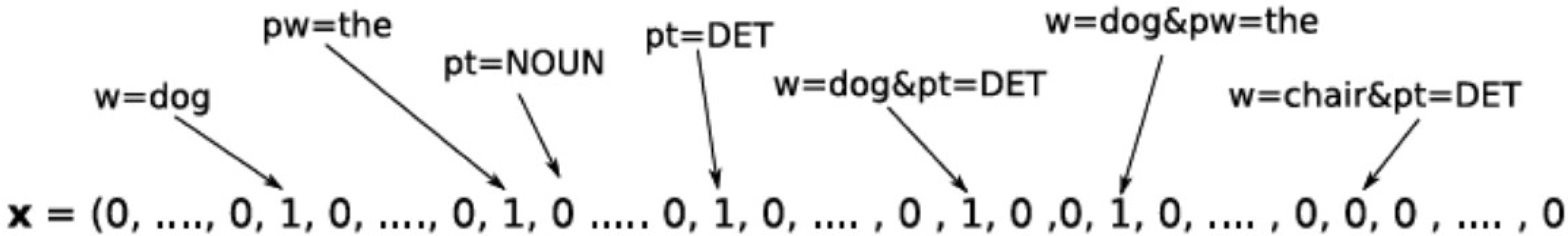
N-gram features
Convolutional Networks

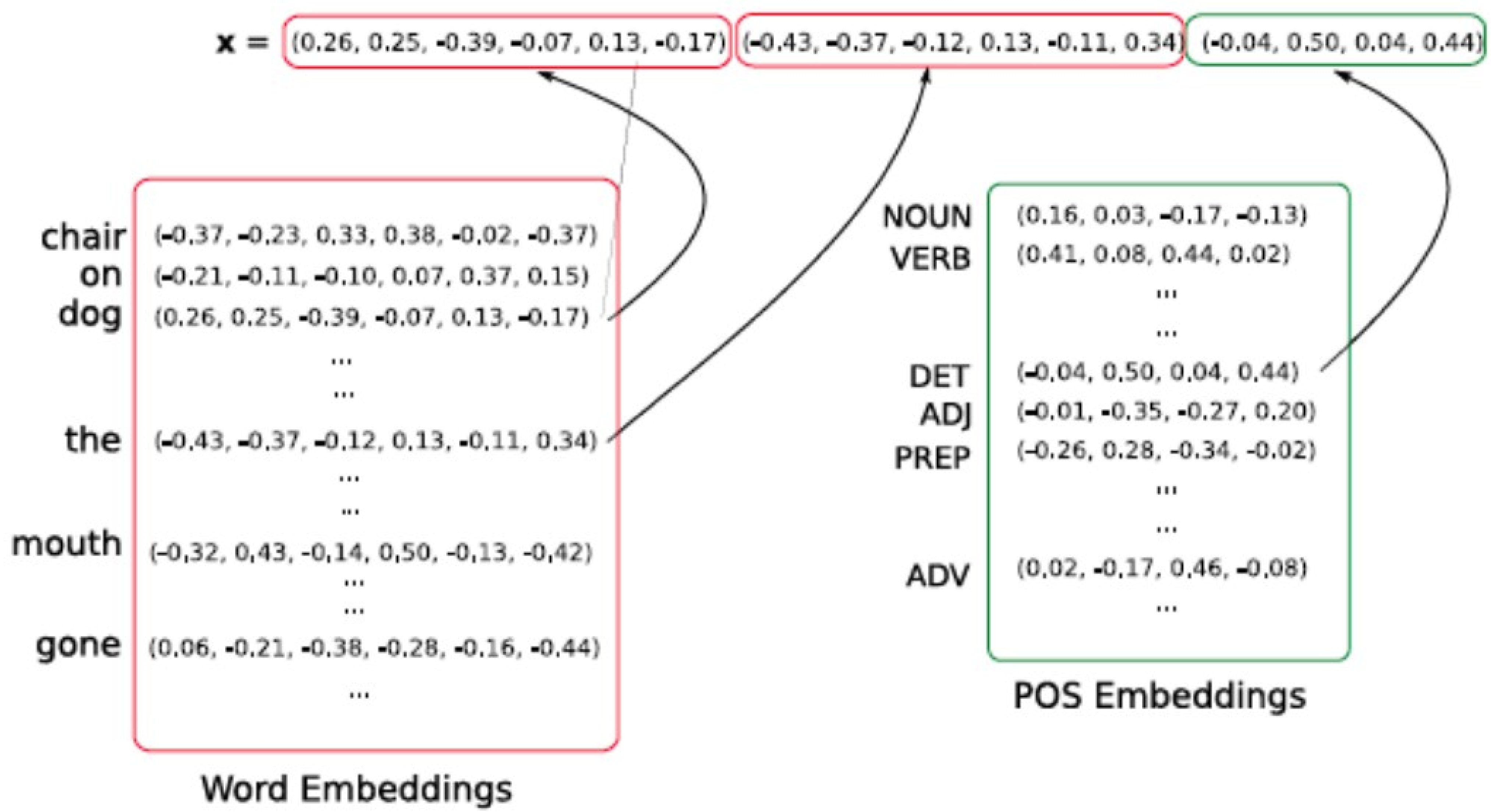
Yoav Goldberg

"feature embeddings"

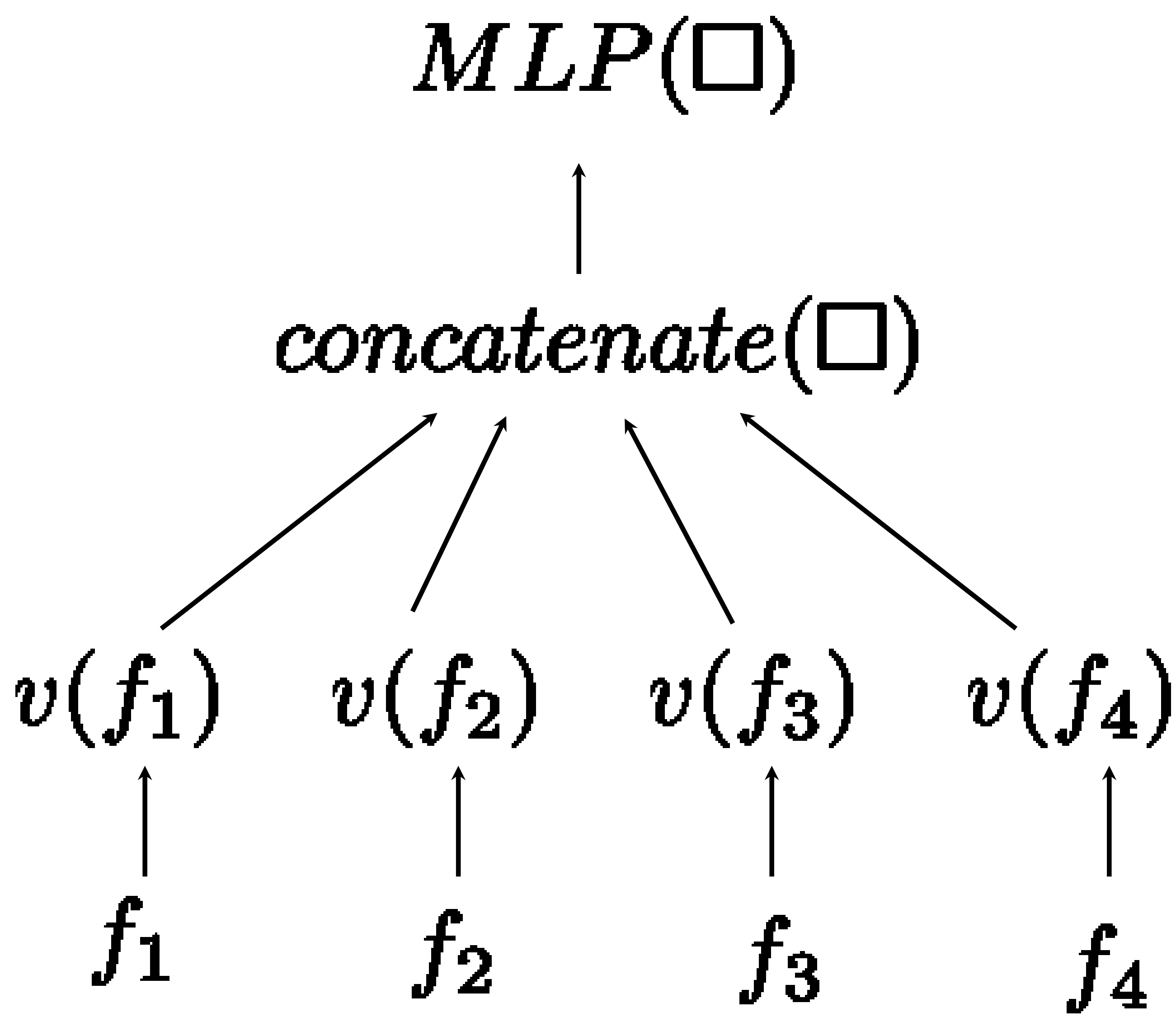
- Each feature is assigned a vector.
- The input is a combination of feature vectors.
- The feature vectors are **parameters of the model** and are trained jointly with the rest of the network.
- **Representation Learning**: similar features will receive similar vectors.

"feature embeddings"

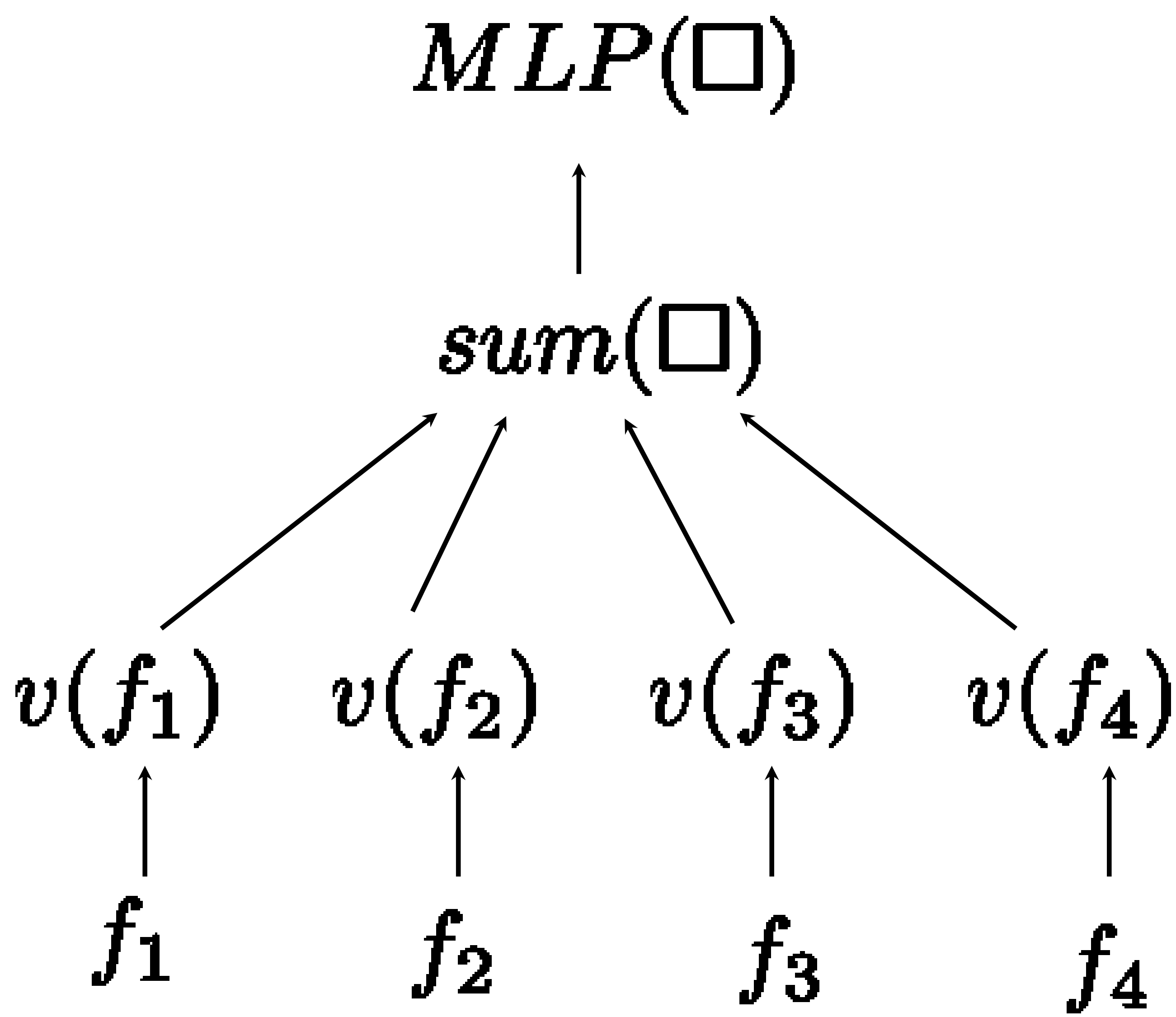




"feature embeddings"



"feature embeddings"



Continuous Bag of Words (CBOW)

$$CBOW(f_1, ..., f_k) = \frac{1}{k}\sum_{i=1}^{k} v(f_i)$$

- a popular choice in document classification.
- can assign a different weight to each feature:

$$WCBOW(f_1, ..., f_k) = \frac{1}{\sum_{i=1}^{k} a_i}\sum_{i=1}^{k} a_i v(f_i)$$

Text Classification with CBOW

scores of labels

$$\uparrow$$

$$softmax(\square)$$

$$\uparrow$$

$$CBOW(\square)$$

$$\uparrow$$

$$w_1, \ldots, w_n$$

"neural bag of words"

scores of labels

$$\uparrow$$

$$softmax(\square)$$

$$\uparrow$$

$$g^2(\mathbf{W}^2\square + \mathbf{b}^2)$$

$$\uparrow$$

$$g^1(\mathbf{W}^1\square + \mathbf{b}^1)$$

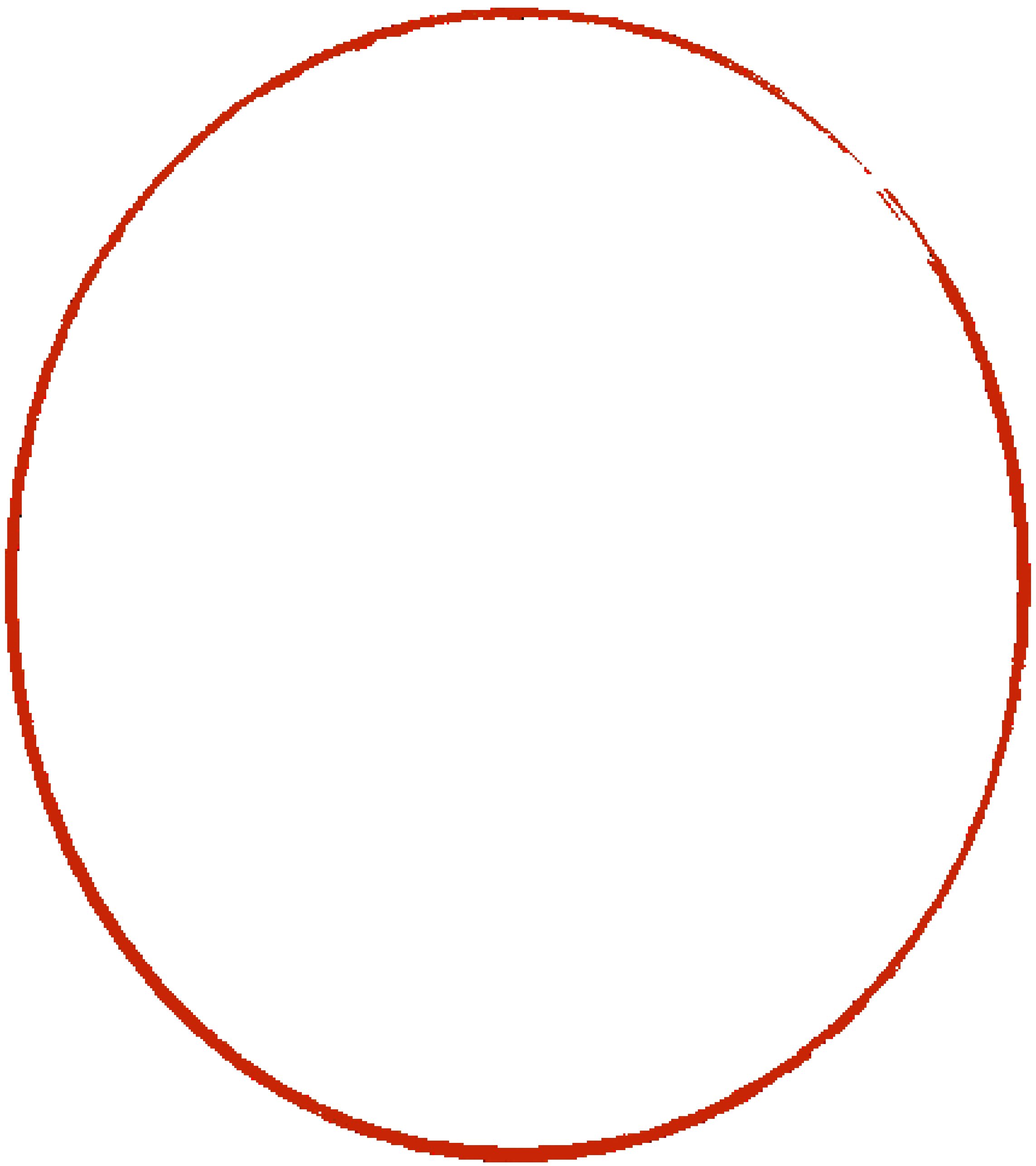
$$\uparrow$$

$$CBOW(\square)$$

$$\uparrow$$

$$w_1, \ldots, w_n$$

"deep averaging network"



"neural bag of words"

If each feature is bigram, works great.

Moving to unigrams, large drop.

Unigrams + MLP --> better but not like bigrams.

Importance of Ngrams

- While we can ignore global order in many cases...
- ... local ordering is still often very important.
- Local sub-sequences encode useful structures.

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- ... local ordering is still often very important.
- Local sub-sequences encode useful structures.

(so why not just assign a vector to each ngram?)

ConvNets

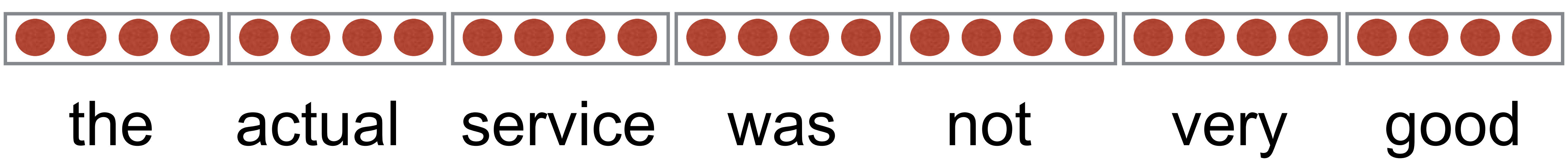
special architecture for local predictors

ConvNets

- CBOW allows encoding arbitrary length sequences, but loses all order information.
- Some local order (i.e. bigrams, trigrams) is informative. Yet, we do not care about exact position in the sequence. (think "good" vs. "not good")
- ConvNets (in language) allow to identify informative local predictors.
- Works by moving a shared function (feature extractor) over a sliding window, then pooling results.

ConvNets

- ConvNets have huge success in computer vision.
- It allows invariance to object position.
- It allows composing large predictors from small.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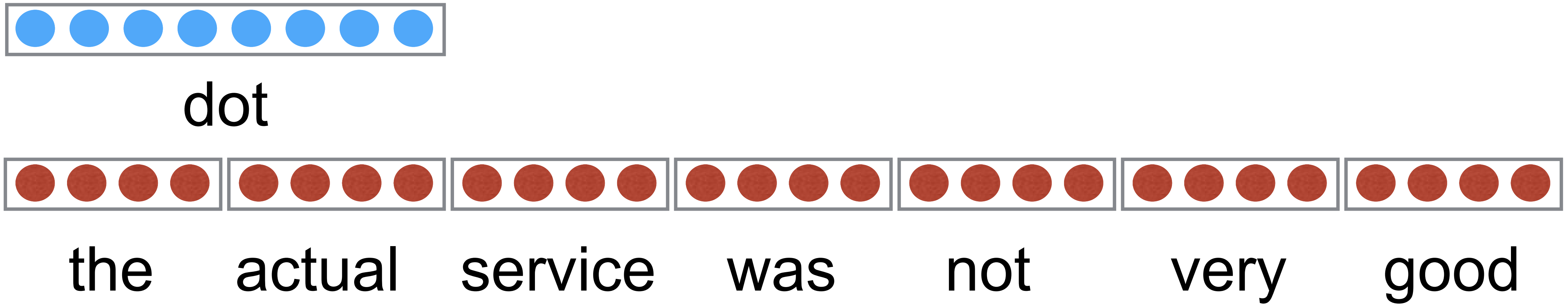
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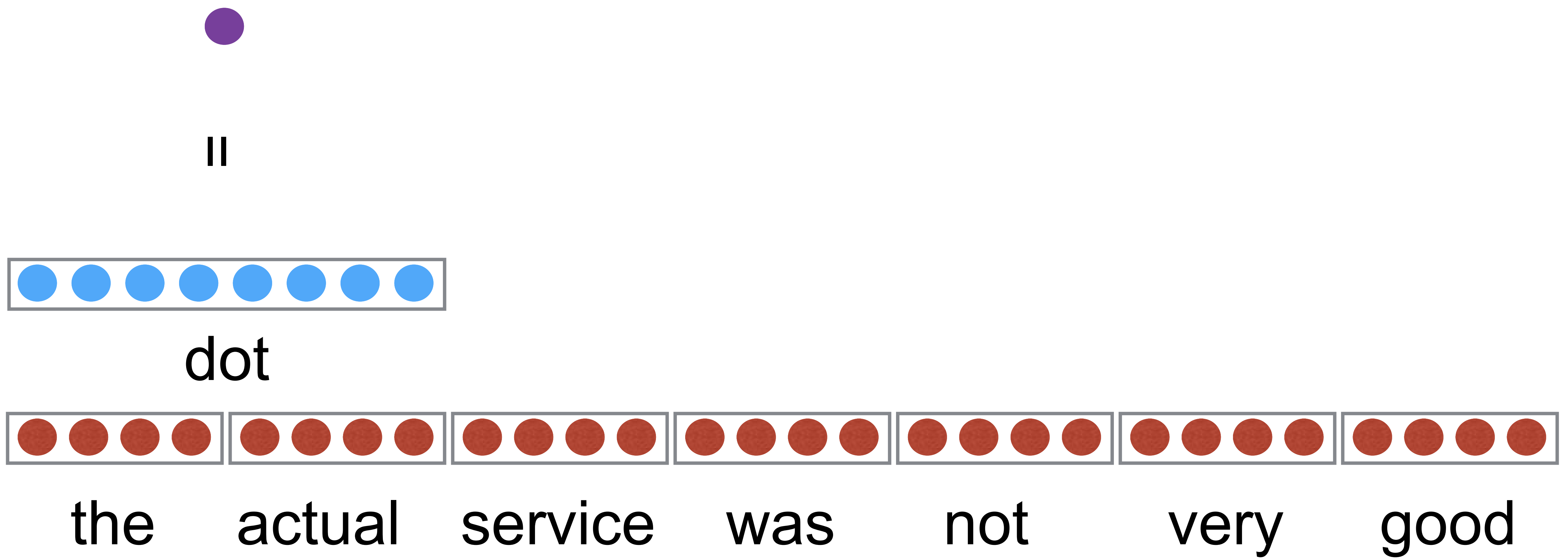
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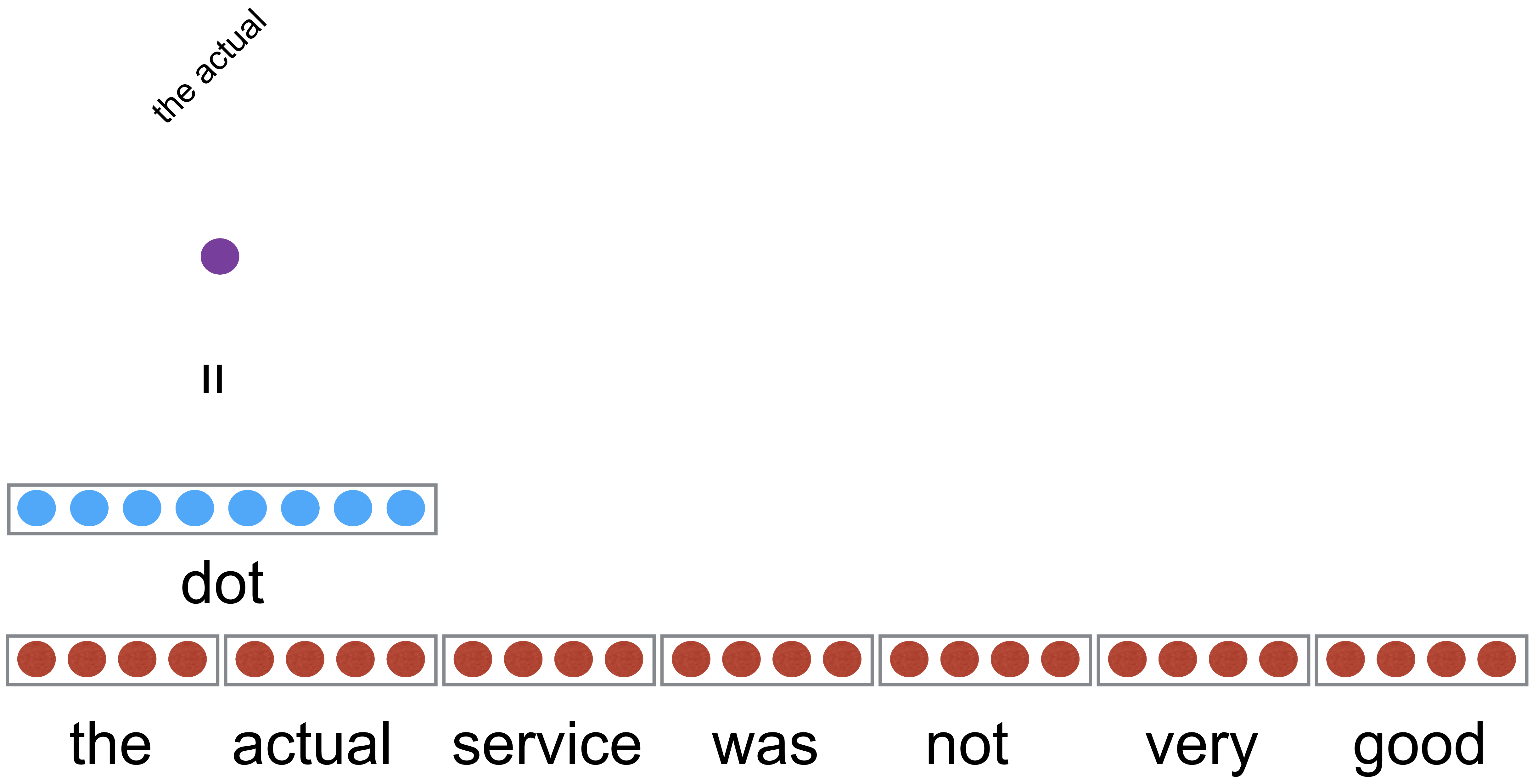
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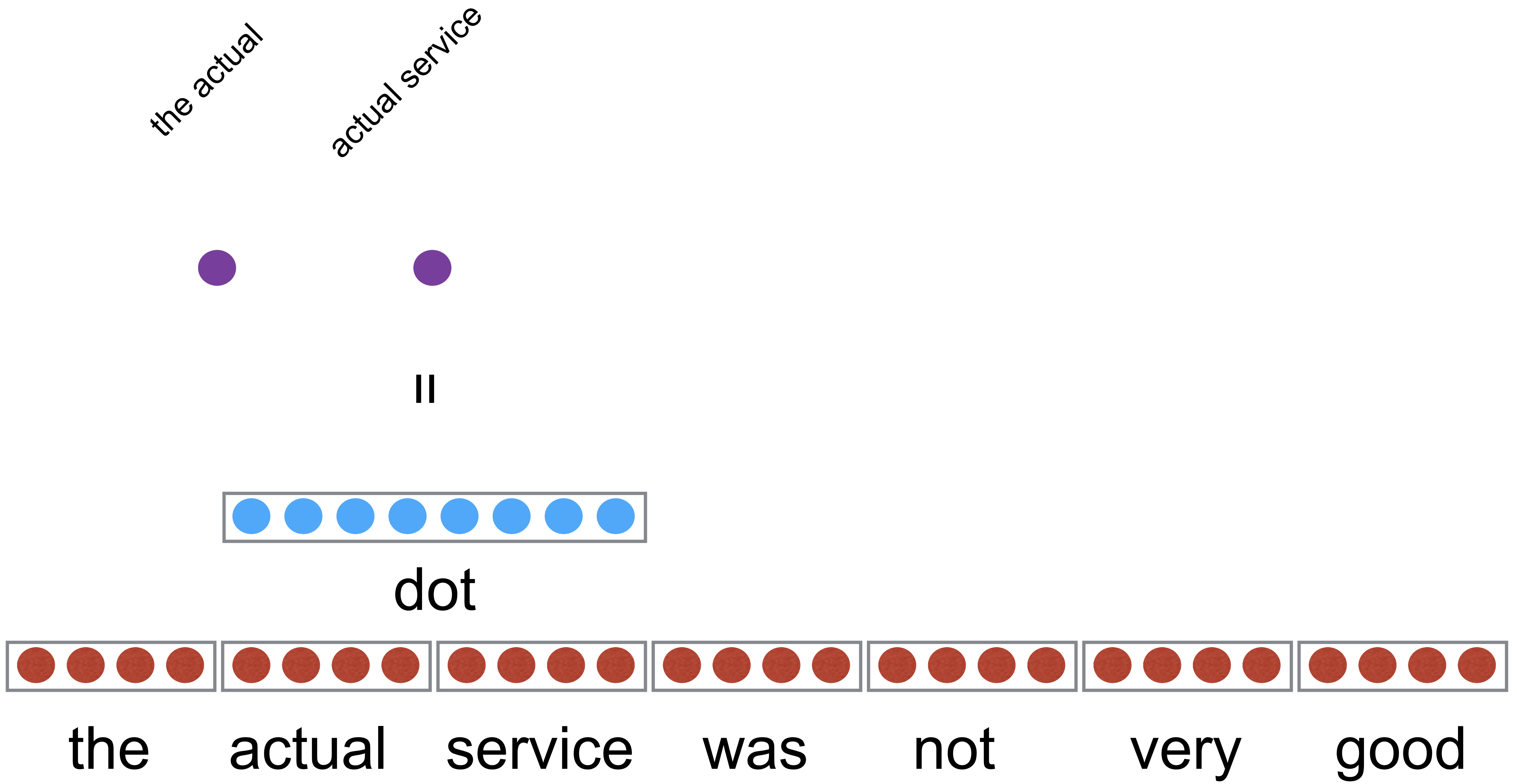
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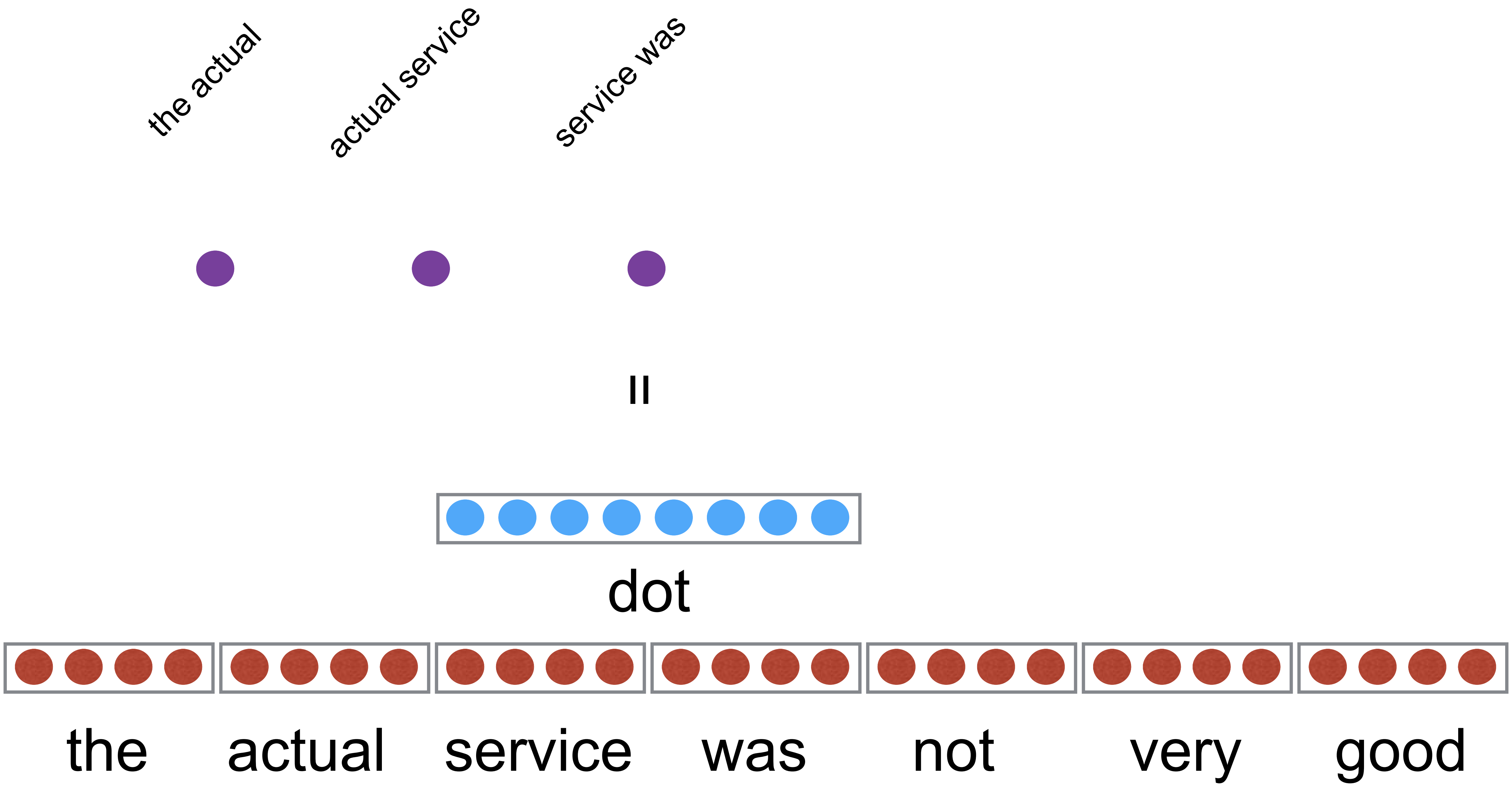

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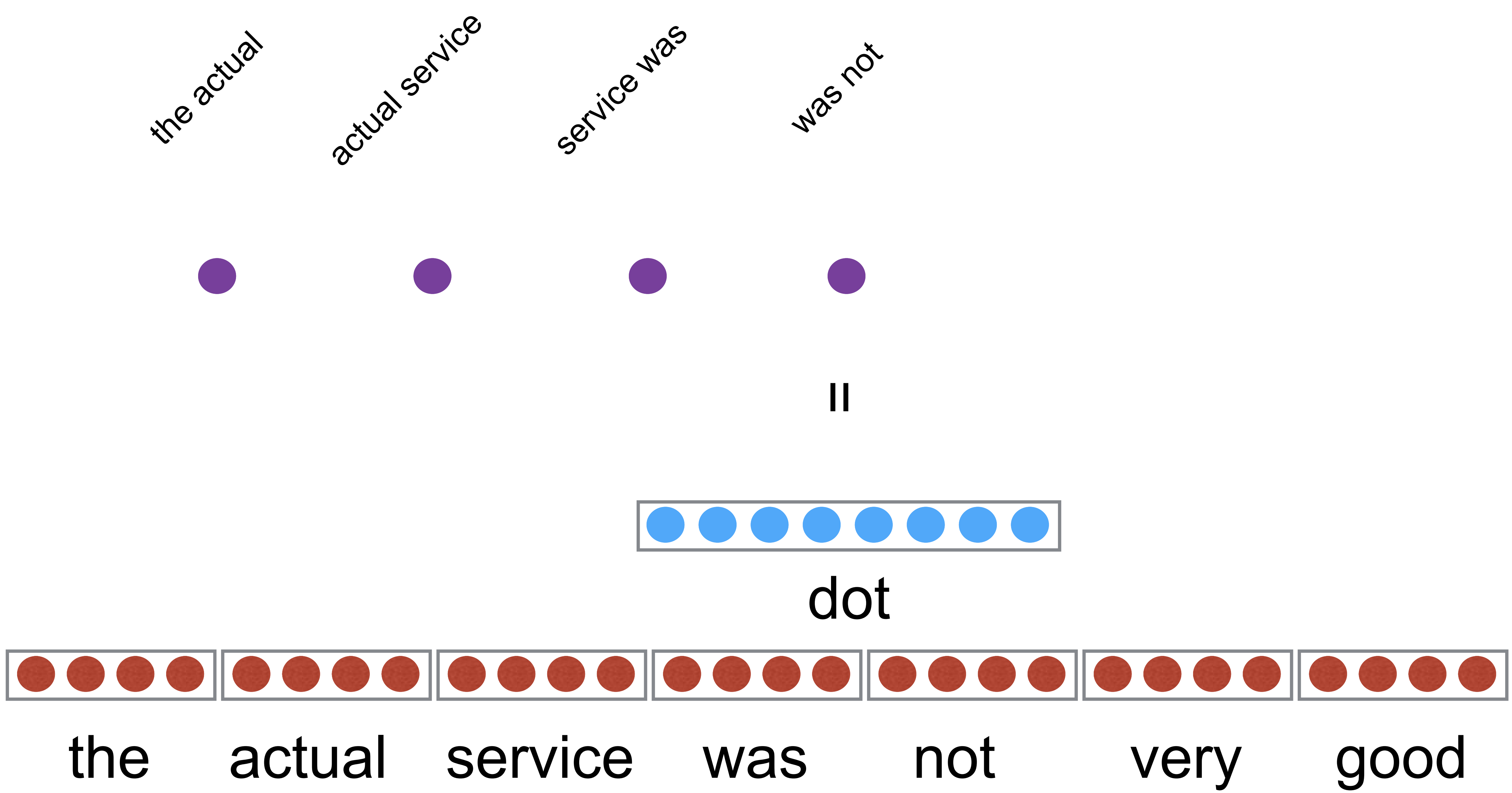
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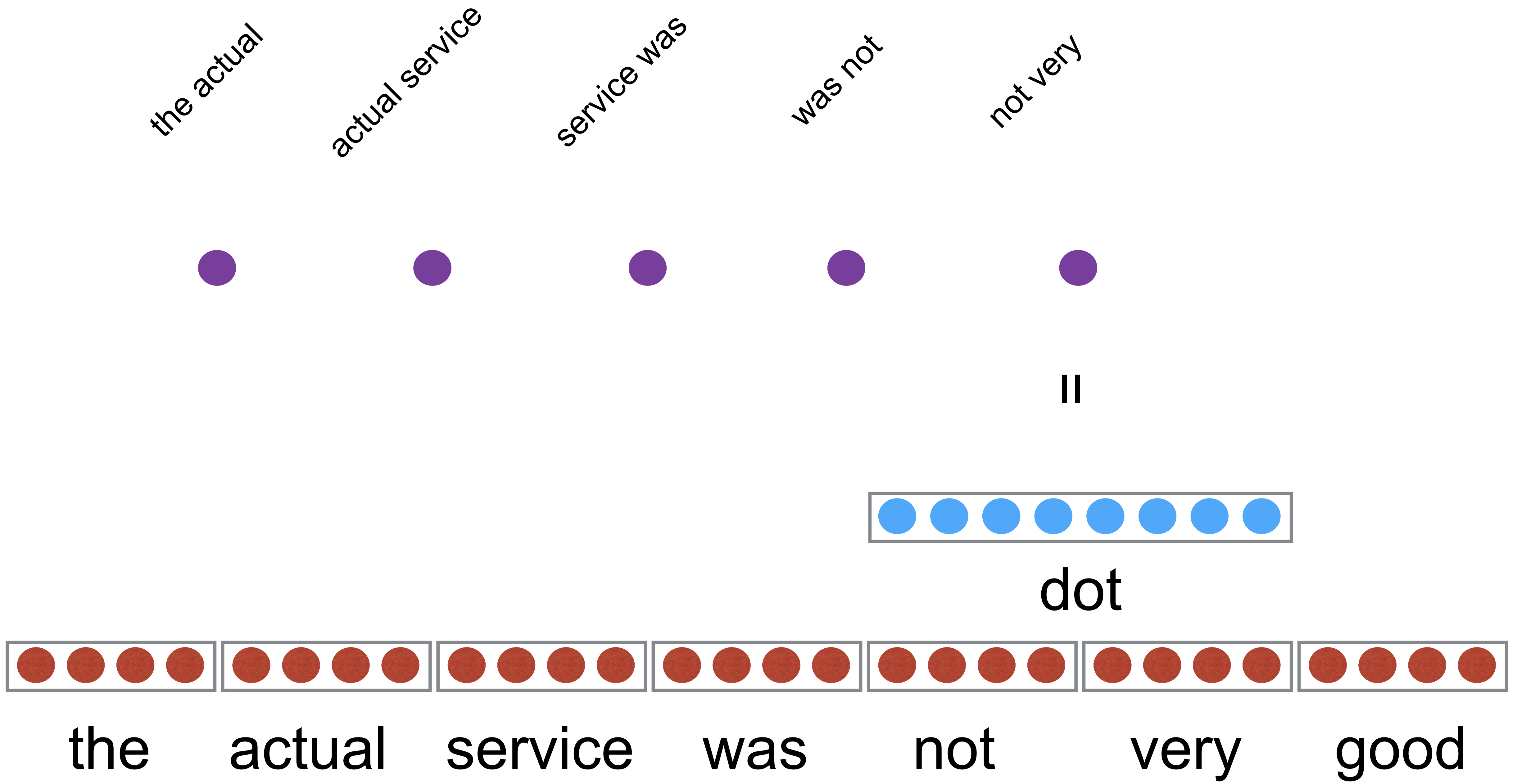

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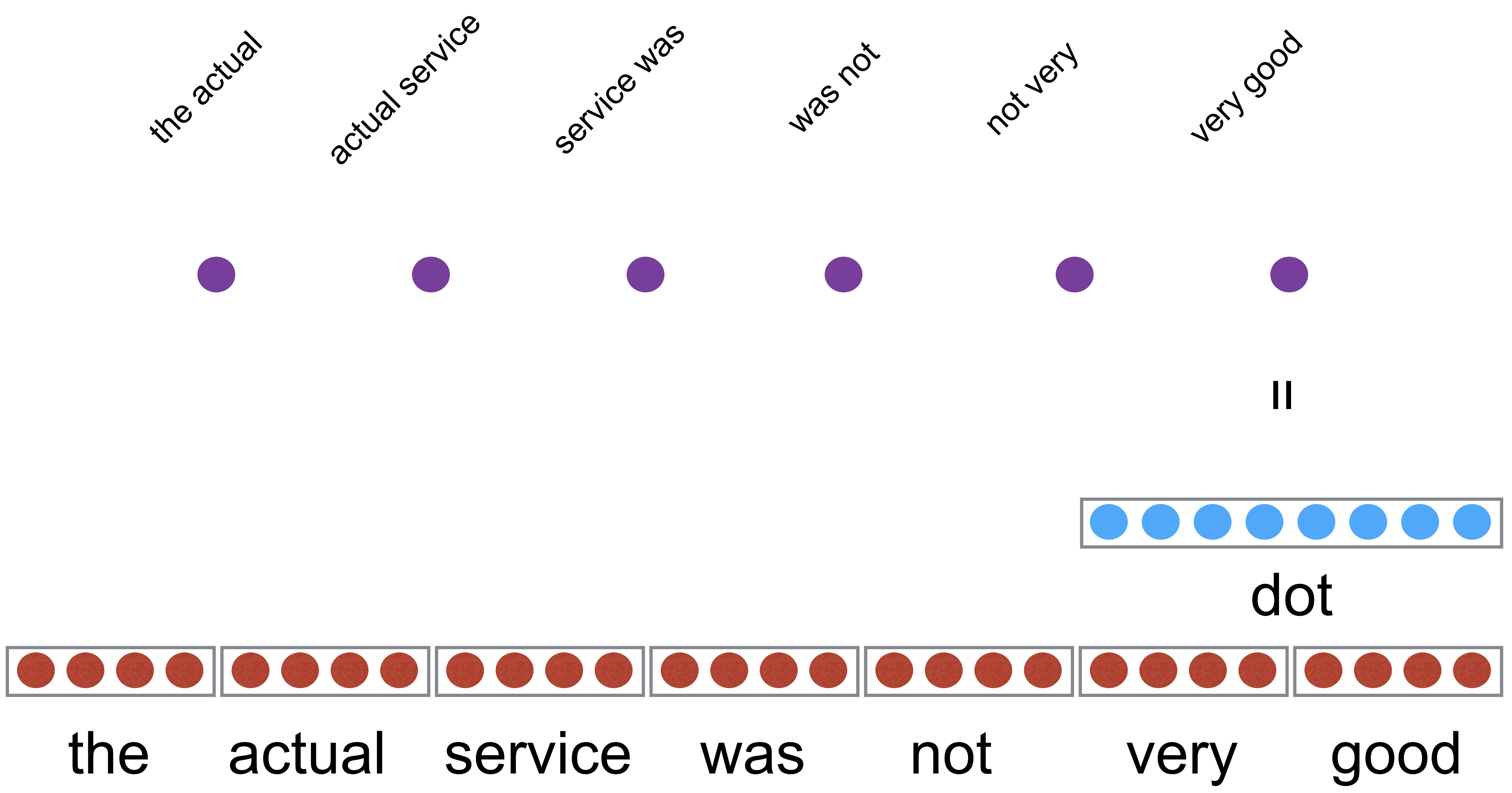

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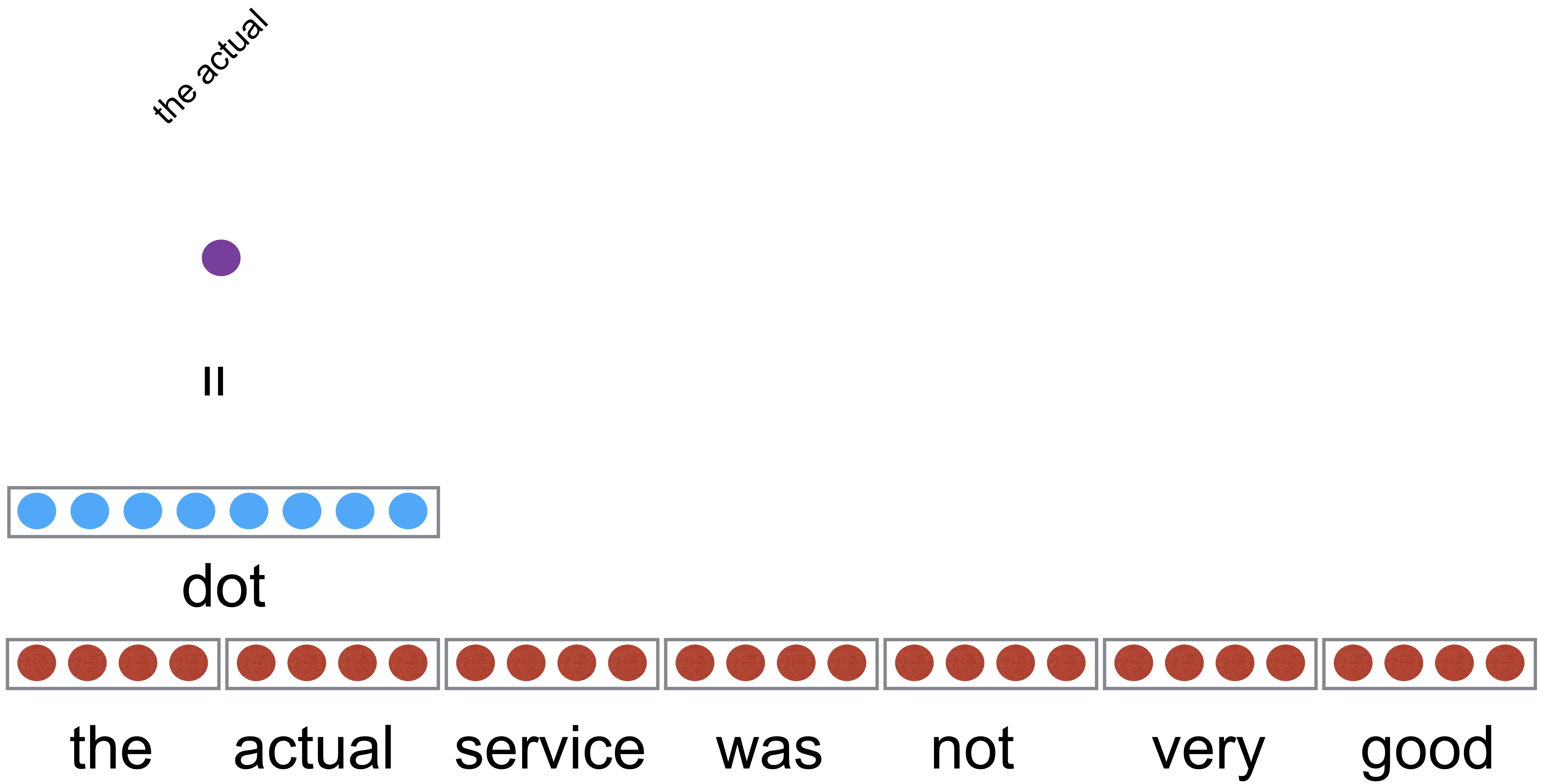

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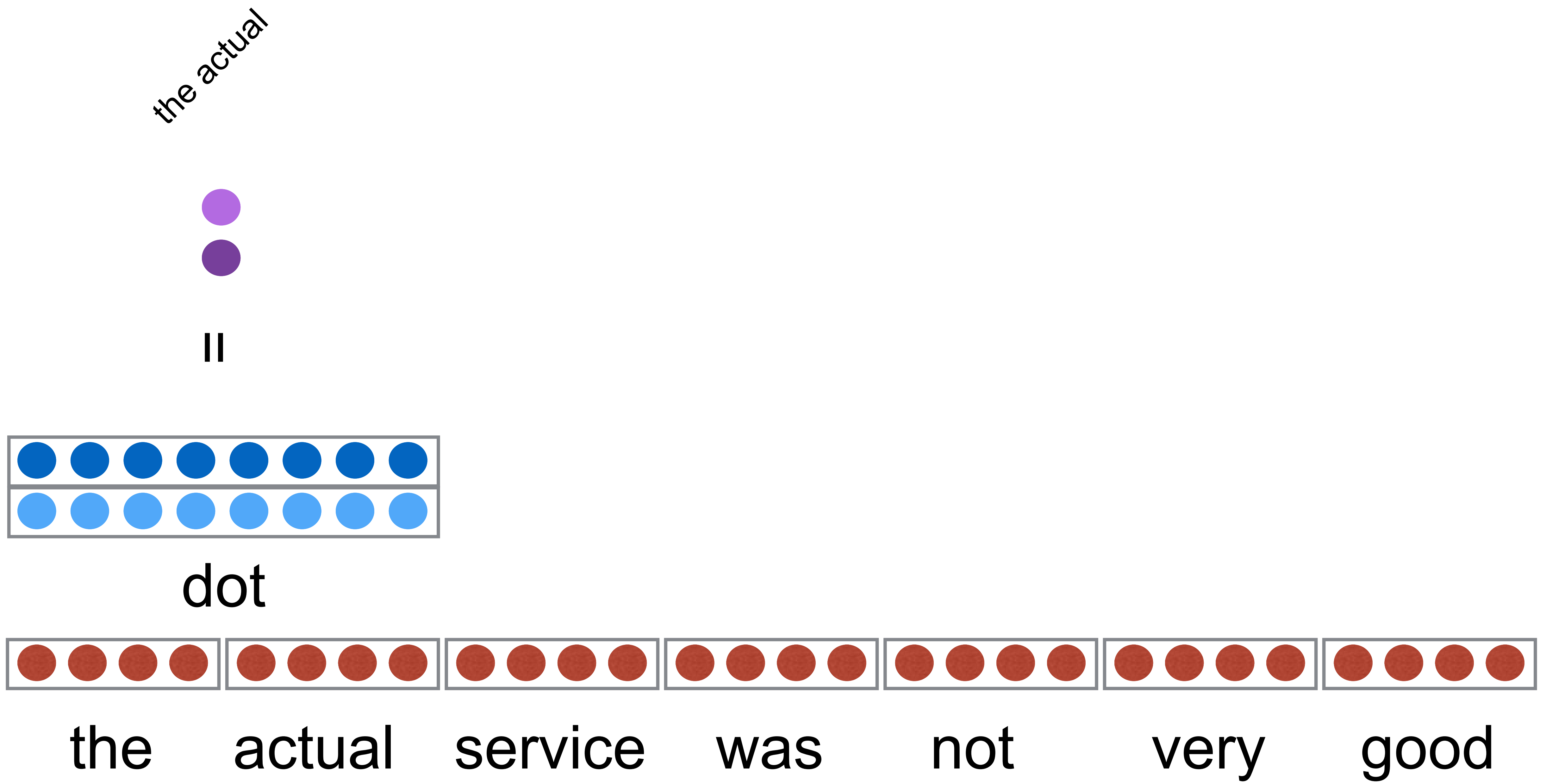
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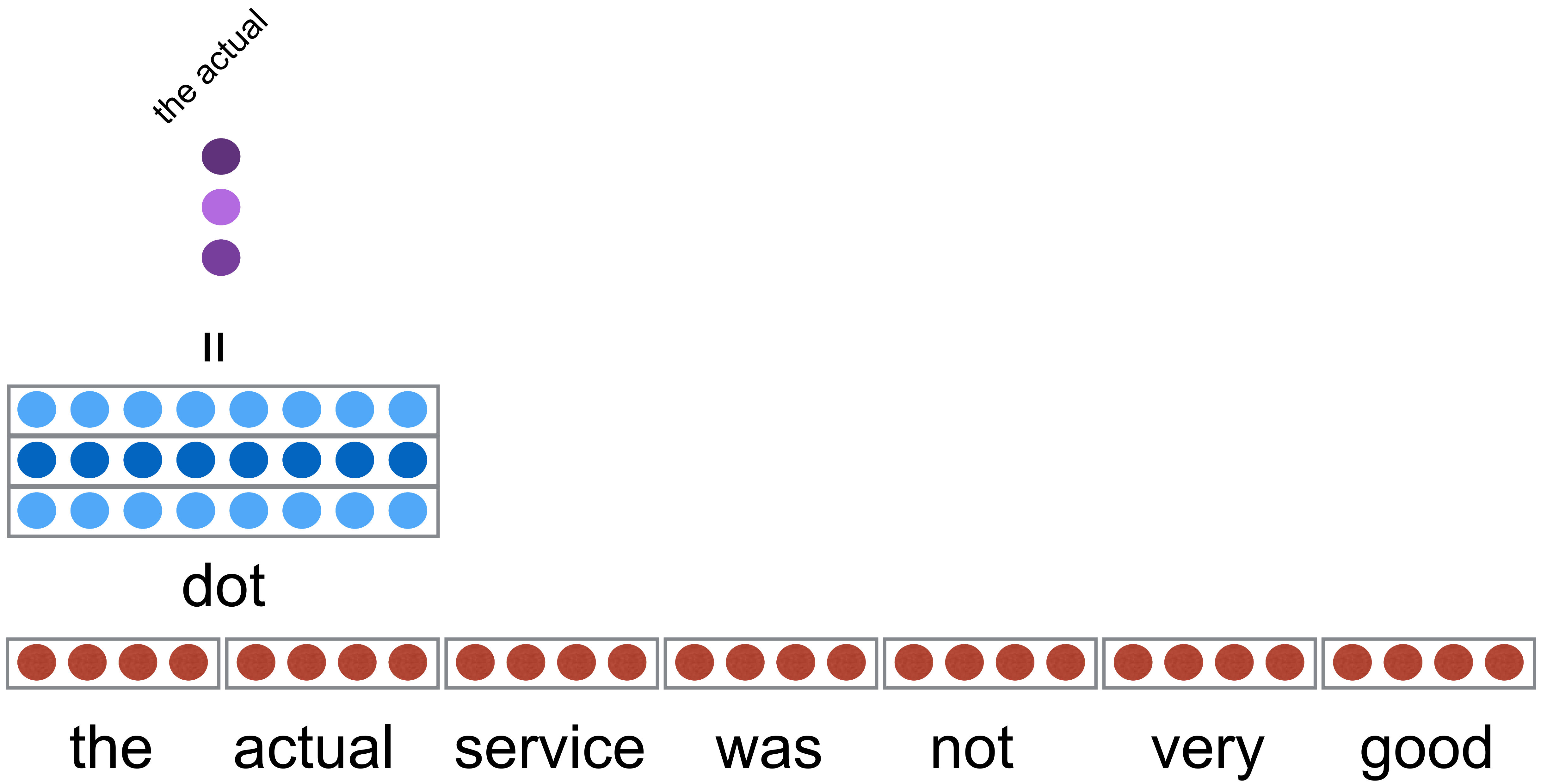
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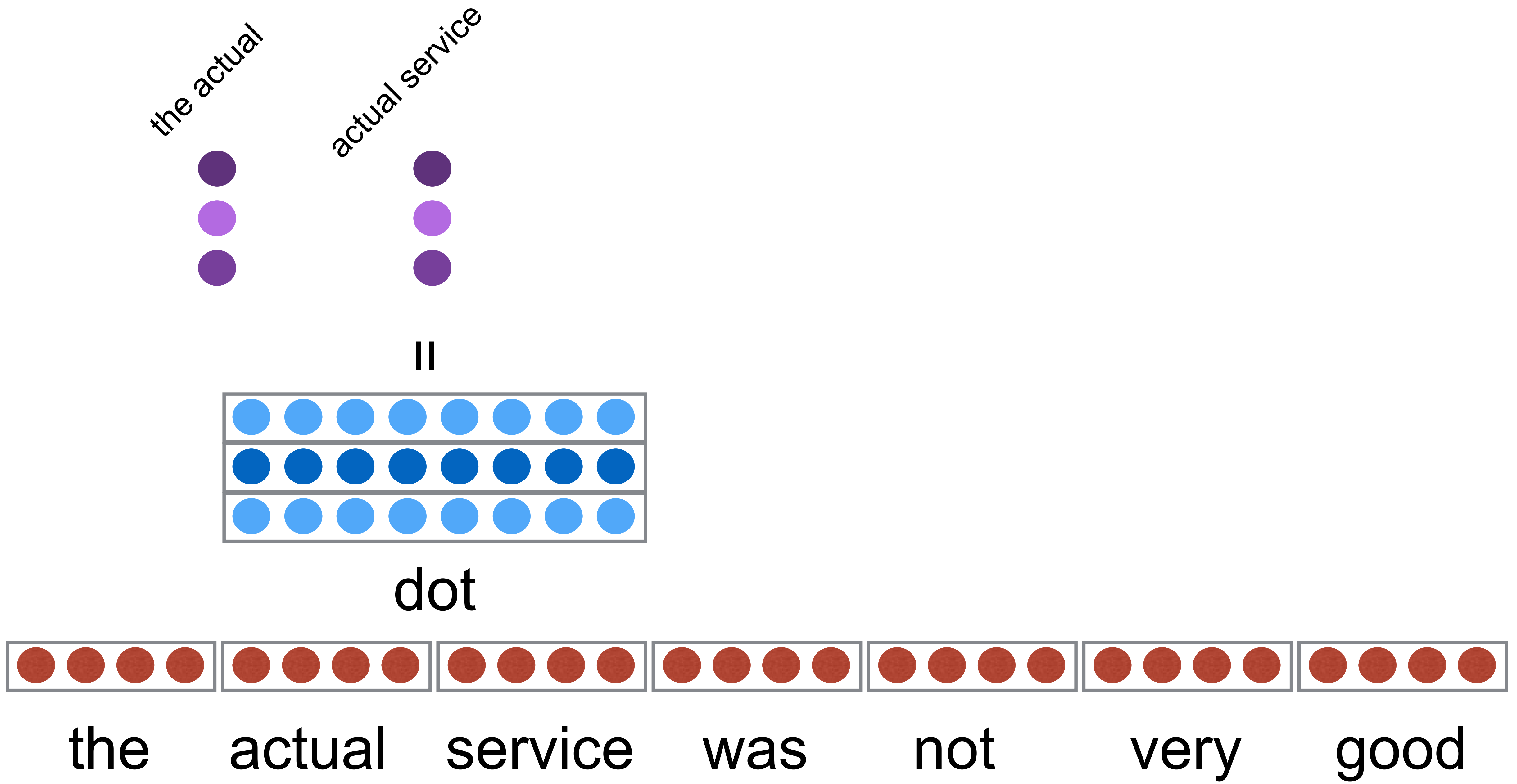
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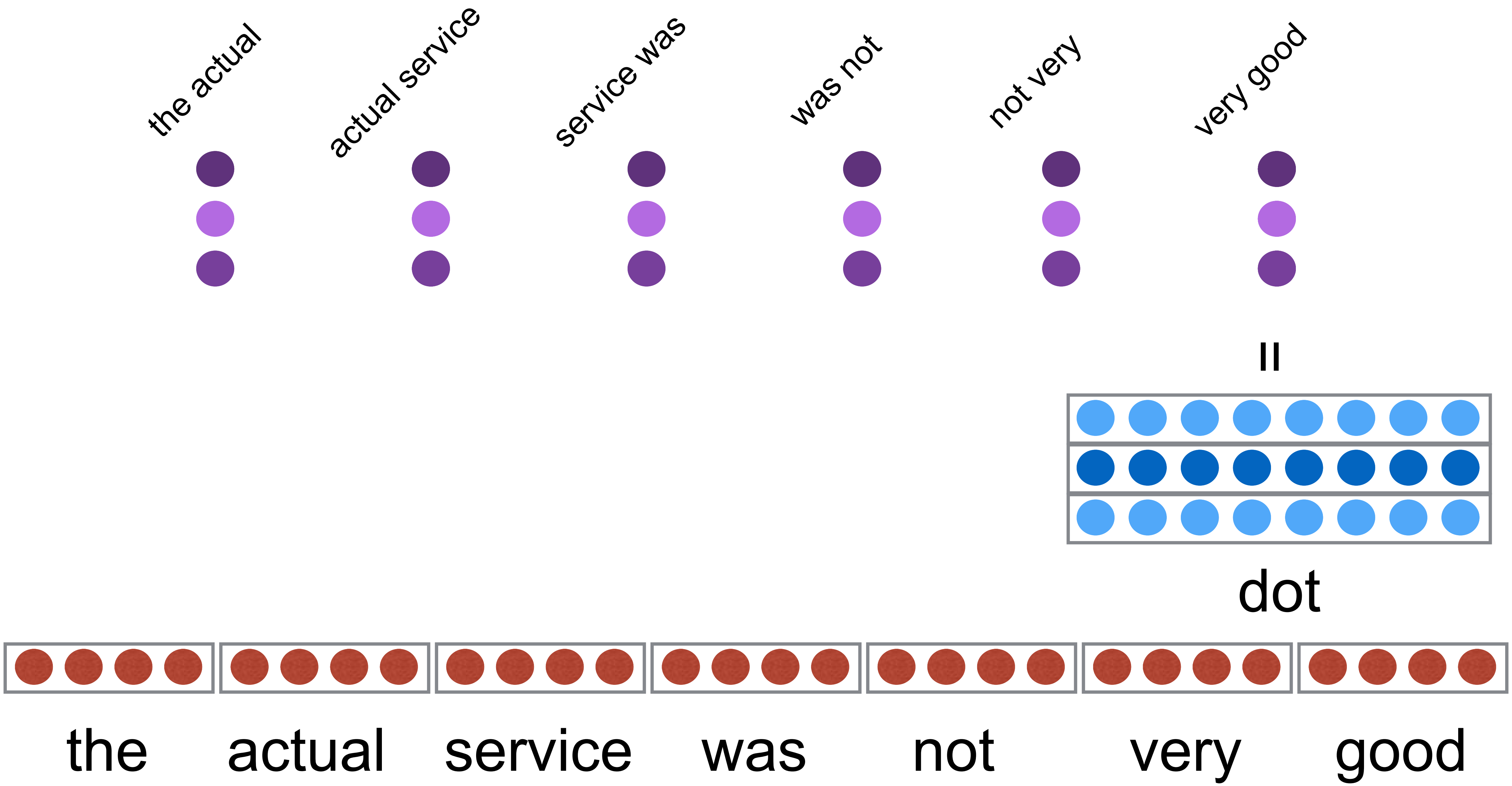

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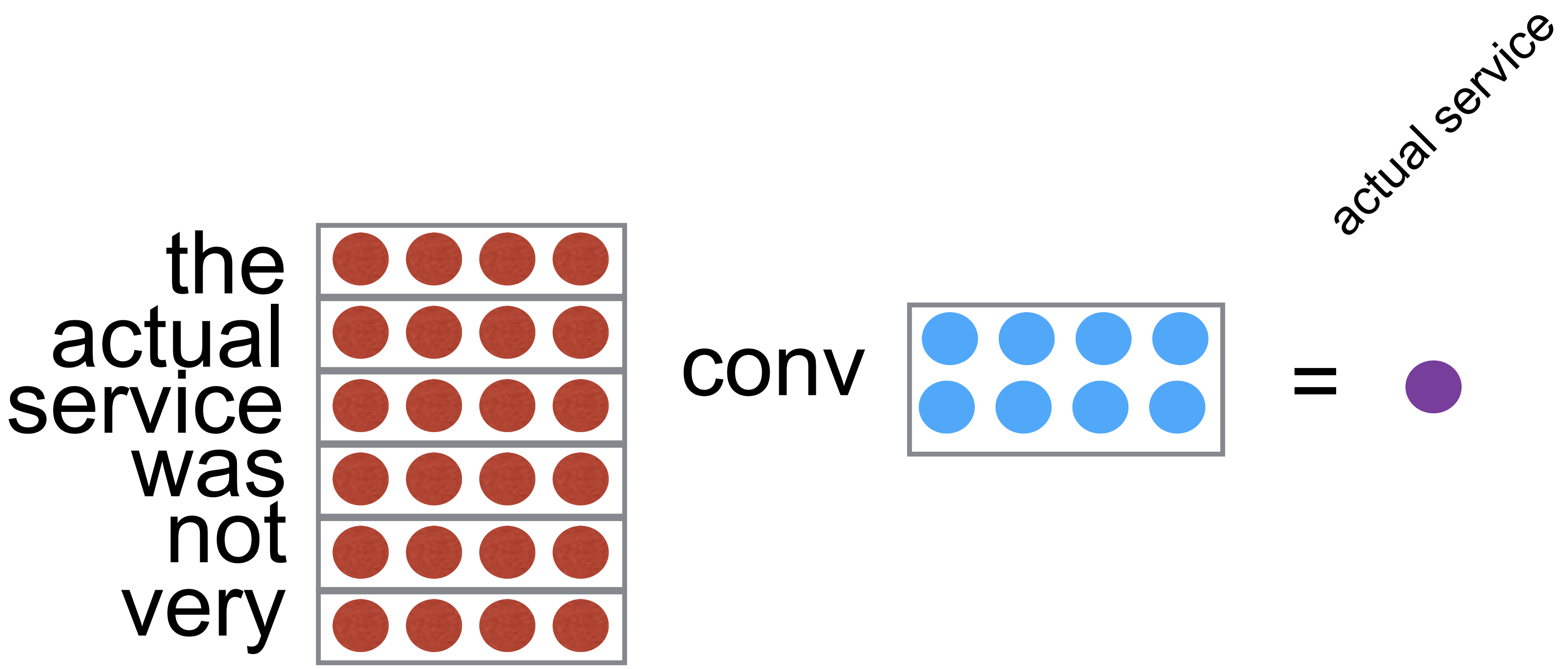
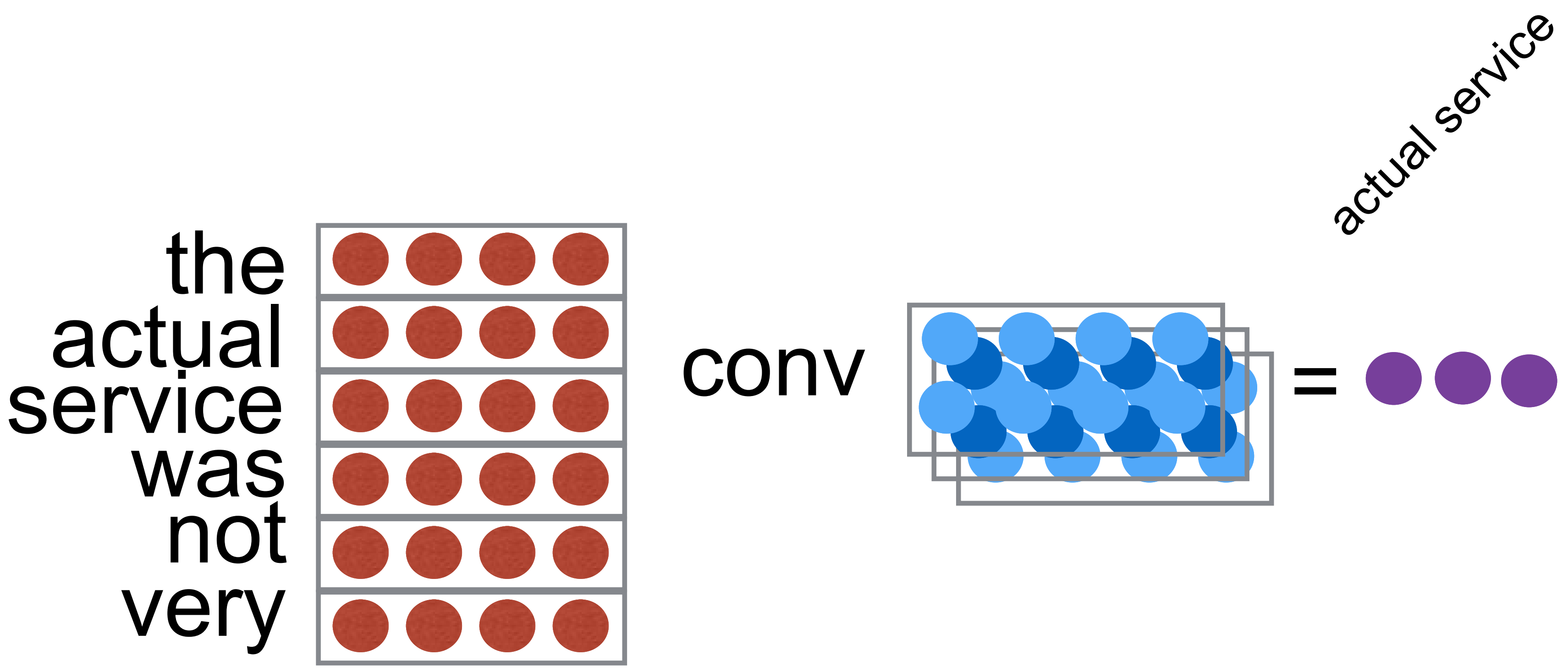


(another way to represent text convolutions)



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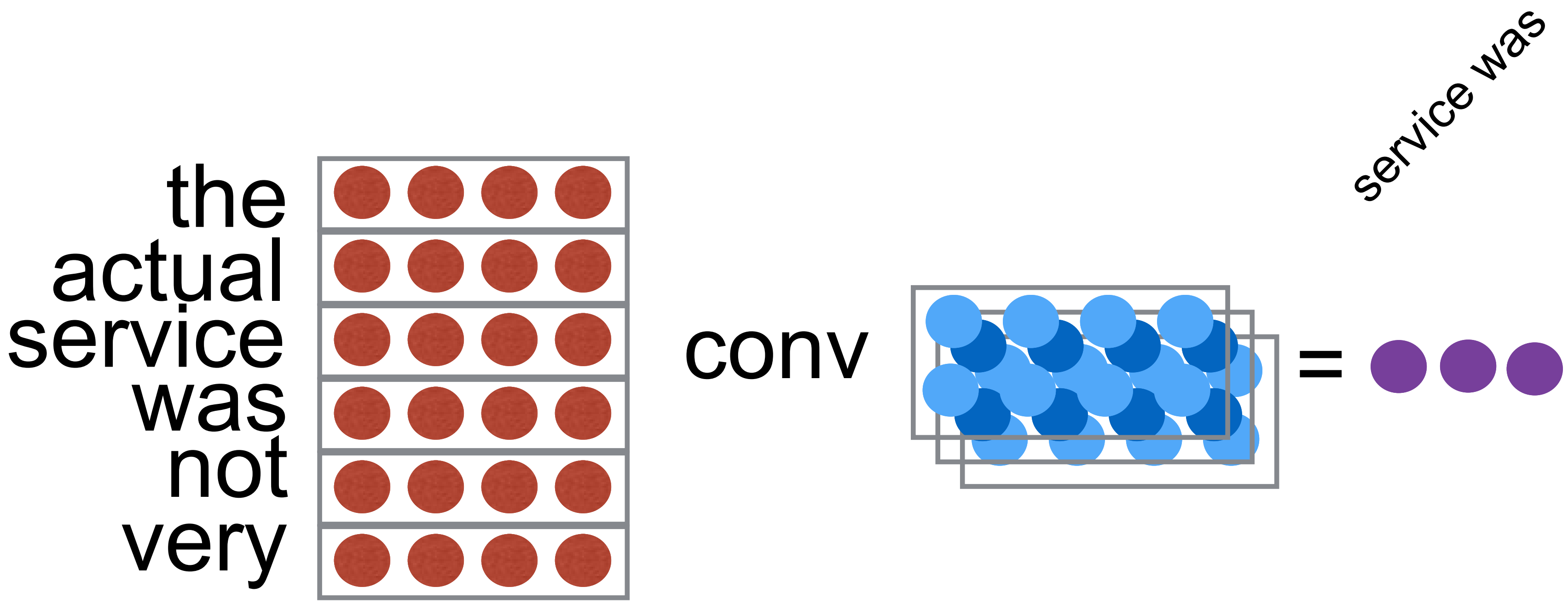

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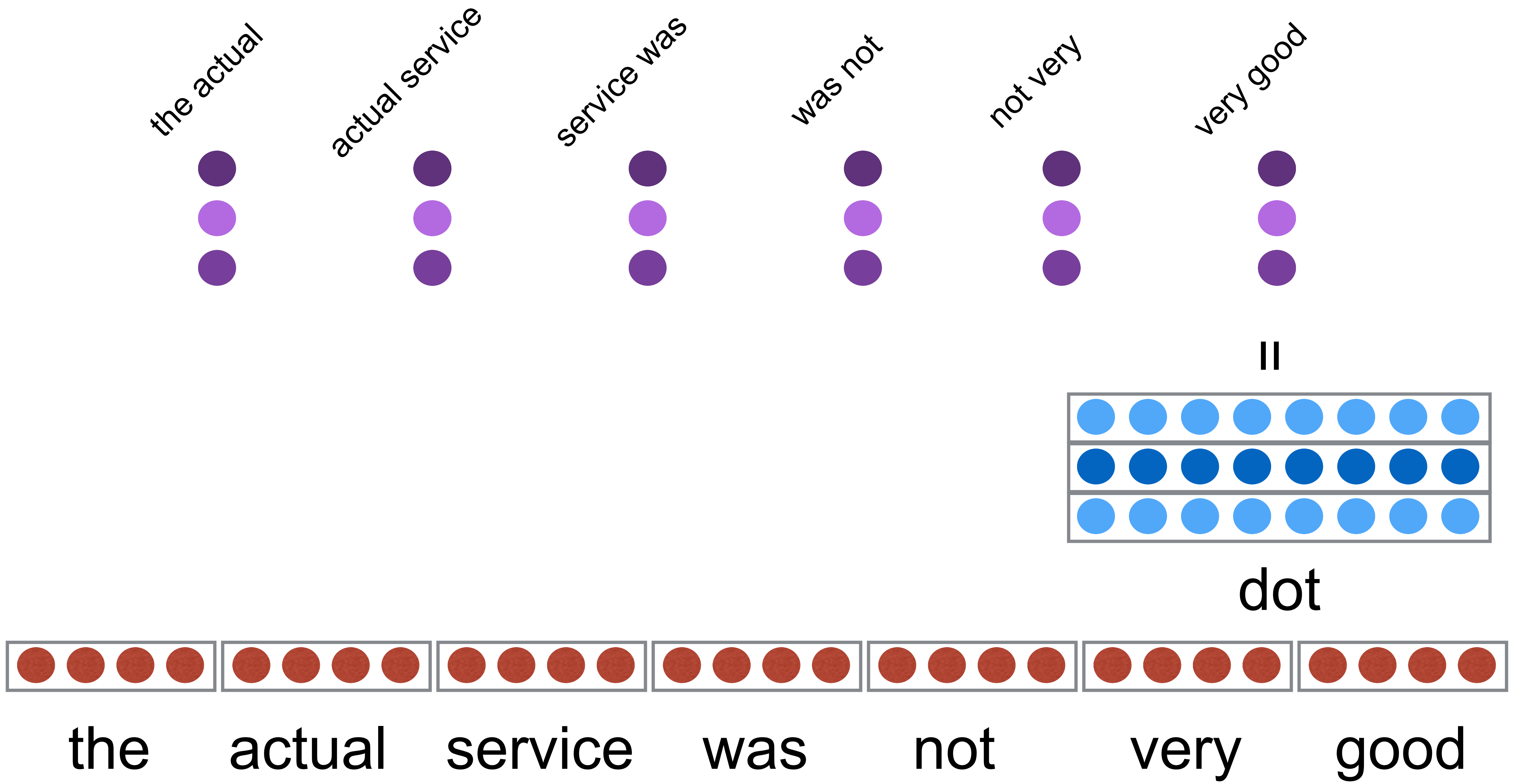
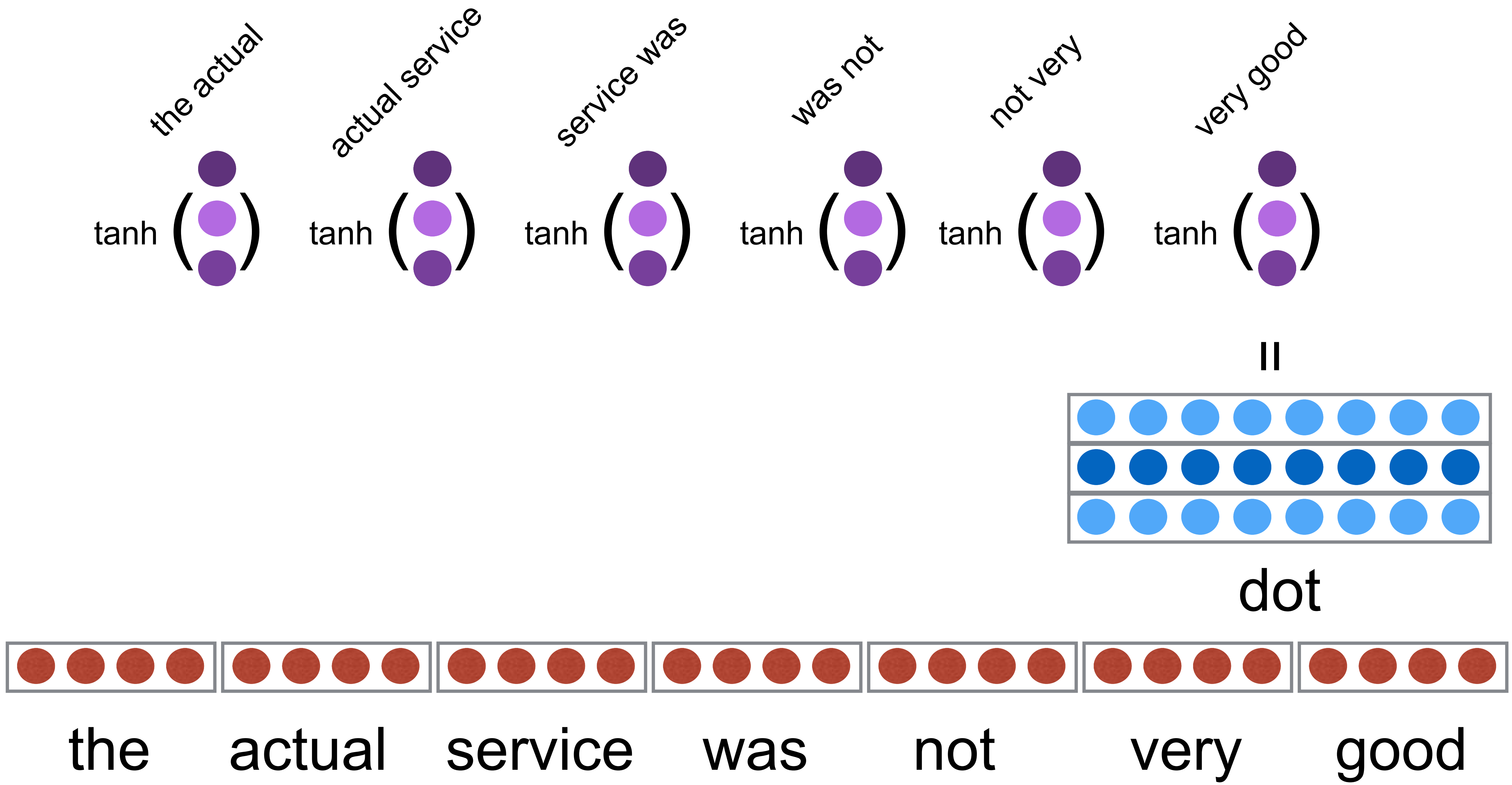
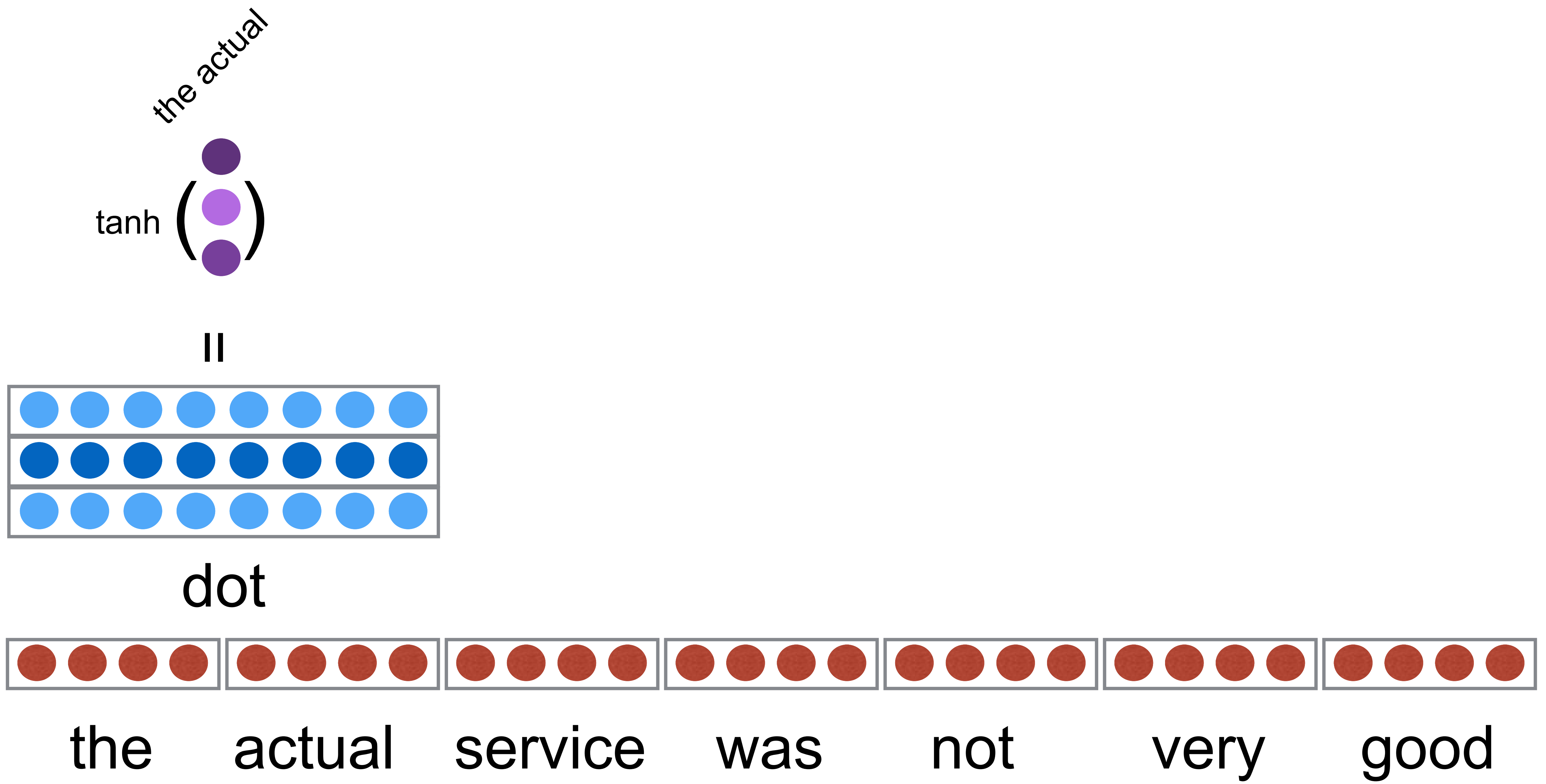


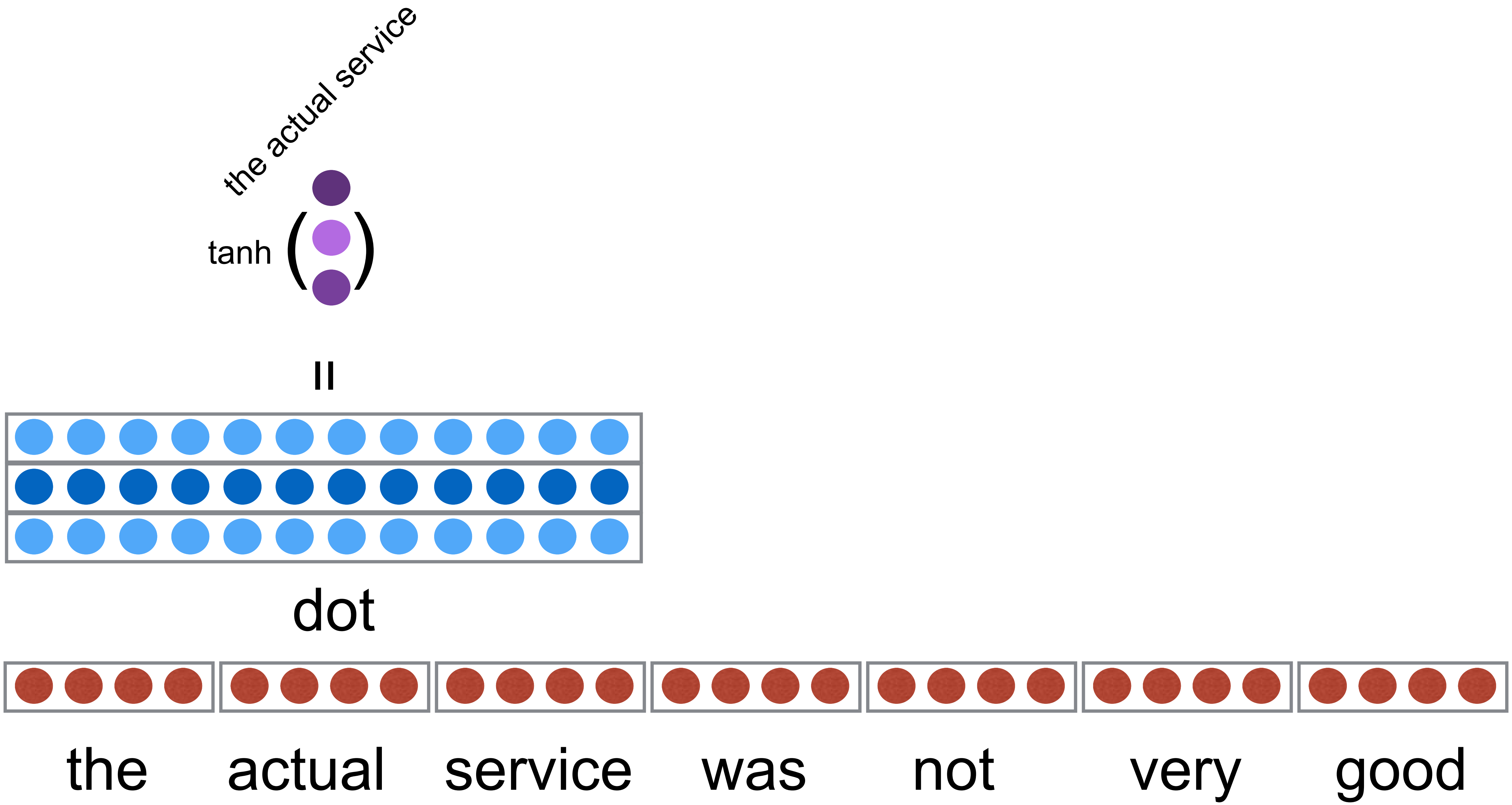
(we'll focus on the 1-d view here, but remember they are equivalent)



(usually also add non linearity)



(can have larger filters)



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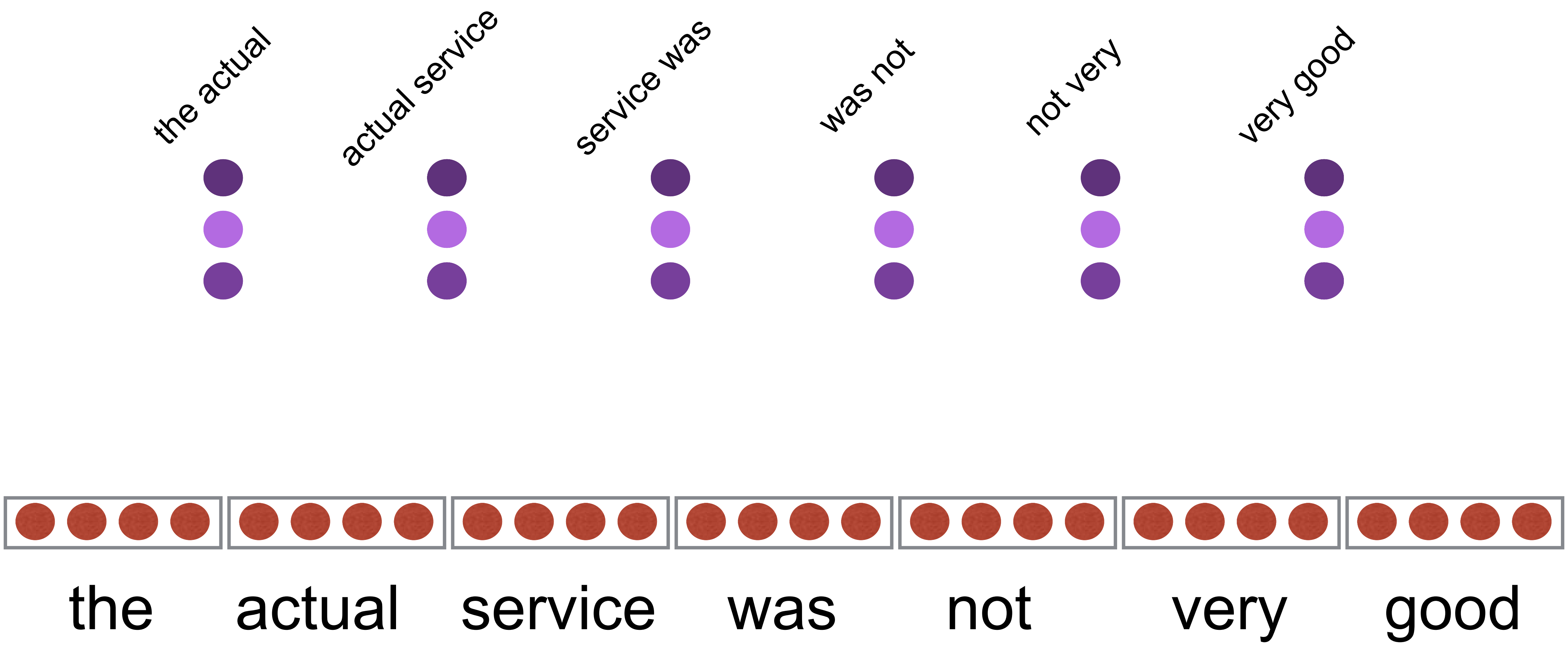
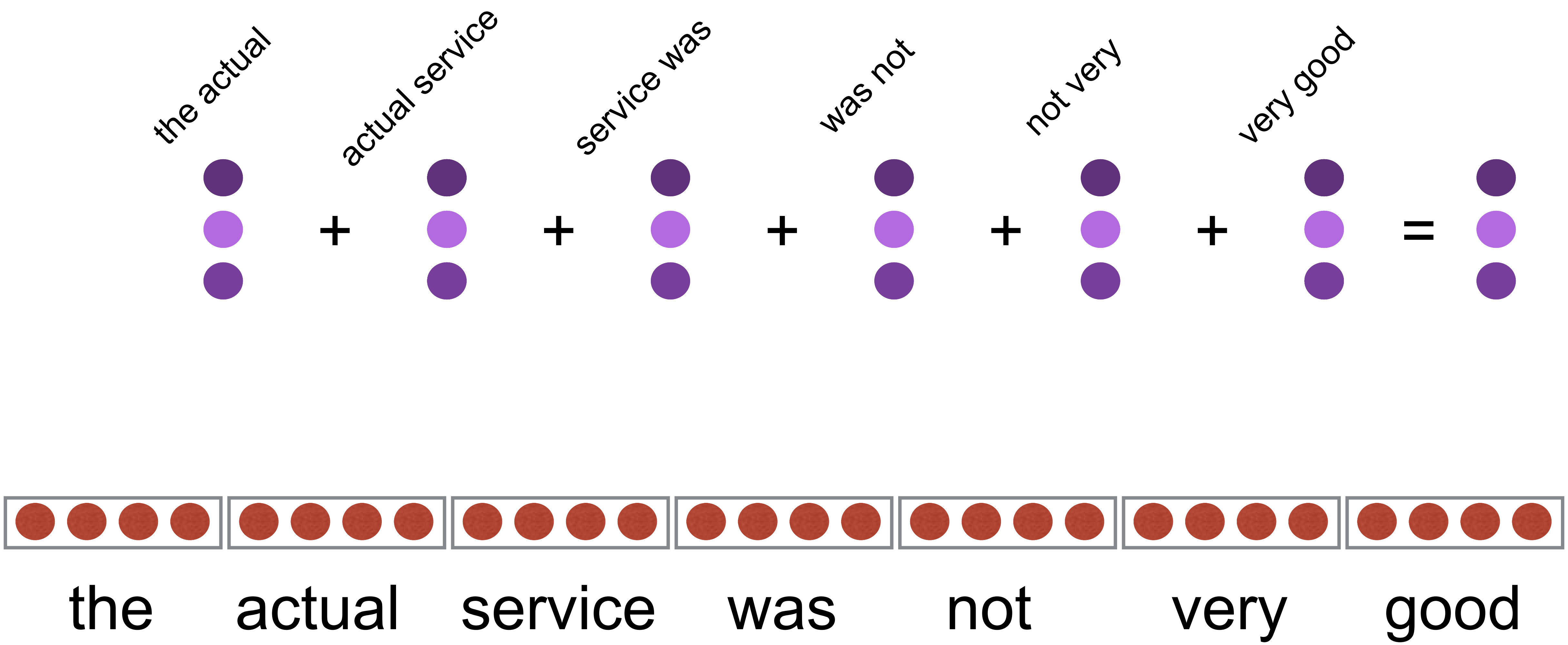


we have the ngram vectors. now what?



can do "pooling"

"Pooling"

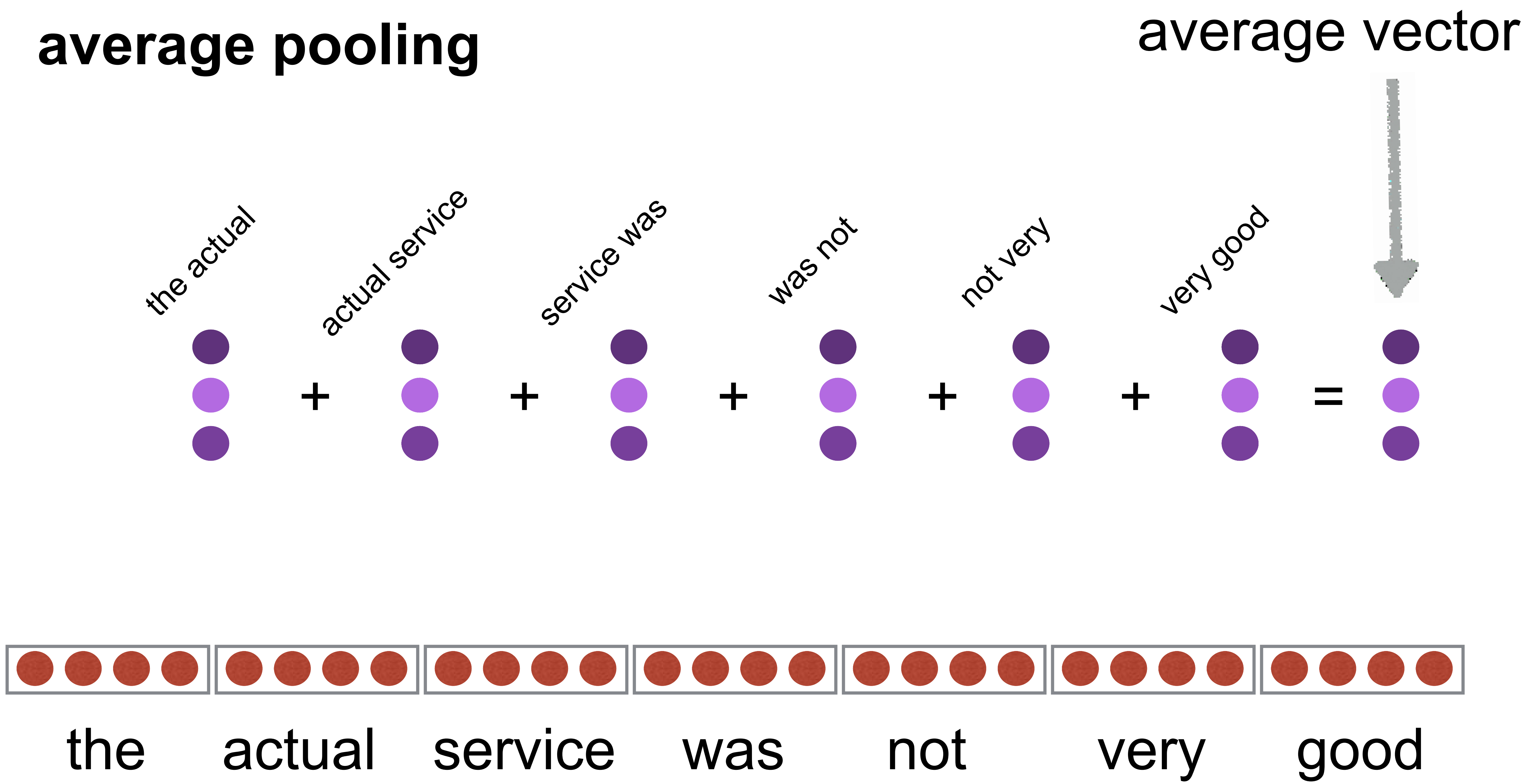
Combine K vectors into a single vector

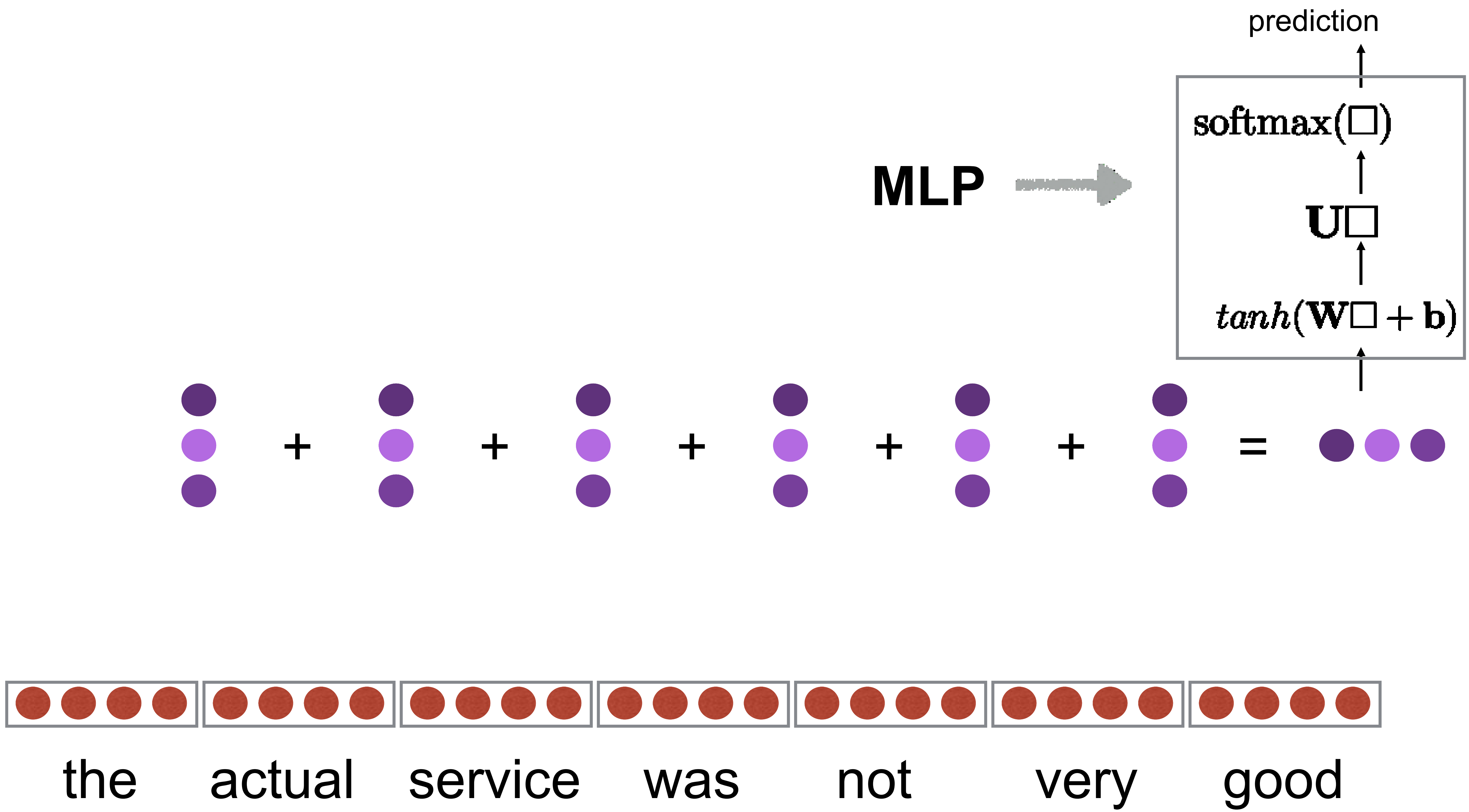
"Pooling"

Combine K vectors into a single vector

This vector is a summary of the K vectors, and can be used for prediction.

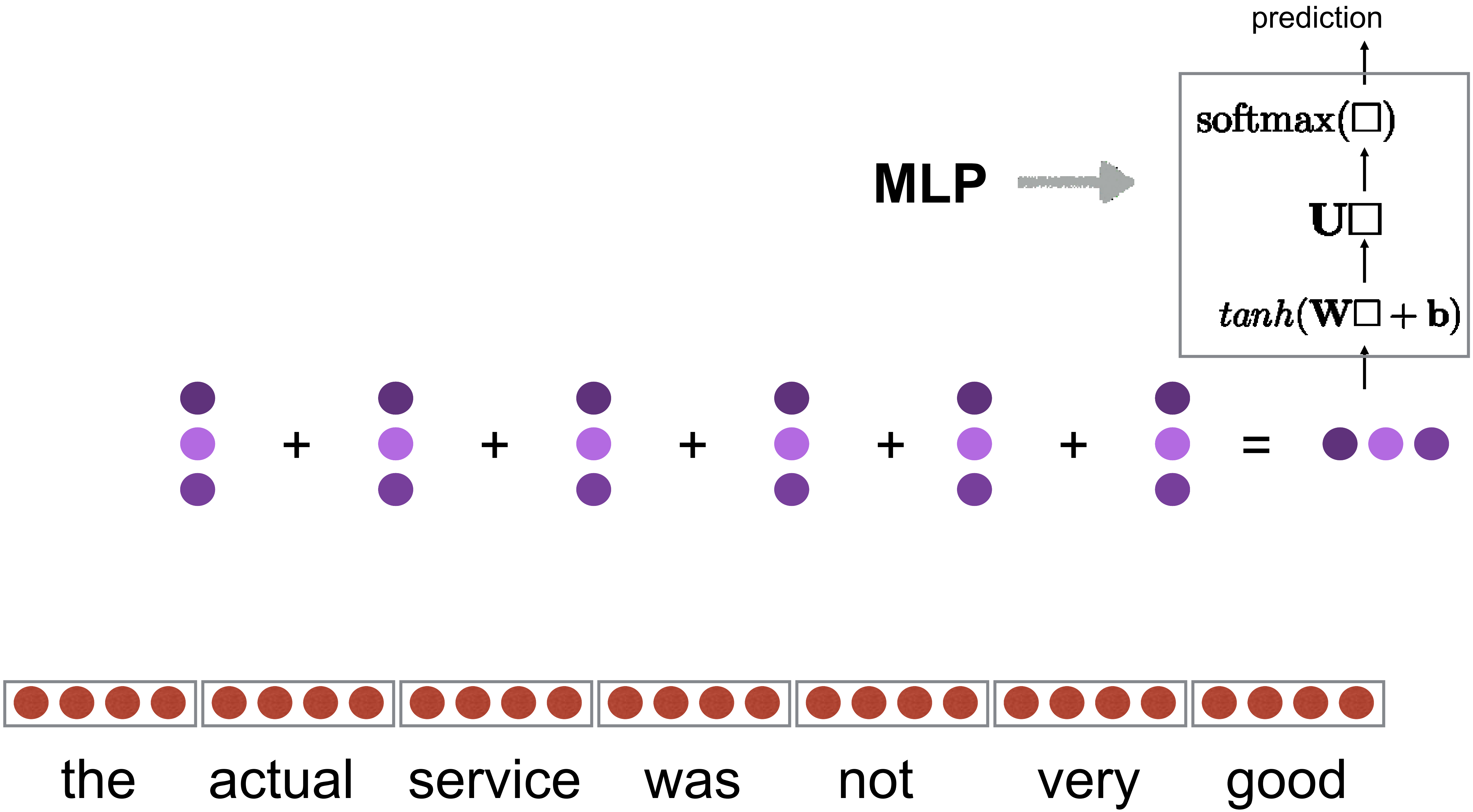
average pooling





train end-to-end for some task

(train the MLP, the filter matrix, and the embeddings together)



train end-to-end for some task

(train the MLP, the filter matrix, and the embeddings together)

the vectors learn to capture what's important

we have the ngram vectors. now what?

Can look at the differences between terms.

microsoft *office* software		car *body* shop	
Free *office* 2000	0.550	car *body* kits	0.698
download *office* excel	0.541	auto *body* repair	0.578
word *office* online	0.502	auto *body* parts	0.555
apartment *office* hours	0.331	wave *body* language	0.301
massachusetts *office* location	0.293	calculate *body* fat	0.220
international *office* berkeley	0.274	forcefield *body* armour	0.165

Table 2: Sample word n-grams and the cosine similarities between the learned word-n-gram feature vectors of "*office*" and "*body*" in different contexts after the CLSM is trained.

A Latent Semantic Model with Convolutional-Pooling Structure for Information Retrieval

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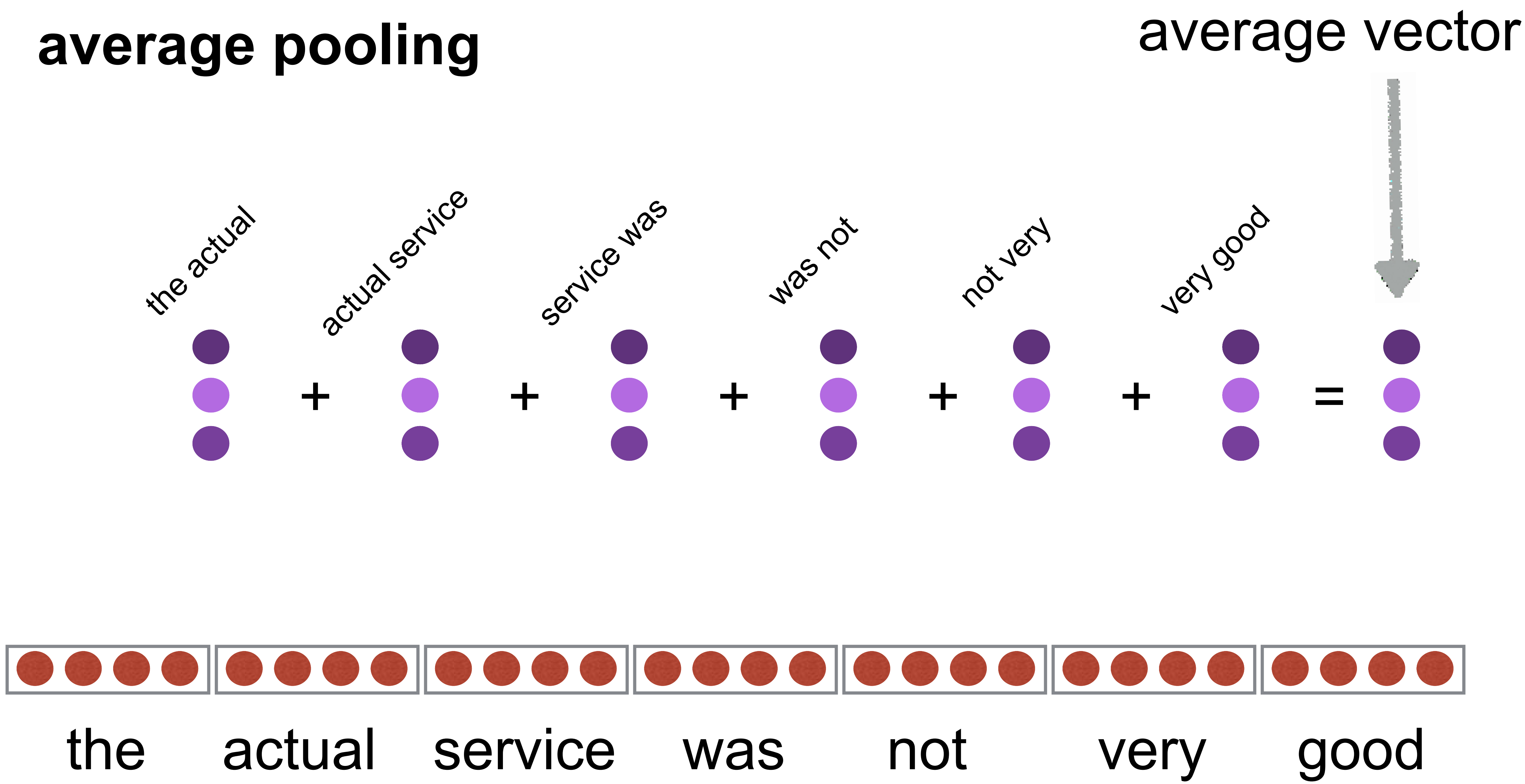
Grégoire Mesnil — University of Montréal, Montréal, Canada — gregoire.mesnil@umontreal.ca


average pooling
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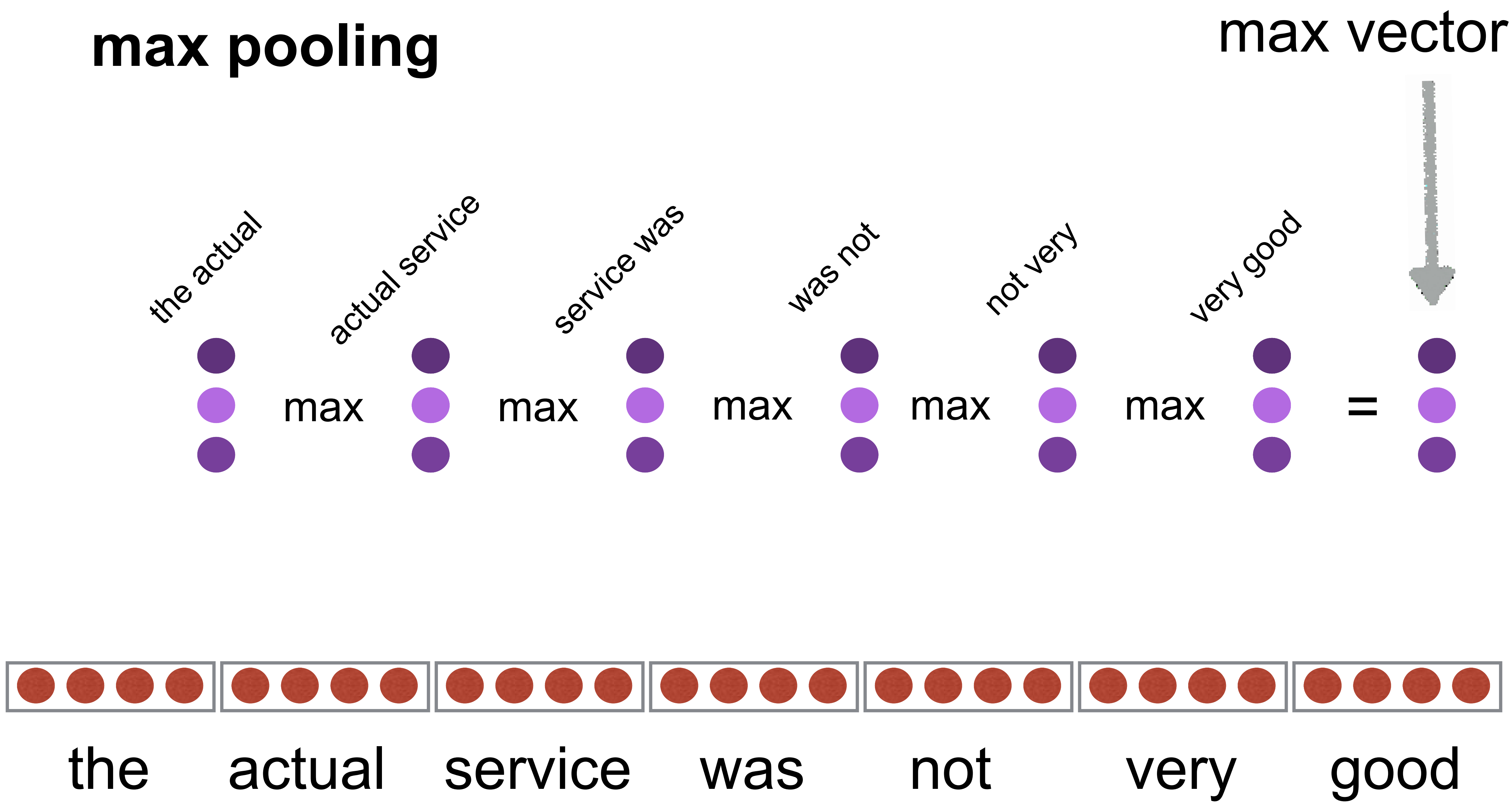
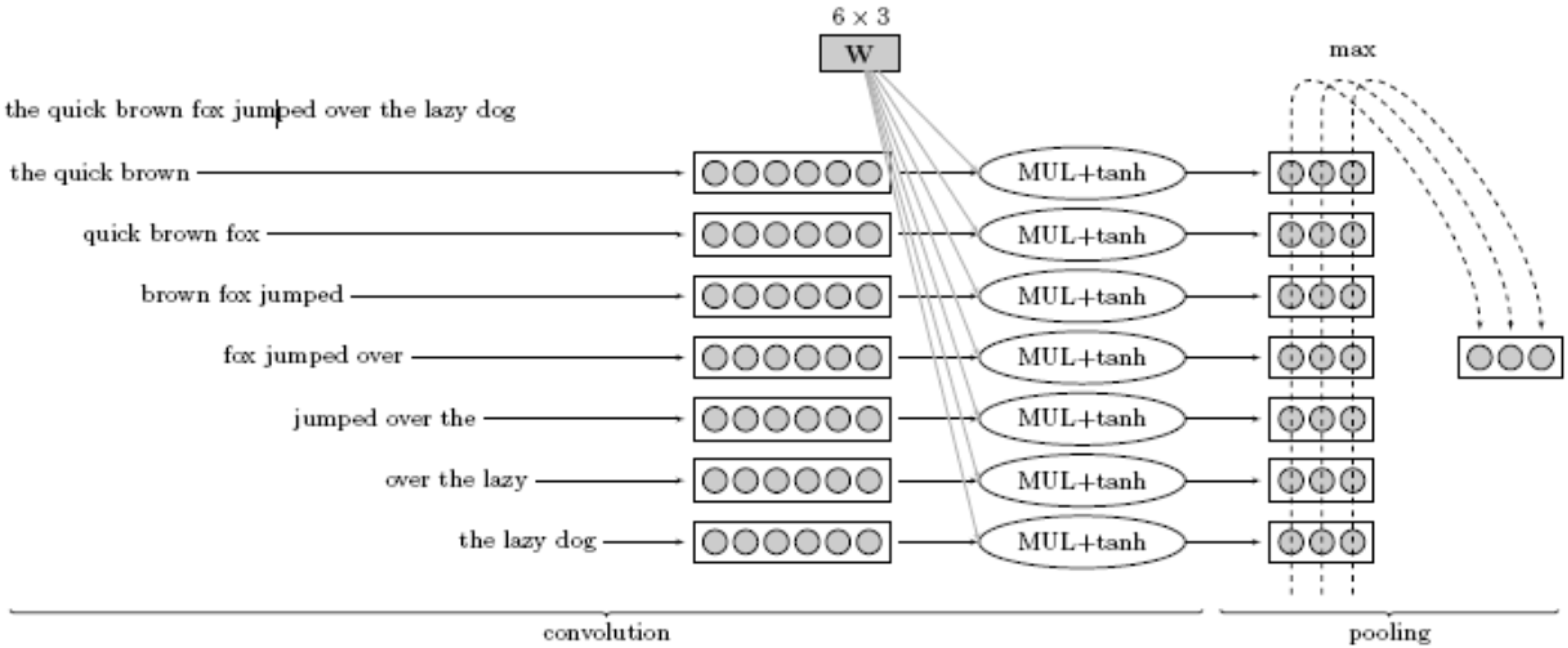
max pooling

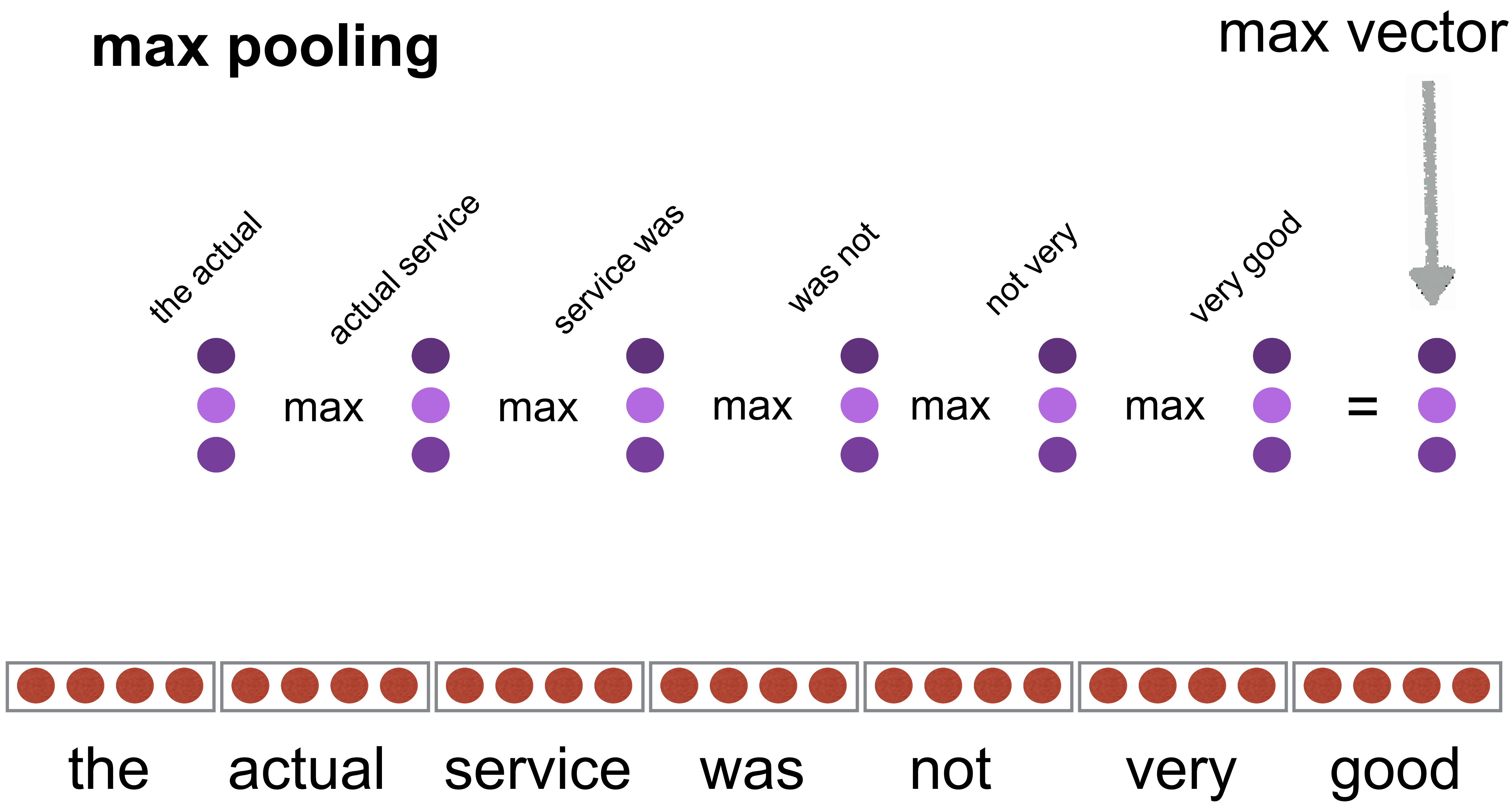


(max in each coordinate)

Another way to draw this:



max pooling



max vs average – discuss

Zhang, Y., & Wallace, B. (2015). A Sensitivity Analysis of (and Practitioners' Guide to) Convolutional Neural Networks for Sentence Classification one benefit of max-pooling: it's "**interpretable**"

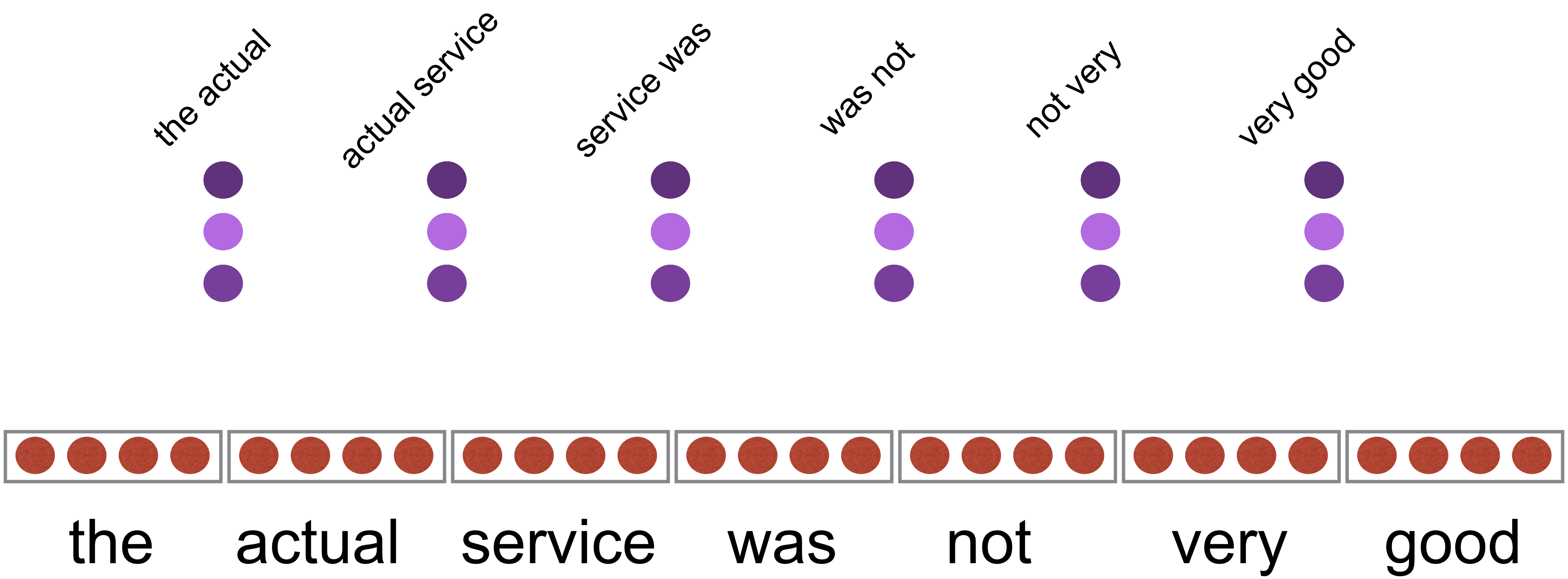
we can know where each element
in the summary vector came from

Examples of resulting "summaries"

microsoft **office excel** could allow remote **code execution**
welcome to the **apartment office**
online **body fat** percentage **calculator**
online **auto body** repair **estimates**
vitamin a the **health** benefits given by **carrots**
calcium supplements and **vitamin d** discussion stop **sarcoidosis**

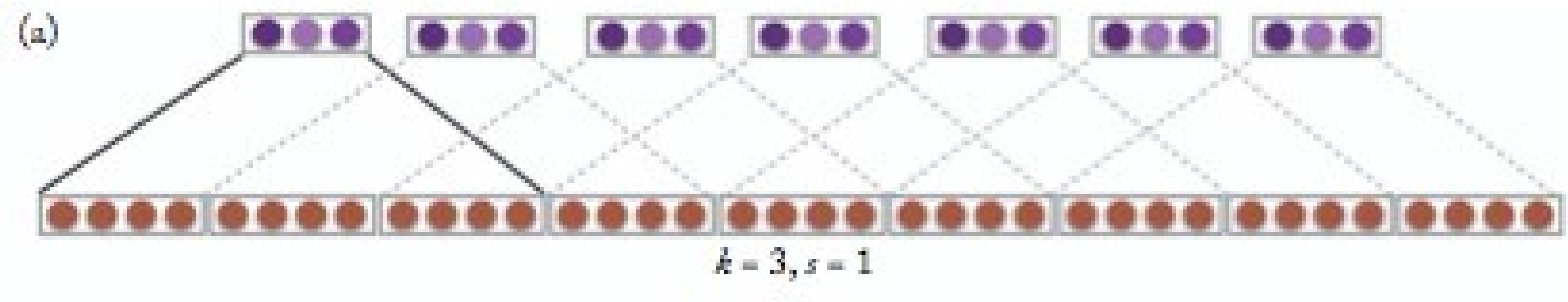
Table 3: Sample document titles. We examine the five most active neurons at the max-pooling layer and highlight the words in **bold** who win at these five neurons in the *max* operation. Note that, the feature of a word is extracted from that word together with the context words around it, but only the center word is highlighted in bold.

Strides



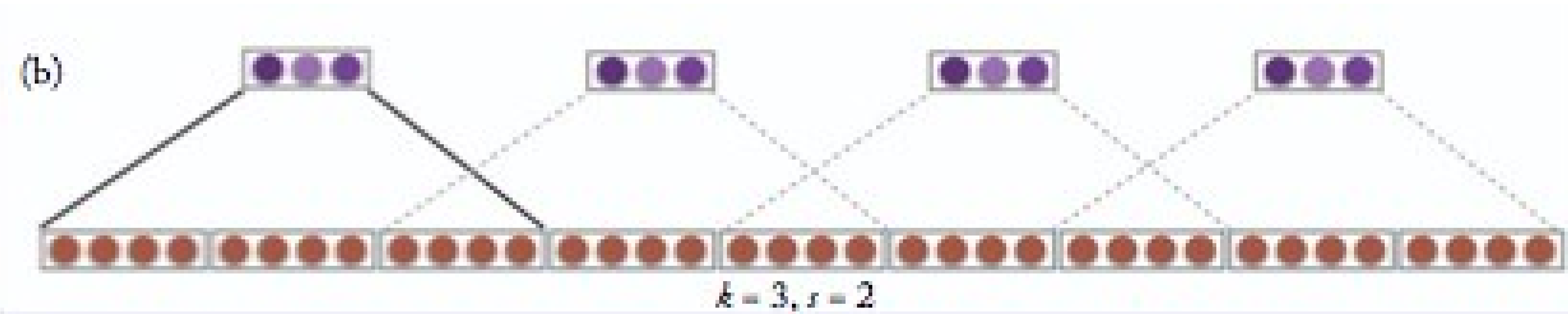
strides = how much you move

Strides



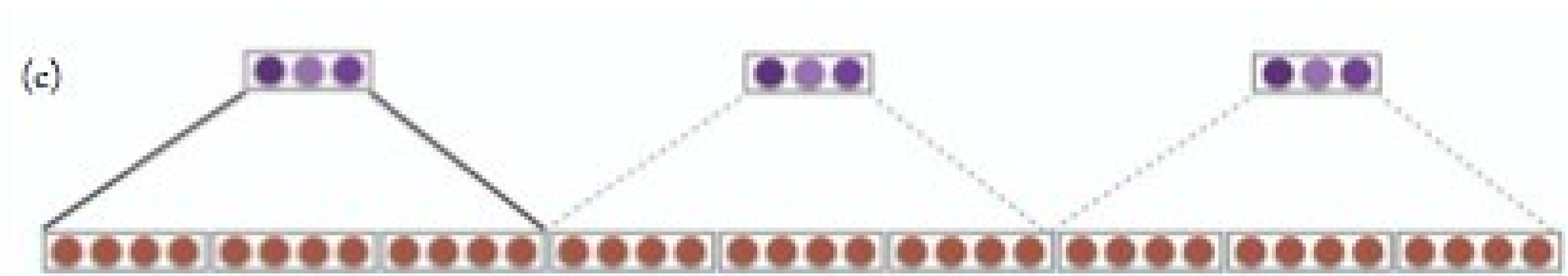
k = 3, stride = 1

Strides



k = 3, stride = 2

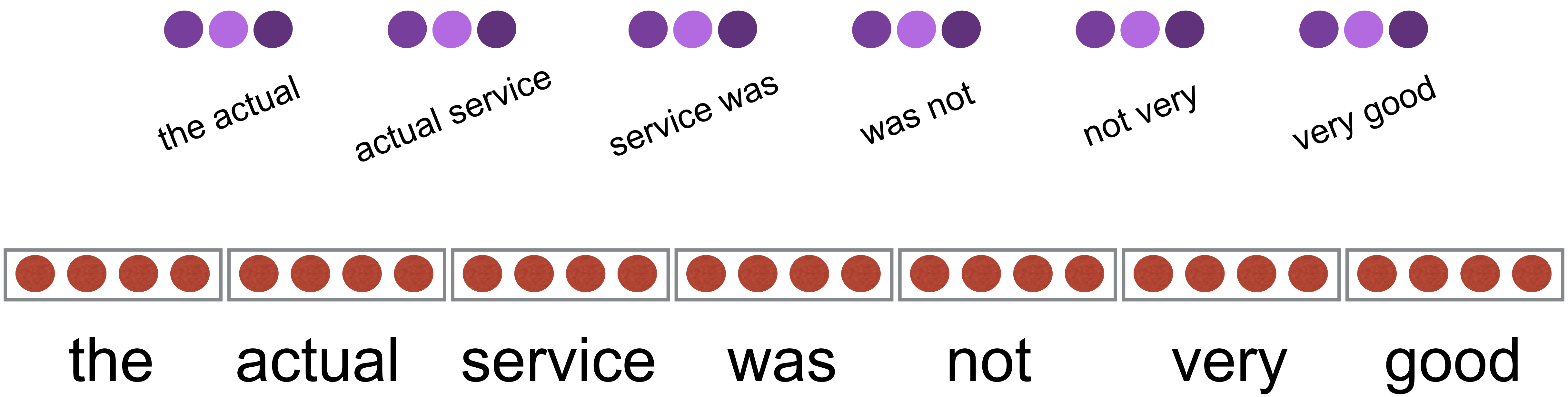
Strides



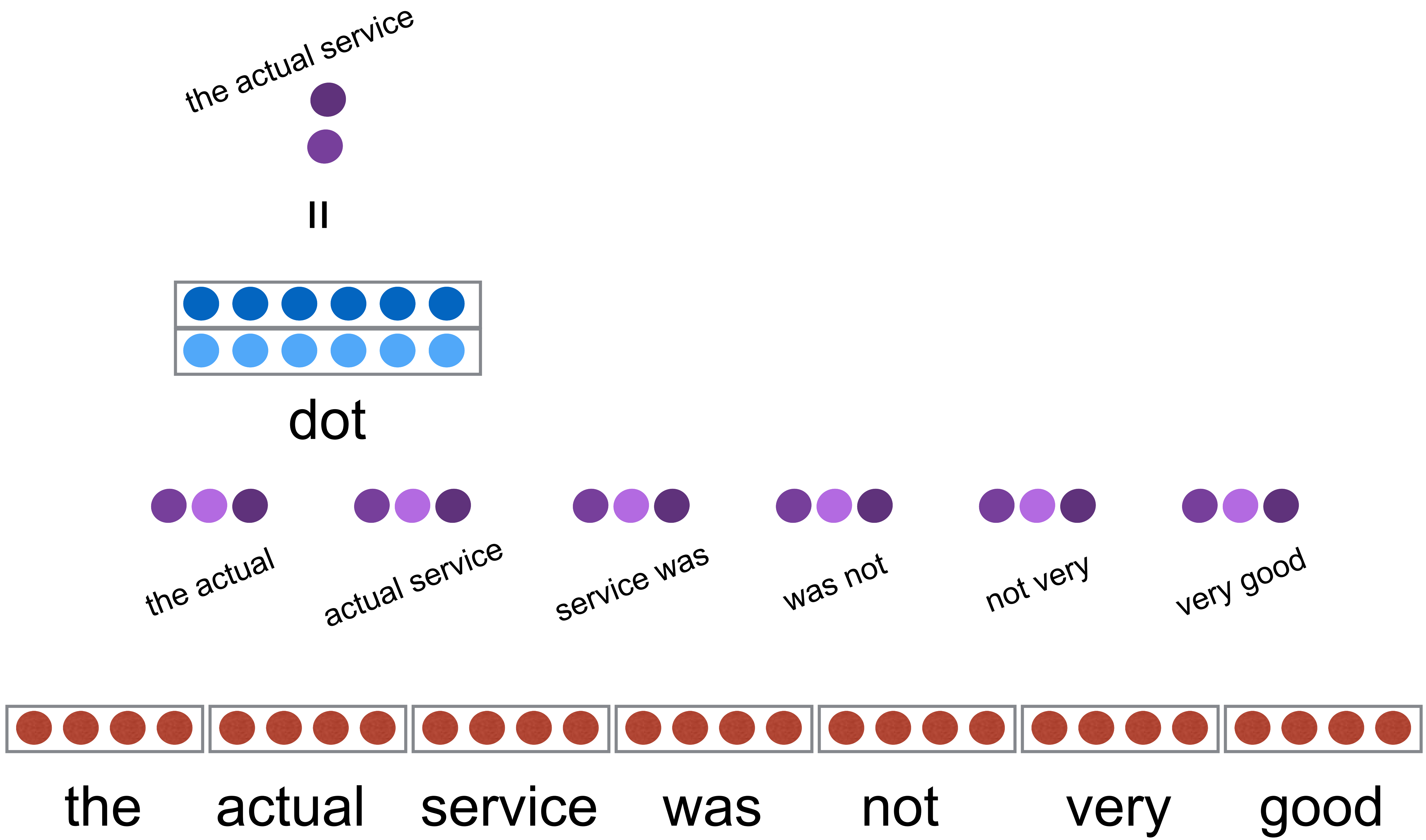
k = 3, stride = 3

Hierarchy

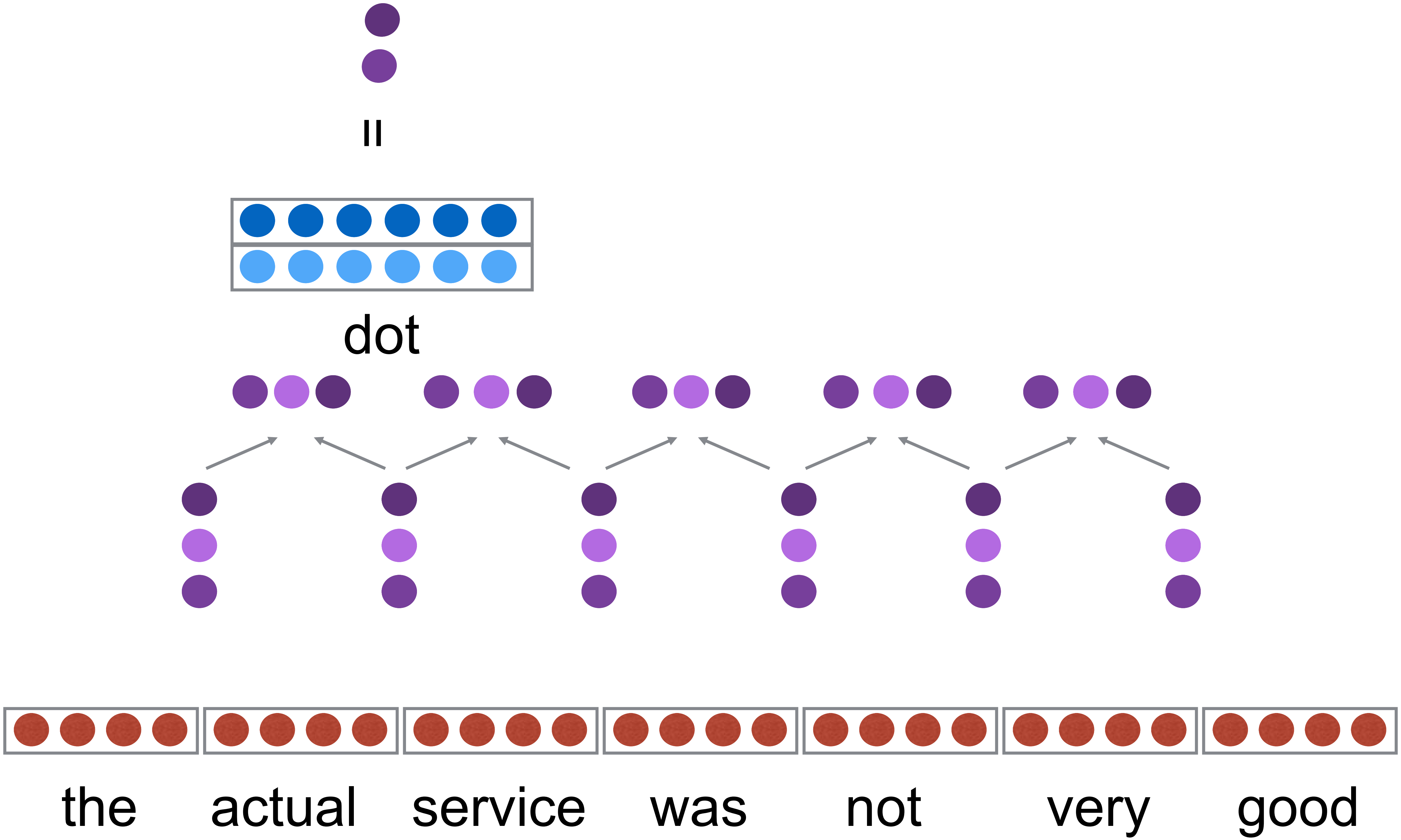
Hierarchy



can have hierarchy

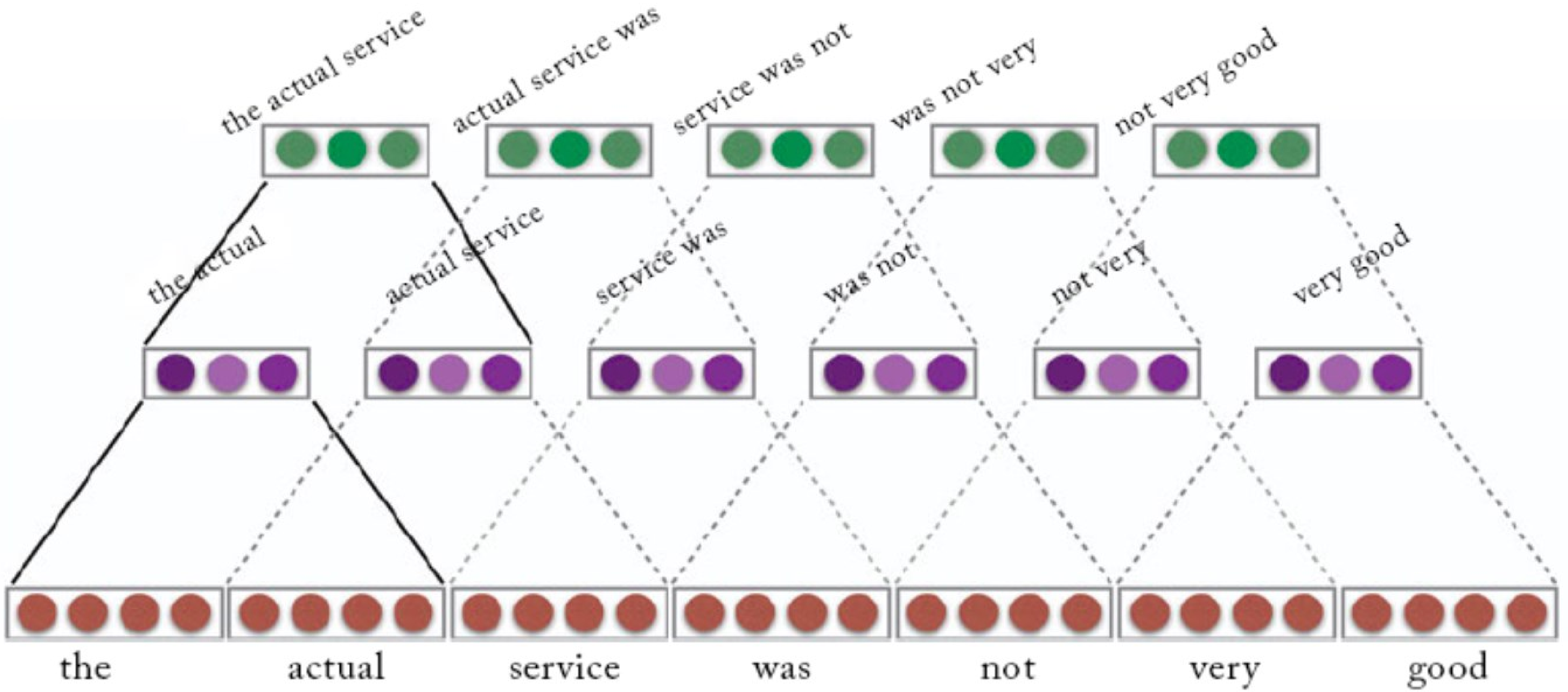


can have hierarchy



(can combine: **pooling + hierarchy**)

Hierarchy



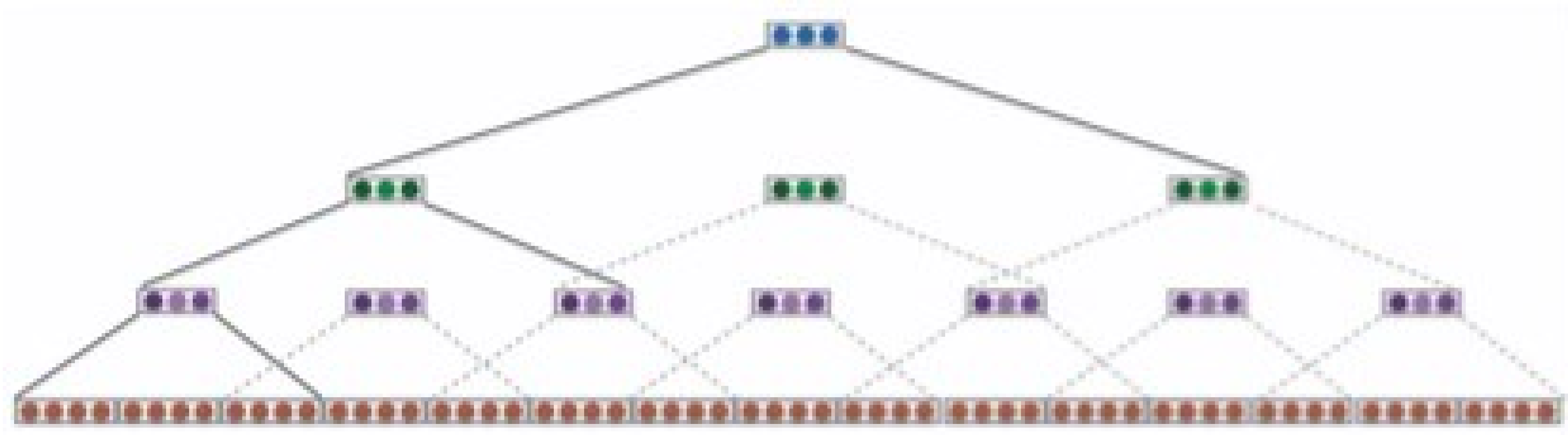
2-layer hierarchical conv with k=2

Dilated Convolutions

we want to cover more of the sequence

idea: strides + hierarchy

Dilated Convolutions



dilated convolution, k=3

idea: strides + hierarchy

ConvNets Summary

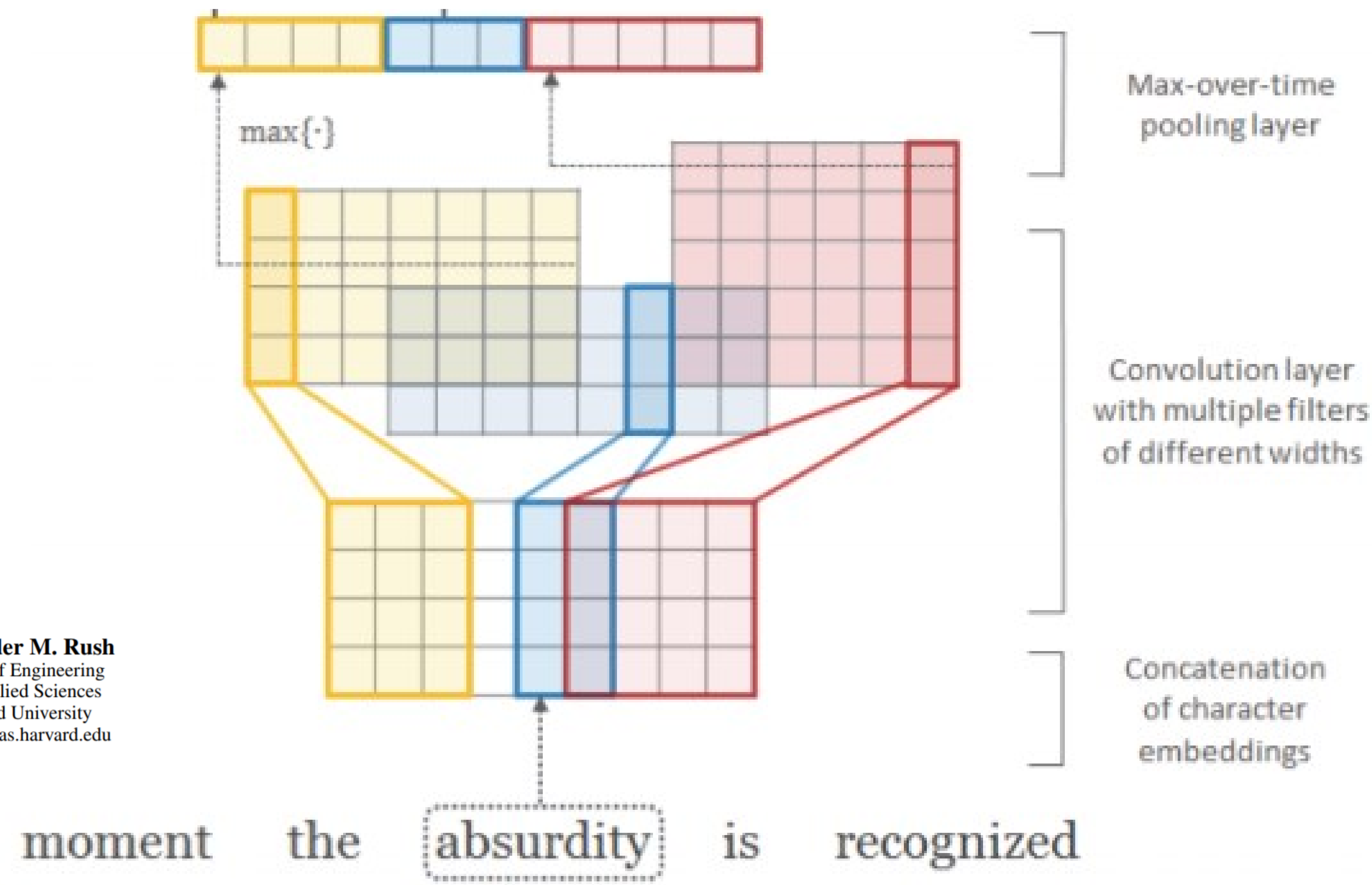
- Shared matrix used as feature detector.
- Extracts interesting ngrams.
- Pool ngrams to get fixed length representation.
- Max-pooling works well.
    - Max vs. Average pooling.
- Use hierarchy / dilation to expand coverage.
- Train end-to-end.

Character CNNs

- Fix the input OOV problem
  - Input: some insight in word shapes (xxxxing, xxxxly)
  - Output: can’t ever output a word not in vocabulary
- Idea
  - Instead (or in addition of) word embedding
    - Use word = CNN over character sequences

Char CNN for Words

- Varied filter sizes
- Word embedding



Character-Aware Neural Language Models

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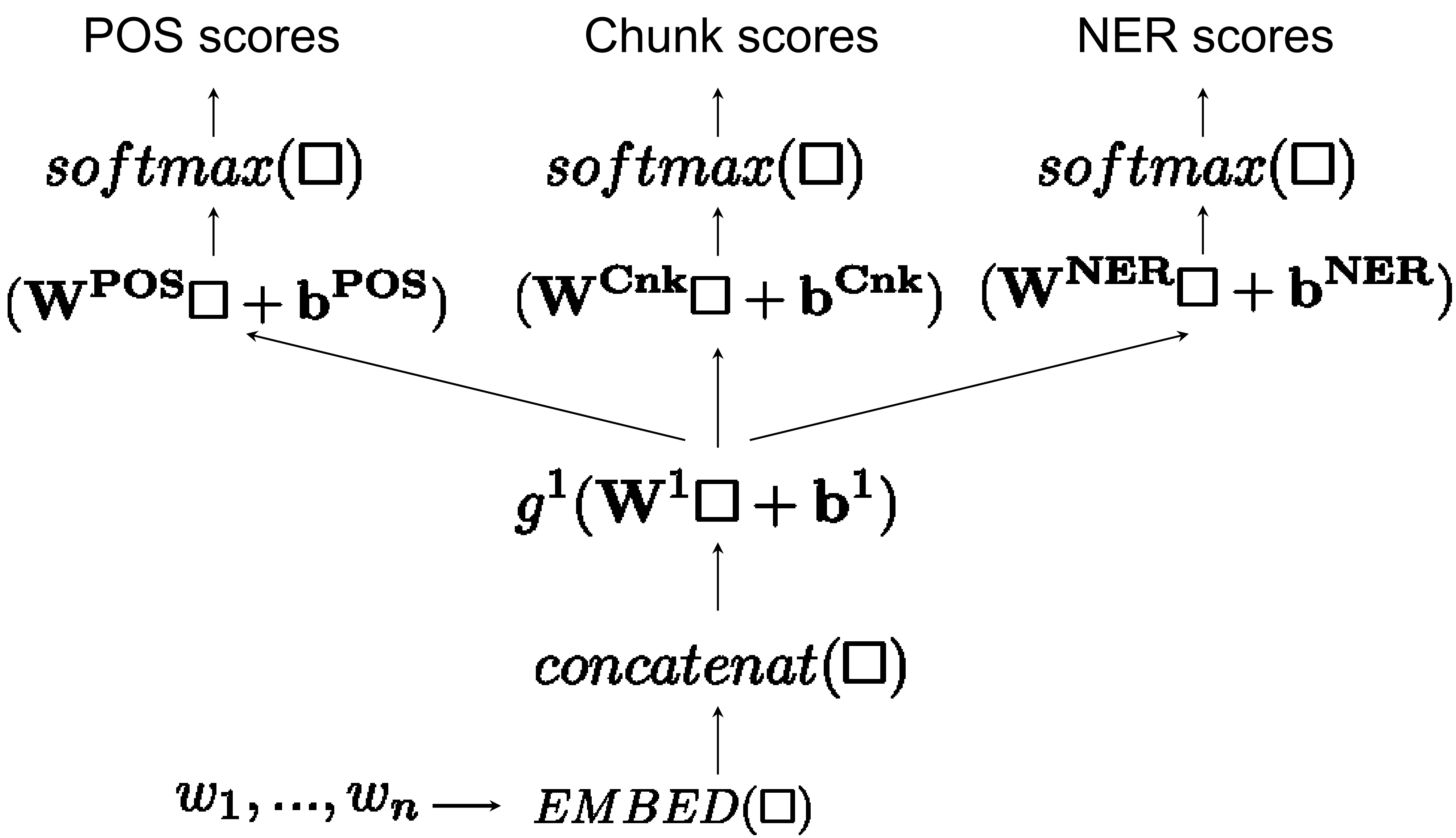
- Can't differentiate between words w similar spellings
- Solution: add small correction [$e_w = CNN(chars_w) + M.corr_w$]

Multi-task Learning

(time permitting)

The pitch

- Different NLP prediction tasks have shared structures.
- Hints for predicting A may help to predict B.
- Instead of training a network to do one thing, train it to do several things.
- YOU ARE ALL WINNERS


POS scores
Chunk scores
NER scores
$softmax(\square)$
$softmax(\square)$
$softmax(\square)$
$(\mathbf{W}^{\mathbf{POS}}\square + \mathbf{b}^{\mathbf{POS}})$
$(\mathbf{W}^{\mathbf{Cnk}}\square + \mathbf{b}^{\mathbf{Cnk}})$
$(\mathbf{W}^{\mathbf{NER}}\square + \mathbf{b}^{\mathbf{NER}})$
$g^1(\mathbf{W}^1\square + \mathbf{b}^1)$
$concatenat(\square)$
$w_1, \ldots, w_n \longrightarrow EMBED(\square)$

Task-specific parameters

$$(\mathbf{W}^{\mathbf{POS}}\square + \mathbf{b}^{\mathbf{POS}}) \qquad (\mathbf{W}^{\mathbf{Cnk}}\square + \mathbf{b}^{\mathbf{Cnk}}) \qquad (\mathbf{W}^{\mathbf{NER}}\square + \mathbf{b}^{\mathbf{NER}})$$

Shared parameters for all tasks

$$g^{1}(\mathbf{W}^{1}\square + \mathbf{b}^{1})$$

$$concatenat(\square)$$

$$w_1, \ldots, w_n \longrightarrow EMBED(\square)$$

Multi-Task Learning

POS scores	Chunk scores	NER scores
$\uparrow$	$\uparrow$	$\uparrow$
$softmax(\square)$	$softmax(\square)$	$softmax(\square)$
$\uparrow$	$\uparrow$	$\uparrow$
$(\mathbf{W}^{\mathbf{POS}}\square + \mathbf{b}^{\mathbf{POS}})$	$(\mathbf{W}^{\mathbf{Cnk}}\square + \mathbf{b}^{\mathbf{Cnk}})$	$(\mathbf{W}^{\mathbf{NER}}\square + \mathbf{b}^{\mathbf{NER}})$

$$g^1(\mathbf{W}^1\square + \mathbf{b}^1)$$

$$\uparrow$$

$$concatenat(\square)$$

$$\uparrow$$

$$w_1, \ldots, w_n \longrightarrow EMBED(\square)$$