Bidirectional Encoder Representations from Transformers (BERT)

Shusen Wang

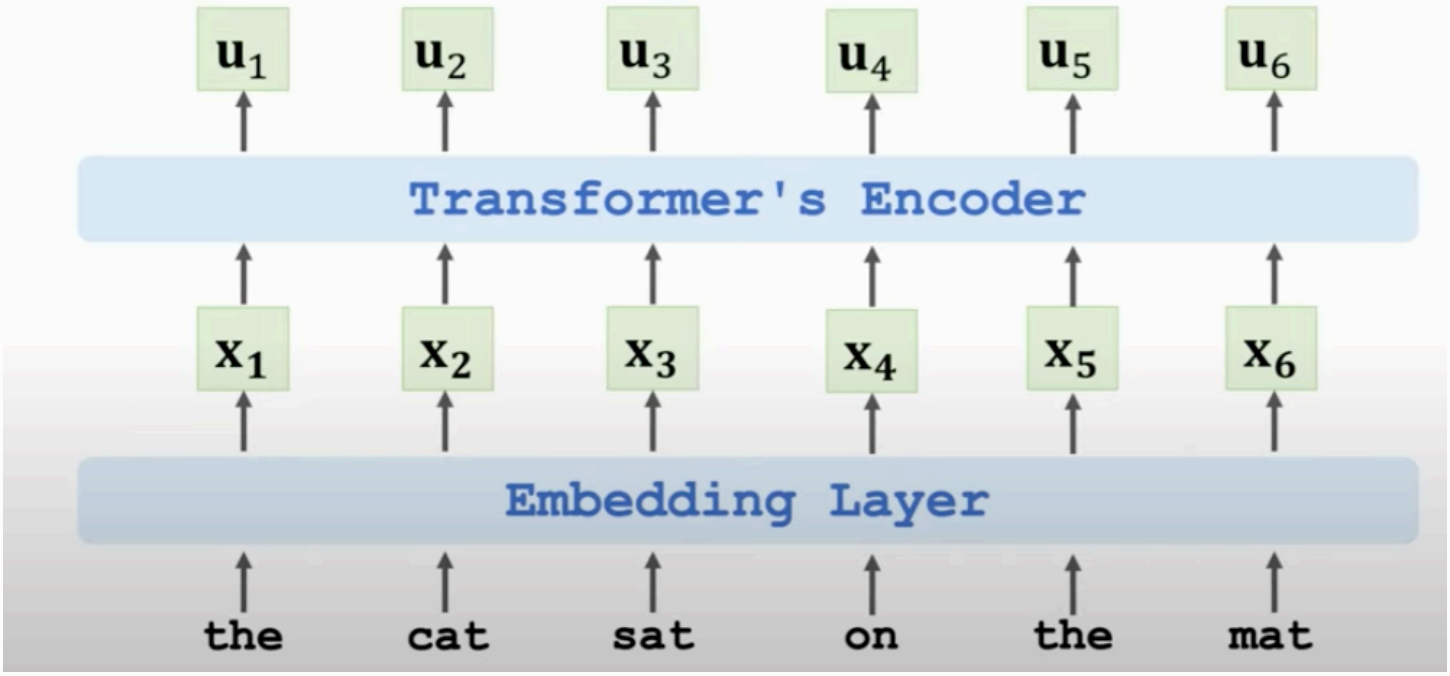
What is BERT?

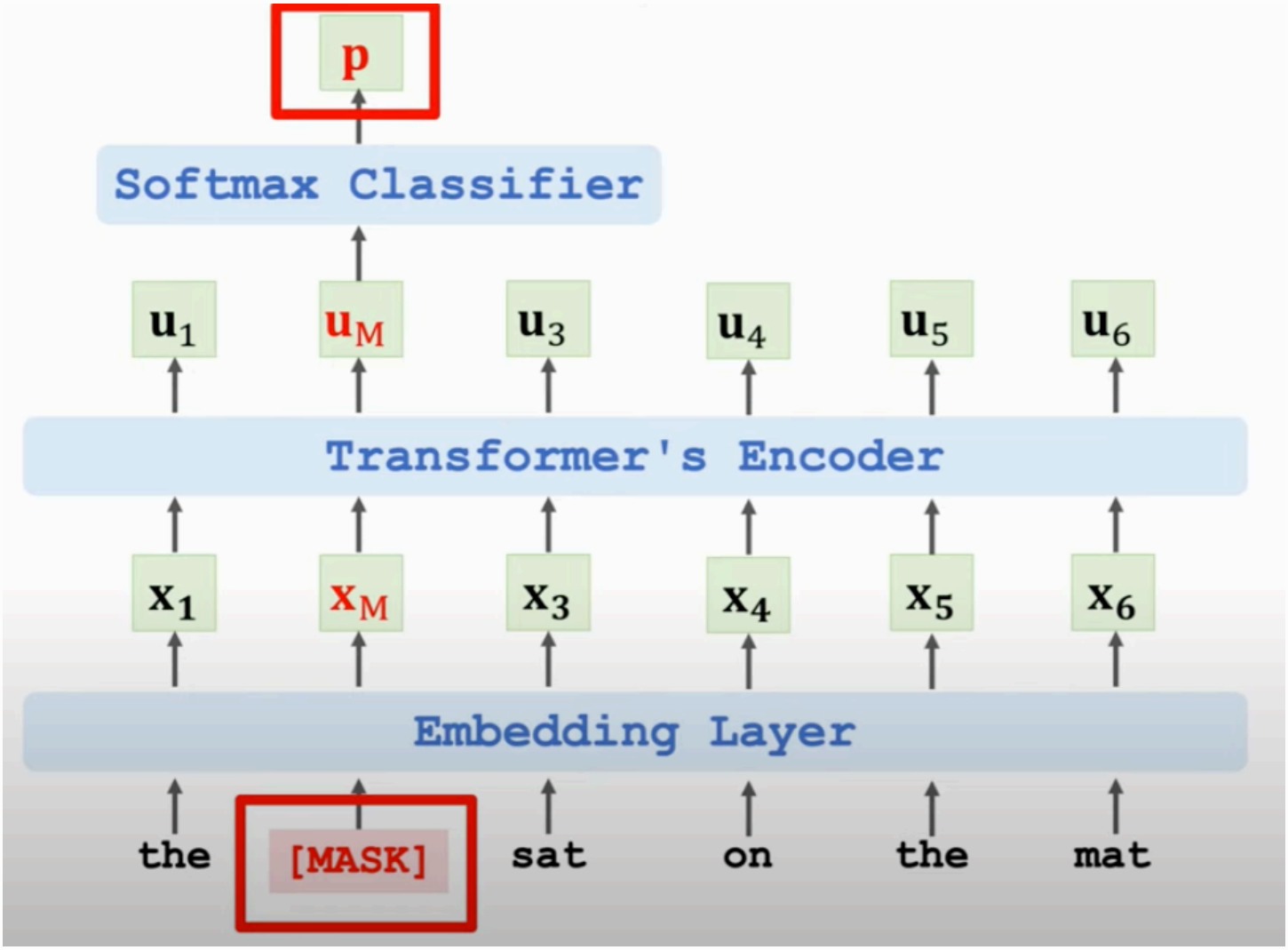
- BERT [1] is for pre-training Transformer's [2] encoder.
- How?
- Predict masked word.
- Predict next sentence.

Reference

1. Devlin, Chang, Lee, and Toutanova. BERT: Pre-training of deep bidirectional transformers for language understanding. In *ACL*, 2019.
2. Vaswani and others. Attention is all you need. In *NIPS*, 2017.

Revisit Transformer's Encoder





Predict the masked word

- **e**: one-hot vector of the masked word "cat".
- **p**: output probability distribution at the masked position.
- $\text{Loss} = \text{CrossEntropy}(\mathbf{e}, \mathbf{p})$.
- Performing one gradient descent to update the model parameters.

Input Representation

- **Input:**

[CLS] "calculus is a branch of math"
[SEP] "it was developed by newton and leibniz"

- **[CLS]** is a token for classification.
- **[SEP]** is for separating sentences.

Input Representation

- **Input:**

[CLS] "calculus is a branch of math"
[SEP] "it was developed by newton and leibniz"

- **Target:** true

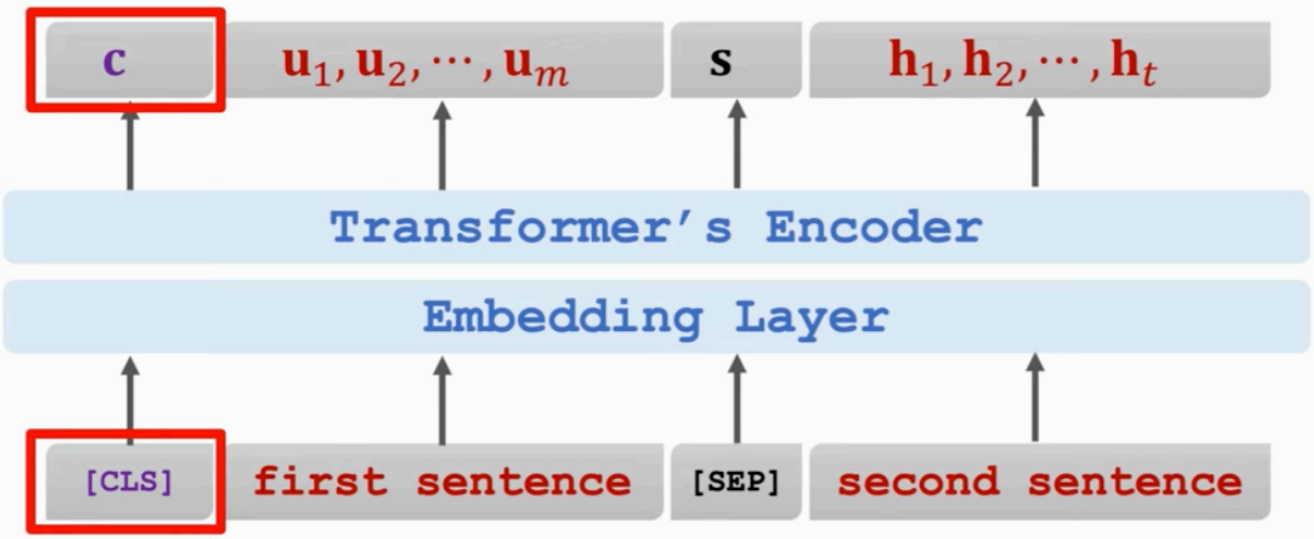
Input Representation

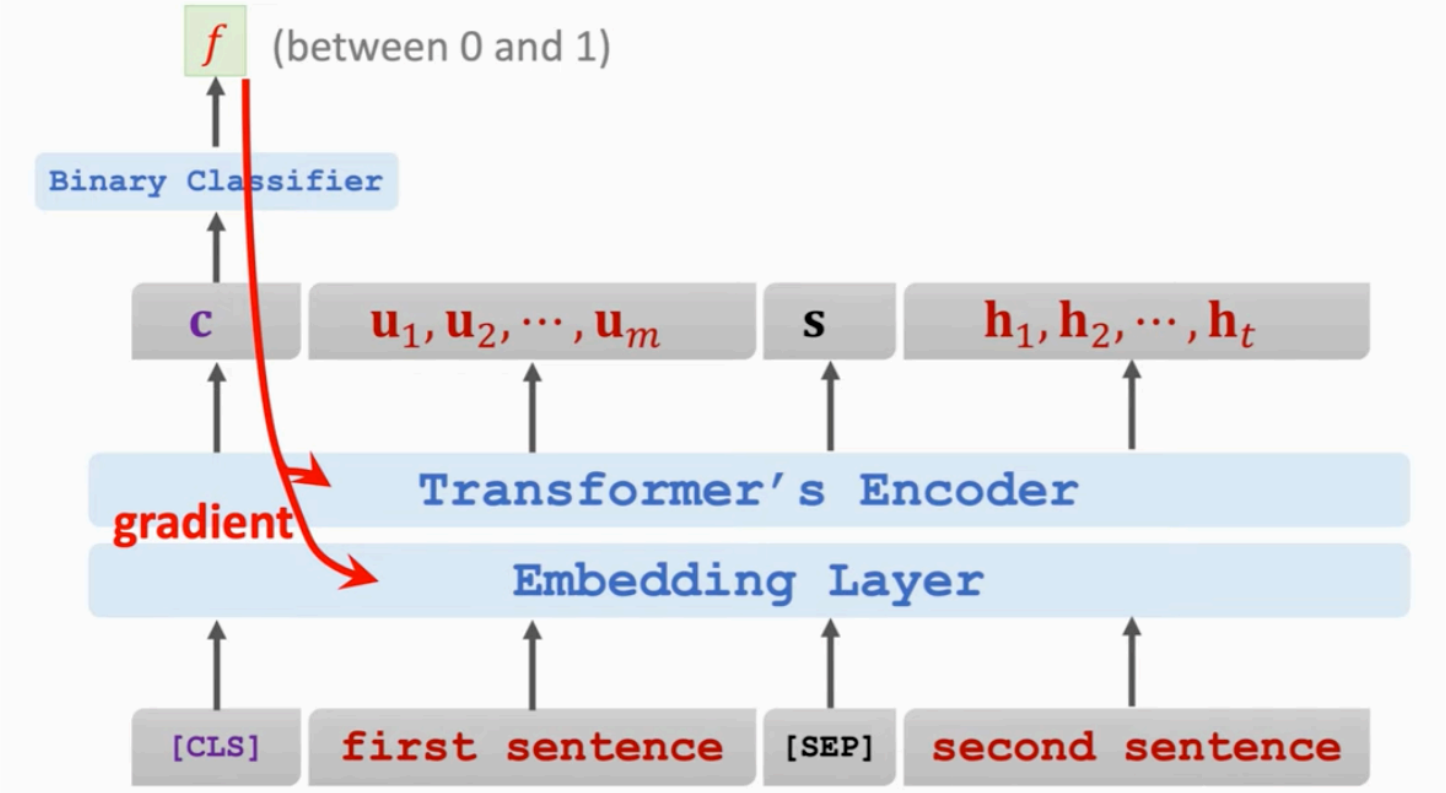
- **Input:**

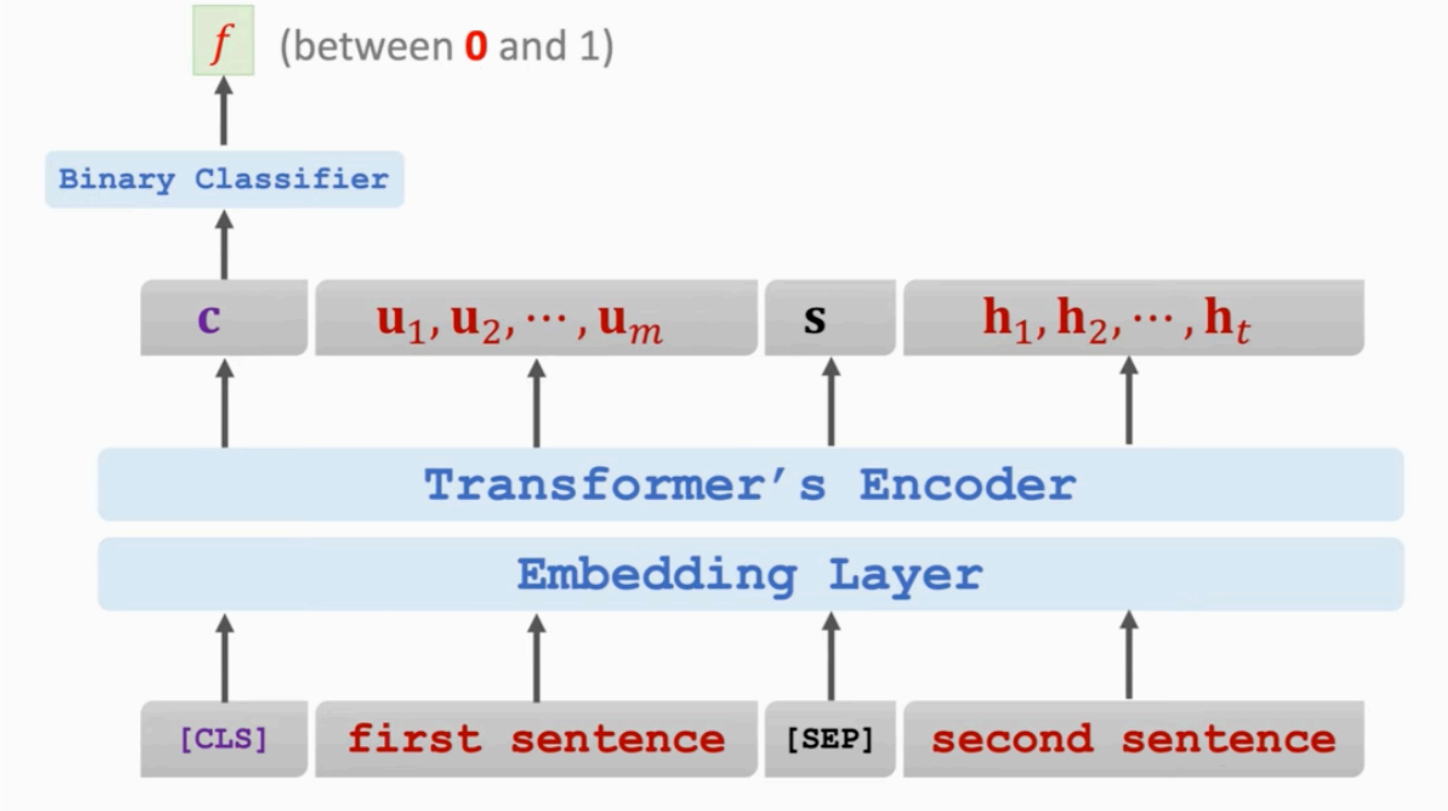
[CLS] "calculus is a branch of math"
[SEP] "panda is native to south central china"

- **Target:** false

Predict the next sentence




f
(between 0 and 1)
Binary Classifier
$\mathbf{c}$
$\mathbf{u}_1, \mathbf{u}_2, \cdots, \mathbf{u}_m$
$\mathbf{s}$
$\mathbf{h}_1, \mathbf{h}_2, \cdots, \mathbf{h}_t$
Transformer's Encoder
gradient
Embedding Layer
[CLS]
first sentence
[SEP]
second sentence



?

Input Representation

- **Input:**

"[CLS] calculus is a **[MASK]** of math
[SEP] it **[MASK]** developed by newton and leibniz".

- **Targets:** true, "branch", "was".

Input Representation

- **Input:**

"[CLS] calculus is a branch of math
[SEP] panda is native to **[MASK]** central china".

- **Targets:** false, "south".

Training

- Loss 1 is for binary classification (i.e., predicting the next sentence.)
- Loss 2 and Loss 3 are for multi-class classification (i.e., predicting the masked words.)
- Objective function is the sum of the three loss functions.
- Update model parameters by performing one gradient descent.

Data

- BERT does not need manually labeled data. (Nice! Manual labeling is expensive.)
- Use large-scale data, e.g., English Wikipedia (2.5 billion words.)

Cost of Computation

- BERT Base
  - 110M parameters.
  - 16 TPUs, 4 days of training (without hyper-parameter tuning.)
- BERT Large
  - 235M parameters.
  - 64 TPUs, 4 days of training (without hyper-parameter tuning.)