

Bidirectional Encoder Representations from Transformers (BERT)

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What is BERT?

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

Reference

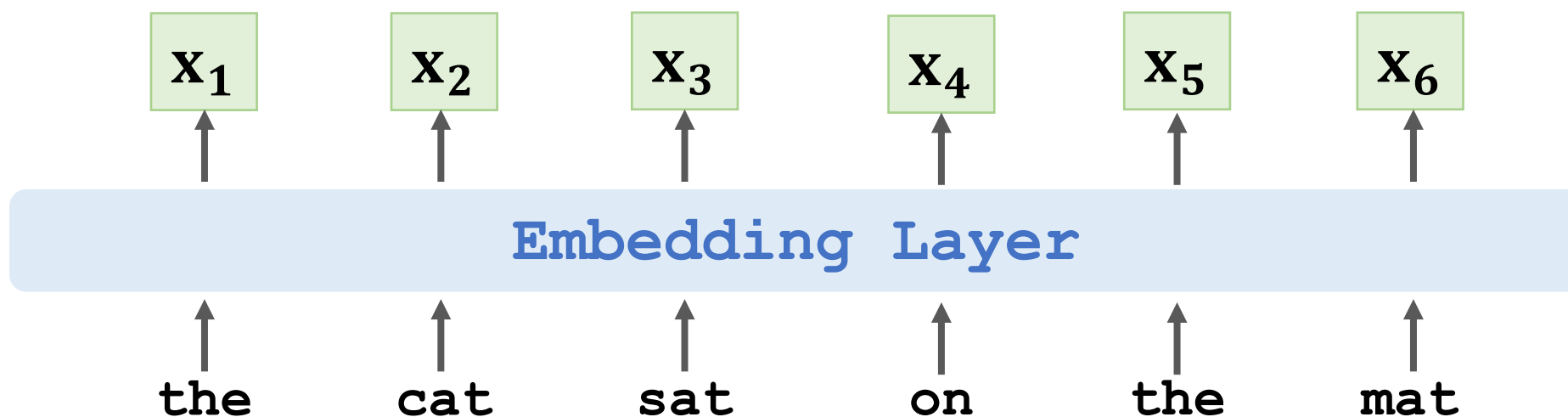
1. Devlin, Chang, Lee, and Toutanova. [BERT: Pre-training of deep bidirectional transformers for language understanding](#). In *ACL*, 2019.
2. Vaswani and others. [Attention is all you need](#). In *NIPS*, 2017.

Task 1: Predict Masked Words

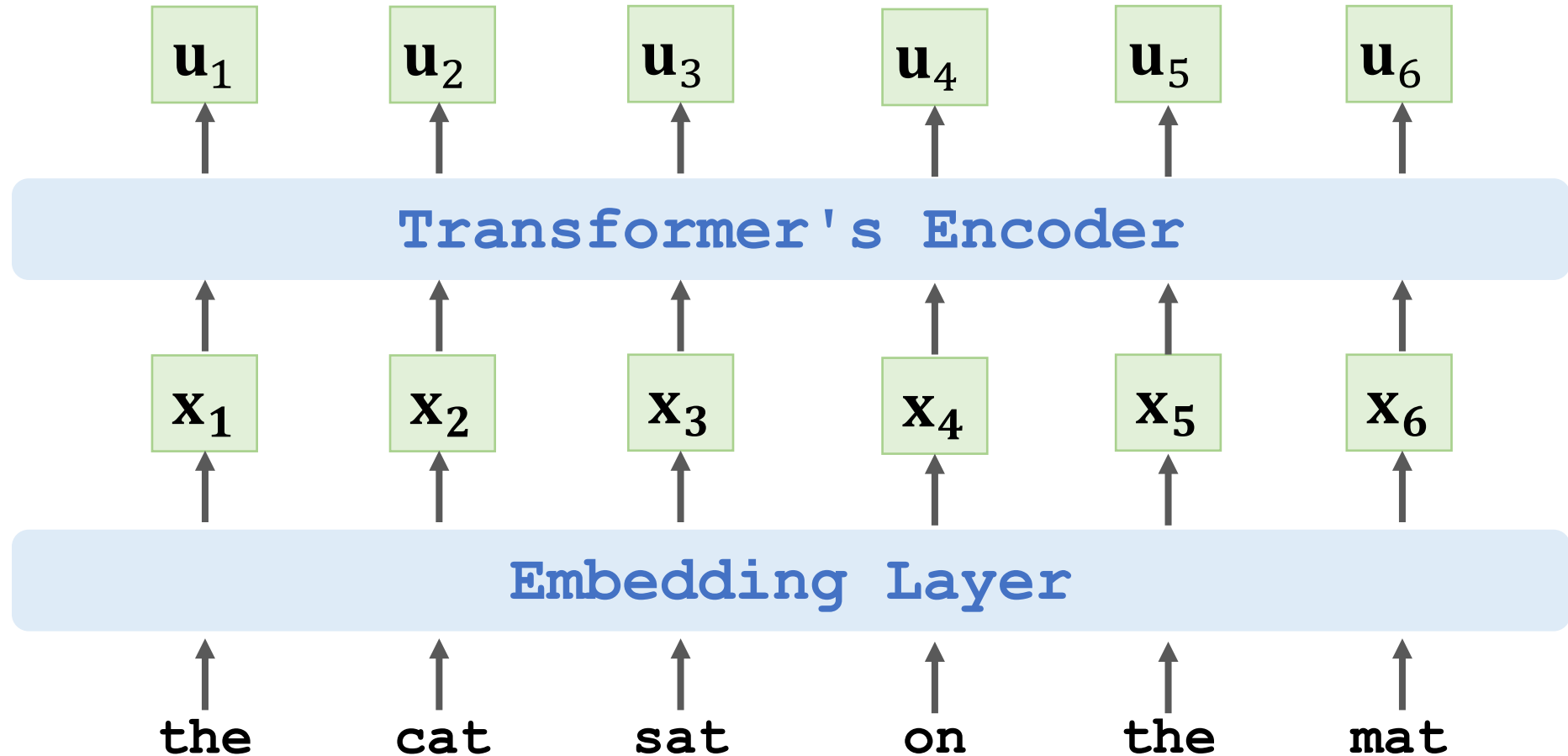
Revisit Transformer's Encoder

the cat sat on the mat

Revisit Transformer's Encoder



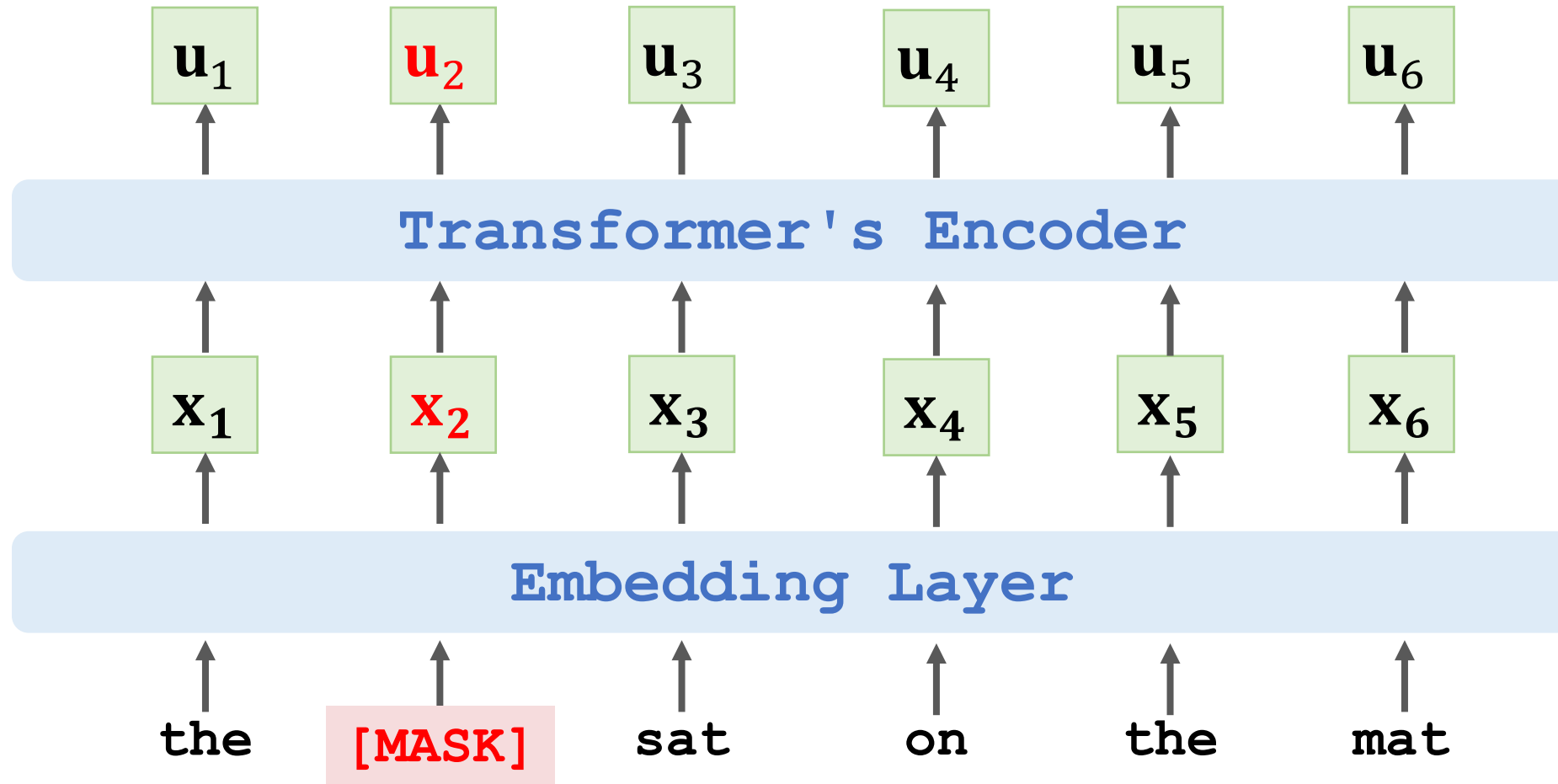
Revisit Transformer's Encoder

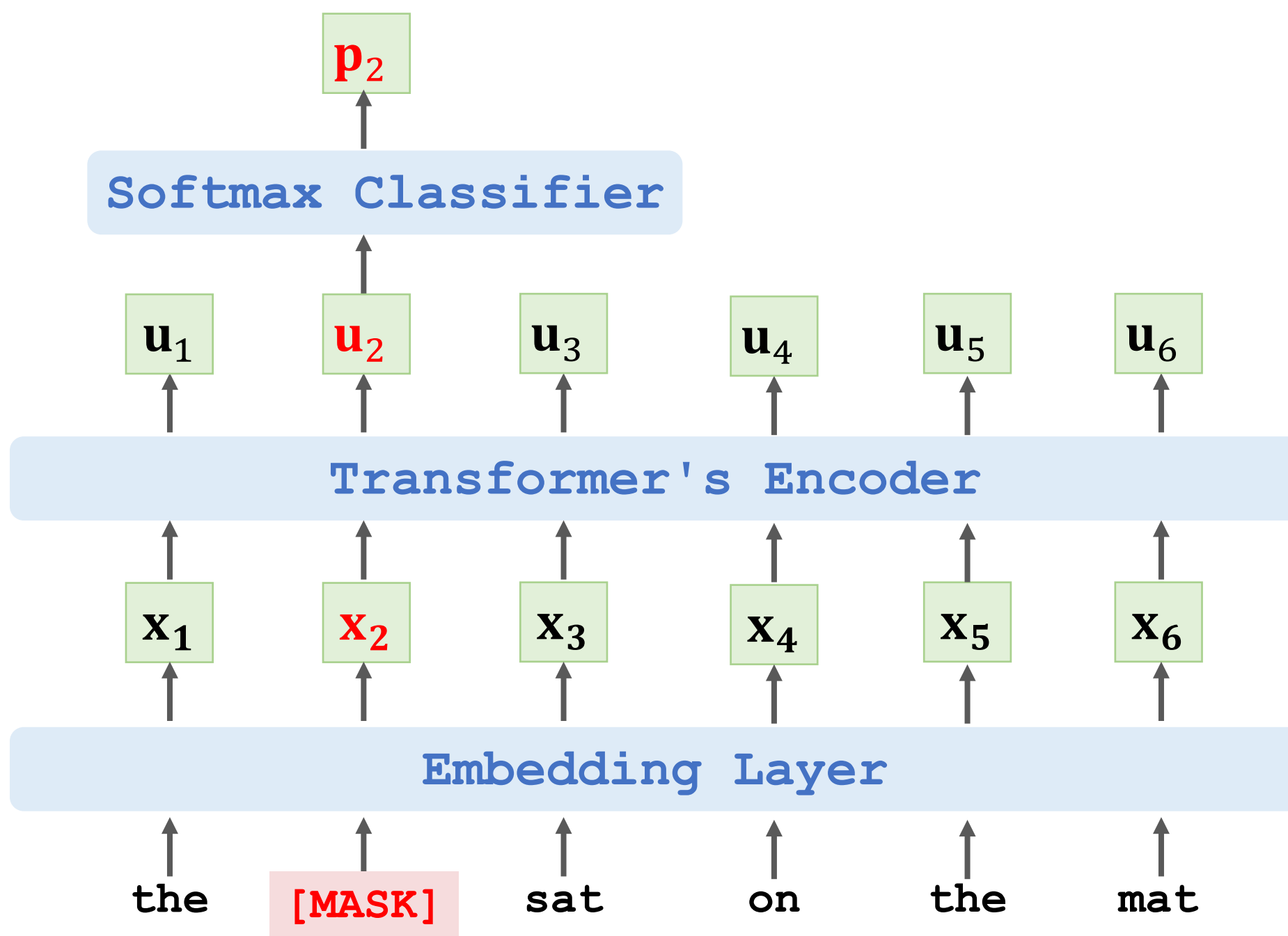


Randomly mask a word

- “The _____ sat on the mat”
- What is the masked word?

Randomly mask a word





Predict the masked word

- \mathbf{e}_2 : one-hot vector of the masked word “cat”.
- \mathbf{p}_2 : output probability distribution at the masked position.
- Loss = CrossEntropy(\mathbf{e}_2 , \mathbf{p}_2).
- Performing one gradient descent to update the model parameters.

Task 2: Predict the Next Sentence

Predict the next sentence

- Given the sentence:

"calculus is a branch of math".

- Is this the next sentence?

"it was developed by newton and leibniz"

- Is this the next sentence?

"panda is native to south central china"

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] "it was developed by newton and leibniz"

- **Target:** true

[CLS]

first sentence

[SEP]

second sentence

Input Representation

- **Input:**

[CLS] "calculus is a branch of math"

[SEP] "panda is native to south central china"

- **Target:** false

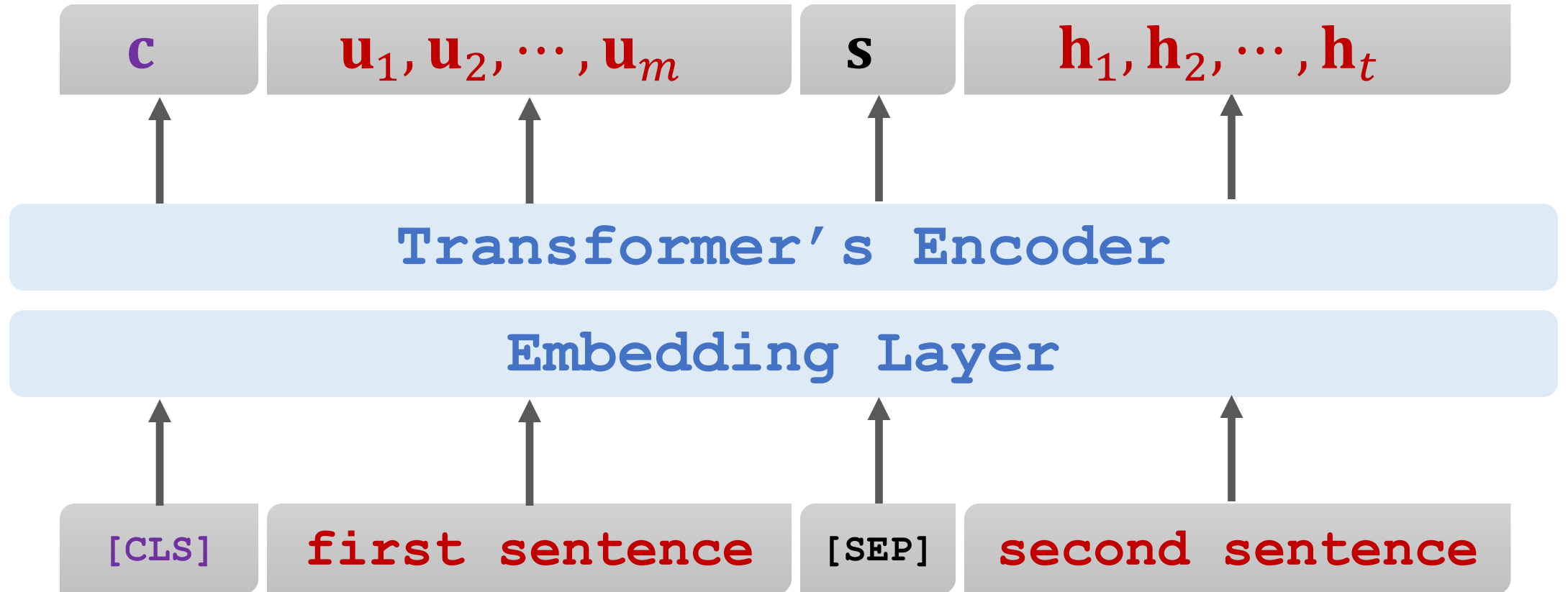
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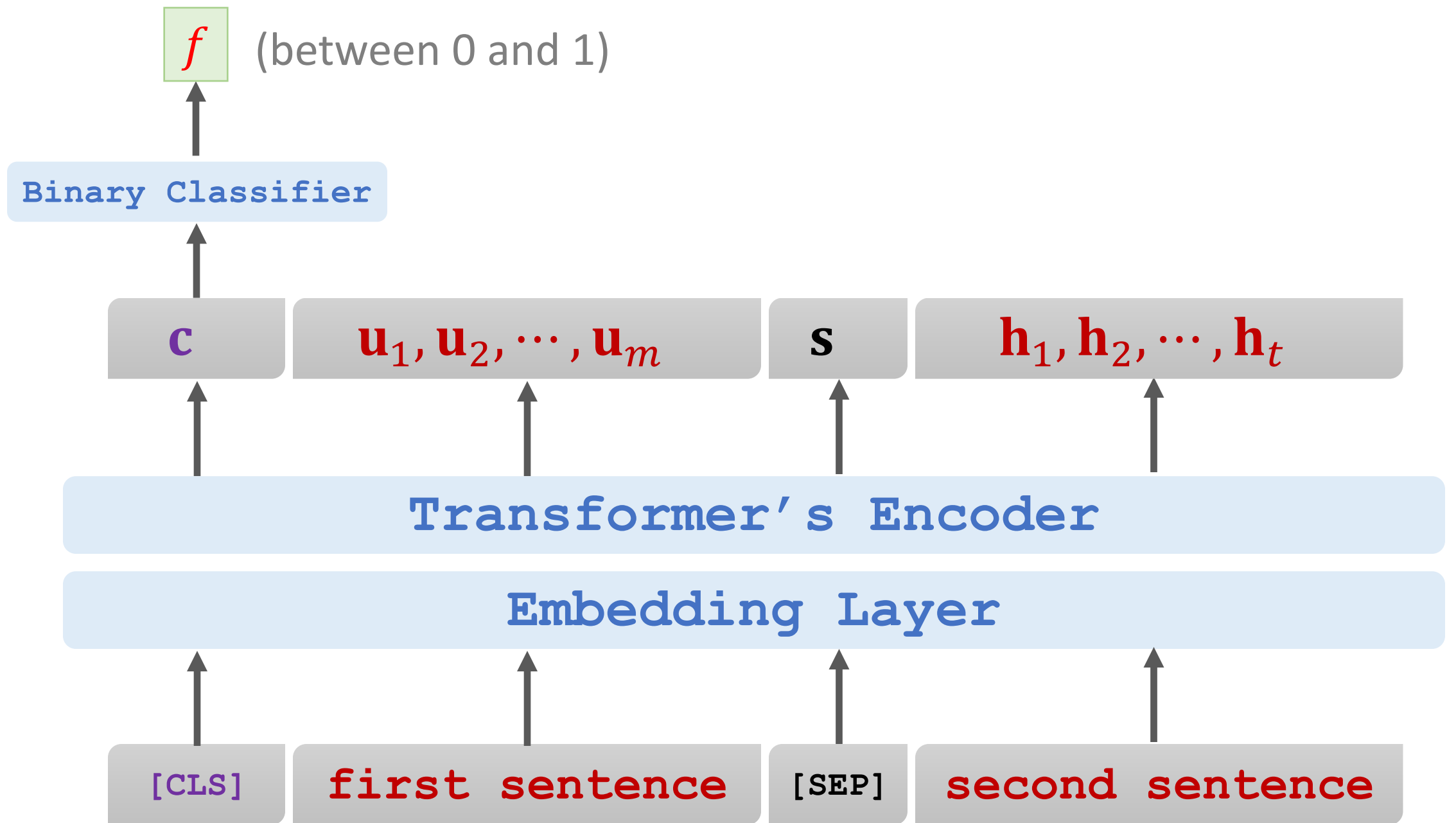
first sentence

[SEP]

second sentence

Predict the next sentence





Combining the two methods

Input Representation

- **Input:**

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

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

[CLS]

first sentence

[SEP]

second sentence

Input Representation

- **Input:**

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

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

[CLS]

first sentence

[SEP]

second sentence

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

- Use large-scale data, e.g., English Wikipedia (2.5 billion words.)
- BERT does not need manually labeled data. (Nice! Manual labeling is expensive.)
- Randomly mask words (with some tricks.)
- 50% of the next sentences are real. (The other 50% are fake.)

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.)

Thank you!