Natural Language Processing

Neural machine translation

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Neural Machine Translation (NMT)

- **Neural machine translation** (**NMT**) models the translation task through a single artificial neural network.

- The first systems for NMT were based on recurrent neural networks; more recent systems typically use Transformers.

- Many practical implementations are based on the OpenNMT ecosystem for neural machine translation.

  Link to OpenNMT

Limitations of statistical machine translation

- Scaling to larger model sizes is problematic, both for computational reasons and because of data sparsity.
- State-of-the-art SMT systems used complex architectures with many components and required extensive tuning.
- Like *n*-gram models, statistical machine translation models are unable to share statistical strength across "similar" translations.

The sequence-to-sequence model (seq2seq)

The sequence-to-sequence model consists of two components:

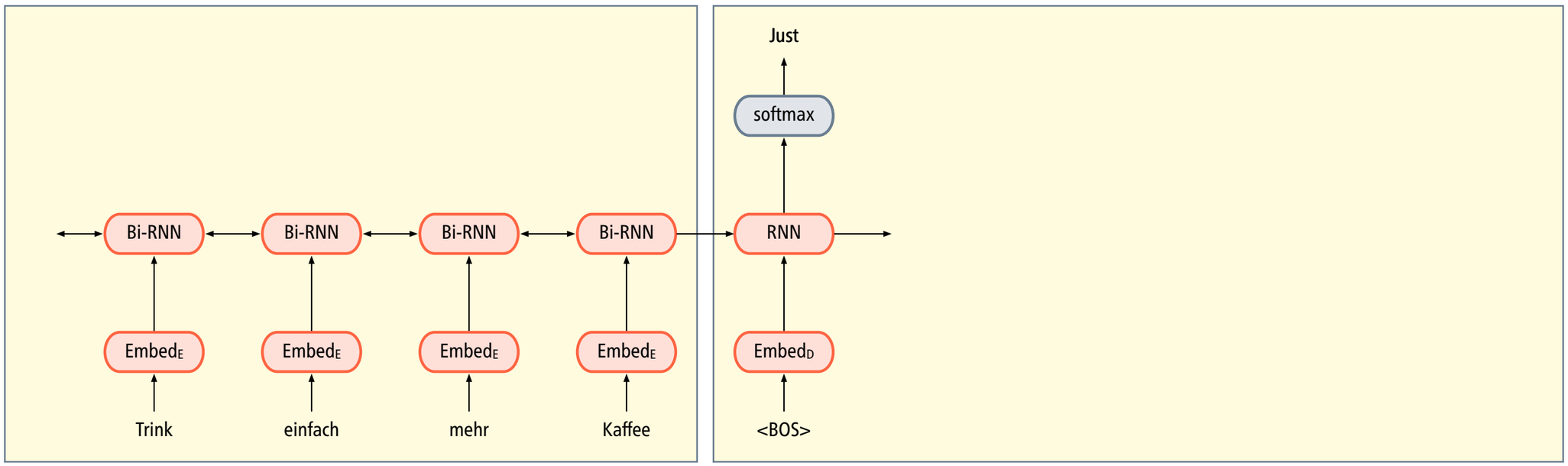
- The **encoder** is a neural network that produces a representation of the source sentence.

  typically implemented as a bidirectional recurrent neural network

- The **decoder** is an autoregressive language model that generates the target sentence, conditioned on the output of the encoder.

  autoregressive = takes its own outputs as new inputs

Standard seq2seq architecture

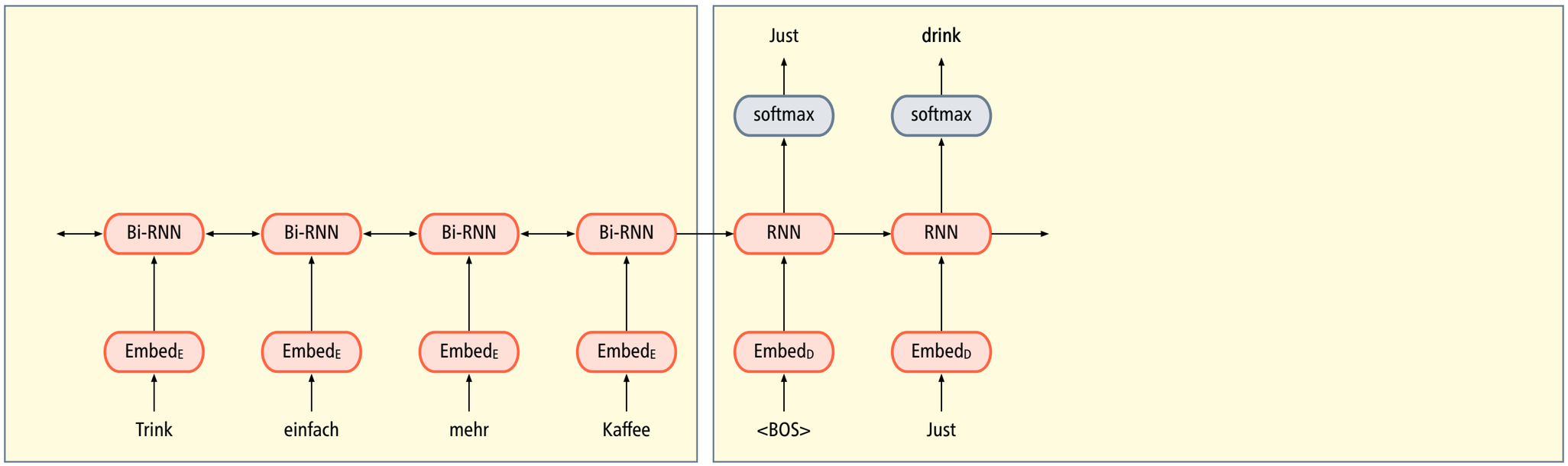


encoder

decoder

Sutskever et al. (2014)

Standard seq2seq architecture

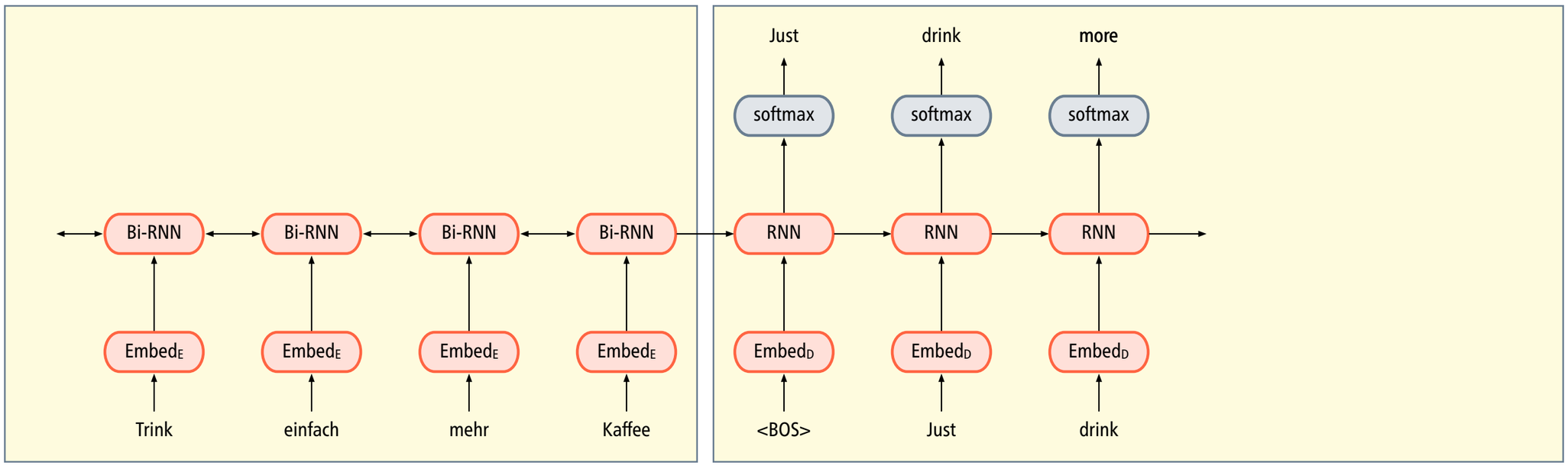


encoder

decoder

Sutskever et al. (2014)

Standard seq2seq architecture

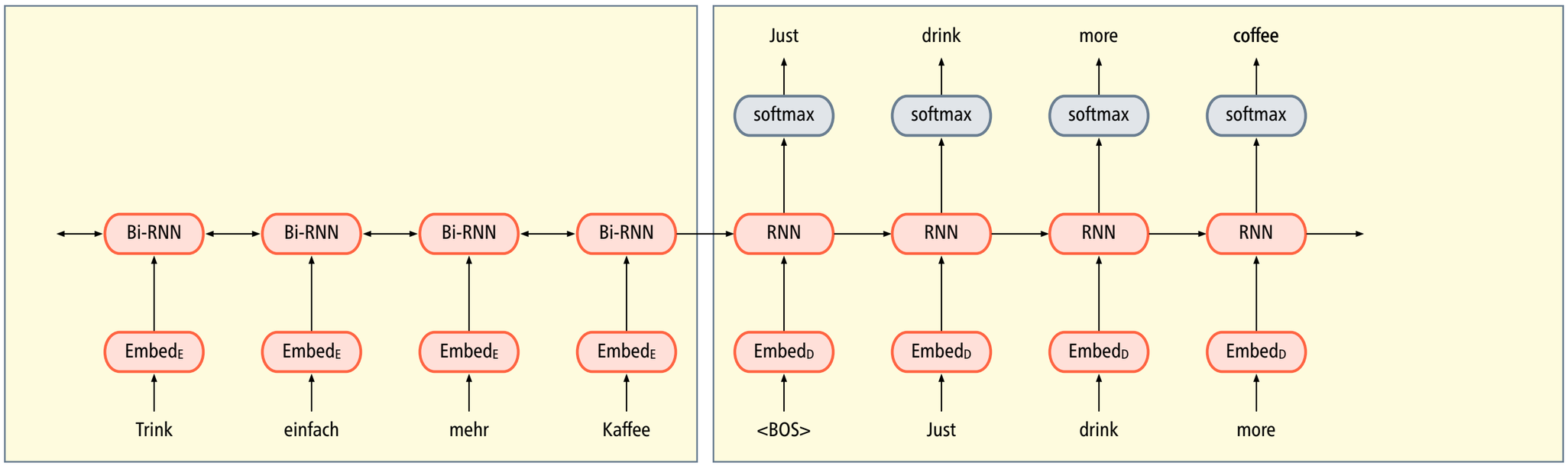


encoder

decoder

[Sutskever et al. (2014)]

Standard seq2seq architecture

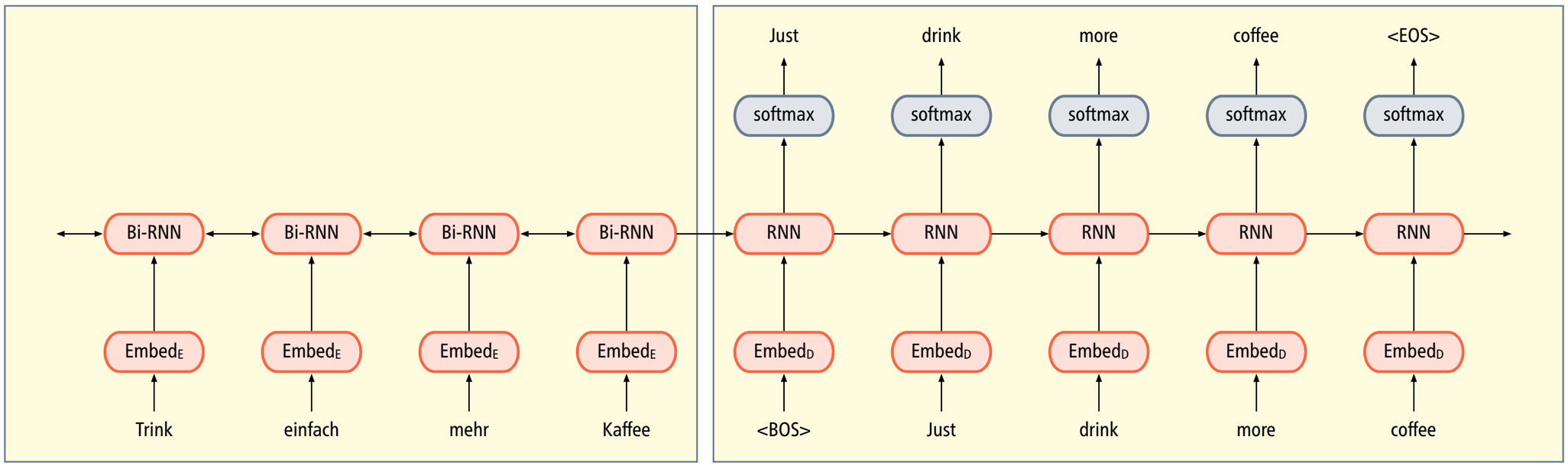


encoder

decoder

Sutskever et al. (2014)

Standard seq2seq architecture



encoder

decoder

[Sutskever et al. (2014)]

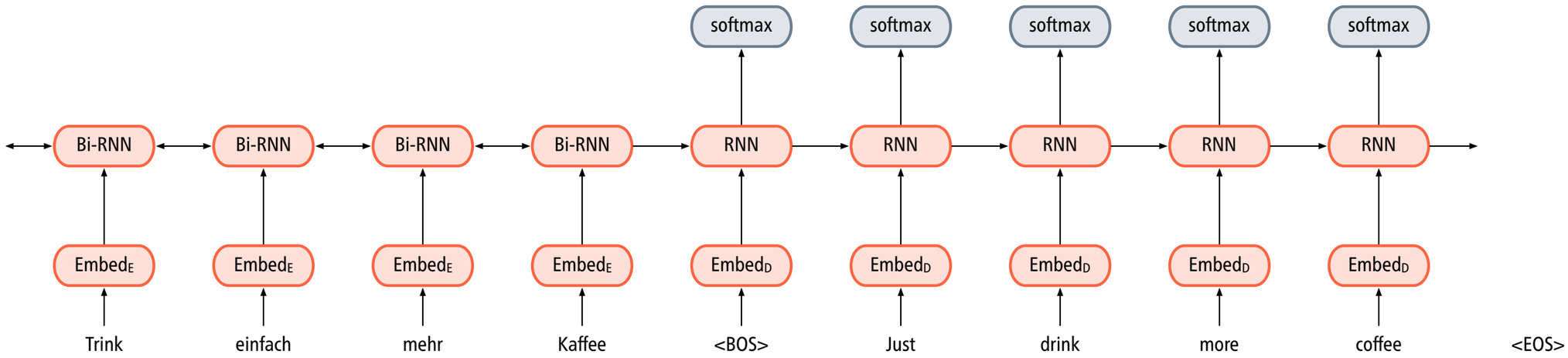
Properties of the seq2seq model

- The seq2seq model directly learns and uses $P(\boldsymbol{y}|\boldsymbol{x})$, rather than decomposing it into $P(\boldsymbol{x}|\boldsymbol{y})$ and $P(\boldsymbol{y})$ as in SMT.
- The model can be trained trained end-to-end using backpropagation, without alignments or auxiliary models.

  only needs parallel data

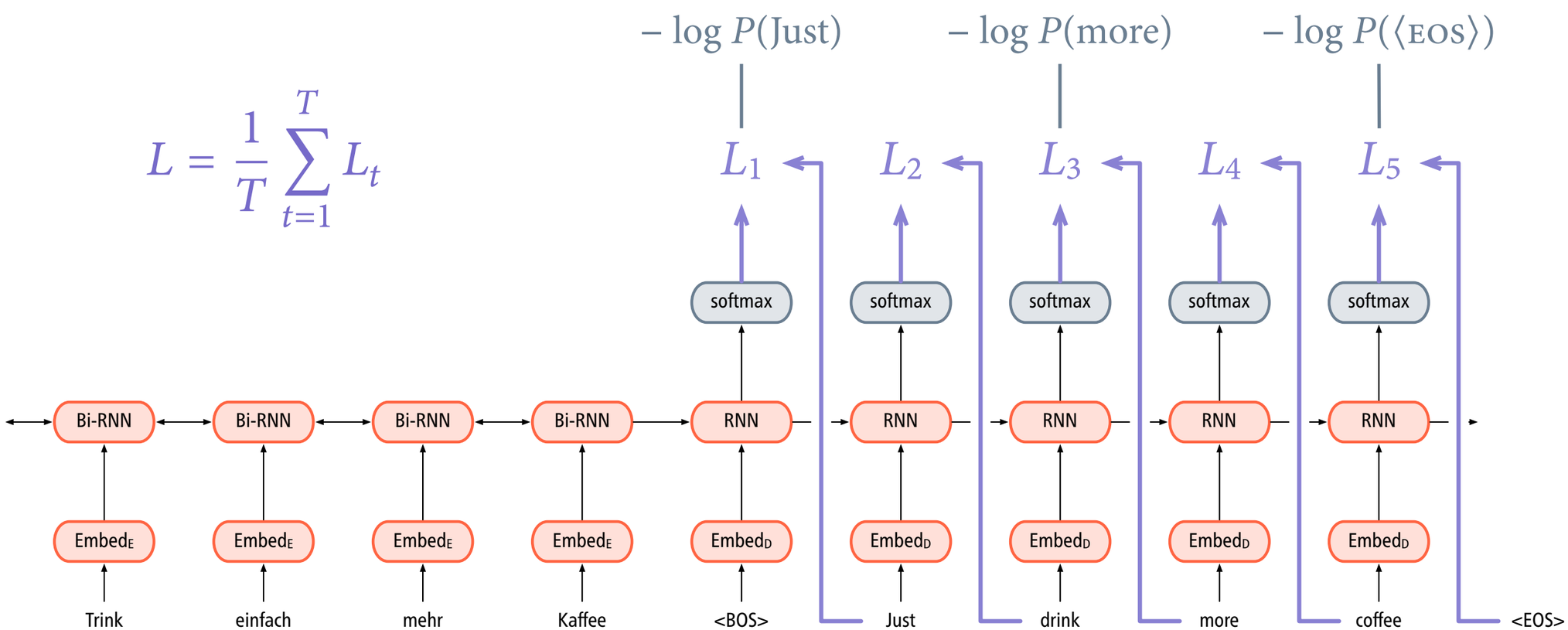
- The seq2seq model is useful for a range of other tasks, including text summarisation, dialogue, and code generation.

Training an encoder–decoder model



Training an encoder–decoder model

$$L = \frac{1}{T}\sum_{t=1}^{T} L_t$$



Decoding algorithms

- **Greedy decoding**

  At each step, predict the highest-probability word. Stop when the end-of-sentence marker is predicted.

- **Beam search**

  Keep a limited number of highest-scoring partial translations. Expand the current beam, score the new translations, and prune.

  Typical beam widths are between 2 and 16.

Beam search example

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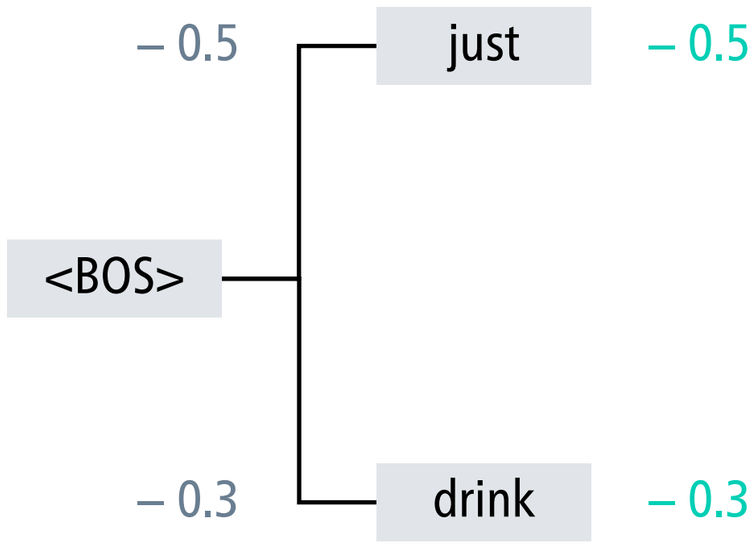
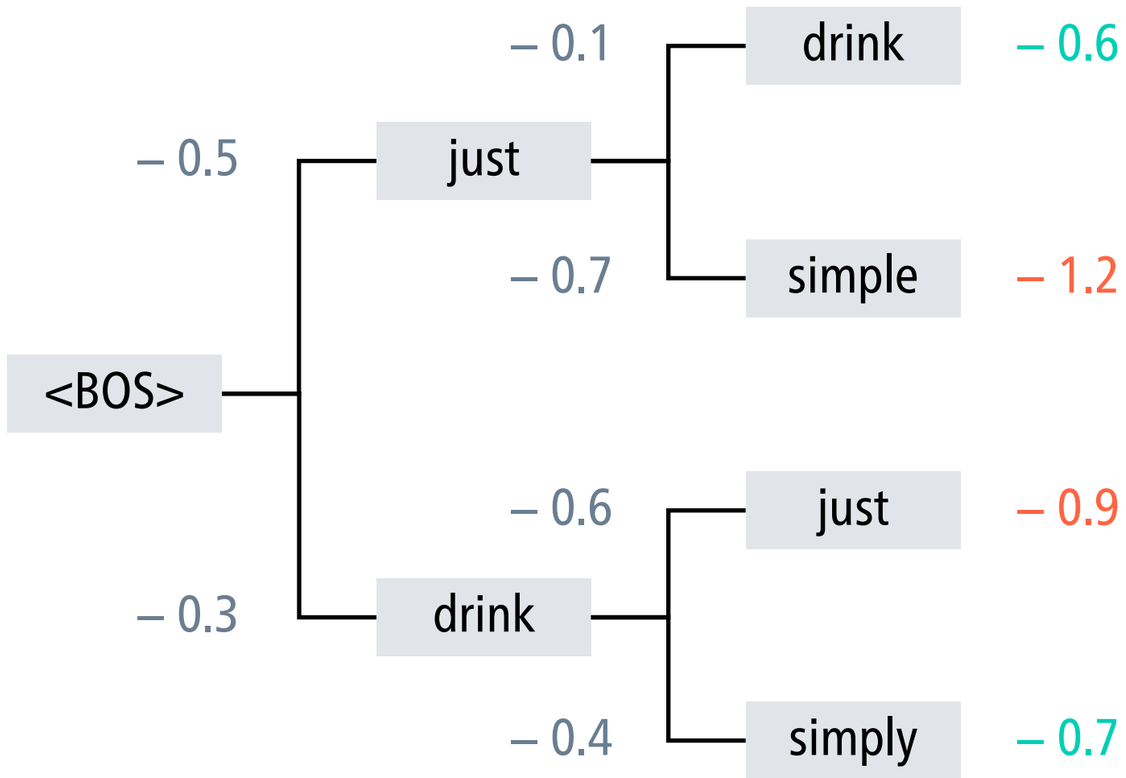
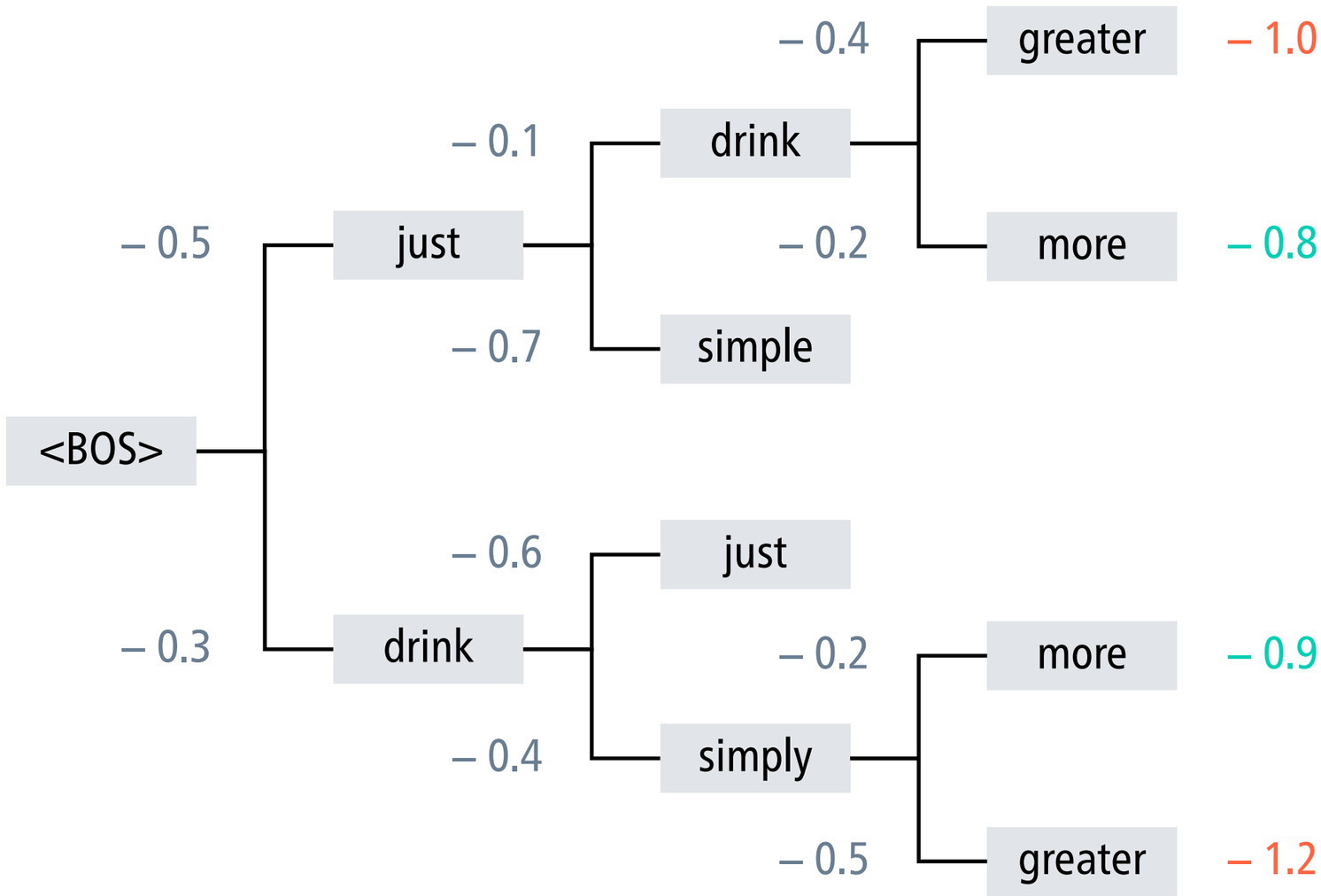
Beam search example



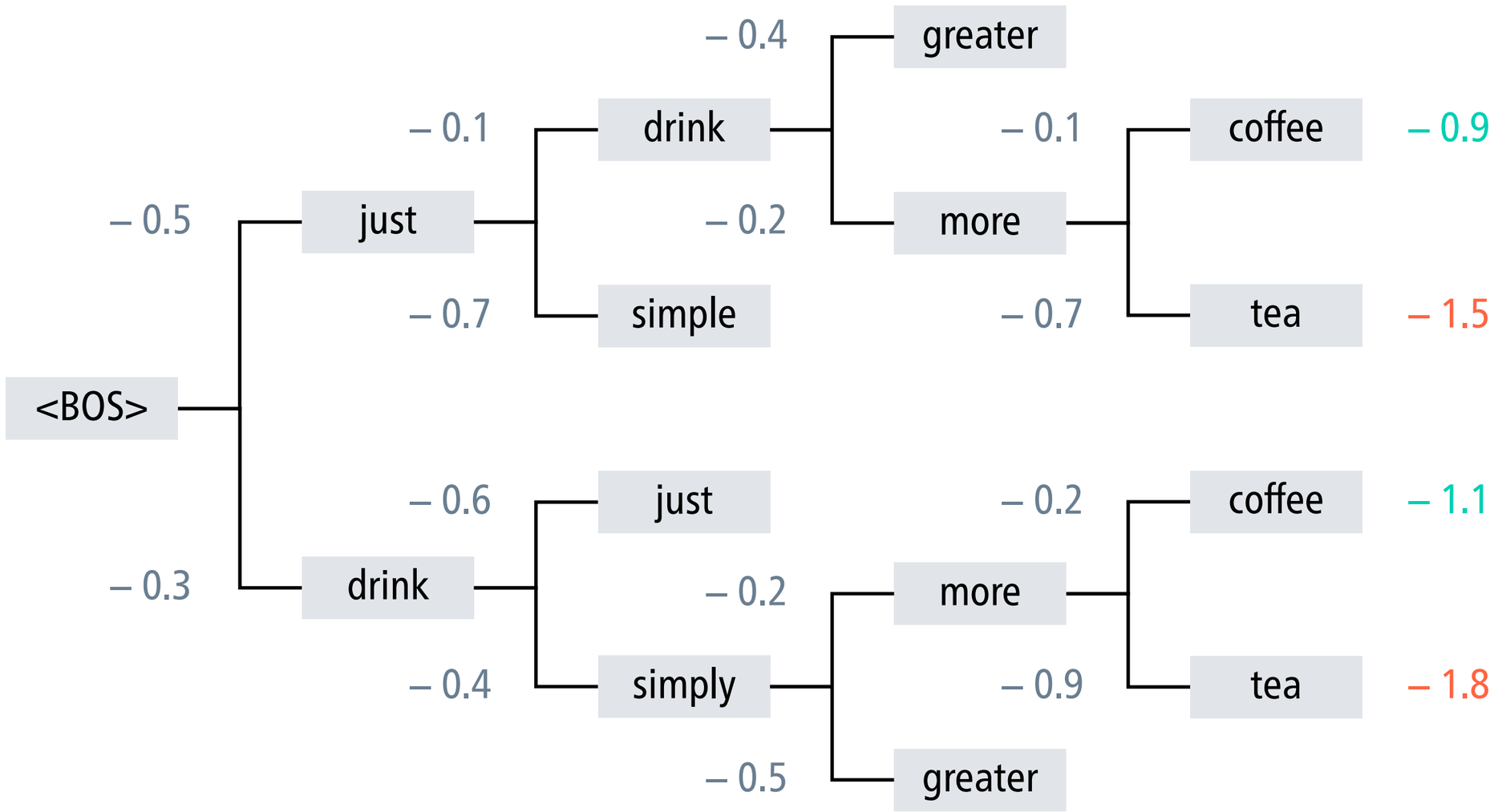
Beam search example



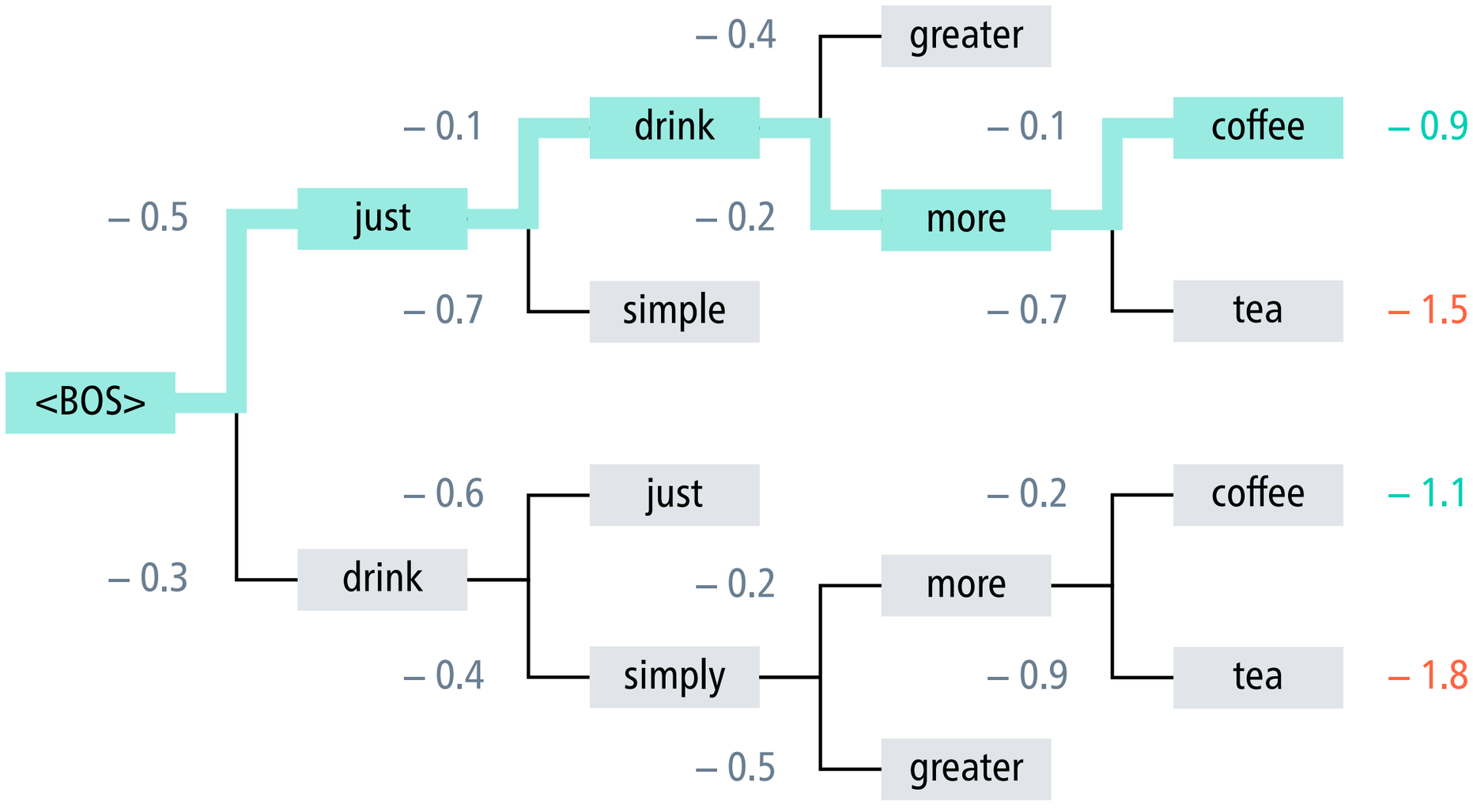
Beam search example



Beam search example



Beam search example



Termination criteria

- When the expansion of a partial translation generates the ⟨EOS⟩ marker, we have a complete translation.
- End the search after a fixed number of steps, or when enough complete translations have been generated.
- Evaluate the translations found during search based on their length-normalised scores and return the highest-scoring one.

  different from standard beam search