

Semantic representations

Sahar Ghannay

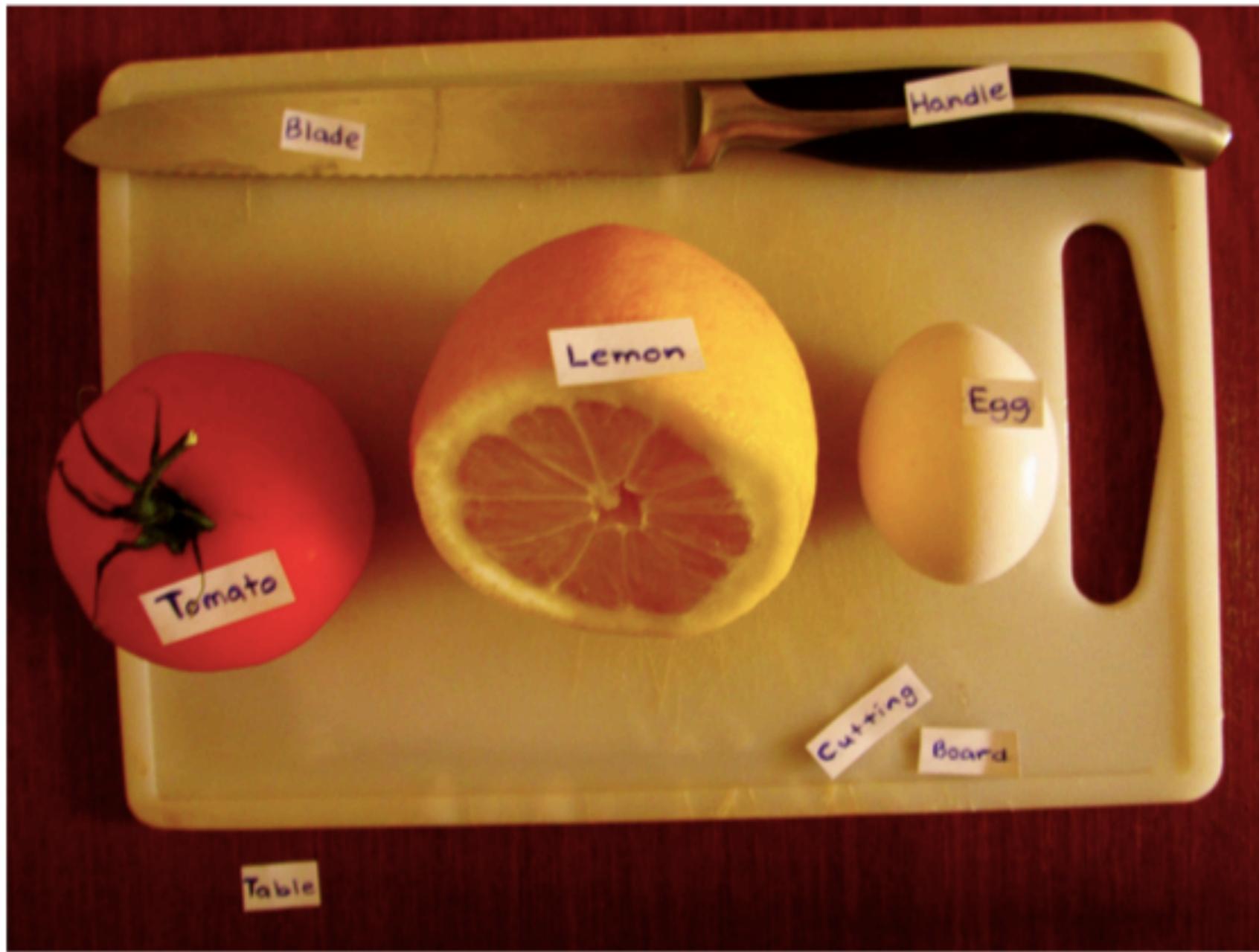
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Introduction

Looking for meaning: what are we talking about? What is the meaning?

- ♣ Définition in a dictionary:
 - ♦ what is meant by a word, text, concept, or action.
- ♣ For an application:
 - ♦ The same, but restricted to the concepts needed for the application

Looking for meaning: what are we talking about? What is the meaning?



Semantic analysis in linguistic technology

- ♣ Information extraction
 - ♦ Analyzing texts to obtain information for a specific application:
 - Example: Named entity recognition
- ♣ Natural language understanding
- ♣ Semantic textual similarity
- ♣ *Etc.*

Semantic analysis in linguistic technology

Named Entity recognition

❖ Named entity recognition:

- ♦ Seeks to locate and classify **named entities** (names of people/places/ organisations, dates) mentioned in unstructured text into pre-defined categories such as **person, organizations, locations, time,**

Semantic analysis in linguistic technology

Named Entity recognition

❖ Exemple :

On the invitation of the Festival de Cannes, the Italian actress Monica Belucci has agreed to play the role of Mistress of the Opening and Closing Ceremonies of the 70th festival de Cannes to be held from 17 to 28 May 2017, under the presidency of Spanish filmmaker Pedro Almodovar. [...] Monica Bellucci's friendship with the Festival de Cannes goes back a long way: in 2000, she walked up the steps for the first time to present *Under Suspicion* by Stephen Hopkins.

Semantic analysis in linguistic technology

Named Entity recognition

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PERSON, ORGANIZATION, LOCATION, DATE

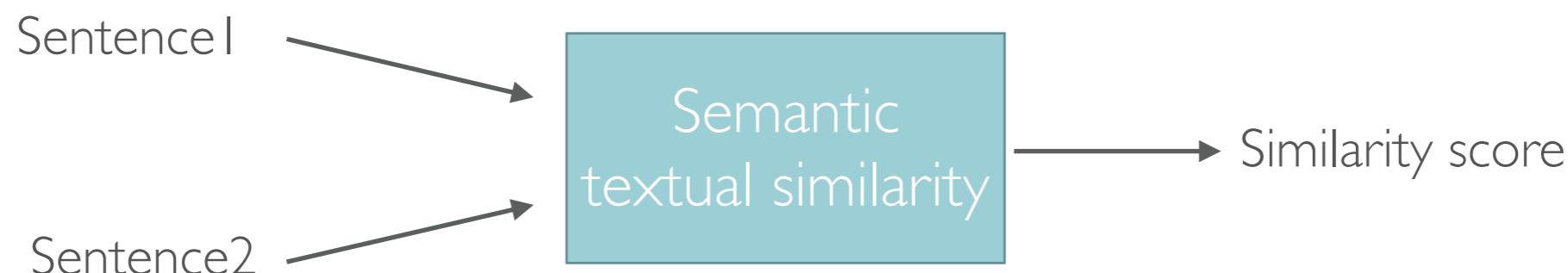
Semantic analysis in linguistic technology

Semantic textual similarity

- ❖ SemEval 2017 task 5

Exemple de paire de phrases

Three men are playing chess.	Two men are playing chess.
A man is playing the cello.	A man seated is playing the cello.
Some men are fighting.	Two men are fighting.



- Evaluate how these sentences are close on a scale of 1 to 5

Semantic analysis in linguistic technology

Natural/Spoken language understanding

- ❖ Natural language understanding system (NLU):
 - ♦ Can be considered as a system that translates a sequence of words to one or more actions:
 1. Associate the sequence of words in the input of the system to intermediate semantic language often called **concepts**.
 - ♦ A concept is a class of words dealing with the same subject and sharing common properties.
 - For example, the words hotel and room can all correspond to the concept of “accommodation” in a tourism application.
 2. Translate the concepts obtained into actions or responses during a sentence interpretation step to respond to the entry request.

❖ Example:

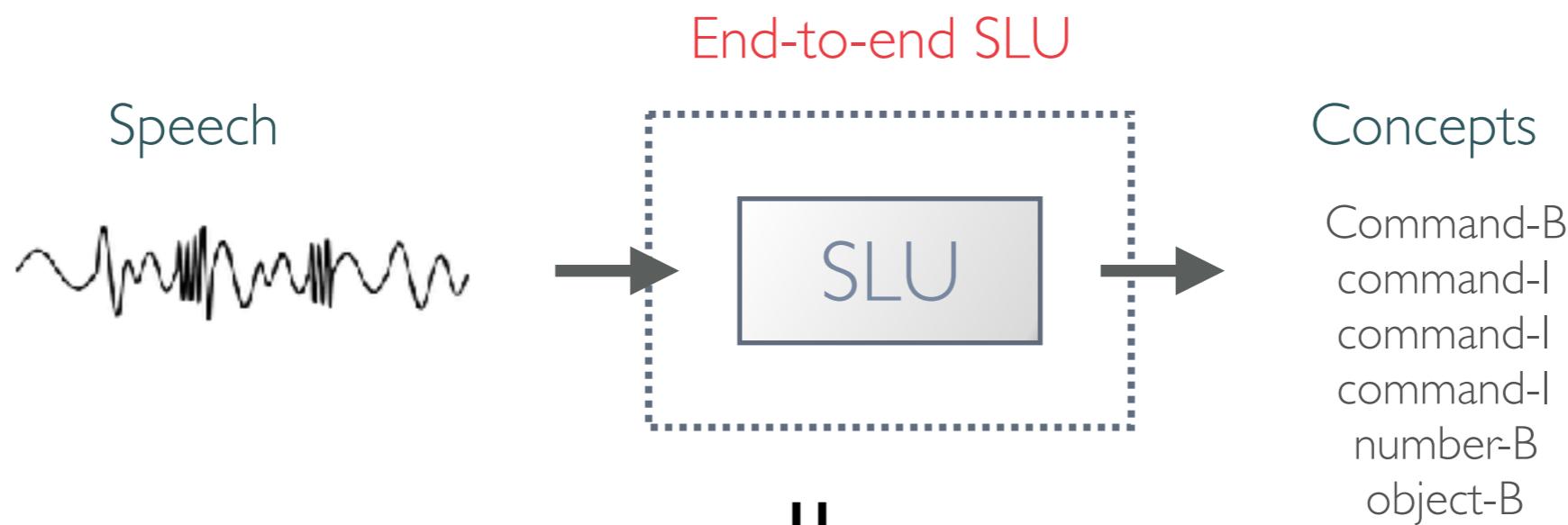
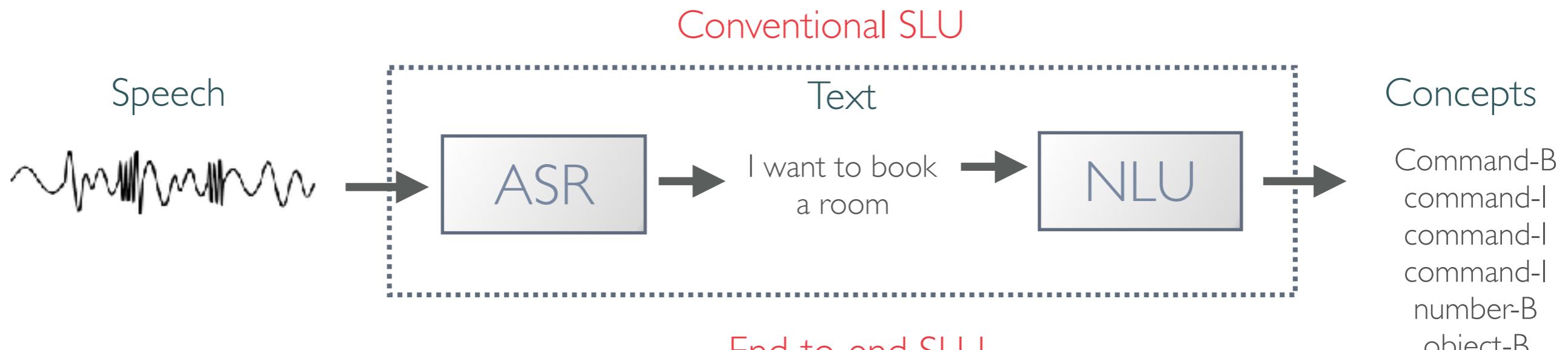
Hyp	I	want	to	book	a	room
Concept		command			number	object
Label	command-B	command-I	command-I	command-I	number-B	object-B
Valeur		Booking			I	room

Semantic analysis in linguistic technology

Natural/Spoken language understanding

- ❖ Spoken language understanding system (SLU):

- ❖ SLU refers to natural language processing tasks related to semantic extraction from the speech signal, like named entity recognition from speech, call routing, slot filling task in a context of human-machine dialogue...



Semantic analysis in linguistic technology

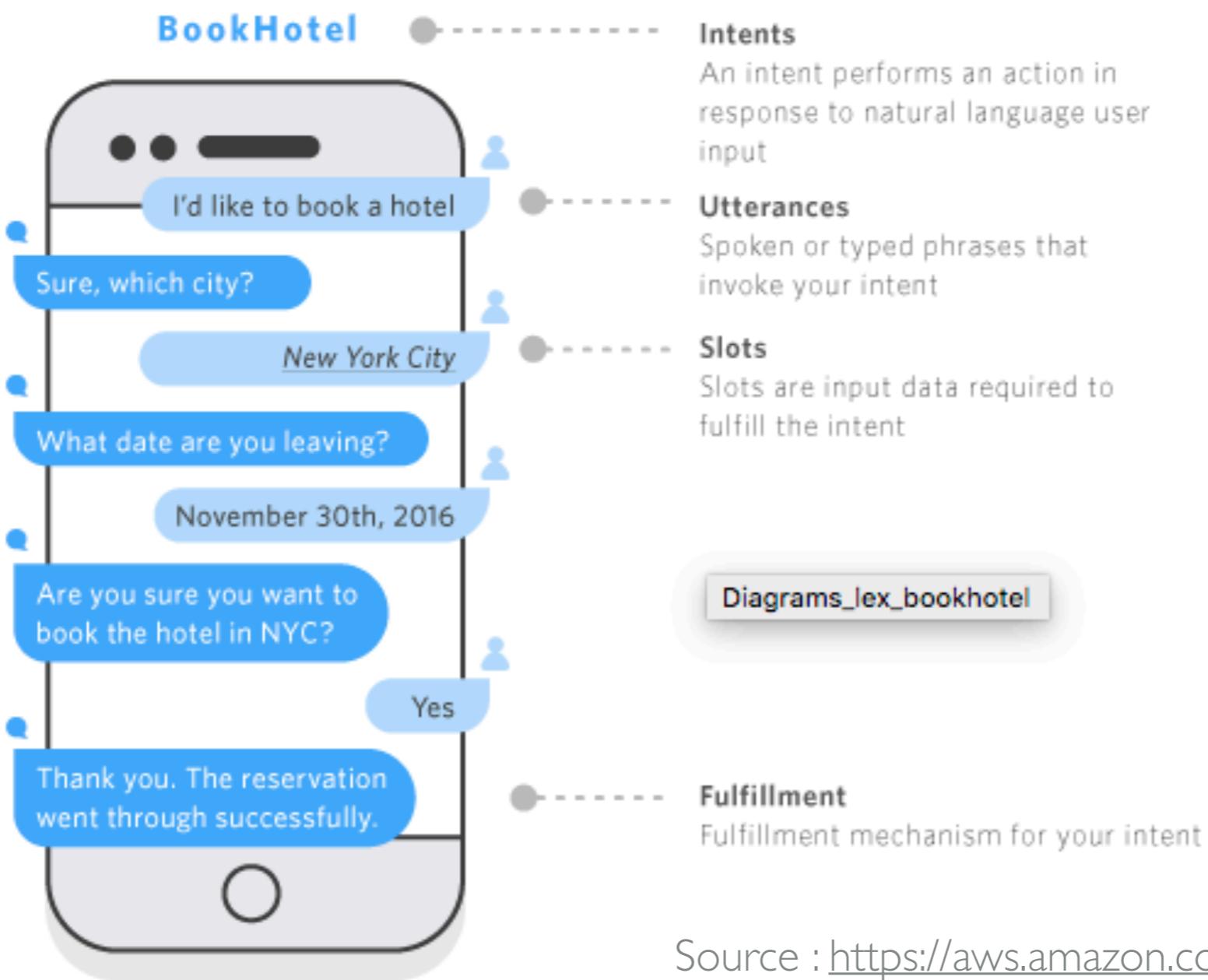
Natural/Spoken language understanding

- ♣ NLU/SLU is an important module in a dialogue system
 - ♦ Provides direct human-machine interaction
 - ♦ Allows the computer to understand human languages

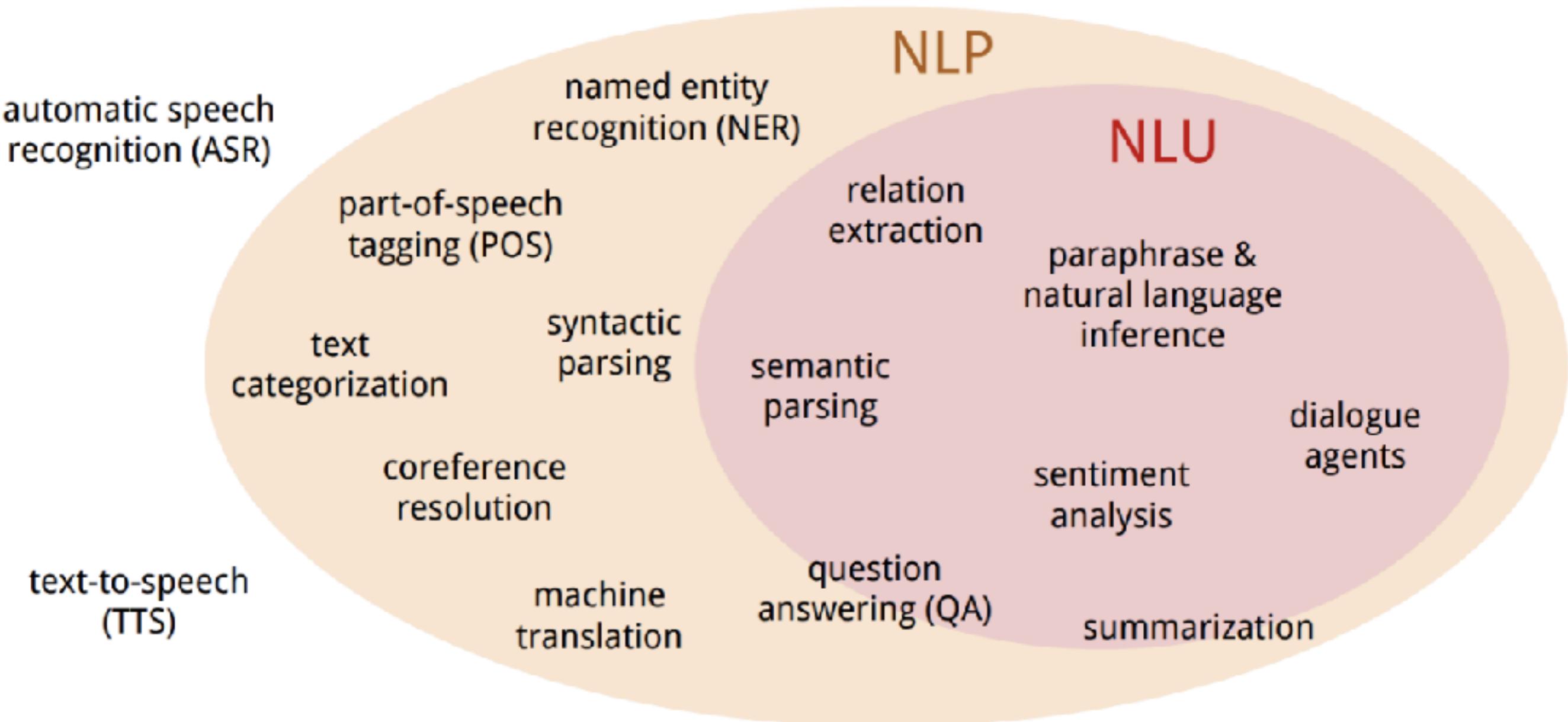
Semantic analysis in linguistic technology

Natural language understanding

❖ Example : Amazon Lex



Terminology: NLU vs. NLP vs. ASR



Recent approaches

❖ Recent approaches for :

- ◆ Information extraction
 - Named entity recognition
- ◆ Semantic textual similarity
- ◆ Natural/Spoken language understanding
- ◆ *Etc.*

→ Are based on **deep learning approaches**

Deep Learning

Deep Learning

- ❖ Deep learning: part of a broader family of machine learning methods based on artificial neural networks with representation learning. Learning can be supervised, semi-supervised or unsupervised
- ❖ Deep learning architectures: Deep Neural Network(DNN), recurrent neural networks, convolutional neural networks, transformers, ...

Machine learning

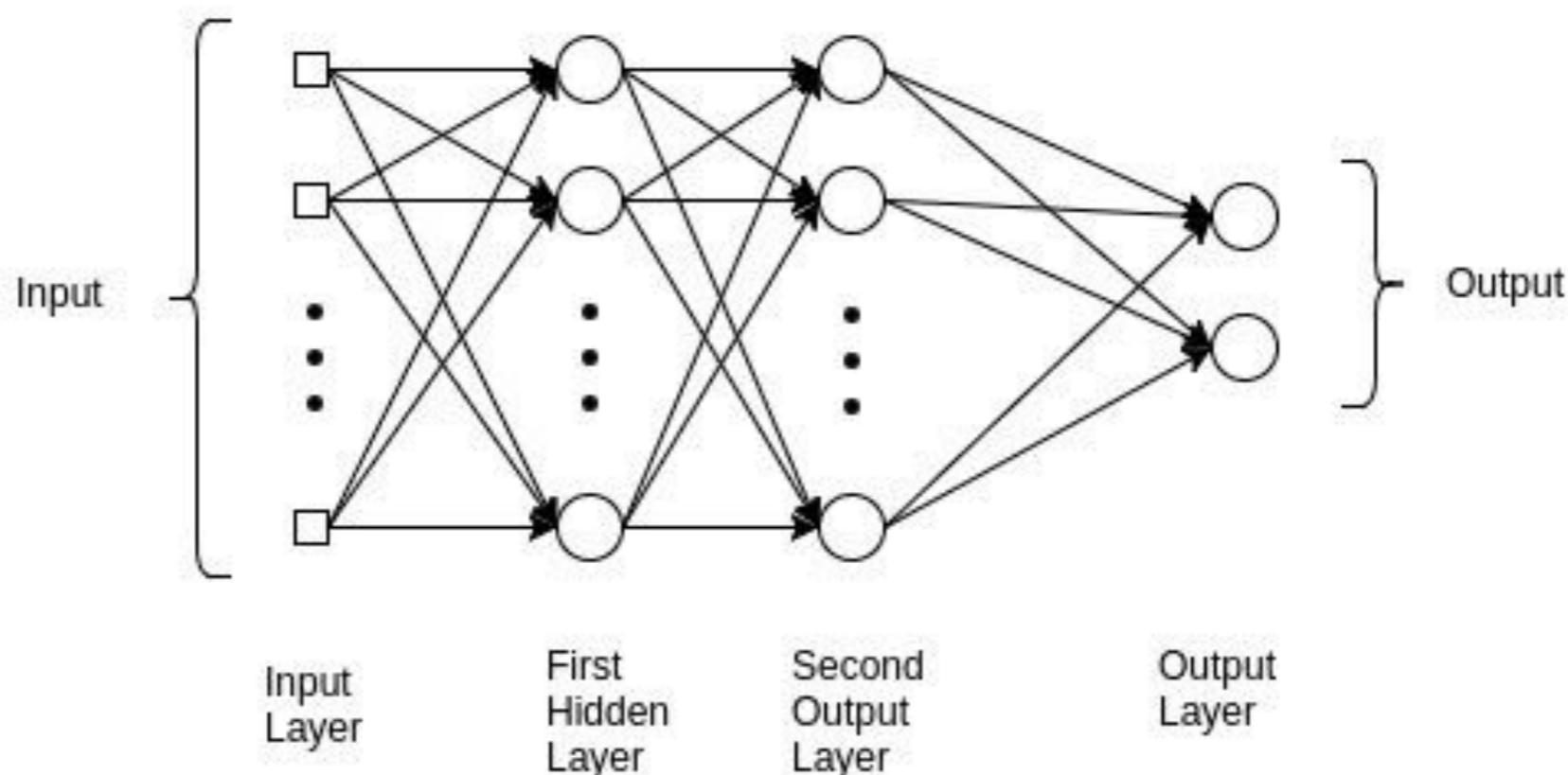
♣ Machine learning:

- ♦ The study of computer algorithms that improve automatically through experience
- ♦ Based on statistical approaches to give the systems the ability to “learn” from data, in order to make predictions or decisions without being explicitly programmed to do so
- ♦ It is seen as a subset of **artificial intelligence** (IA)

Neural network architectures

❖ Multilayer perceptron

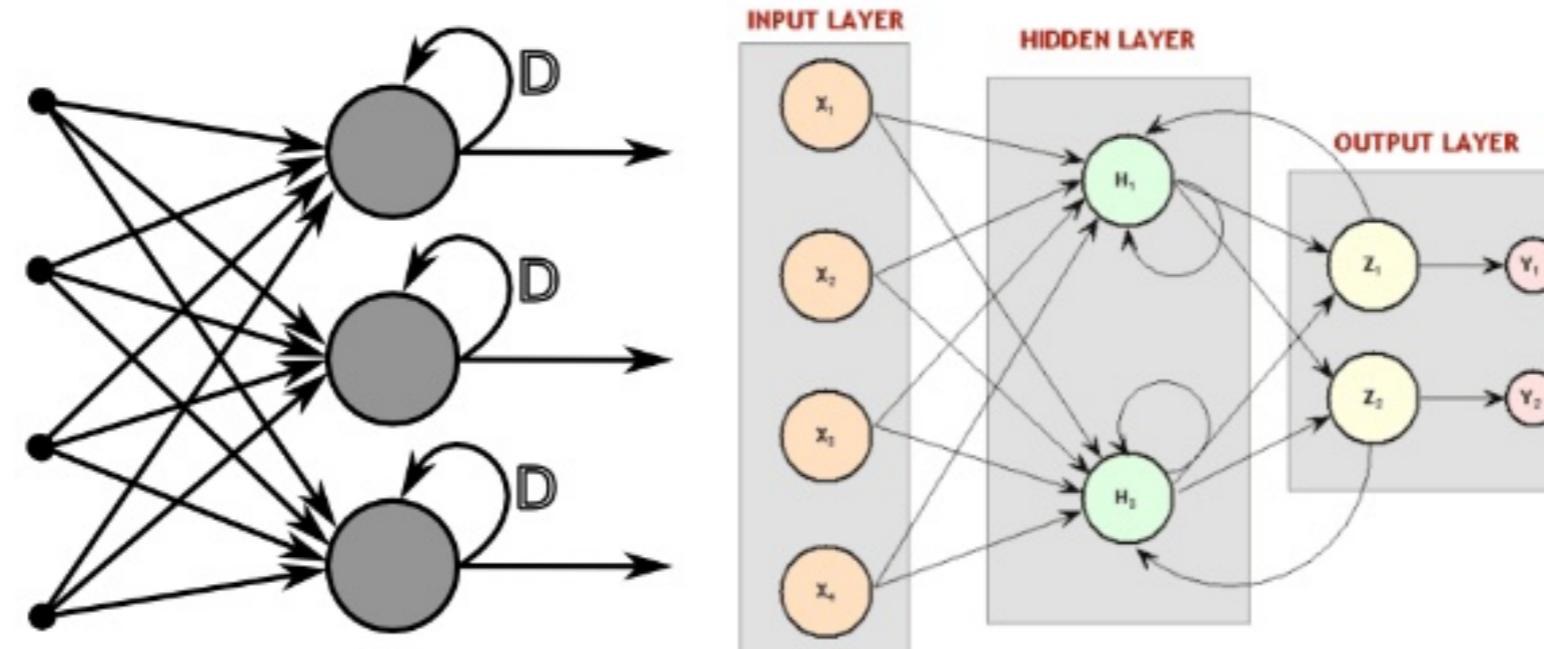
- ♦ Is a class of feedforward artificial neural network, wherein connections between the nodes do *not* form a cycle



Neural network architectures

❖ Recurrent neural network (RNN)

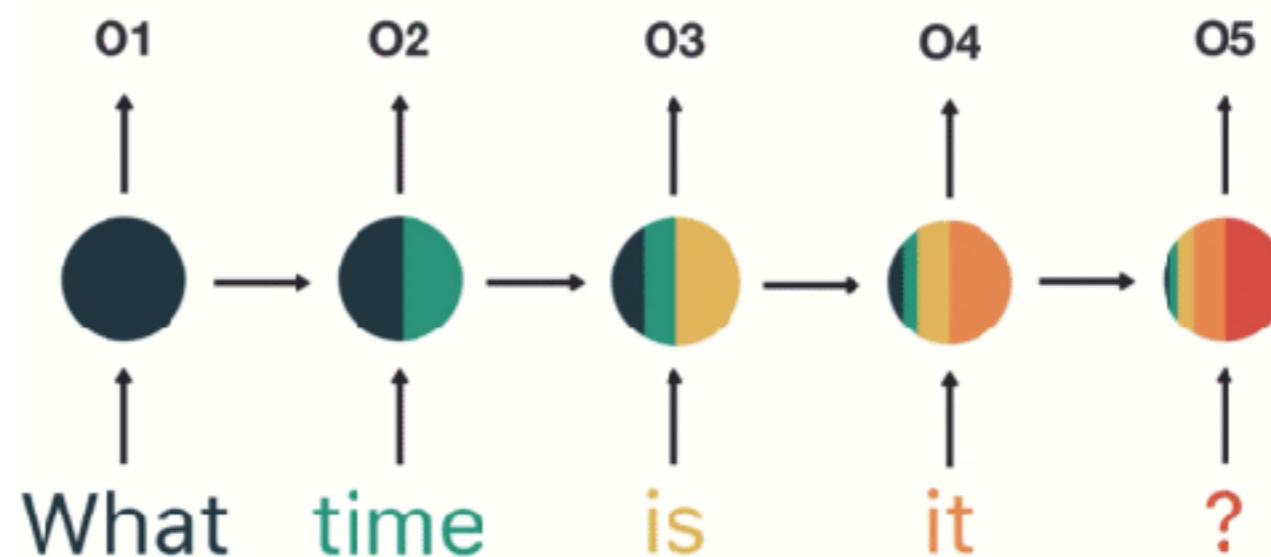
- ♦ Is a type of neural network that contains loops, allowing information to be stored within the network
- ♦ Use their reasoning from previous experiences to inform the upcoming events
- During training, gradients may explode (tend to infinity) or vanish (tend to zero) because of temporal depth



Neural network architectures

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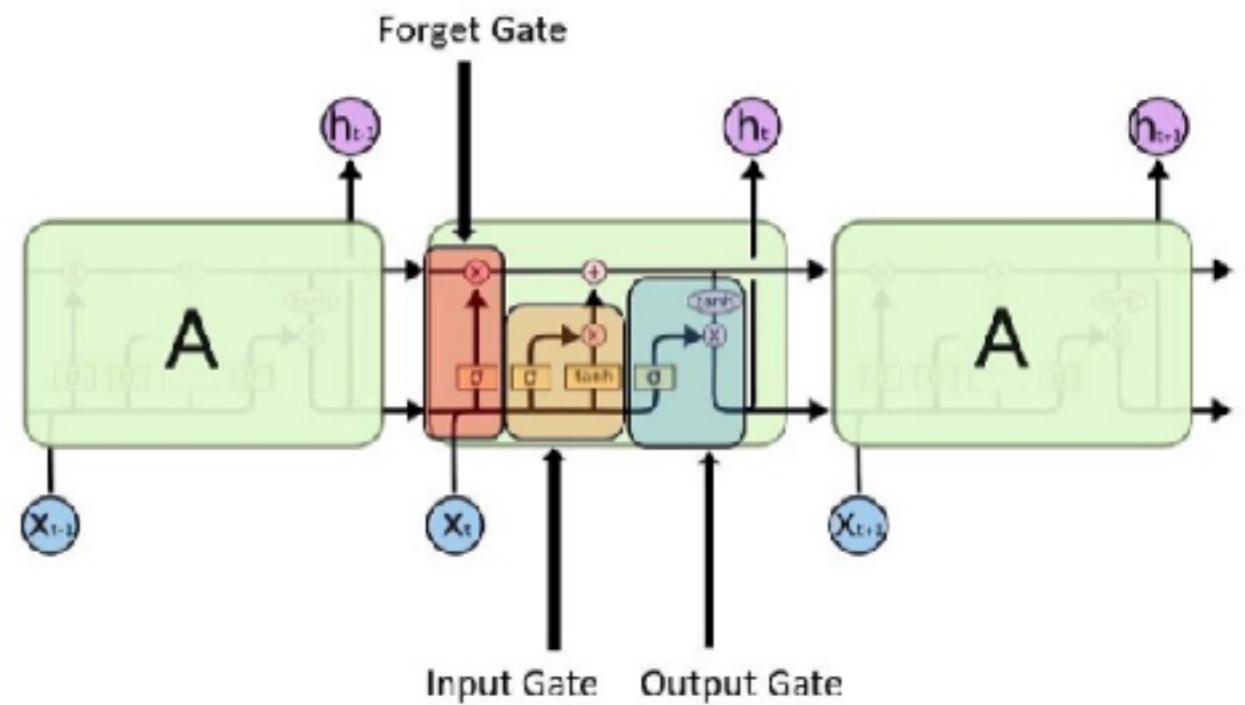


Source: Michael Nguyen / Learned Vector

Neural network architectures

❖ LSTM (log short term memory)

- ◆ is a special kind of RNN's, capable of learning long-term dependencies.
- ◆ Solve vanishing gradient problem
- ◆ LSTM's have skills to remember the information for a long periods of time.
- ◆ LSTMs' core component is the memory cell
 - can maintain its state over time, consisting of an explicit memory and gating units.
 - Gating units regulate the information flow into and out of the memory.

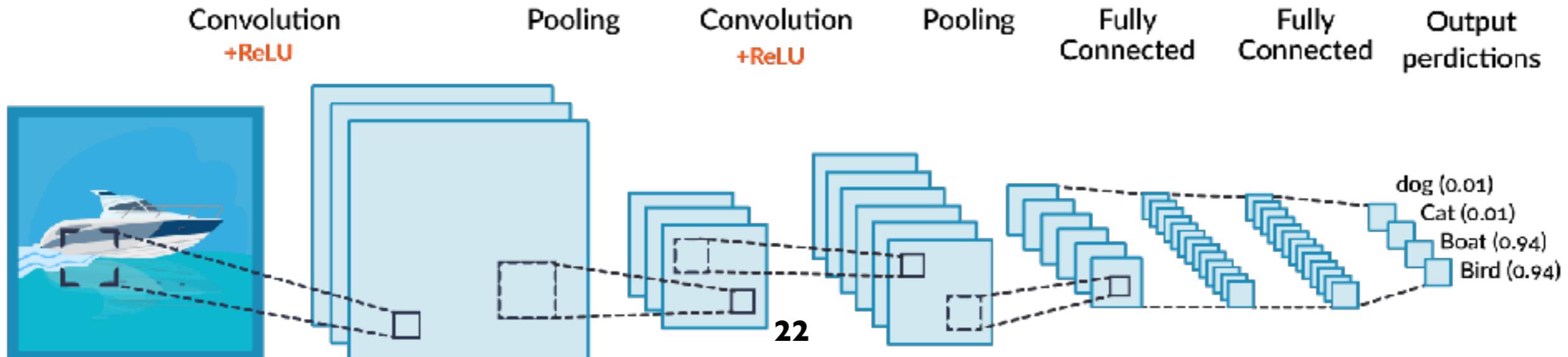


LSTM module has 3 gates named as Forget gate, Input gate, Output gate.

Neural network architectures

❖ Convolution neural network

- ◆ is the foundation of most computer vision technologies.
- ◆ uses two basic operations:
 - convolution using multiple filters is able to extract features (feature map) from the data set, through which their corresponding spatial information can be preserved.
 - pooling, also called subsampling, is used to reduce the dimensionality of feature maps from the convolution operation.
 - max pooling and average pooling are the most common pooling operations used in the CNN.



Neural network architectures

♣ Transformers

- ♦ Is based entirely on **attention mechanism**, replacing the recurrent layers most commonly used in encoder-decoder architectures with **multi-headed self-attention**

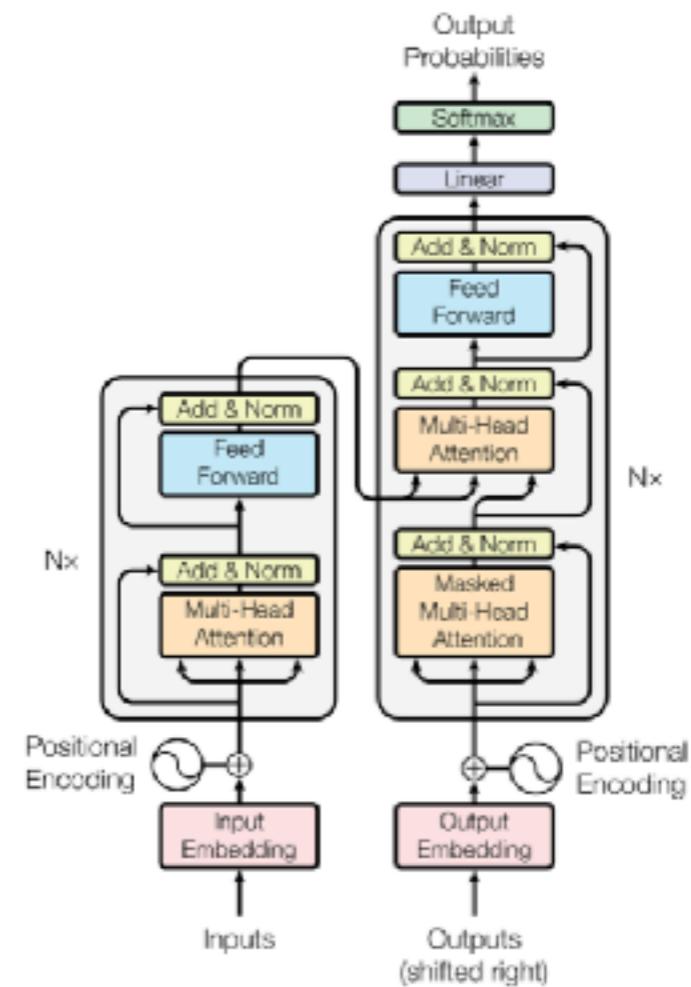


Figure 1: The Transformer - model architecture.

Neural network architectures

❖ Transformers

- ❖ The main characteristics are:
 - Non sequential: sentences are processed as a whole rather than word by word.
 - Self Attention: this is the newly introduced 'unit' used to compute similarity scores between words in a sentence.
 - Positional embeddings: another innovation introduced to replace recurrence. The idea is to use fixed or learned weights which encode information related to a specific position of a token in a sentence.

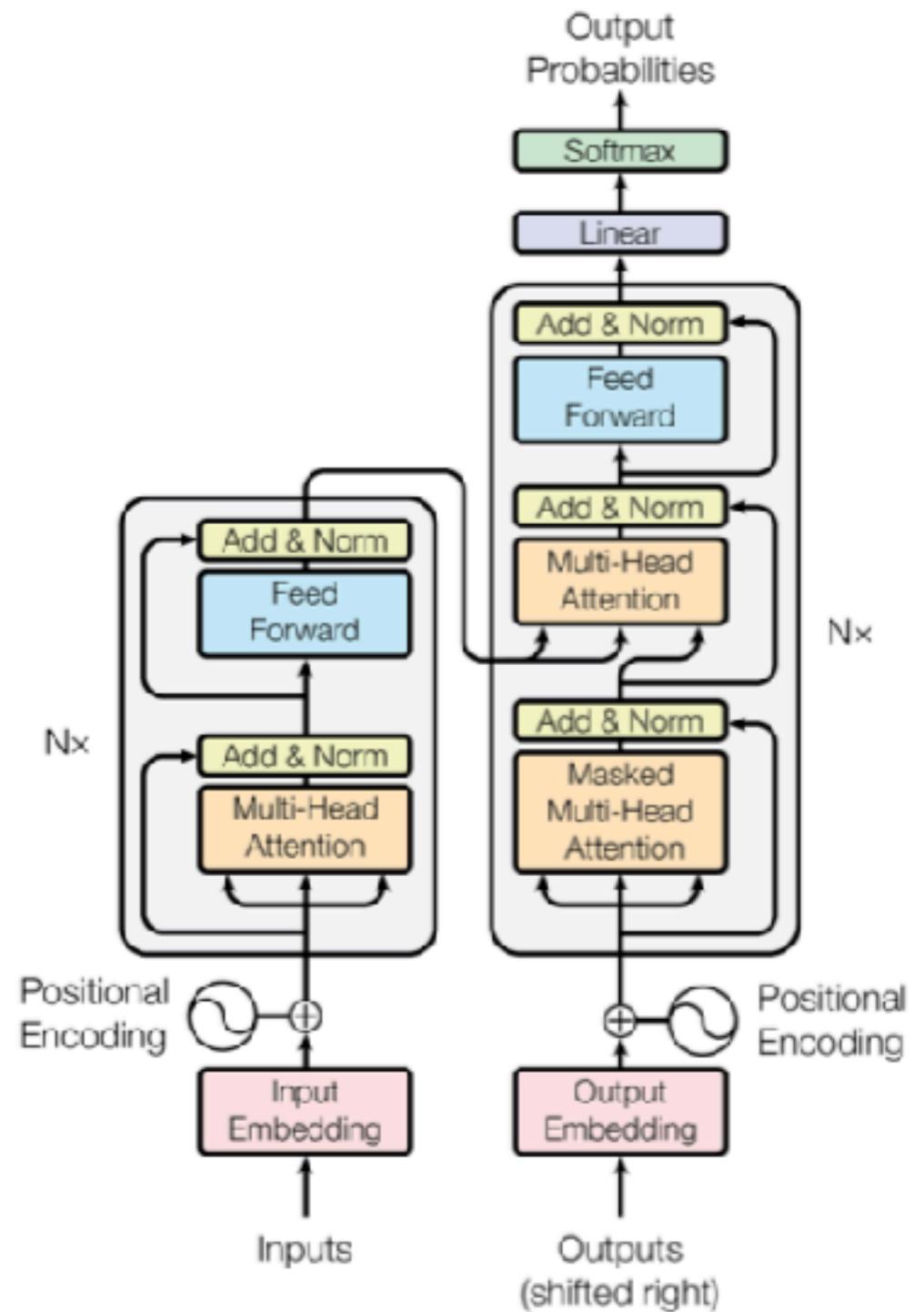


Figure 1: The Transformer - model architecture.

Attention Is All You Need

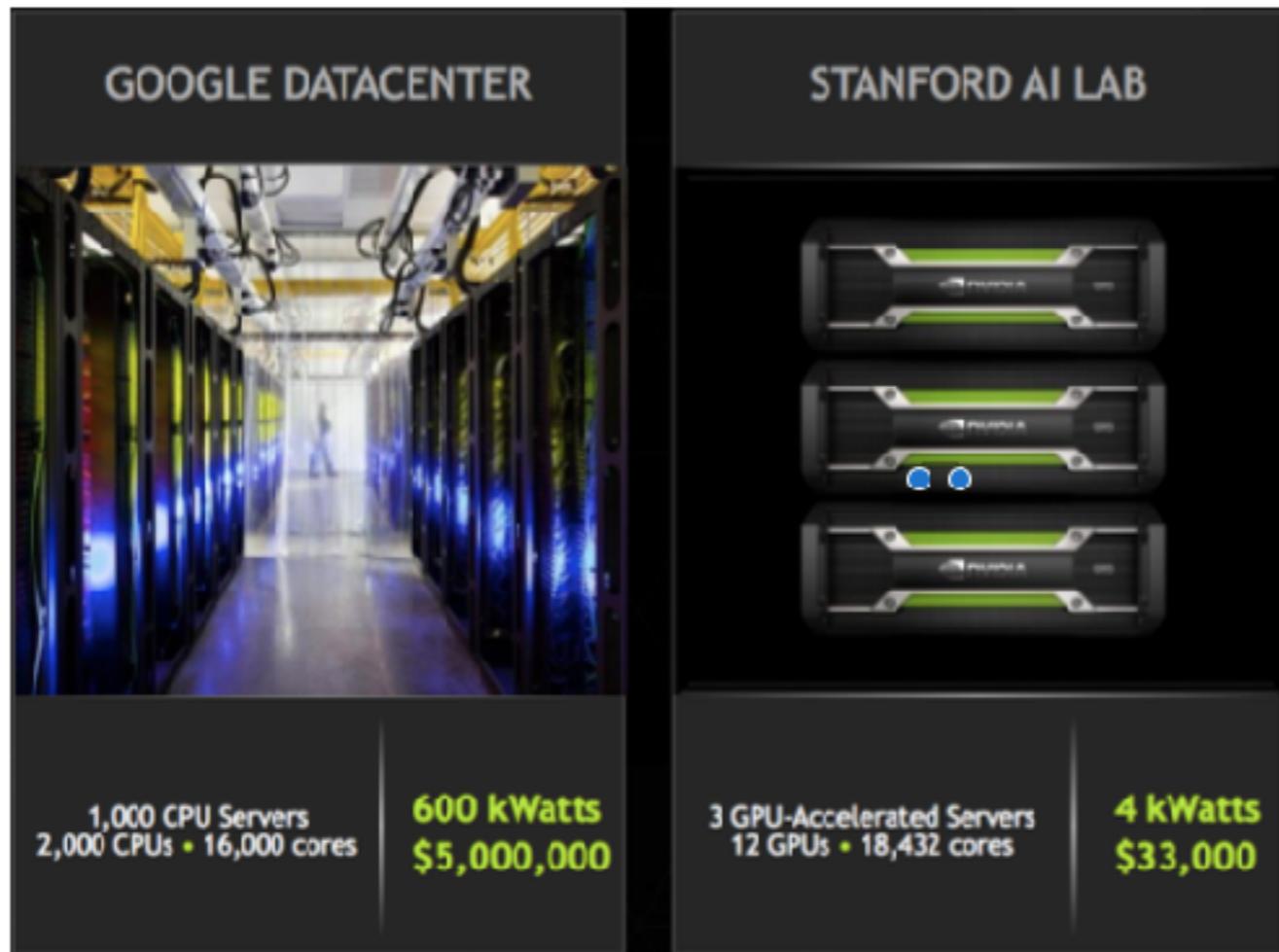
Why DNNs Work Better Now?

DNN and computing power

- ♣ Why did DNNs not work so well before, when neural networks have been experimented since the 1980s for acoustic modeling?
- ♣ A first element of response:
 - ♦ DNNs are particularly well suited to graphics cards (GPUs) that achieve phenomenal computing power ...

DNN and computing power

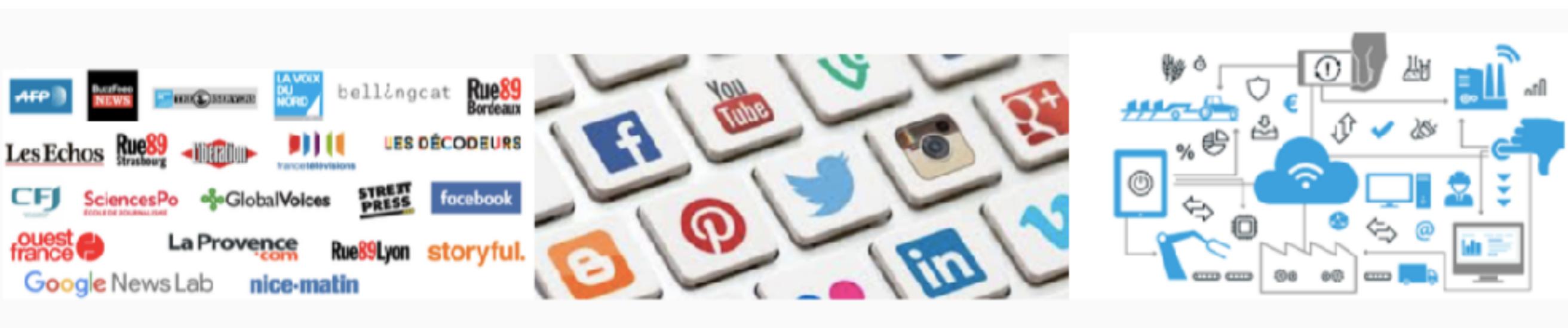
- ❖ ... at a very competitive price!
 - This makes accessible reasonable training time and therefore feasible experiments.



DNN and data

- ❖ Availability of large amount of data

- ❖ i.e. text, images, audio published via news sites, social media, collaborative platforms, smartphones, etc.



DNN and learning algorithms

- ♣ A third answer comes from the progress made by researchers for training DNNs:
 - ♦ best learning algorithms (pre-training RBM, SDAE, learning rate dynamique,...)
 - ♦ New architectures (transformers, attention mechanism, LSTM, GRU...)
 - ➡ use continuous representations able to encode different types of hidden relations (syntactic, semantic, contextual,..)

Continuous word representations

WORD REPRESENTATIONS

I. One hot:

- ◆ Example : Merci ID=3, vocabulary=10 words

Merci :

0	0	1	0	0	0	0	0	0	0
---	---	---	---	---	---	---	---	---	---

- ◆ Difficulty:
 - can not detect the relationships between words
 - Vector size depends on vocabulary size

WORD REPRESENTATIONS

2. Continuous word representations:

- ◆ Capture relationships between words
- ◆ Different approaches have been studied in the NLP (Natural language processing) community:
 - Clustering
 - distributional word representations
 - Distributed word representations (neural) (known by: word embeddings, continuous word representations)

CONTINUOUS WORD REPRESENTATIONS

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- ❖ Clustering (Brown *et al.* 1992) :

- ✓ Grouping words into clusters (group) based on their contexts (**bigrams**)
- ✓ **Disadvantage:** does not consider the use of words in a larger context

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- ❖ Distributional word representations exp. PMI (Pointwise Mutual Information):

- ✓ Known as *Count based models* ou *global matrix factorization*
 - ✓ Use of word co-occurrence matrix
 - ✓ The word is represented by a vector in which each entry is a measure of association between the word and a particular context
 - ✓ **Disadvantage:** very high dimensional **sparse** vector (most elements are zero) (same vocabulary size)

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- ✓ Low dimensional **dense** vector with real values

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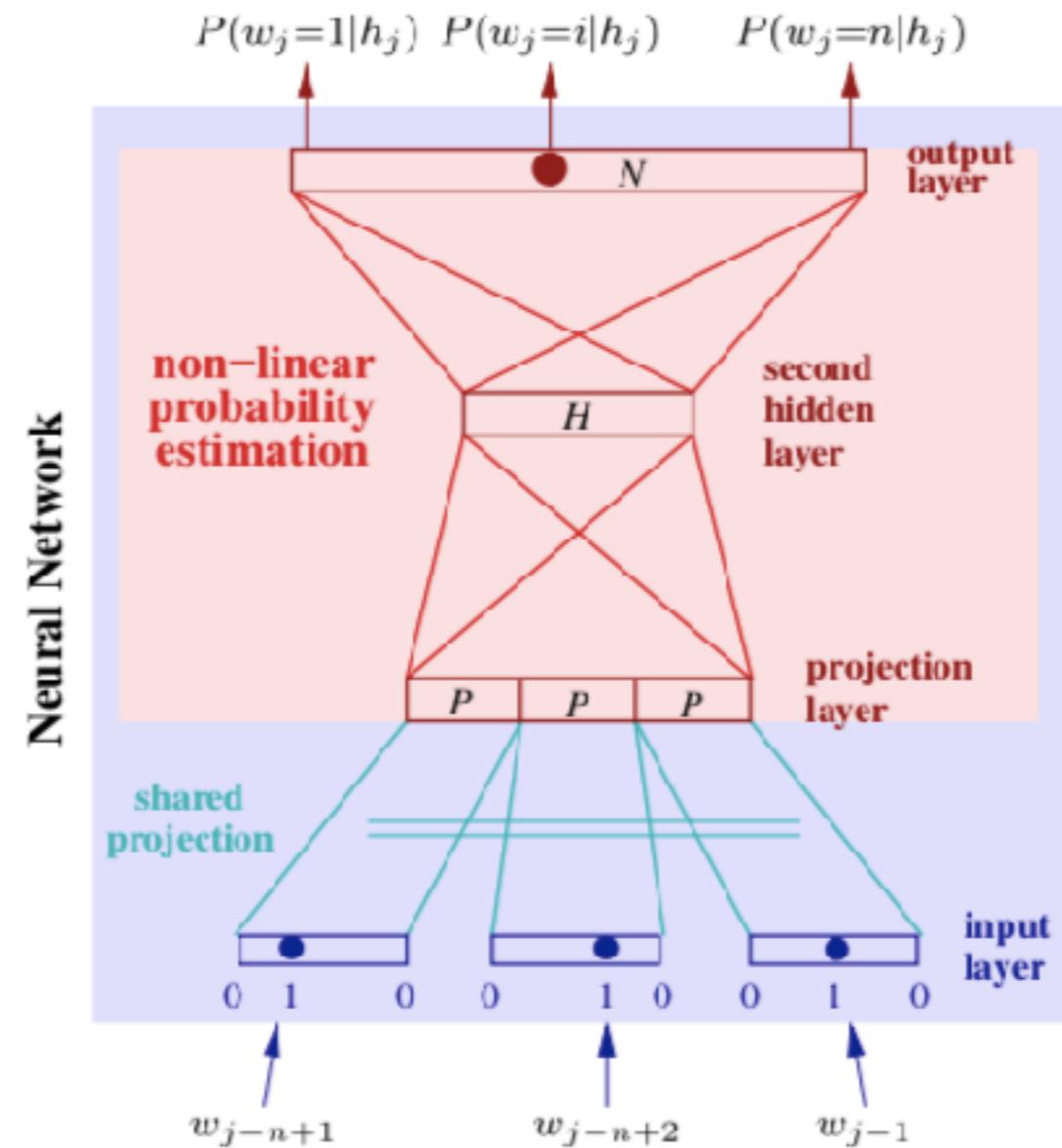
- * Why dense vectors?:

- ♦ Short vectors can be easily used in machine learning (less weight to optimize)
- ♦ Dense vectors can generalize better
- ♦ etc.

CONTINUOUS WORD REPRESENTATIONS

Word embeddings :

- Introduced through neural language models training [Y.Bengio et al. 2003, H.Schwenk et al. 2006]



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$$R : Words = \{W_1, \dots, W_n\} \rightarrow Vectors = \{R(W_1), \dots, R(W_n)\} \subset R^d$$

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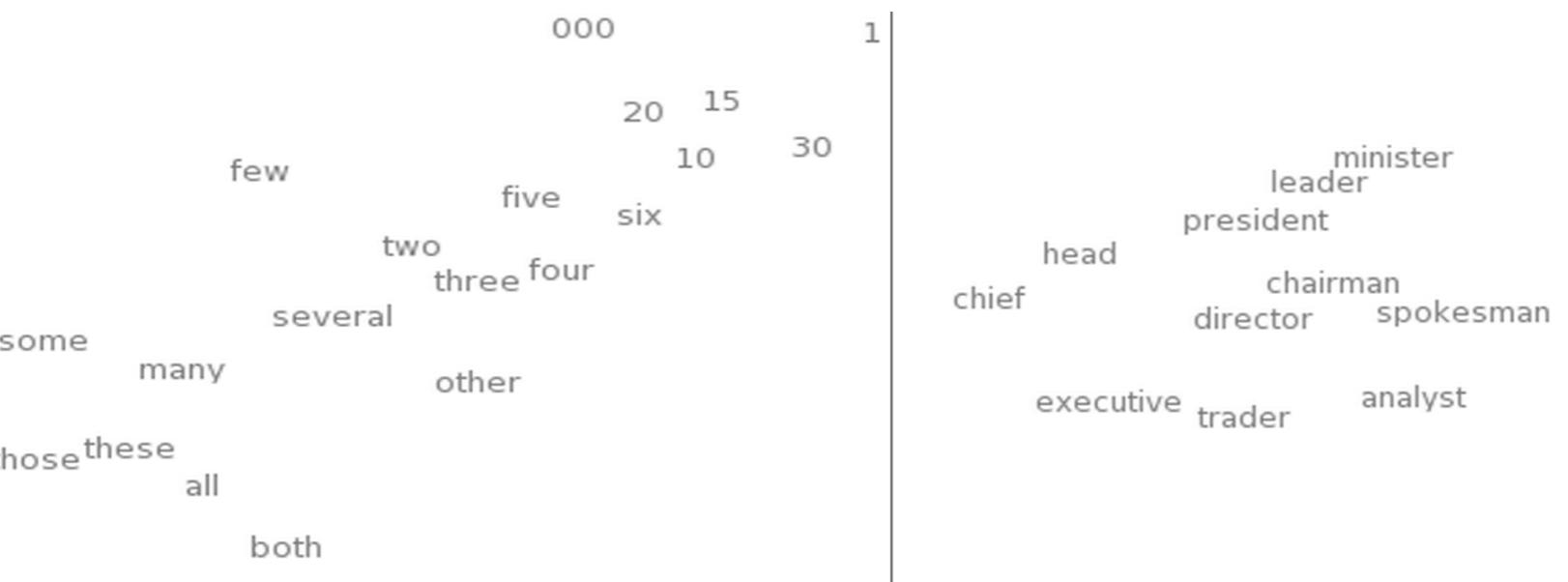
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- ❖ Each dimension represents a latent characteristic of the word, which can capture syntactic and semantic properties.

CONTINUOUS WORD REPRESENTATIONS

Word embeddings visualisation:



2D t-SNE visualizations of word embeddings. Left:
Number Region; Right: Jobs Region [J.Turian et al . 2010]

CONTINUOUS WORD REPRESENTATIONS

Word embeddings visualisation:



2D t-SNE visualizations of word embeddings. Left:
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What words have embeddings closest to a given word? [R.Collobert et al . 2011]

CONTINUOUS WORD REPRESENTATIONS

Word embeddings :

- ❖ Efficient for many tasks [R. Collobert et al 2011], [M. Bansal 2014] et [J. Turian et al 2010]:
 - ◆ Named entity recognition
 - ◆ Part of speech tagging
 - ◆ Natural language understanding
 - ◆ Question answering
 - ◆ etc.

CONTINUOUS WORD REPRESENTATIONS

RECENT APPROACHES

❖ Context-independent (static) word embeddings:

- The occurrences of the same word have the same representation
- Skipgram, CBOW, Glove, w2vf-deps, fasttext

❖ Contextual word embeddings:

- Each occurrence of the word has a different representation calculated based on its context
- Internal representations of words are a function of the entire input sentence
- Exemple : ELMo, BERT, GPT-2



CONTINUOUS WORD REPRESENTATIONS CONTEXT-INDEPENDENT

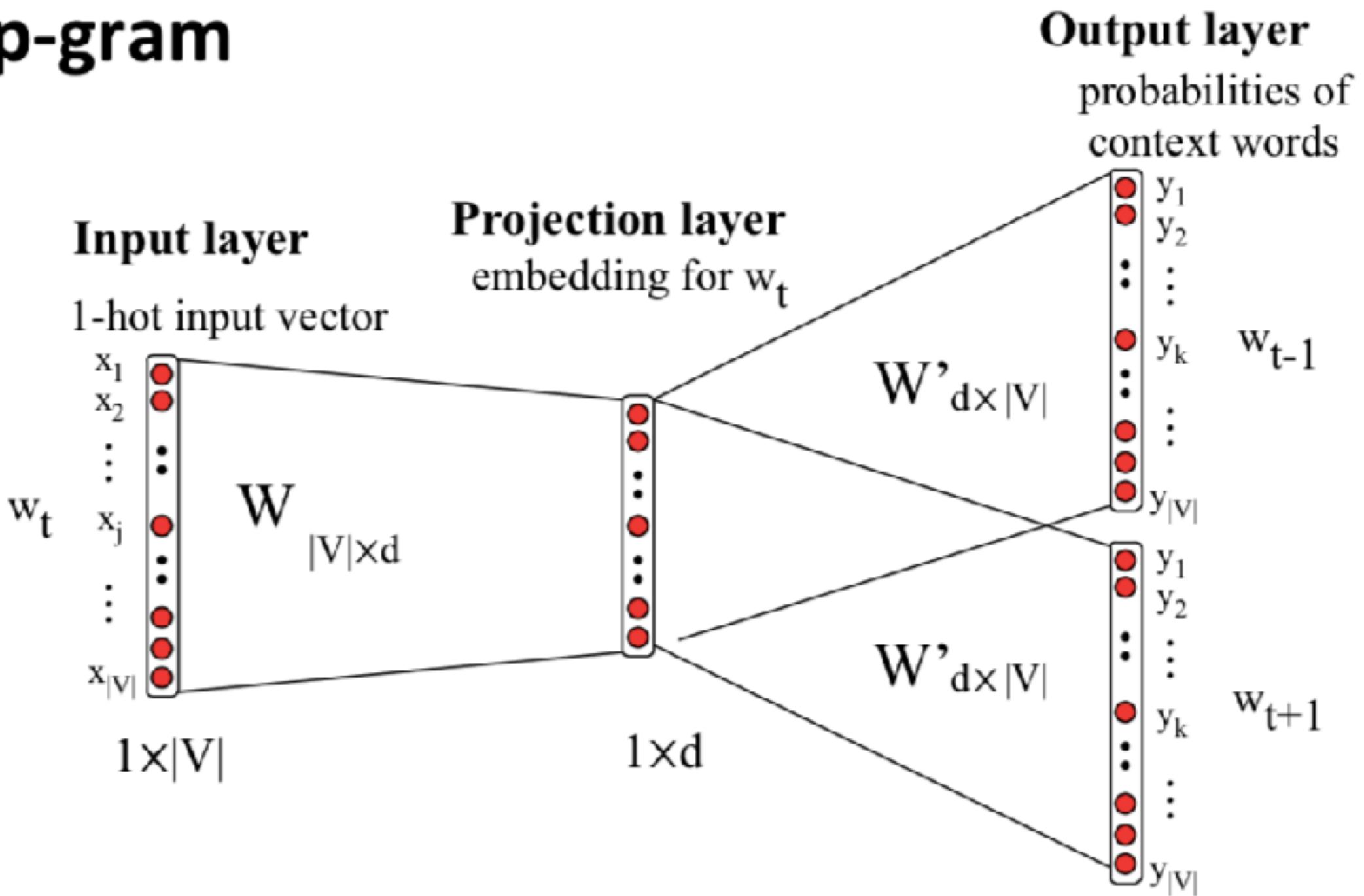
Skip-gram (Mikolov et al. 2013a) and CBOW (Mikolov et al. 2013a)

- ❖ Learn word embeddings as part of the word prediction process.
 - ◆ Inspired by neural language models.

CONTINUOUS WORD REPRESENTATIONS

CONTEXT-INDEPENDENT

Skip-gram



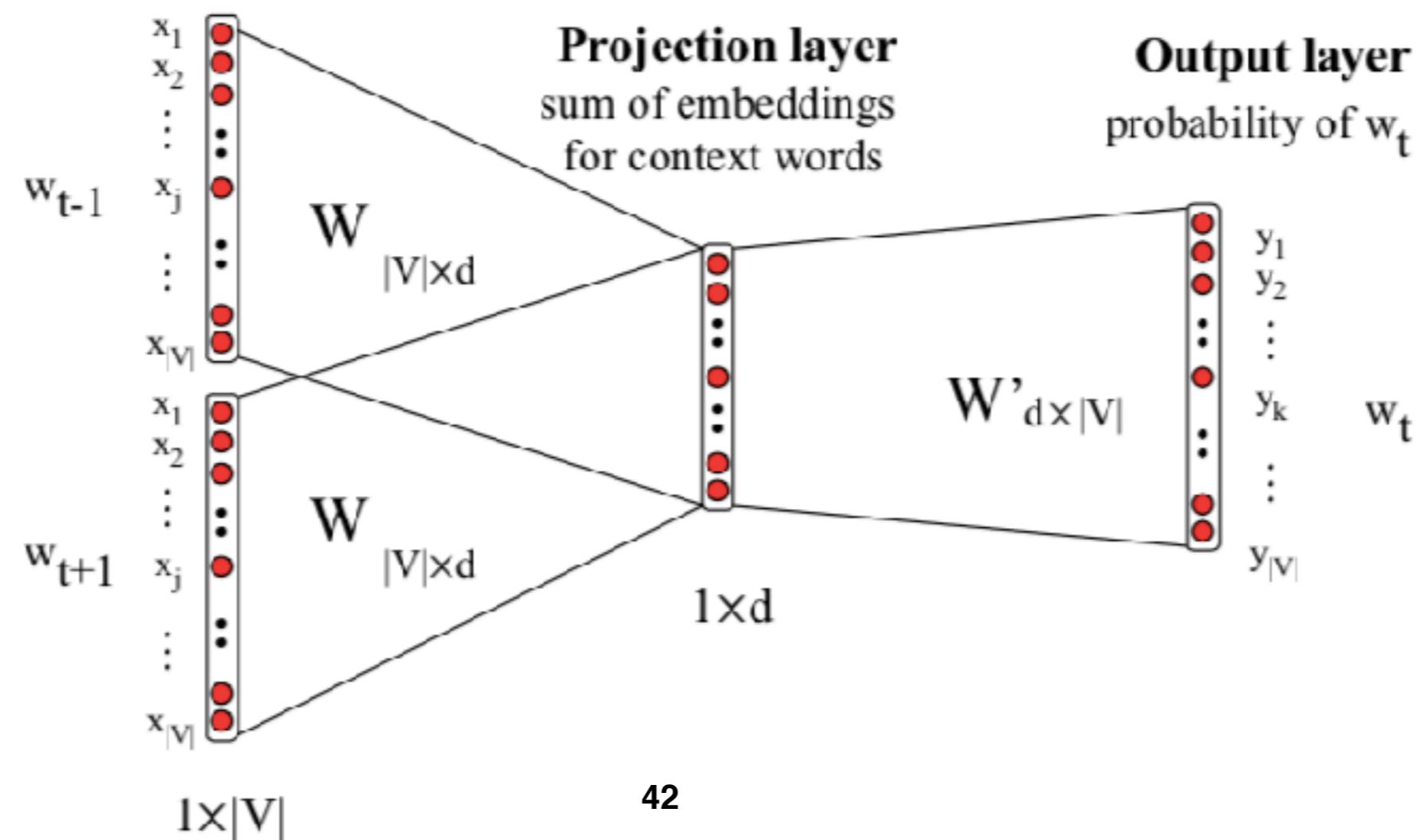
CONTINUOUS WORD REPRESENTATIONS

CONTEXT-INDEPENDENT

CBOW (Continuous Bag of Words)

Input layer

1-hot input vectors
for each context word

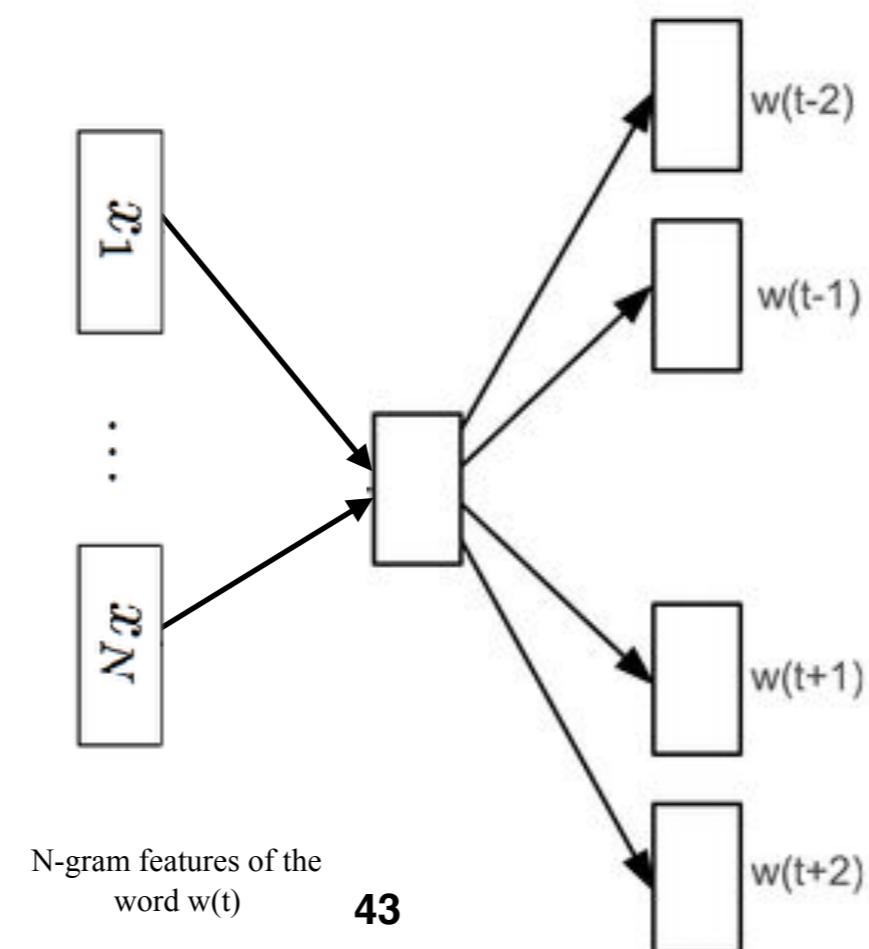


CONTINUOUS WORD REPRESENTATIONS

CONTEXT-INDEPENDENT

FastText (P. Bojanowski et al. 2017)

- ❖ Learn word embeddings as part of the word prediction process based on the skipgram architecture
 - ◆ Takes into account the morphological information of a word represented in the form of character ngrams
 - ◆ Each word is represented as the sum of representations of its characters n grams.
 - ◆ Computes word representations for words that do not appear in the training data, which is not the case for other approaches (word2vec)

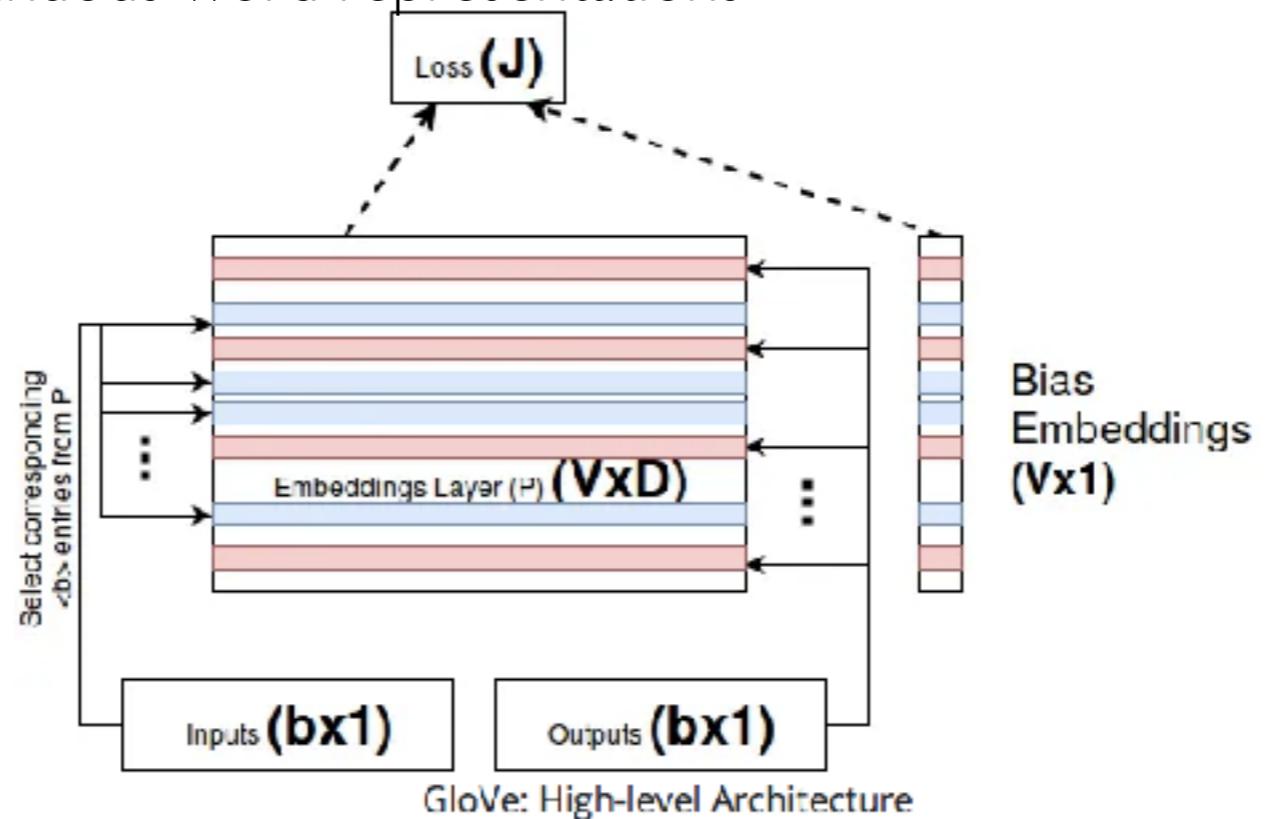


CONTINUOUS WORD REPRESENTATIONS

CONTEXT-INDEPENDENT

Glove (J. Pennington et al 2014)

- ❖ Count based approach
 - ❖ Based on the analysis of the co-occurrences of words in the corpus
 - ◆ Co-occurrence matrix construction: use of sliding window
 - ◆ Estimation of continuous word representations



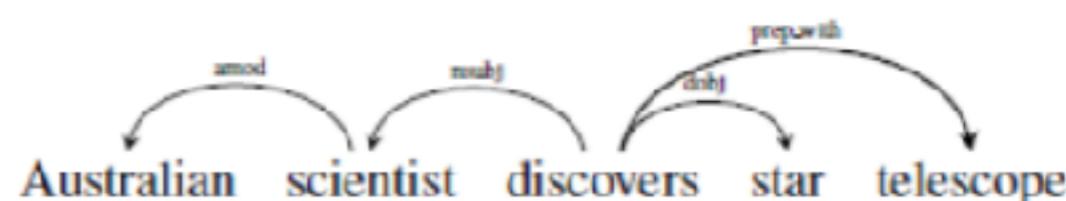
CONTINUOUS WORD REPRESENTATIONS

CONTEXT-INDEPENDENT



w2vf-deps : dependency based word embeddings (O. Levy et al. 2014)

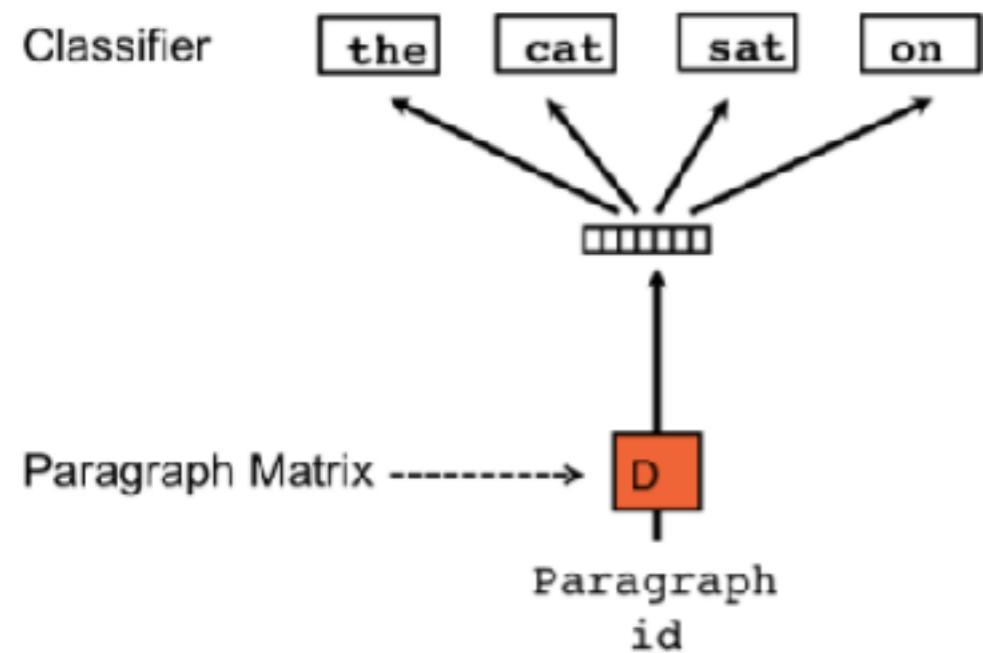
- ❖ Generalization of the skip-gram model with negative samples
- ❖ Use syntactic relationships (root words, dependency between root word and dependent words) to extract words in context
 - ◆ capture relations between distant words: can not be detected in a small context window



WORD	CONTEXTS
australian	scientist/amod ⁻¹
scientist	australian/amod, discovers/nsubj ⁻¹
discovers	scientist/nsubj, star/dobj, telescope/prep_with
star	discovers/dobj ⁻¹
telescope	discovers/prep_with ⁻¹

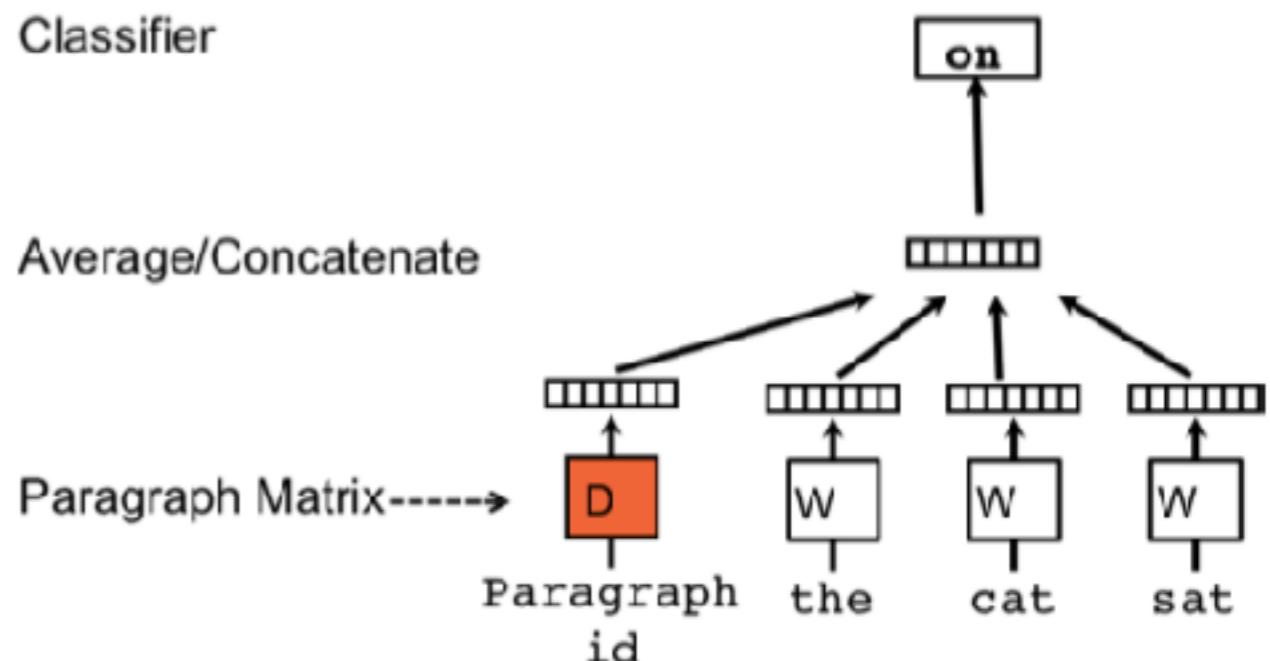
CONTINUOUS DOCUMENT REPRESENTATIONS

Distributed bag of words



(Mikolov et al. 2013b)

Distributed Memory model

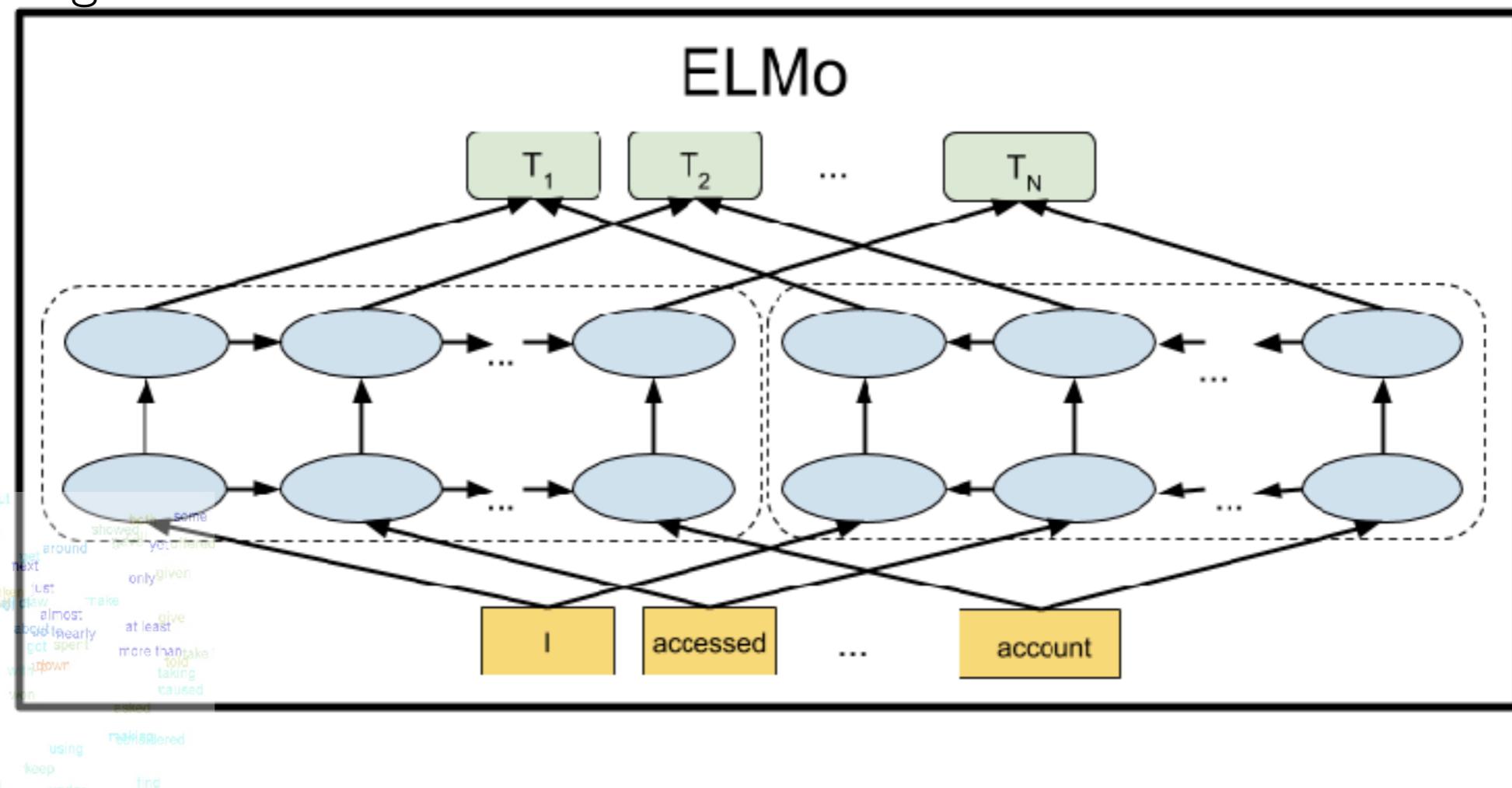


CONTINUOUS WORD REPRESENTATIONS

CONTEXTUAL

ELMo (Embeddings from Language Models)(Peters, et al, 2018)

- ❖ Learn word embeddings by creating bidirectional language models
 - ❖ creates contextualized representations of each token by concatenating the internal states of a 2-layer biLSTM trained on a bidirectional language modeling task



CONTINUOUS WORD REPRESENTATIONS

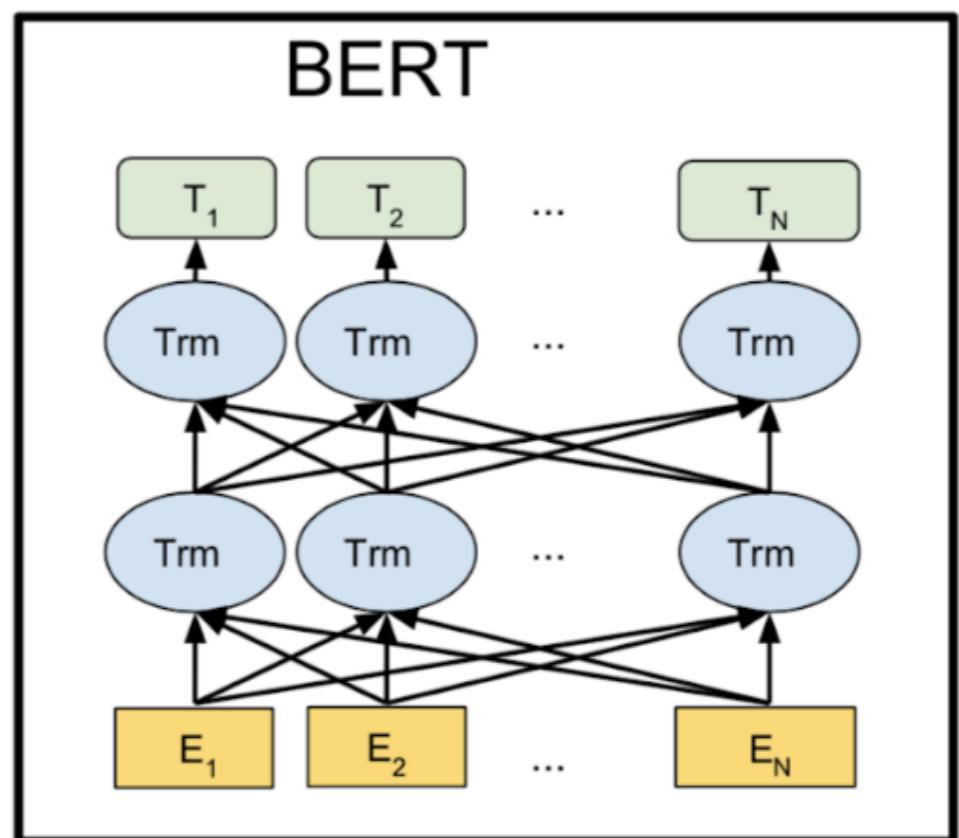
CONTEXTUAL



BERT (Bidirectional Encoder Representations from Transformers) (Devlin, et al., 2019)

- ❖ It's a bidirectional transformer pre-trained using a combination of masked language modeling objective and next sentence prediction on a large corpus.
- ❖ Each transformer layer of 12-layer creates a contextualized representation of each token by attending to different parts of the input sentence

try
able
seeking
information
decided
planned
scheduled
while
very
as
against
for
in
inside
between
win
using
keep
under
find



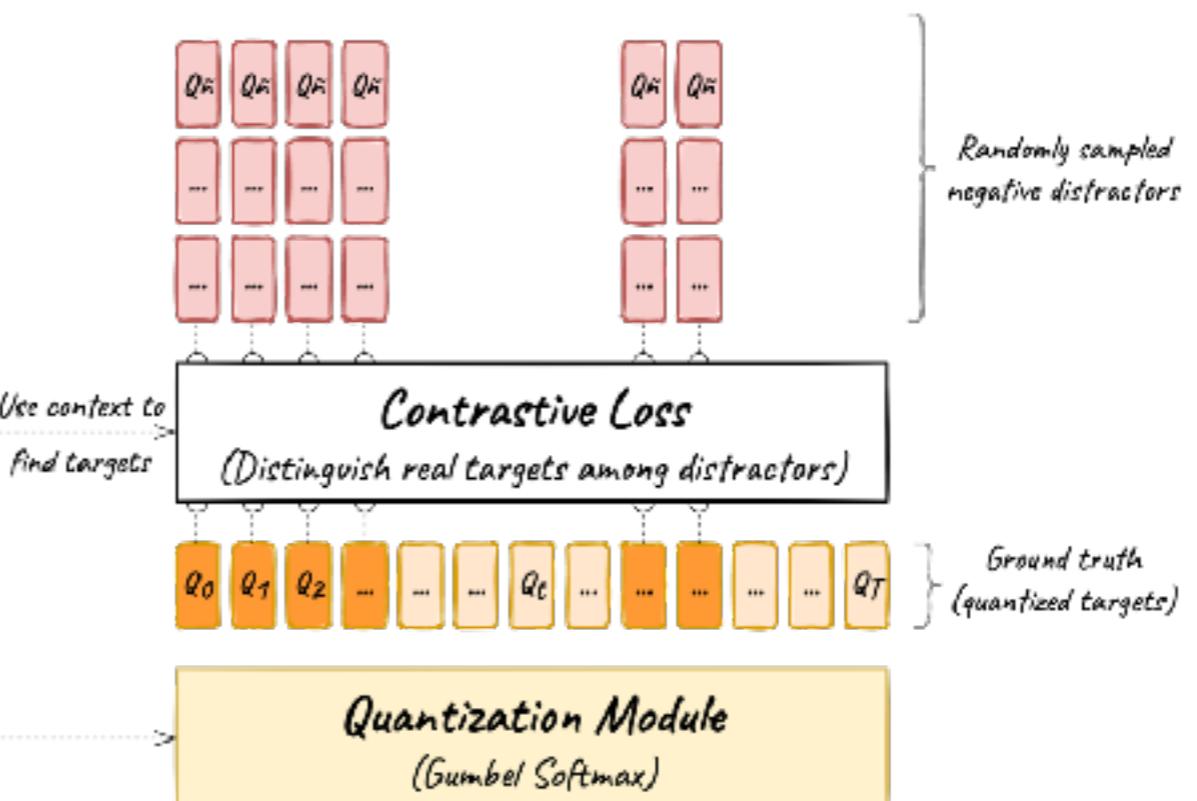
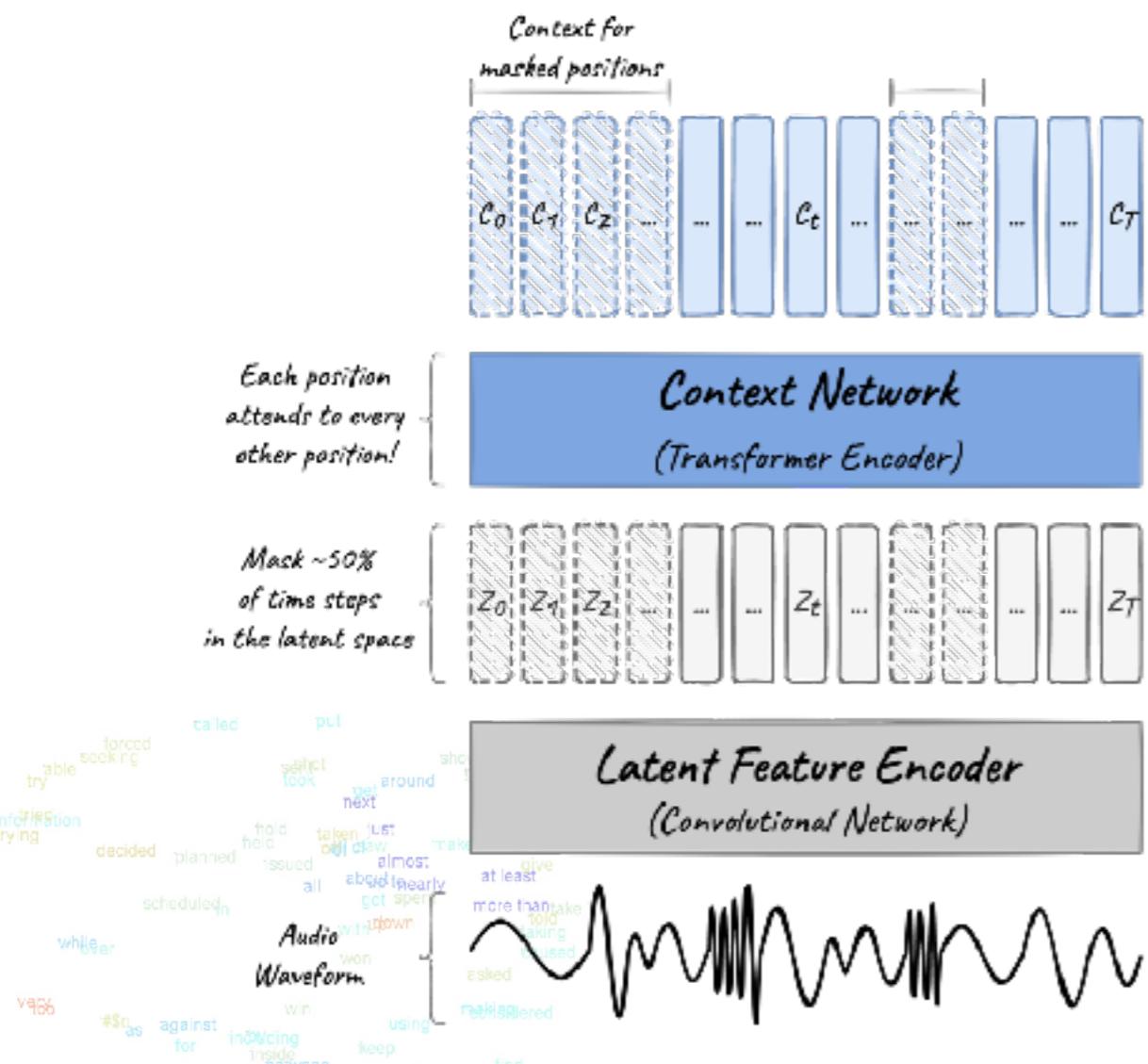
CONTINUOUS REPRESENTATIONS FOR SPEECH

CONTEXTUAL



Wav2vec 2.0 (baevski et al., 2020) is a model pre-trained through self-supervision. It takes raw audio as input and computes contextual representations that can be used as input for speech recognition systems.

Wav2vec 2.0 Pre-training

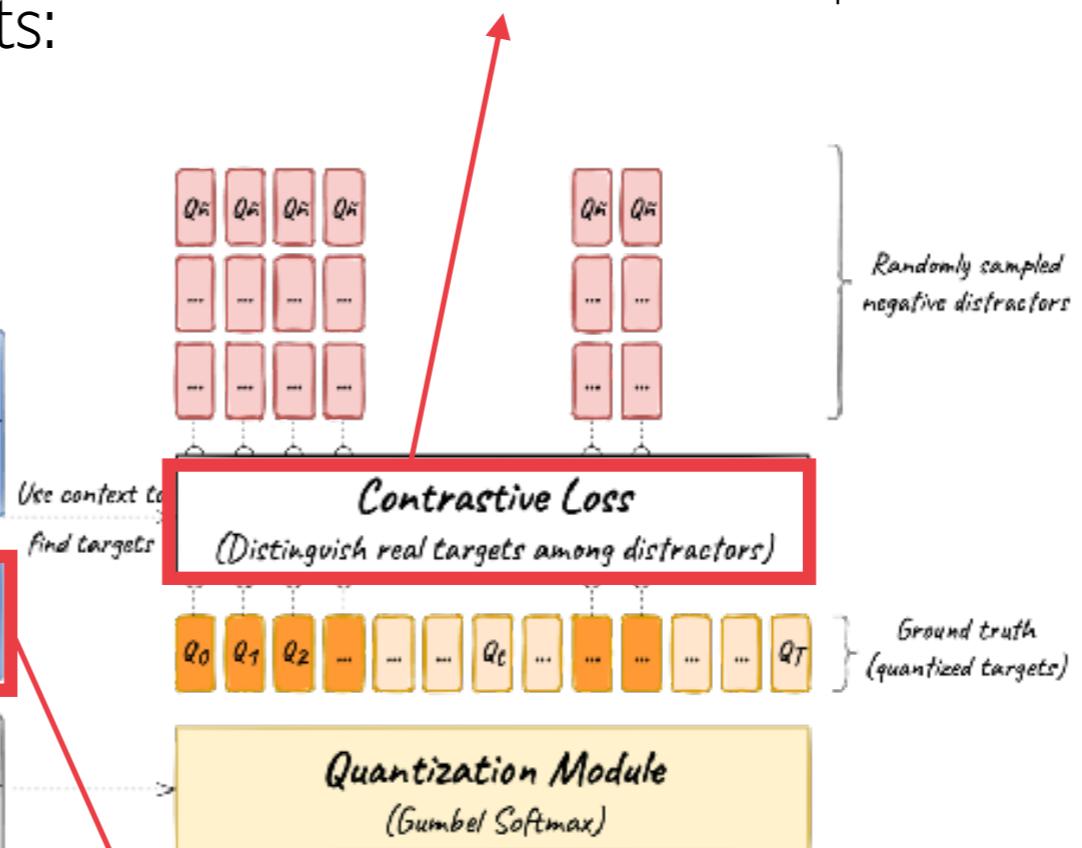
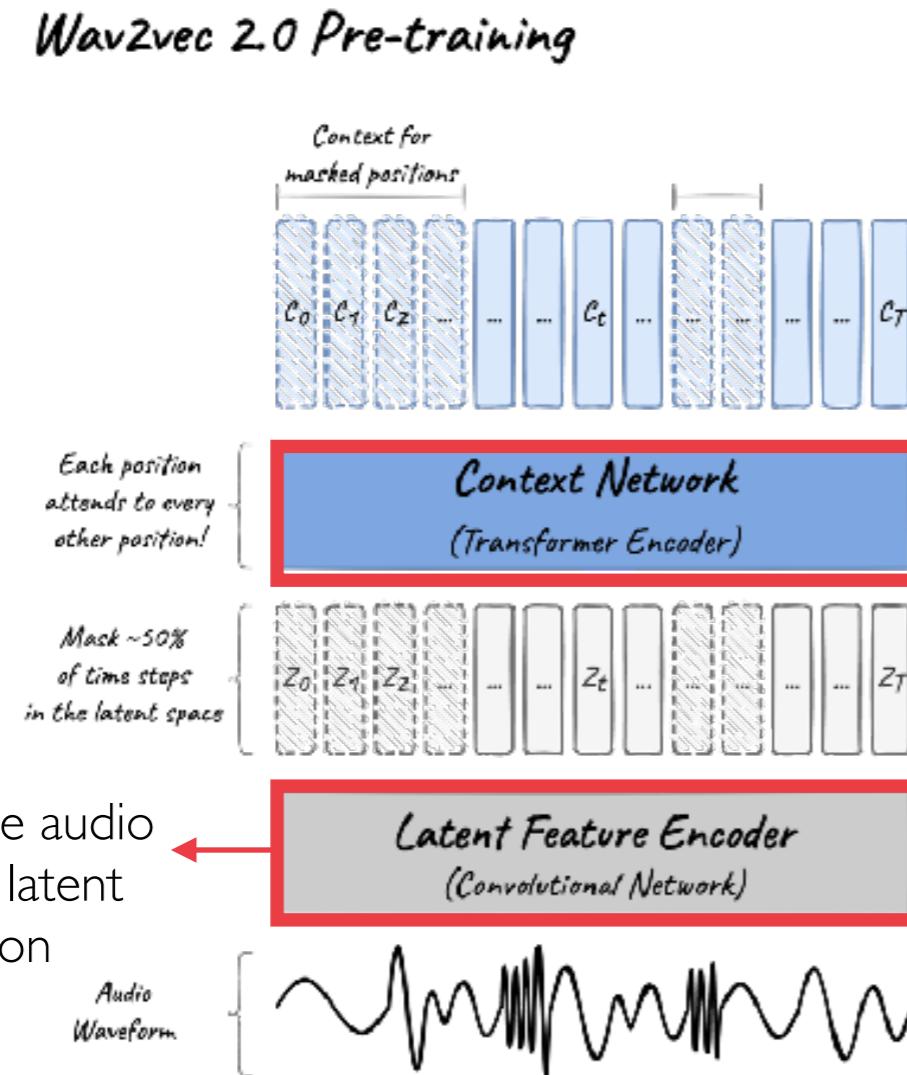


CONTINUOUS REPRESENTATIONS FOR SPEECH

CONTEXTUAL

Wav2vec 2.0 (baevski et al., 2020)

❖ It contains three main components:



- Is used to map the values from a continuous space into a finite set of values in a discrete space

- Consists of a succession of several transformer encoder blocks.
 - It takes care of the context.

CONTINUOUS WORD REPRESENTATIONS

EVALUATION TASKS

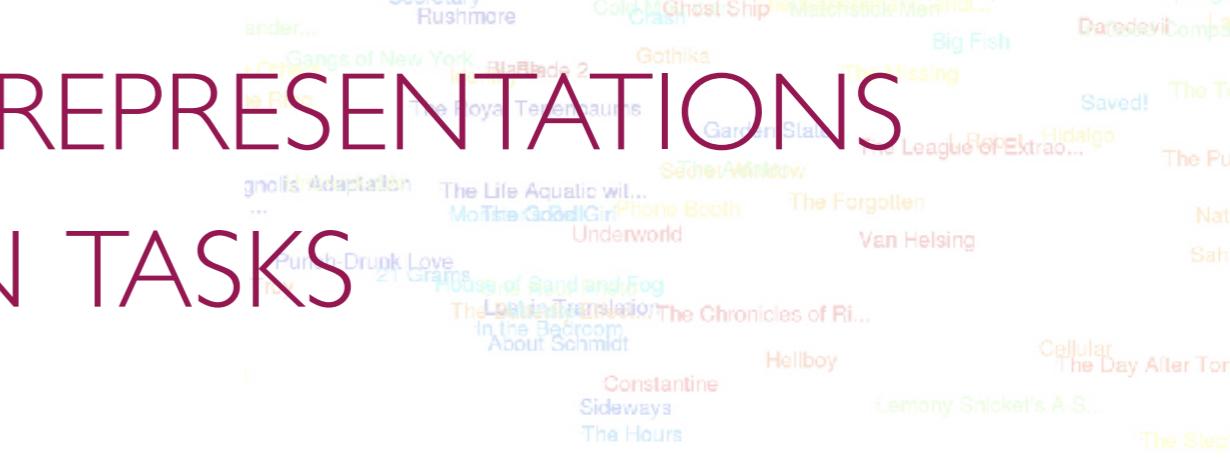
I. Natural language processing tasks (NLP)

- ♦ Part-of-speech tagging (POS): syntactic roles (noun, adverb, etc.)
- ♦ Chunking (CHK): syntactic constituent (noun phrase, verb phrase, etc.)
- ♦ Named Entity recognition (NER): person, company, etc.
- ♦ Mention detection (MENT): begin, inside, and outside
- ♦ Spoken language understanding task (SLU)

CONTINUOUS WORD REPRESENTATIONS

EVALUATION TASKS

2. Word semantic similarity (Kiela et al., 2015)



CONTINUOUS WORD REPRESENTATIONS

EVALUATION TASKS

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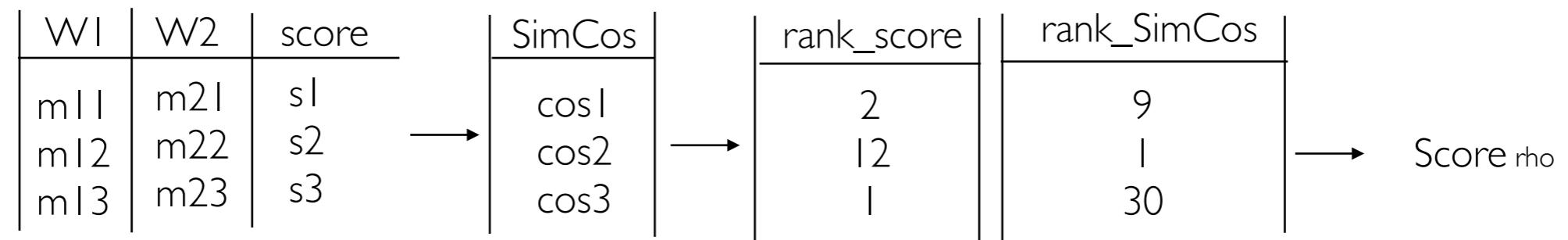
- ♦ Is based on an idea that the distances between words in an embedding space could be evaluated through the human heuristic judgments on the actual semantic distances between these words
 - e.g., the distance between *cup* and *mug* defined in an continuous interval $\{0, 1\}$ would be 0.8 since these words are synonymous, but not really the same thing.
- ♦ The assessor is given a set of pairs of words and asked to assess the degree of similarity for each pair.
- ♦ The distances between these pairs are also collected in a word embeddings space, and the two obtained distances sets are compared.
- ♦ The more similar they are, the better are embeddings

CONTINUOUS WORD REPRESENTATIONS

EVALUATION TASKS

2. Word semantic similarity (Kiela et al., 2015)

- ♦ Is based on an idea that the distances between words in an embedding space could be evaluated through the human heuristic judgments on the actual semantic distances between these words
 - e.g., the distance between *cup* and *mug* defined in an continuous interval $\{0, 1\}$ would be 0.8 since these words are synonymous, but not really the same thing.
- ♦ The assessor is given a set of pairs of words and asked to assess the degree of similarity for each pair.
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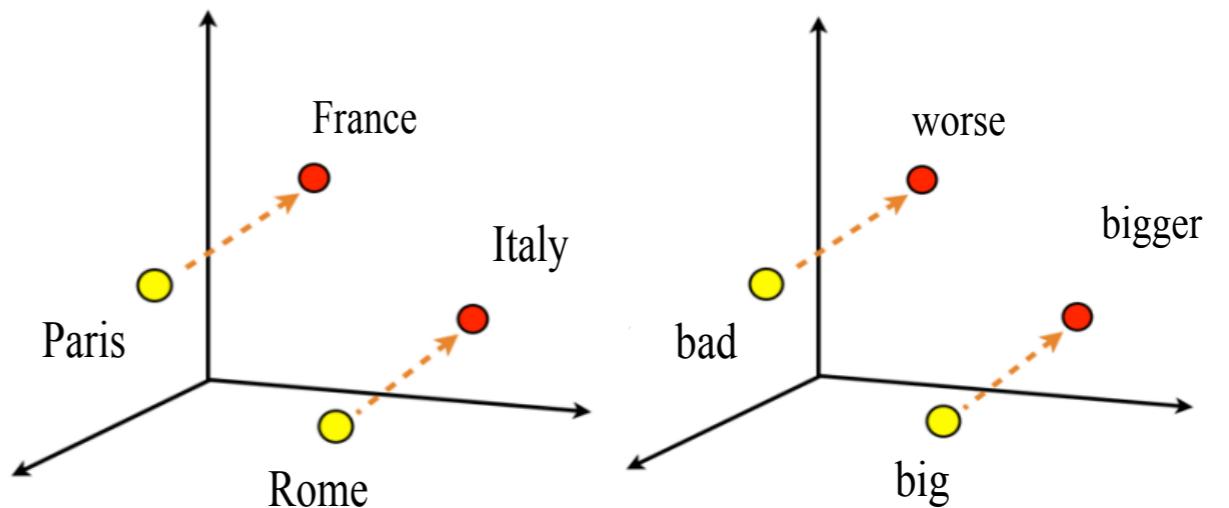
CONTINUOUS WORD REPRESENTATIONS

EVALUATION TASKS

- Is based on the idea that arithmetic operations in a word vector space could be predicted by humans:
 - given a set of three words, a, a^* and b , the task is to identify such word b^* that the relation $b:b^*$ is the same as the relation $a:a^*$.
 - For instance, one has words $a=Paris, a^*=France, b=Rome$.
 - Then the target word would be Italy since the relation $a:a^*$ is capital:country , so one needs to find the capital of which country is $Rome$

Semantic: Paris:France → Rome:?

Syntactic: bad:worse → big:?



CONTINUOUS WORD REPRESENTATIONS

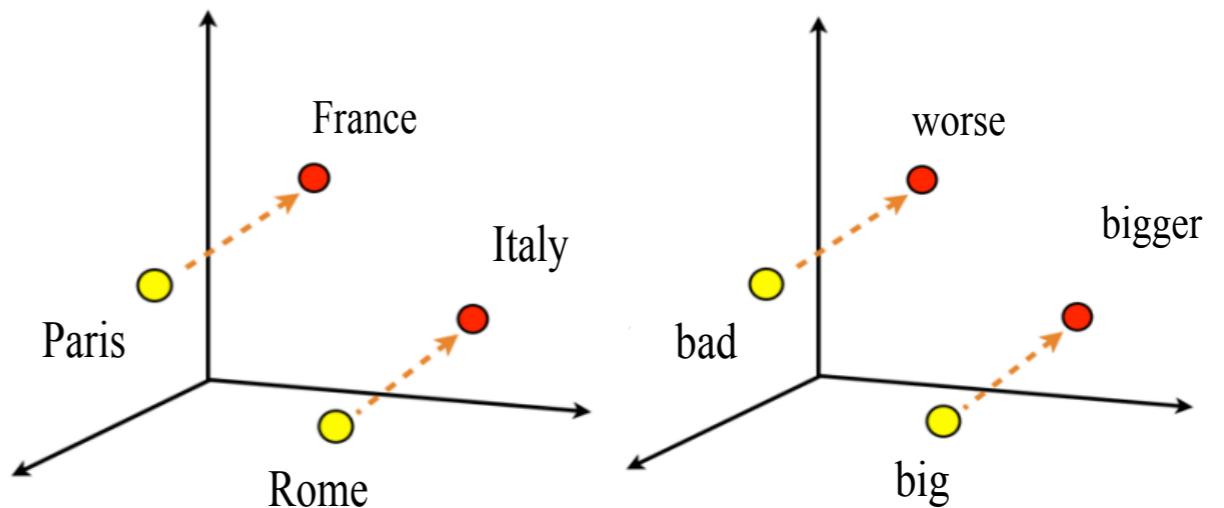
EVALUATION TASKS

3. Word analogy

- Is based on the idea that arithmetic operations in a word vector space could be predicted by humans:
 - given a set of three words, a, a^* and b , the task is to identify such word b^* that the relation $b:b^*$ is the same as the relation $a:a^*$.
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Semantic: Paris:France → Rome:?

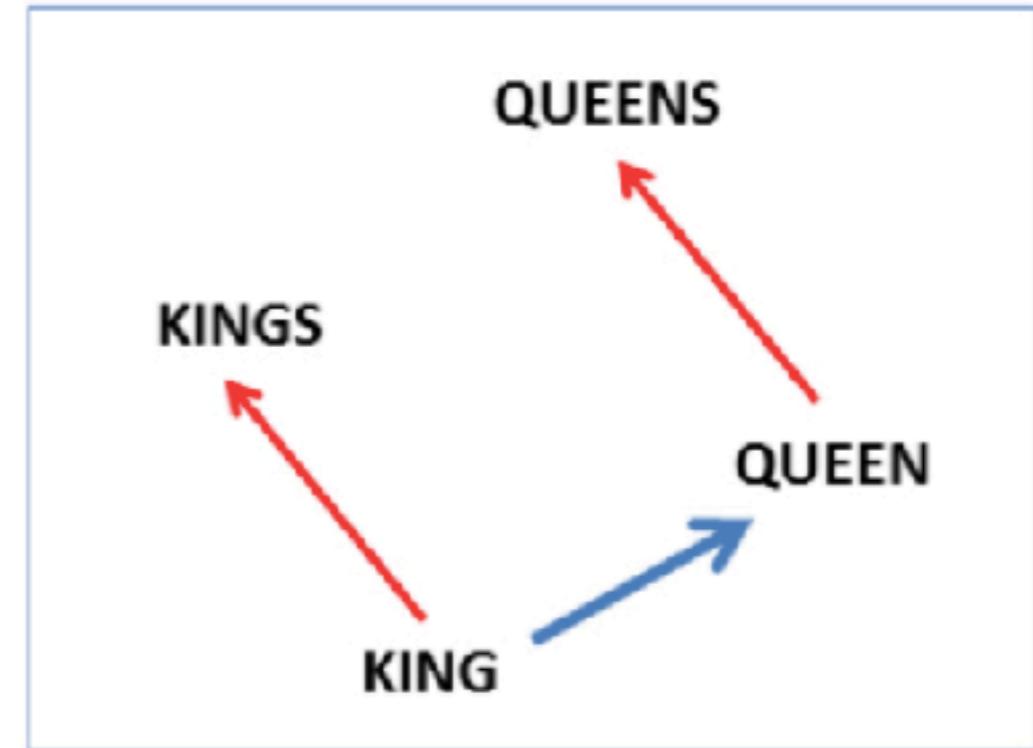
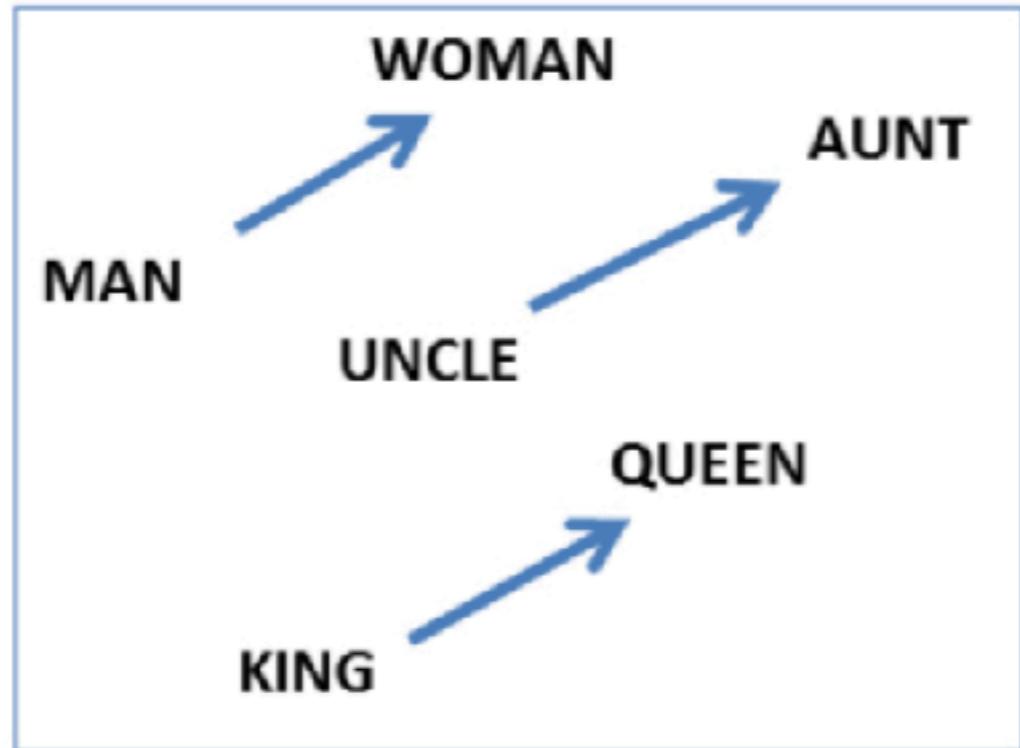
Syntactic: bad:worse → big:?



CONTINUOUS WORD REPRESENTATIONS

EVALUATION TASKS

vector('king') - vector('man') + vector('woman') \approx vector('queen')
vector('Paris') - vector('France') + vector('Italy') \approx vector('Rome')



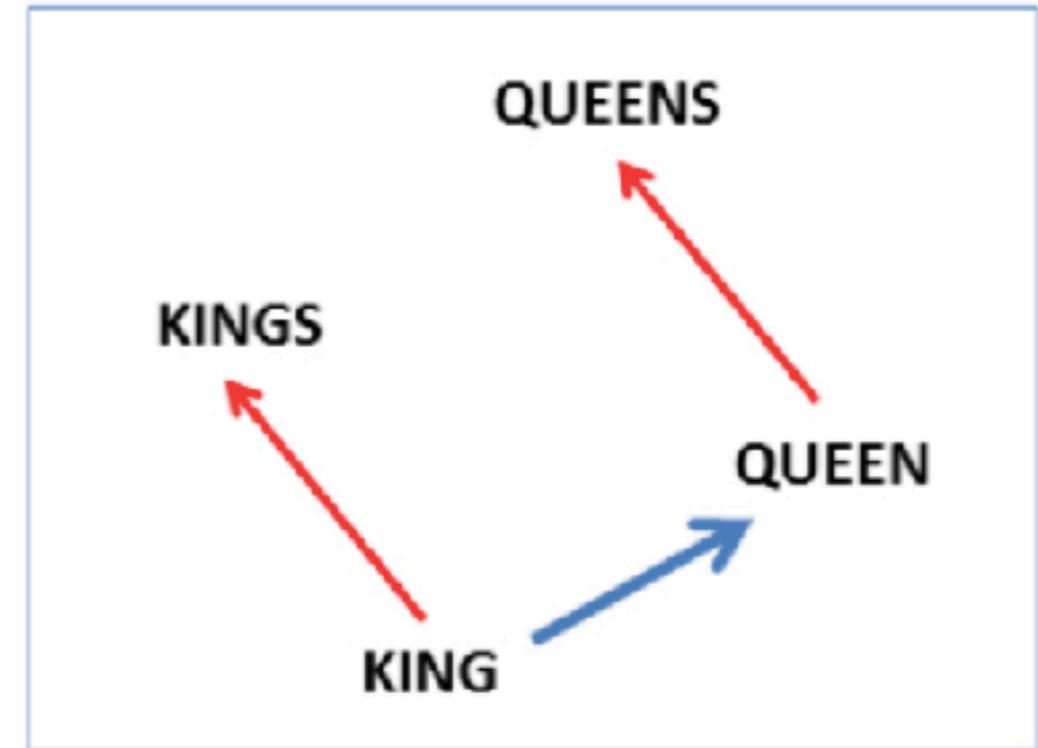
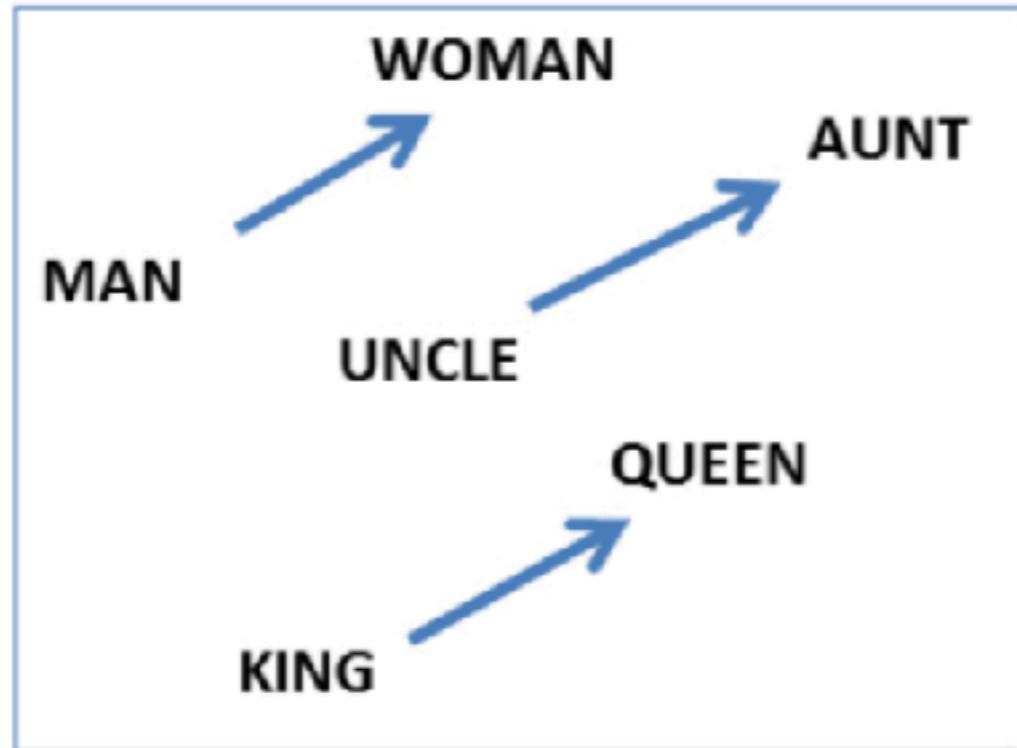
CONTINUOUS WORD REPRESENTATIONS

EVALUATION TASKS

3. Word analogy

$\text{vector('king')} - \text{vector('man')} + \text{vector('woman')} \approx \text{vector('queen')}$

$\text{vector('Paris')} - \text{vector('France')} + \text{vector('Italy')} \approx \text{vector('Rome')}$



CONTINUOUS WORD REPRESENTATIONS

EVALUATION TASKS

ble seeking
decided planned held issued all scheduled while over
as against for in inducing inside between win using keep under find
selected took around next get taken lost off day walk eat live at least more than take told taking caused asked making considered

Evaluation data

- ❖ Word embeddings:
 - ◆ data: corpus Gigaword (english)
 - ◆ Vocabulary: 239k words
 - ◆ Parameters:

Embeddings	Tail.	Dim.	Neg.
CBOW			5
Skip-gram	5		5
GloVe		200	-

w2vf-deps	-		5
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- ❖ Analogy task
 - ◆ Questions:
 - 8869 semantic
 - 10675 syntactic

- ❖ Similarity task:
 - ◆ Data:
 - WordSim353
 - RW (2034)
 - MEN (3000)

- ❖ NLP tasks
 - ◆ Data:

Tâche	Benchmark	Train	Dev	Test
POS	Penn Treebank	958k	34k	58k
CHK	CoNLL 2000	191k	21k	47k
NER	CoNLL 2003	205k	52k	47k
MENT	Ontonotes	736k	102k	105k

CONTINUOUS WORD REPRESENTATIONS

EVALUATION TASKS

Embeddings	Tâches TALN				Tâche de similarité			Tâche d'analogie
	POS	CHK	NER	MENT	WS353	RW	MEN	
	Acc.	F1			Spearman's rank rho			
CBOW	96,01	0,904	0,783	0,554	0,590	0,465	0,609	57,20
Skip-gram	96,43	0,896	0,776	0,578	0,558	0,502	0,662	62,30
w2v-deps	96,66	0,92	0,793	0,580	0,523	0,435	0,557	42,70
GloVe	95,79	0,869	0,764	0,544	0,533	0,410	0,660	65,50

[Ghannay, et al., 2016]

CONTINUOUS WORD REPRESENTATIONS

EVALUATION TASKS

Embeddings	Tâches TALN				Tâche de similarité			Tâche d'analogie
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[Ghannay, et al., 2016]

→ These embeddings carry different information

CONTINUOUS WORD REPRESENTATIONS EVALUATION TASKS

TASK-DEPENDENT DATA VS OUT OF DOMAIN DATA

QUANTITATIVE EVALUATION

Bench.	task-dependent					Out-of-domain				
	ELMo	FastText	GloVe	Skip-gram	CBOW	ELMo	FastText	GloVe	Skip-gram	CBOW
M2M	88.89	72.13	92.54	88.87	89.39	91.14	93.01	91.77	93.19	92.13
ATIS	94.38	85.72	92.95	90.84	91.87	94.93	95.52	95.35	95.62	95.77
SNIPS	78.68	76.35	87.40	82.10	83.94	90.29	94.85	93.90	94.43	94.05
SNIPS70	53.06	38.19	63.65	47.11	49.76	75.19	79.75	78.68	78.90	80.13
MEDIA	80.26	71.73	82.66	80.01	79.57	86.42	85.30	85.11	85.95	86.06

Tagging performance of different word embeddings trained on task-dependent corpus (ATIS, MEDIA, M2M, SNIPS or SNIPS70) and on huge and out of domain corpus (WIKI English or French) on all benchmark corpora in terms of F1 using conlleval scoring script (in %)

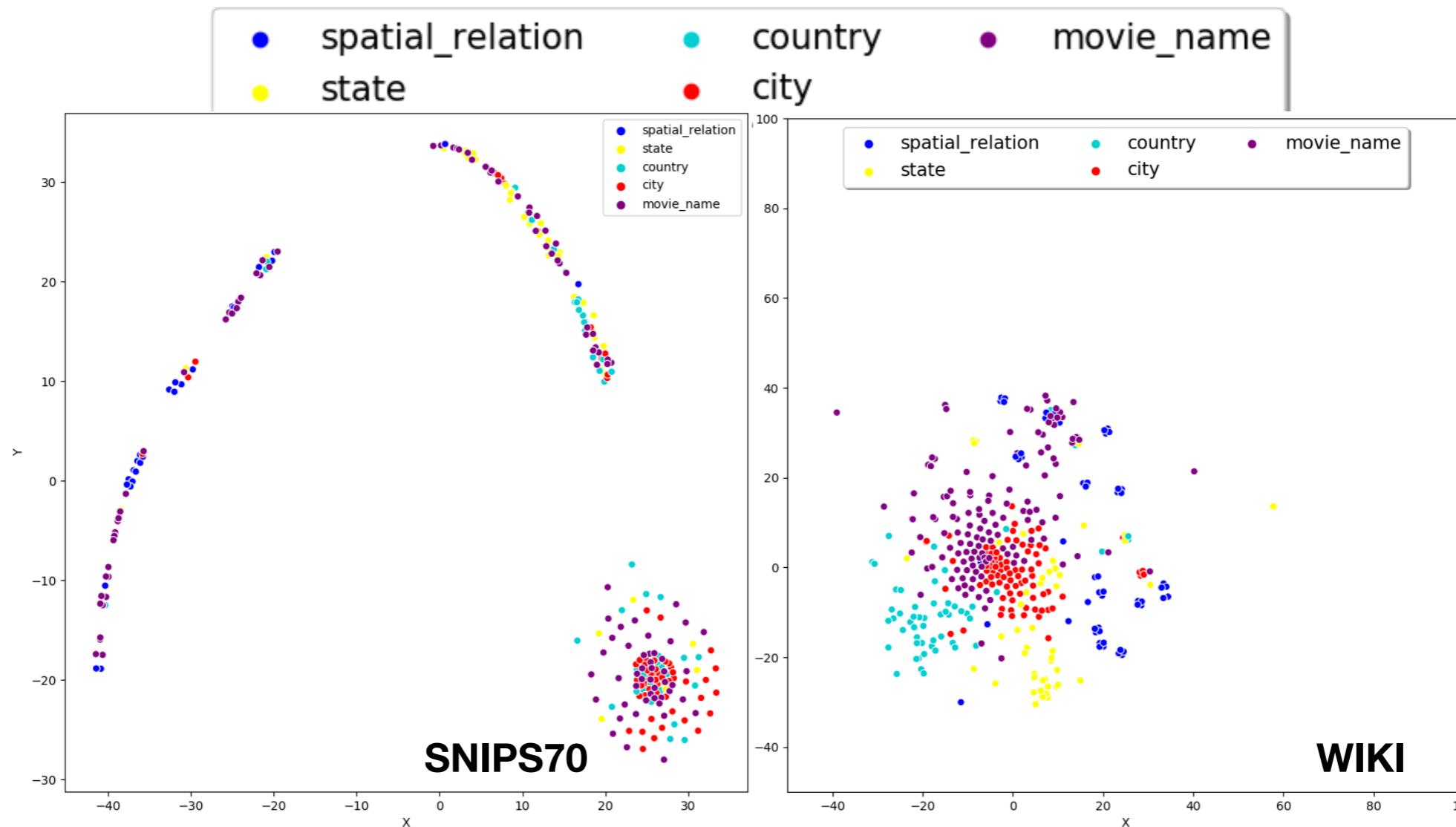
[Ghannay, et al., 2020]

CONTINUOUS WORD REPRESENTATIONS

EVALUATION TASKS

TASK-DEPENDENT DATA VS OUT OF DOMAIN DATA

Qualitative evaluation: CBOW

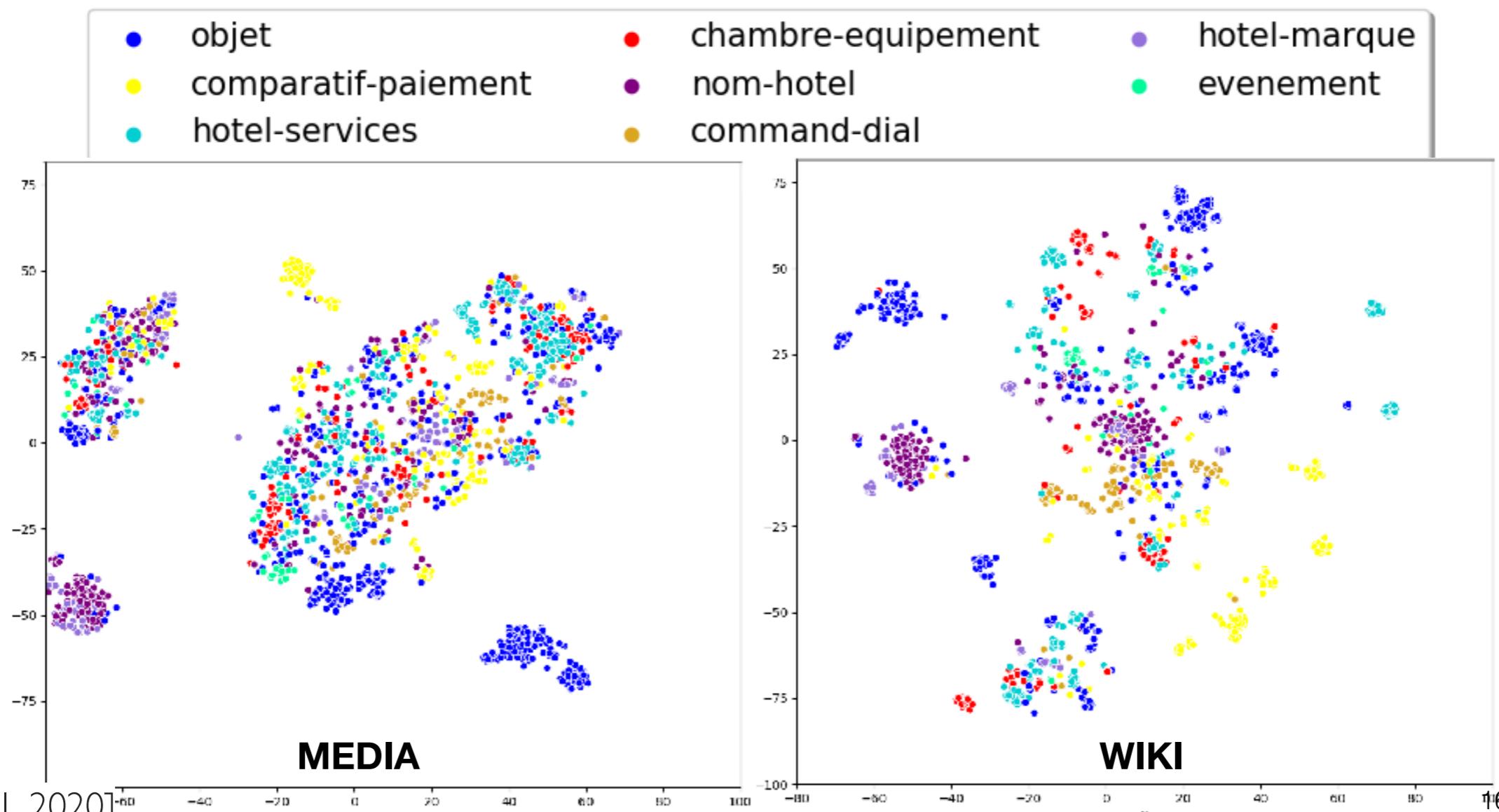


CONTINUOUS WORD REPRESENTATIONS

EVALUATION TASKS

TASK-DEPENDENT DATA VS OUT OF DOMAIN DATA

Qualitative evaluation: ELMo



TOOLS

Tools available to build the embeddings

- ♦ Word2vec Mikolov: <https://github.com/tmikolov/word2vec>
- ♦ W2vf-deps Levy: <https://levyomer.wordpress.com/2014/04/25/dependency-based-word-embeddings/>
- ♦ Glove Pennington: <https://nlp.stanford.edu/projects/glove/>
- ♦ Fasttext: <https://fasttext.cc/docs/en/support.html>
- ♦ ELMo: allenlp https://github.com/allenai/allennlp/blob/master/tutorials/how_to/elmo.md
- ♦ BERT: <https://pypi.org/project/bert-embedding/>
- ♦ wav2vec 2.0: <https://ai.facebook.com/blog/wav2vec-20-learning-the-structure-of-speech-from-raw-audio/>
- ♦ Python library: gensim

Sitography/cknowledgment

- Lectures:
 - Dan Jurafsky: Vector Sementic, Standford university
 - Yannick Estève: Semantics, Avignon université
 - Sophie Rosset, LISN, CNRS :
 - <https://sophierosset.github.io/docs/eidi-dhm.pdf>
 - <https://bigdataspeech.github.io/EN/>
- Tutorials:
 - <https://ahmetozlu93.medium.com/long-short-term-memory-lstm-networks-in-a-nutshell-363cd470ccac>
 - <https://missinglink.ai/guides/convolutional-neural-networks/convolutional-neural-network-tutorial-basic-advanced/>

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Practical session

Lectures: https://saharghannay.github.io/files/Cours_Master_EN2022.pdf

PS: <https://saharghannay.github.io/courses/cours1/example1/>