

Lecture 12:

Advanced Sequence Models

Deep Learning for Natural Language Processing

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Lecture Contents

Part 1: Introduction & Review

Part 2: Bidirectional RNNs

Part 3: Sequence-to-Sequence Models

Part 4: Teacher Forcing

Part 5: Attention Mechanism Basics

Part 6: Practical Implementation Tips

Part 7: Conclusion & Next Steps

Part 1/7:

Introduction & Review

- 1.** Review of Last Lesson
- 2.** Today's Learning Objectives
- 3.** Exploring the Limitations of RNNs

Review of Last Lesson

Part 1/7: Introduction & Review



Recurrent Neural Networks

RNNs process sequential data by maintaining **hidden states** that carry information across time



Hidden States

Hidden states act as **memory**, carrying contextual information from previous time steps to future



Gradient Challenges

Vanishing/exploding gradients make it difficult to learn long-term dependencies in sequences



LSTM & GRU Solutions

LSTM and GRU architectures use gates to mitigate gradient problems and capture long-term patterns



Gate Control Flow

Gates control information flow: **forget gate** (what to discard), **input gate** (what to add), **output gate**



Key Applications

RNNs excel at: **language modeling**, **time series prediction**, and **speech recognition**

1

Understand RNN Limitations

Explore vanishing gradients and long-term dependency issues

2

Master Bidirectional RNNs

Learn architecture and applications for context-aware processing

3

Implement Seq2Seq Models

Build encoder-decoder architectures with attention mechanism

4

Apply Advanced Techniques

Use teacher forcing, batching, and masking in practice

Key Limitations of Standard RNNs



Vanishing Gradient Problem



- Gradients diminish exponentially during backpropagation
- Early time steps receive negligible weight updates
- Hinders learning from distant past information



Long-term Dependencies



Information decays over long sequences

- Difficulty capturing dependencies across long sequences
- Context from early tokens gets lost or diluted
- Limits performance on tasks requiring long-range context



Exploding Gradient Problem



Sequential Processing Bottleneck





- Gradients grow exponentially during backpropagation
- Causes numerical instability and training divergence
- Requires gradient clipping to stabilize training

Cannot parallelize ▲

- Must process sequence step-by-step sequentially
- Cannot leverage parallel computation effectively
- Slow training and inference on long sequences

Part 2/7:

Bidirectional RNNs

- 4.** Why Bidirectional?
- 5.** Bidirectional RNN Architecture
- 6.** BiRNN Formulas and Operations
- 7.** BiRNN Pros and Cons & Applications

Context Matters: Unidirectional vs Bidirectional Processing

Unidirectional RNN



The cat sat on the bank
of the river



Limited Context

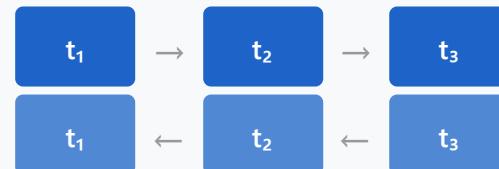
Only sees **past** words. At "bank", cannot see "river" yet.

- ✗ Cannot disambiguate without future context
- ✗ Incomplete understanding at each time step

Bidirectional RNN



The cat sat on the bank
of the river



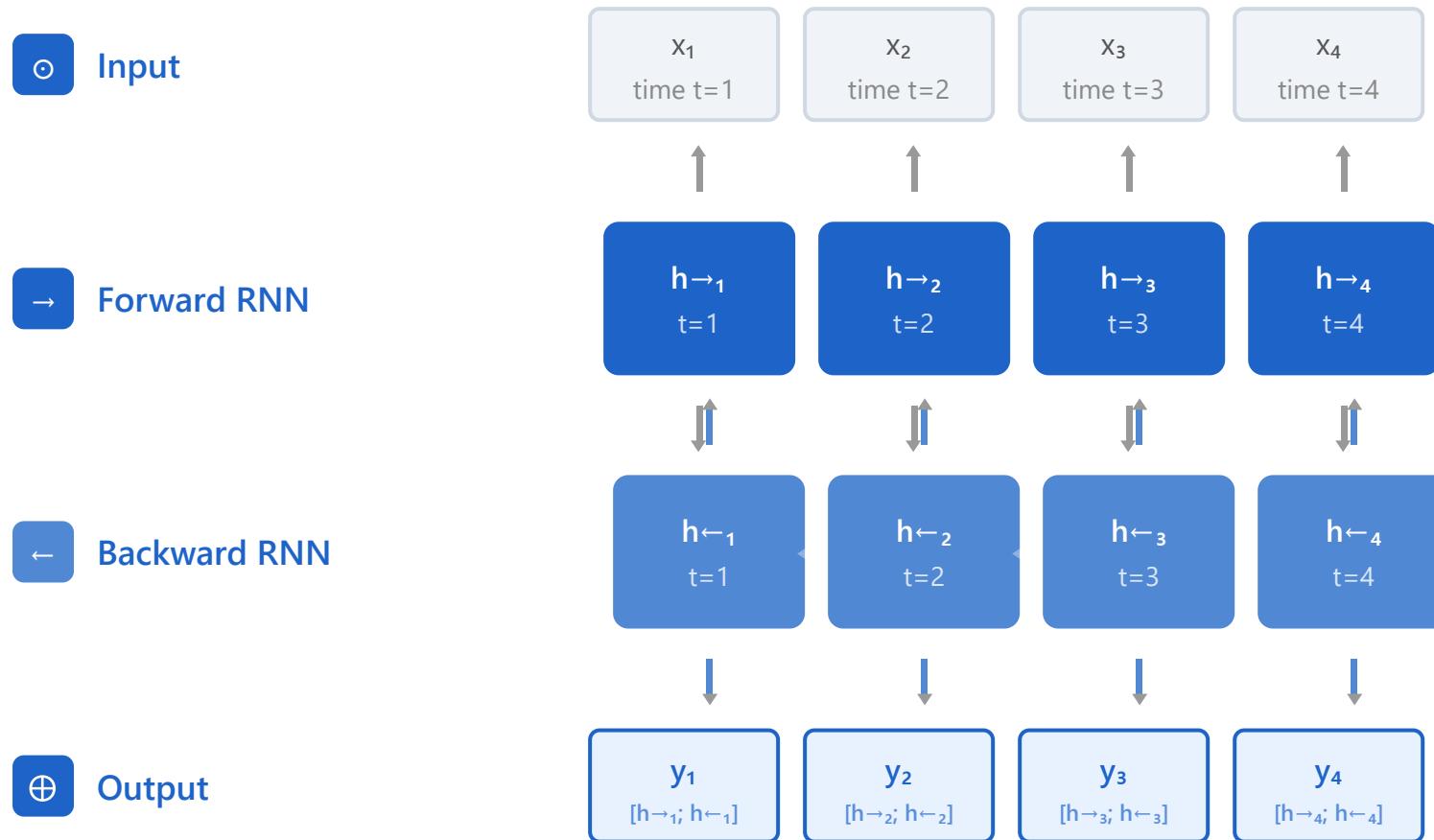
Full Context

Sees **both past and future** words. At "bank", also sees "river".

- ✓ Complete context for better disambiguation
- ✓ Richer representations at each time step

✗ Poor performance on tasks requiring full sentence context

✓ Superior for NER, POS tagging, sentiment analysis



Key Feature

BiRNN processes sequences in both directions, concatenating forward ($h \rightarrow$) and backward ($h \leftarrow$) hidden states to capture full context at each time step.

BiRNN Formulas and Operations

Notation Guide

x_t

Input at time t

\vec{h}_t

Forward hidden state

\hat{h}_t

Backward hidden state

W_f, U_f

Forward weights

W_b, U_b

Backward weights

y_t

Output at time t



Forward RNN (Left to Right)

Hidden State:

$$\vec{h}_t = \tanh(W_f \cdot x_t + U_f \cdot \vec{h}_{t-1} + b_f)$$

Processes sequence from **start to end**, capturing past context. Each hidden state depends on current input and previous hidden state.



Backward RNN (Right to Left)

Hidden State:

$$\hat{h}_t = \tanh(W_b \cdot x_t + U_b \cdot \hat{h}_{t+1} + b_b)$$

Processes sequence from **end to start**, capturing future context. Each hidden state depends on current input and next hidden state.



Output Combination

Concatenation:

$$h_t = [h_t^{\text{F}} ; h_t^{\text{B}}]$$

Output Layer:

$$y_t = W_o \cdot h_t + b_o = W_o \cdot [h_t^{\text{F}} ; h_t^{\text{B}}] + b_o$$

Combines both directions by **concatenating** forward and backward hidden states, creating a representation with **full context** (past + future).



Key Computational Points



Independent Processing

Forward and backward RNNs have separate parameters and process independently



Double Dimensionality

Output dimension is $2 \times$ hidden size due to concatenation:
 $[h_t^{\text{F}}; h_t^{\text{B}}]$



Parallel Computation



Full Sequence Required

Forward and backward passes can be computed in parallel for efficiency

Complete sequence must be available before backward RNN can start processing



Implementation Note

In practice, frameworks like PyTorch and TensorFlow handle BiRNN efficiently with built-in functions (e.g., `nn.LSTM(bidirectional=True)`). The framework automatically manages the forward and backward passes, parameter initialization, and output concatenation.



Advantages

- ✓ **Full context** - captures both past and future information
- ✓ **Better representations** - richer hidden states at each time step
- ✓ **Improved accuracy** - superior performance on many NLP tasks
- ✓ **Disambiguation** - resolves ambiguity using surrounding context



Disadvantages

- ✗ **Cannot stream** - requires full sequence before processing
- ✗ **Higher computation** - 2x parameters and memory compared to unidirectional
- ✗ **Not for generation** - unsuitable for autoregressive tasks
- ✗ **Slower training** - increased training time and inference latency



Key Applications



Named Entity Recognition



POS Tagging



Sentiment Analysis

Capture sentiment from entire text

Identify entities using full sentence context

Accurate part-of-speech labeling with context



Slot Filling

Extract structured info from utterances



Dependency Parsing

Understand syntactic relationships



Speech Recognition

Phoneme prediction with context

Part 3/7:

Sequence-to-Sequence

- 8.** The Need for Seq2Seq
- 9.** Encoder-Decoder Architecture
- 10.** Encoder Details
- 11.** Decoder Details
- 12.** Overall Seq2Seq Process

Why Do We Need Sequence-to-Sequence Models?

⚠ Challenge: Variable-Length Input → Variable-Length Output

Machine Translation

Hello



안녕하세요

Text Summarization

Long article...



Short summary

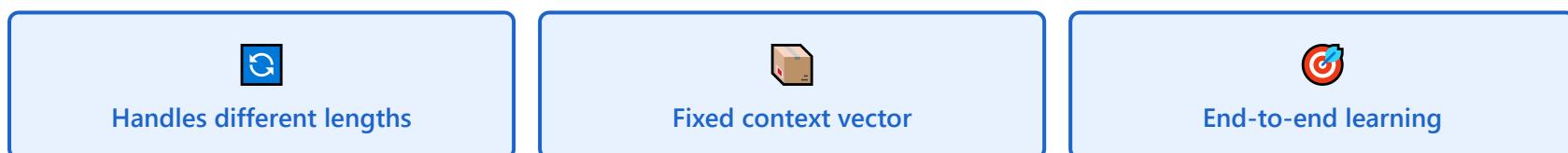
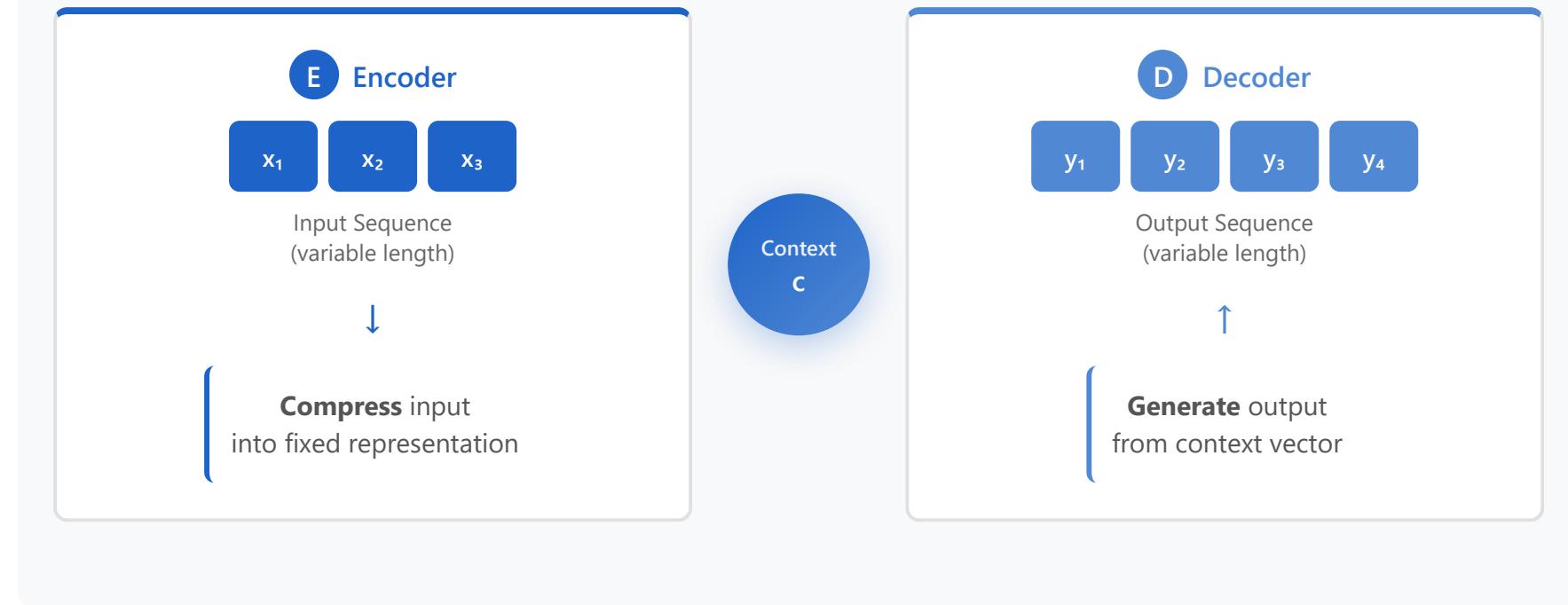
Question Answering

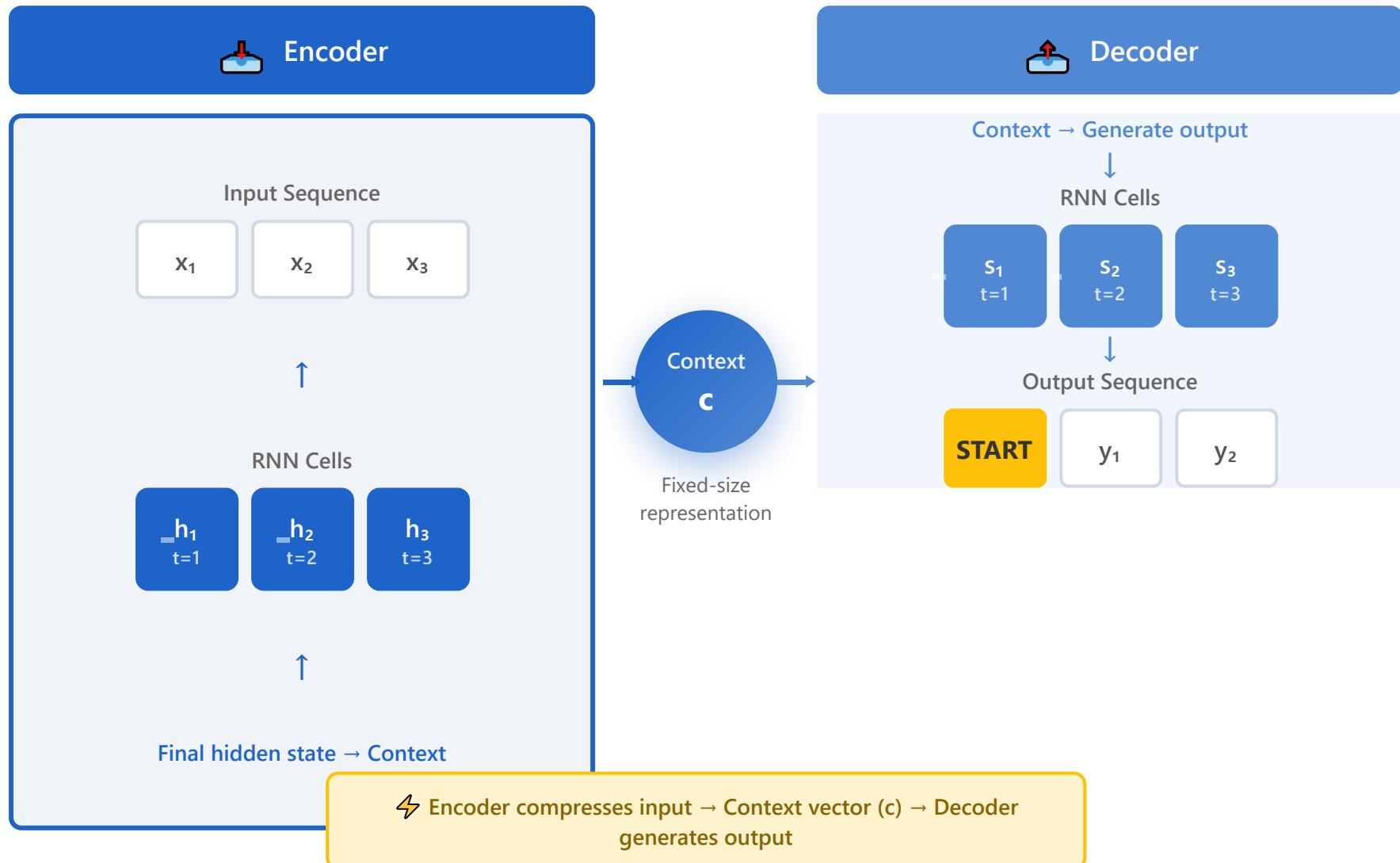
What is AI?



AI is...

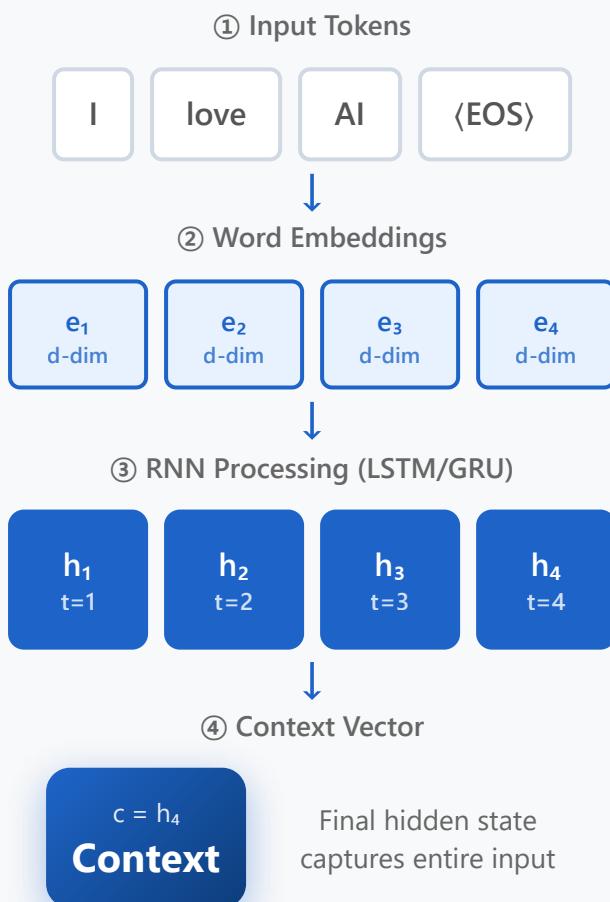
✓ Solution: Encoder-Decoder Architecture







Encoder Processing Flow



Key Components

- **Embedding Layer:** Convert tokens to vectors
- **RNN:** LSTM or GRU for sequential processing
- **Hidden States:** Maintain temporal information



Computation

- Process input sequentially left-to-right
- Each step updates hidden state

$$h_t = f(x_t, h_{t-1})$$



Output

- **Context vector (c):** Final hidden state h_n
- Fixed-size representation of variable-length input
- Passed to decoder as initial state



Decoder Processing Flow

① Context Vector (from Encoder)

Context
c

Initializes decoder state: $s_0 = c$



② Initial Input Token

<START>

Special token to begin generation



③ RNN Processing (Autoregressive)

s_1
t=1

s_2
t=2

s_3
t=3

s_4
t=4



④ Generated Output Tokens

나는
 y_1

AI를
 y_2

사랑해
 y_3

<EOS>
 y_4



Key Components

- **Initial State:** $s_0 = \text{context vector } c$
- **RNN:** LSTM or GRU for generation
- **Softmax:** Predicts next token



Computation

- Each step takes previous output as input
- Updates hidden state and predicts next token

```
s_t = f(y_{t-1}, s_{t-1})  
y_t = softmax(W · s_t)
```



Generation Process

- **Autoregressive:** Uses own predictions
- Stops when <EOS> token is generated
- Can use greedy or beam search decoding

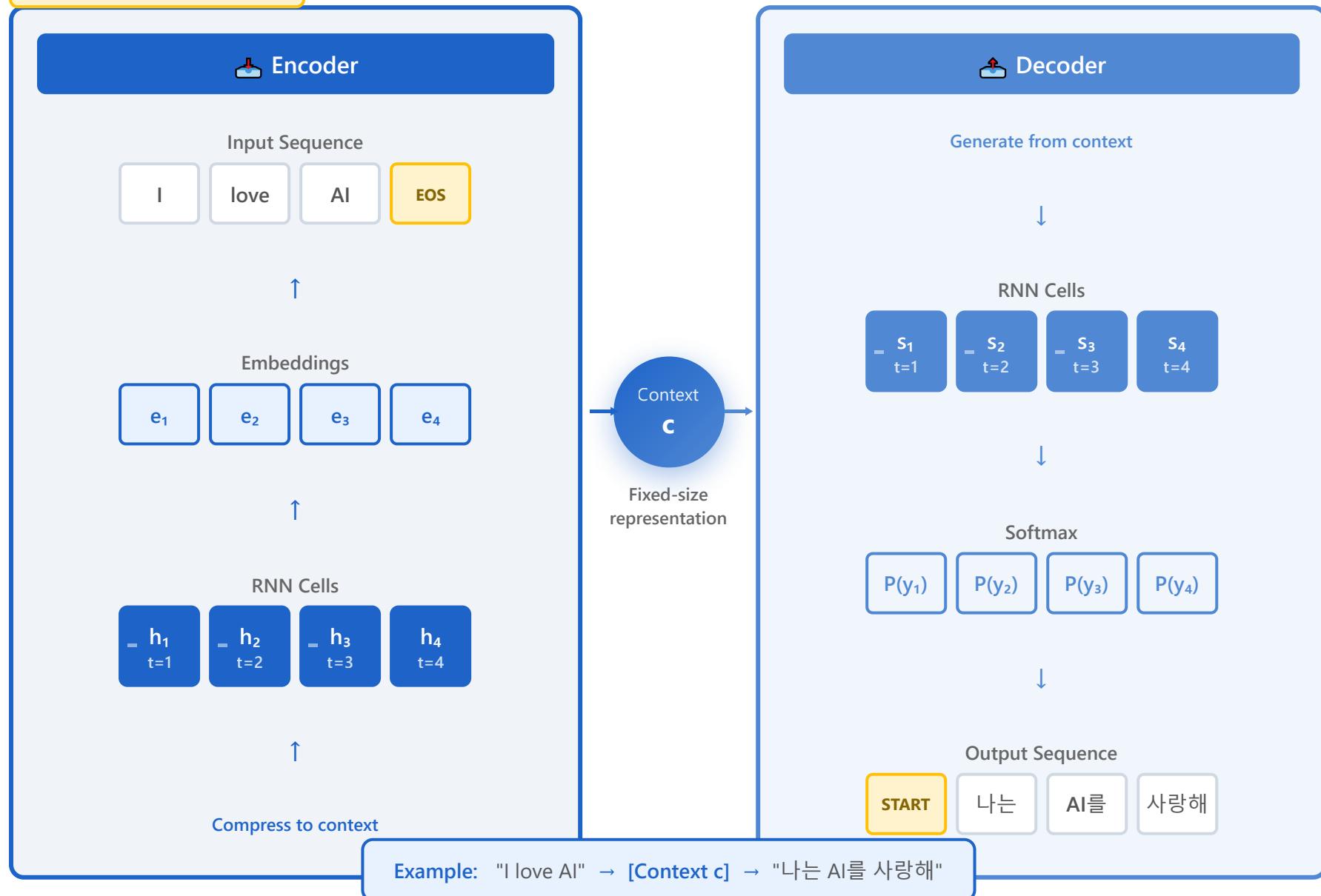
△ Key Difference

Decoder uses its own previous predictions as input (autoregressive), unlike encoder which

processes fixed input.

Variable Input → Fixed Context → Variable Output

Complete Sequence-to-Sequence Process



Part 4/7:

Teacher Forcing

- 13.** What is Teacher Forcing?
- 14.** Teacher Forcing vs. Autoregressive
- 15.** Teacher Forcing Problems and Solutions

What is Teacher Forcing?

Definition

Teacher Forcing is a training strategy where the **ground-truth (target) tokens** from the training data are used as inputs to the decoder at each time step, instead of the model's own predictions.

Without Teacher Forcing

(Autoregressive)

Step 1:



With Teacher Forcing

(Training Mode)

Step 1:





↳ Uses own predictions (errors accumulate!)

- ✗ Errors compound over time
- ✗ Slower training convergence
- ✗ Exposure bias problem



↳ Uses ground-truth targets (no error accumulation!)

- ✓ Faster training convergence
- ✓ Prevents error accumulation
- ✓ More stable gradient flow



Teacher Forcing is used during **training** to speed up learning. During **inference**, the model uses its own predictions (autoregressive).

Teacher Forcing vs. Autoregressive Decoding

Teacher Forcing

Training

How it Works

- Uses **ground-truth** target tokens as input
- Model receives correct previous token
- No error accumulation during training

✓ Advantages

- + Faster convergence
- + Stable gradients

Autoregressive

Inference

How it Works

- Uses model's **own predictions** as input
- Each prediction feeds into next step
- Errors can compound over sequence

✓ Advantages

- + Matches inference mode
- + More realistic training

- + Easier to train
- + Parallel processing

- + Better generalization
- + No exposure bias

X Disadvantages

- Exposure bias problem
- Train/test mismatch
- Less robust at inference
- Can't handle own errors

X Disadvantages

- Slower training
- Unstable gradients
- Error accumulation
- Sequential processing

Quick Comparison

Aspect	Teacher Forcing	Autoregressive
Input Source	Ground truth	Model predictions
Usage Phase	Training	Inference
Training Speed	Fast ⚡	Slow 🐀
Robustness	Lower 📈	Higher ✅

Teacher Forcing: Problems and Solutions

⚠ Key Problems

✗ Exposure Bias

Model never sees its own mistakes during training, struggles at inference

✗ Train-Test Mismatch

Training uses ground truth, but inference uses predictions

✗ Error Recovery

Model doesn't learn to recover from its own errors

✗ Overconfidence

Model becomes overconfident on ground-truth inputs

✓ Solutions & Techniques

1 Scheduled Sampling

Gradually mix ground-truth and model predictions during training

Training Progress

100% GT 100% Pred

Early → $\epsilon = 0.1$ → Mid → $\epsilon = 0.5$ →
Late → $\epsilon = 0.9$

2 Mixed Training

Randomly alternate between teacher forcing and autoregressive modes

Random Sampling

GT Pr GT GT Pr

$p = 0.5$ (50% chance each)

3 Curriculum Learning

Start with easier tasks and progressively increase difficulty

Learning Stages

1. Short sequences
2. Medium sequences
3. Long sequences
4. Full complexity

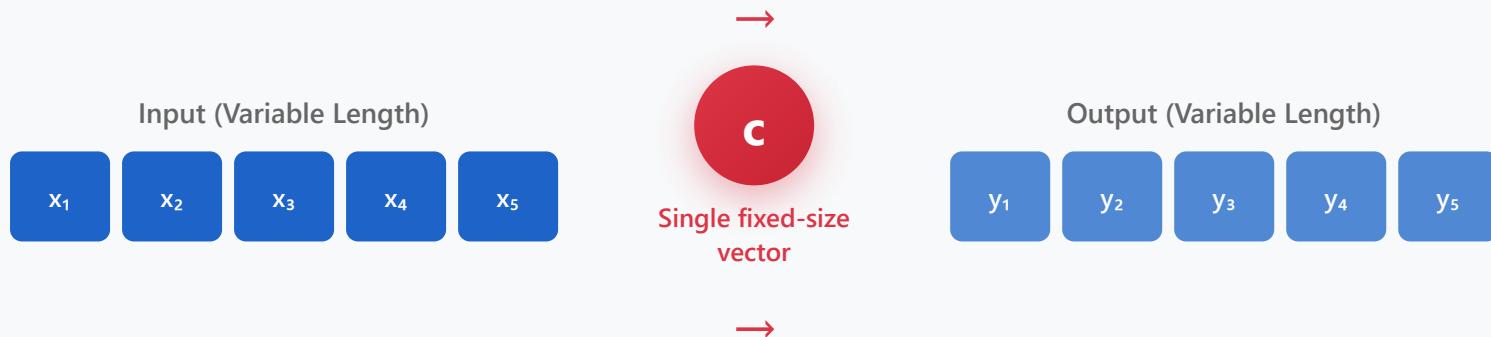
Part 5/7:

Attention Mechanism Basics

- 16.** Limitations of Seq2Seq
- 17.** Core Ideas of Attention
- 18.** Attention Mechanism Structure
- 19.** Attention Formula
- 20.** Effects of Attention

Limitations of Basic Seq2Seq Models

⚠ The Information Bottleneck Problem



1 Information Bottleneck

All input information must be compressed into a **single fixed-size context vector**, regardless of input length.

Impact:

Long sequences lose critical information. Model struggles with lengthy inputs.

2 Gradient Vanishing

Earlier tokens in long sequences have **vanishing gradients** as information must flow through many time steps.

Impact:

Poor performance on long-range dependencies and long documents.

3 Equal Weighting

All input tokens treated equally when creating context vector - **no selective focus** on important parts.

Impact:

Cannot emphasize relevant information for each output step.

4 No Alignment

Decoder has **no mechanism to look back** at specific input positions when generating each output token.

Impact:

Difficult tasks requiring input-output alignment (e.g., translation).



Solution needed: **Attention Mechanism** allows decoder to selectively focus on different parts of input for each output step!

Core Ideas of Attention Mechanism

💡 Central Concept

Instead of compressing everything into a single context vector, **let the decoder selectively focus on different parts of the input** at each time step based on what's most relevant.

Without Attention

Encoder: h_1, h_2, h_3, h_4



Fixed
 C



Decoder

With Attention

Encoder: h_1, h_2, h_3, h_4



Weights:

0.1, 0.2, 0.6, 0.1



Dynamic
 c_t



Decoder

Same static context for all decoder steps. Information bottleneck. Long sequences lose details.

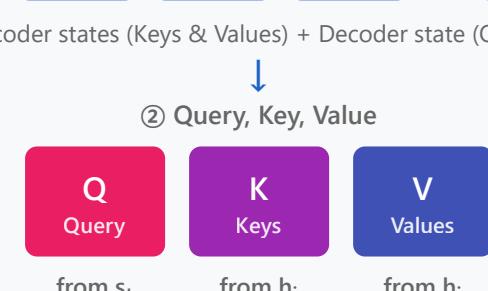
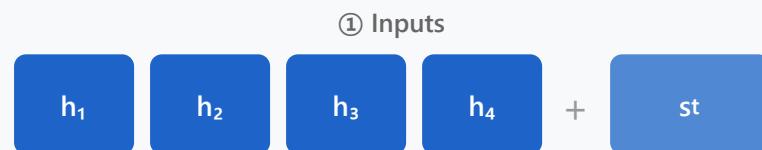
Dynamic context computed at each step. Weighted focus on relevant parts. Full input information accessible.

Key Benefits of Attention

- ✓ No information bottleneck
- ✓ Handles long sequences
- ✓ Selective focus
- ✓ Better alignment
- ✓ Interpretable weights
- ✓ Improved performance

Attention Mechanism Structure

Step-by-Step Attention Computation



↓

③ Compute Scores

$$\text{score} = Q \cdot K^T$$

Similarity between Q and each K

↓

④ Attention Weights (Softmax)

$\alpha_1: 0.1 \quad \alpha_2: 0.2 \quad \alpha_3: 0.6 \quad \alpha_4: 0.1$

Normalized scores (sum to 1.0)

↓

⑤ Context Vector

Query

"What am I looking for?" Derived from current decoder state to find relevant encoder states.

$$Q = W_Q \times s_t$$

Key

"What do I contain?" Encoder states transformed to be compared with query.

$$K = W_K \times h_i$$

Value

"What information to extract?" Actual content to be aggregated based on attention weights.

$$V = W_V \times h_i$$

Weighted sum

c_t

$$c_t = \sum (\alpha_i \times V_i)$$

Attention Mechanism: Mathematical Formulas

Compute Attention Scores

Similarity

1

$$e_{t,i} = \text{score}(s_t, h_i) = s_t^T W_a h_i$$

Calculate similarity between decoder state s_t and each encoder hidden state h_i using learnable weight matrix W_a

Compute Attention Weights

Softmax

2

$$\alpha_{t,i} = \exp(e_{t,i}) / \sum_j \exp(e_{t,j})$$

Normalize scores using softmax to obtain attention weights that sum to 1. Higher scores → higher attention weights

Compute Context Vector

Weighted Sum

3

$$c_t = \sum_i \alpha_{t,i} \times h_i$$

Weighted sum of encoder hidden states using attention weights. More relevant states contribute more to the context

Generate Output

Prediction

4

$$\hat{y}_t = \text{softmax}(W_o [s_t; c_t] + b_o)$$

Concatenate decoder state and context vector, then pass through output layer to predict next token

Key Components Summary

Input Dimensions

$$s_t \in \mathbb{R}^d$$

$$h_i \in \mathbb{R}^d$$

$$W_a \in \mathbb{R}^{d \times d}$$

Attention Properties

$$\sum_i \alpha_{t,i} = 1$$

$$\alpha_{t,i} \in [0, 1]$$

$$0 \leq \alpha_{t,i} \leq 1$$

Output

$$c_t \in \mathbb{R}^d$$

Dynamic context

Per time step

s_t: Decoder hidden state **h_i:** Encoder hidden state **e_{t,i}:** Attention score **α_{t,i}:** Attention weight **c_t:** Context vector
W_a: Alignment weight matrix



Concrete Example with 3D Vectors



Setup: d = 3 (vector dimension), using 2 encoder hidden states (h₁, h₂).

1

Given Input Data

Decoder hidden state (s_t):

$$s_t = [1, 2, 1]^T$$

Encoder hidden states:

$$h_1 = [2, 0, 1]^T$$

$h_2 = [1, 1, 2]^T$

Weight matrix (W_a) $\in \mathbb{R}^{3 \times 3}$:

$W_a = [1 \ 0 \ 0] \ [0 \ 1 \ 0] \ [0 \ 0 \ 1]$

(Using Identity Matrix for simplicity)

2

Compute Attention Scores

► Formula: $e_{t,i} = s_t^T W_a h_i$

• Score for h_1 :

$$\begin{aligned} e_{t,1} &= s_t^T W_a h_1 = [1, 2, 1] \cdot [2, 0, 1]^T \\ &= (1 \times 2) + (2 \times 0) + (1 \times 1) \\ &= 2 + 0 + 1 \\ &= 3 \end{aligned}$$

• Score for h_2 :

$$\begin{aligned} e_{t,2} &= s_t^T W_a h_2 = [1, 2, 1] \cdot [1, 1, 2]^T \\ &= (1 \times 1) + (2 \times 1) + (1 \times 2) \\ &= 1 + 2 + 2 \\ &= 5 \end{aligned}$$



Attention Scores:

$$e_{t,1} = 3, e_{t,2} = 5$$

3

Compute Attention Weights (Softmax)

► Formula: $\alpha_{t,i} = \exp(e_{t,i}) / \sum_j \exp(e_{t,j})$

- Exponential calculation:

$$\exp(e_{t,1}) = \exp(3) \approx 20.09$$

$$\exp(e_{t,2}) = \exp(5) \approx 148.41$$

- Sum:

$$\sum \exp(e_{t,j}) = 20.09 + 148.41 = 168.50$$

- Attention Weights:

$$\alpha_{t,1} = 20.09 / 168.50 \approx 0.119$$

$$\alpha_{t,2} = 148.41 / 168.50 \approx 0.881$$

- Verification:

$$\alpha_{t,1} + \alpha_{t,2} = 0.119 + 0.881 = 1.000 \checkmark$$



Attention Weights:

$$\alpha_{t,1} \approx 0.119 \text{ (11.9\%)}, \alpha_{t,2} \approx 0.881 \text{ (88.1\%)}$$

 **Interpretation:** h_2 receives about 88% attention because it's more similar to s_t !

4 Compute Context Vector

 **Formula:** $c_t = \sum_i \alpha_{t,i} \times h_i$

- **Weighted sum calculation:**

$$c_t = \alpha_{t,1} \times h_1 + \alpha_{t,2} \times h_2$$

- **First term:**

$$\begin{aligned}\alpha_{t,1} \times h_1 &= 0.119 \times [2, 0, 1]^T \\ &= [0.238, 0.000, 0.119]^T\end{aligned}$$

- **Second term:**

$$\begin{aligned}\alpha_{t,2} \times h_2 &= 0.881 \times [1, 1, 2]^T \\ &= [0.881, 0.881, 1.762]^T\end{aligned}$$

- **Final Context Vector:**

$$\begin{aligned}c_t &= [0.238, 0.000, 0.119]^T + [0.881, 0.881, 1.762]^T \\ &= [1.119, 0.881, 1.881]^T\end{aligned}$$



Final Context Vector:

$$c_t = [1.119, 0.881, 1.881]^T$$

 **Result Interpretation:** The context vector is formed closer to h_2 (88.1% weight). This means the current decoder state is more relevant to h_2 .

Key Takeaways

1. Attention Score measures similarity via dot product between two vectors
2. Softmax normalizes scores into probabilities between 0 and 1
3. Context Vector is a weighted average, focusing on important information
4. High similarity → high attention weight → greater influence

The Effects of Attention Mechanism

Before Attention

All inputs treated equally

	x_1	x_2	x_3	x_4
y_1	0.25	0.25	0.25	0.25
y_2	0.25	0.25	0.25	0.25
y_3	0.25	0.25	0.25	0.25

Static context: Same fixed representation used for all outputs. No selective focus on relevant information.

With Attention

Dynamic attention weights

	x_1	x_2	x_3	x_4
y_1	0.7	0.2	0.05	0.05
y_2	0.1	0.6	0.25	0.05
y_3	0.05	0.15	0.3	0.5

Dynamic context: Different attention distribution for each output. Focuses on most relevant inputs at each step.



Better Alignment

Learns input-output correspondence automatically. Essential for translation tasks.



Long Sequences

Handles long inputs effectively without information bottleneck. No gradient vanishing.



Interpretability

Attention weights visualize what model focuses on. Debugging and understanding easier.

Translation Quality

↑ 15-20%

BLEU Score Improvement

Long Sequences

↑ 30-40%

Performance on 50+ tokens

Gradient Flow

✓ Stable

Direct path to each input

Part 6/7:

Practical Implementation Tips

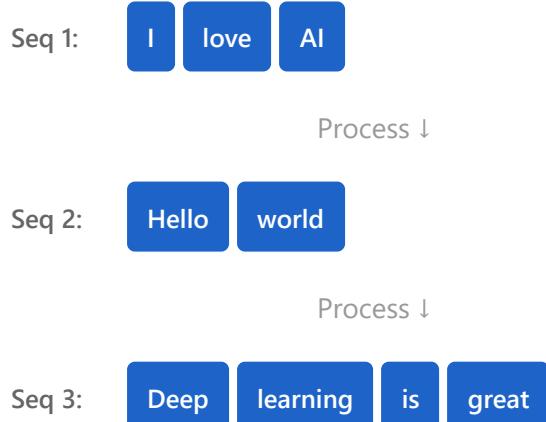
- 21.** Batching
- 22.** Masking
- 23.** Practical Checklist

Batching in Sequence Models

⚠ Challenge: Variable-Length Sequences

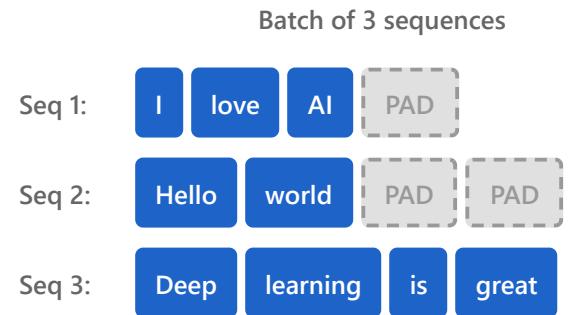
Sequences in a batch often have different lengths. We need to pad them to the same length for efficient parallel processing on GPUs.

Without Batching



Sequential processing: Process one sequence at a time.
Slow and inefficient. Cannot leverage GPU parallelism.

With Batching (Padded)



All padded to max length (4 tokens)

⚡ Parallel: 1x time (3x faster!)

Parallel processing: Process all sequences simultaneously.
Fast and efficient. Full GPU utilization. Need masking!



Padding Strategy

Add special PAD tokens to shorter sequences to match the longest sequence in batch.

```
pad_sequence(sequences,  
             batch_first=True,  
             padding_value=0)
```



Use Masking

Create masks to ignore PAD tokens during attention computation and loss calculation.

```
mask = (input != PAD)  
scores.masked_fill(  
    ~mask, -inf)
```



Batch Size

Balance between memory and speed.
Larger batches = faster but more memory. Typical: 32-128.

```
# Common sizes  
batch_size = 32  
batch_size = 64  
batch_size = 128
```

Masking in Sequence Models

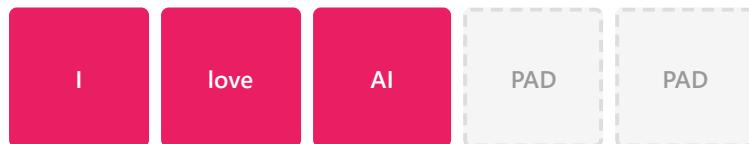
💡 Why Do We Need Masking?

Masks prevent the model from attending to **invalid positions** like padding tokens or future tokens, ensuring correct computation and preventing information leakage.

Padding Mask

Ignore PAD tokens in attention computation

Example: Sequence with padding



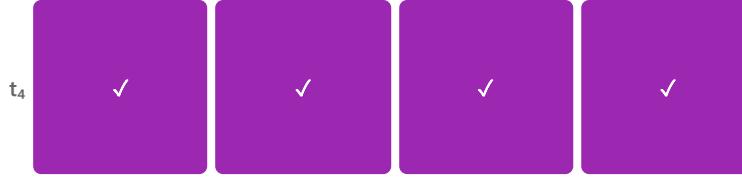
■ Valid (1) □ Masked (0)

Look-ahead Mask

Prevent attending to future tokens (causal)

Attention mask matrix (lower triangular)

	t ₁	t ₂	t ₃	t ₄
t ₁	✓	X	X	X
t ₂	✓	✓	X	X
t ₃	✓	✓	✓	X



```
mask = (input != PAD_TOKEN)
scores.masked_fill(~mask, -∞)
```

Can attend Blocked

① Create Mask

```
# Padding mask
pad_mask = (x != PAD)

# Shape: (batch, seq_len)
```

② Apply to Attention

```
# Before softmax
scores = scores.masked_fill(
    ~mask, float('-inf'))
attn = softmax(scores)
```

```
mask = torch.tril(
    torch.ones(seq_len, seq_len))
```

③ Combine Masks

```
# Both padding + lookahead
mask = pad_mask &
       lookahead_mask
# Logical AND
```

Sequence Models: Practical Implementation Checklist

Essential considerations before deploying your model



Data Preparation

Tokenization

Choose appropriate tokenizer (BPE, WordPiece, SentencePiece)

Vocabulary Size

Balance between coverage and efficiency (typically 10K-50K)

Special Tokens

Define PAD, UNK, BOS, EOS tokens correctly

Sequence Length

Set max length based on data distribution (e.g., 128, 256, 512)



Model Architecture

Hidden Dimensions

Choose appropriate size (256, 512, 1024) based on task

Number of Layers

Balance depth and training time (2-12 layers typical)

Attention Mechanism

Implement proper attention with correct masking

Dropout Rates

Add dropout for regularization (0.1-0.3 typical)



Training Strategy

Teacher Forcing

Use during training, consider scheduled sampling

Batch Size

Optimize for GPU memory (32-128 typical)



Implementation Details

Padding & Masking

Properly handle variable-length sequences

Loss Calculation

Ignore padding tokens in loss computation

Learning Rate

Use warmup + decay schedule (e.g., 1e-4 to 1e-5)

 Gradient Clipping

Prevent exploding gradients (clip norm 1.0-5.0)

 Inference Strategy

Choose beam search, greedy, or sampling decoding

 Evaluation Metrics

Track BLEU, perplexity, or task-specific metrics

 **Quick Reference: Typical Hyperparameters****Hidden Size**

256-1024

**Batch Size**

32-128

**Vocab Size**

10K-50K

**Learning Rate**

1e-4 ~ 1e-3

Part 7/7:

Conclusion & Next Steps

24. Summary and Preview of Next Lecture

Advanced Sequence Models: Summary & Preview



What We Learned Today

1

Seq2Seq Architecture

- Encoder-Decoder
- Context vector
- Variable length I/O

2

RNN Variants

- LSTM cells
- GRU cells
- Gradient flow

3

Bidirectional RNN

- Forward + Backward
- Context from both
- Better encoding

4

Teacher Forcing

- Training strategy
- Exposure bias
- Scheduled sampling

5

Attention Mechanism

- Query, Key, Value
- Dynamic context
- Alignment weights

6

Implementation

- Batching & Padding
- Masking strategies
- Practical tips



Next Lecture: Transformers & Modern Architectures



Self-Attention



Transformer Architecture



Multi-Head Attention



BERT & GPT



Key Takeaway: Attention mechanism revolutionized sequence modeling by allowing models to selectively focus on relevant parts of input, solving the information bottleneck problem!

Thank you

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