Neural Semantic Parsing with Type Constraints

Jayant Krishnamurthy, Pradeep Dasigi, Matt Gardner

Semantic Parsing: Language → Programs

Question

Which player was from South Korea?

Knowledge Source

Athlete	Nation
Sonja Henie	Norway
Kim Yu-Na	South Korea

Semantic Parsing

Logical Form

```
((row2cell athlete)
(cell2row south_korea))
```

Execution

Answer

Kim Yu-Na

[Zelle and Mooney, 1996]

Lexicalized Grammars for Semantic Parsing

If all the frogs died the population of raccoon would _ ?

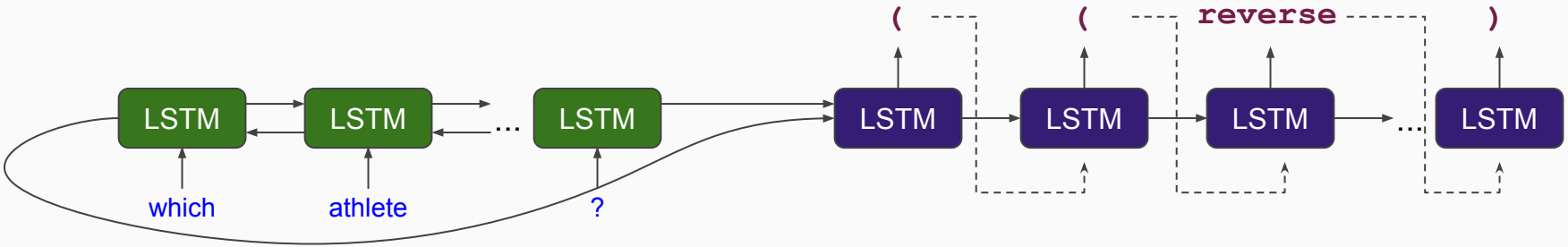
NP :	S\NP :	NP :	(S\S)\NP :
`frog`	`λx.decrease(x)`	`raccoon`	`λx.λe.λf.cause(e, f(x))`

S : `decrease(frog)` (S\S) : `λe.λf.cause(e, f(raccoon))`

S : `λf.cause(decrease(frog), f(raccoon))`

[Zettlemoyer and Collins 2005]
[Liang et al., 2011] [Krishnamurthy and Mitchell, 2012]
[Kwiatkowski et al., 2013] [Artzi et al., 2013], ...

Semantic Parsing via Machine Translation



[Andreas et al., 2013]
[Jia and Liang, 2016] [Dong and Lapata, 2016]
[Locascio et al., 2016] [Ling et al., 2016]
[Yin and Neubig, 2017] [Rabinovich et al., 2017]

Traditional vs Neural Semantic Parsing

	Guaranteed to produce valid logical form	No grammar induction	Train on Question/ Answer Pairs	Joint Entity Linking
Traditional Semantic Parsing	✓	✗	✓	✗/✓
Neural Semantic Parsing	✗	✓	✗	✗
This Work	✓	✓	✓	✓

Outline

- WikiTableQuestions
- Neural Semantic Parser
  - Type Constraints
  - Joint Entity Linking
  - QA Supervision
- Experimental Results

Dataset: WikiTableQuestions

[Pasupat and Liang, 2015]

Athlete	Nation	Olympics	Gold	Silver	Bronze
Gillis Grafström	Sweden	1932	3	1	0
Evgeni Plushenko	Russia	2014	2	2	0
Sonja Henie	Norway	1936	3	0	0
Kim Yu-na	S Korea	2014	1	1	0

Q: Which athlete was from South Korea after the year 2010?

A: Kim Yu-Na

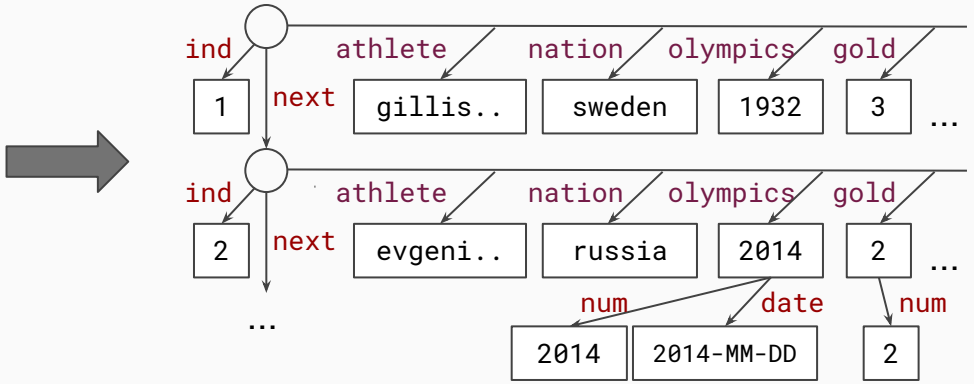
Q: How many more silver medals did Gillis Grafström have than Sonja Henie?

A: 1

Table Knowledge Graphs

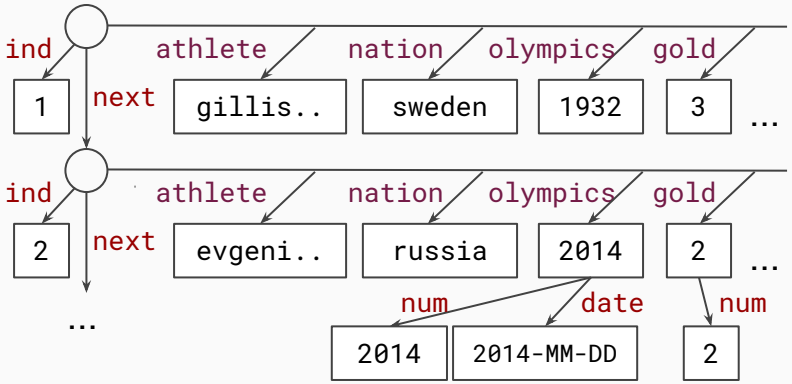
[Pasupat and Liang, 2015]

Athlete	Nation	Olympics	Gold	Silver	Bronze
Gillis Grafström	Sweden	1932	3	1	0
Evgeni Plushenko	Russia	2014	2	2	0
Sonja Henie	Norway	1936	3	0	0
Kim Yu-na	S Korea	2014	1	1	0



Logical Forms

[Pasupat and Liang, 2015]



Q: Which athlete was from South Korea after the year 2010?

```
((reverse athlete) (and (nation south_korea)
                        (year ((reverse date) (>= 2010-mm-dd)))))
```

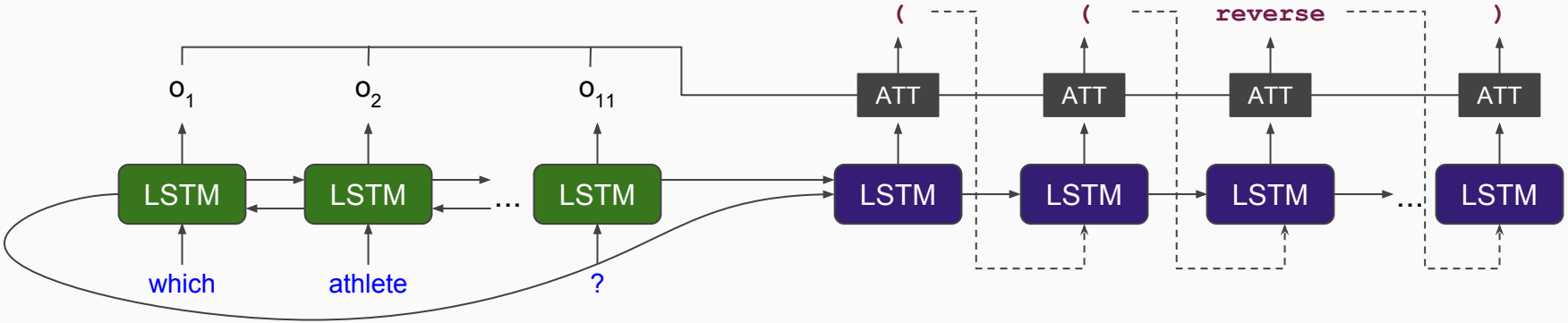
Q: How many more silver medals did Gillis Grafström have than Sonja Henie?

```
(- (num (silver (athlete gillis_grafstorm)))
   (num (silver (athlete sonja_henie))))
```

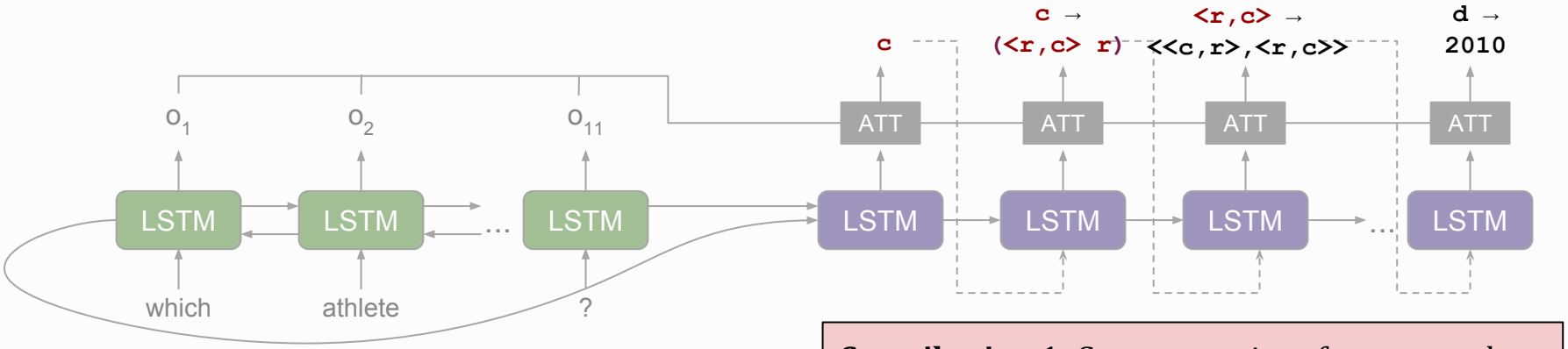
Outline

- WikiTableQuestions
- Neural Semantic Parser
  - Type Constraints
  - Joint Entity Linking
  - QA Supervision
- Experimental Results

Seq2seq Semantic Parser



Our Model



<u>Contribution 1:</u> Generate actions from a typed grammar instead of tokens from the logical form.

Type-constrained Decoding

Which athlete was from South Korea after the year 2010?

Generated Actions

C

Logical Form

C

Type-constrained Decoding

Which athlete was from South Korea after the year 2010?

Generated Actions

c

Logical Form

c

Type-constrained Decoding

Which athlete was from South Korea after the year 2010?

Generated Actions

c

c→(<r,c> r)

Logical Form

(<r,c> r)

Type-constrained Decoding

Which athlete was from South Korea after the year 2010?

Generated Actions

```
c
c→(<r,c> r)
```

Logical Form

```
(<r,c> r)
```

Type-constrained Decoding

Which athlete was from South Korea after the year 2010?

Generated Actions

c
c→(<r,c> r)
<r,c>→(<<c,r>,<r,c>> <c,r>)

Logical Form

((<<c,r>,<r,c>> <c,r>) r)

Type-constrained Decoding

Which athlete was from South Korea after the year 2010?

Generated Actions

```
c
c→(<r,c> r)
<r,c>→(<<c,r>,<r,c>> <c,r>)
```

Logical Form

```
((<<c,r>,<r,c>> <c,r>) r)
```

Type-constrained Decoding

Which athlete was from South Korea after the year 2010?

Generated Actions

c
c→(<r,c> r)
<r,c>→(<<c,r>,<r,c>> <c,r>)
<<c,r>,<r,c>>→**reverse**

Logical Form

((reverse <c,r>) r)

Type-constrained Decoding

Which athlete was from South Korea after the year 2010?

Generated Actions

```
c
c→(<r,c> r)
<r,c>→(<<c,r>,<r,c>> <c,r>)
<<c,r>,<r,c>>→reverse
```

Logical Form

```
((reverse <c,r>) r)
```

Type-constrained Decoding

Which athlete was from South Korea after the year 2010?

Generated Actions

```
c
c→(<r,c> r)
<r,c>→(<<c,r>,<r,c>> <c,r>)
<<c,r>,<r,c>>→reverse
<c,r>→athlete
```

Logical Form

```
((reverse athlete) r)
```

Type-constrained Decoding

Which athlete was from South Korea after the year 2010?

Generated Actions

```
c
c→(<r,c> r)
<r,c>→(<<c,r>,<r,c>> <c,r>)
<<c,r>,<r,c>>→reverse
<c,r>→athlete
r→(<r,<r,r>> r r)
<r,<r,r>>→and
r→(<c,r> c)
<c,r>→nation
c→south_korea
r→(<c,r> c)
<c,r>→year
c→(<r,c> r)
<r,c>→(<<c,r>,<r,c>> <c,r>)
```

Logical Form

```
((reverse athlete)
 (and (nation south_korea)
      (year ((<<c,r>,<r,c>>
              <c,r>)
             r))))
```

Type-constrained Decoding

Which athlete was from South Korea after the year 2010?

Generated Actions

```
c
c→(<r,c> r)
<r,c>→(<<c,r>,<r,c>> <c,r>)
<<c,r>,<r,c>>→reverse
<c,r>→athlete
r→(<r,<r,r>> r r)
<r,<r,r>>→and
r→(<c,r> c)
<c,r>→nation
c→south_korea
r→(<c,r> c)
<c,r>→year
c→(<r,c> r)
<r,c>→(<<c,r>,<r,c>> <c,r>)
<<c,r>,<r,c>>→reverse
<c,r>→date
r→(>= d)
d→2010.mm.dd
```

Logical Form

```
((reverse athlete)
 (and (nation south_korea)
      (year ((reverse date)
             (>= 2010-mm-dd)))
```

Type-constrained Decoding

Which athlete was from South Korea after the year 2010?

Generated Actions

```
c
c→(<r,c> r)
<r,c>→(<<c,r>,<r,c>> <c,r>)
<<c,r>,<r,c>>→reverse
<c,r>→athlete
r→(<r,<r,r>> r r)
<r,<r,r>>→and
r→(<c,r> c)
<c,r>→nation
c→south_korea
r→(<c,r> c)
<c,r>→year
c→(<r,c> r)
<r,c>→(<<c,r>,<r,c>> <c,r>)
<<c,r>,<r,c>>→reverse
<c,r>→date
r→(>= d)
d→2010.mm.dd
```

Logical Form

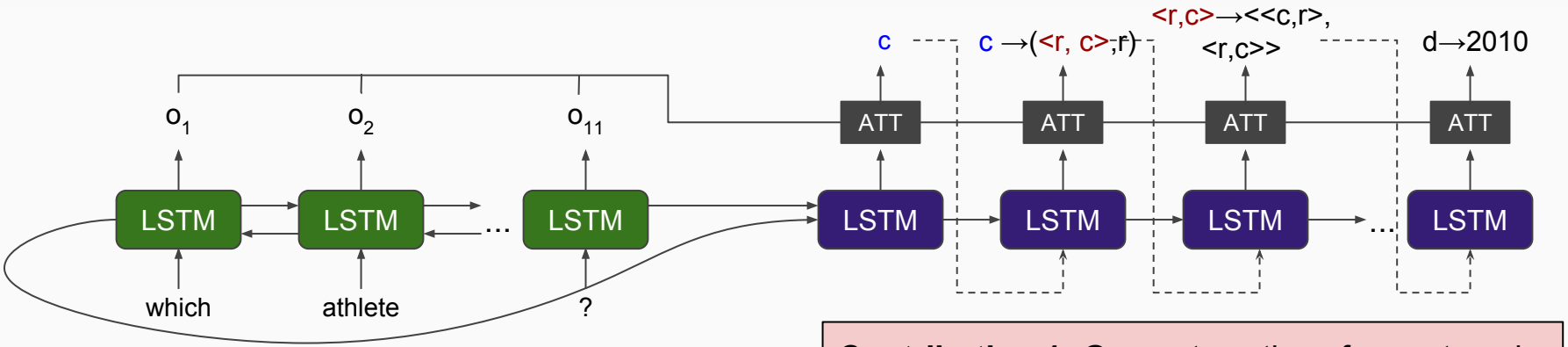
```
((reverse athlete)
 (and (nation south_korea)
      (year ((reverse date)
             (>= 2010-mm-dd)))
```

Four transformation rules:

- Constant
- Application
- Lambda
- Variable

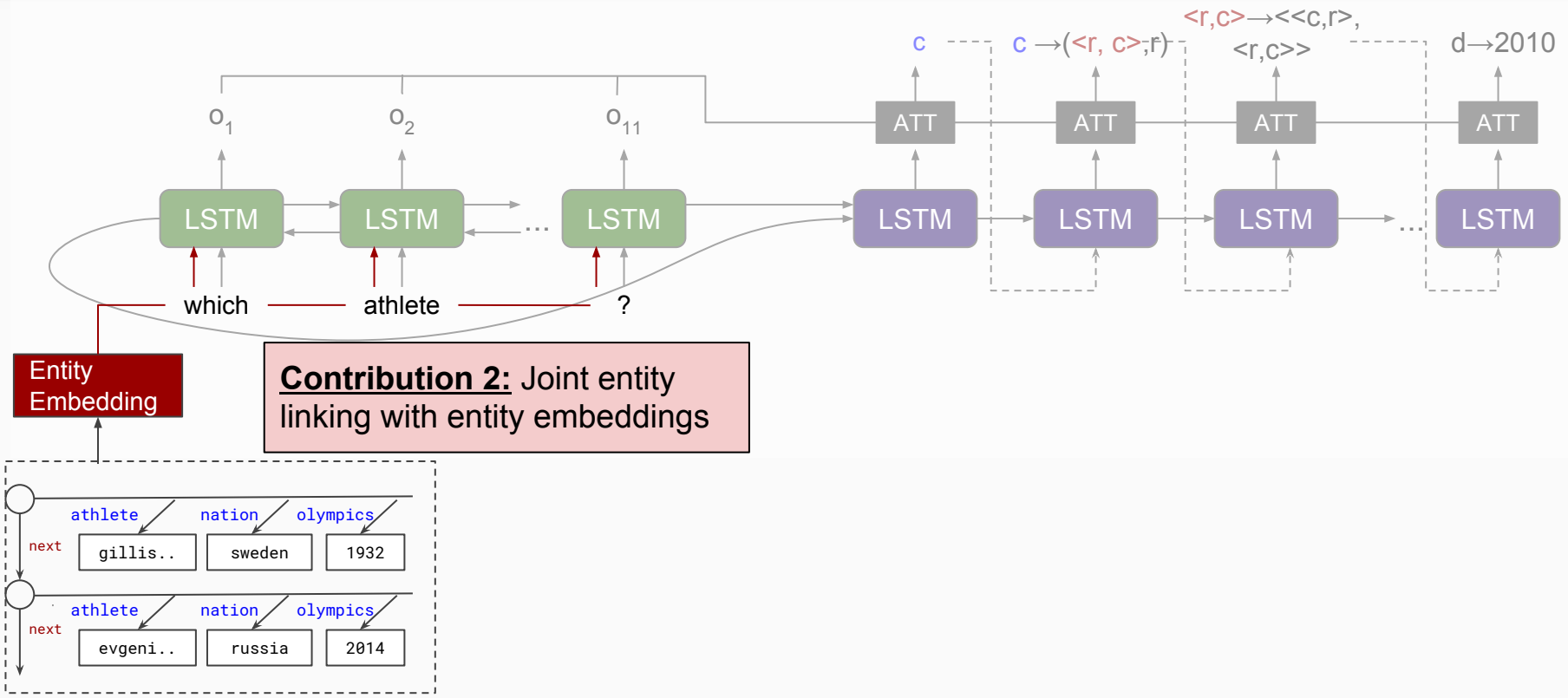
Instantiations with concrete types automatically induced from corpus

Our Model

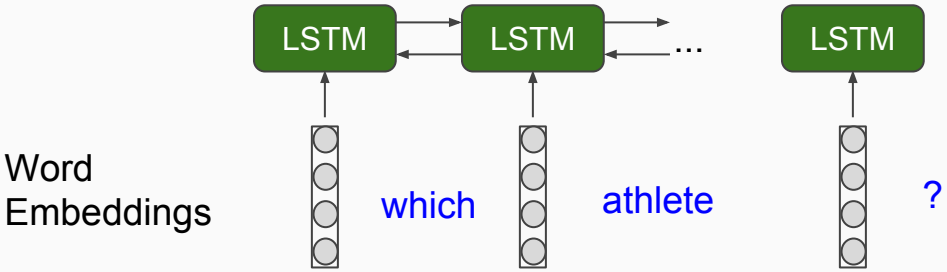


Contribution 1: Generate actions from a typed grammar instead of tokens from the logical form.

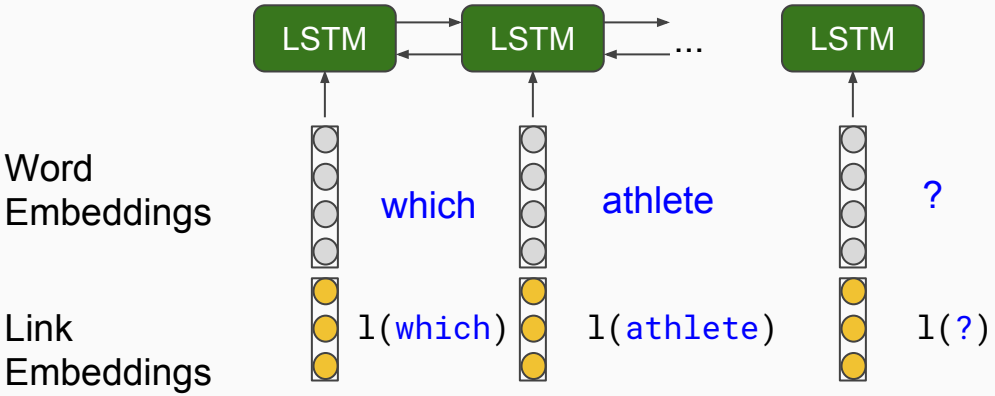
Our Model


c
c →(<r, c>,r)
<r,c>→<<c,r>, <r,c>>
d→2010
ATT
ATT
ATT
ATT
o1
o2
o11
LSTM
LSTM
LSTM
LSTM
LSTM
LSTM
LSTM
LSTM
which
athlete
?
Entity Embedding
Contribution 2: Joint entity linking with entity embeddings
athlete
nation
olympics
next
gillis..
sweden
1932
athlete
nation
olympics
next
evgeni..
russia
2014

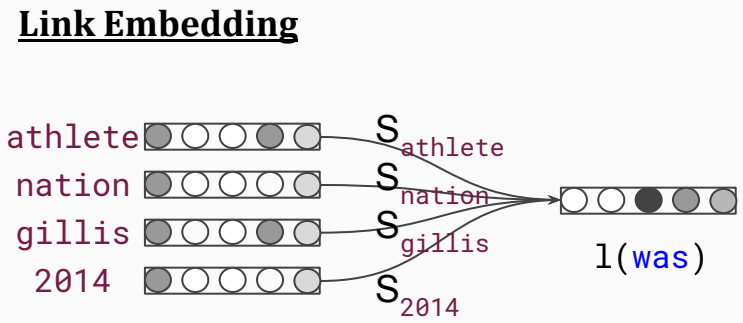
Entity Embedding and Linking



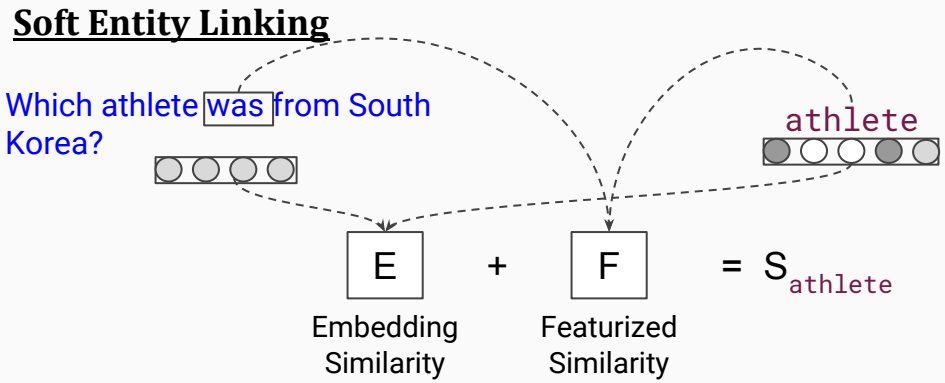
Entity Embedding and Linking

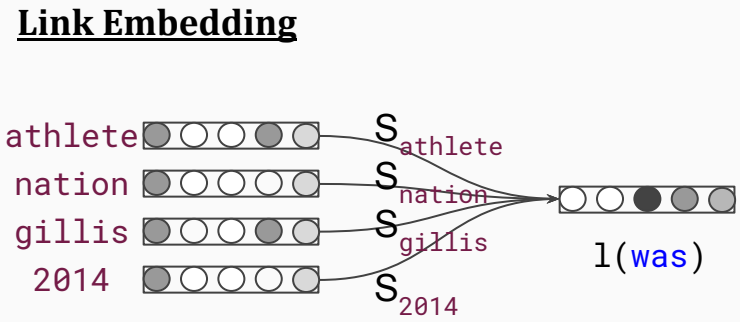


Entity Embedding and Linking



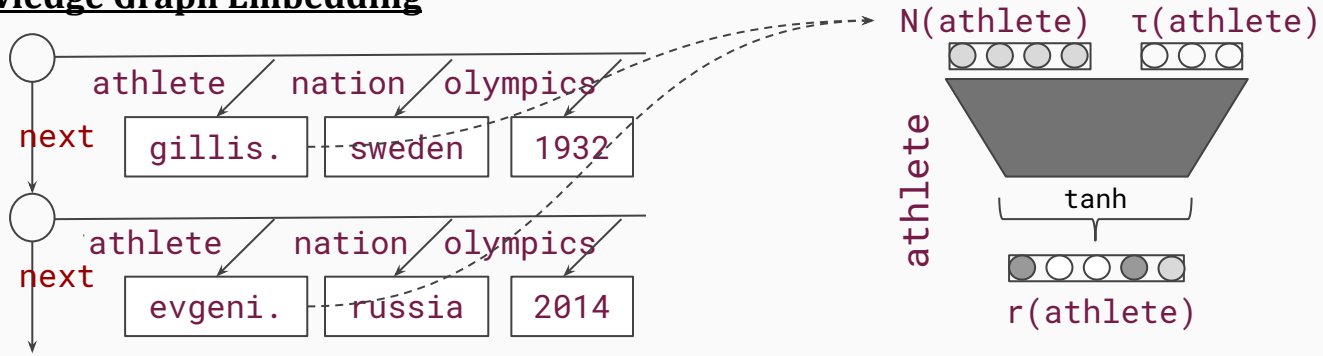
Entity Embedding and Linking



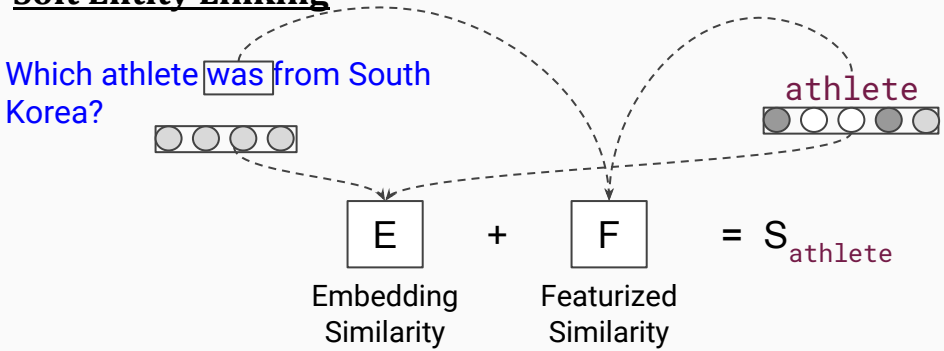


Entity Embedding and Linking

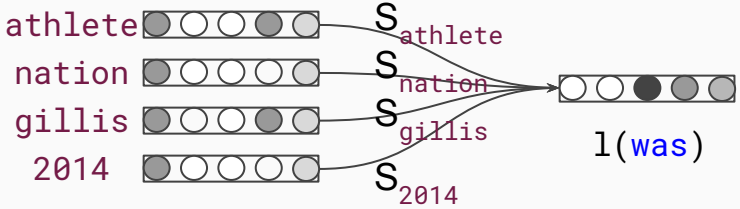
Knowledge Graph Embedding



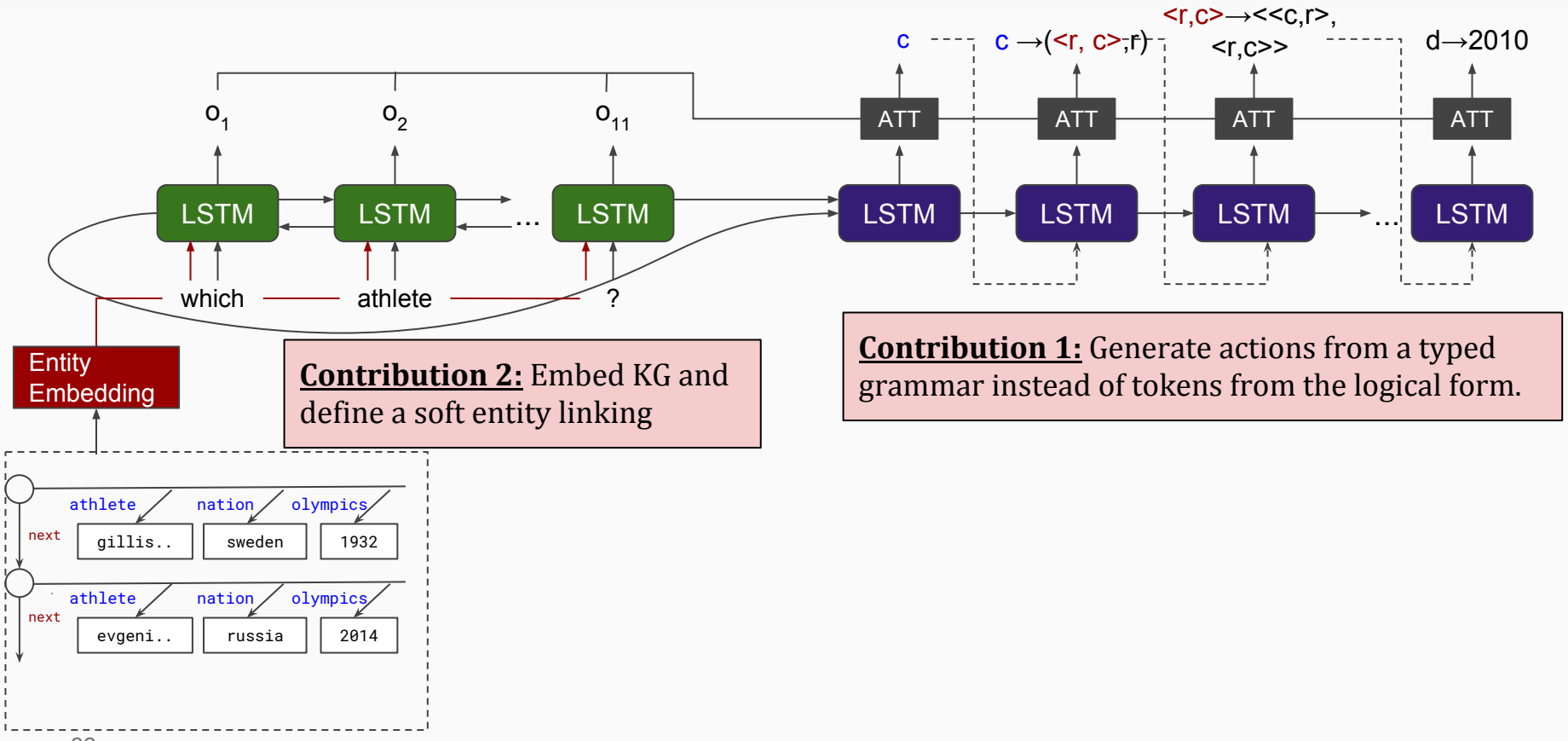
Soft Entity Linking



Link Embedding



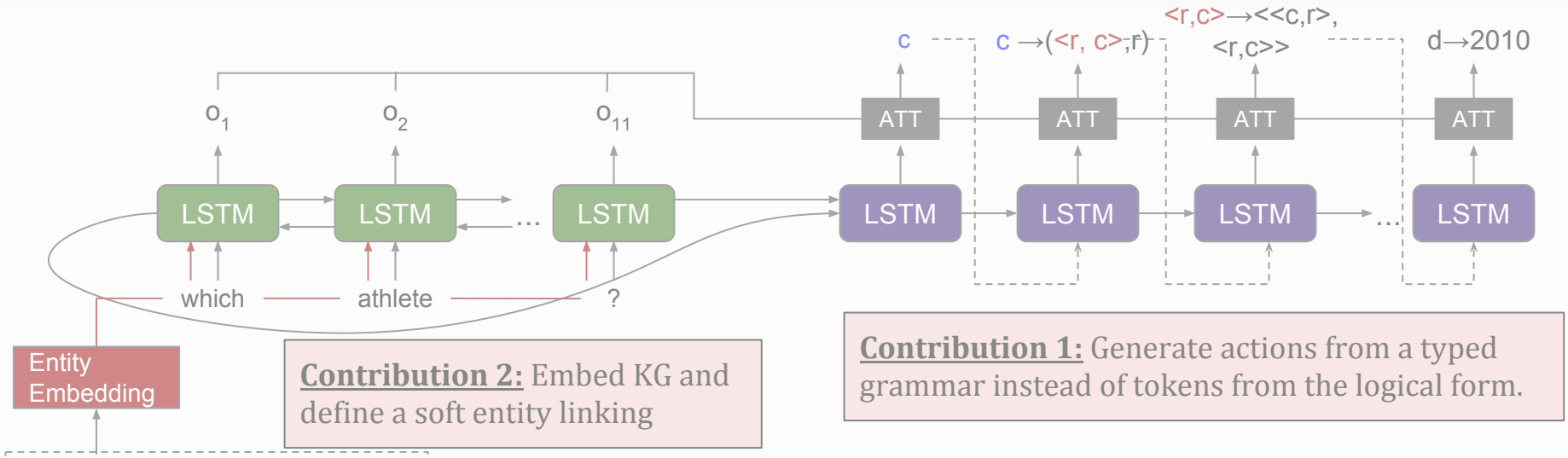
Moving towards our model



Contribution 2: Embed KG and define a soft entity linking

Contribution 1: Generate actions from a typed grammar instead of tokens from the logical form.

Our model



Contribution 2: Embed KG and define a soft entity linking

Contribution 1: Generate actions from a typed grammar instead of tokens from the logical form.

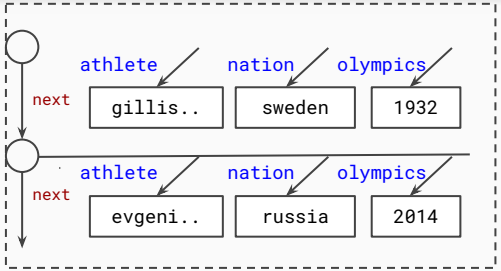
Training Data:
Q: Which athlete was from South Korea after the year 2010?
A: Kim yu-na

Contribution 3: Train on QA pairs, using logical forms from dynamic programming on denotations

Training with DPD

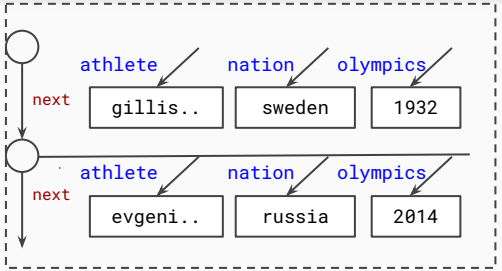
Q: Which athlete was from South Korea after the year 2010?

A: Kim yu-na



Training with DPD

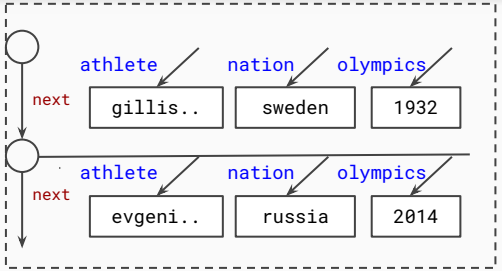
Q: Which athlete was from South Korea after the year 2010?
A: Kim yu-na




```
((reverse athlete) (and (nation south_korea) (year ((reverse date) (>= 2010-mm-dd)))))
((reverse athlete) (and (nation south_korea))
((reverse athlete) (argmax ind))
...
```

Training with DPD

Q: Which athlete was from South Korea after the year 2010?
A: Kim yu-na



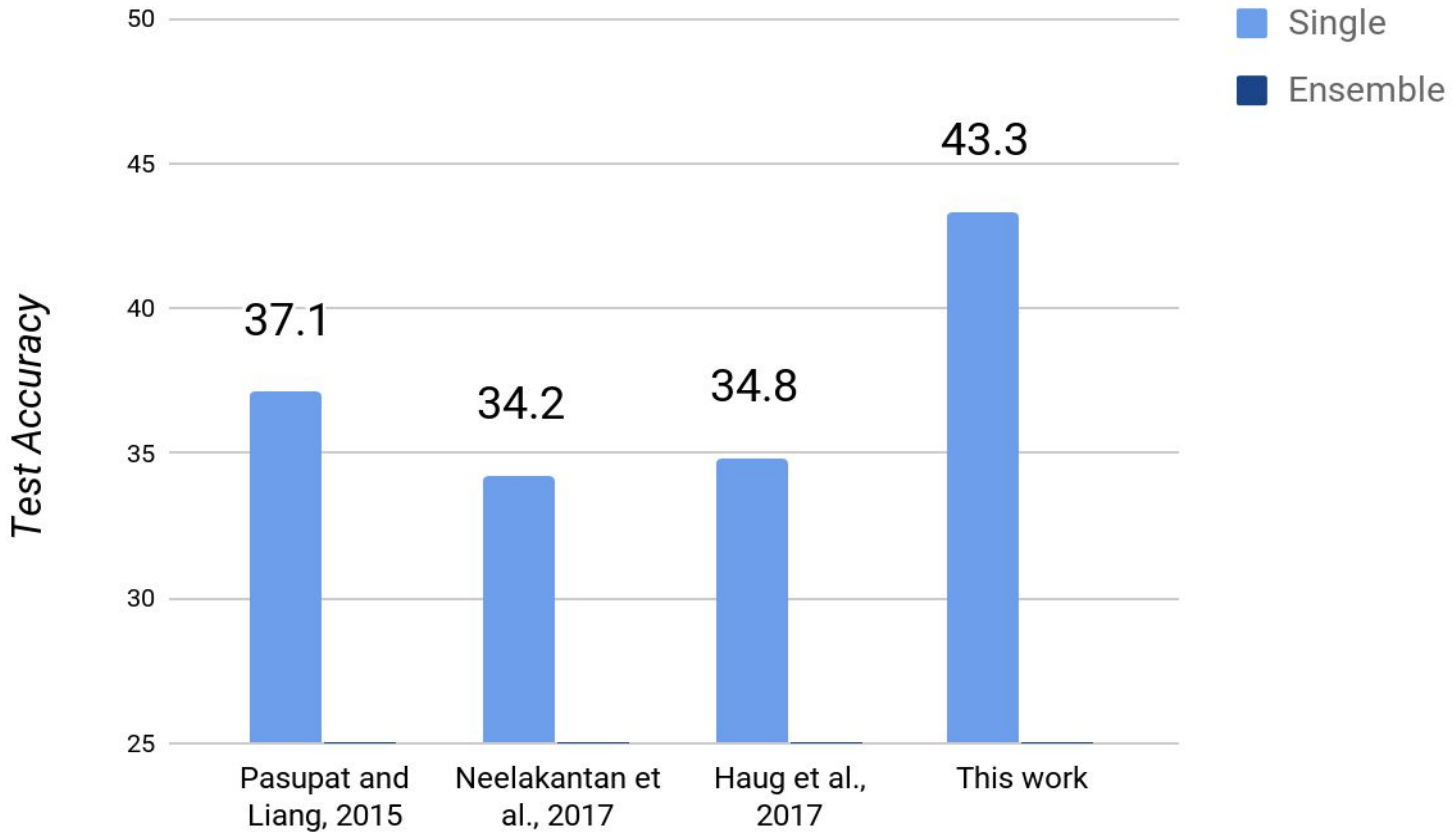

```
((reverse athlete) (and (nation south_korea) (year ((reverse date) (>= 2010-mm-dd)))))
((reverse athlete) (and (nation south_korea))
((reverse athlete) (argmax ind))
...
```

$$\mathcal{O}(\theta) = \sum_{i=1}^{n} \log \sum_{\ell \in \mathcal{L}^i} P(\ell | q^i, T^i; \theta)$$

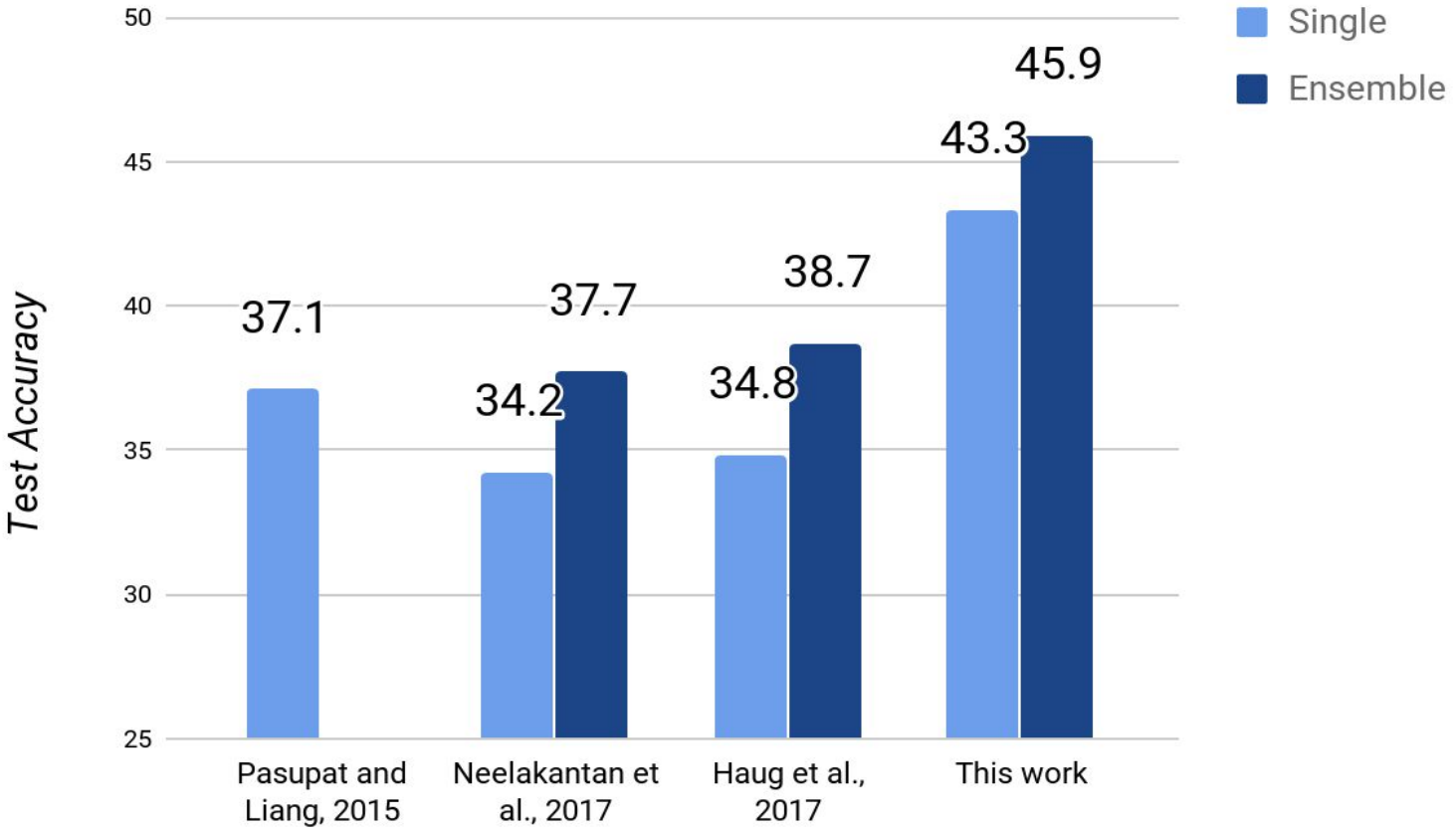
Outline

- WikiTableQuestions
- Neural Semantic Parser
  - Type Constraints
  - Joint Entity Linking
  - QA Supervision
- Experimental Results

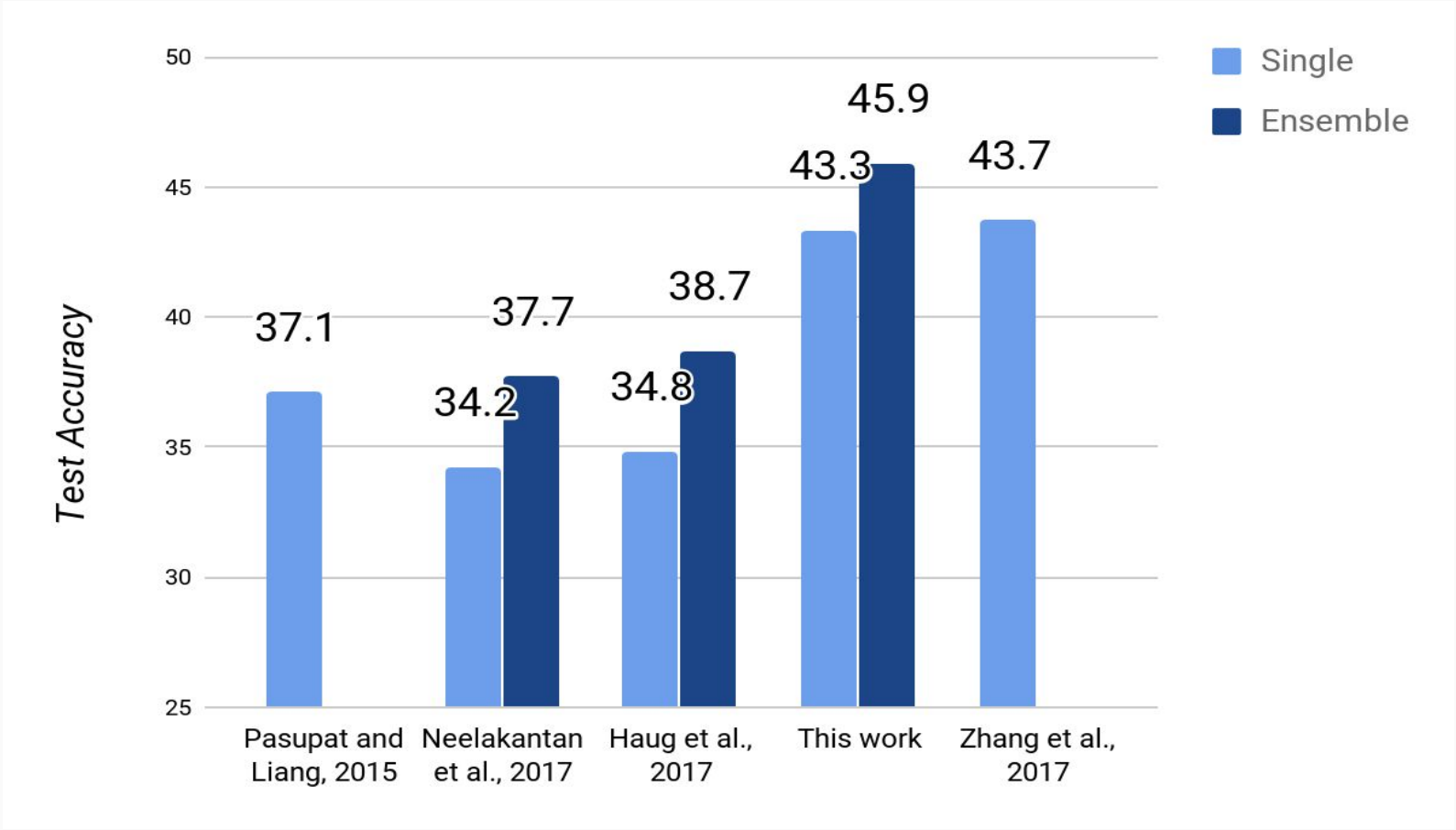
Comparison with Prior Work



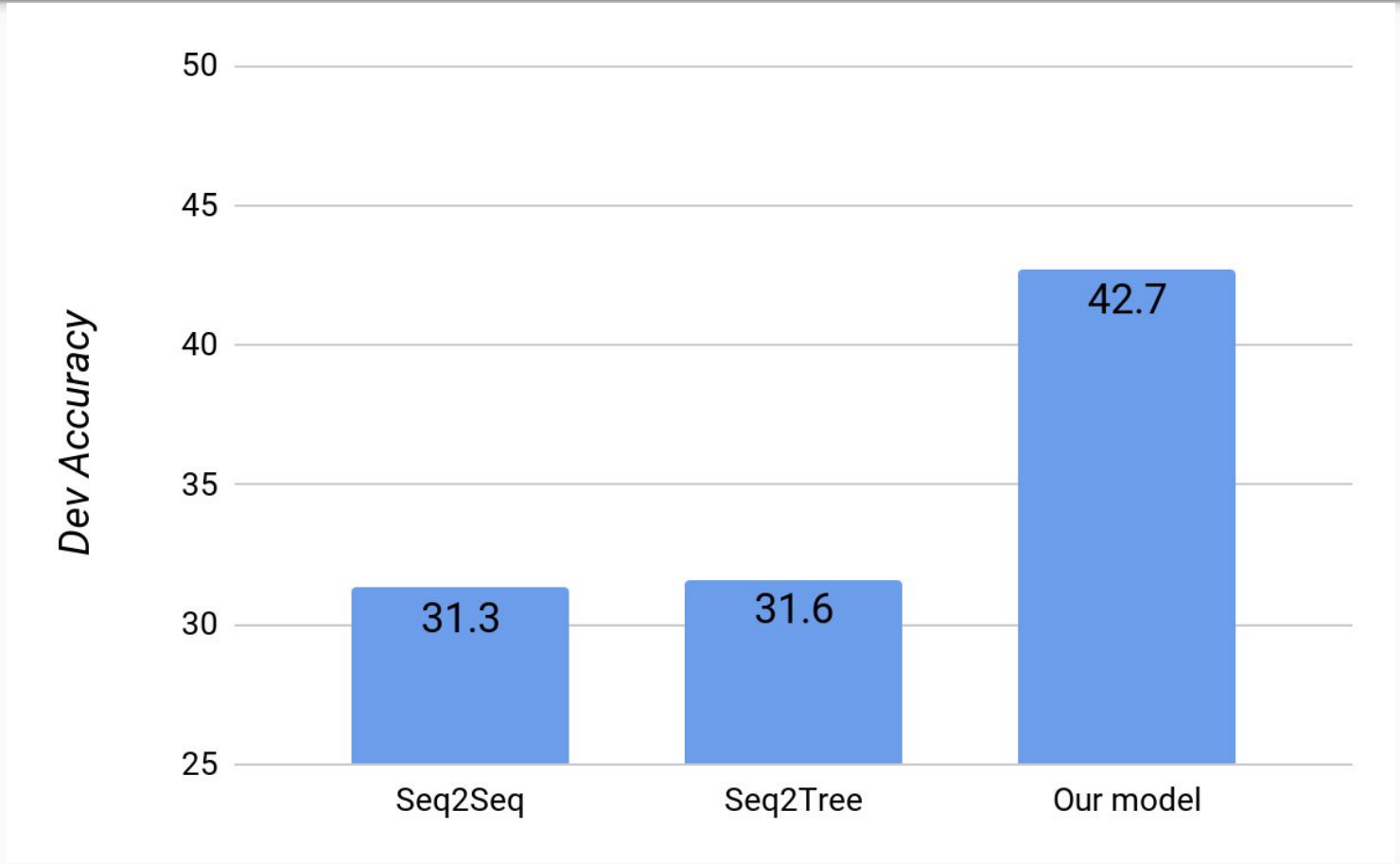
Comparison with Prior Work



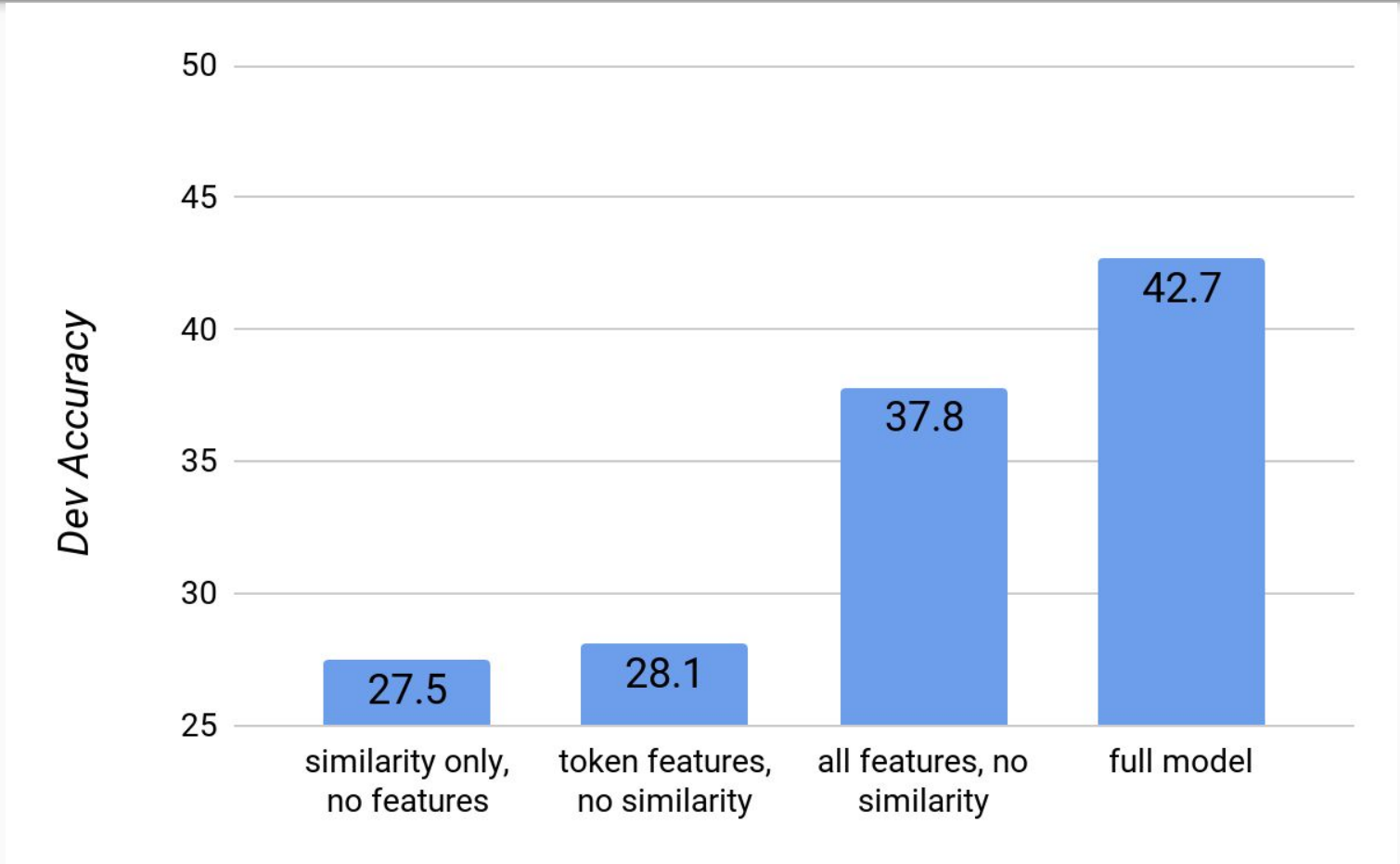
Comparison with Prior Work



Do Type Constraints Help?



Entity Linking Ablations



Error Analysis

Precision Errors (41%)

- Select an answer from a given list of options (**15%**)

  Q: Which David D'or album was the bigger seller - Changing Heights or In The Soul?

- Complex background knowledge (**13%**)

  Q: Which train ran for the longest time?
  (time = Year Discontinued - Year Began)

Error Analysis

Recall Errors (36%)

- Complex cell values (**15%**)

Name	Fate
Jervis	Sold for scrap
Janus	Torpedoed and sunk off Anzio

Q: How many of these ships were sunk?

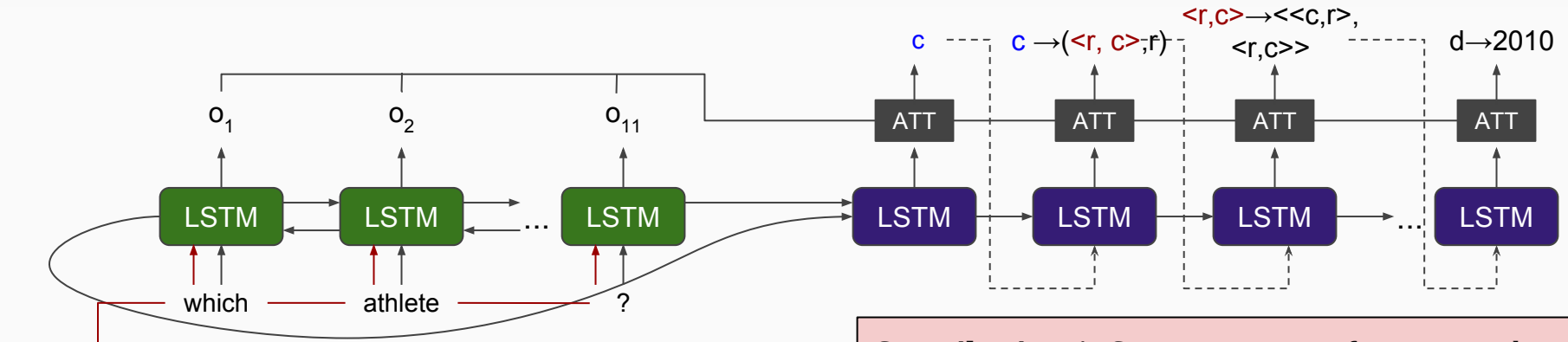
- Unusual table structures (**10%**)

  Tables with a total row

- Unsupported Operations (**11%**)

  (Average, Percents, String operations)

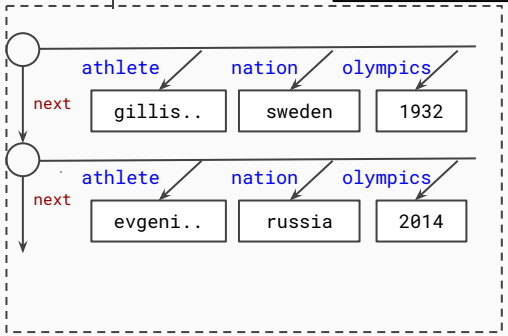
Neural Semantic Parsing with Type Constraints



Contribution 1: Generate actions from a typed grammar instead of tokens from the logical form.

Entity Embedding

Contribution 2: Embed KG and define a soft entity linking



Training Data:
Q: Which athlete was from South Korea after the
A: Kim yu-na

State-of-the-art on WikiTableQuestions

Contribution 3: Train on QA pairs, using logical forms from dynamic programming on denotations

Summary

Contributions

1. Neural semantic parsing with type-constrained decoding to generate valid logical forms
2. Novel soft entity linking trained jointly with semantic parser
3. Training with QA supervision using dynamic programming on denotations

State of the art on WikitableQuestions dataset

Error Analysis

Precision Errors (41%)

- Selecting an answer from a given list of options (**15%**)

  Which David D'or album was the bigger seller - Changing Heights or In The Soul?

- Requiring background knowledge (**13%**)

  Which train ran for the longest time? (time = Year Discontinued - Year Began)

Recall Errors (36%)

Table representation failures (25%)

- Complex cell values (**15%**)

Name	Fate
Jervis	Sold for scrap
Janus	Torpedoed and sunk off Anzio

Q: How many of these ships were sunk?

- Unusual table structures (**10%**)

  Tables with a total row

Unsupported operations (11%)

- Average
- Percentages
- String operations

Training using DPD

- Dynamic Programming on Denotations (Pasupat and Liang, 2016)
- Generate **consistent** logical forms given denotation
- Maximize marginal likelihood of all consistent logical forms, using SGD

$$\mathcal{O}(\theta) = \sum_{i=1}^{n} \log \sum_{\ell \in \mathcal{L}^i} P(\ell | q^i, T^i; \theta)$$