

An Overview of Natural Language Processing

From TF-IDF To GPT

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QNAP

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Introduction



What is natural language processing



Natural Language Processing (NLP) is a branch of Artificial Intelligence (AI) that focuses on the interaction between computers and humans using natural language. The goal of NLP is to enable computers to understand, interpret, and generate human language.  

NLP involves the use of techniques from computer science, linguistics, and machine learning to process, analyze, and generate natural language. Some common applications of NLP include sentiment analysis, language translation, text classification, chatbots, and speech recognition.

NLP is a rapidly evolving field with new developments and advancements being made regularly. As computers become better at processing language, the potential applications for NLP continue to expand, making it an important field of study in both industry and academia.

Applications in NLP

- Natural Language Processing (NLP) is now maturely developed in many tasks.
 1. Documents could be classified into several categories for as to search files easily.
 2. Text could be generated by AI such as GPT series and ChatGPT.
- In general, NLP is used in the following several scenarios:
 1. **Named-Entity Recognition**
 2. **Document Classification**
 3. Machine Translation
 4. ChatBot
 5. Text Semantic Analysis
 6. Text Generation

TF-IDF

Defects of Word Frequency

- The central idea of the NLP is how to quantify the content of the document.
- Term-frequency (TF) could be a measure to the document, but words inside such as "the" and "this" will be regard as an important words since they occurred in the document many times.
- Another approach is to look at the inverse document frequency (IDF) of the word.
 1. Decreases the weight for commonly occurred words
 2. Increases the weight for words that are not commonly occurred in documents

- Now we're going to define the term-frequency and inverse document frequency:

Definition (Term-Frequency)

Term-Frequency is the frequency of the word t in the document d which can count as follows:

$$tf_{t,d} = \frac{n_{t,d}}{\sum_{k \in d} n_{k,d}}$$

where $n_{t,d}$ is the number of words t in the document d .

Definition (Inverse Document Frequency)

Inverse Document Frequency is defined as follows:

$$idf_t = \log\left(\frac{N}{df_t}\right)$$

where N is the number of documents and df_t is the the number of documents where word t occurs.

Definition (TF-IDF Score)

The TF-IDF Score of the word t in the document d is defined as follows:

$$tfidf_{t,d} = tf_{t,d} \times idf_t$$

Example

- Here we have an example of implementing tf-idf in these three sentences:
 - Text processing is necessary.
 - Text processing is necessary and important.
 - Text processing is easy.
- The result would be:

Word	TF		IDF	TFIDF	
	Doc 1	Doc 2		Doc 1	Doc 2
Text	1/4	1/6	$\log(2/2) = 0$	0	0
Processing	1/4	1/6	$\log(2/2) = 0$	0	0
Is	1/4	1/6	$\log(2/2) = 0$	0	0
Necessary	1/4	1/6	$\log(2/2) = 0$	0	0
And	0/4	1/6	$\log(2/1) = 0.3$	0	0.05
Important	0/4	1/6	$\log(2/1) = 0.3$	0	0.05

[Source of Example]

Word2Vec

Issues in Word Representation

- Words are often represented as one-hot encoding in computer.
- For example, we can set hotel and motel to two different representative as one-hot encoding:

$$v_{motel} = \begin{pmatrix} 1 \\ 0 \\ 0 \\ \vdots \\ 0 \end{pmatrix}, v_{hotel} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ \vdots \\ 0 \end{pmatrix},$$

- However, we cannot gain information of relation between words.
 - We have no idea how motel and hotel are relate to each other while those two vectors are **orthogonal**! i.e. $\langle v_{motel}, v_{hotel} \rangle = 0$
- That's why we introduce word embedding approach to tackle these problems. [1]

Word Embedding

Vocabulary:
Man, woman, boy,
girl, prince,
princess, queen,
king, monarch



	1	2	3	4	5	6	7	8	9
man	1	0	0	0	0	0	0	0	0
woman	0	1	0	0	0	0	0	0	0
boy	0	0	1	0	0	0	0	0	0
girl	0	0	0	1	0	0	0	0	0
prince	0	0	0	0	1	0	0	0	0
princess	0	0	0	0	0	1	0	0	0
queen	0	0	0	0	0	0	1	0	0
king	0	0	0	0	0	0	0	1	0
monarch	0	0	0	0	0	0	0	0	1

Each word gets
a 1x9 vector
representation

Try to build a lower dimensional embedding

Vocabulary:
Man, woman, boy,
girl, prince,
princess, queen,
king, monarch



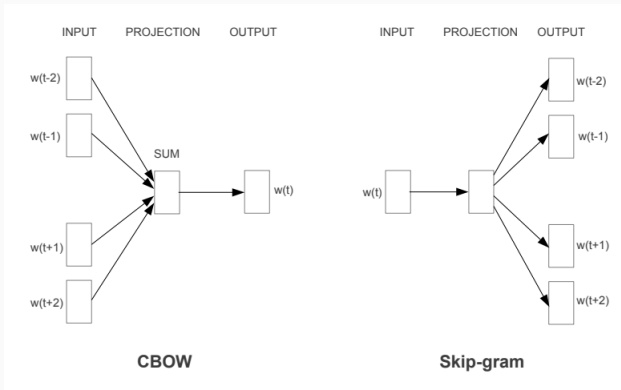
	Femininity	Youth	Royalty
Man	0	0	0
Woman	1	0	0
Boy	0	1	0
Girl	1	1	0
Prince	0	1	1
Princess	1	1	1
Queen	1	0	1
King	0	0	1
Monarch	0.5	0.5	1

Each word gets a
1x3 vector

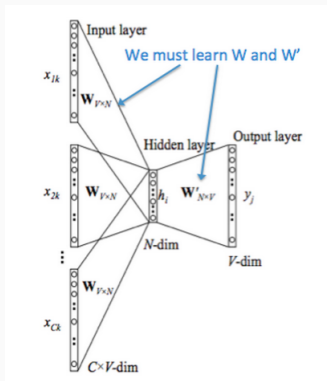
Similar words...
similar vectors

[@shane_a_lynn](#) | [@TeamEdgeTier](#)

[Image Source]



[Image Source]



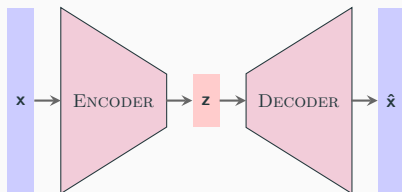
[Image Source]

- Use probability $P(y_i | x_{1k}, x_{2k}, \dots, x_{Ck})$ to learn the weight matrix W !
- W is used to be the pre-trained model when we transform the words into embedding vectors in the unseen documents.

Transformer

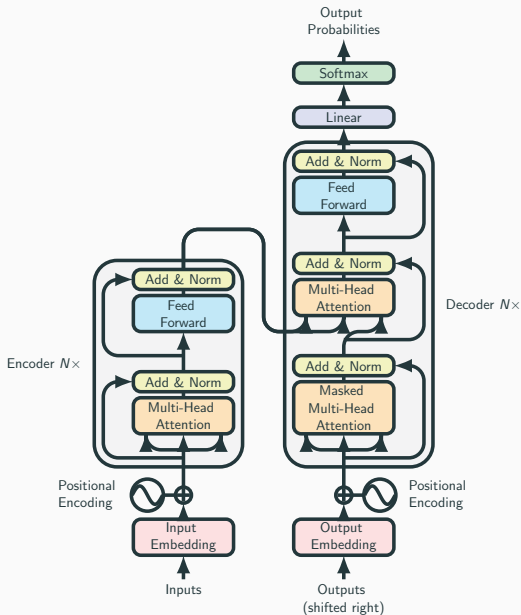
Sequence to Sequence (Seq2Seq)

- Many NLP tasks viewed sequence-to-sequence:
 1. Summarization (whole document \rightarrow shorter text)
 2. Machine Translation (one language \rightarrow target language)



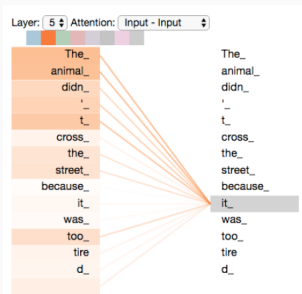
- For example, x is the input sequence (input je suis étudiant) and \hat{x} is the output sequence (I am a student).
- Seq2Seq is constructed by encoder and decoder.
 1. Encoder: Decode the meaning of the source text.
 2. Decoder: Re-encode the meaning to the target language.

Attention Is All You Need [2]



Attention (Self-Attention Mechanism)

- Assume we want to translate a sentence: "The animal didn't cross the street because it was too tired"

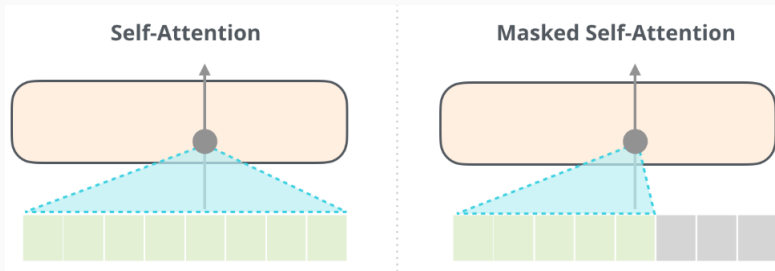


[Image Source]

- Advantages:
 1. Interaction distance
 2. Parallelizability
 3. Interpretability

Masked Self-Attention

- Masked Self-Attention prevents a word to peak at tokens to its right.



[Image Source]

- This distinction is the major difference between GPT and BERT.

BERT

Overview

1 - Semi-supervised training on large amounts of text (books, wikipedia..etc).

The model is trained on a certain task that enables it to grasp patterns in language. By the end of the training process, BERT has language-processing abilities capable of empowering many models we later need to build and train in a supervised way.

Semi-supervised Learning Step

Model:



Dataset:



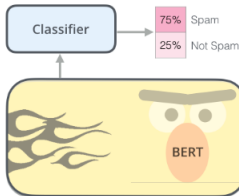
Objective:

Predict the masked word
(language modeling)

2 - Supervised training on a specific task with a labeled dataset.

Supervised Learning Step

Model:
(pre-trained
in step #1)



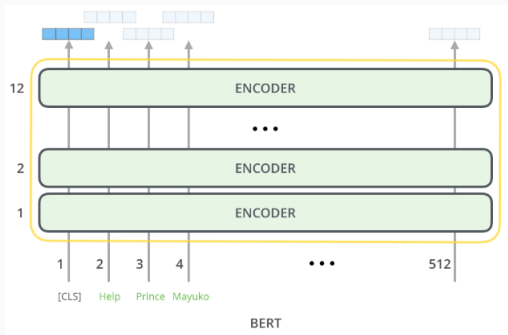
Dataset:

Email message	Class
Buy these pills	Spam
Win cash prizes	Spam
Dear Mr. Atreides, please find attached...	Not Spam

[Image Source]

Architecture

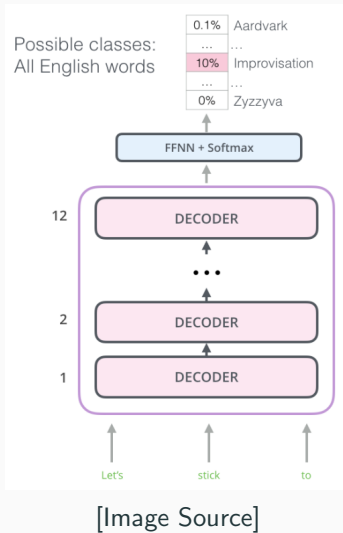
- BERT = Bidirectional Encoder Representations from Transformers



[Image Source]

GPT

Architecture



Questions?



T. Mikolov, K. Chen, G. Corrado, and J. Dean.

Efficient estimation of word representations in vector space.

arXiv preprint arXiv:1301.3781, 2013.



A. Vaswani, N. Shazeer, N. Parmar, J. Uszkoreit, L. Jones, A. N. Gomez, Ł. Kaiser, and I. Polosukhin.

Attention is all you need.

Advances in neural information processing systems, 30, 2017.