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Introduction to AI (ID-AI101B)
Even Semester
Session 2025-26

Language Translation with Sequence Models

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Language Translation with Sequence Models

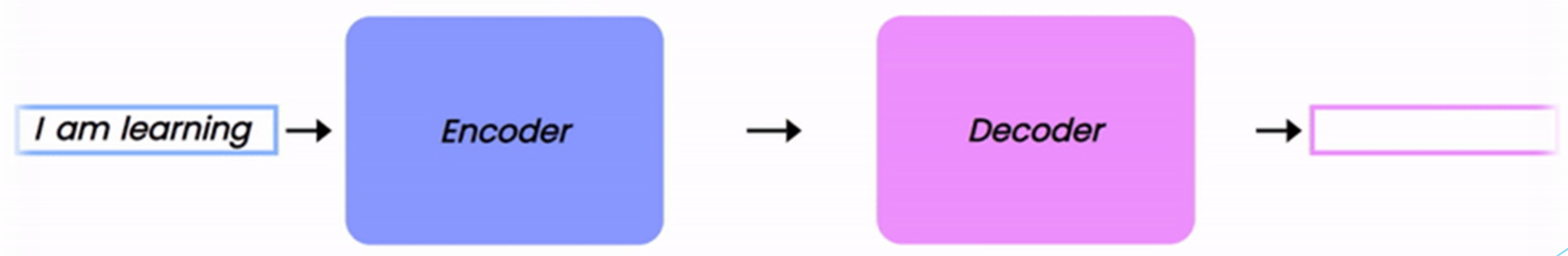
- Converts text from one language to another while preserving meaning.
- Sequence models handle text as ordered data, capturing word relationships.
- Uses Encoder-Decoder architecture for understanding and generating text.
- Powered by models like RNNs, LSTMs, GRUs, and Transformers.

Objectives

- To **automate translation** between different human languages.
- To **preserve meaning and context** while translating text.
- To **handle variable-length sequences** like full sentences or paragraphs.
- To **improve translation quality** using advanced models (e.g., attention, transformers).
- To **enable real-time translation** in applications like chatbots and translators.

The Encoder-Decoder Architecture

•**Encoder**: Processes the input sentence and compresses it into a fixed-size context vector (a summary of the sentence).
•**Context Vector**: Acts as a bridge, carrying the essential meaning from the encoder to the decoder.
•**Decoder**: Takes the context vector and generates the translated sentence one word at a time.
•**Training**: The model learns to map input sequences to output sequences using large parallel corpora (source-target language pairs).



Attention Mechanisms: A Breakthrough

- **Problem with Basic Encoder-Decoder**: Fixed-size context vector struggles with long or complex sentences.
- **Solution – Attention**: Allows the decoder to focus on different parts of the input sentence at each step.
- **How it Works**: Calculates a set of weights that highlight relevant words in the input for each output word.
- **Impact**: Greatly improves translation accuracy, especially for longer texts and complex sentence structures.

Algorithms Used in Language Translation

•**Sequence-to-Sequence (Seq2Seq) Algorithm**
•Translates a sequence (like a sentence) from one language to another using encoder-decoder models.
•**Attention Mechanism**
•Allows the model to focus on specific words in the input while generating each word of the output.
•**Transformer Algorithm**
•Uses self-attention to process all words at once, improving translation speed and accuracy.
•**Beam Search**
•A smart search algorithm that chooses the best possible translation from multiple candidates.
•**Tokenization**
•Splits text into smaller pieces (words or subwords) that the model can understand and translate.

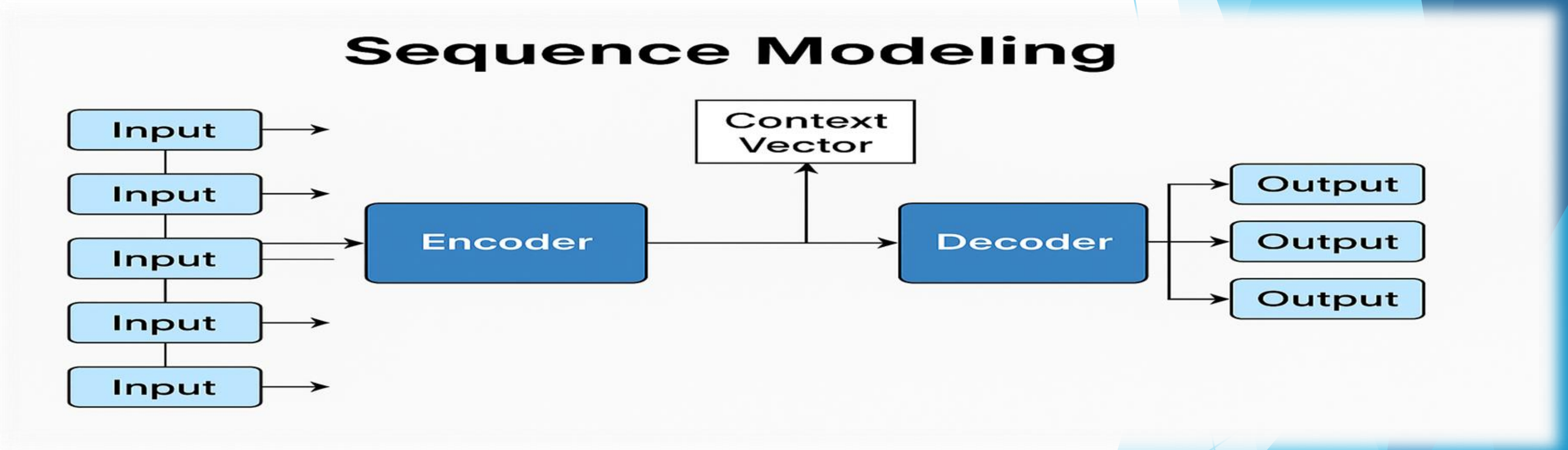
Sequence-to-Sequence Models

•**Definition**: Neural network models designed to convert one sequence into another — commonly used for tasks like language translation.

•**Architecture**: Composed of two main parts —

• **Encoder** (processes input)

•**Decoder** (generates output).



•**Training**: Learns to map input-output pairs (e.g., English ↔ Hindi) using supervised learning on parallel datasets.

•**Applications**: Language translation, text summarization, chatbot responses, and more

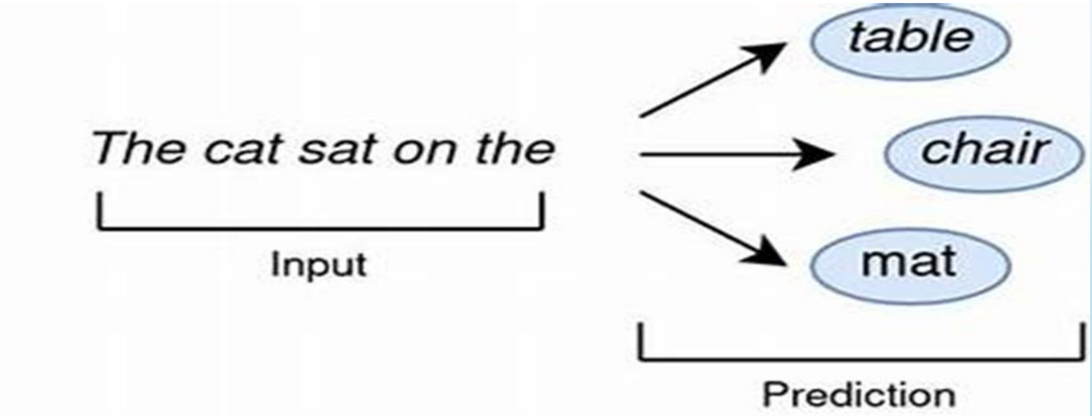
TRAINING SEQUENCE MODELS

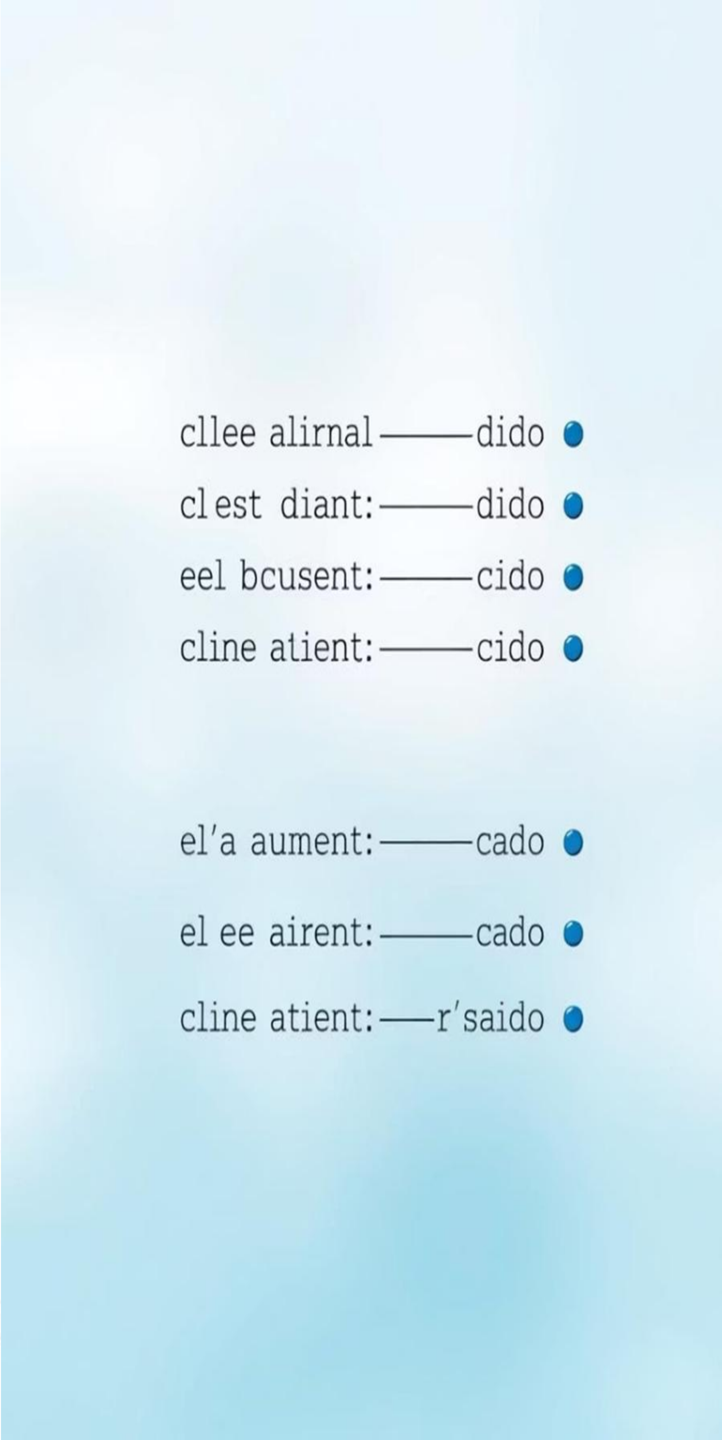
•**Data**: Requires large parallel datasets (input and translated text pairs).

•**Tokenization**: Converts sentences into tokens (words or subwords) that the model can process.

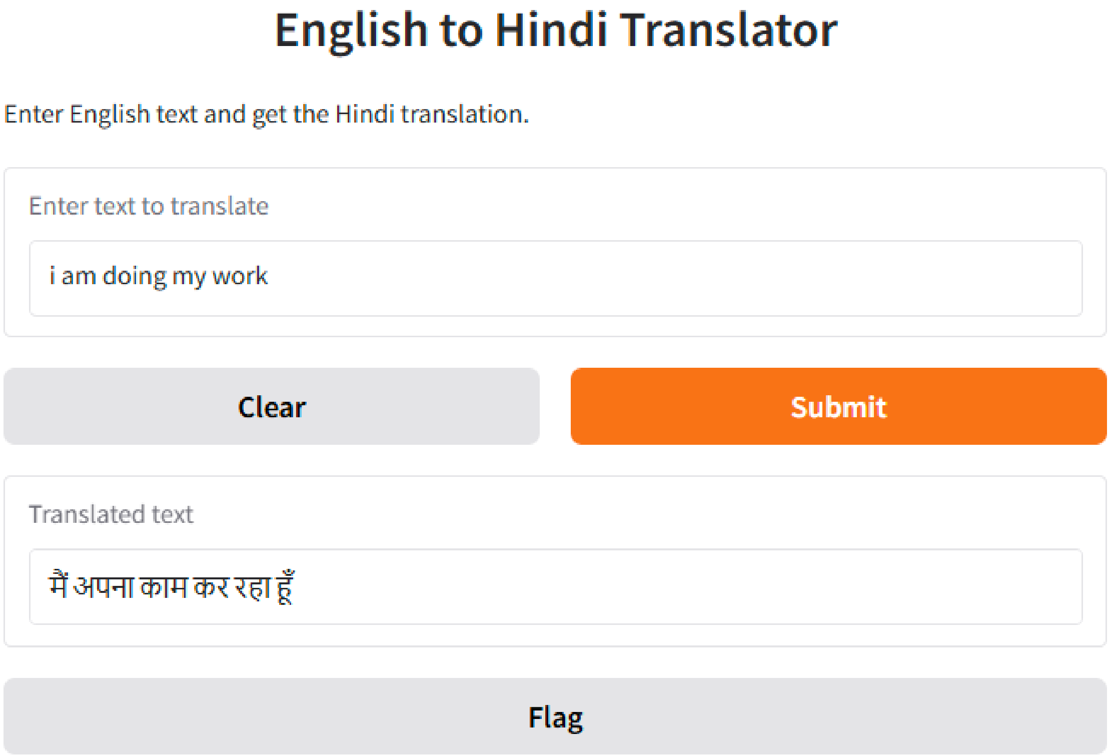
•**Loss Function**: Uses **Cross-Entropy Loss** to measure how close the prediction is to the actual output.

•**Backpropagation**: Updates model weights using **Backpropagation Through Time (BPTT)**.





Output

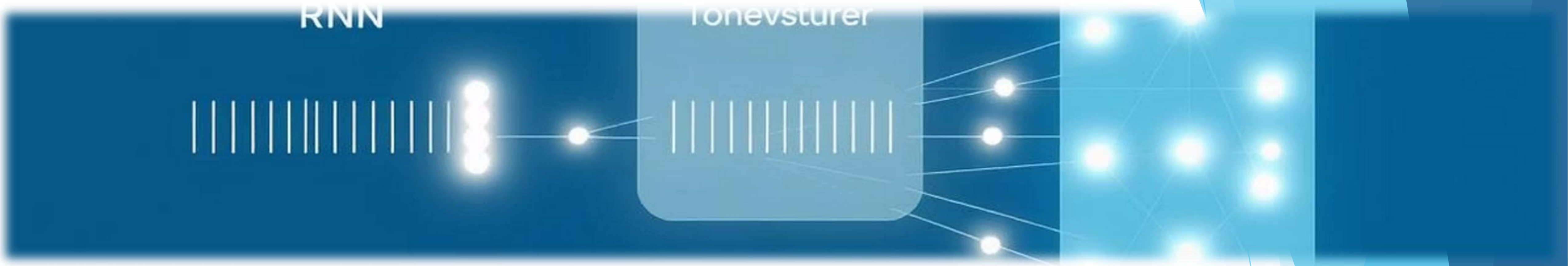

English to Hindi Translator
Enter English text and get the Hindi translation.
Enter text to translate
i am doing my work
Clear
Submit
Translated text
मैं अपना काम कर रहा हूँ
Flag

OBSERVATION AND FINDINGS

- Sequence models can translate languages accurately.
- Attention mechanism improves focus on important words.
- Transformer models perform better than older models (like RNN, LSTM).
- Models can be trained for multiple languages.
- Still face problems with rare words, slang, and cultural meaning.
- Can be used in real-time apps (like Gradio demo).

Challenges and Limitations

- ***Long-Term Dependencies***: *Difficulty in capturing relationships between distant words in a sentence.*
- ***Fixed Context Vector*** *(in basic models): Limits performance on long or complex sentences.*
- ***Data Dependency:*** *Requires large, high-quality parallel datasets for effective training.*
- ***Generalization Issues***: *Struggles with rare words, idioms, and out-of-domain language use*



Future Directions

•**Transformer Models**: Continued advancements with architectures like BERT, GPT, and T5.
•**Multilingual Models**: Unified models that handle multiple languages with shared representations.
•**Low-Resource Translation**: Improved techniques for translating underrepresented languages.
•**Real-Time & Context-Aware Systems**: Smarter, faster translation with cultural and contextual understanding.

THANK YOU