Semantic Parsing
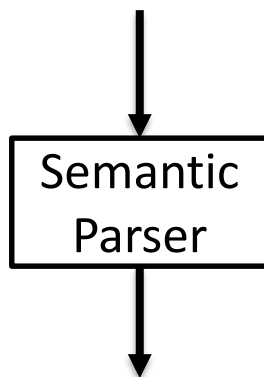
Transform natural language to logical form

Human friendly -> computer friendly

What is the highest mountain in Alaska ?

Semantic
Parser

(argmax $0 (and (mountain:t $0) (loc:t $0 alaska:s)) (elevation:i $0))

* Example from GeoQuery

Semantic Parsing - SOTA

(natural language, logical form) pairs

(Miller et al., 1996; Zelle and Mooney, 1996; Tang and Mooney, 2000; Thomspon and Mooney, 2003; Kate et al., 2005; Ge and Mooney, 2005; Kate and Mooney, 2006; Wong and Mooney, 2006;Wong and Mooney, 2007; Zettlemoyer and Collins, 2005; 2007; Lu et al., 2008; Kwiatkowski et al., 2010; 2011; Andreas et al., 2013; Zhao and Huang, 2015;)

(natural language, answer) pairs

(Clarke et al., 2010; Artzi and Zettlemoyer, 2011; Chen and Mooney, 2011; Goldwasser and Roth, 2011; Artzi and Zettlemoyer, 2013; Liang et al., 2013; Krishnamurthy and Mitchell, 2012; Cai and Yates, 2013; Reddy et al., 2014;)

What is the highest mountain in Alaska ?

```
Latent
Parse Structure
```
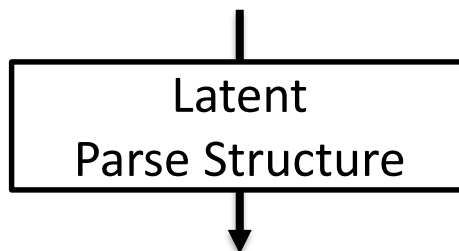
(argmax $0 (and (mountain:t $0) (loc:t $0 alaska:s)) (elevation:i $0))

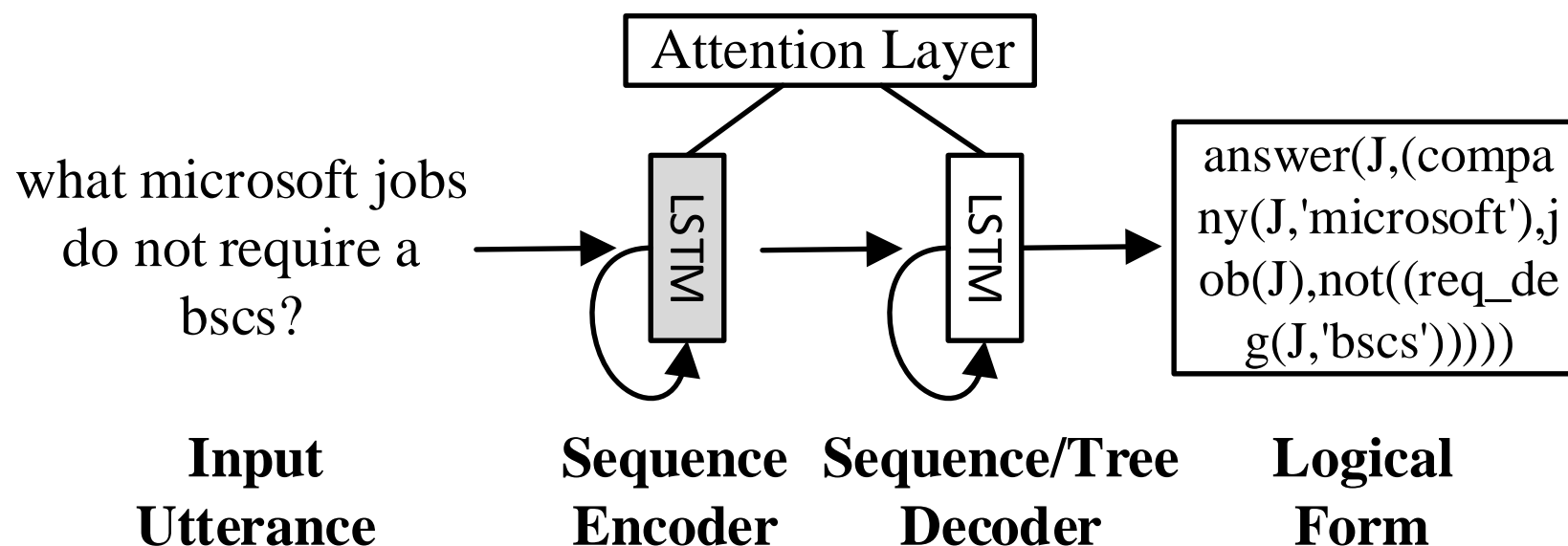# Semantic Parsing - SOTA

- Manually designed features
- Predefined templates
- Lexicon seeds

-> Domain- or representation-specific

Research Goal

- Reduce reliance on domain knowledge

- Use NNs to replace manually designed features

- Build a general-purpose parser: easy to adapt across domains and meaning representations

Our Work

what microsoft jobs do not require a bscs?

Input Utterance   **Sequence Encoder**   **Sequence/Tree Decoder**   **Logical Form**

Attention Layer

LSTM   LSTM

answer(J,(company(J,'microsoft'),job(J),not((req_deg(J,'bscs')))))

(Kalchbrenner and Blunsom, 2013; Cho et al., 2014; Sutskever et al., 2014; Karpathy and Fei-Fei, 2015; Vinyals et al., 2015;)

Sequence-to-Sequence (Seq2Seq) Model
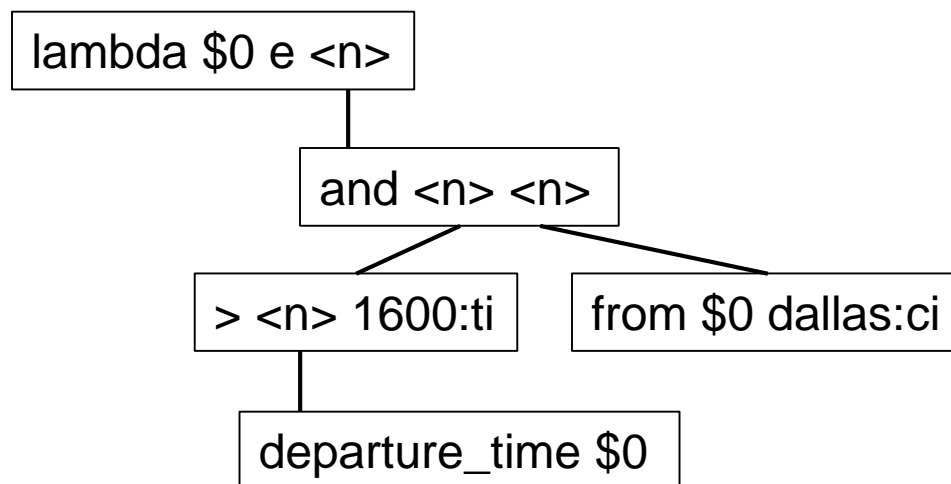
Decoder
Output: $a = y_1 \dots y_{|a|}$

Input: $q = x_1 \dots x_{|q|}$
Encoder
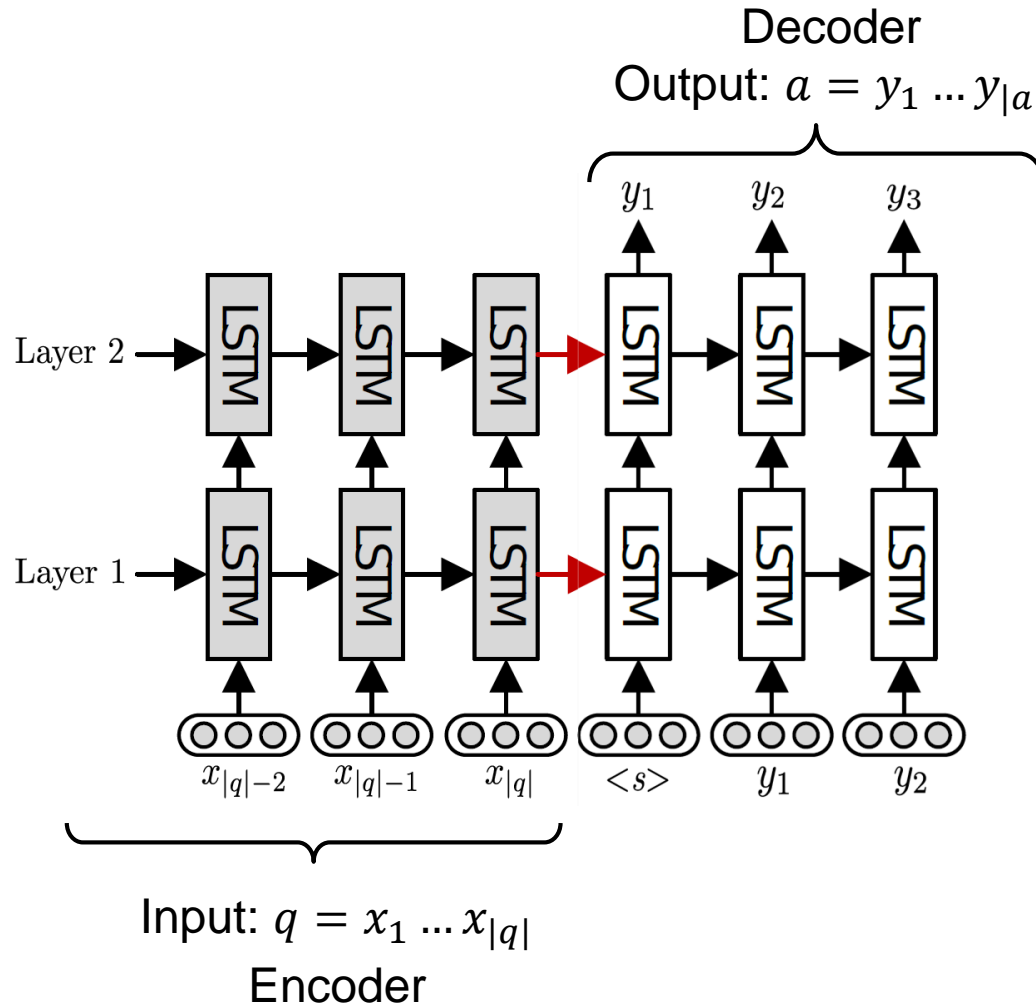
Drawback of Seq2Seq Model

Ignore the hierarchical structure of logical forms
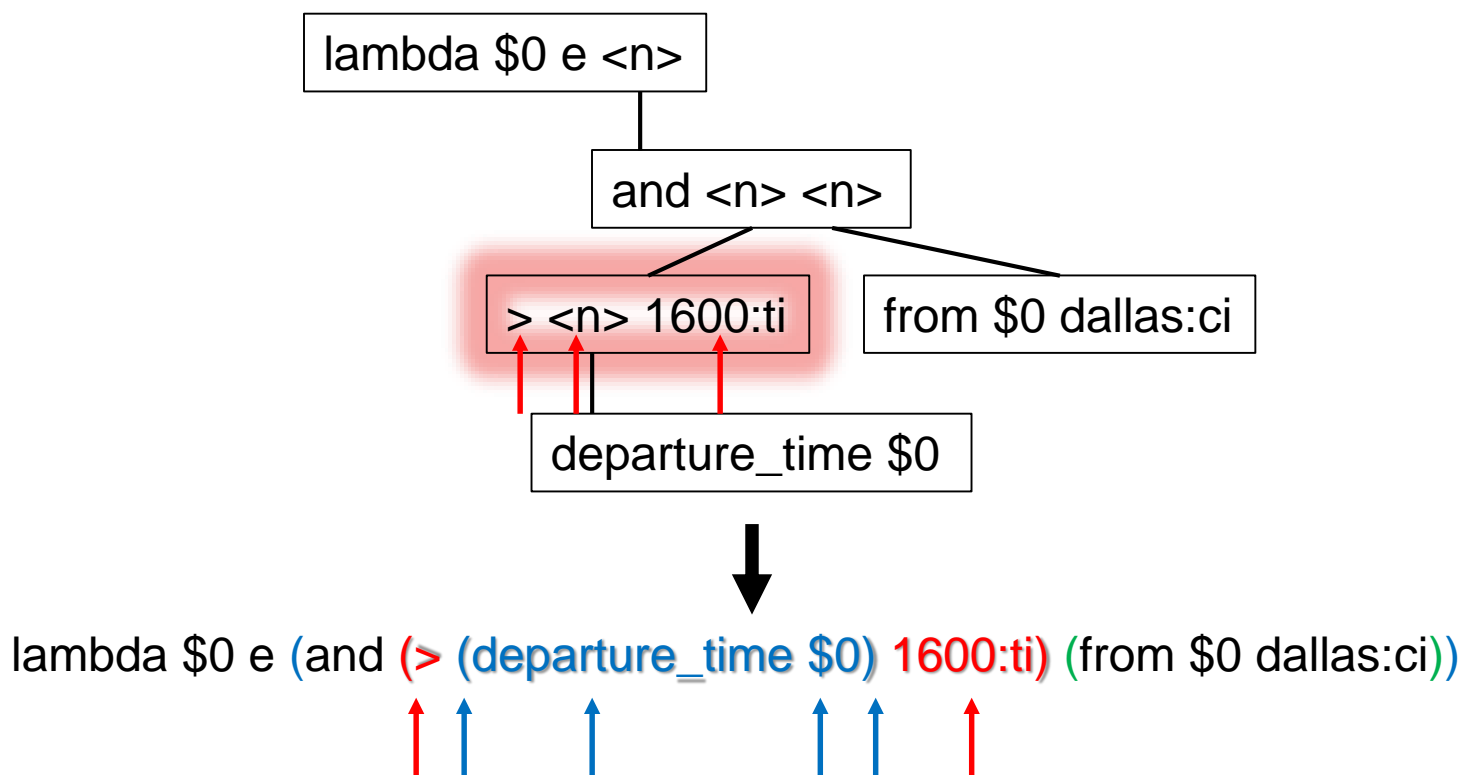
Use ``( )'' to linearize logical form

lambda $0 e (and (> (departure_time $0) 1600:ti) (from $0 dallas:ci))
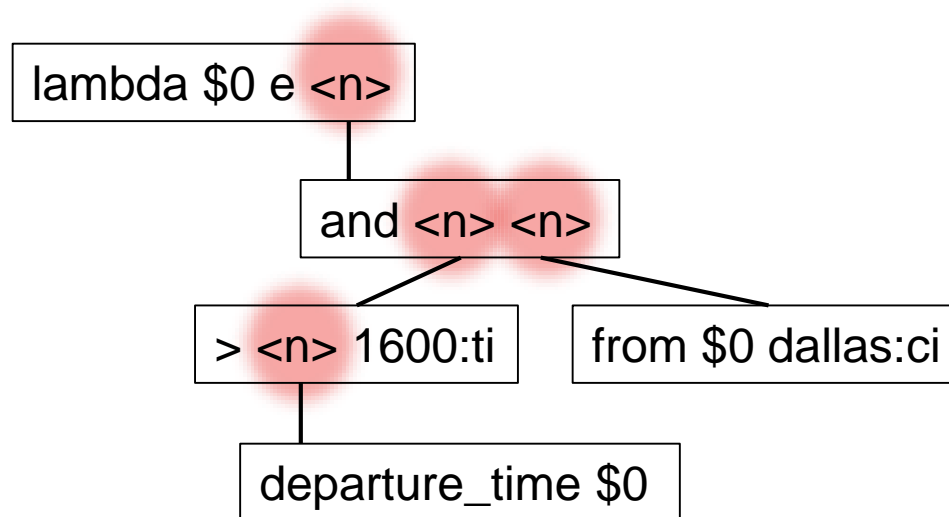
Drawback of Seq2Seq Model

Ignore the hierarchical structure of logical forms
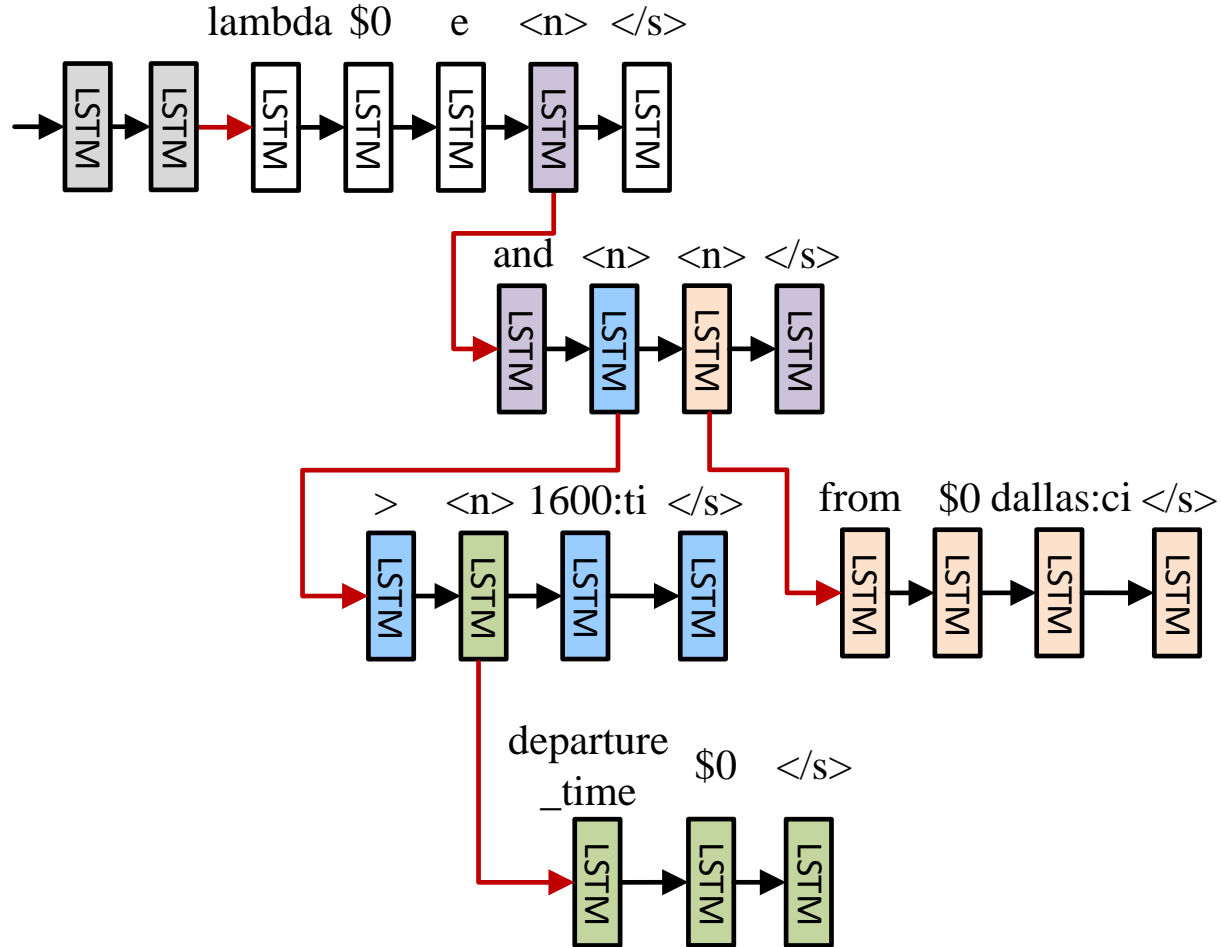
More long-distance dependency during decoding

lambda \$0 e (and (> (departure_time \$0) 1600:ti) (from \$0 dallas:ci))

Sequence-to-Tree (Seq2Tree) Model
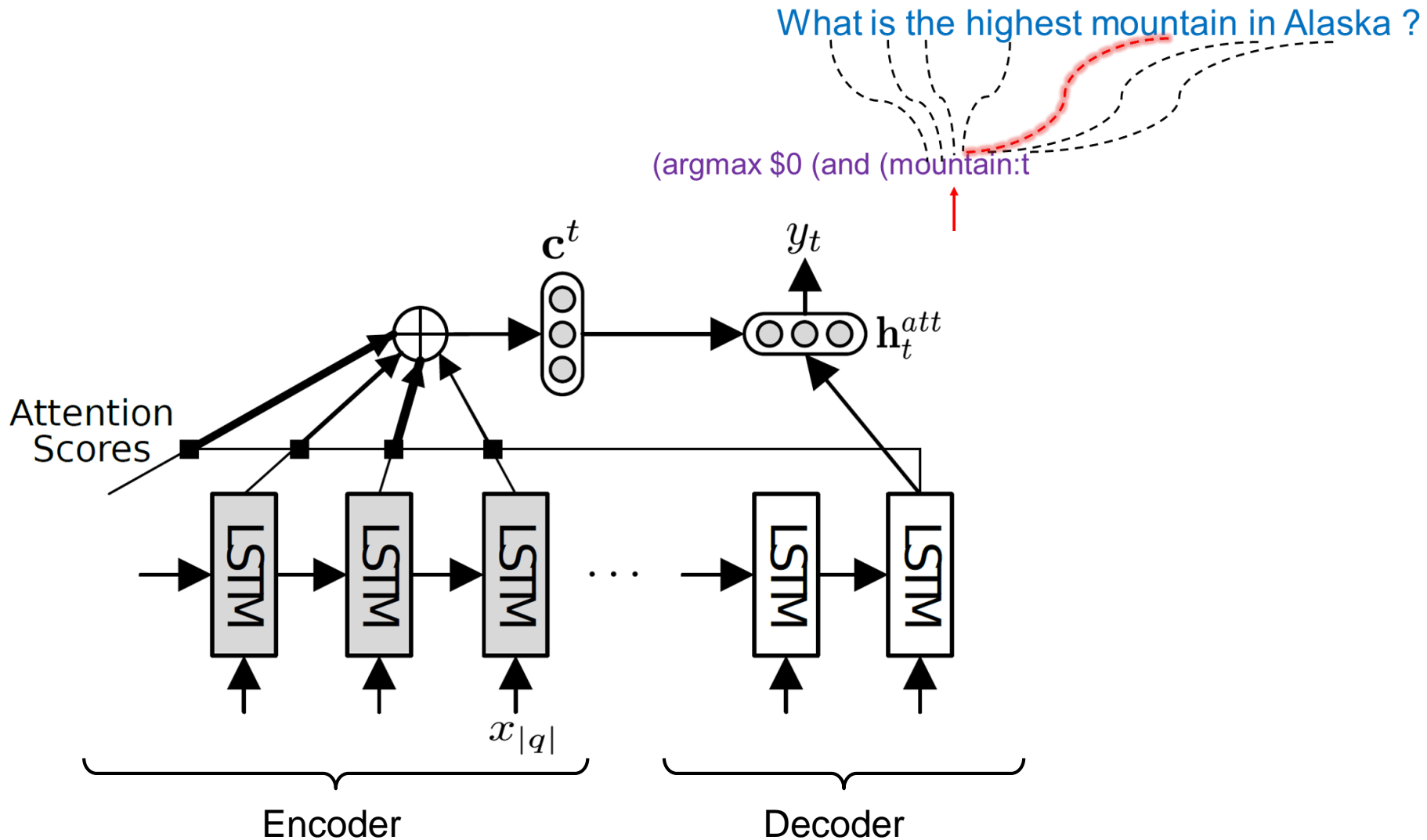
Define a "nonterminal" <n> token to indicate subtrees in decoder

Seq2Tree Decoder

Attention Mechanism – Soft Alignment

What is the highest mountain in Alaska ?

(argmax $0 (and (mountain:t

Attention Scores

$\mathbf{c}^t$

y_t

$\mathbf{h}_t^{att}$

LSTM

$x_{|q|}$

Encoder

Decoder

(Bahdanau et al., 2015; Luong et al., 2015b; Xu et al., 2015)

Training and Inference

- Training

$$\text{maximize} \sum_{(q,a)\in D} \log p(a|q)$$

- Inference

  - $\hat{a} = \underset{a'}{\text{argmax}}\, p(a'|q)$

  - Greedy/Beam search

Argument Identification

Many questions contain entities or numbers

- Unavoidably rare
- Or do not appear in the training set at all

jobs with a salary of <unk>

job(ANS), salary greater than(ANS, <unk> *year)*

Replace rare words with <unk> (Luong et al., 2015; Jean et al., 2015)

Detrimental for semantic parsing

Argument Identification

- Pre-process entities and numbers to $\underline{type_i}$

- At inference time, a post-processing step recovers maskers to their corresponding logical constants

jobs with a salary of $\boxed{\underline{num_0}}$

job(ANS), salary greater than(ANS, $\boxed{\underline{num_0}}$ *year)*

Experiments

Length	Jobs
9.80	what microsoft jobs do not require a bscs?
22.90	answer(J,company(J,'microsoft'),job(J),not((req deg(J,'bscs'))))

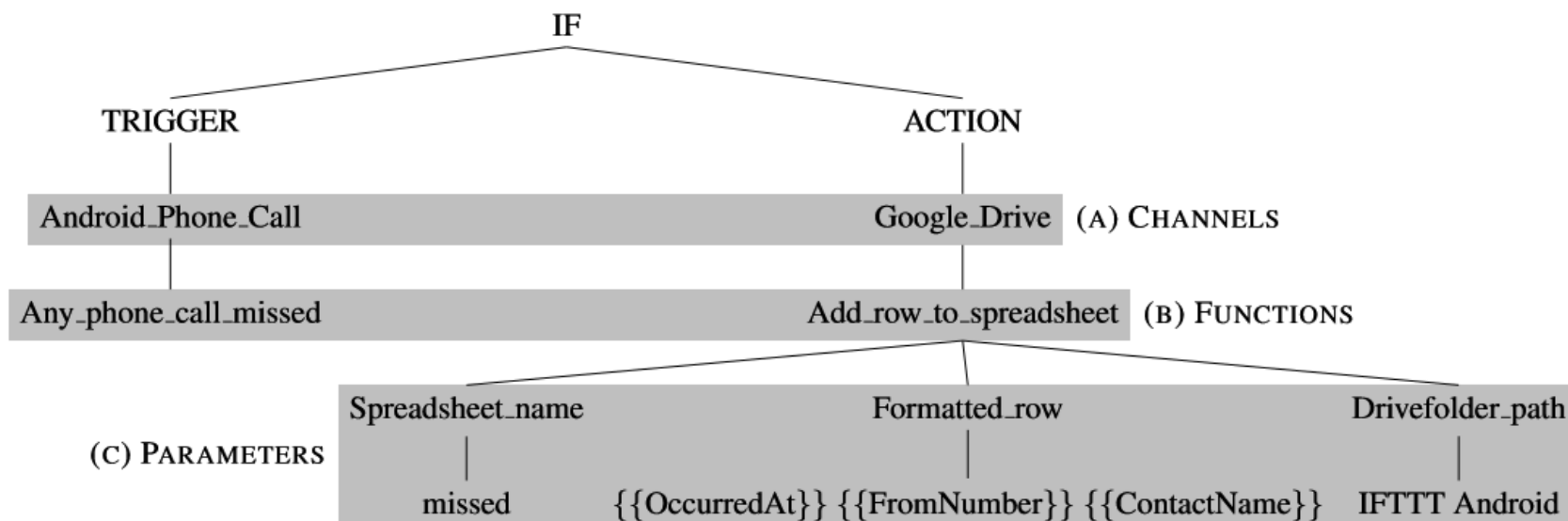| Length	Geo
7.60	what is the population of the state with the largest area?
19.10	(argmax $0 (and (mountain:t $0) (loc:t $0 alaska:s)) (elevation:i $0))

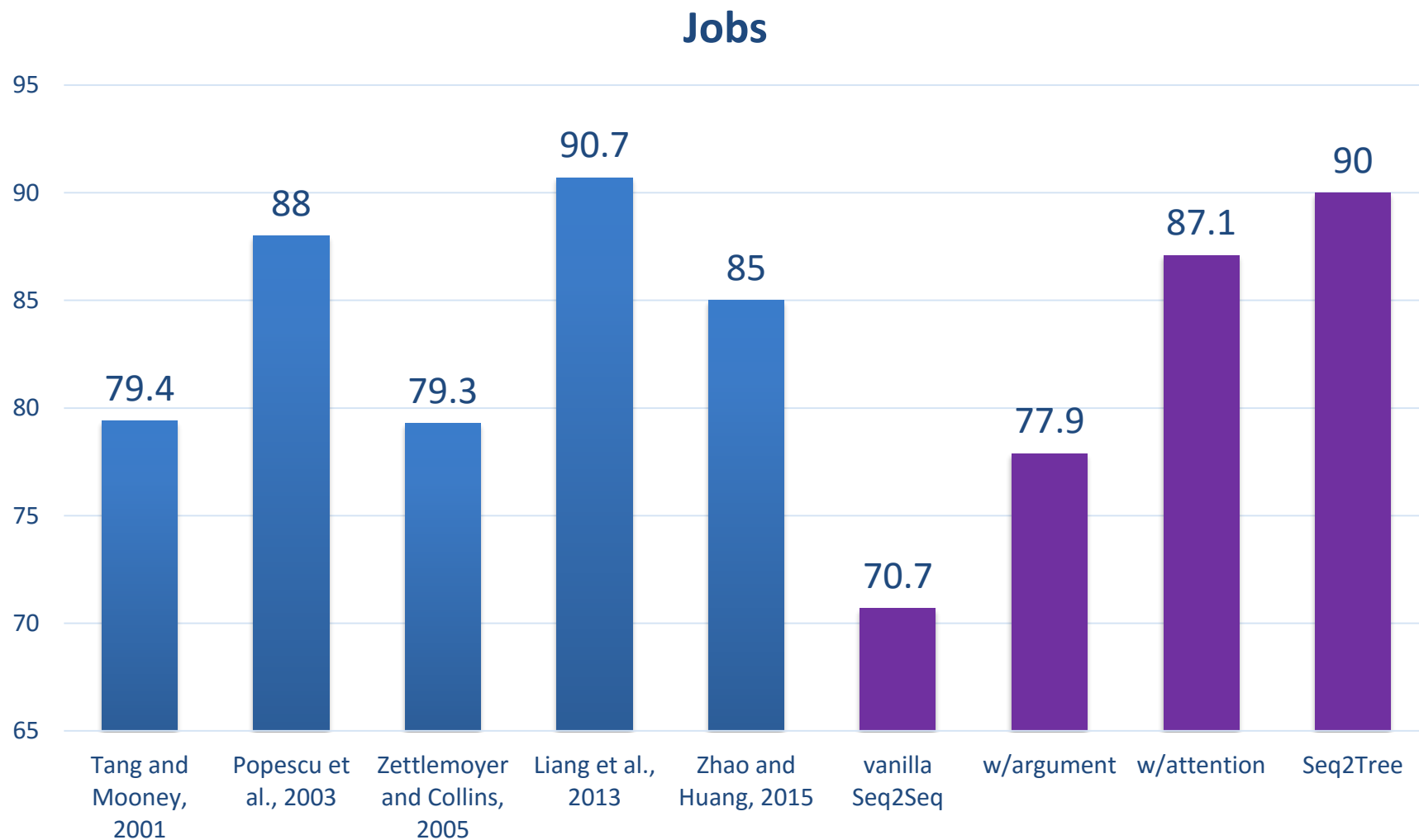| Length	ATIS
11.10	dallas to san francisco leaving after 4 in the afternoon please
28.10	(lambda $0 e (and (>(departure time $0) 1600:ti) (from $0 dallas:ci) (to $0 san francisco:ci)))

IF-This-Then-That

- turn on my lights when I arrive home

- text me if the door opens

- remind me to drink water if I've been at a bar for more than two hours

Archive your missed calls from Android to Google Drive

Experimental Results

Jobs
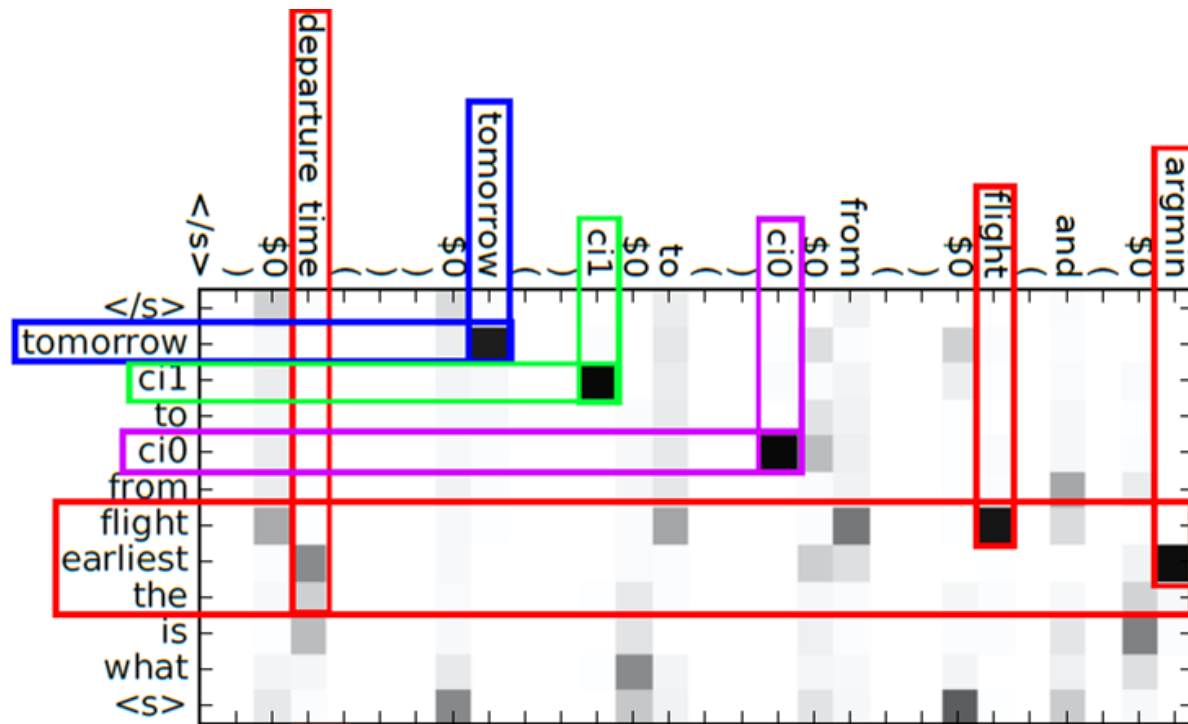
Bar chart values:
- Tang and Mooney, 2001: 79.4
- Popescu et al., 2003: 88
- Zettlemoyer and Collins, 2005: 79.3
- Liang et al., 2013: 90.7
- Zhao and Huang, 2015: 85
- vanilla Seq2Seq: 70.7
- w/argument: 77.9
- w/attention: 87.1
- Seq2Tree: 90

Experimental Results

Geo

Method	Score
Zettlemoyer and Collins,…	79.3
Zettlemoyer and Collins,…	86.1
Kwiatkowski et al., 2010	87.9
Kwiatkowski et al., 2011	88.6
Kwiatkowski et al., 2013	89
Liang et al., 2013	87.9
Zhao and Huang, 2015	88.9
vanilla Seq2Seq	68.6
w/argument	72.9
w/attention	84.6
Seq2Tree	87.1

IFTTT

Method	Score
retrieval	56.2
phrasal	45.5
sync	42.8
classifier	65
posclass	66.5
vanilla Seq2Seq	70.8
w/argument	72.9
w/attention	73.7
Seq2Tree	74.2

(Quirk et al., 2015): IFTTT baselines
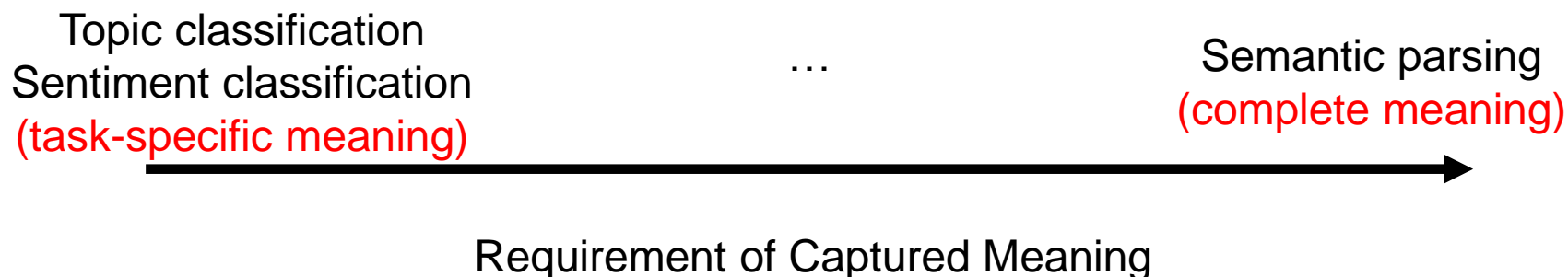
Attention Score

Darker color represents higher attention score

Example: what is the earliest flight from ci0 to ci1 tomorrow

Contributions

- Encoder-Decoder with Neural Networks
  - Seq2Seq/Seq2Tree models perform competitively on semantic parsing
  - A good task to understand the limitations of neural networks

Topic classification
Sentiment classification
(task-specific meaning)

…

Semantic parsing
(complete meaning)

Requirement of Captured Meaning

Contributions

- Encoder-Decoder with Neural Networks

  Seq2Seq/Seq2Tree models perform competitively on semantic parsing

- Tree decoder

  - Utilizing hierarchical structure of logical form improves performance

  - Structure prior/constraint of decoding results

  - Compositional nature of logical form

Contributions

- Encoder-Decoder with Neural Networks

  Seq2Seq/Seq2Tree models perform competitively on semantic parsing

- Tree decoder

  Utilizing hierarchical structure of logical form improves performance

- Attention mechanism

  Learn soft alignments between question and logical form

Future Work

- Weakly supervised learning

  Learn from (question, answer) pairs

- Open-domain

  QA over Freebase

- Utilize parsing results of questions

  CCG / Dependency / AMR

- Apply Seq2Tree model to related structured prediction tasks

Thanks!

Q&A

(Q-👋😃->🚦-💁->A)

Code Available:
http://homepages.inf.ed.ac.uk/s1478528