

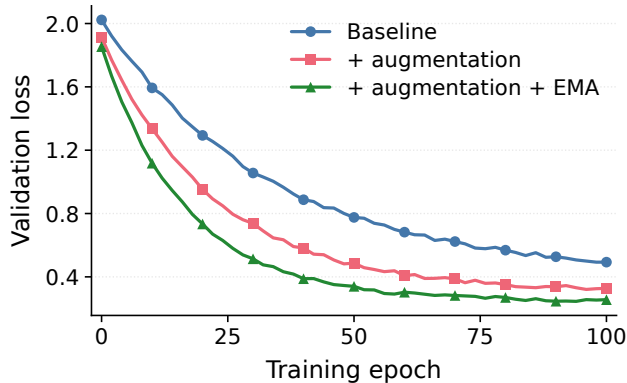


Figure 1. Synthetic evaluation fixture, not a result. Rendered by matplotlib-prefab from line-multi.json and placed at one column. This page exists only to show the figure at its final printed size in the ICML 2026 body text; the surrounding prose is an excerpt reproduced as typographic context. Case line-multi.

Self-attention, sometimes called intra-attention is an attention mechanism relating different positions of a single sequence in order to compute a representation of the sequence. Self-attention has been used successfully in a variety of tasks including reading comprehension, abstractive summarization, textual entailment and learning task-independent sentence representations (Cheng et al., 2016; Parikh et al., 2016; Paulus et al., 2017; Lin et al., 2017).

End-to-end memory networks are based on a recurrent attention mechanism instead of sequence-aligned recurrence and have been shown to perform well on simple-language question answering and language modeling tasks (Sukhbaatar et al., 2015).

To the best of our knowledge, however, the Transformer is the first transduction model relying entirely on self-attention to compute representations of its input and output without using sequence-aligned RNNs or convolution. In the following sections, we will describe the Transformer, motivate self-attention and discuss its advantages over models such as (Kaiser & Sutskever, 2015; Kalchbrenner et al., 2016) and (Gehring et al., 2017).

3. Attention

An attention function can be described as mapping a query and a set of key-value pairs to an output, where the query, keys, values, and output are all vectors. The output is computed as a weighted sum of the values, where the weight assigned to each value is computed by a compatibility function of the query with the corresponding key.

In practice, we compute the attention function on a set of queries simultaneously, packed together into a matrix Q . The keys and values are also packed together into matrices

K and V . The input consists of queries and keys of dimension d_k , and values of dimension d_v . We compute the dot products of the query with all keys, divide each by $\sqrt{d_k}$, and apply a softmax function to obtain the weights on the values.

References

- Bahdanau, D., Cho, K., and Bengio, Y. Neural machine translation by jointly learning to align and translate. *arXiv preprint arXiv:1409.0473*, 2014.
- Cheng, J., Dong, L., and Lapata, M. Long short-term memory-networks for machine reading. *arXiv preprint arXiv:1601.06733*, 2016.
- Cho, K., van Merriënboer, B., Gulcehre, C., Bahdanau, D., Bougares, F., Schwenk, H., and Bengio, Y. Learning phrase representations using RNN encoder-decoder for statistical machine translation. *arXiv preprint arXiv:1406.1078*, 2014.
- Chung, J., Gulcehre, C., Cho, K., and Bengio, Y. Empirical evaluation of gated recurrent neural networks on sequence modeling. *arXiv preprint arXiv:1412.3555*, 2014.
- Gehring, J., Auli, M., Grangier, D., Yarats, D., and Dauphin, Y. N. Convolutional sequence to sequence learning. *arXiv preprint arXiv:1705.03122*, 2017.
- Hochreiter, S. and Schmidhuber, J. Long short-term memory. *Neural Computation*, 9(8):1735–1780, 1997.
- Hochreiter, S., Bengio, Y., Frasconi, P., and Schmidhuber, J. Gradient flow in recurrent nets: the difficulty of learning long-term dependencies. In Kremer, S. C. and Kolen, J. F. (eds.), *A Field Guide to Dynamical Recurrent Neural Networks*. IEEE Press, 2001.
- Jozefowicz, R., Vinyals, O., Schuster, M., Shazeer, N., and Wu, Y. Exploring the limits of language modeling. *arXiv preprint arXiv:1602.02410*, 2016.
- Kaiser, Ł. and Bengio, S. Can active memory replace attention? *arXiv preprint arXiv:1610.08613*, 2016.
- Kaiser, Ł. and Sutskever, I. Neural GPUs learn algorithms. *arXiv preprint arXiv:1511.08228*, 2015.
- Kalchbrenner, N., Espeholt, L., Simonyan, K., van den Oord, A., Graves, A., and Kavukcuoglu, K. Neural machine translation in linear time. *arXiv preprint arXiv:1610.10099*, 2016.
- Kim, Y., Denton, C., Hoang, L., and Rush, A. M. Structured attention networks. *arXiv preprint arXiv:1702.00887*, 2017.