Bridging Languages

Lecture 15: Machine Translation

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What is Machine Translation (MT)?

Definition

Machine Translation (MT) is the task of automatically converting text or speech from one natural language (the source language) into another (the target language).

Example:

- English: "Hello, how are you?"
- French: "Bonjour, comment allez-vous ?"

MT is one of the oldest and most challenging tasks in NLP, requiring deep linguistic understanding and generation capabilities.

Evolution of Machine Translation

- **Rule-based MT (RBMT)** (1950s-1980s):
  - Relied on hand-crafted linguistic rules and dictionaries.
  - High quality for narrow domains, but brittle and hard to scale.
- **Statistical MT (SMT)** (1990s-2010s):
  - Used statistical models trained on large parallel corpora (texts and their human translations).
  - Learned translation probabilities from data.
  - Phrase-based SMT was dominant.
- **Neural MT (NMT)** (2014-Present):
  - Uses neural networks, primarily sequence-to-sequence models.
  - Current state-of-the-art, achieving remarkable fluency and accuracy.

Sequence-to-Sequence (Seq2Seq) Models

NMT models are typically based on the **Sequence-to-Sequence (Seq2Seq)** architecture.

- **Encoder**: Reads the entire source sequence and compresses it into a fixed-size context vector (or a sequence of context vectors).
- **Decoder**: Generates the target sequence word by word, using the context vector from the encoder and previously generated words.

The Attention Mechanism

A crucial innovation in Seq2Seq models, especially for longer sequences.

Attention allows the decoder to focus on different parts of the source sequence at each step of generating the target sequence.

- Instead of relying on a single fixed-size context vector, attention creates a dynamic context for each output word.
- This significantly improves translation quality, especially for long sentences.

The Transformer architecture (Lab 9) is built entirely on attention mechanisms.

Using Hugging Face Transformers for MT

The ‘transformers‘ library makes it easy to use pre-trained NMT models.

```
from transformers import pipeline

# Load a pre-trained English to French model
translator = pipeline("translation_en_to_fr", model="Helsink

text_to_translate = "Hello, how are you?"
translated_text = translator(text_to_translate)
print(translated_text)
# Output: [{'translation_text': 'Bonjour, comment allez-vous
```

Many models are available for various language pairs.

Evaluation: BLEU Score

BLEU (Bilingual Evaluation Understudy) is a widely used metric for evaluating the quality of machine-translated text.

- It measures the similarity between the machine-generated translation and one or more human-generated reference translations.
- Based on the precision of n-grams (how many n-grams in the candidate translation appear in the reference translation).
- Scores range from 0 to 1 (or 0 to 100), with higher scores indicating better quality.

We discussed BLEU in Lab 12 (LLM Evaluation).

Next Steps

Time for Lab 15!

Objective:

- Implement a ‘Translator‘ class using Hugging Face pipelines.
- Translate text between languages.
- (Bonus) Evaluate translations using BLEU score.