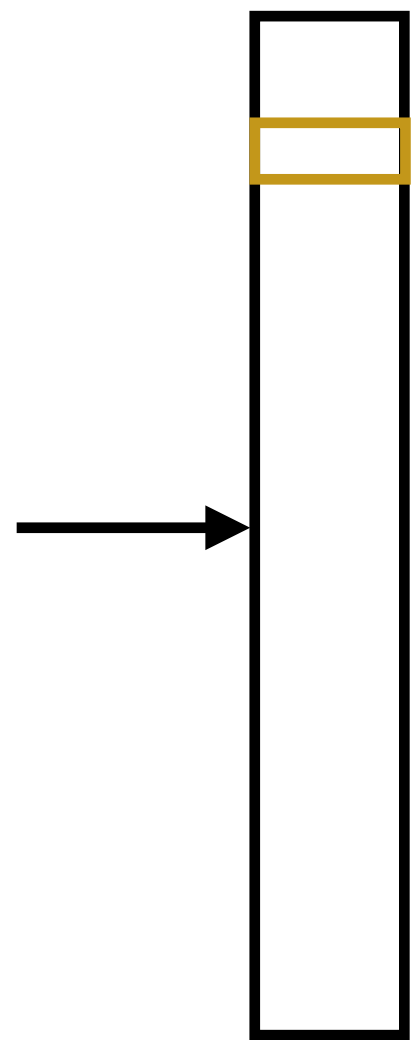


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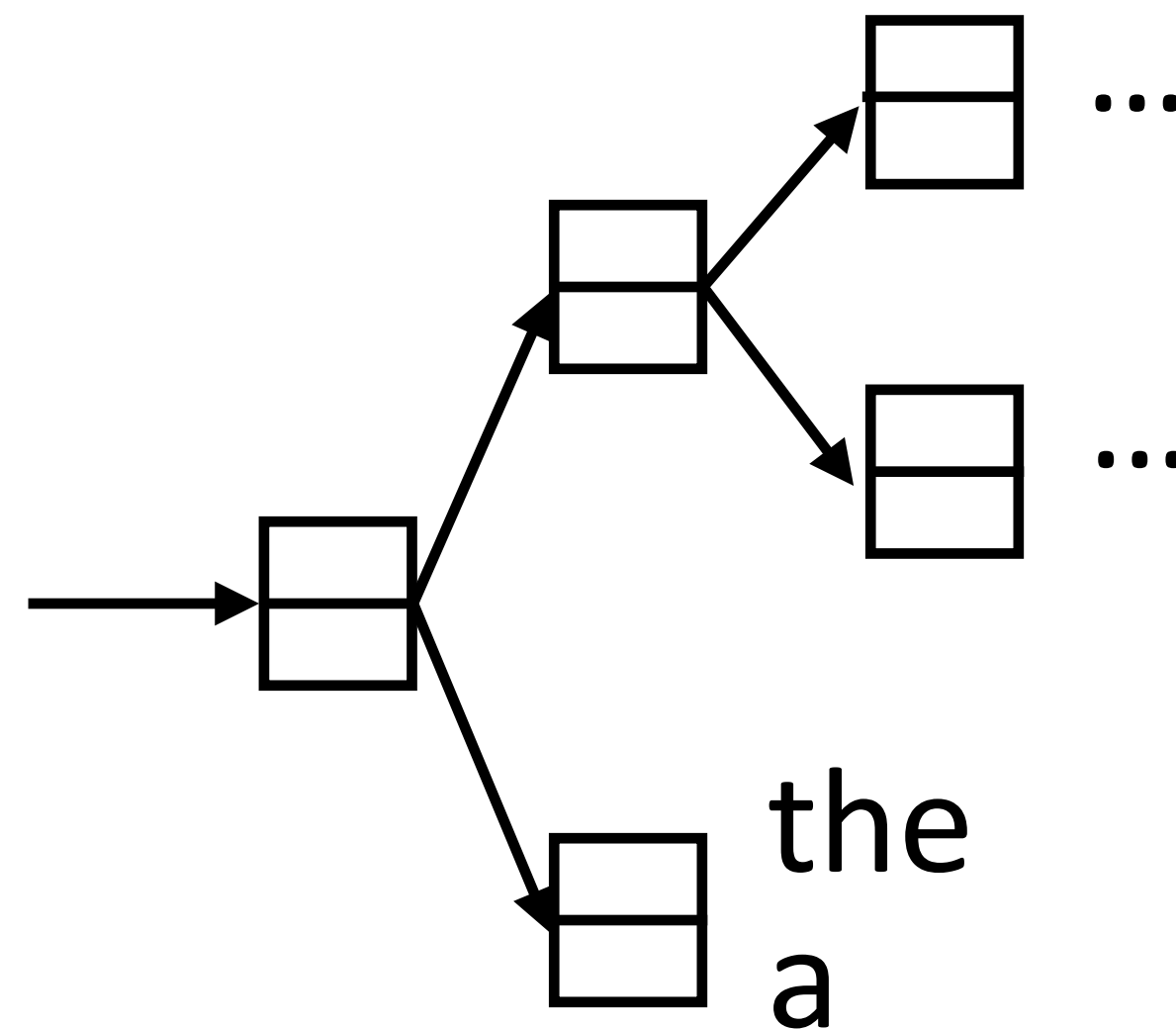
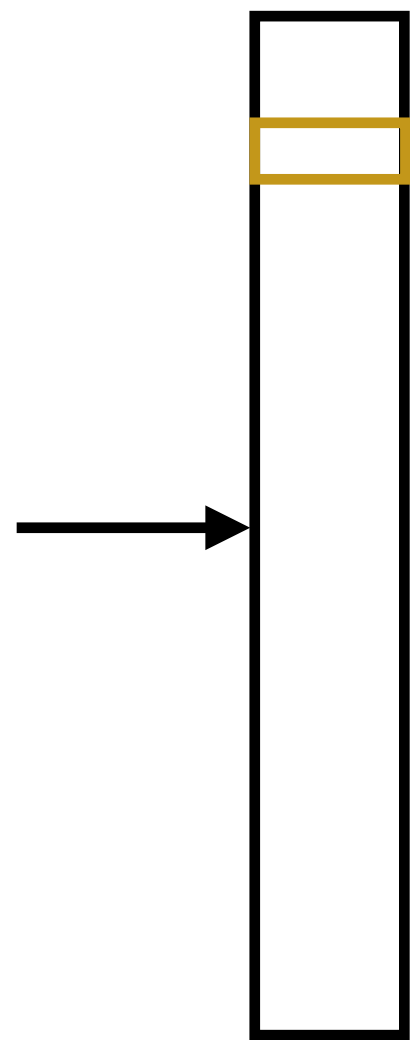


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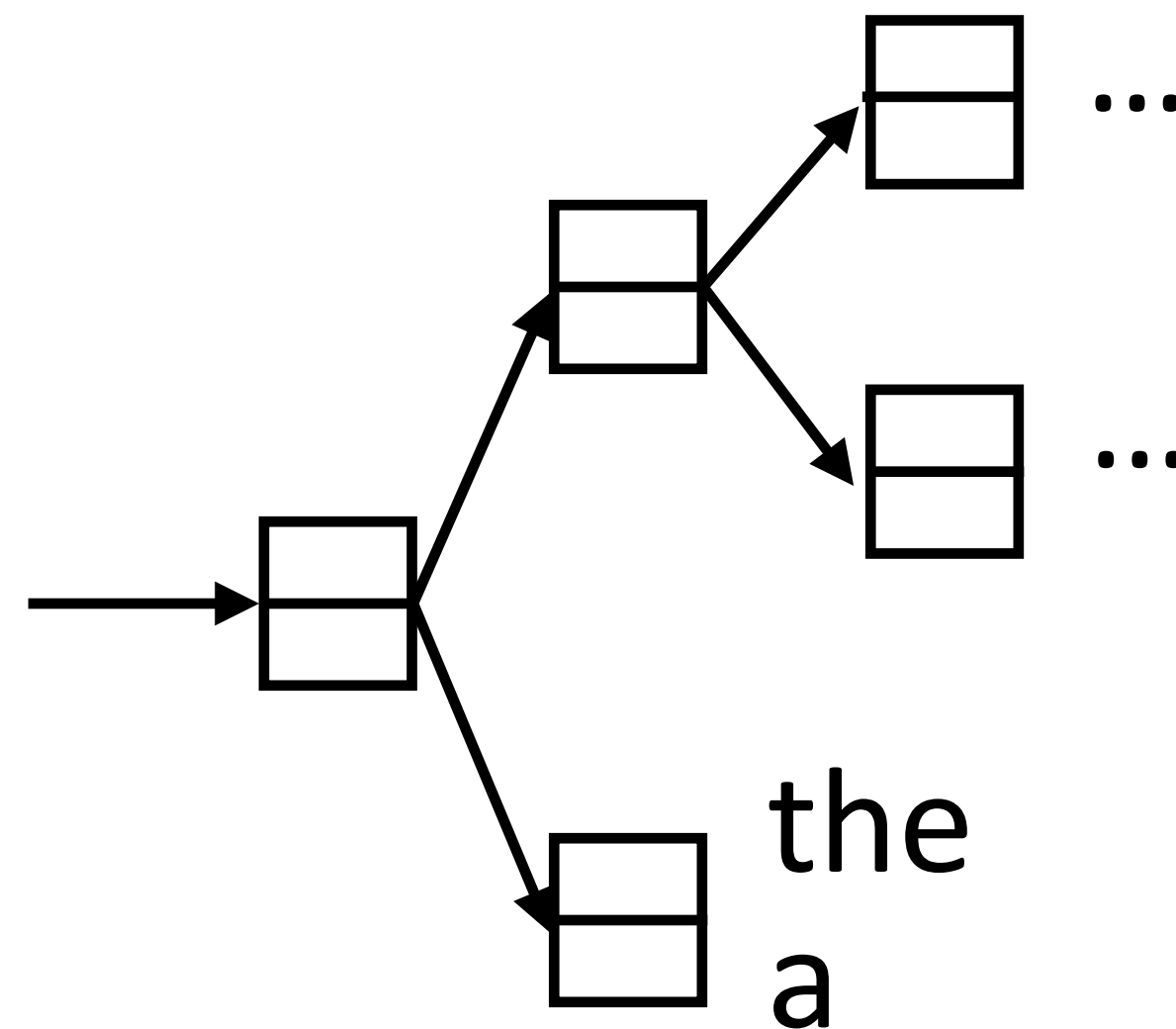
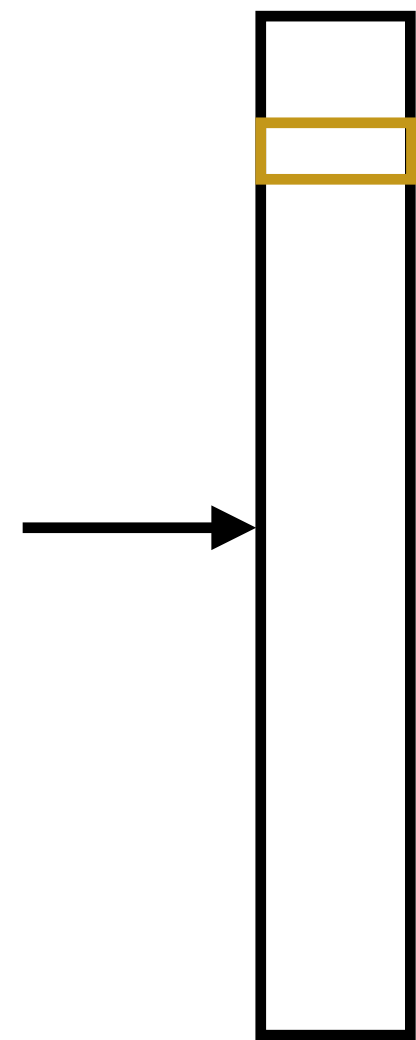


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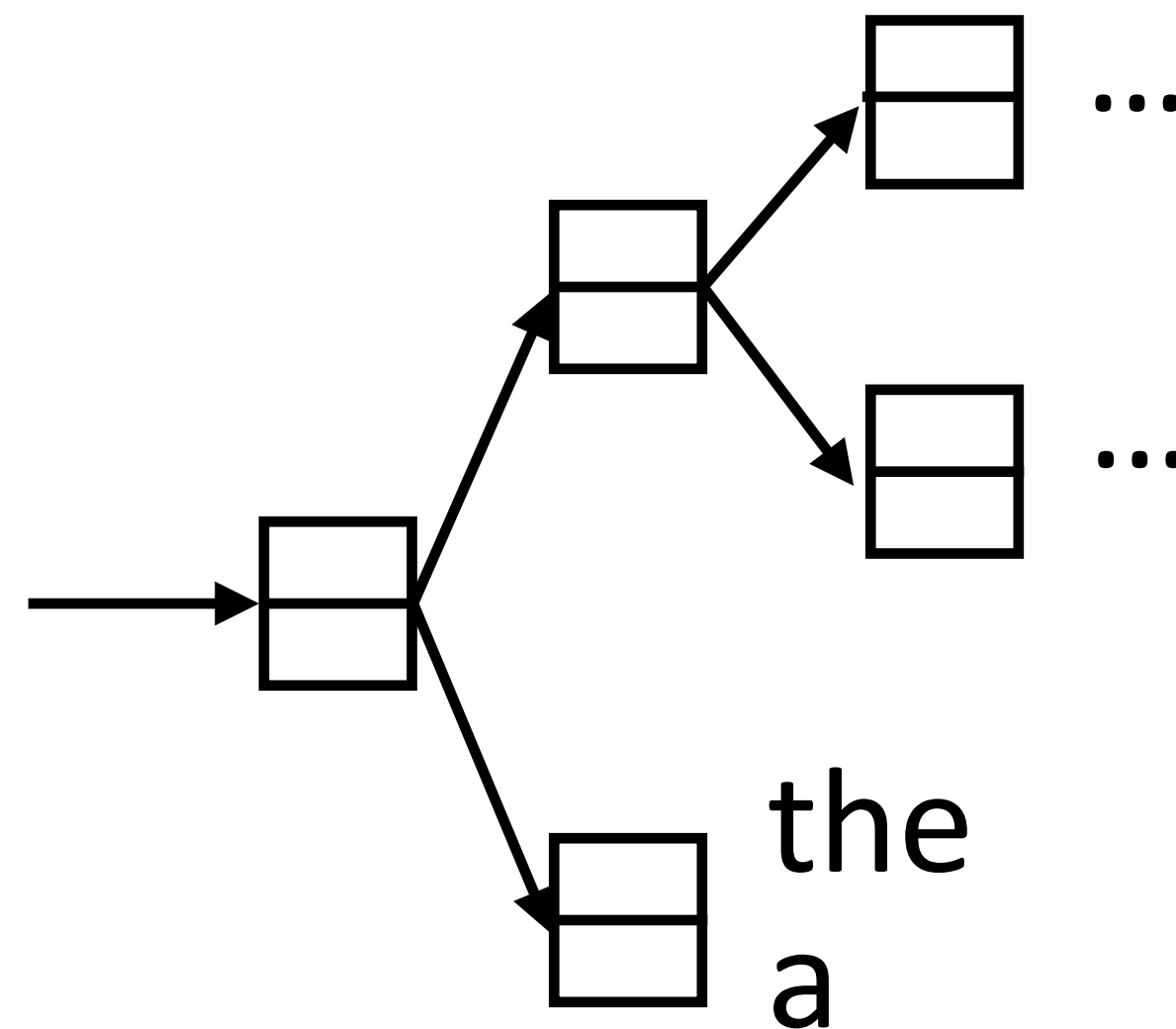
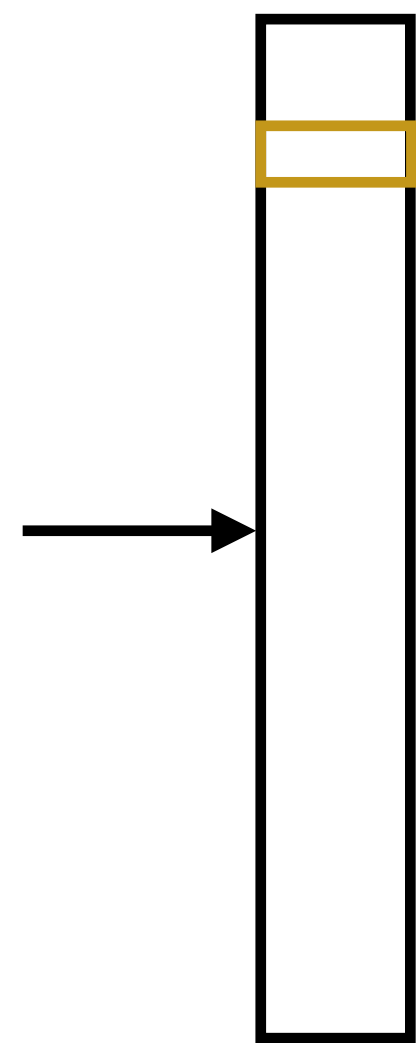
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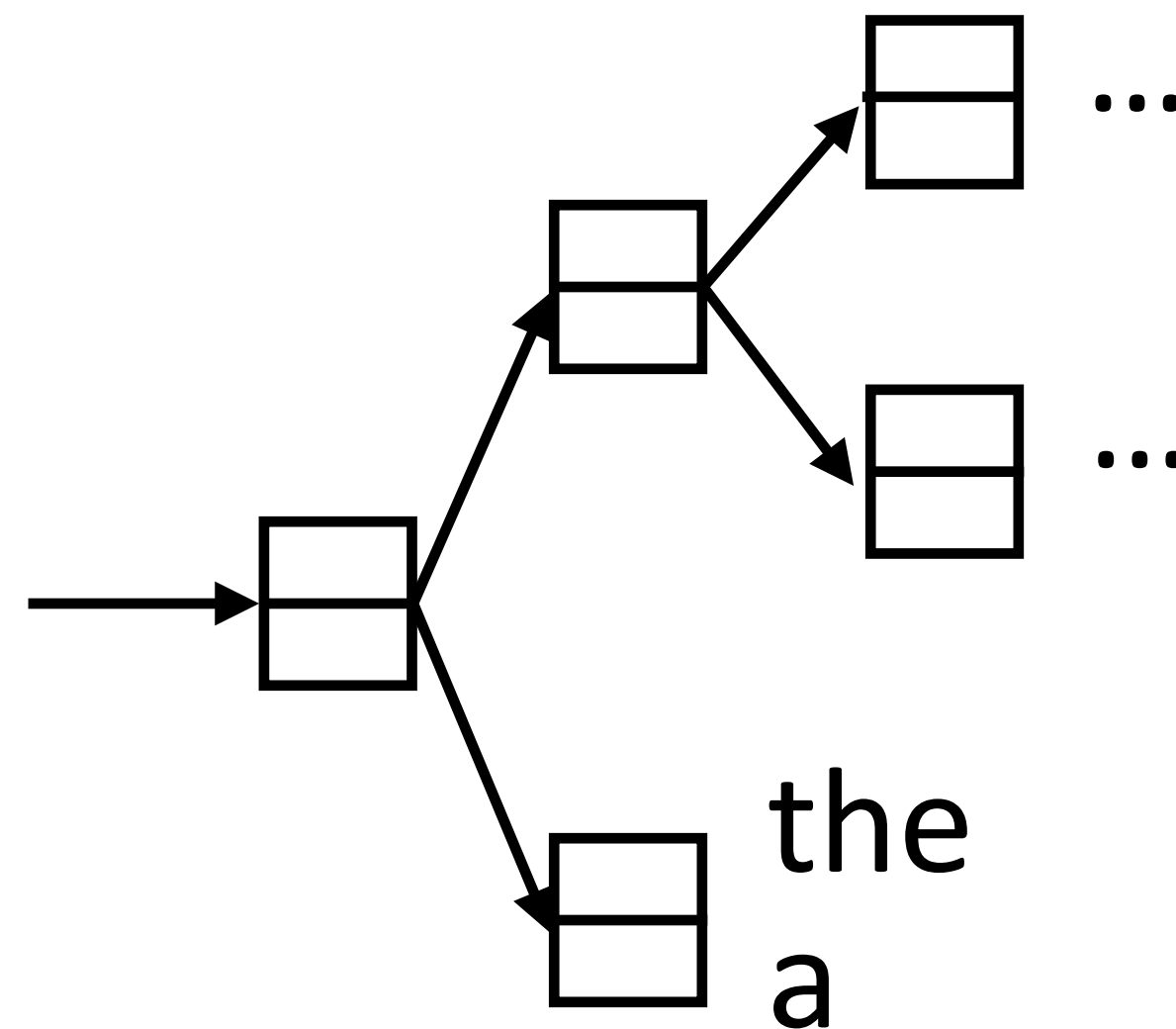
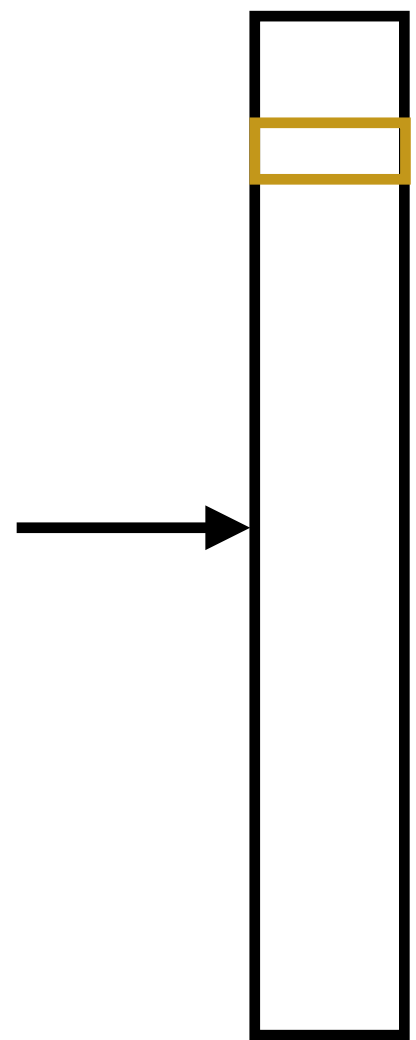


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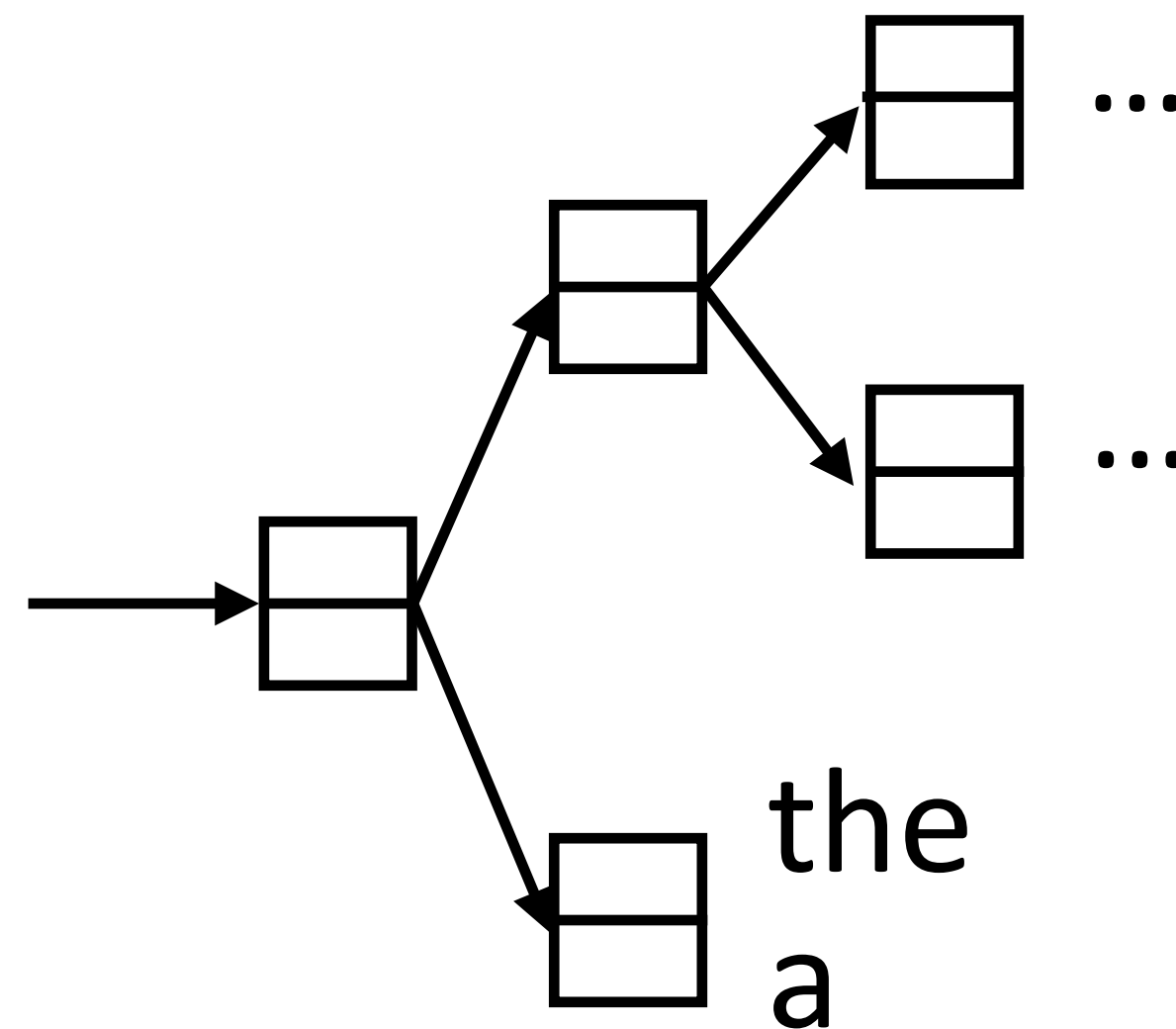
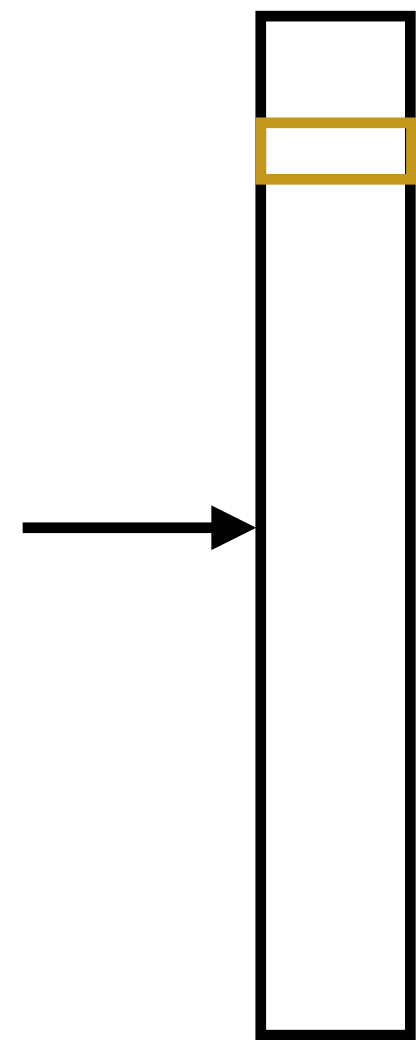
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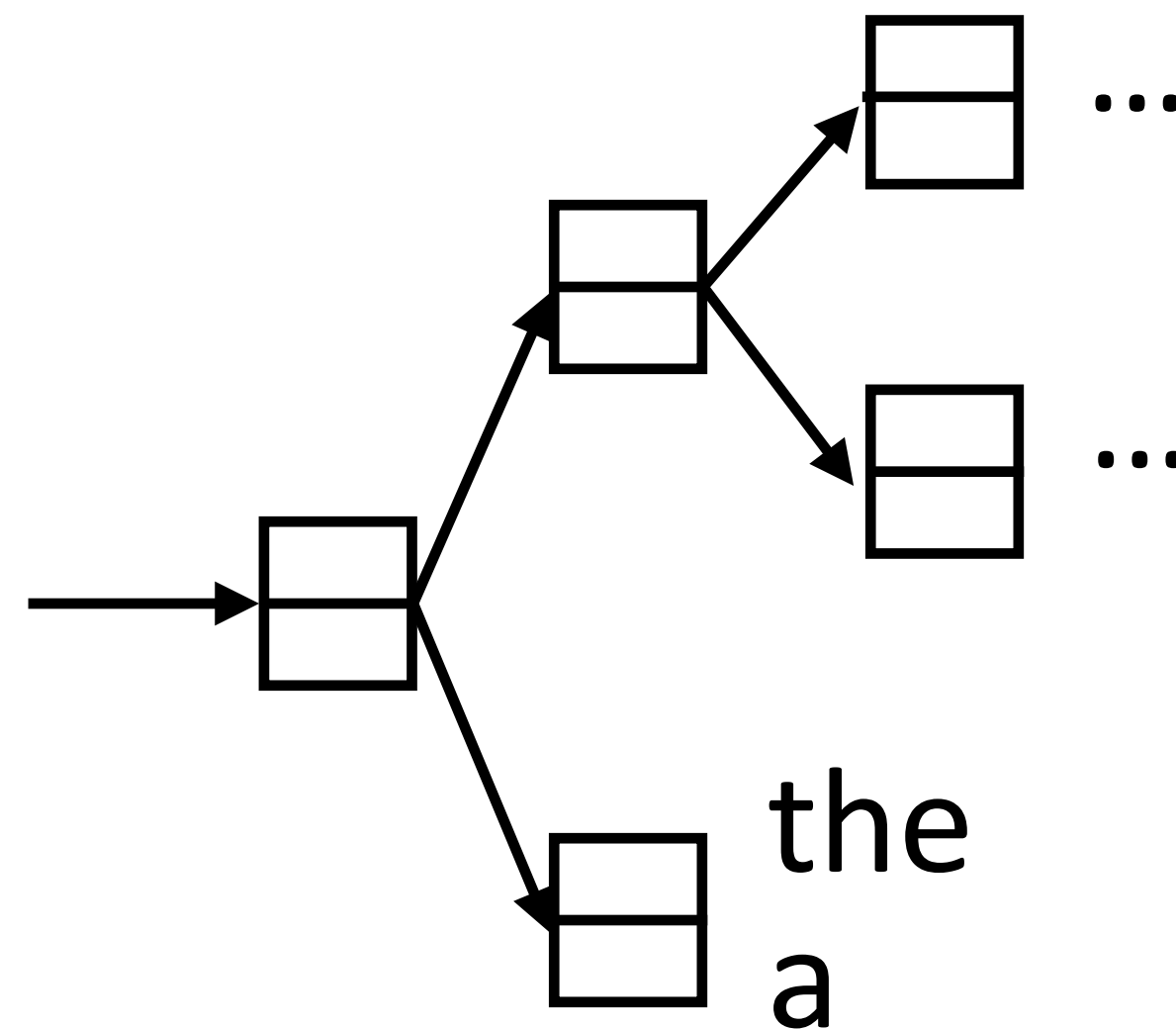
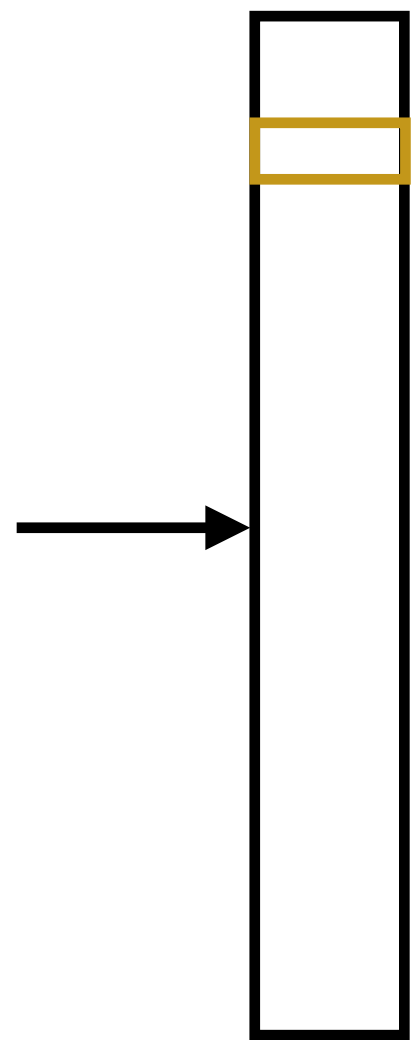
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 $|V| \times d$ parameters

Mikolov et al. (2013)

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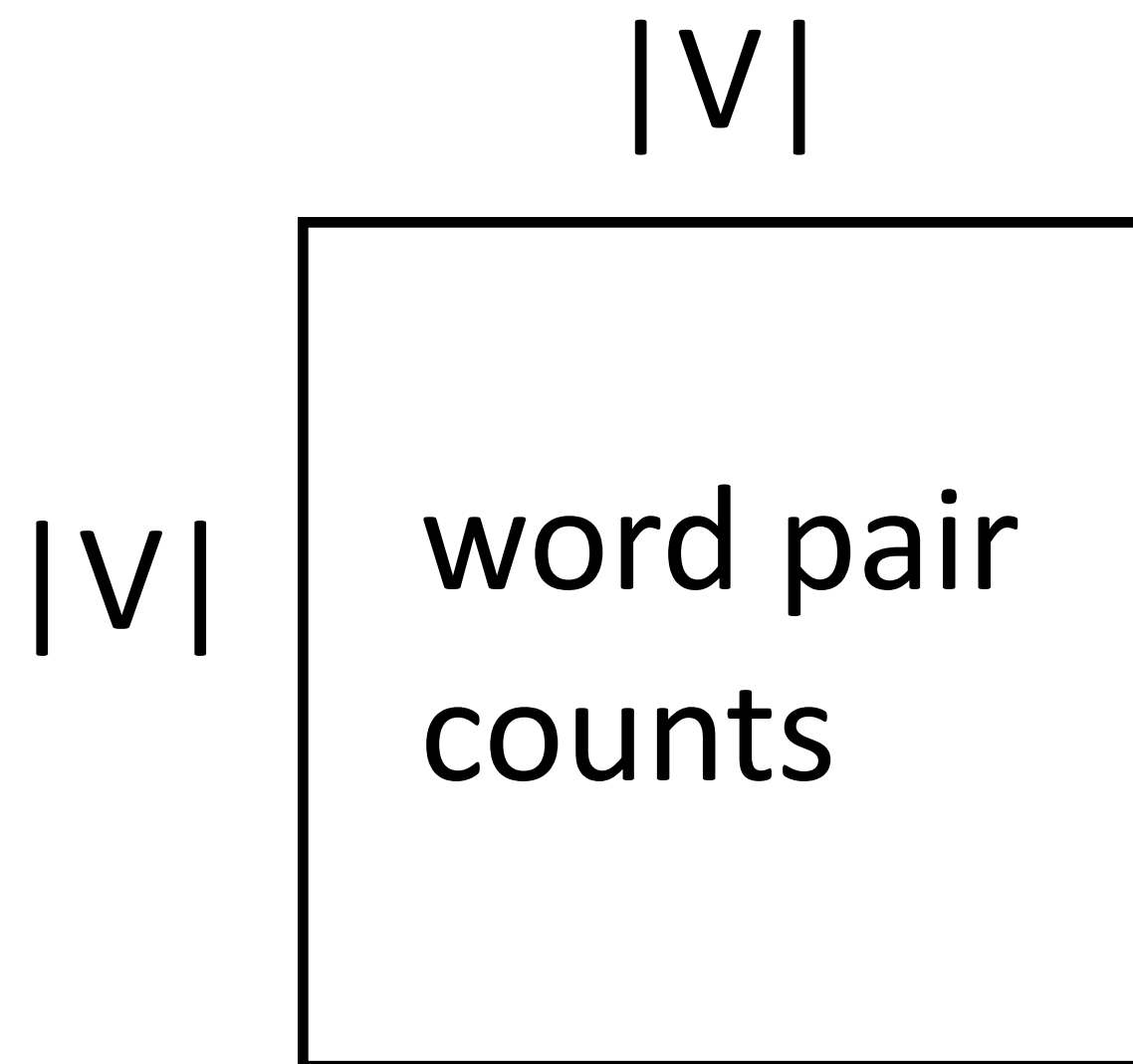
Mikolov et al. (2013)

Connections with Matrix Factorization

- ▶ Skip-gram model looks at word-word co-occurrences and produces two types of vectors

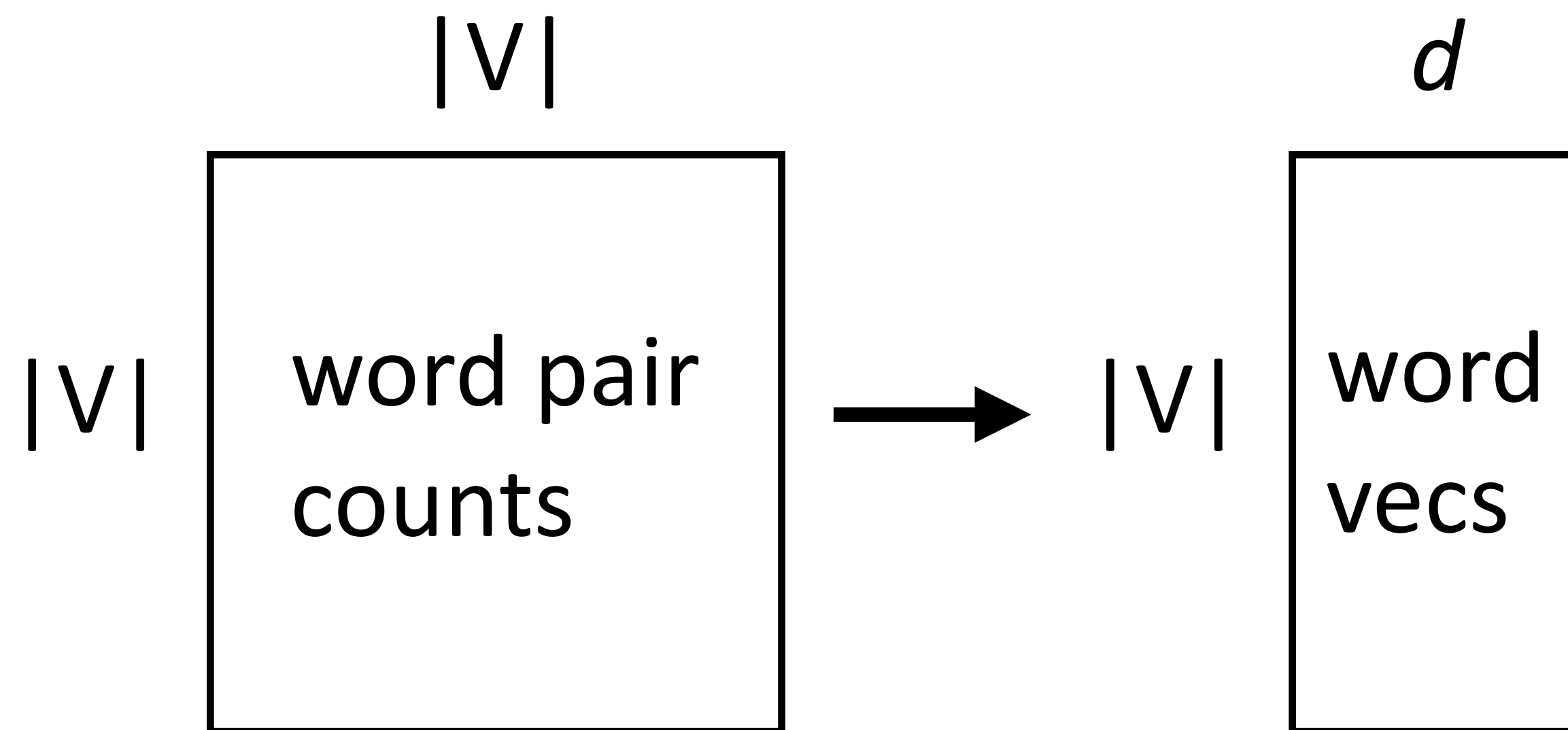
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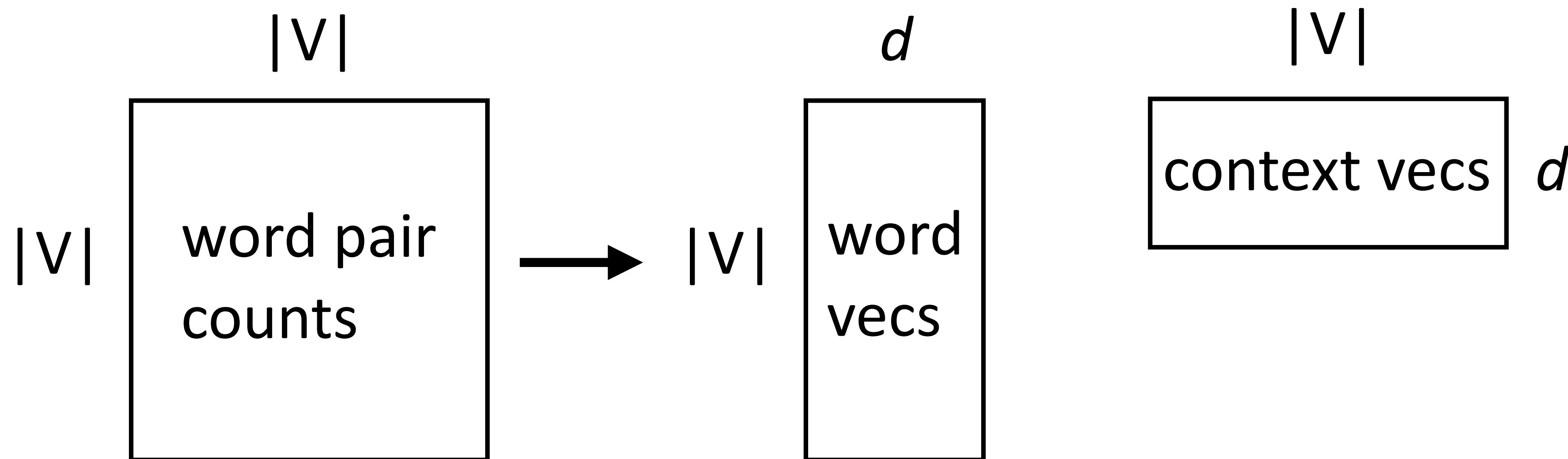
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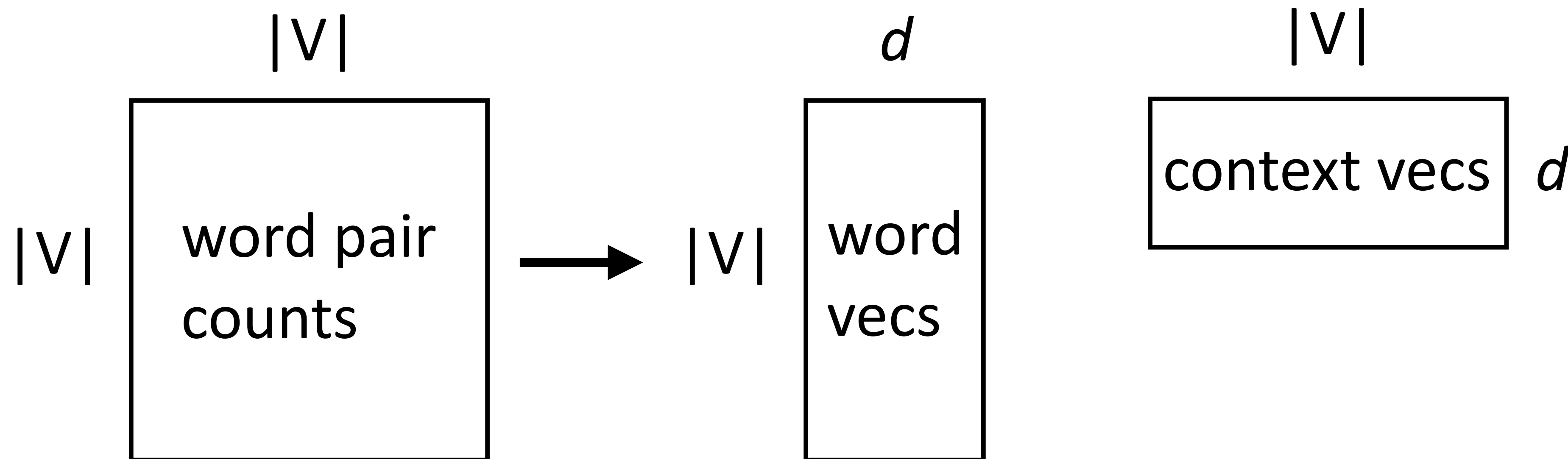
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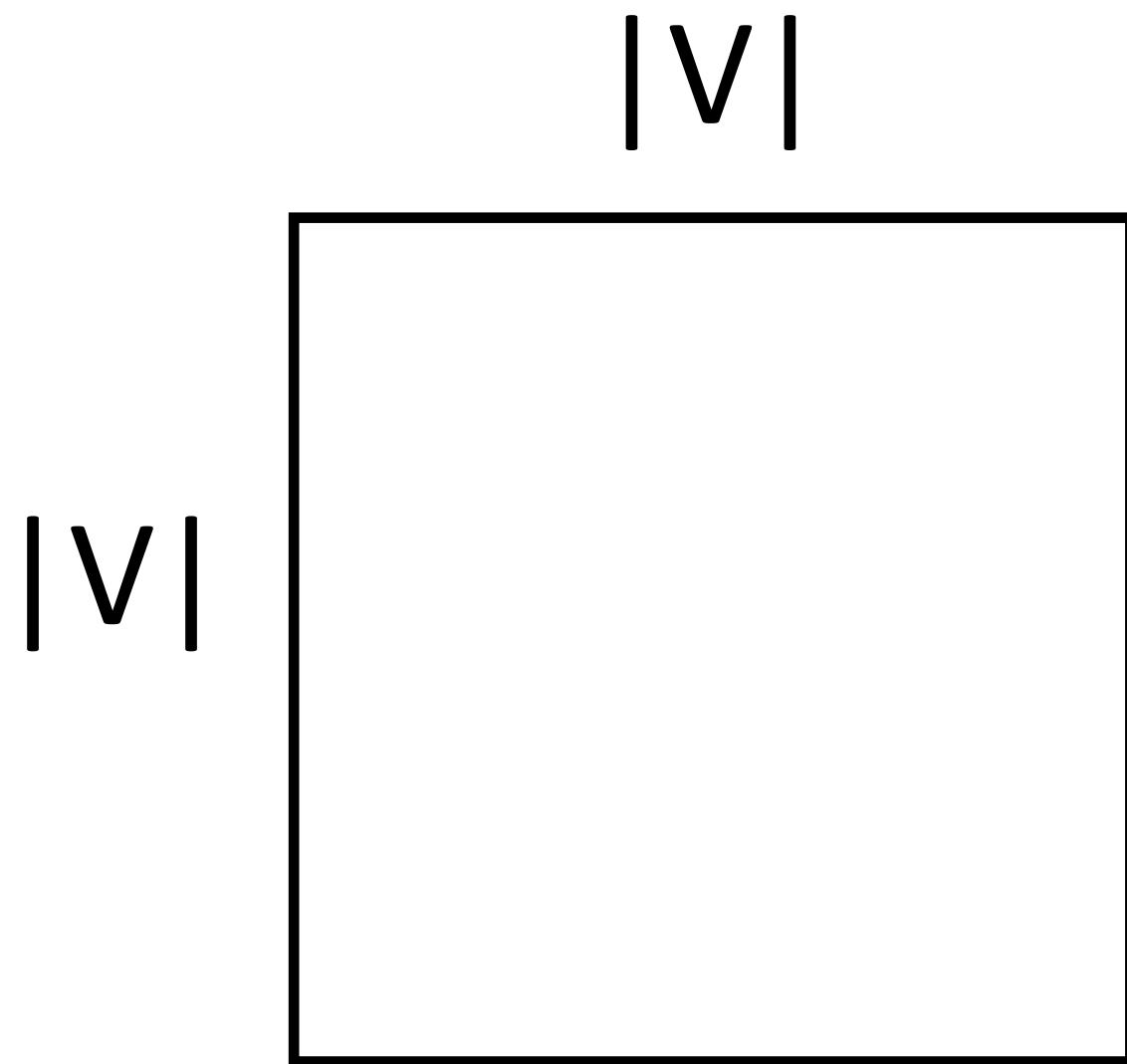
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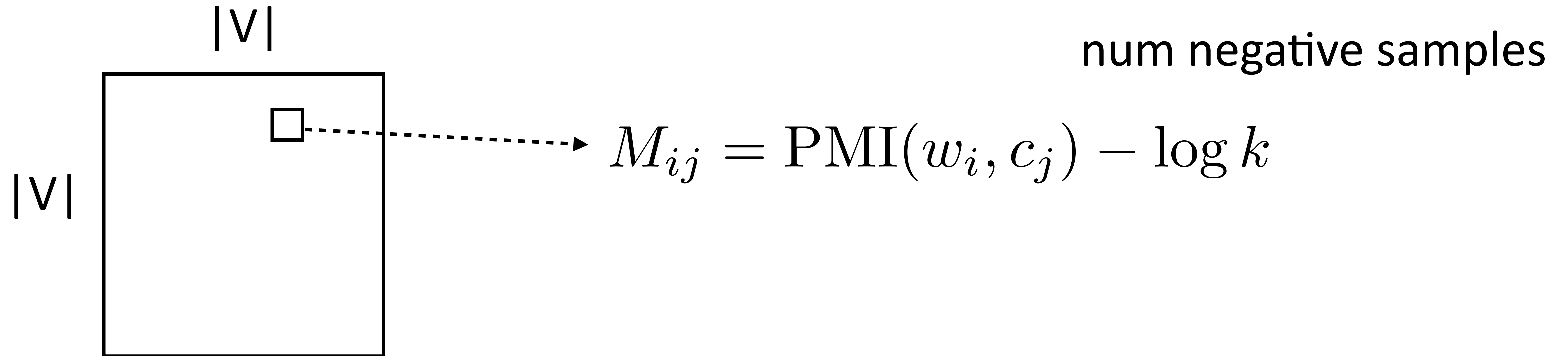


- ▶ Looks almost like a matrix factorization...can we interpret it this way?

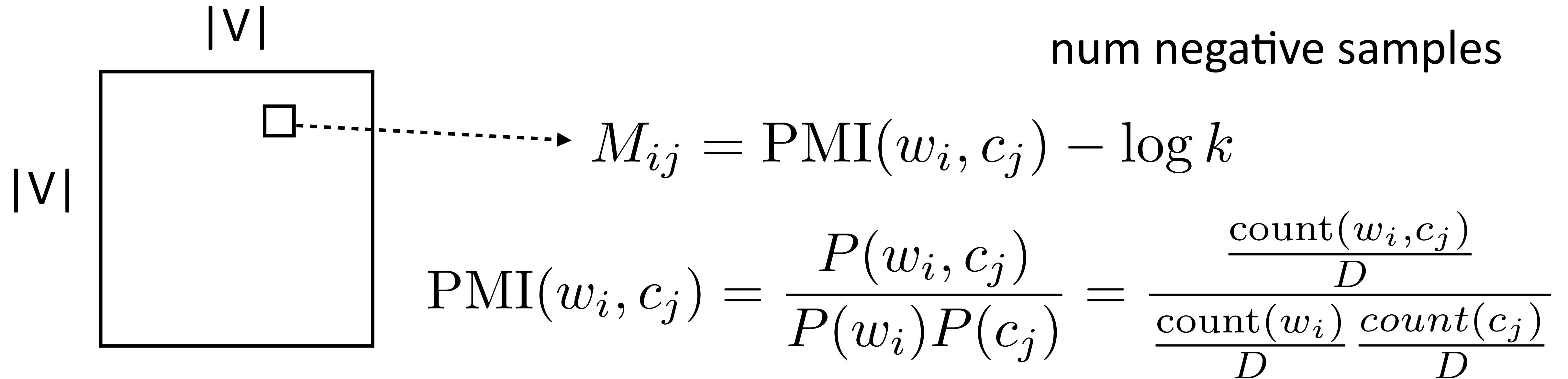
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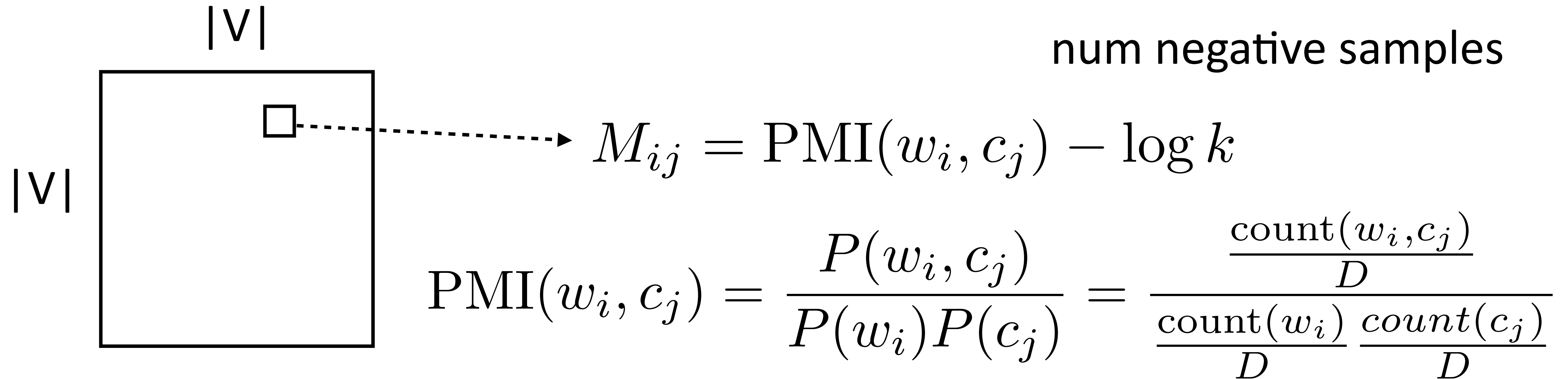
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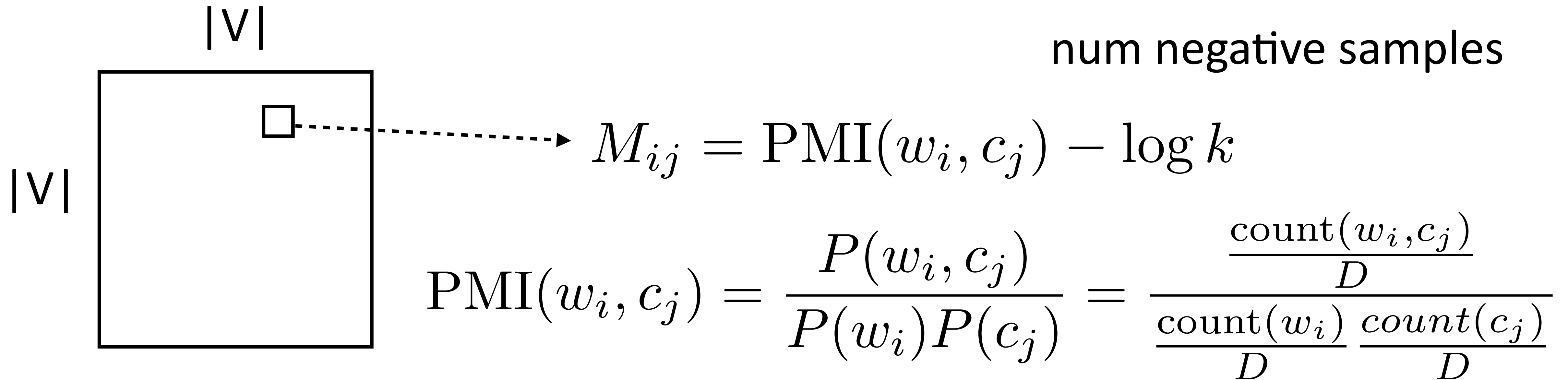


Skip-Gram as Matrix Factorization



Skip-gram objective *exactly* corresponds to factoring this matrix:

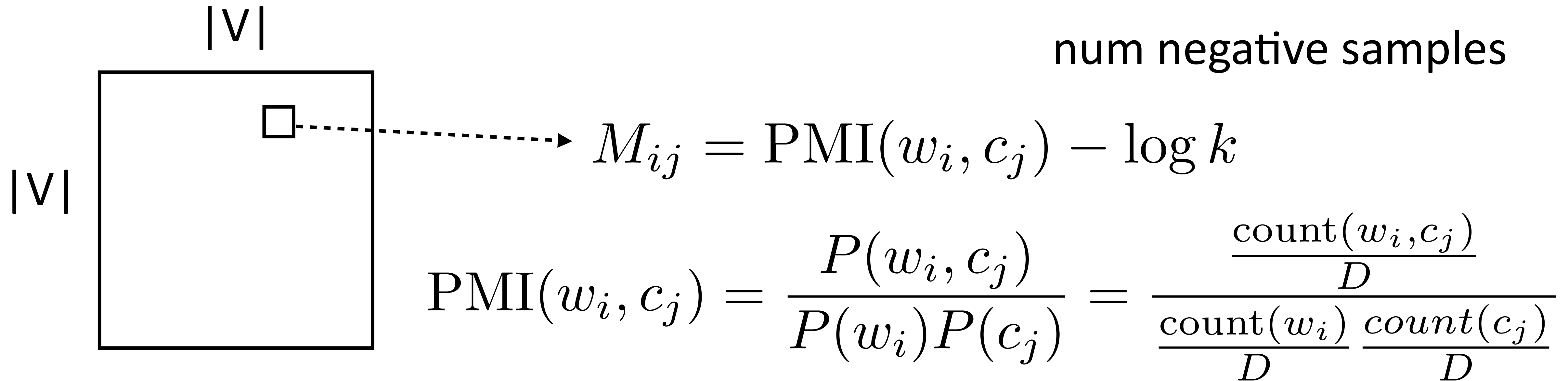
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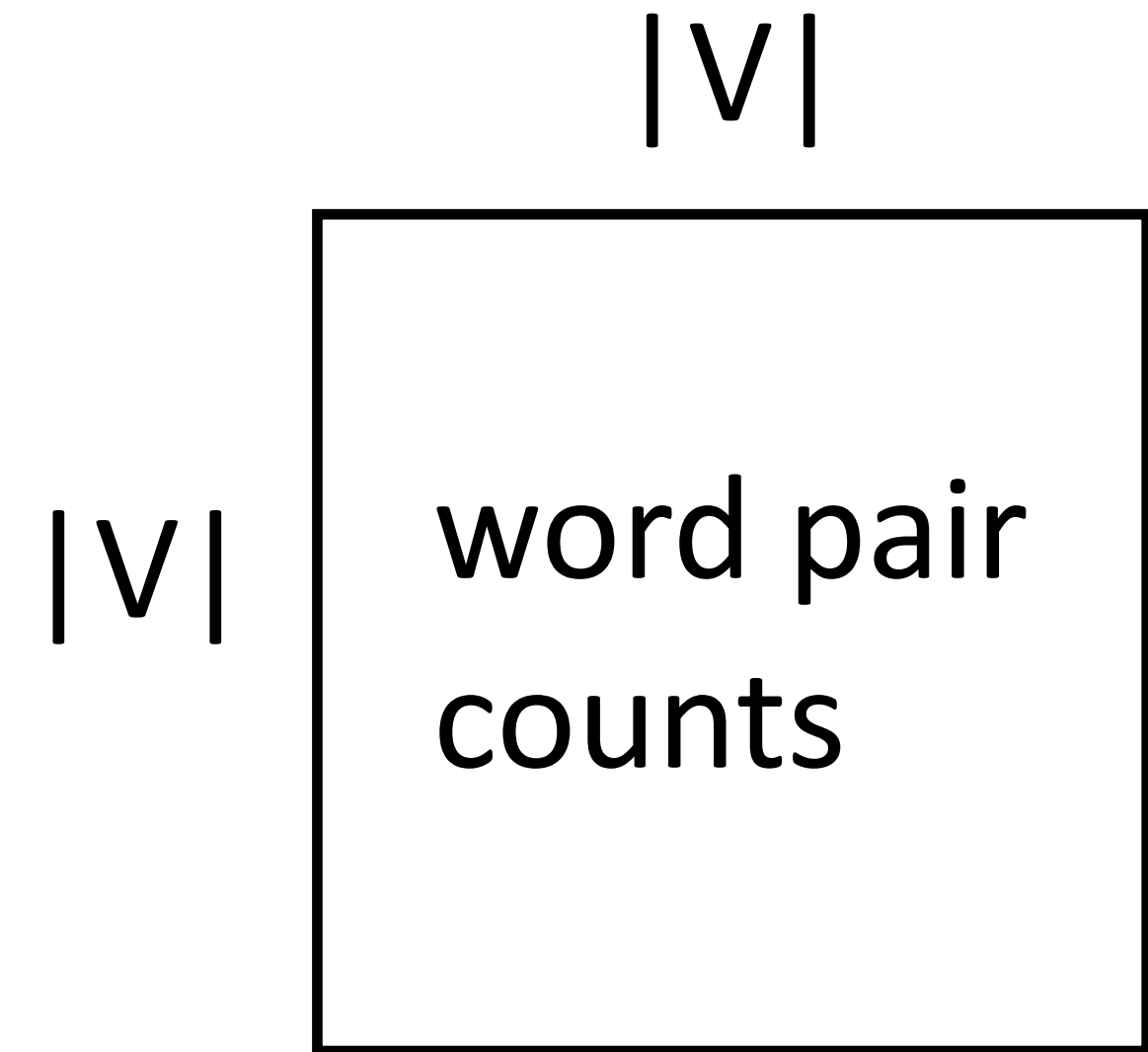


Skip-gram objective *exactly* corresponds to factoring this matrix:

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- ▶ ...and it's a *weighted* factorization problem (weighted by word freq)

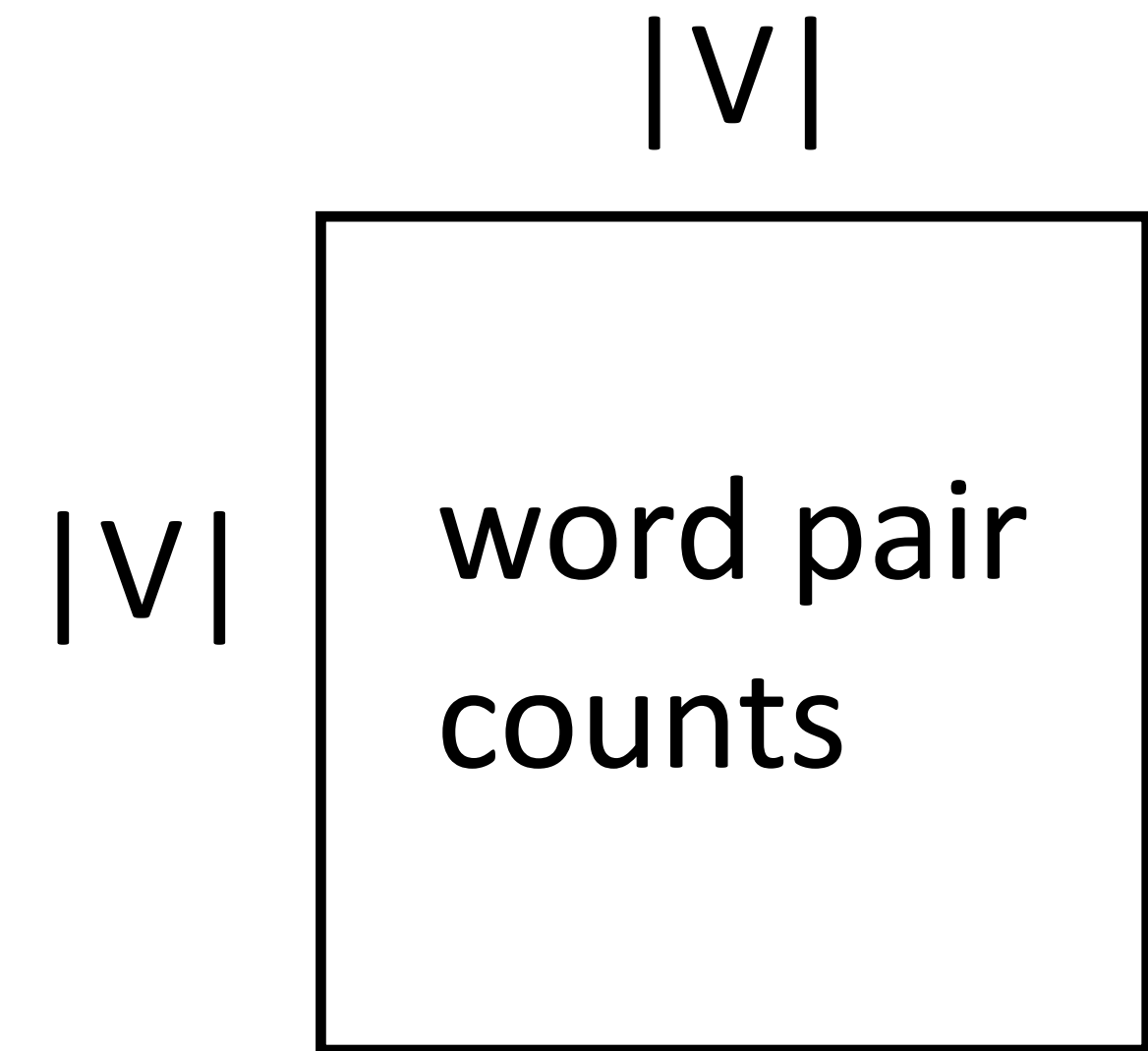
GloVe (Global Vectors)

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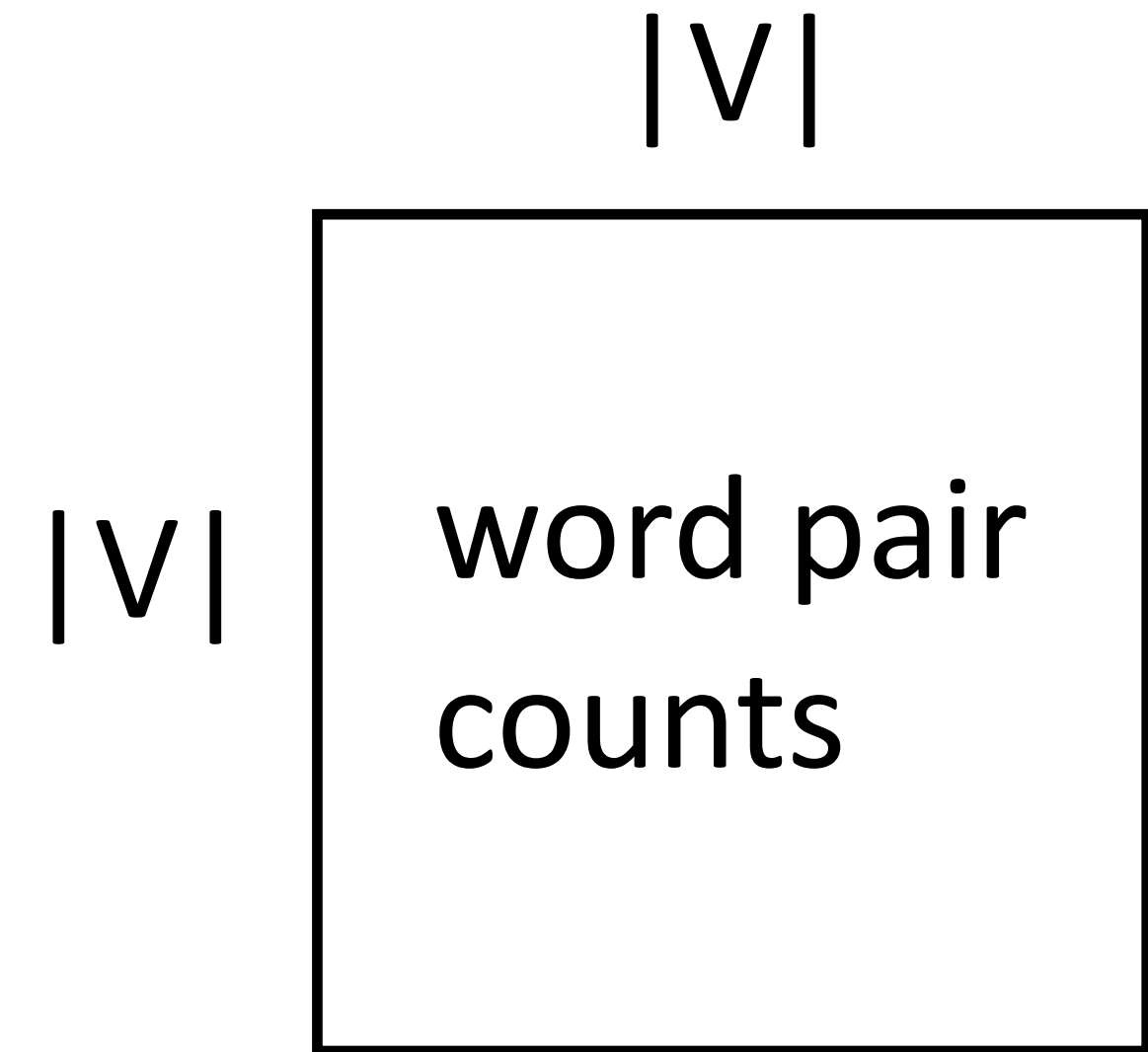
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- ▶ Loss
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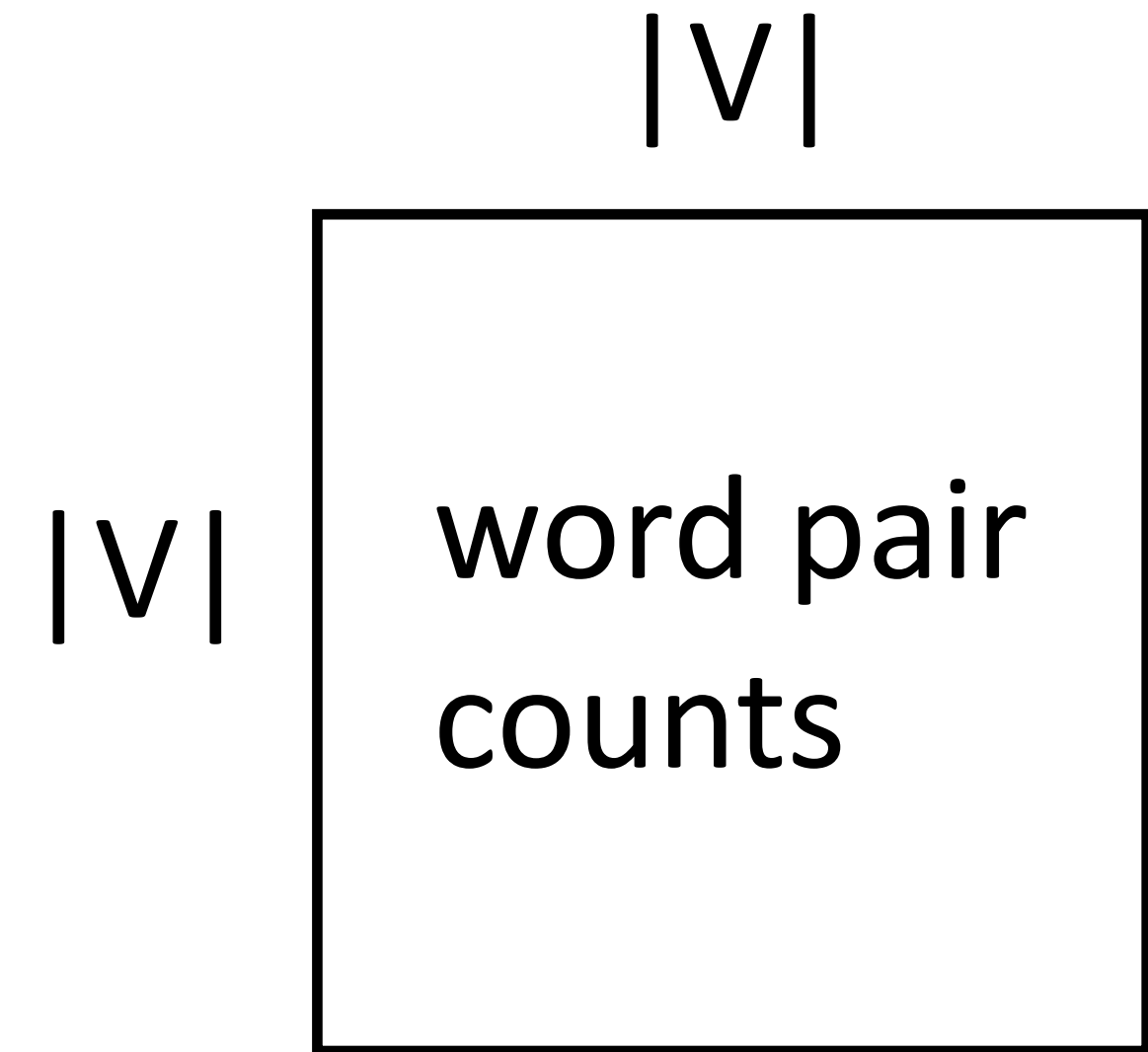
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- ▶ Constant in the dataset size (just need counts), quadratic in voc size
- ▶ By far the most common (uncontextualized) word vectors used today (20,000+ citations)

Pennington et al. (2014)

Preview: Context-dependent Embeddings

- ▶ How to handle different word senses? One vector for *balls*

they dance at balls

they hit the balls

Preview: Context-dependent Embeddings

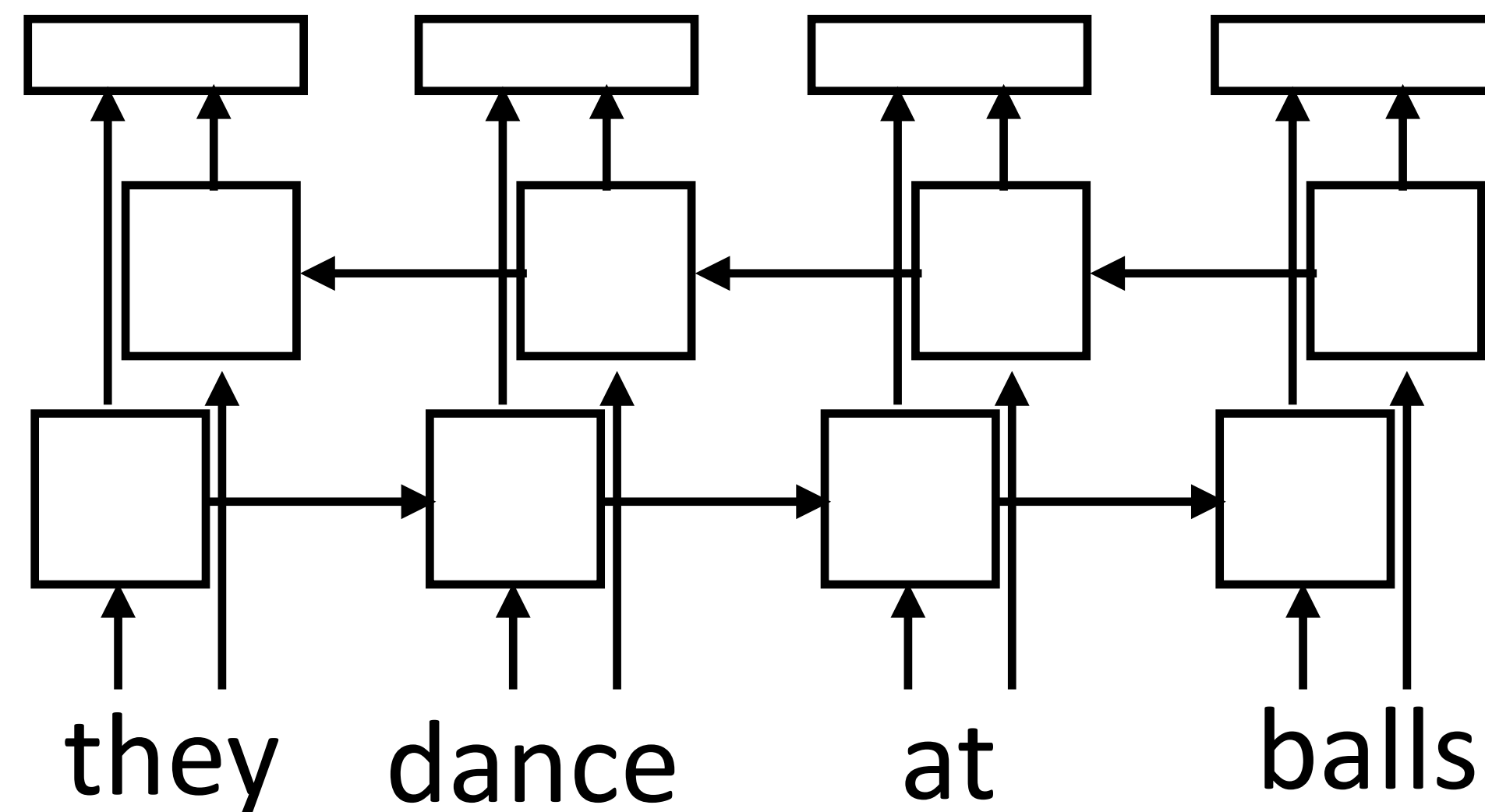
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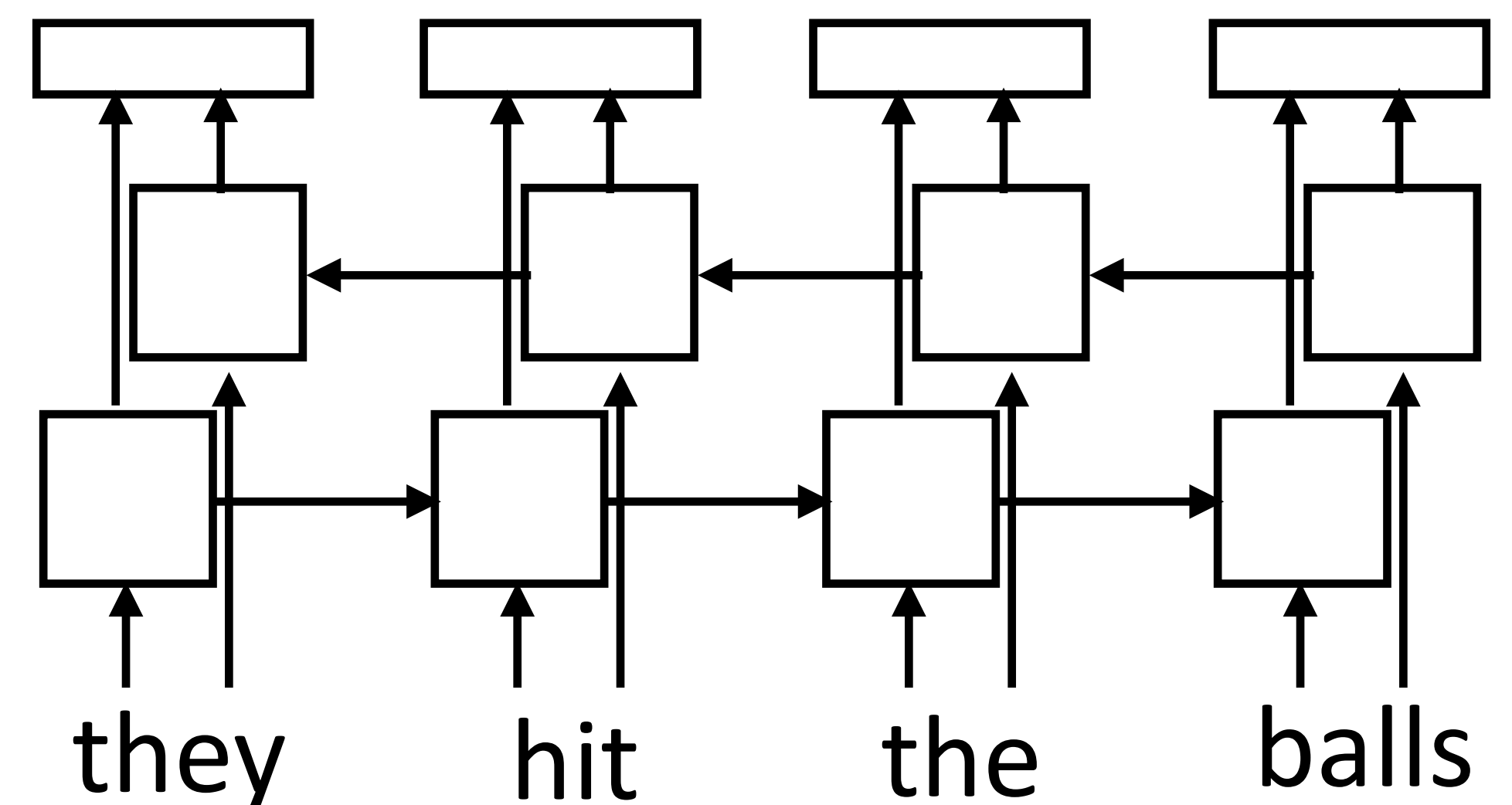
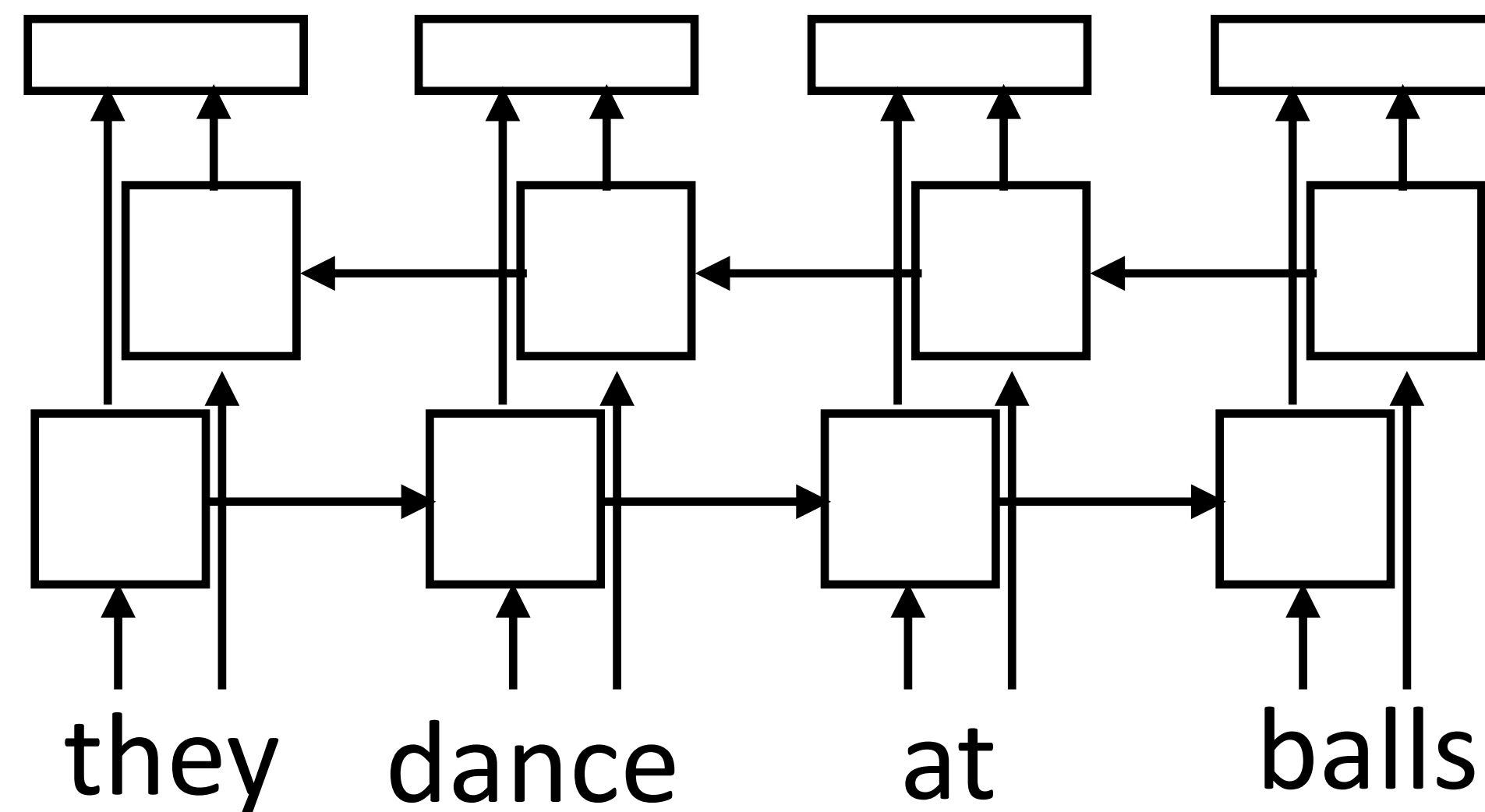


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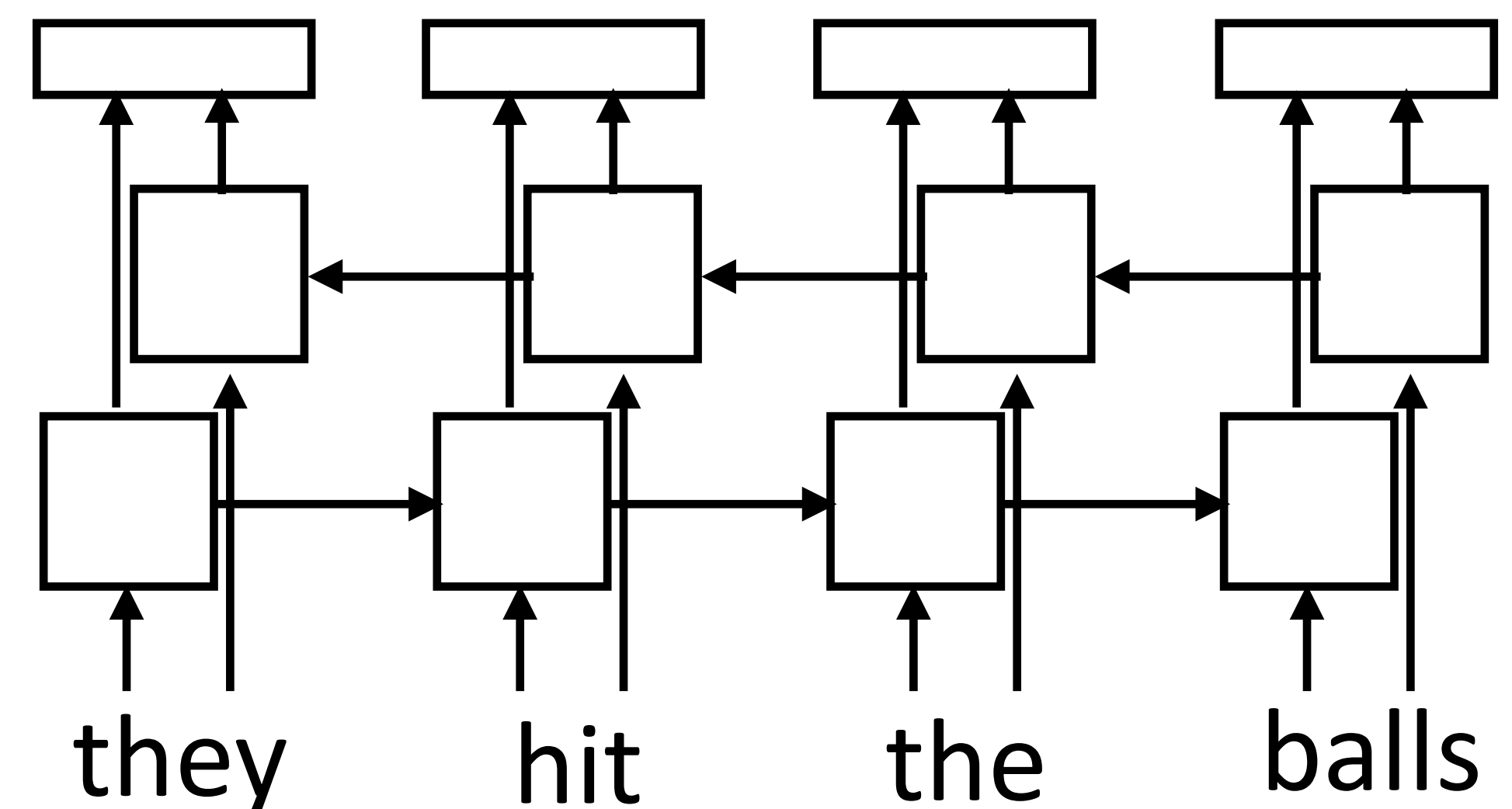
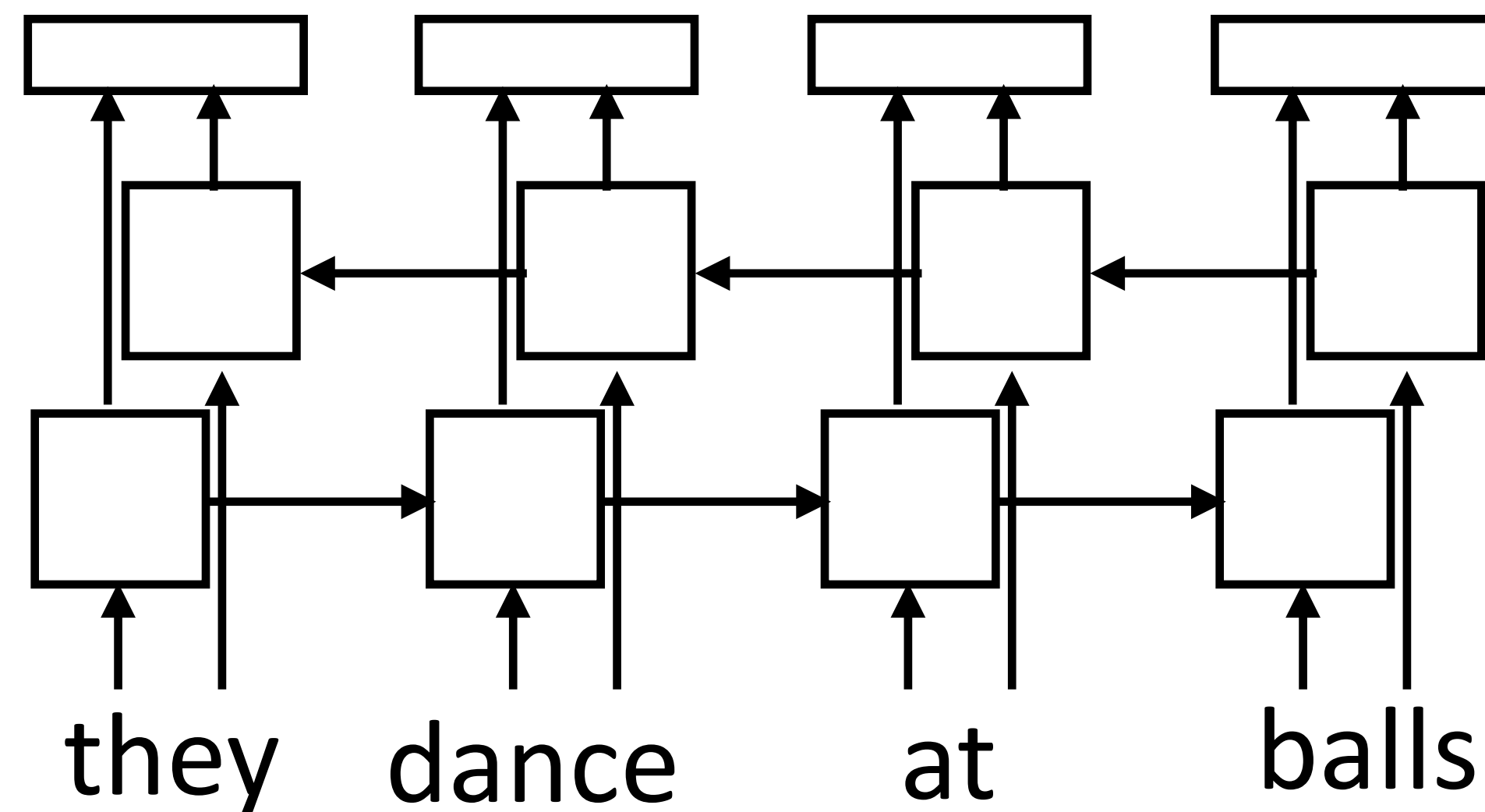
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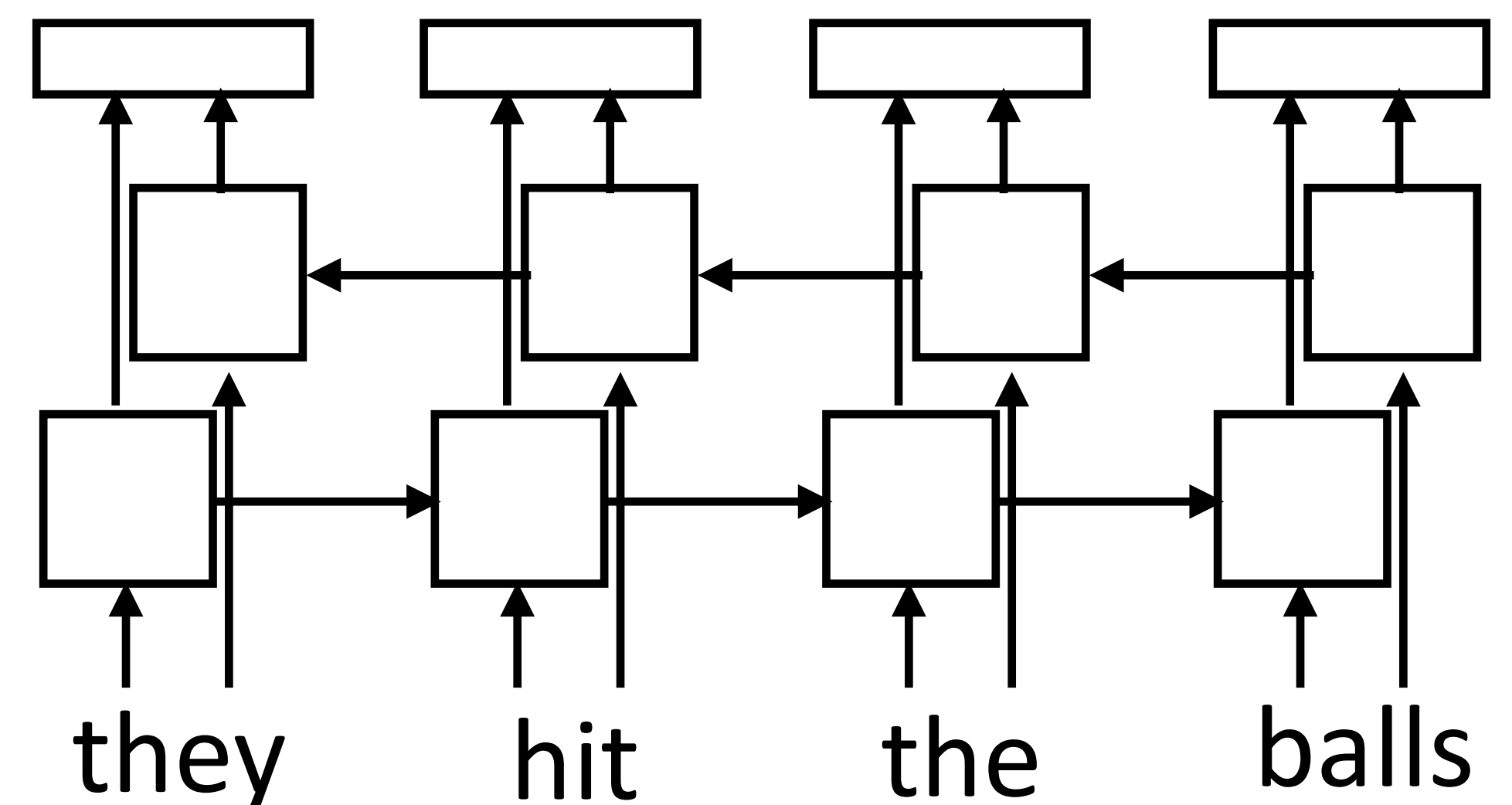
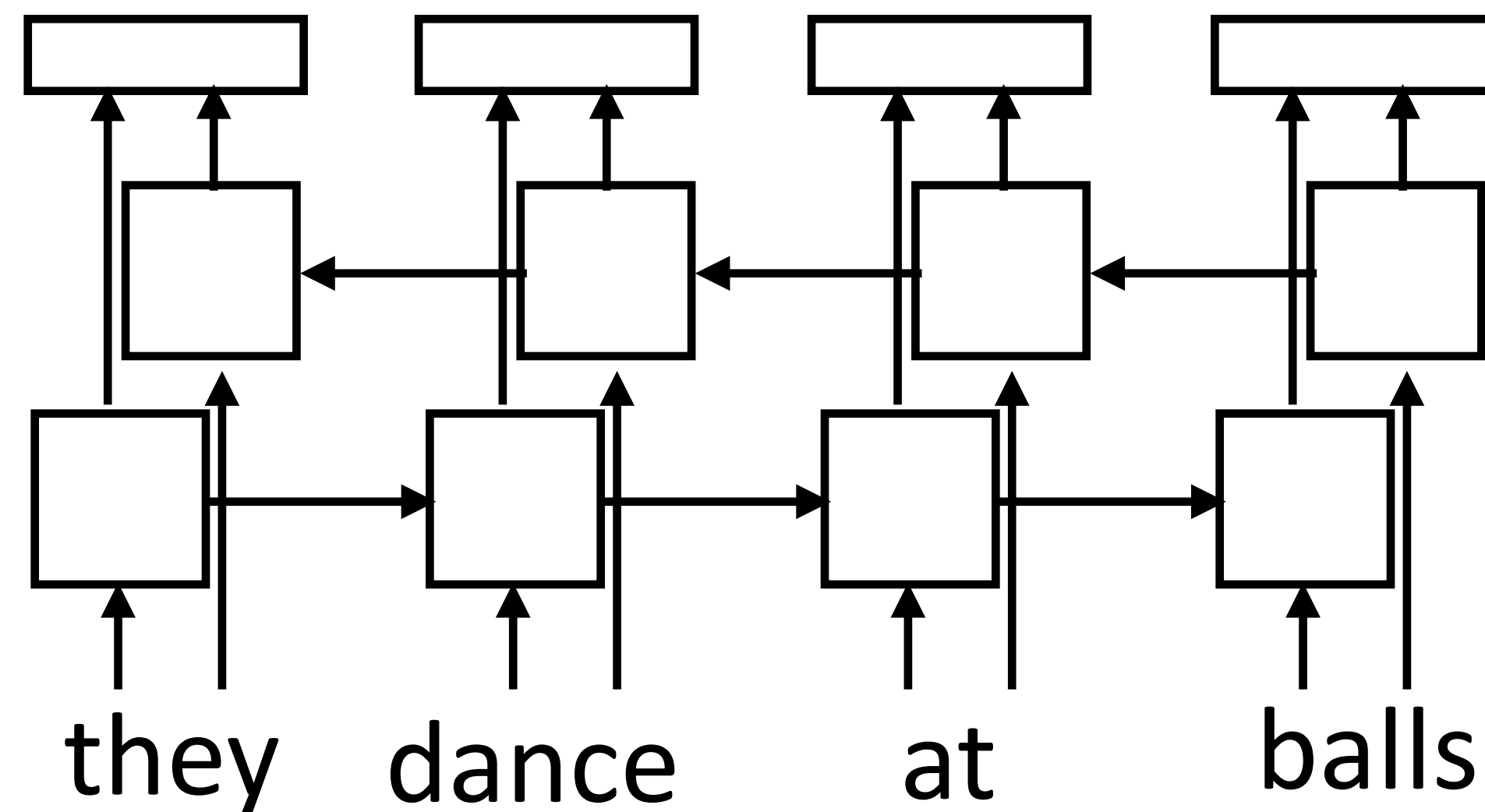
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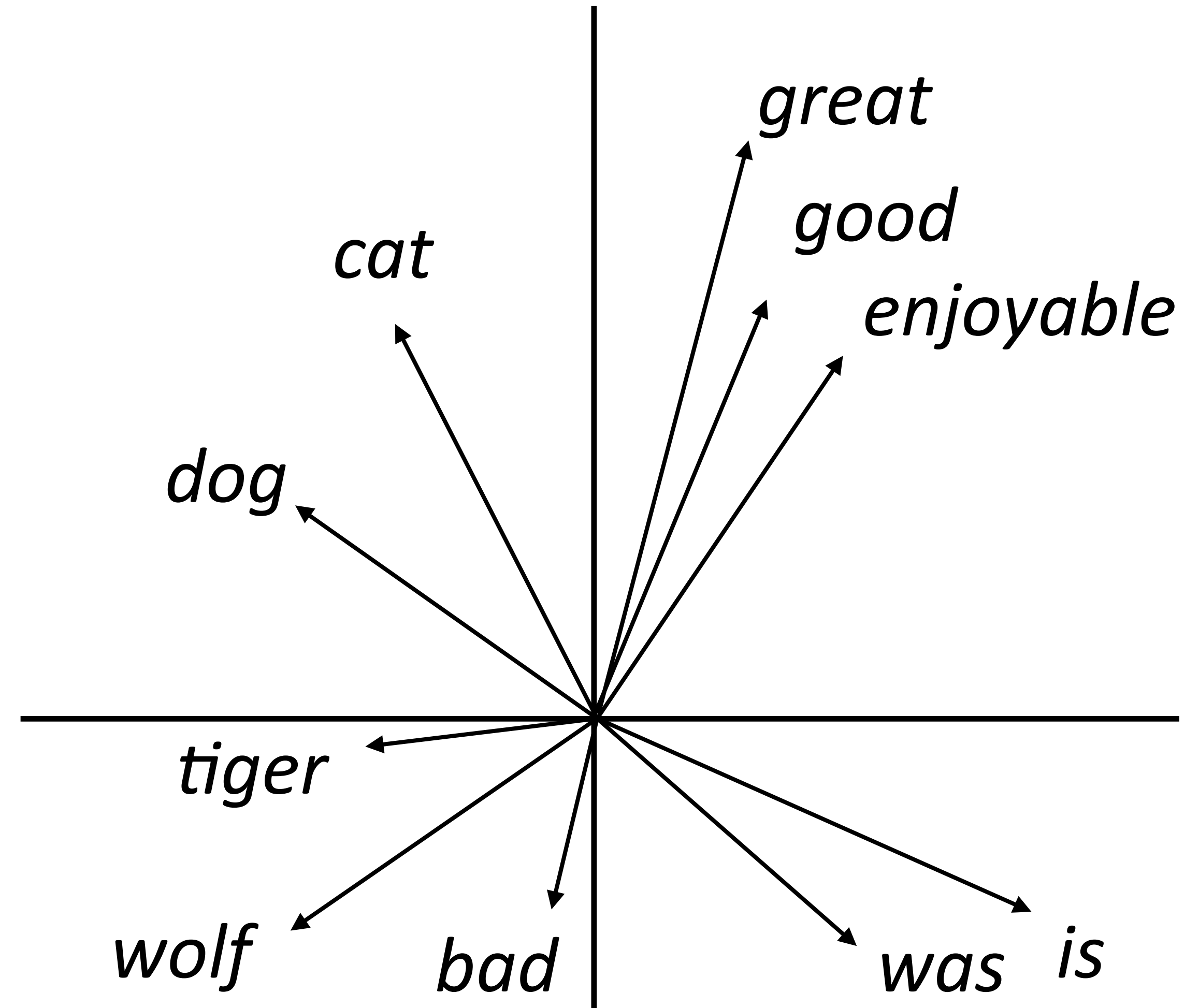
- ▶ Train a neural language model to predict the next word given previous words in the sentence, use its internal representations as word vectors
- ▶ *Context-sensitive* word embeddings: depend on rest of the sentence
- ▶ *Huge* improvements across nearly all NLP tasks over GloVe

Peters et al. (2018)

Evaluation

Evaluating Word Embeddings

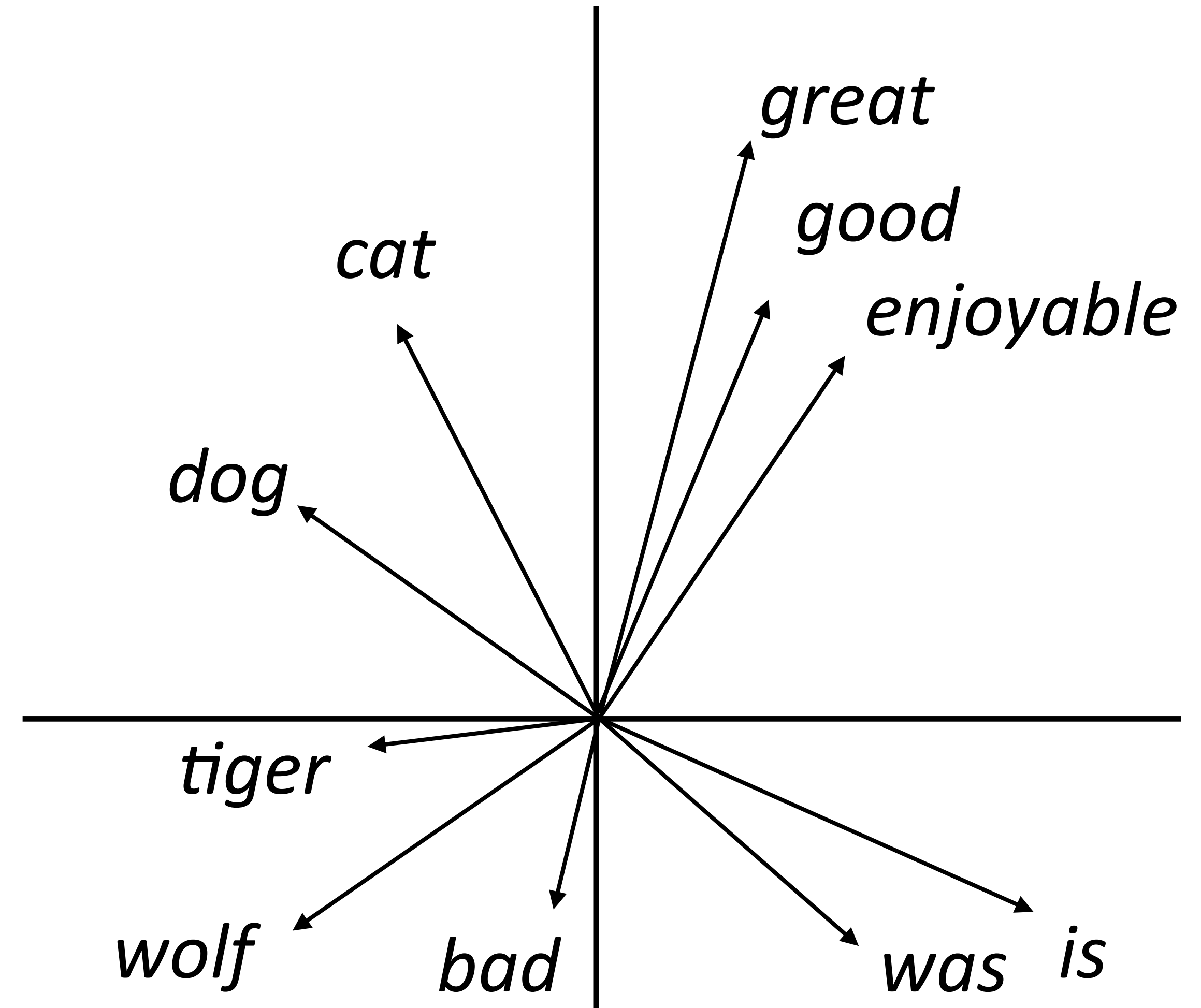
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Evaluating Word Embeddings

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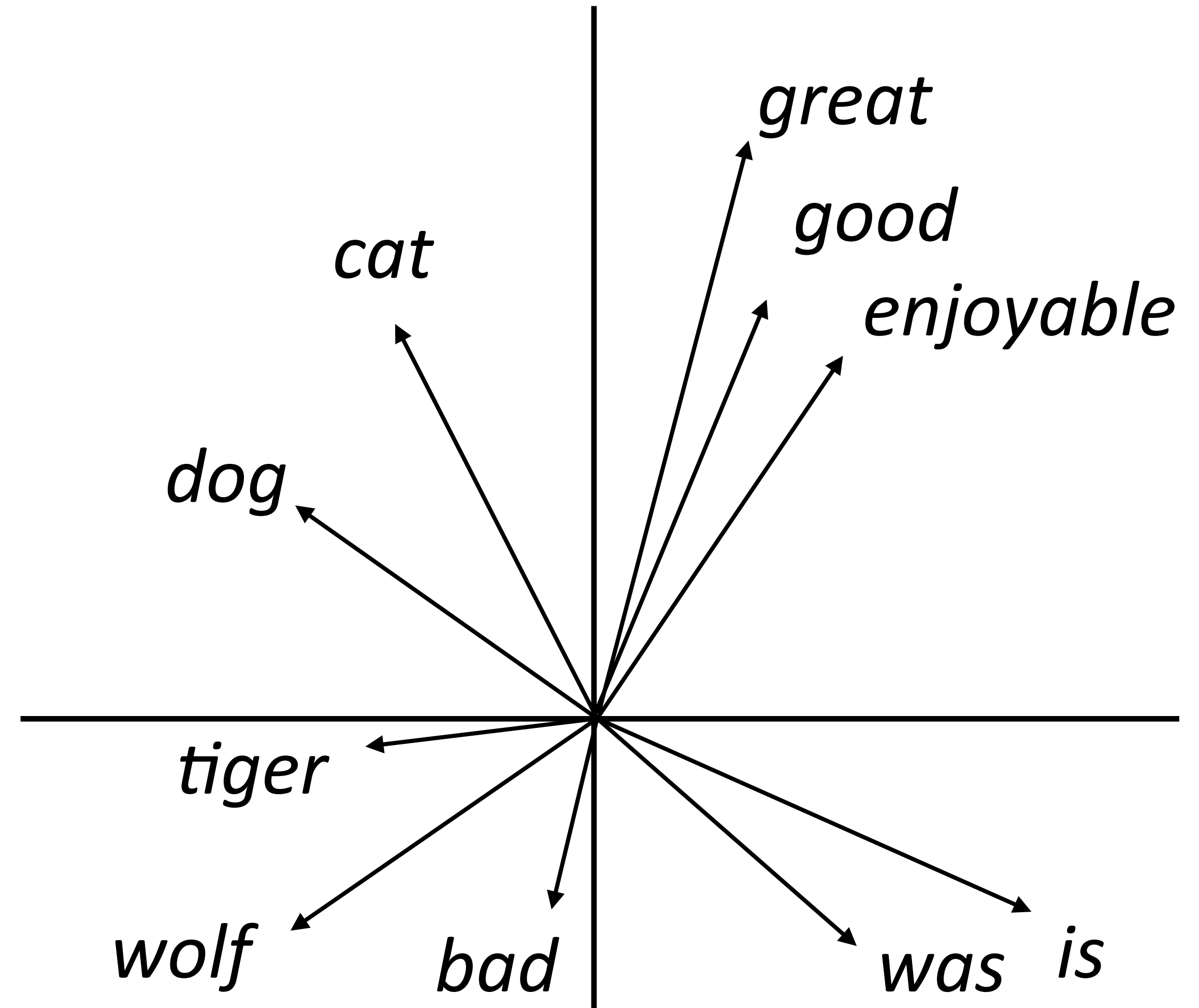


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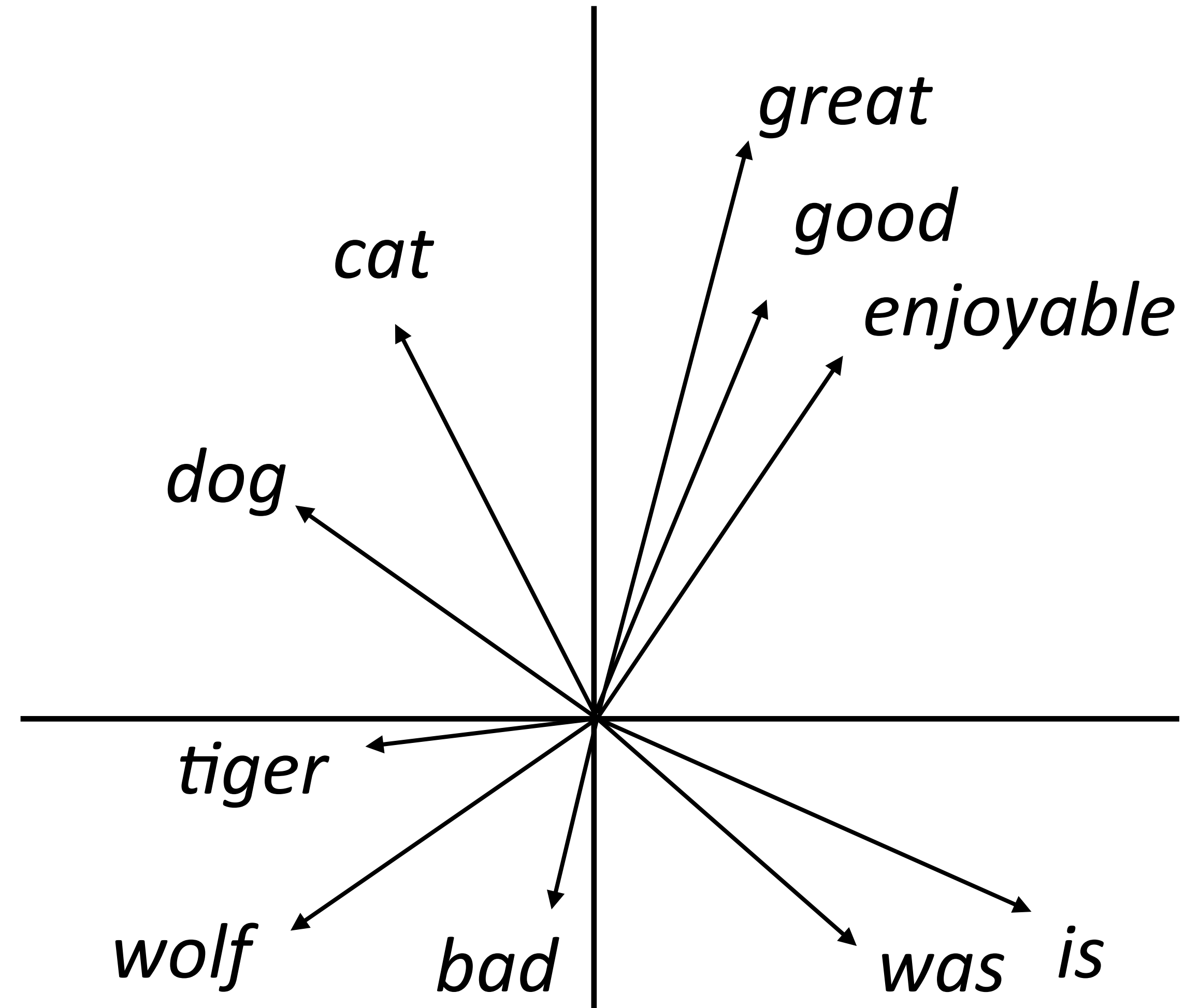


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good is to best as smart is to ???



Evaluating Word Embeddings

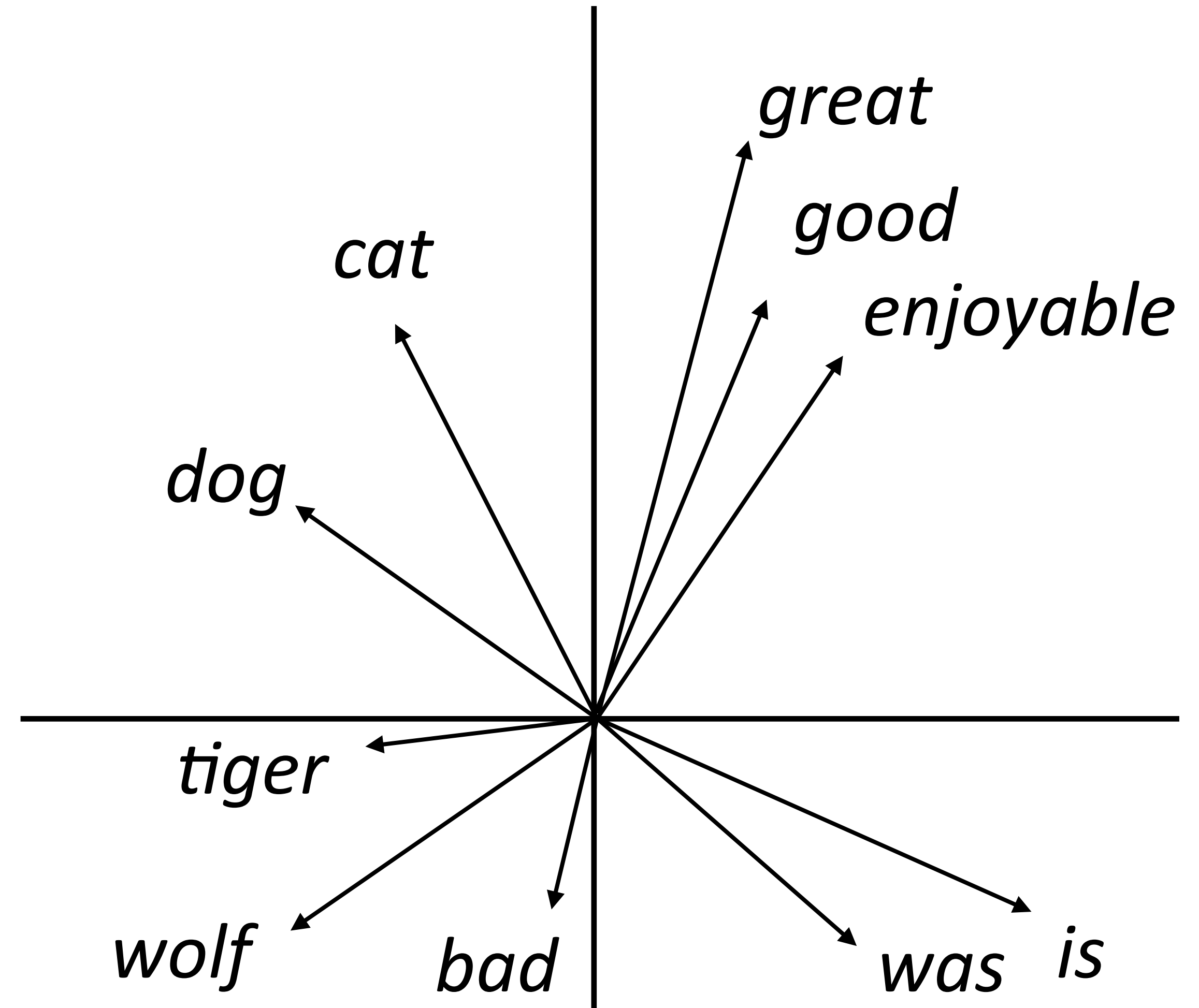
- ▶ What properties of language should word embeddings capture?

- ▶ Similarity: similar words are close to each other

- ▶ Analogy:

good is to best as smart is to ???

Paris is to France as Tokyo is to ???



Similarity

Method	WordSim Similarity	WordSim Relatedness	Bruni et al. MEN	Radinsky et al. M. Turk	Luong et al. Rare Words	Hill et al. SimLex
PPMI	.755	.697	.745	.686	.462	.393
SVD	.793	.691	.778	.666	.514	.432
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- ▶ SVD = singular value decomposition on PMI matrix
- ▶ GloVe does not appear to be the best when experiments are carefully controlled, but it depends on hyperparameters + these distinctions don't matter in practice

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GE + C	53.9	36.0	21.6	58.2	26.1
GE + KL	52.0	39.4	23.7	54.4	25.9
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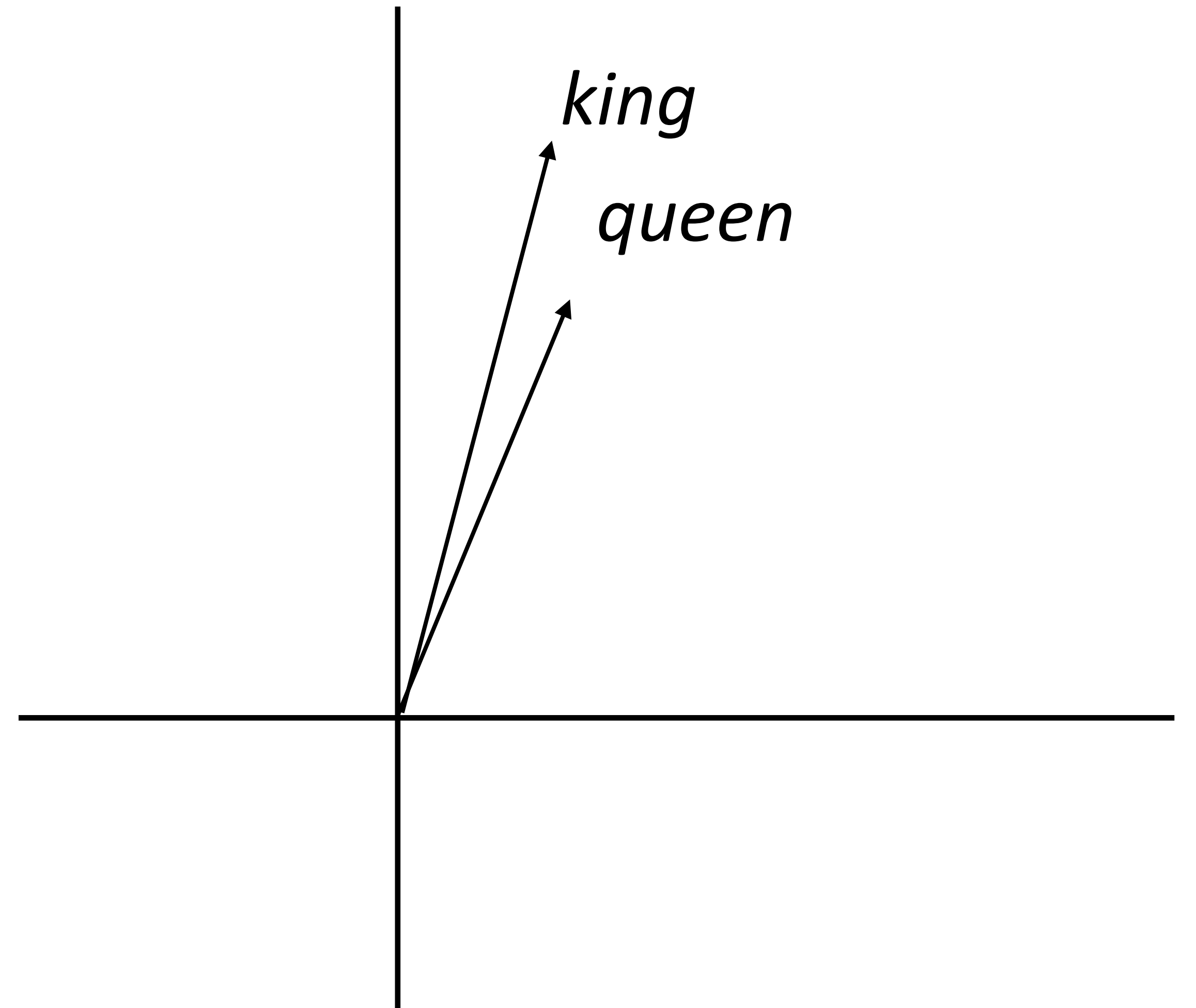
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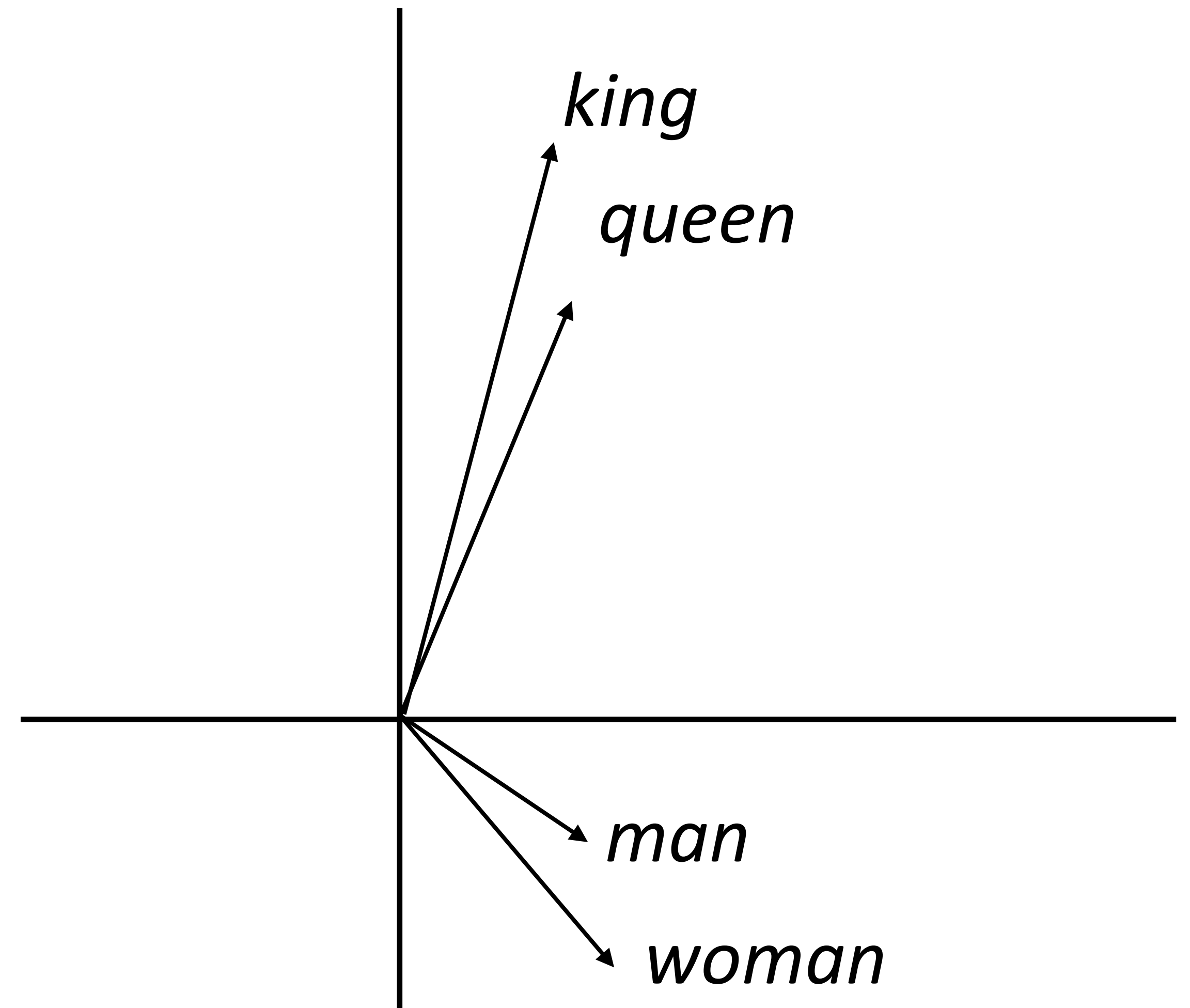
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- ▶ word2vec (SGNS) works barely better than random guessing here

Analogies

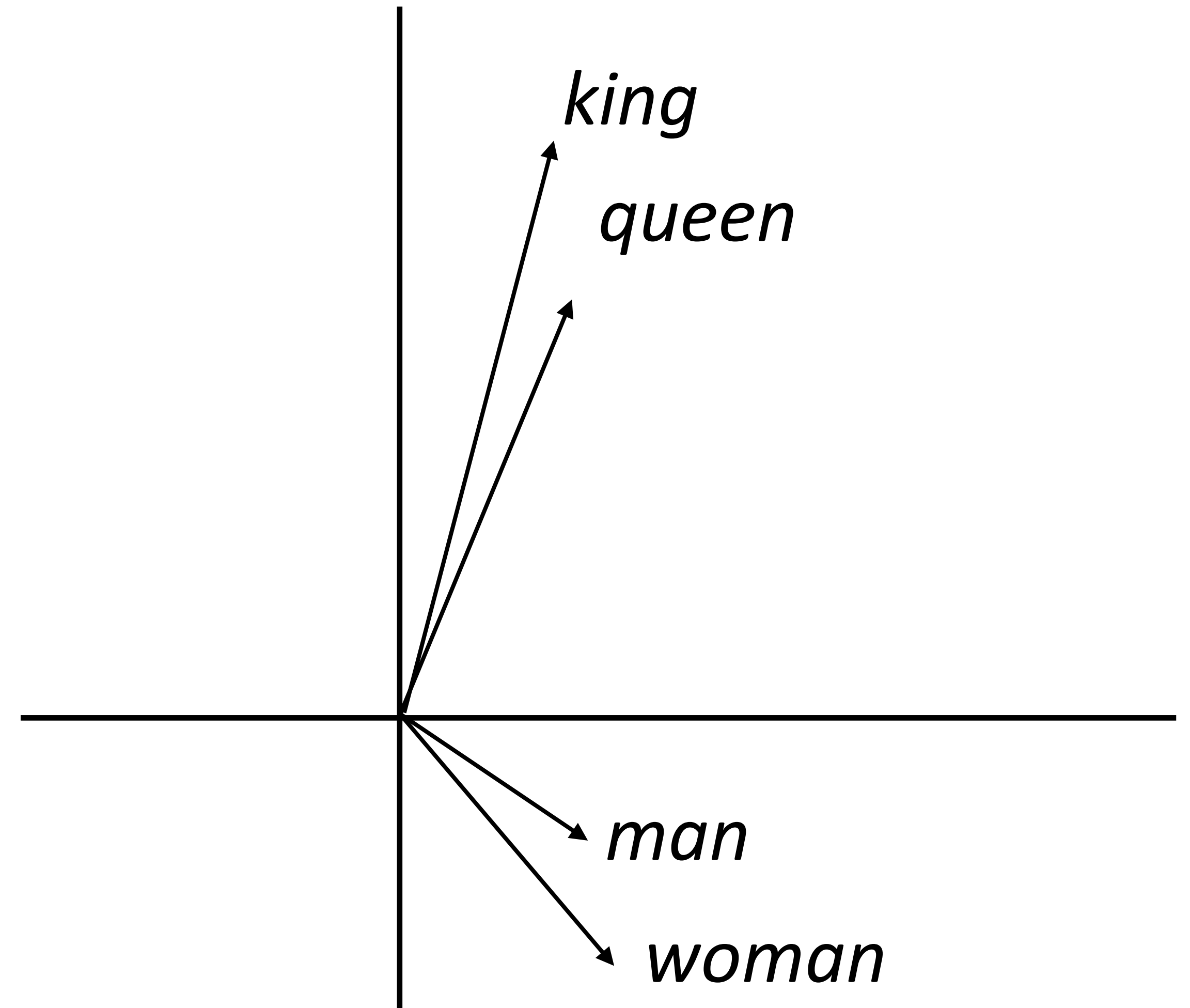


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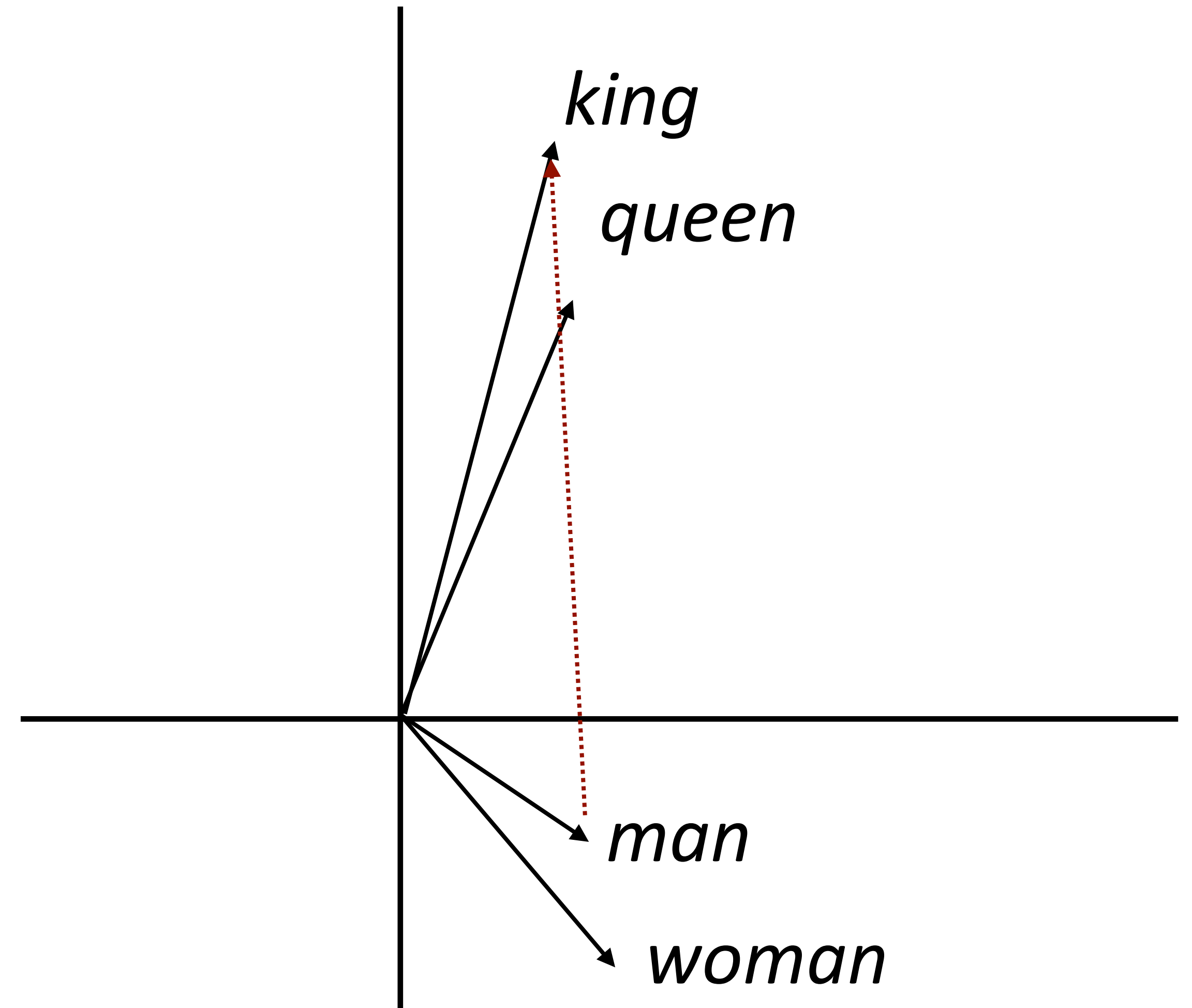
Analogies

(king - man) + woman = queen



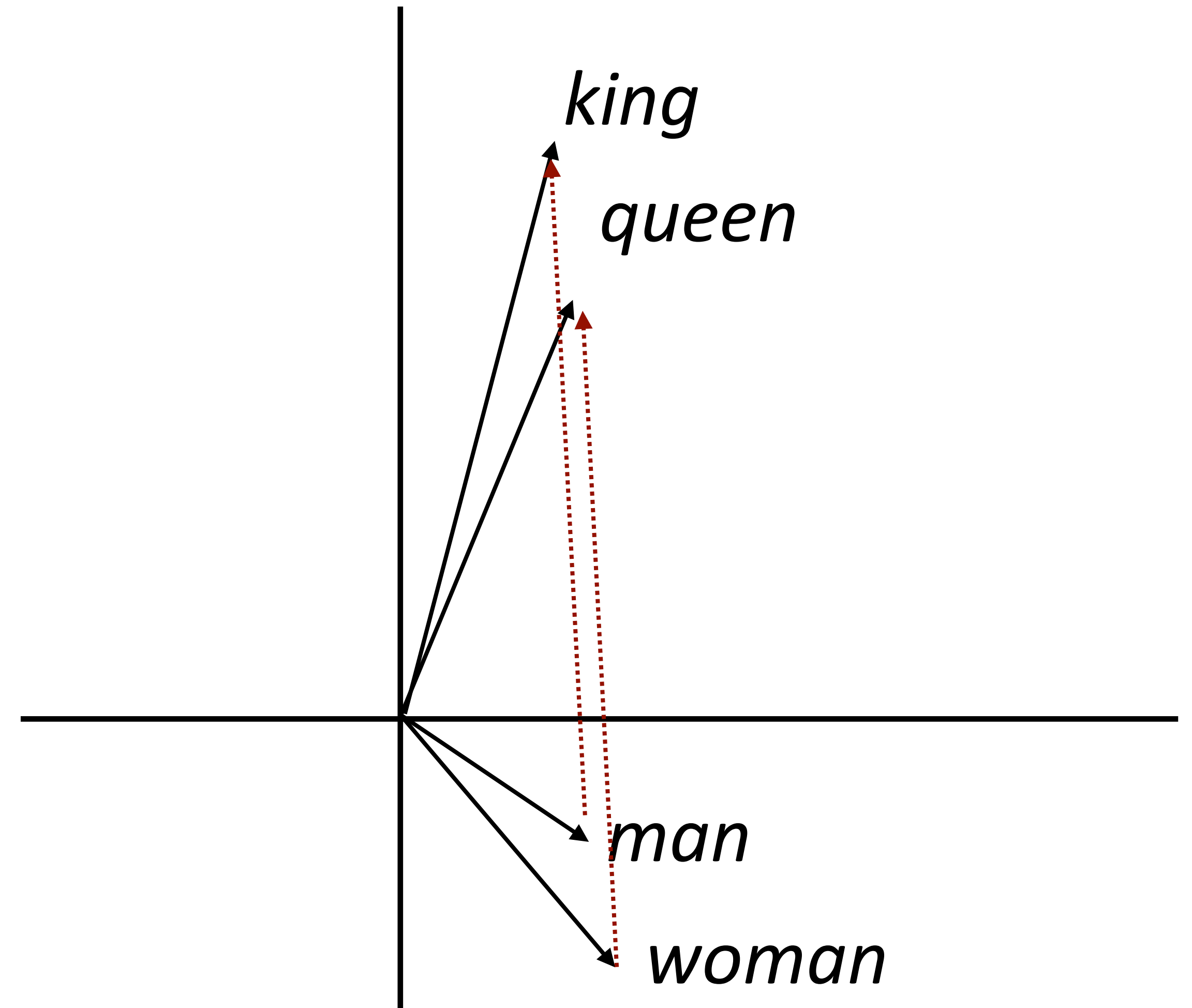
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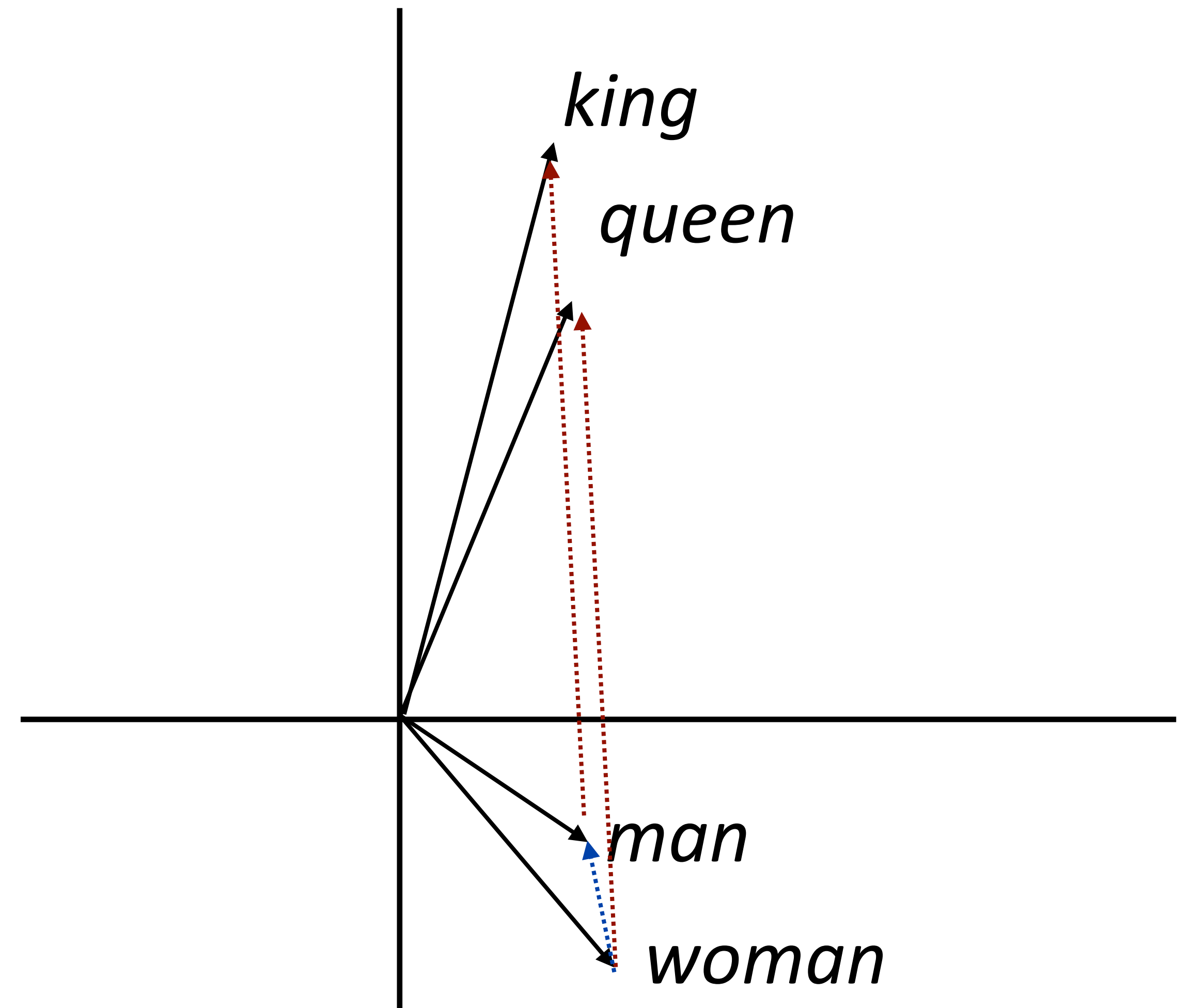


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$king + (woman - man) = queen$

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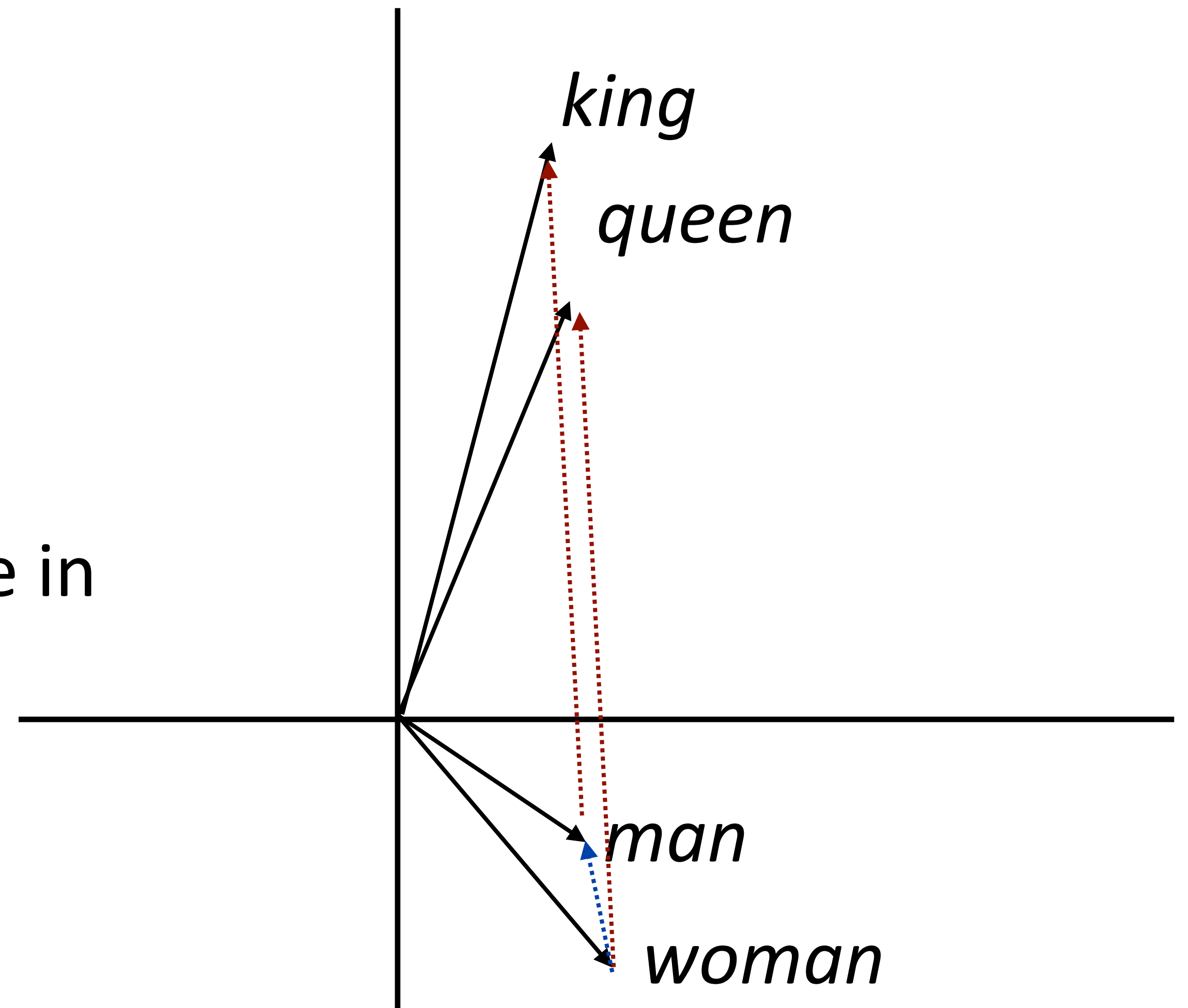


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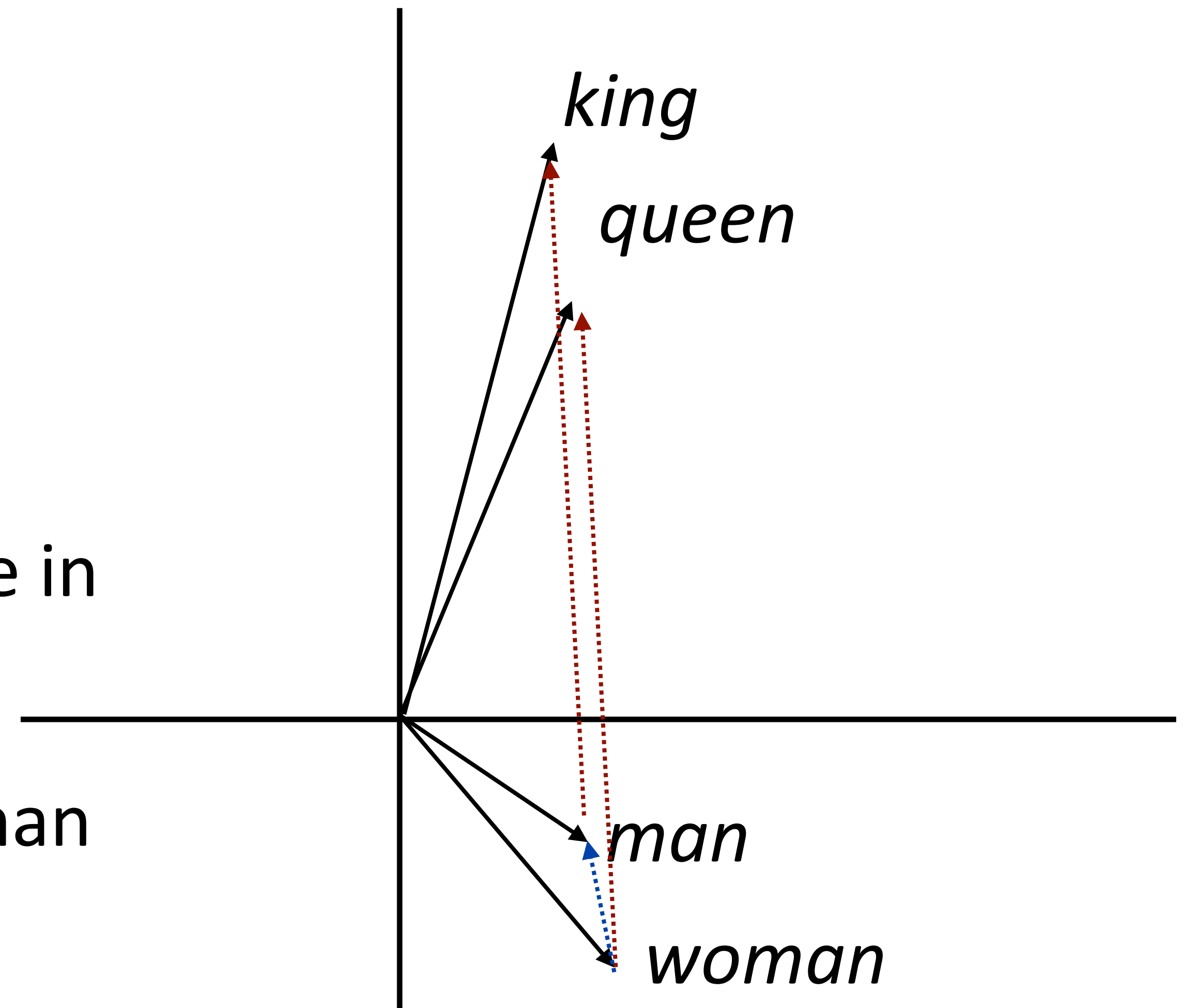


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- ▶ Why would this be?
- ▶ woman - man captures the difference in the contexts that these occur in
- ▶ Dominant change: more “he” with man and “she” with woman — similar to difference between king and queen



Analogies

Method	Google	MSR
	Add / Mul	Add / Mul
PPMI	.553 / .679	.306 / .535
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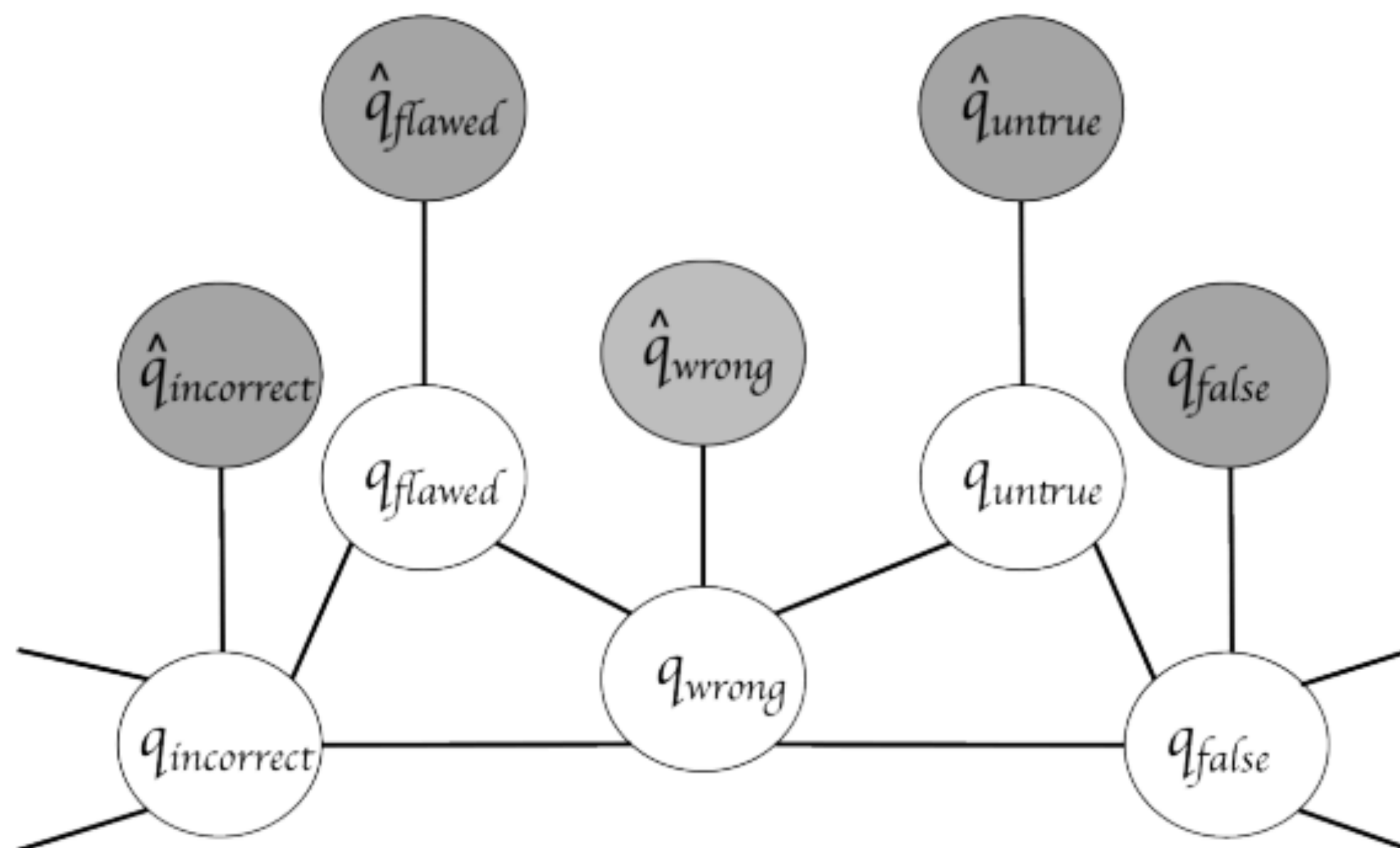
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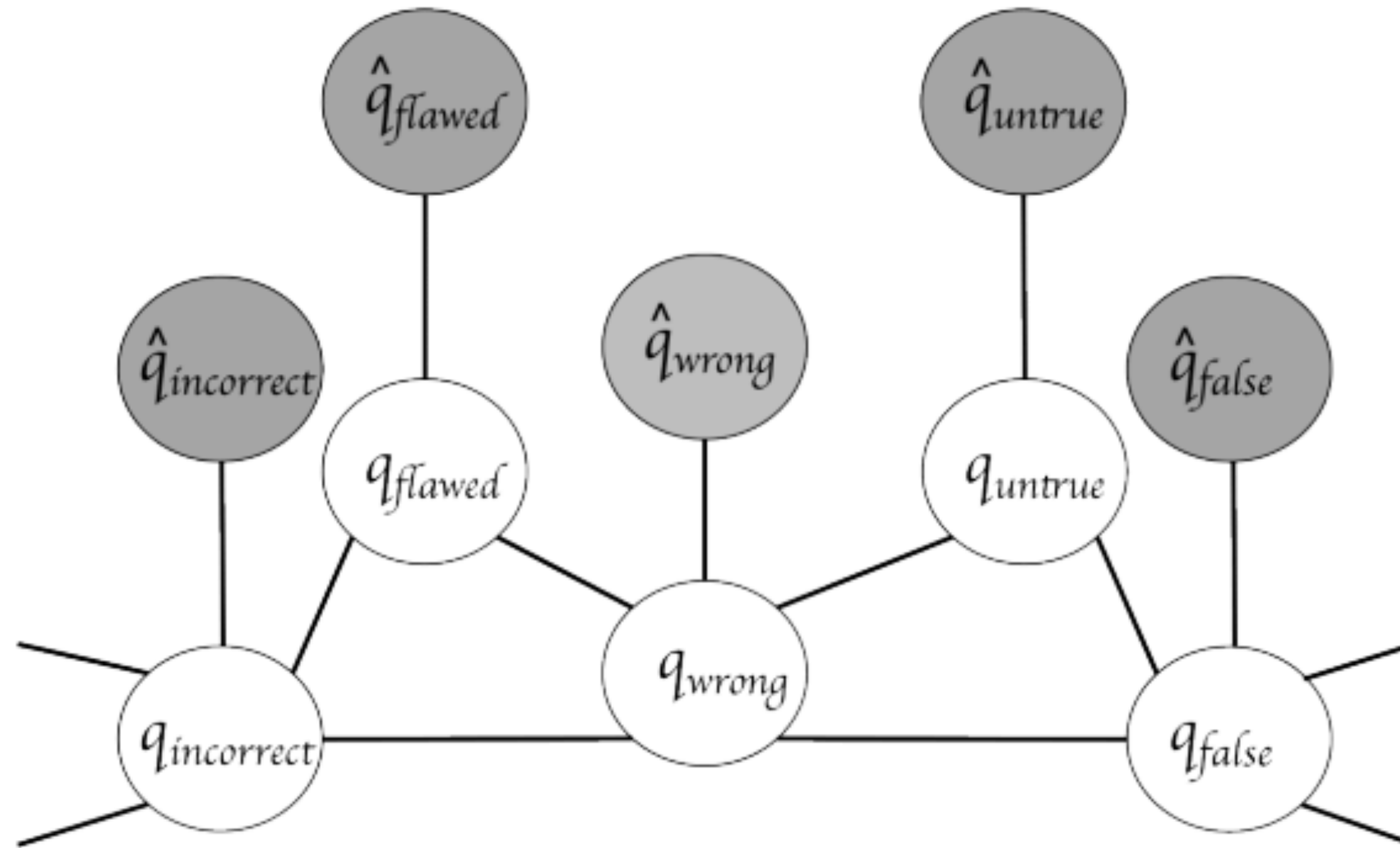
$$\text{Maximizing for } b: \text{Add} = \cos(b, a_2 - a_1 + b_1) \quad \text{Mul} = \frac{\cos(b_2, a_2) \cos(b_2, b_1)}{\cos(b_2, a_1) + \epsilon}$$

Levy et al. (2015)

Using Semantic Knowledge

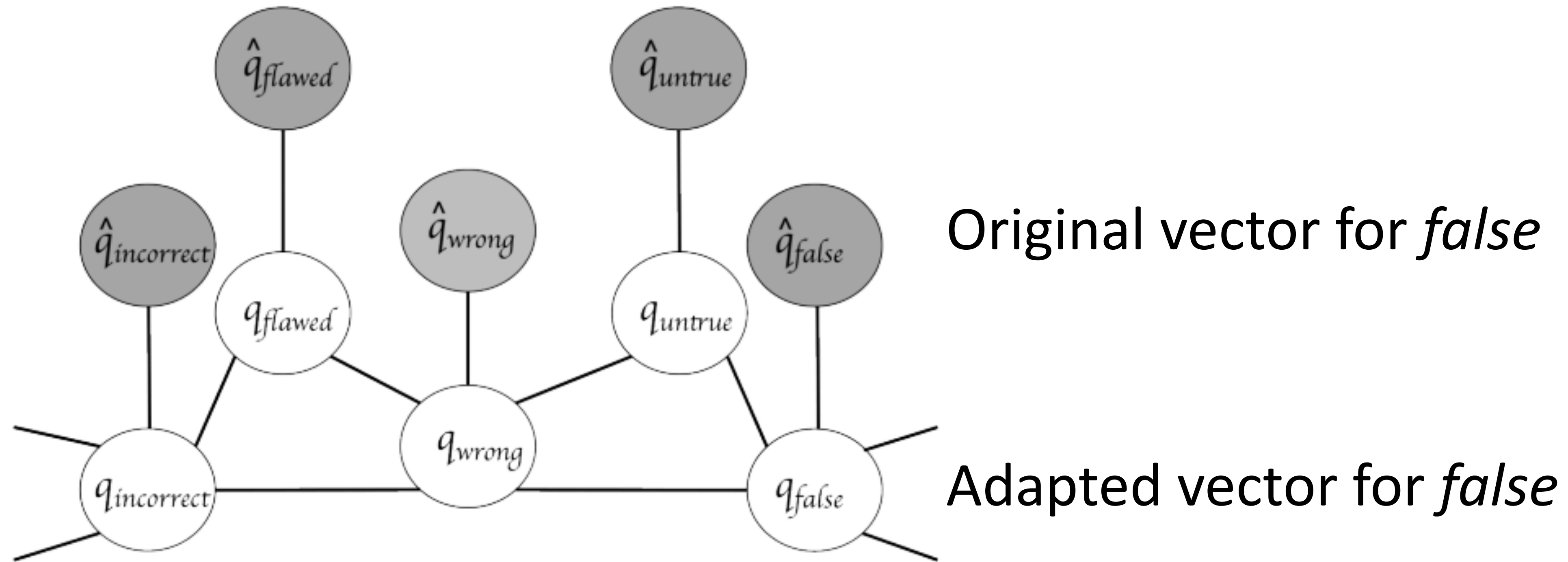


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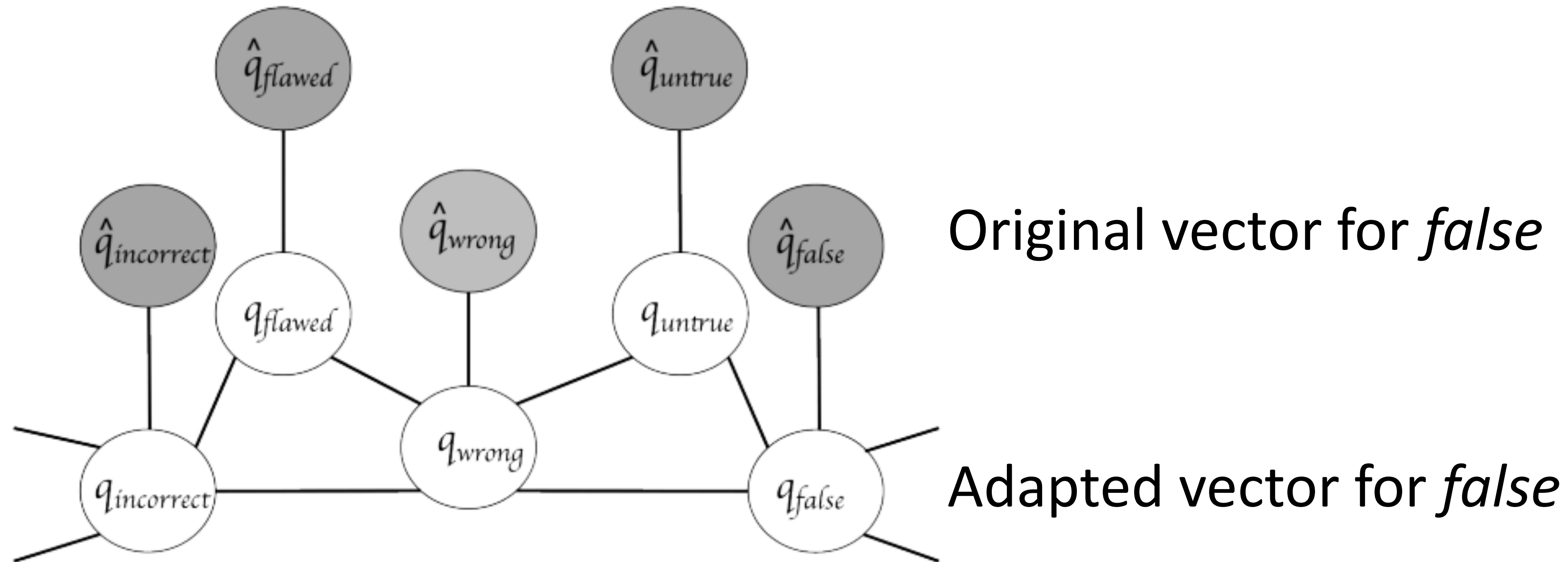
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Using Semantic Knowledge



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Using Semantic Knowledge



- ▶ Structure derived from a resource like WordNet
- ▶ Doesn't help most problems

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- ▶ Approach 3: initialize using GloVe, fine-tune
 - ▶ Works best for some tasks, but not used for ELMo

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- ▶ Will return to this in a few weeks

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- ▶ Next time: RNNs and CNNs