Carnegie Mellon University
Language Technologies Institute

Neuro-Symbolic Language Modeling with Retrieval Automaton

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CMU

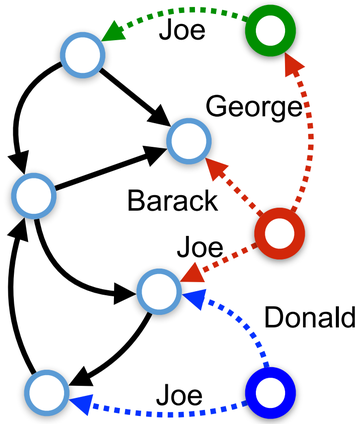
RetoMaton - TL;DR:

Given a trained LM and its training corpus, we construct a **weighted finite-state automaton**.

At inference time, we traverse the automaton in parallel with the LM.

We interpolate this automaton's probability with the base LM's probability.

Automaton

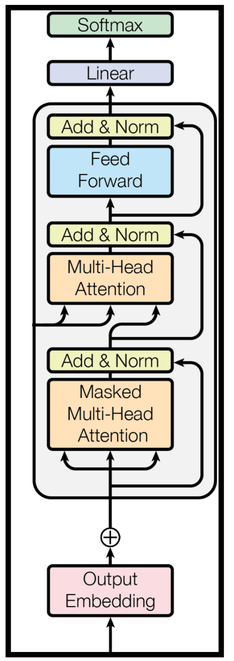


States: clusters of training examples, encoded by the LM

Edges: pointers between consecutive examples, shared in cluster

Weights: $-\|h^{(t)}, h_i\|_2$

Trained LM



$$\lambda P_{auto} + (1 - \lambda) P_{LM}$$

Background: K-Nearest Neighbor Language Model (kNN-LM)

(Khandelwal et al., ICLR'2020)

The	president	is	___

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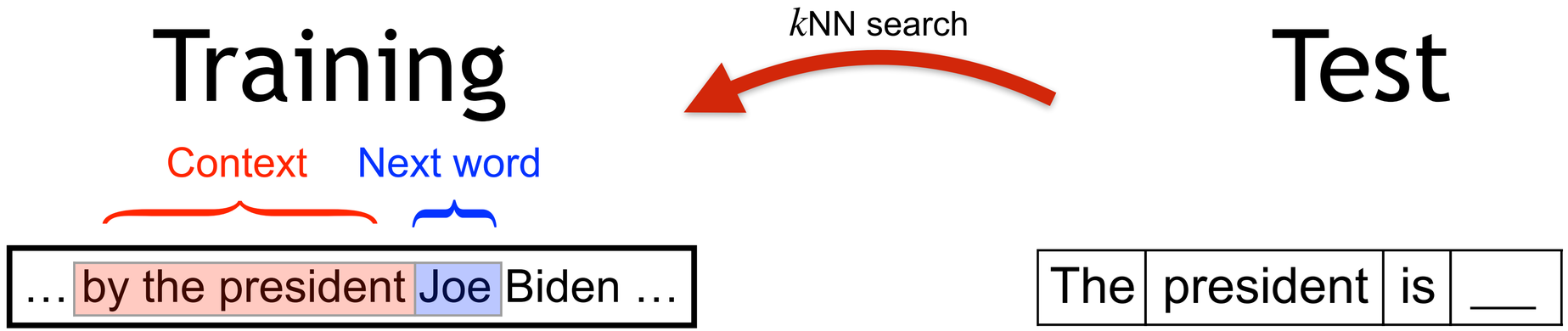

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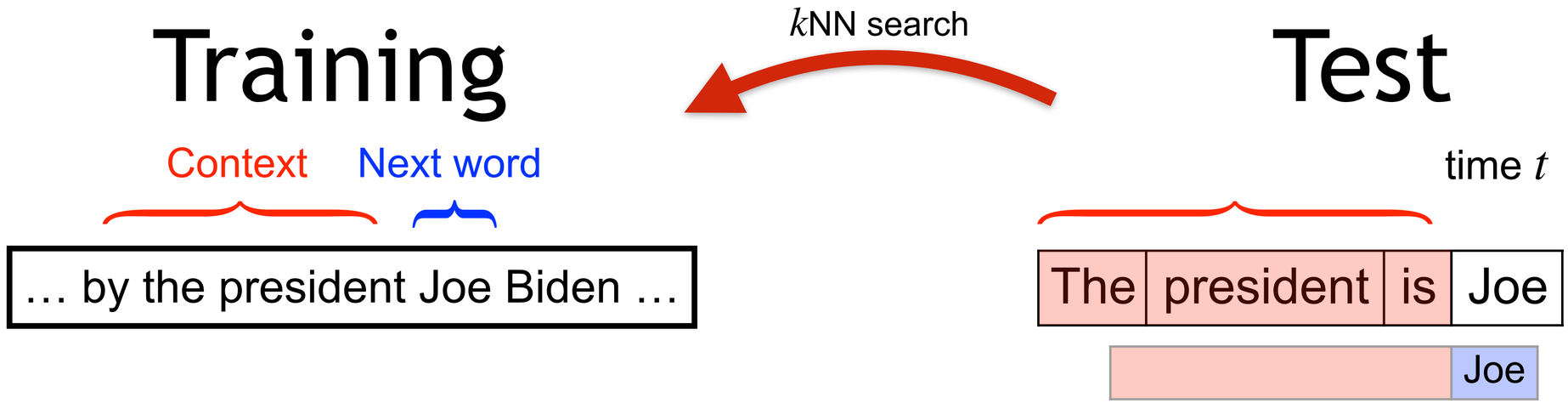

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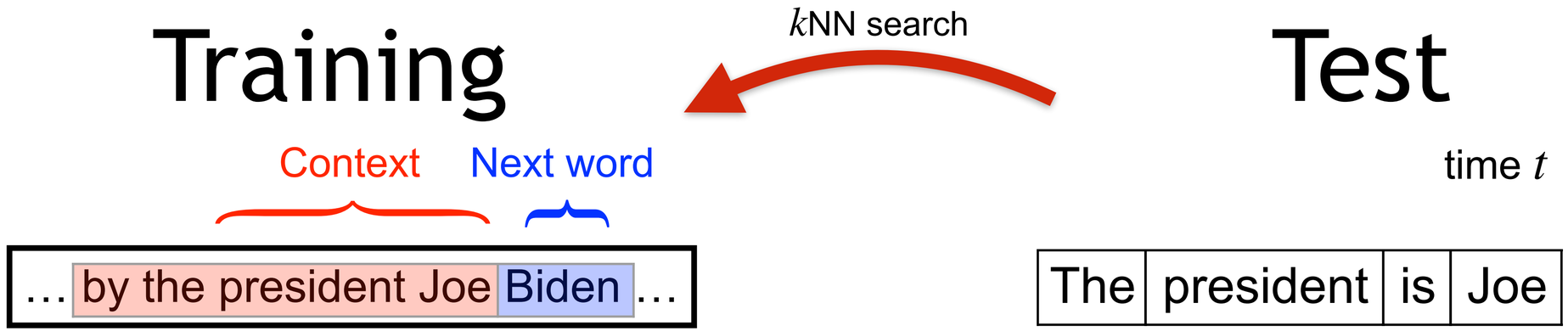

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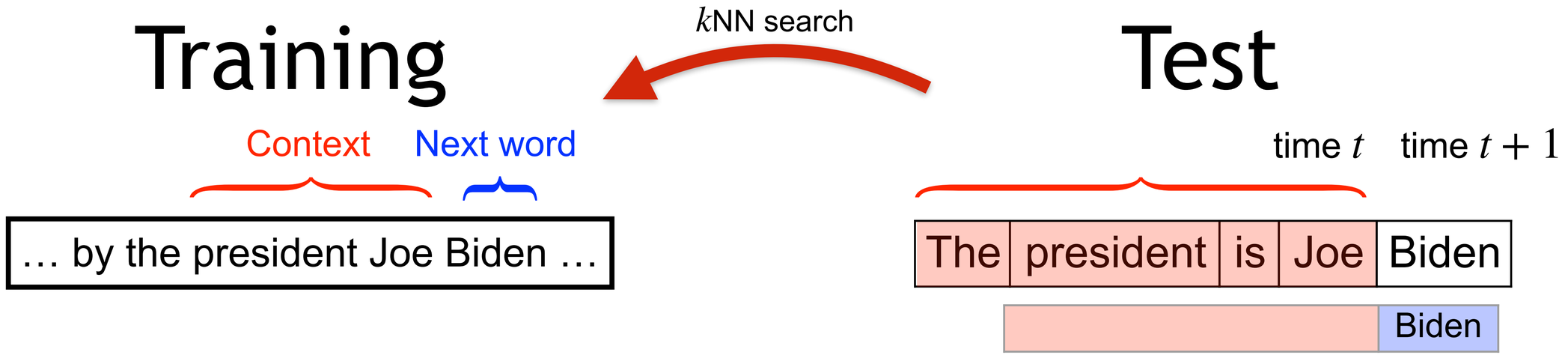

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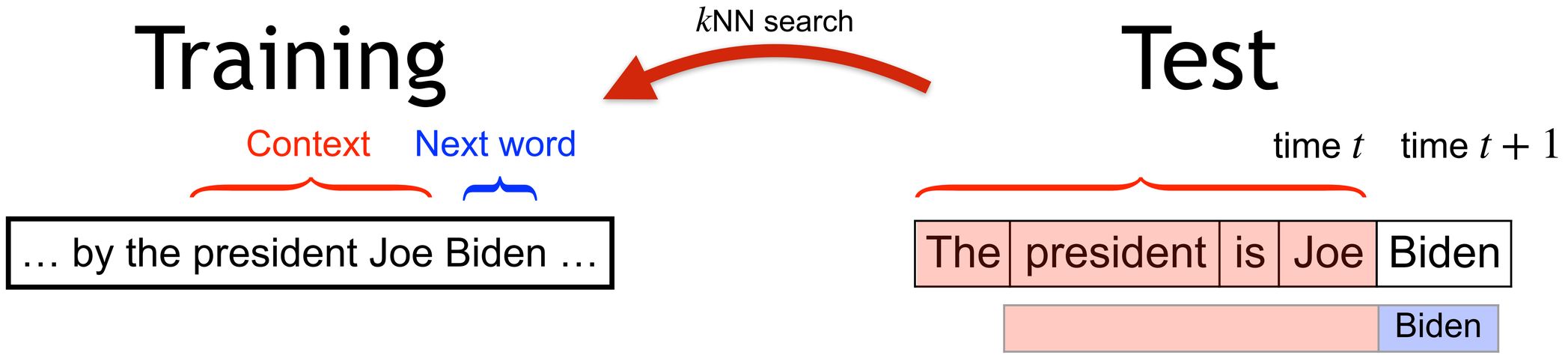


K-nearest neighbor search: for **every generated token**

$$\text{time}\left(k\text{NN search}\right) >> \text{time}\left(\text{forward pass}\right)$$

If we performed **kNN search** to retrieve "Joe",
can we save the search when predicting "Biden"?

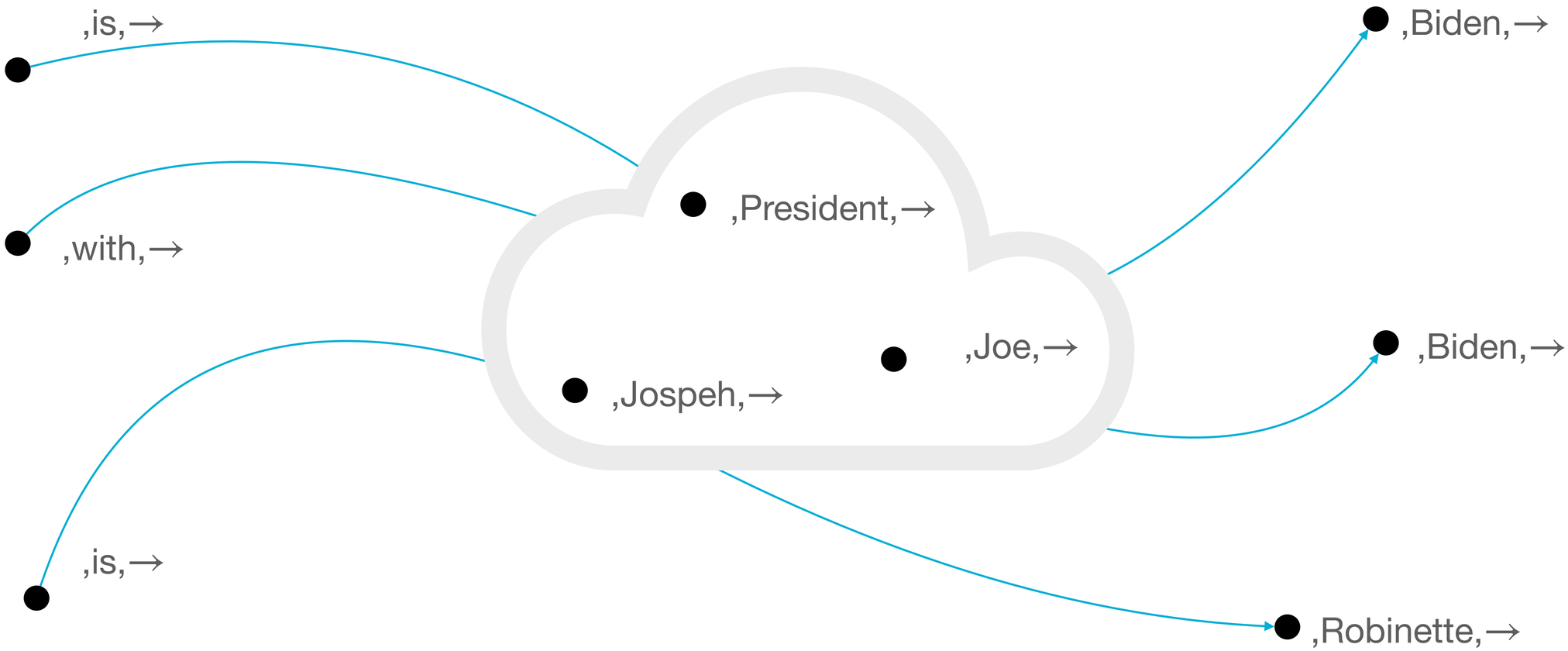
Adding Pointers Between Datastore Entries

Training

… by the president Joe Biden …

We still need to perform k**NN search** once, but in the following time steps, we can just follow pointers instead!

Clustering Entries with Close Keys



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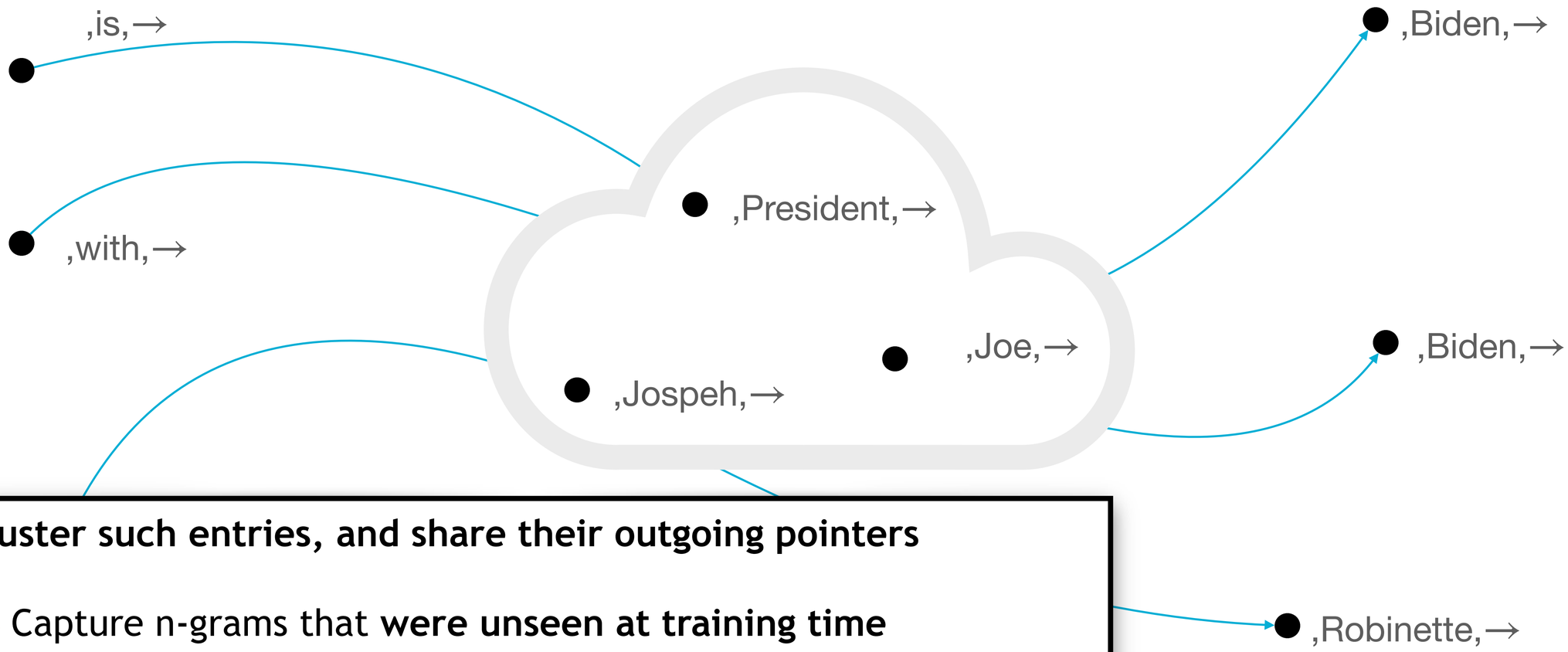

Cluster such entries, and share their outgoing pointers

👍 Capture n-grams that **were unseen at training time**

👍 Longer pointer traversal, without backing up to kNN search

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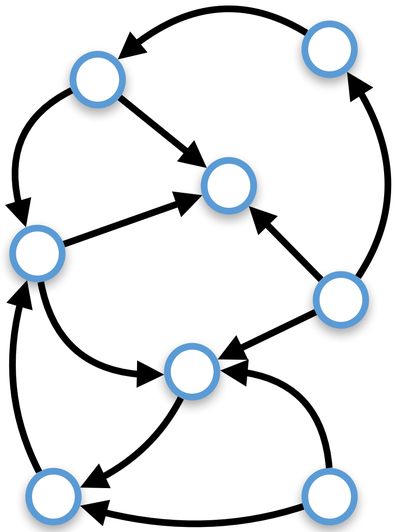
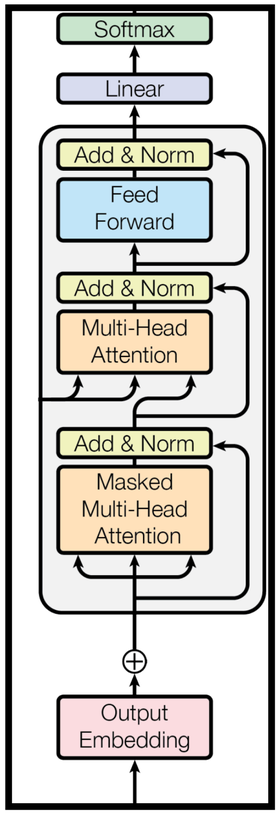
Automaton



$$\lambda P_{auto} + (1 - \lambda)\ P_{LM}$$

Trained LM



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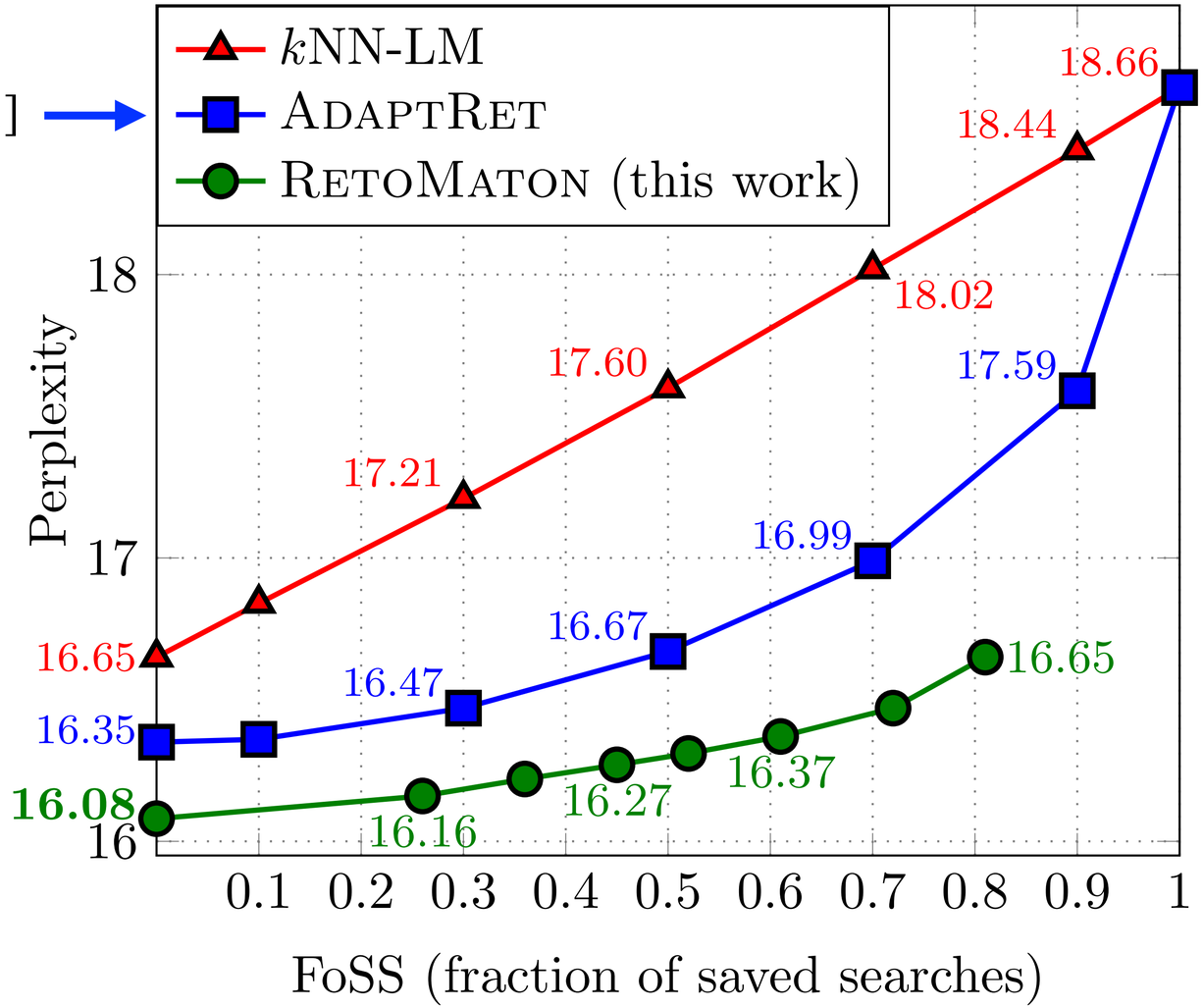
Wikitext-103

[He et al., EMNLP'2021]



Wikitext-103

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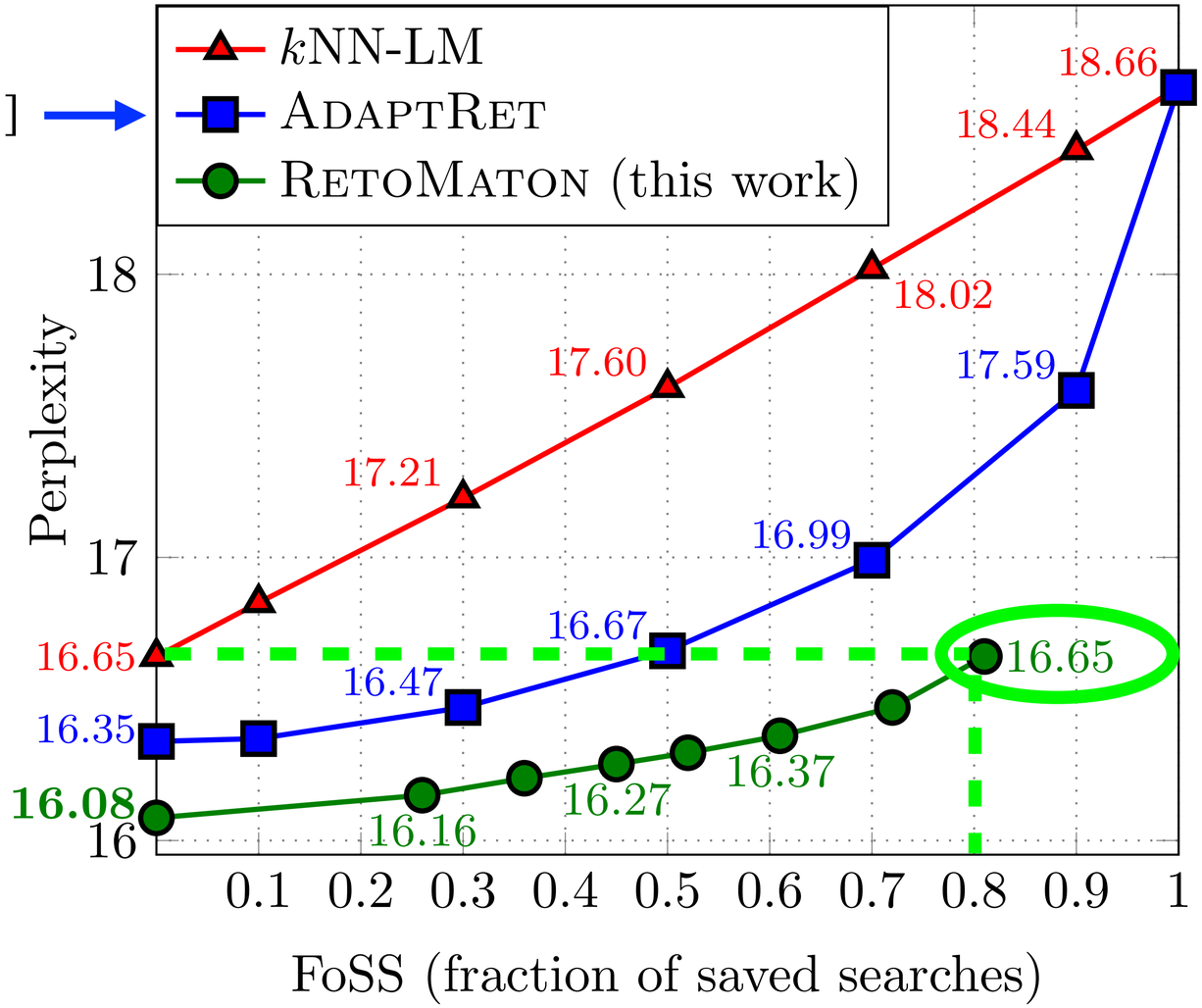

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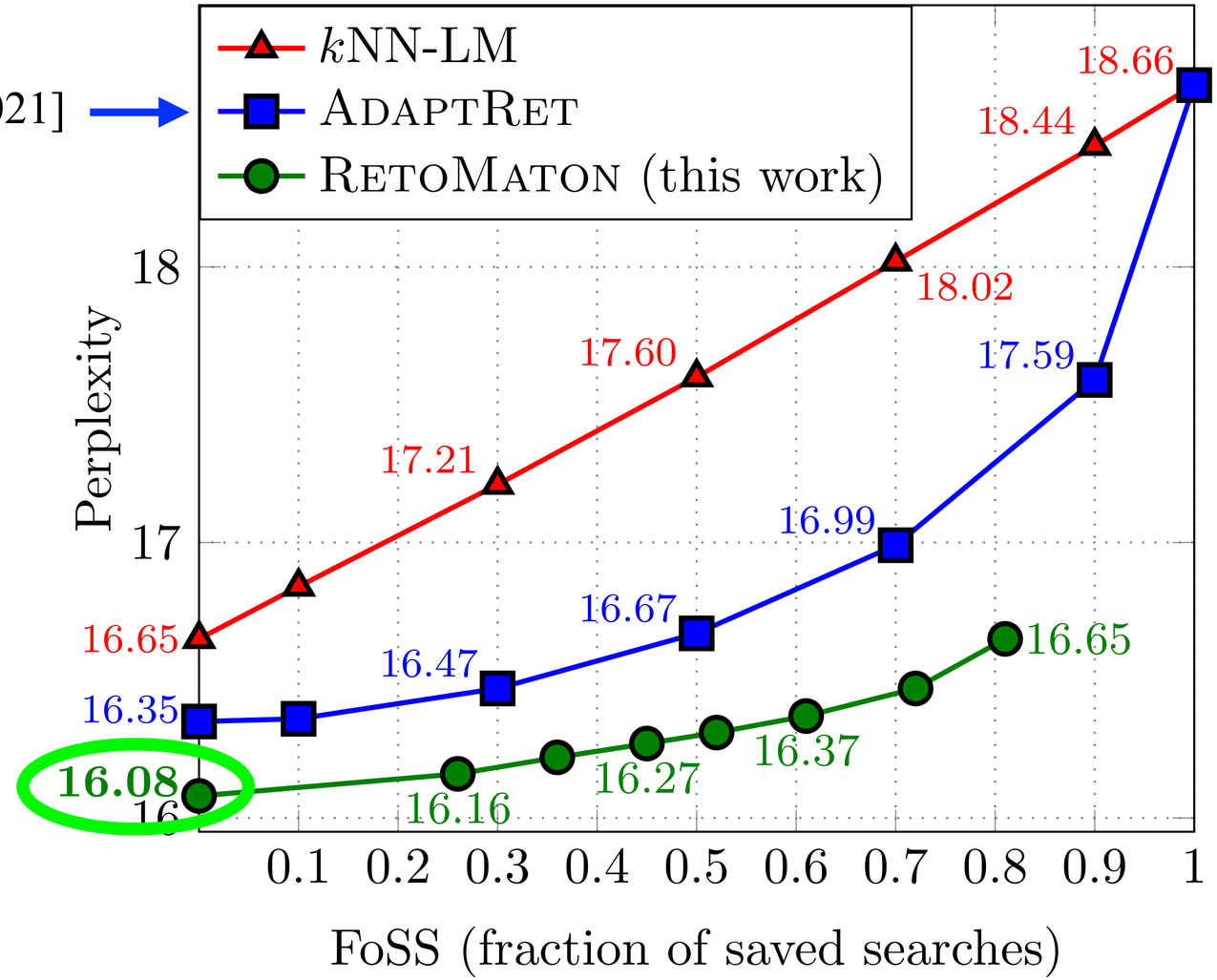
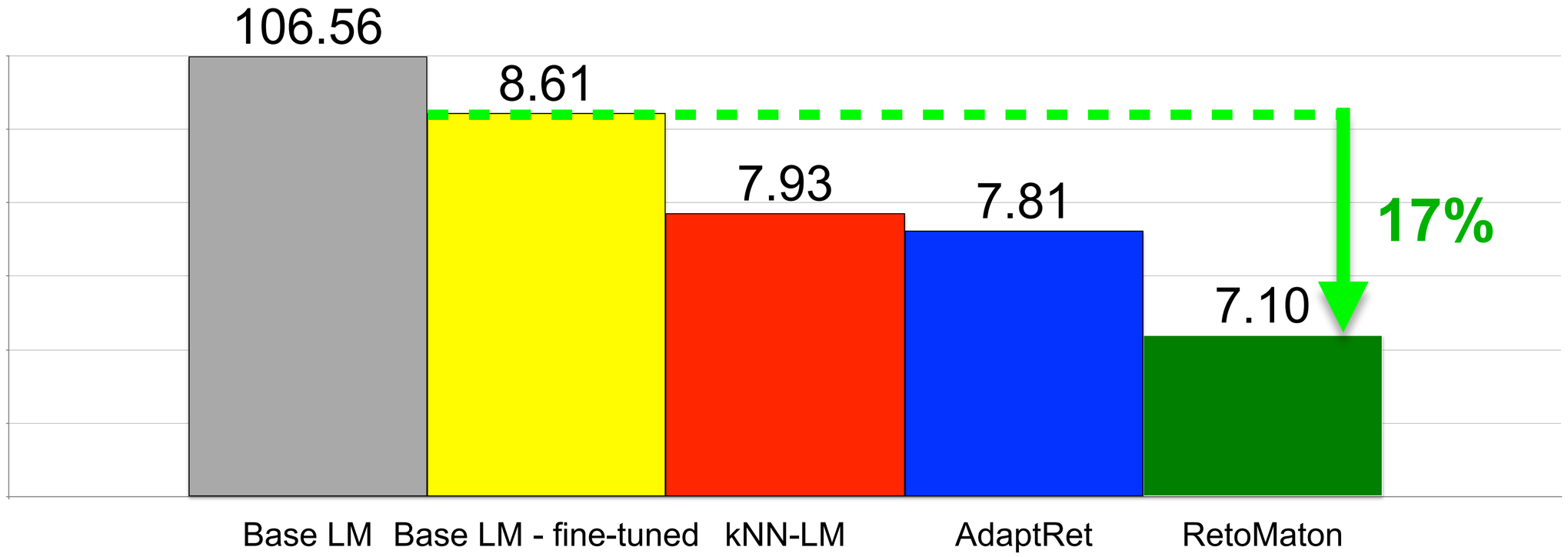


Domain Adaptation

Train on WMT News Crawl; **Test**+build datastore on Law



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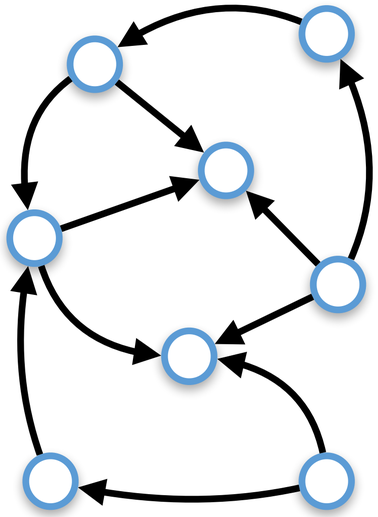
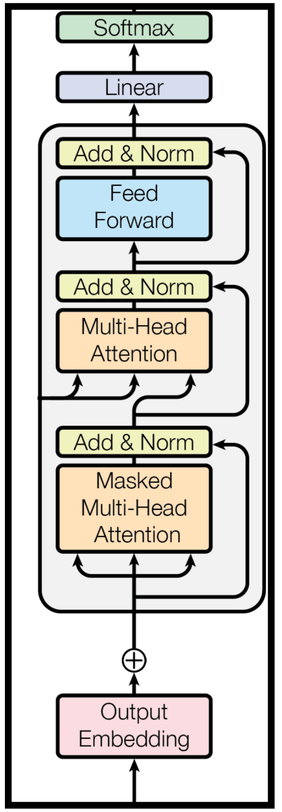
- Synergy between a **symbolic** automaton and a **neural** LM
  - Saving **pointers** between training entries
  - **Clustering** of entries into automaton states
  - ***Dynamic*** transition scores
- Lower perplexity than the base LM, while saving up to **83%** of the kNN searches compared to kNN-LM
- The creation of the automaton is **unsupervised**
  - Constructed from the original training data
  - Another domain





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http://urialon.ml
ualon@cs.cmu.edu

https://github.com/neulab/retomaton
https://github.com/neulab/knn-transformers