Deep Natural Language Processing in Search Systems

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LinkedIn AI
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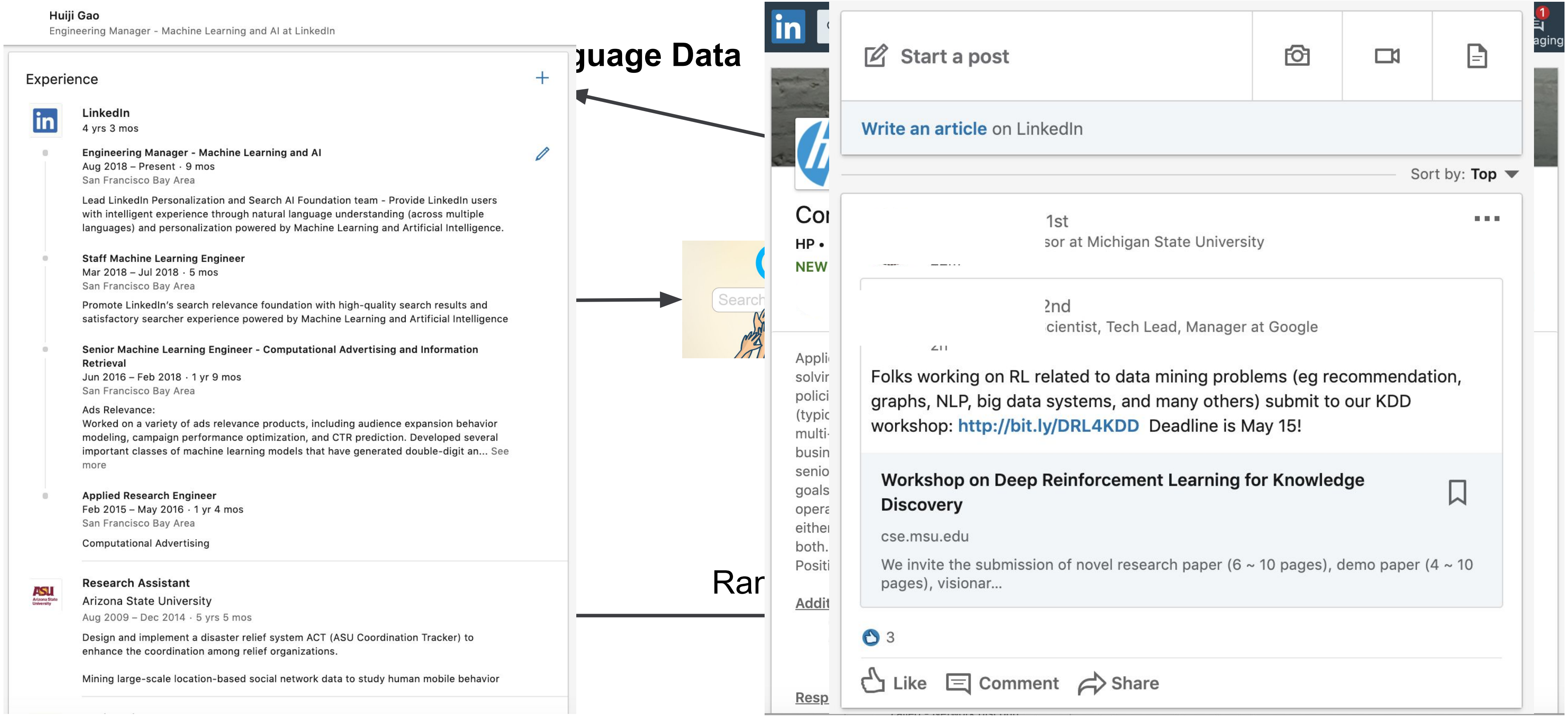
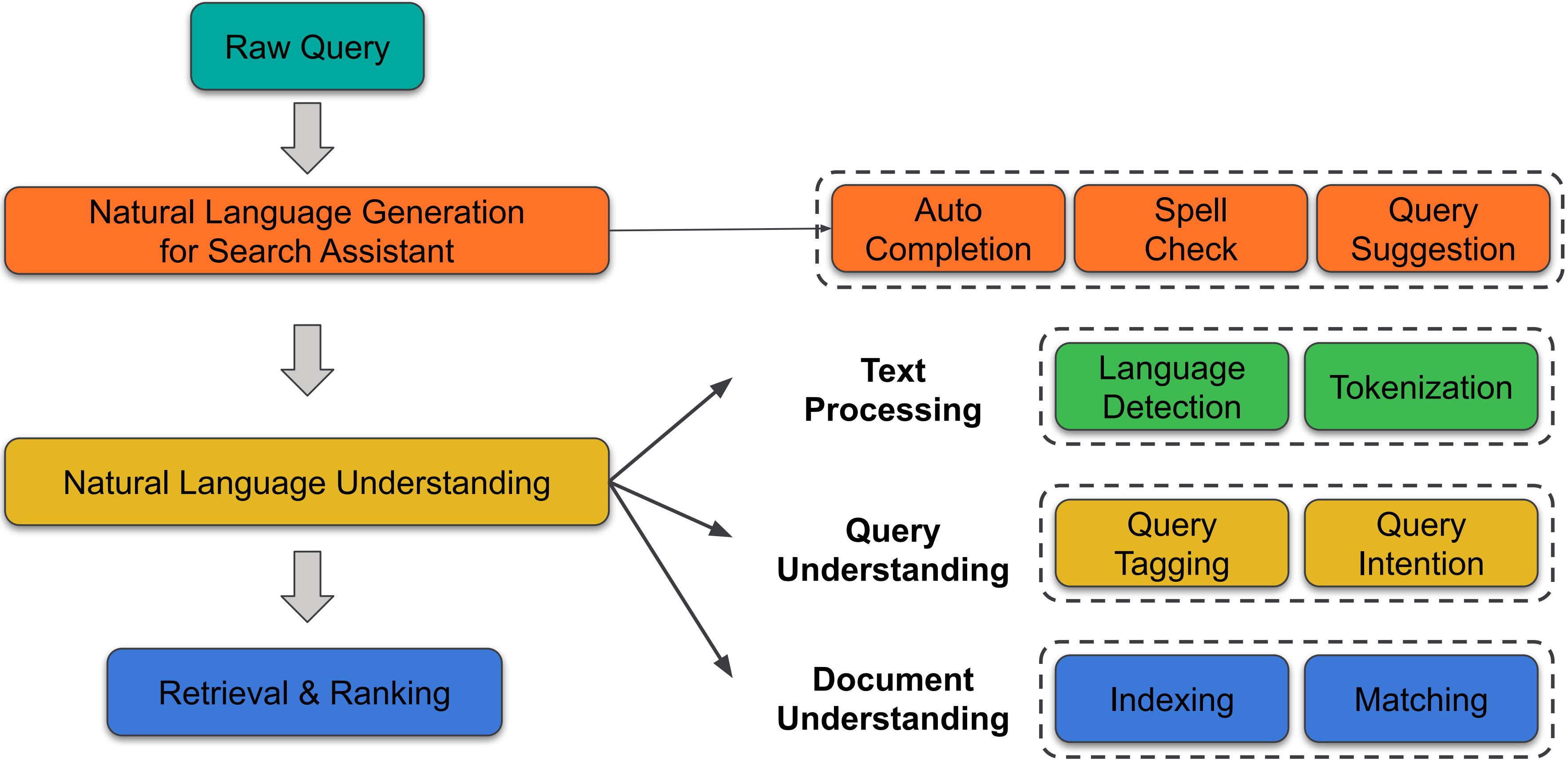
Natural Language Data in Search Systems



Natural Language Processing in Search Ecosystem



NLP in Search Systems: Challenges

- **Data Ambiguity**
  - Short query text
    - "abc"
  - No strict syntax
    - "bing search engineer"
  - Strong correlation to the searcher
    - "looking for new jobs"
- **Deep Semantics**
  - Representations for query & document w.r.t. search intent, entities, topics
    - "Engineering Openings" -> job posts

Deep NLP in Search: Challenges

- **Complicated Search Ecosystem**
  - Query suggestion affects both recall and precision in downstream retrieval and ranking.
  - Query tagging needs to be compatible with indexing and align with ranking features.

- **Product Oriented Model Design**
  - Design deep NLP algorithms for specific search components
  - Consider business rules, post filters, results blender, user experience, etc

- **Online Latency**
  - Serving deep NLP models with product latency restriction

Applying Deep NLP in Search

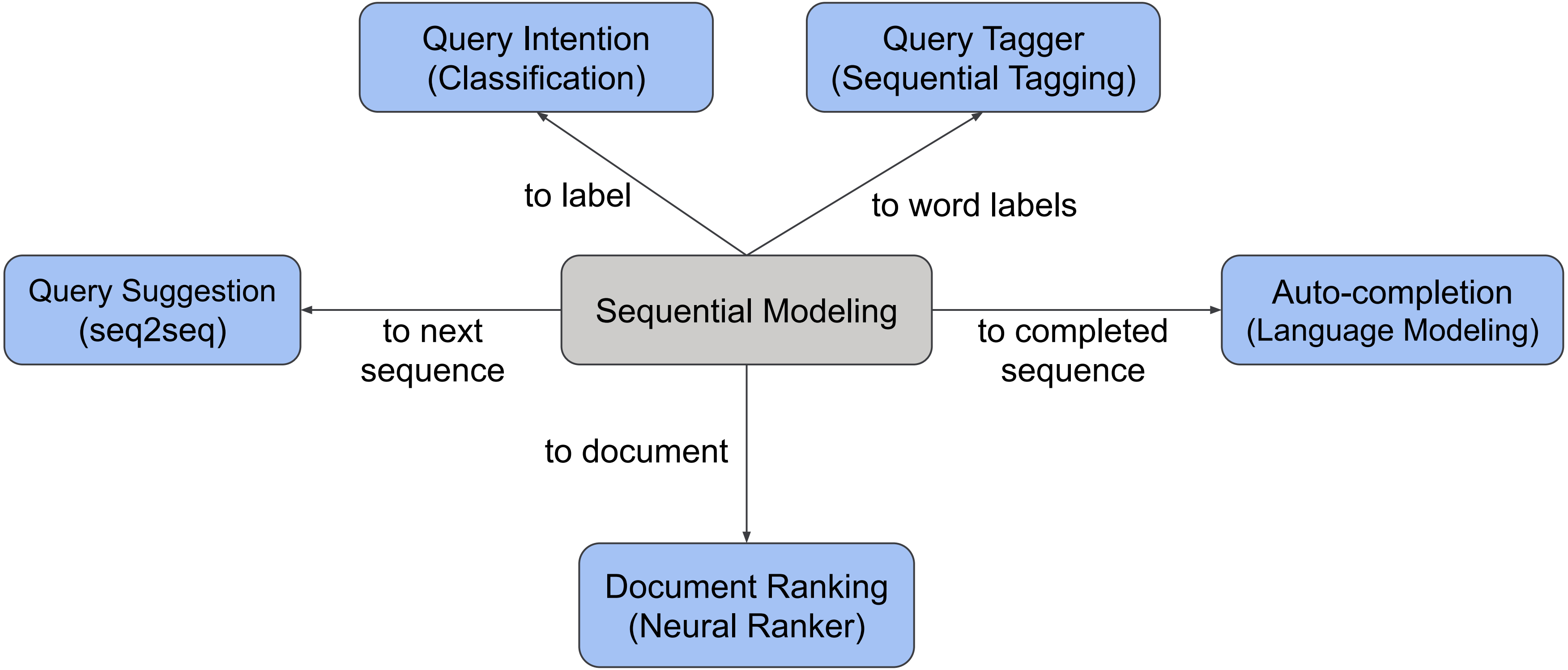
- **Feature Driven**
  - Representation Learning

    using features generated from deep learning models

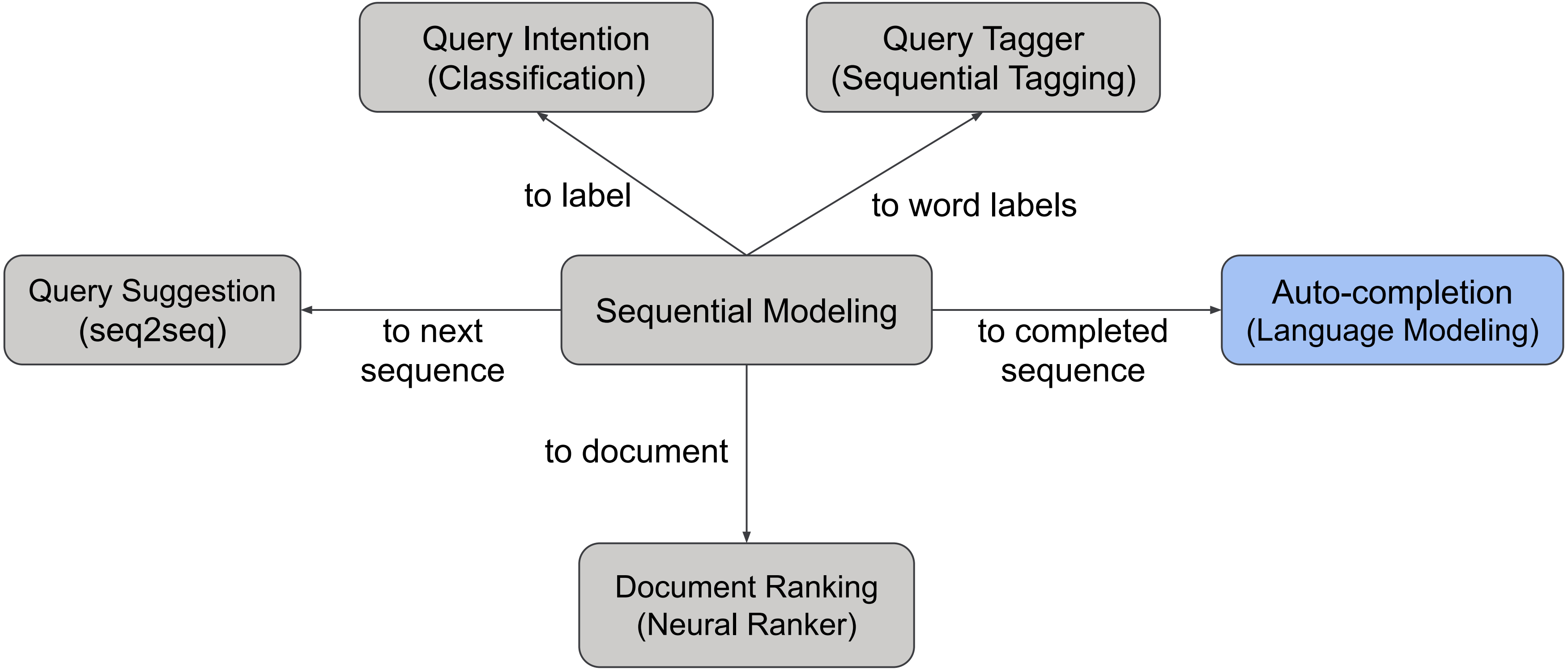
    e.g., word embedding

- **Model Driven**
  - Power product features directly with deep learning models
    - CNN/LSTM/Seq2seq/GAN/BERT based deep NLP models

Deep Learning for Natural Language Processing



Deep Learning for Natural Language Processing



Natural Language Generation: Auto-Completion

- Given a prefix, predict the **completed query**, rather than the **completed word**

Auto-completion Challenges

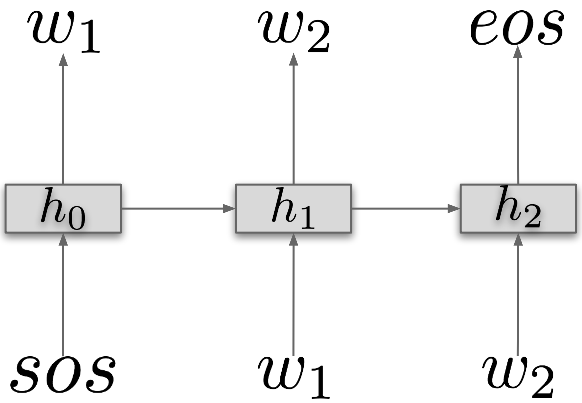
- High requirement of latency
  - Have to adopt simple and fast models
- Traditional methods cannot encode powerful textual features
  - Usually the helpful feature is the query frequency

A Two-step Approach: Generation and Ranking

- Candidate Generation
  - Collect query frequency from search log
  - For any prefix, FST returns the most frequent completed queries
  - When a prefix is never seen, remove one word from beginning
    - e.g., “metamind sof” → “sof”

- Candidate Ranking
  - Neural Language Model serves as a scoring function

Auto-Completion: Neural Language Model as Scoring/Ranking



$$s(q) = \sum_i \log P(w_{i+1} | h_i)$$

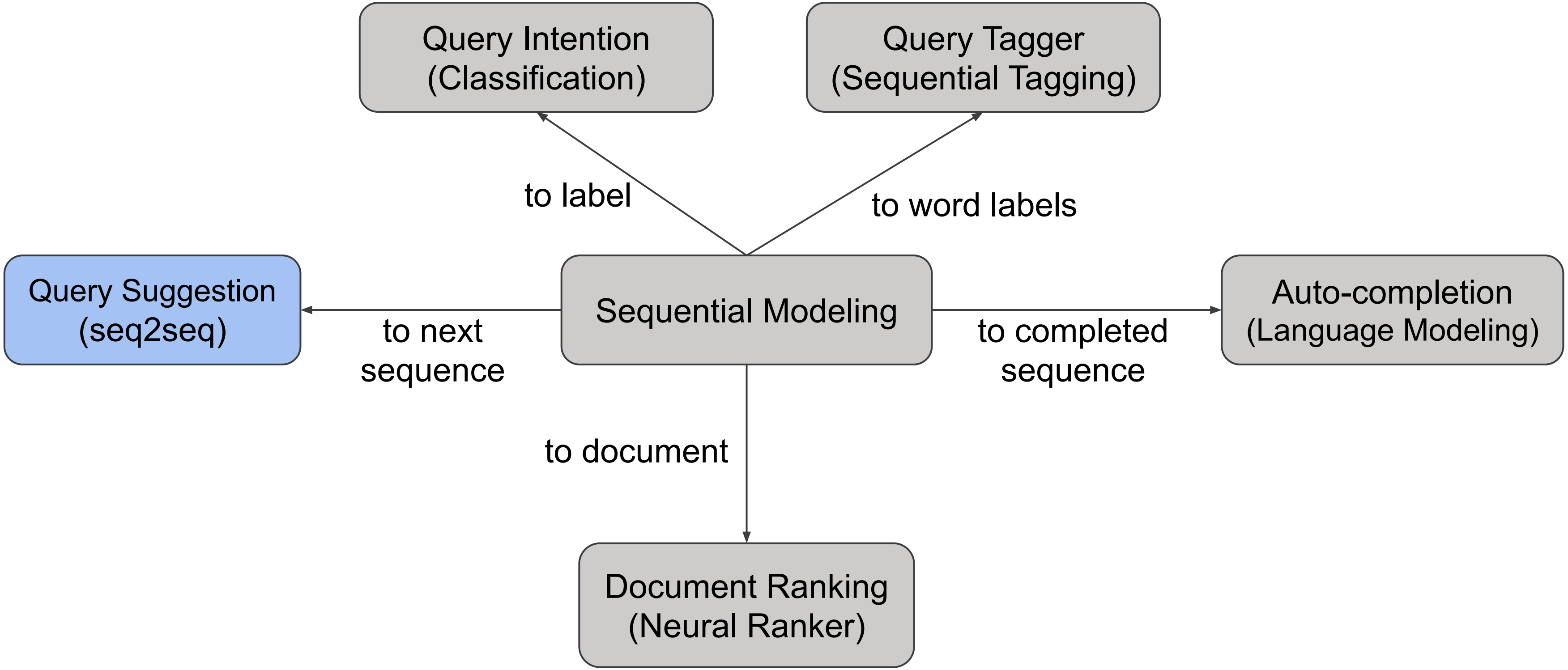
- Achieved 6x speedup with optimization

Auto-Completion Offline Experiments

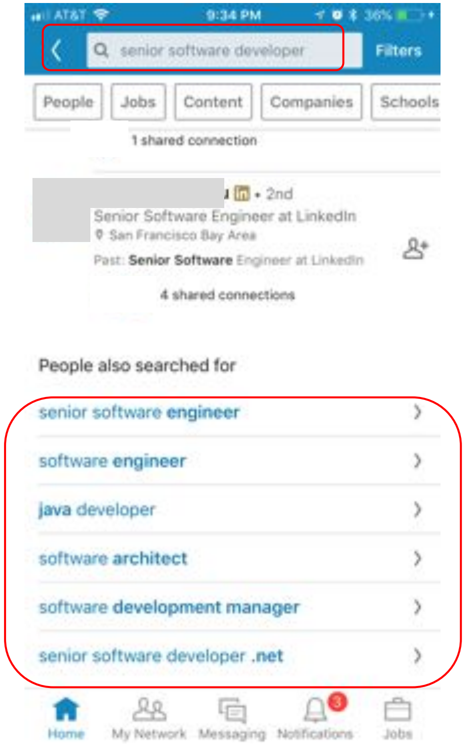
- Public Data Set: AOL
  - Baseline: Most Popular Candidate (MPC), FST-backoff
  - Evaluation metrics: MRR, 4th place → 0.25

Generation	Ranking	dev	test
MPC		18.097	17.032
FST-backoff		33.274 (+83.8%)	32.331 (+89.8%)
FST-backoff	neural	34.877 (+92.7%)	33.784 (+98.3%)

Deep Learning for Natural Language Processing

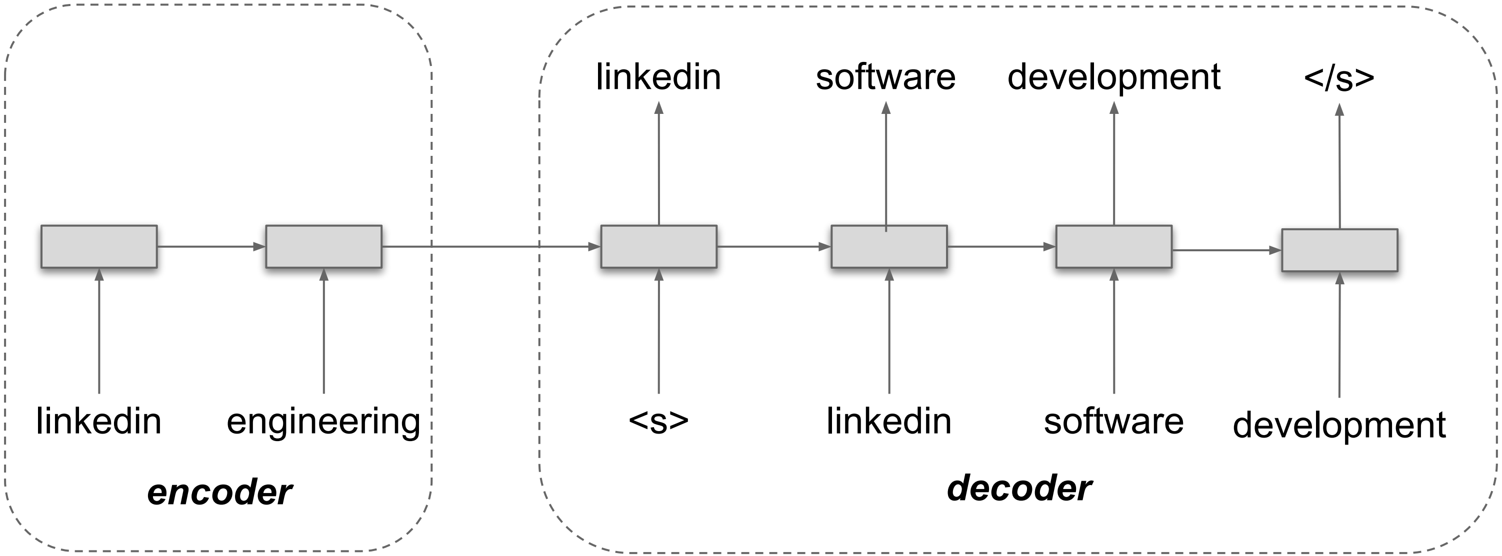


Natural Language Generation: Query Suggestion



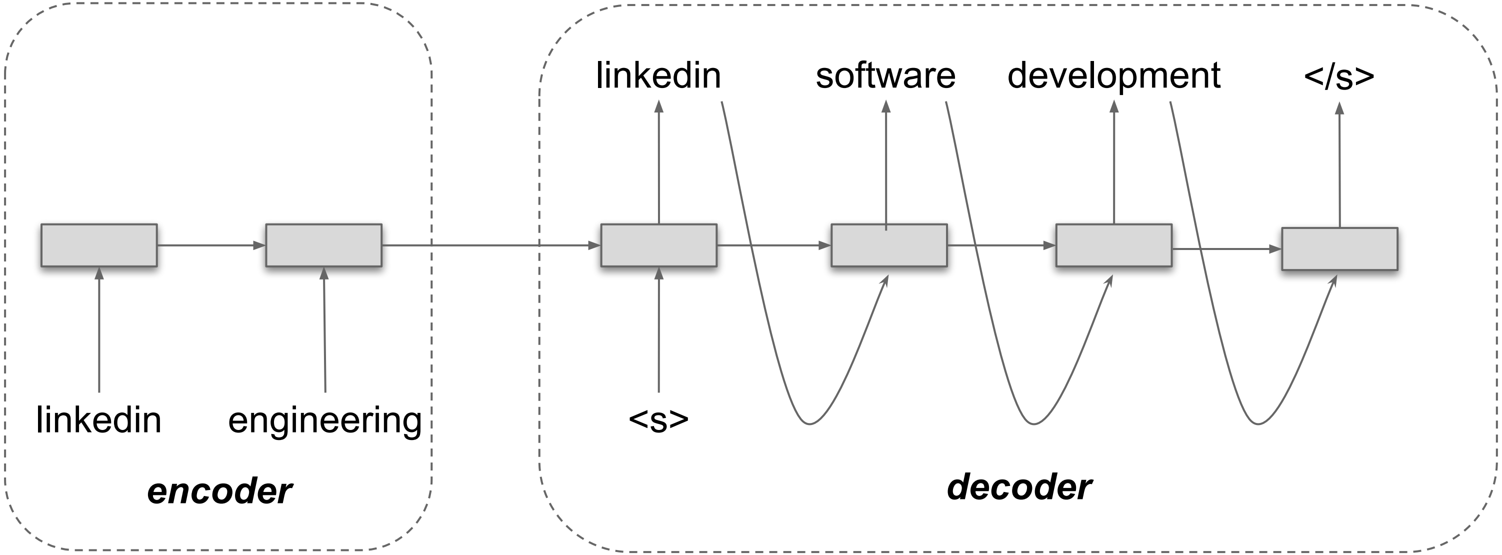
- Traditional frequency based methods
  - Collect <q1, q2> pairs from search log
  - Save the frequent pairs in a key-value store
- Lack of generalization
  - Purely string matching
  - Cannot handle unseen queries, rare words
- Seq2seq: capture query reformulation

Query Suggestion: Reformulate to Related Queries



- Training: the 2nd query is given
- Maximize $P(\mathbf{y}|\mathbf{x}) = \prod P(y_i|h_i)$

Query Suggestion: Reformulate to Related Queries



- Inference: the 2nd query is unknown
- Beam search instead of greedy search

Query Suggestion: How to Handle Online Latency

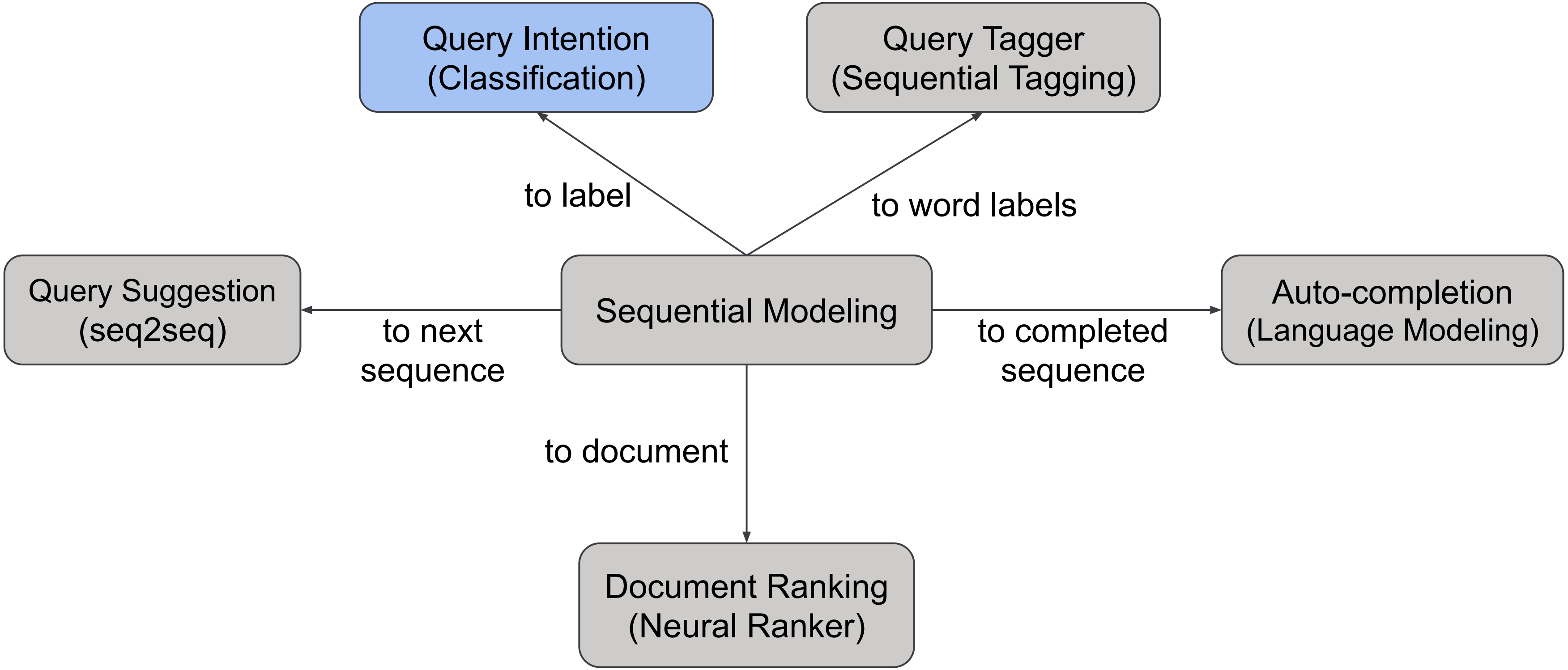
- Latency too long for one query

- Make it parallel with search ranking

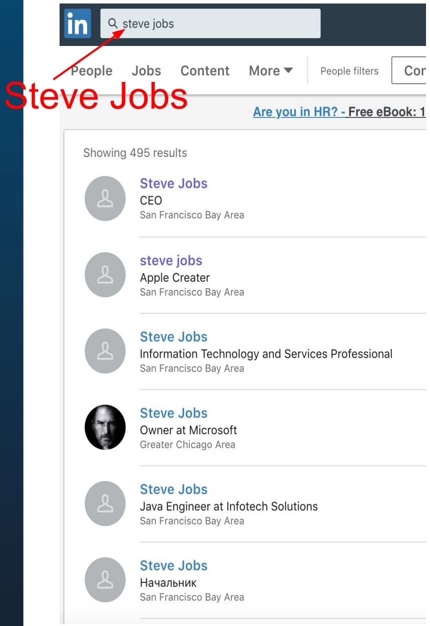
Online Performance

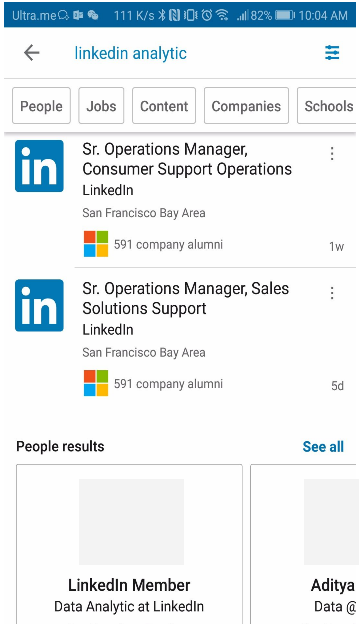
- English Market
  - Coverage: +80% Impressions, +26% CTR
  - +1% Total job application
- I18n Market
  - +3.2% Successful Searches
  - +28.6% First Order Actions

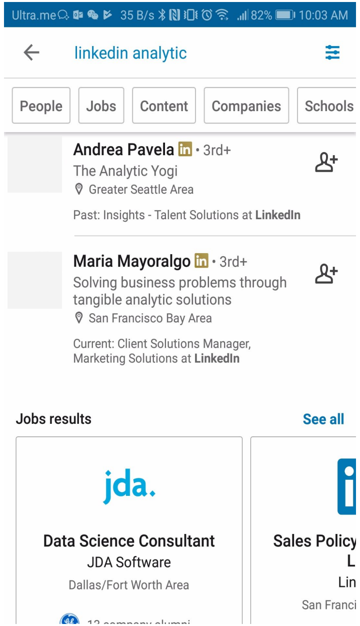
Deep Learning for Natural Language Processing



Natural Language Understanding: Query Intent







Motivation:

- To understand the task user wants to finish on LinkedIn

Challenges:

- Complicated Semantics
- Personalization

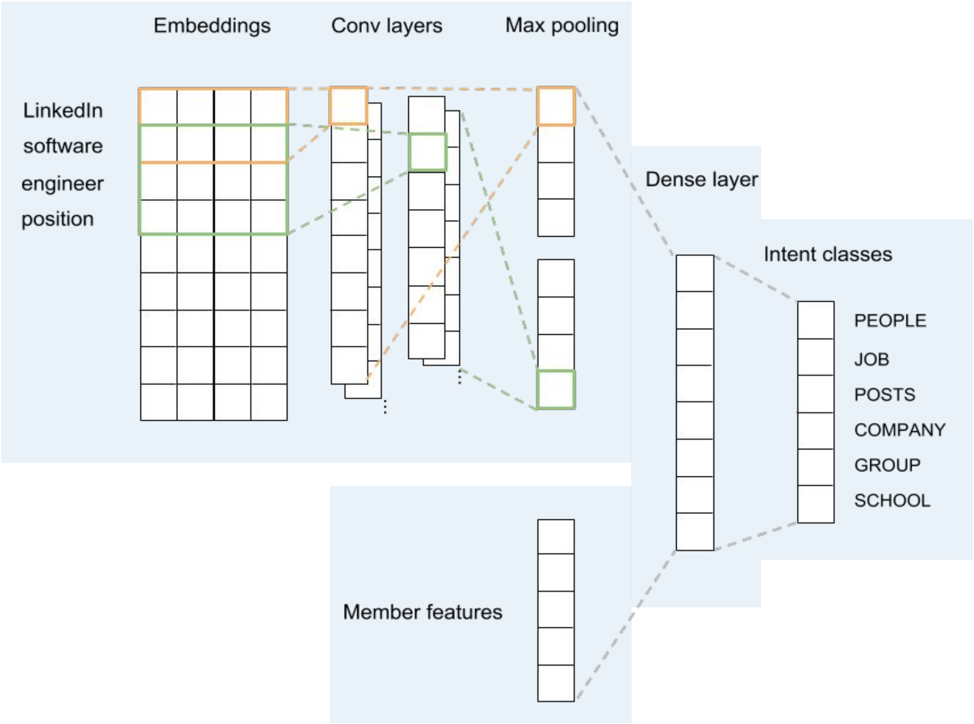
CNN Based Query Intention Model

CNN for Semantic Feature Extraction

- Word/query representations
- Generalization power
- Word n-gram patterns

Personalization

- Member-level Features



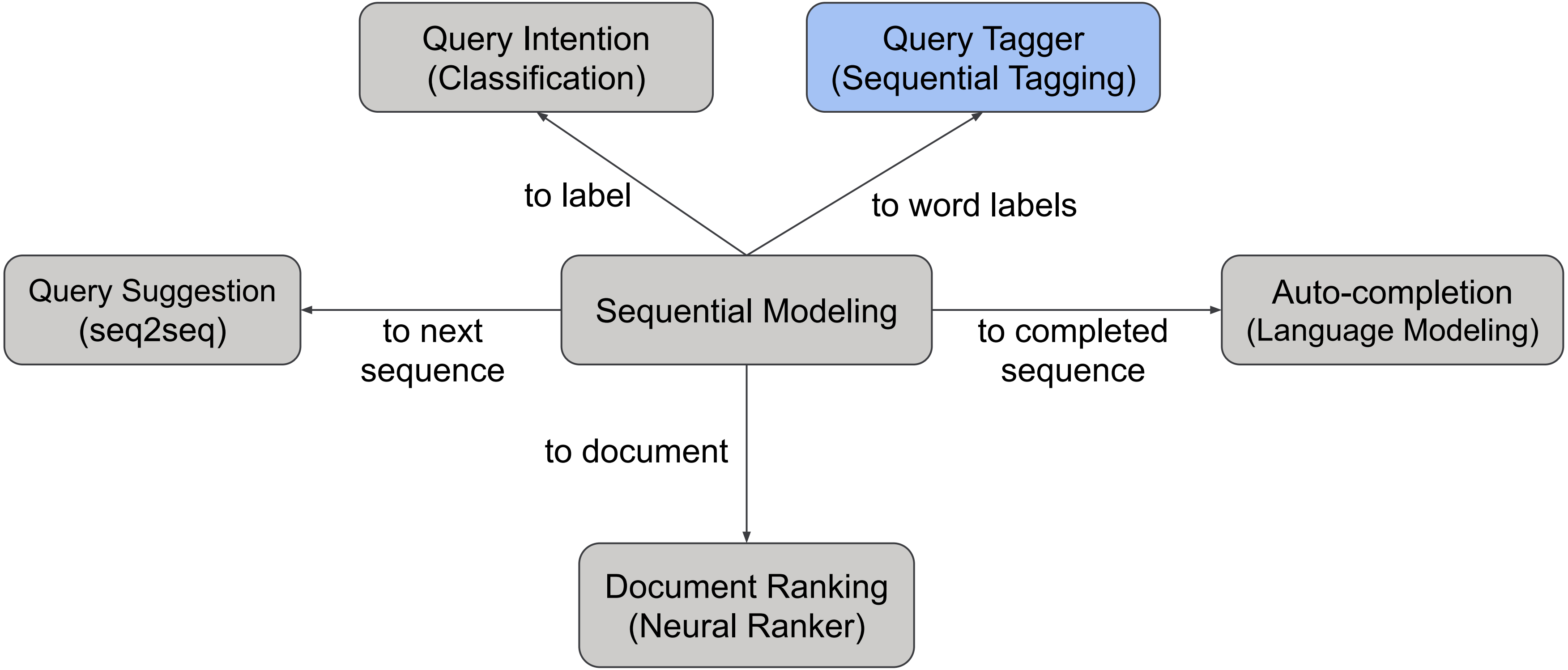
Query Intent

- Offline results

	Overall Accuracy	F1 on PEOPLE	F1 on JOB
LR (Baseline)	-	-	-
LR + BOW	+1.3%	+4.1%	+0.8%
CNN	+2.9%	+11.9%	+1.7%

- Online results
  - + 0.65% JOB Ctr At 1 Serp
  - + 0.90% Overall Cluster Ctr, + 4.03% Cluster Ctr Via Entity Click

Deep Learning for Natural Language Processing



Natural Language Understanding: Query Tagger

LinkedIn	software	engineer	data	scientist	jobs
CN	T	T	T	T	O
B-CN	B-T	I-T	B-T	I-T	O

B-CN: beginning of a company name

I-CN: Inside of a company name

B-T: beginning of a job title

I-T: Inside of a job title

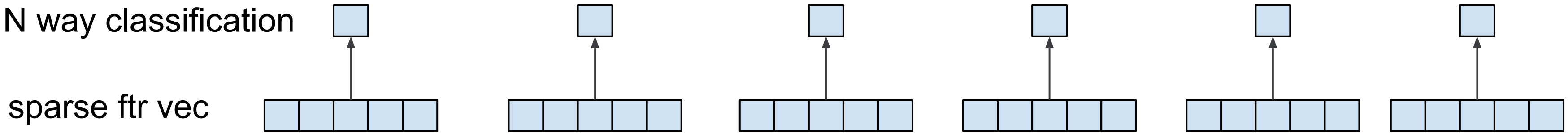
O: Not an entity

B-PN: beginning of person name

…

Query Tagger: Logistic Regression

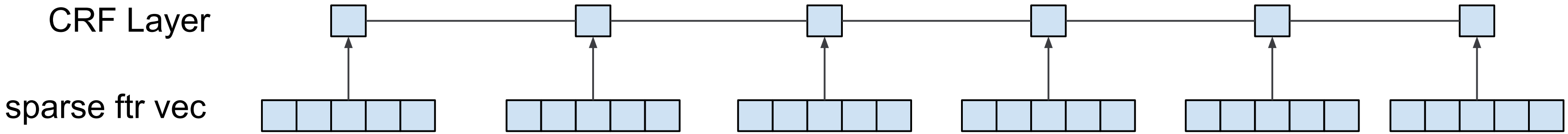
LinkedIn	software	engineer	data	scientist	jobs
B-CN	B-T	I-T	B-T	I-T	O



ftr 0: whether the current word is “linkedin”
ftr 1: whether the current word is “facebook”
…
ftr n: whether the next word is “software”
ftr n+1: whether the next word is “linkedin”
….

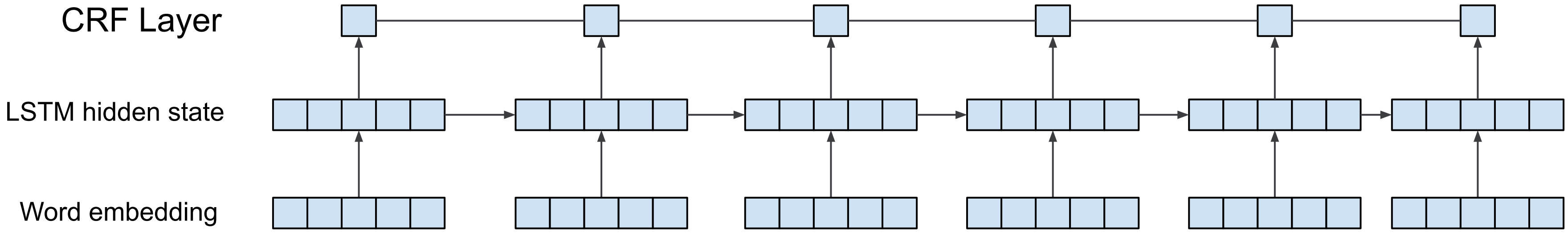
Query Tagger: CRF

LinkedIn	software	engineer	data	scientist	jobs
B-CN	B-T	I-T	B-T	I-T	O

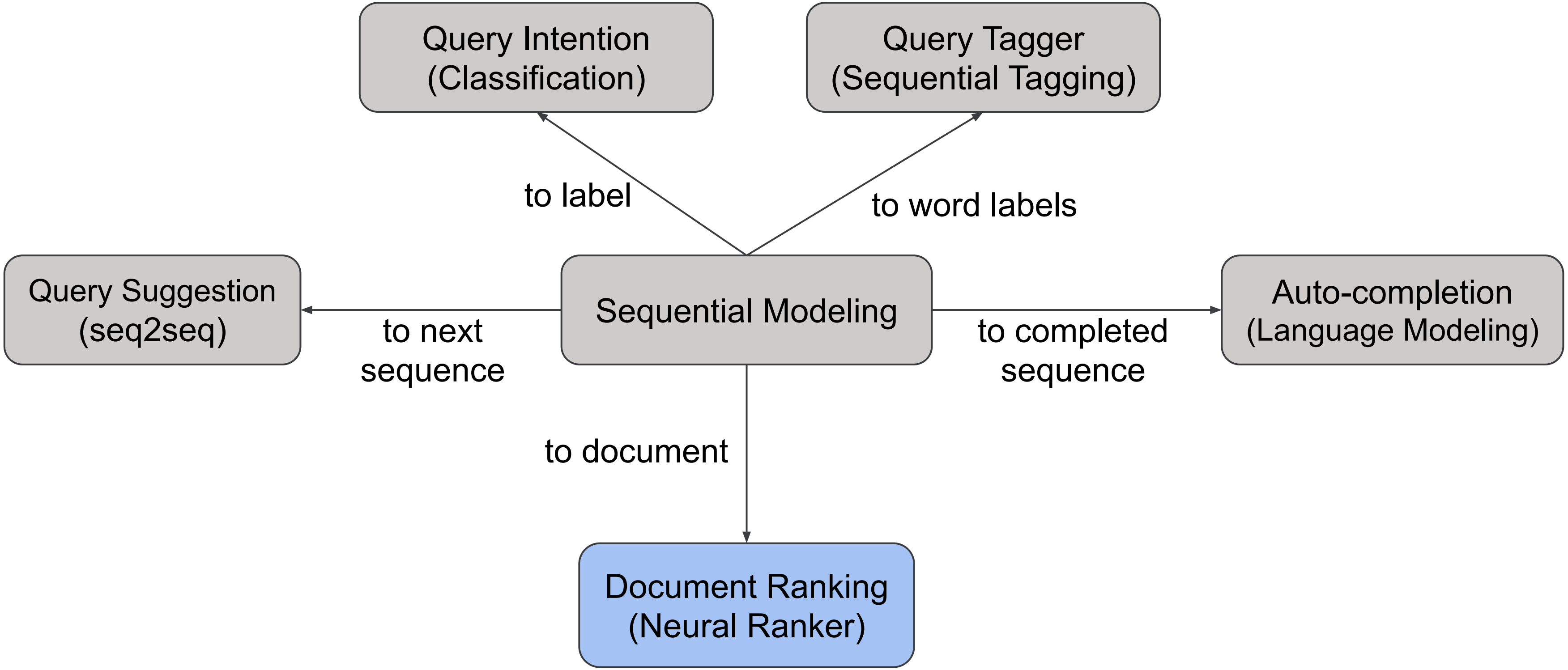


Query Tagger: CRF + LSTM

LinkedIn	software	engineer	data	scientist	jobs
B-CN	B-T	I-T	B-T	I-T	O



Deep Learning for Natural Language Processing



Natural Language Understanding: Document Ranking

LinkedIn Help

how to hide my profile update

Viewing and Deleting Profile Activity Updates ARTICLE

When you make changes to your profile, these updates are visible to your network. However, you have the option to view and delete your profile activity updates. To view your profile activity updates: Click the Me icon at the top of your…

Hiding Your Public Profile ARTICLE

Your public profile will be visible to people who aren't members, who aren't signed in to LinkedIn, or those who haven't linked their LinkedIn account to their account on other approved services. To set limits on how much of your profile…

Sharing Profile Changes with Your Network ARTICLE

You can choose to notify your network about changes made to a specific section on your profile, such as when you: Add a new or current position Edit a current position Celebrate a work anniversary When you're adding or making changes to…

Help LinkedIn

how to hide my profile update

Viewing and Deleting Profile Activity Updates ARTICLE

When you make changes to your profile, these updates are visible to your network. However, you have the option to view and delete your profile activity updates. To view your profile activity updates: Click the Me icon at the top of your...

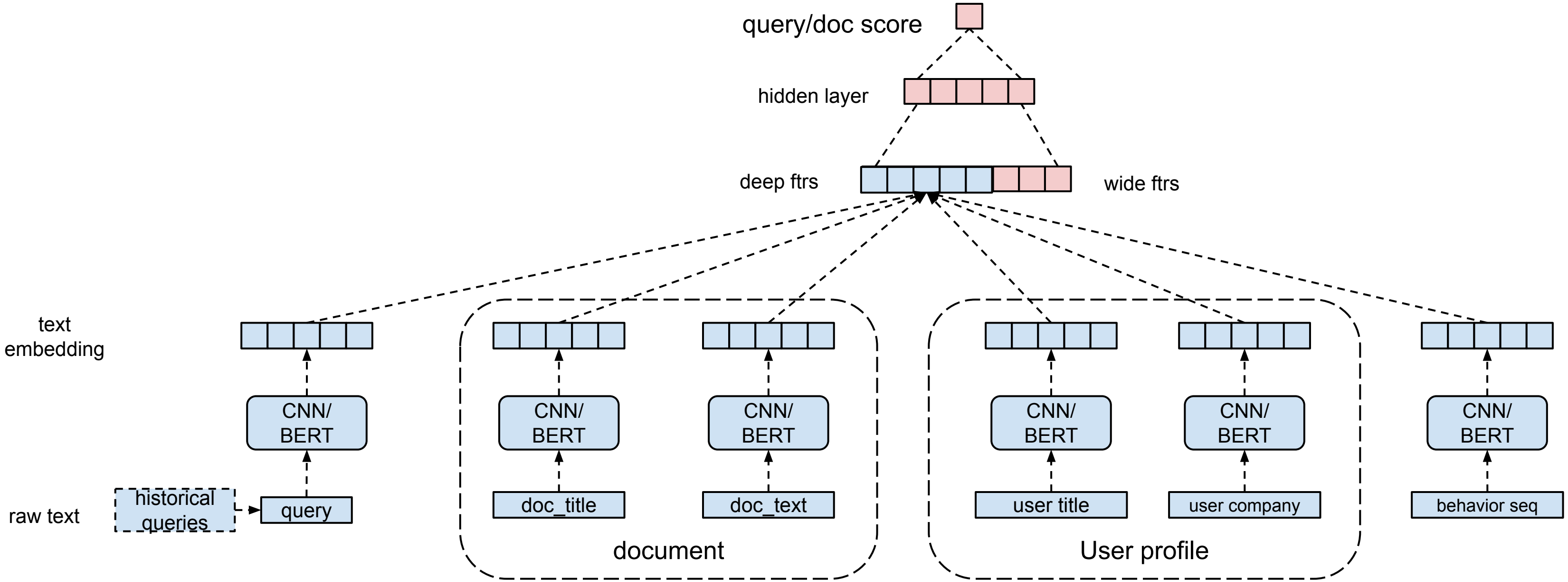
Sharing Profile Changes with Your Network ARTICLE

You can choose to notify your network about important changes made to certain sections on your profile. To adjust notifications sent to your network about profile changes from your Settings & Privacy page: Click the Me icon at the top...

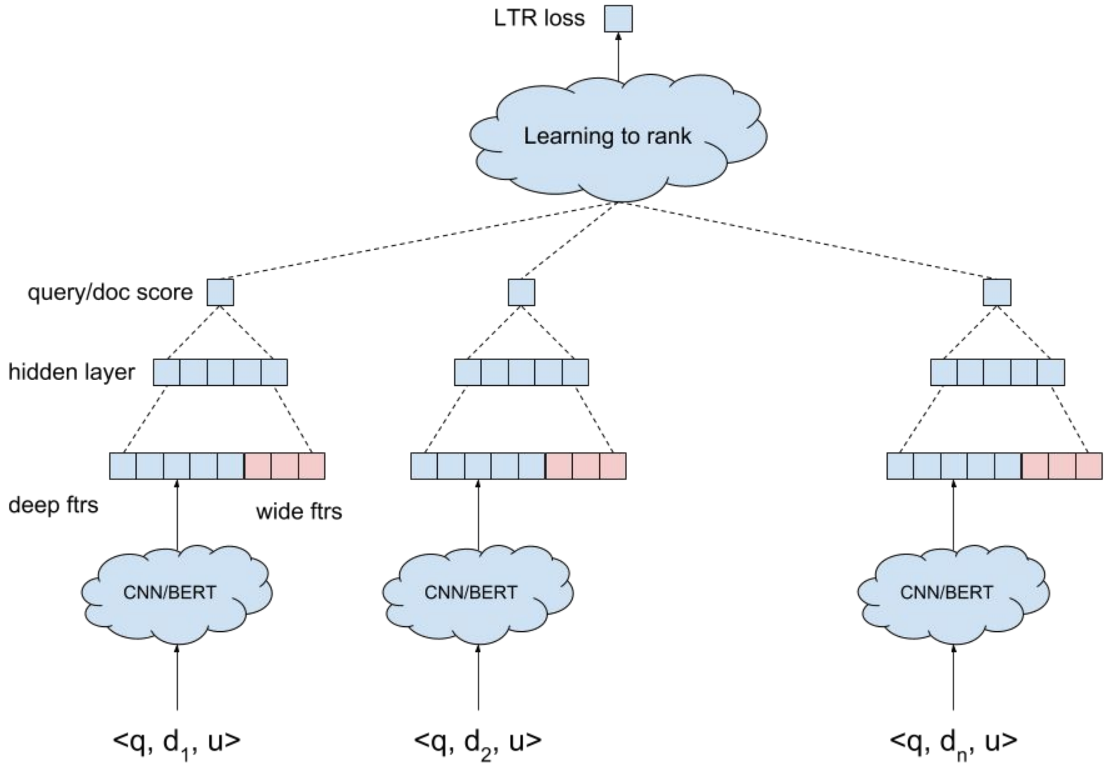
Visibility of Your Updates, Posts, and Activity ARTICLE

Your activity on LinkedIn shows all recent posts you've shared, and changes you've made to your profile. It also determines the type of content that will be displayed on your LinkedIn feed. Your activity will be visible to other members...

Neural Ranking: Scoring a Query/Document Pair



Neural Ranking: Training



Offline Experiments

People Search Ranking (NDCG@10)	
Wide Features	
CNN	+1.32%
BERT (google pretrained)	+1.52%
BERT (linkedin pretrained)	+1.96%

Online Experiments (100% Ramp)

- Help center ranking (BERT vs CNN)
  - +9.5% search ctr
  - +7% search clicks

Conclusions & Future Work

- Deep NLP technologies can power various search components directly with proper handling on challenges such as latency
- Design deep NLP technologies needs to consider the specific product properties as well as user experience
- Multilingual learning can be exploited for developing advanced deep NLP technologies