Next Article:
Natural Language Processing (NLP) - Overview

BERT Model - NLP

Last Updated : 17 Jul, 2025

BERT (Bidirectional Encoder Representations from Transformers) stands as an open-source machine l designed for the natural language processing (NLP). The article aims to explore the architecture, work of BERT.

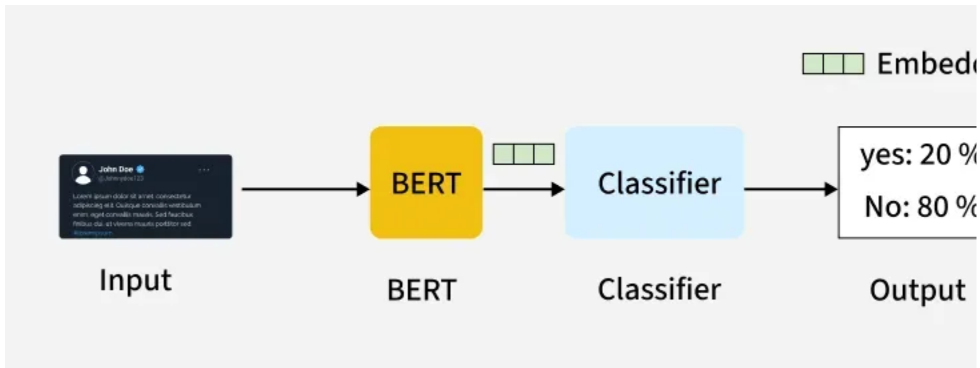


Illustration of BERT Model Use Case

What is BERT?

BERT (Bidirectional Encoder Representations from Transformers) leverages a transformer-based ne understand and generate human-like language. BERT employs an encoder-only architecture. In the or **architecture,** there are both encoder and decoder modules. The decision to use an encoder-only archit suggests a primary emphasis on understanding input sequences rather than generating output seque

Traditional language models process text sequentially, either from left to right or right to left. This me model's awareness to the immediate context preceding the target word. BERT uses a bi-directional ap both the left and right context of words in a sentence, instead of analyzing the text sequentially, BERT words in a sentence simultaneously.

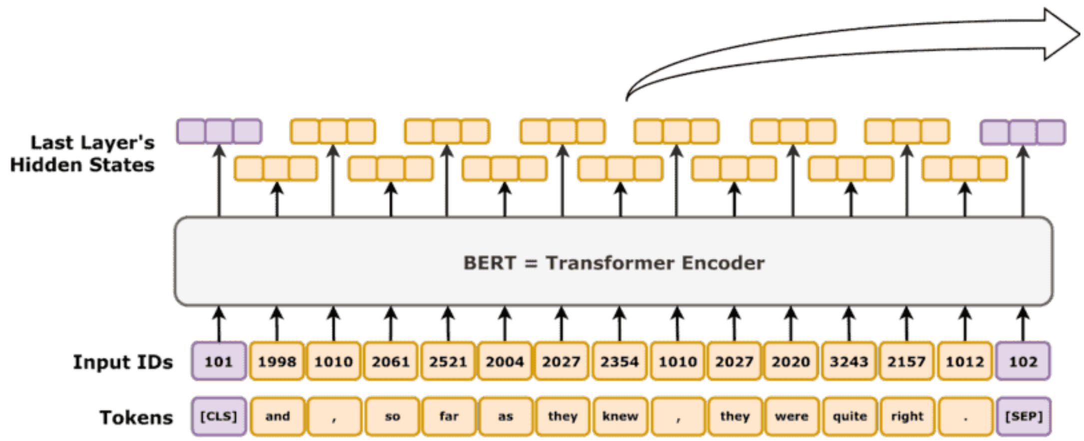
Pre-training BERT Model

The BERT model undergoes Pre-training on Large amounts of unlabeled text to learn contextual emb

- BERT is pre-trained on large amount of unlabeled text data. The model learns contextual embeddi representations of words that take into account their surrounding context in a sentence.
- BERT engages in various unsupervised pre-training tasks. For instance, it might learn to predict mis sentence (Masked Language Model or MLM task), understand the relationship between two senter next sentence in a pair.

Workflow of BERT

BERT is designed to generate a language model so, only the encoder mechanism is used. Sequence of the Transformer encoder. These tokens are first embedded into vectors and then processed in the neu output is a sequence of vectors, each corresponding to an input token, providing contextualized repres training language models, defining a prediction goal is a challenge. Many models predict the next wor which is a directional approach and may limit context learning.



BERT Model Working

BERT addresses this challenge with two innovative training strategies:

1. Masked Language Model (MLM)
2. Next Sentence Prediction (NSP)

1. Masked Language Model (MLM)

In BERT's pre-training process, a portion of words in each input sequence is masked and the model is original values of these masked words based on the context provided by the surrounding words.

1. BERT adds a classification layer on top of the output from the encoder. This layer is important for p words.
2. The output vectors from the classification layer are multiplied by the embedding matrix, transformi vocabulary dimension. This step helps align the predicted representations with the vocabulary spa
3. The probability of each word in the vocabulary is calculated using the SoftMax activation function. a probability distribution over the entire vocabulary for each masked position.
4. The loss function used during training considers only the prediction of the masked values. The moc the deviation between its predictions and the actual values of the masked words.
5. The model converges slower than directional models because during training, BERT is only concerr the masked values, ignoring the prediction of the non-masked words. The increased context aware through this strategy compensates for the slower convergence.

2. Next Sentence Prediction (NSP)

BERT predicts if the second sentence is connected to the first. This is done by transforming the output into a 2×1 shaped vector using a classification layer, and then calculating the probability of whether tl follows the first using SoftMax.

1. In the training process, BERT learns to understand the relationship between pairs of sentences, pre sentence follows the first in the original document.
2. 50% of the input pairs have the second sentence as the subsequent sentence in the original docum 50% have a randomly chosen sentence.
3. To help the model distinguish between connected and disconnected sentence pairs. The input is pr entering the model.
4. BERT predicts if the second sentence is connected to the first. This is done by transforming the out token into a 2×1 shaped vector using a classification layer, and then calculating the probability of v sentence follows the first using SoftMax.

> *During the training of BERT model, the Masked LM and Next Sentence Prediction are trained toget aims to minimize the combined loss function of the Masked LM and Next Sentence Prediction, lead language model with enhanced capabilities in understanding context within sentences and relatior sentences.*

Why to train Masked LM and Next Sentence Prediction together?

Masked LM helps BERT to understand the context within a sentence and Next Sentence Prediction he connection or relationship between pairs of sentences. Hence, training both the strategies together er learns a broad and comprehensive understanding of language, capturing both details within sentence between sentences.

Fine-Tuning on Labeled Data

We perform Fine-tuning on labeled data for specific NLP tasks.

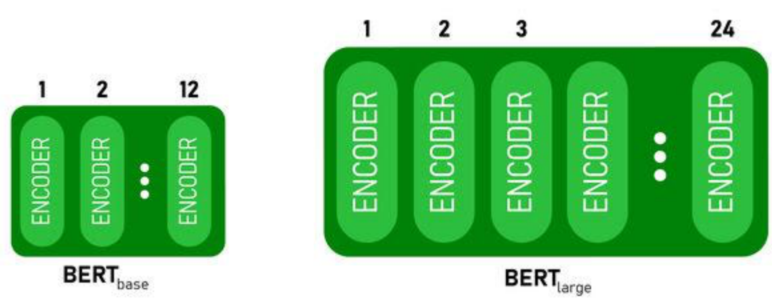
- After the pre-training phase, the BERT model, armed with its contextual embeddings, is fine-tuned language processing (NLP) tasks. This step tailors the model to more targeted applications by ada language understanding to the nuances of the particular task.
- BERT is fine-tuned using labeled data specific to the downstream tasks of interest. These tasks co analysis, question-answering, named entity recognition, or any other NLP application. The model's adjusted to optimize its performance for the particular requirements of the task at hand.

BERT's unified architecture allows it to adapt to various downstream tasks with minimal modifications versatile and highly effective tool in natural language understanding and processing.

BERT Architecture

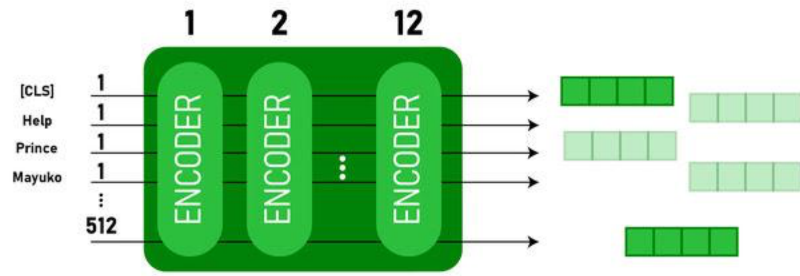
The architecture of BERT is a multilayer bidirectional transformer encoder which is quite similar to the A transformer architecture is an encoder-decoder network that uses self-attention on the encoder side the decoder side.

1. $BERT_{BASE}$ has 12 layers in the Encoder stack while $BERT_{LARGE}$ has 24 layers in the Encoder stack. the Transformer architecture described in the original paper (6 encoder layers).
2. BERT architectures (BASE and LARGE) also have larger feedforward networks (768 and 1024 hidc respectively), and more attention heads (12 and 16 respectively) than the Transformer architecture original paper. It contains 512 hidden units and 8 attention heads.
3. $BERT_{BASE}$ contains 110M parameters while $BERT_{LARGE}$ has 340M parameters.



BERT BASE and BERT LARGE architecture

This model takes the CLS token as input first, then it is followed by a sequence of words as input. Her classification token. It then passes the input to the above layers. Each layer applies self-attention and through a feedforward network after then it hands off to the next encoder. The model outputs a vecto for BERT BASE). If we want to output a classifier from this model we can take the output correspondi



BERT output as Embeddings

Now, this trained vector can be used to perform a number of tasks such as classification, translation, e
paper achieves great results just by using a single layer Neural Network on the BERT model in the cla

How to use BERT model in NLP?

BERT can be used for various natural language processing (NLP) tasks such as:

1. Classification Task

- BERT can be used for classification task like sentiment analysis, the goal is to classify the text into (positive/ negative/ neutral), BERT can be employed by adding a classification layer on the top of th output for the [CLS] token.
- The [CLS] token represents the aggregated information from the entire input sequence. This pooled then be used as input for a classification layer to make predictions for the specific task.

2. Question Answering

- In question answering tasks, where the model is required to locate and mark the answer within a g BERT can be trained for this purpose.
- BERT is trained for question answering by learning two additional vectors that mark the beginning answer. During training, the model is provided with questions and corresponding passages, and it l start and end positions of the answer within the passage.

3. Named Entity Recognition (NER)

- BERT can be utilized for NER, where the goal is to identify and classify entities (e.g., Person, Organ text sequence.
- A BERT-based NER model is trained by taking the output vector of each token form the Transforme a classification layer. The layer predicts the named entity label for each token, indicating the type o

How to Tokenize and Encode Text using BERT?

To tokenize and encode text using BERT, we will be using the 'transformer' library in Python.

Command to install transformers:

```
pip install transformers
```

- We will load the pretrained BERT tokenize with a cased vocabulary using BertTokenizer.from_pretr cased").
- tokenizer.encode(text) tokenizes the input text and converts it into a sequence of token IDs.
- print("Token IDs:", encoding) prints the token IDs obtained after encoding.
- tokenizer.convert_ids_to_tokens(encoding) converts the token IDs back to their corresponding toker
- print("Tokens:", tokens) prints the tokens obtained after converting the token IDs

```
from transformers import BertTokenizer

tokenizer = BertTokenizer.from_pretrained("bert-base-cased")
text = 'ChatGPT is a language model developed by OpenAI, based on the GPT (Generati
Transformer) architecture. '

# Tokenize and encode the text
encoding = tokenizer.encode(text)
print("Token IDs:", encoding)

# Convert token IDs back to tokens
tokens = tokenizer.convert_ids_to_tokens(encoding)
print("Tokens:", tokens)
```

Output

Token IDs: [101, 24705, 1204, 17095, 1942, 1110, 170, 1846, 2235, 1872, 1118, 3353, 1592, 22 1113, 1103, 15175, 1942, 113, 9066, 15306, 11689, 118, 3972, 13809, 23763, 114, 4220, 119,

Tokens: ['[CLS]', 'Cha', '##t', '##GP', '##T', 'is', 'a', 'language', 'model', 'developed', 'by', 'Open', '##A 'on', 'the', 'GP', '##T', '(', 'Gene', '##rative', 'Pre', '-', 'trained', 'Trans', '##former', ')', 'architecture', '.',

The tokenizer.encode method adds the special [CLS] - classification and [SEP] - separator tokens at th of the encoded sequence. In the token IDs section, token id: 101 refers to the start of the sentence anc represents the end of the sentence.

Application of BERT

BERT is used for various applications. Some of these are:

1. **Text Representation:** BERT is used to generate word embeddings or representation for words in a
2. **Named Entity Recognition (NER)**: BERT can be fine-tuned for named entity recognition tasks, whe identify entities such as names of people, organizations, locations, etc., in a given text.
3. **Text Classification:** BERT is widely used for text classification tasks, including sentiment analysis, topic categorization. It has demonstrated excellent performance in understanding and classifying tl data.
4. **Question-Answering Systems:** BERT has been applied to question-answering systems, where the understand the context of a question and provide relevant answers. This is particularly useful for ta comprehension.
5. **Machine Translation:** BERT's contextual embeddings can be leveraged for improving machine tran model captures the nuances of language that are crucial for accurate translation.
6. **Text Summarization:** BERT can be used for abstractive text summarization, where the model gene meaningful summaries of longer texts by understanding the context and semantics.
7. **Conversational AI:** BERT is employed in building conversational AI systems, such as chatbots, virtu dialogue systems. Its ability to grasp context makes it effective for understanding and generating n responses.
8. **Semantic Similarity:** BERT embeddings can be used to measure semantic similarity between sente This is valuable in tasks like duplicate detection, paraphrase identification, and information retrieva

BERT vs GPT

The difference between BERT and GPT are as follows:

	BERT	GPT
Architecture	Bidirectional; predicts masked words based on left, right context.	Unidirectional; predicts preceding co
Pre-training Objectives	BERT is pre-trained using a masked language model objective and next sentence prediction.	GPT is pre-trained using N only.
Context Understanding	Strong at understanding and analyzing text.	Strong in generating contextually rele
Tasks and Use Cases	Commonly used in tasks like text classification, NER, sentiment analysis, and QA	Applied to tasks like text summarizatio
Fine-tuning vs Few-Shot Learning	Fine-tuning with labeled data to adapt its pre-trained representations to the task at hand.	GPT is designed to perforr shot learning, where it ca minimal task-spe

> ***Example to differentiate between output by BERT and GPT: "The bank is situated on the _____***
>
> *In the above example, we can observe that BERT considers bidirectional approach enabling a more understanding compared to unidirectional models.*

Related Articles

- How to Generate Word Embedding using BERT?
- Sentiment Classification Using BERT
- Toxic Comment Classification using BERT
- Fine-tuning BERT for Sentiment Analysis
- Sentence Similarity using BERT
- BART Model for Text Auto Completion in NLP