Learning Semantic Parsers from Denotations with Latent Structured Alignments and Abstract Programs

Bailin Wang, Ivan Titov, Mirella Lapata

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Edinburgh
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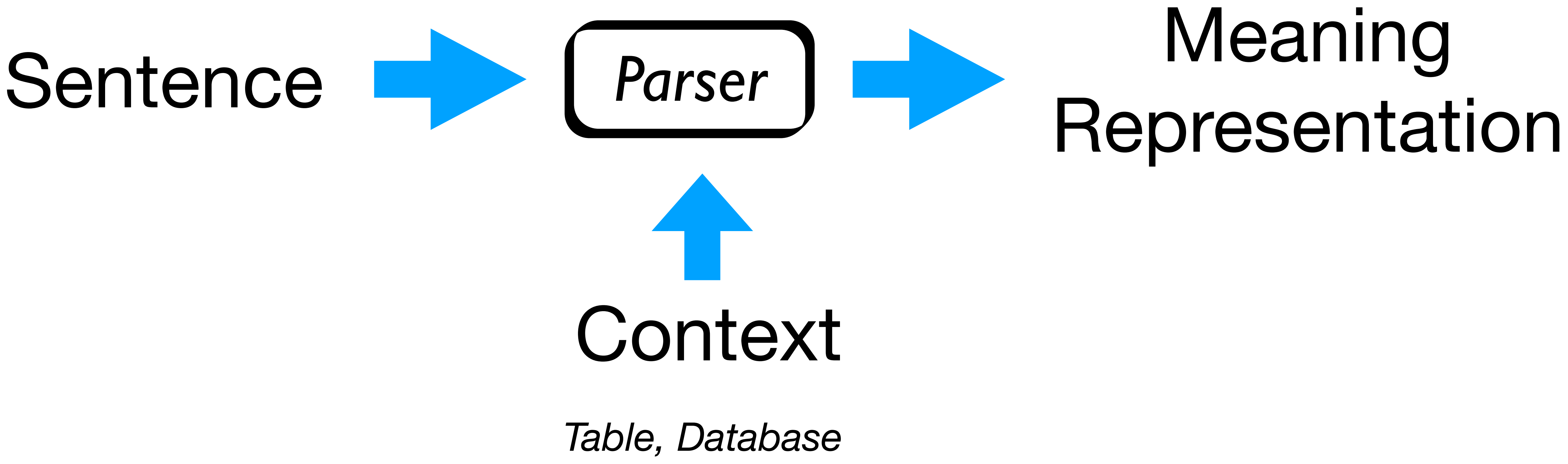
Natural Language Processing
NLP

Background



Sentence

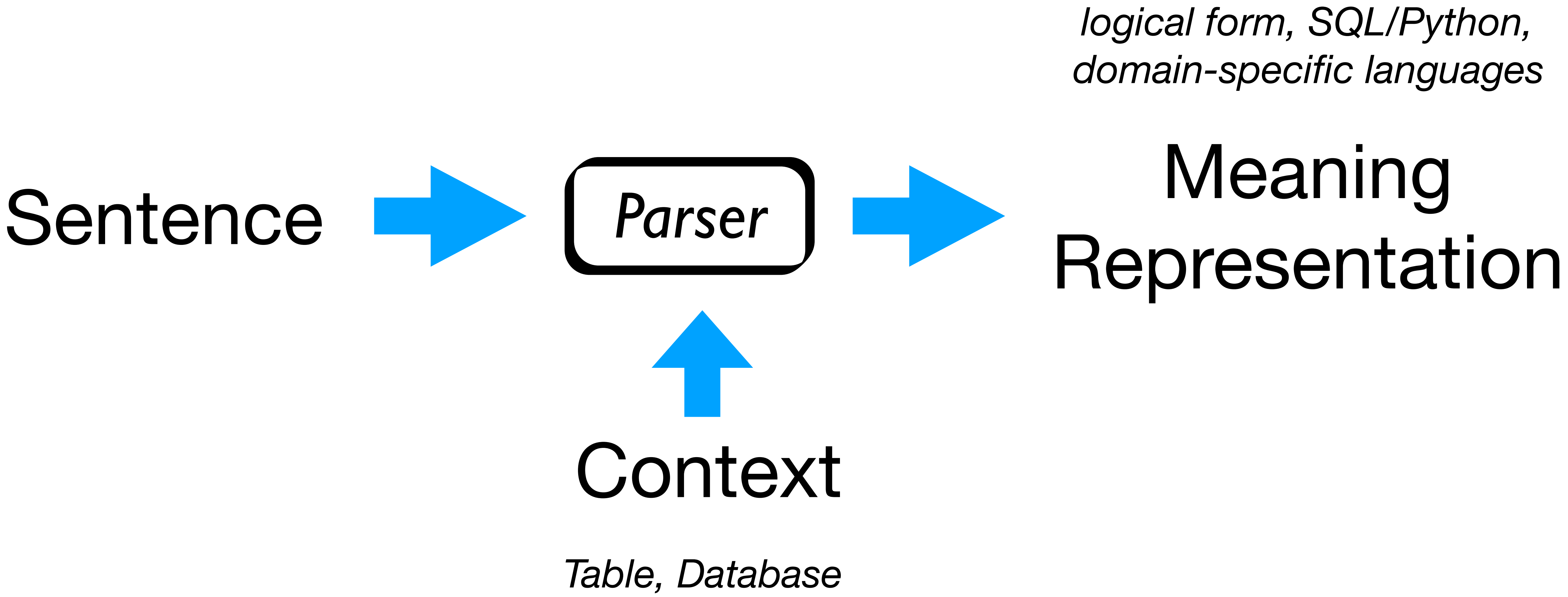
Parser

Meaning Representation

Context

Table, Database

Background



logical form, SQL/Python, domain-specific languages

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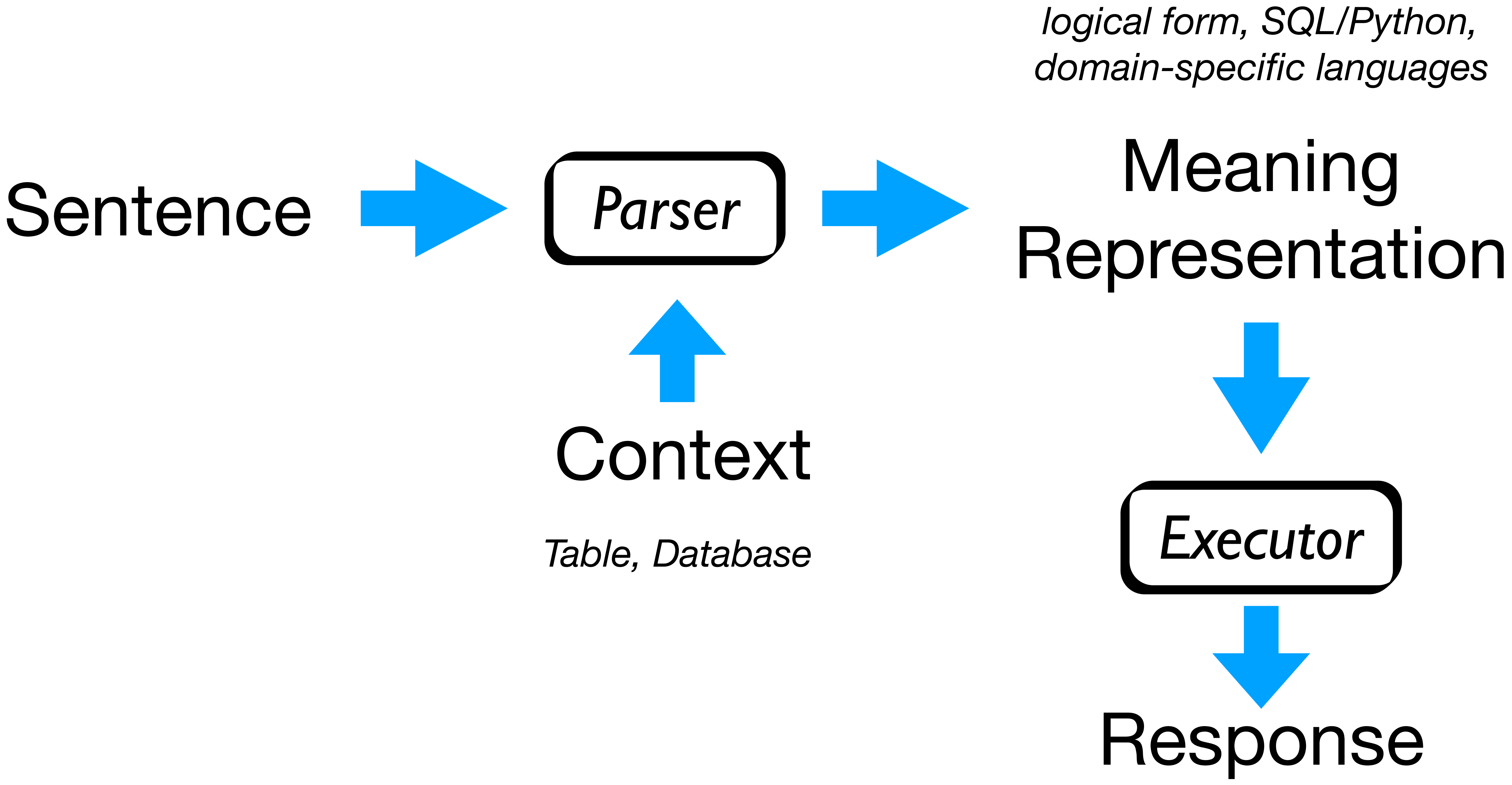

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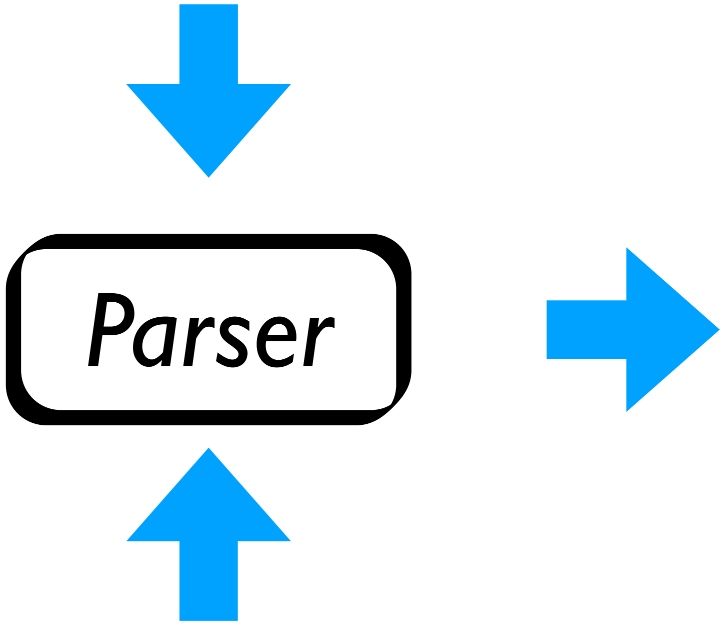
Executor

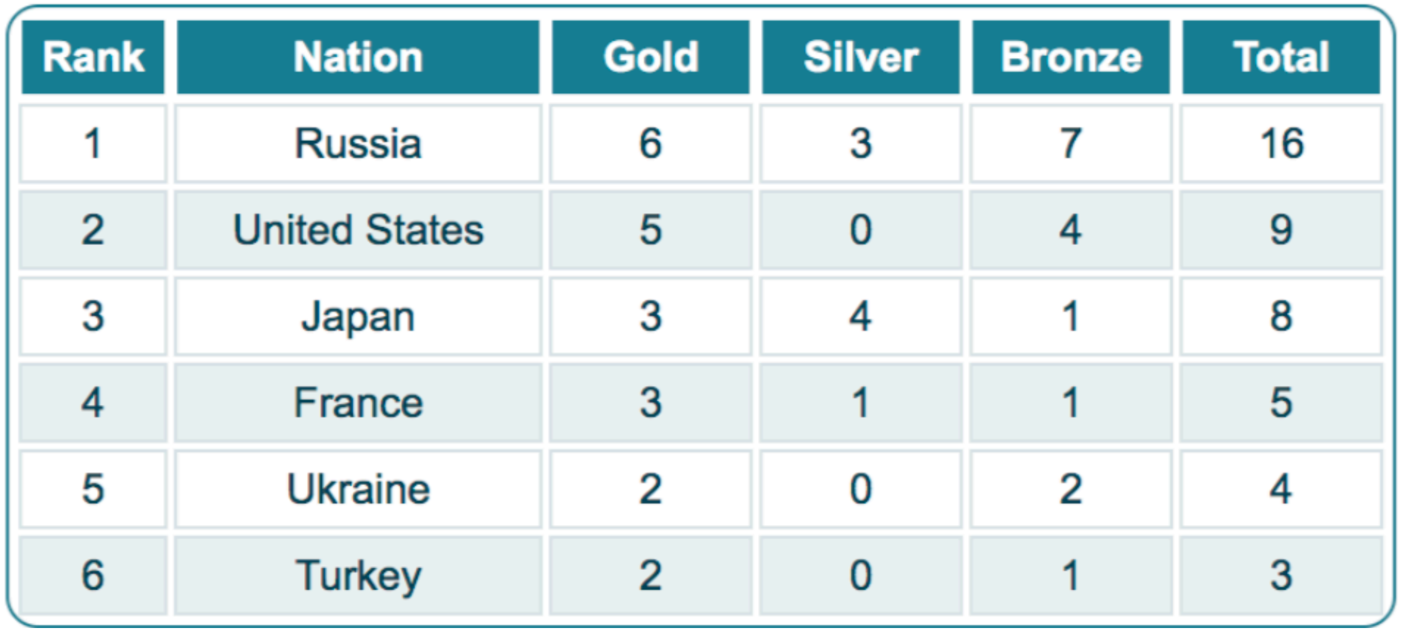
Response

Executable Semantic Parsing

how many silver medals did the nation of Turkey win?



select([nation =“Turkey”], silver)



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2	United States	5	0	4	9
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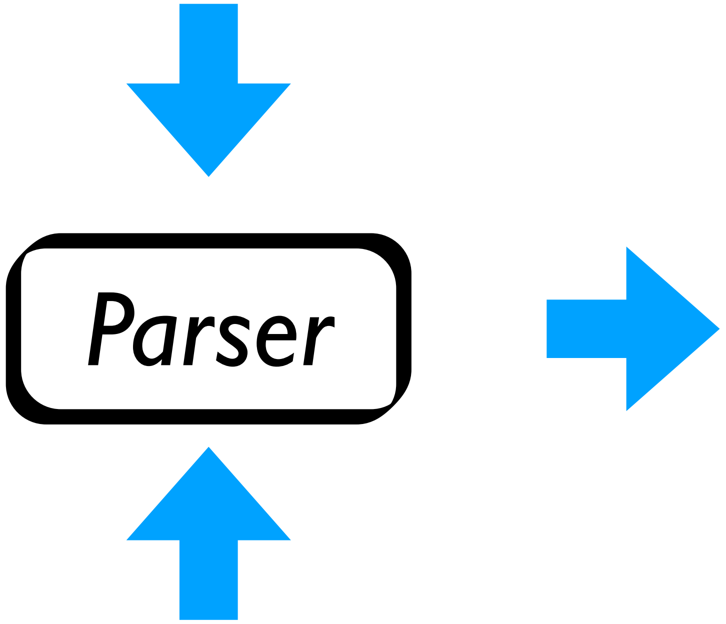
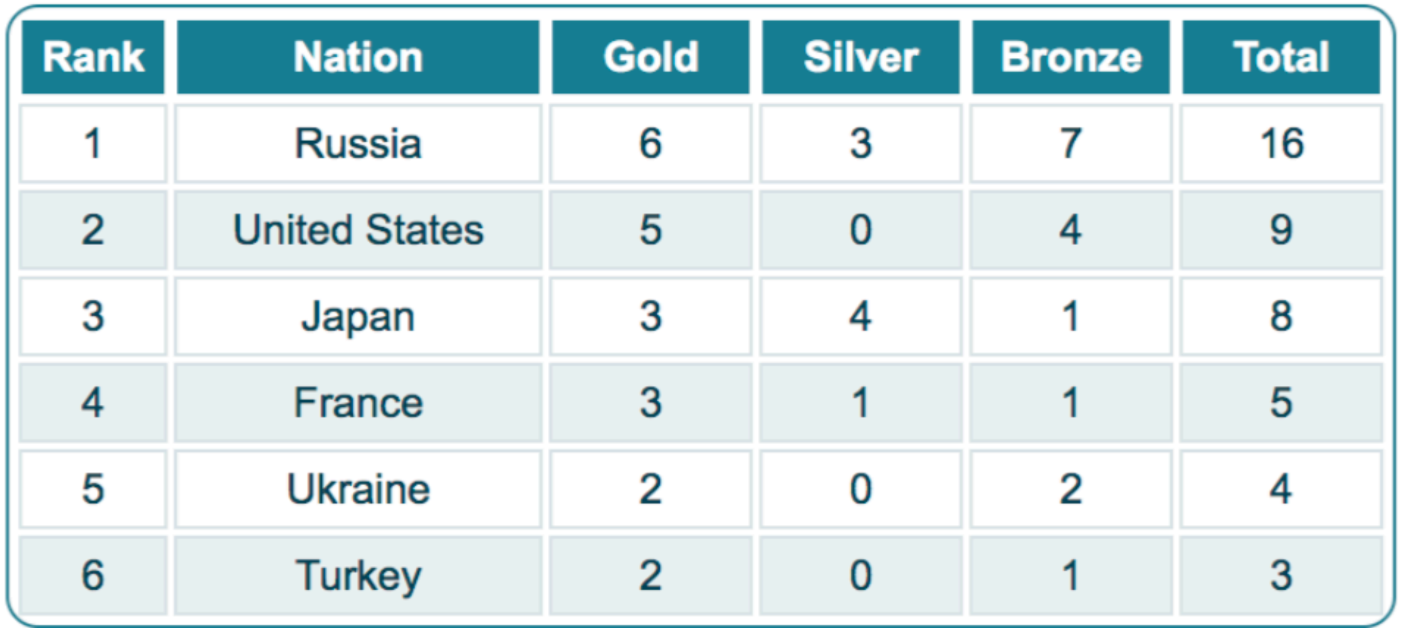


Parser

[nation =“Turkey”]



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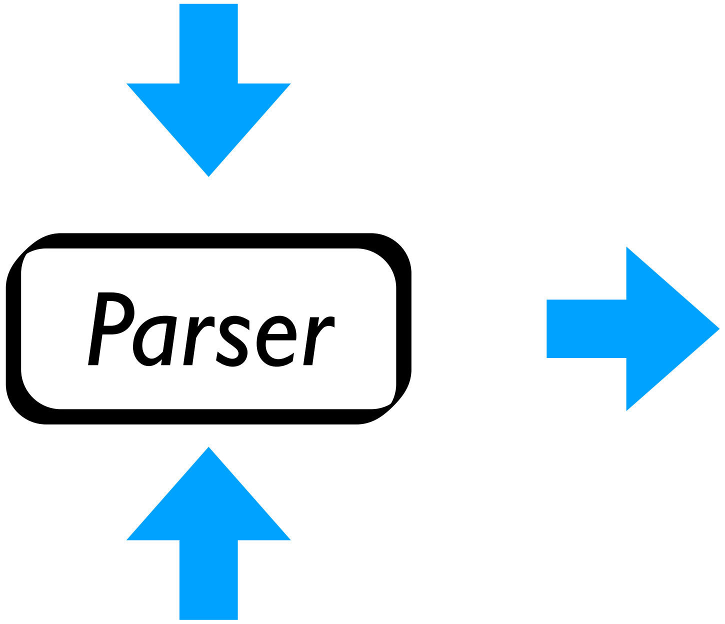

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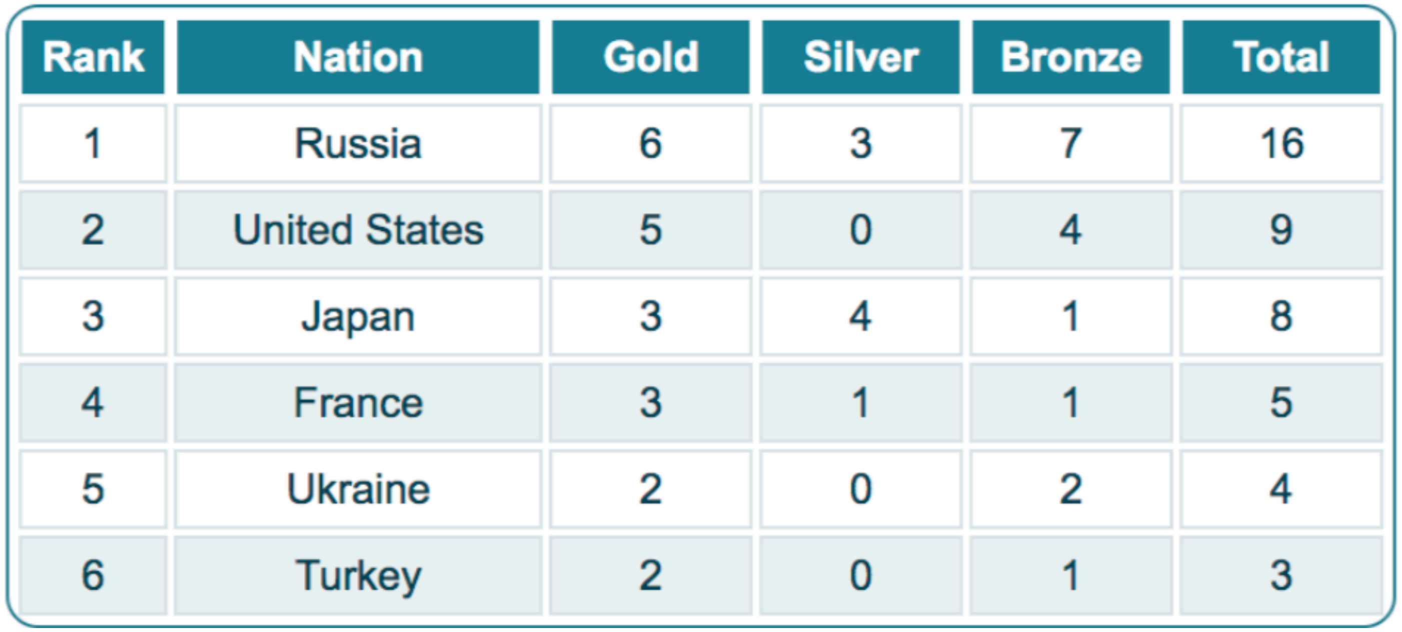

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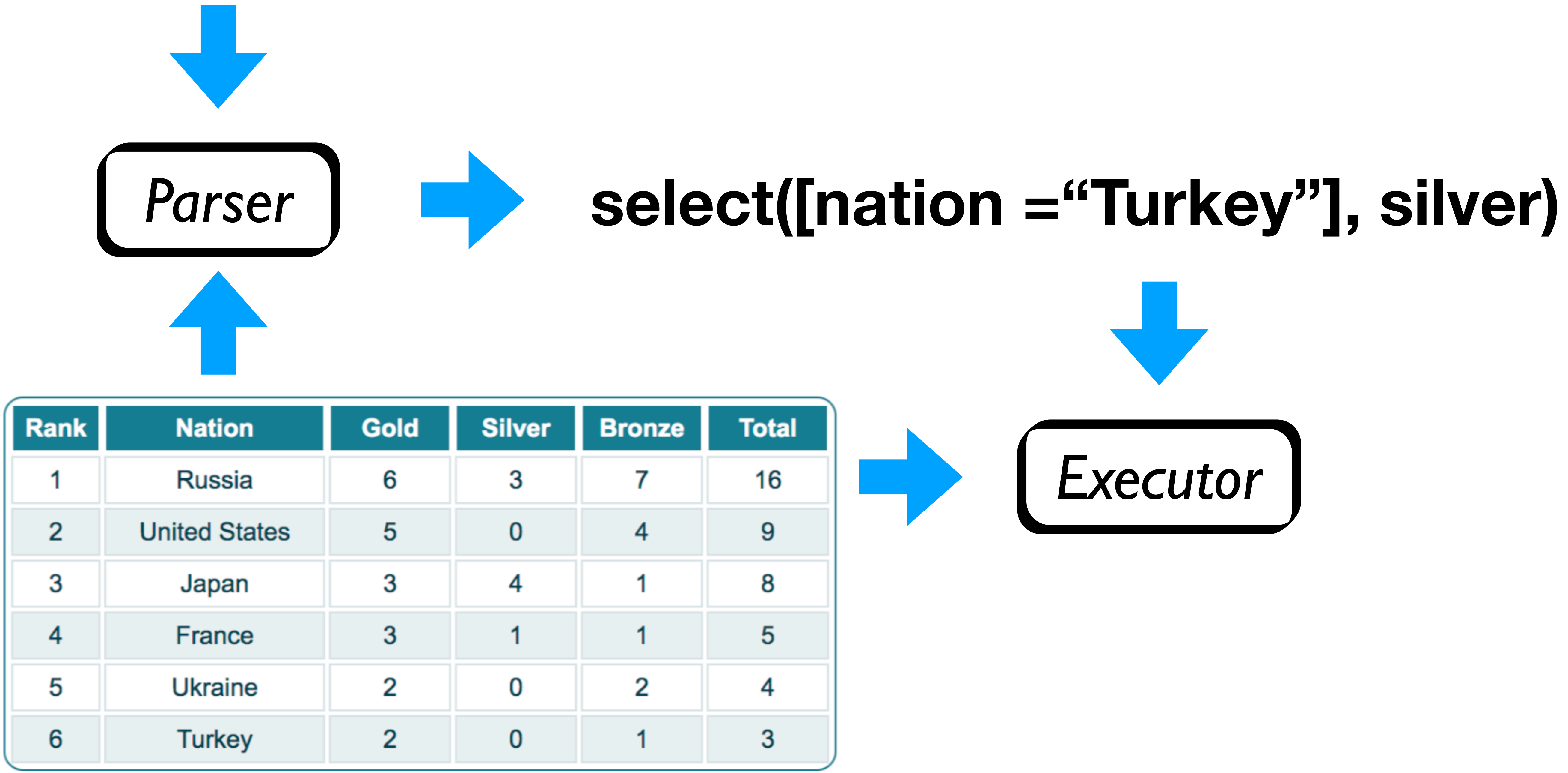

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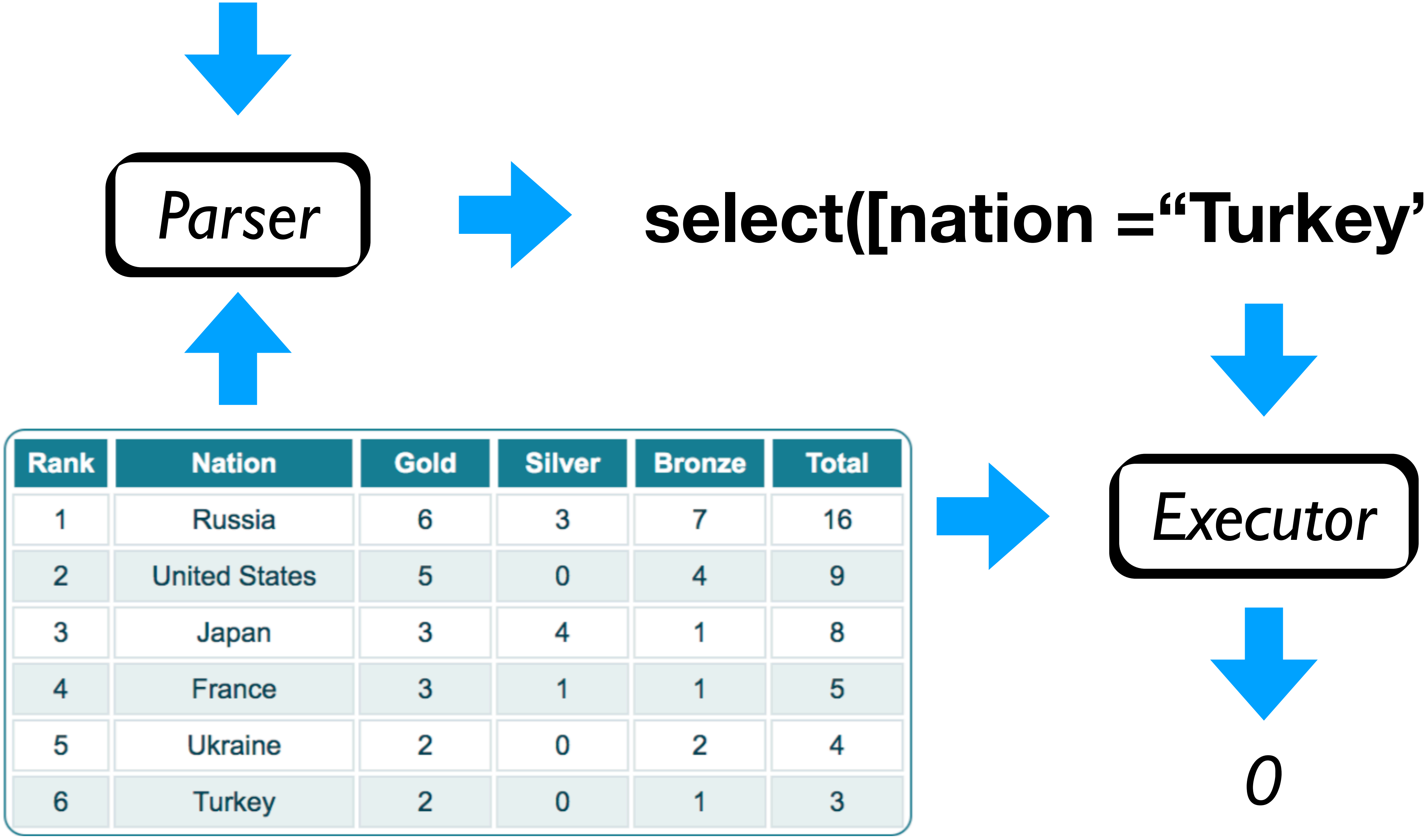

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0

Question-Program Pairs

how many silver medals did the nation of Turkey win?

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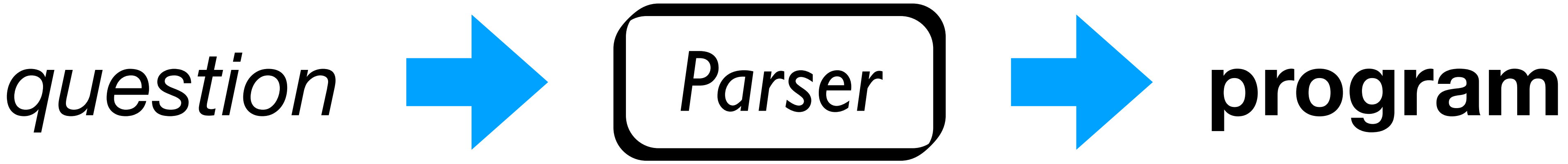


question *Parser* **program**

[Zettlemoyer and Collins, 2005; Wong and Mooney, 2007; Lu et al., 2008; Jia and Liang, 2016]

Question-Program Pairs

how many silver medals did the nation of Turkey win?

select([nation =“Turkey”], silver)

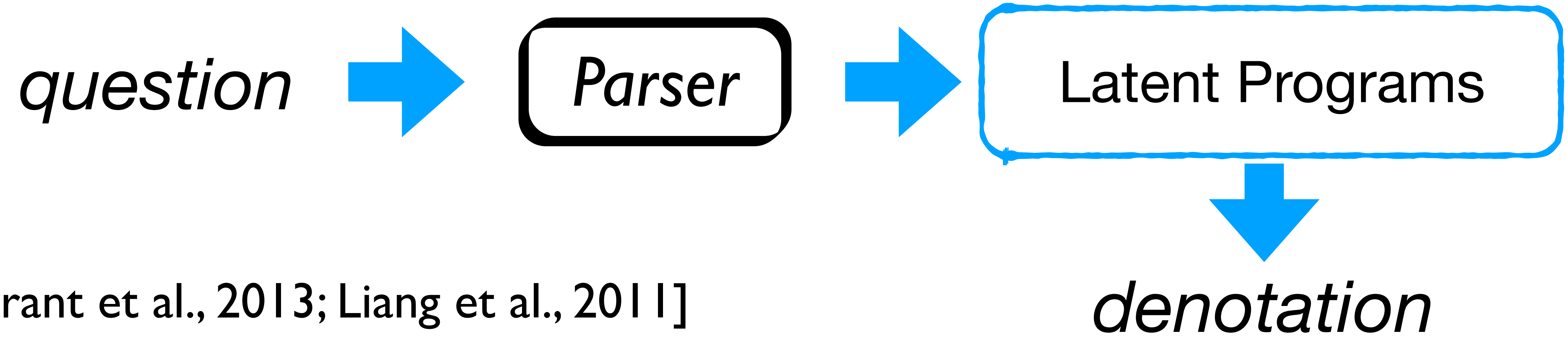
Expensive to collect!

[Zettlemoyer and Collins, 2005; Wong and Mooney, 2007; Lu et al., 2008; Jia and Liang, 2016]

Question-Denotation Pairs

how many silver medals did the nation of Turkey win?

Denotation: 0



question

Parser

Latent Programs

denotation

[Berant et al., 2013; Liang et al., 2011]

Structure

- **Challenges with learning from denotation**
- Our approach
- Experiments and analysis

Large Search Space

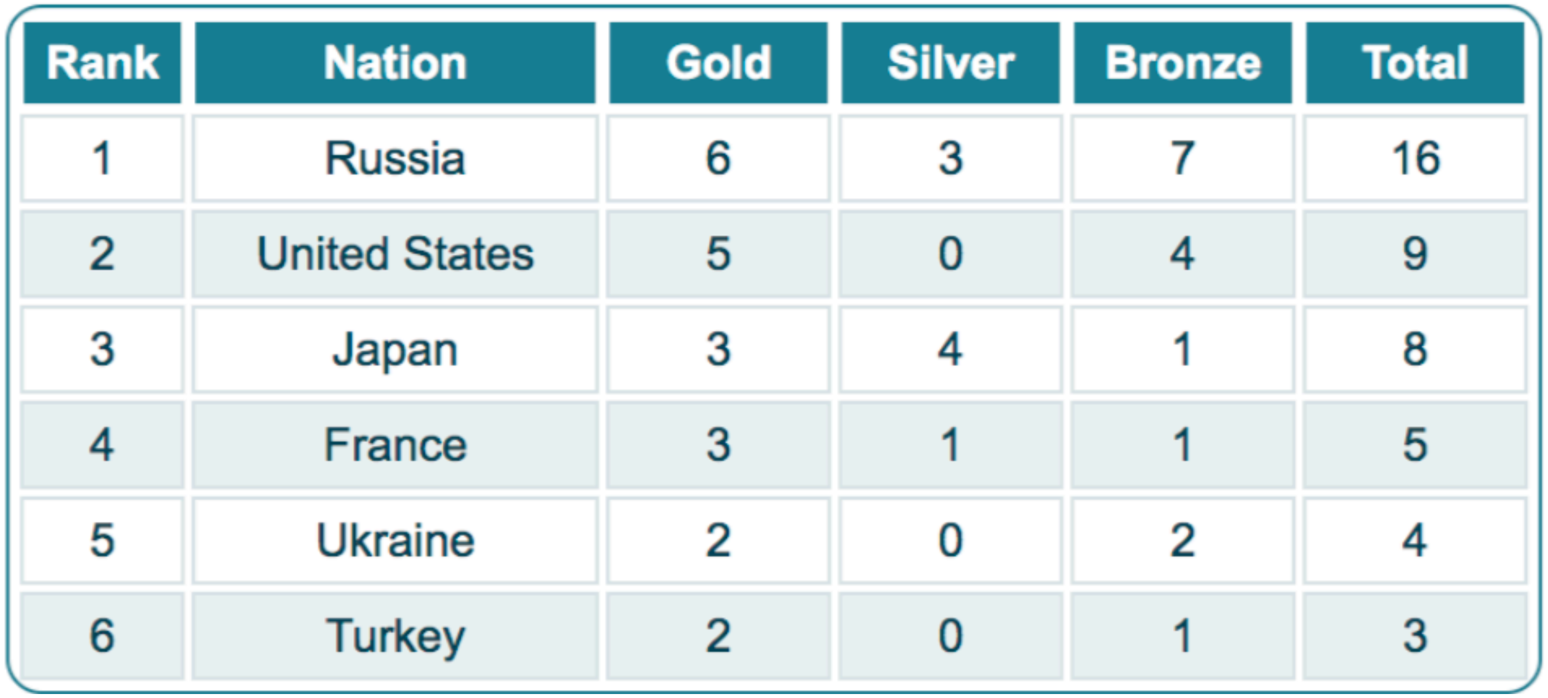
how many silver medals did the nation of Turkey win?

Program		***Denotation***	
count([nation =“Turkey”])	→	**1**	✗
sum(all_rows, silver)	→	**8**	✗
select([nation =“Turkey”], silver)	→	**0**	✓
select([nation =“Turkey”], nation)	→	**Turkey**	✗
select(argmax([all_rows], silver), silver)	→	**4**	✗

⋮

Spurious Programs

how many silver medals did the nation of Turkey win?



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Consistent Programs

select([nation =“Turkey”], silver) → **0** ✓

select(previous(argmax([all_rows], silver), silver) → **0** ✓

select(argmin([all_rows], silver))), silver) → **0** ✓

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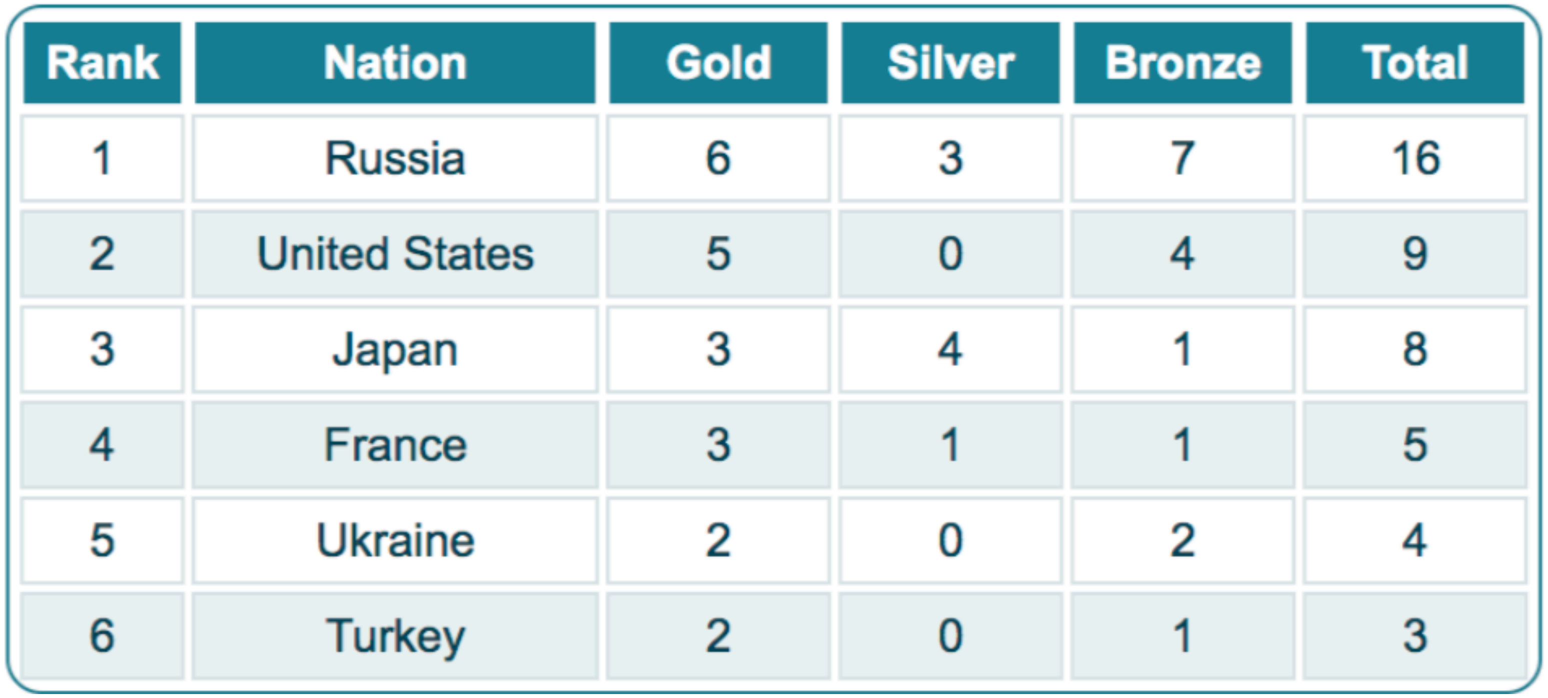

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Consistent Programs = **Spurious Programs**

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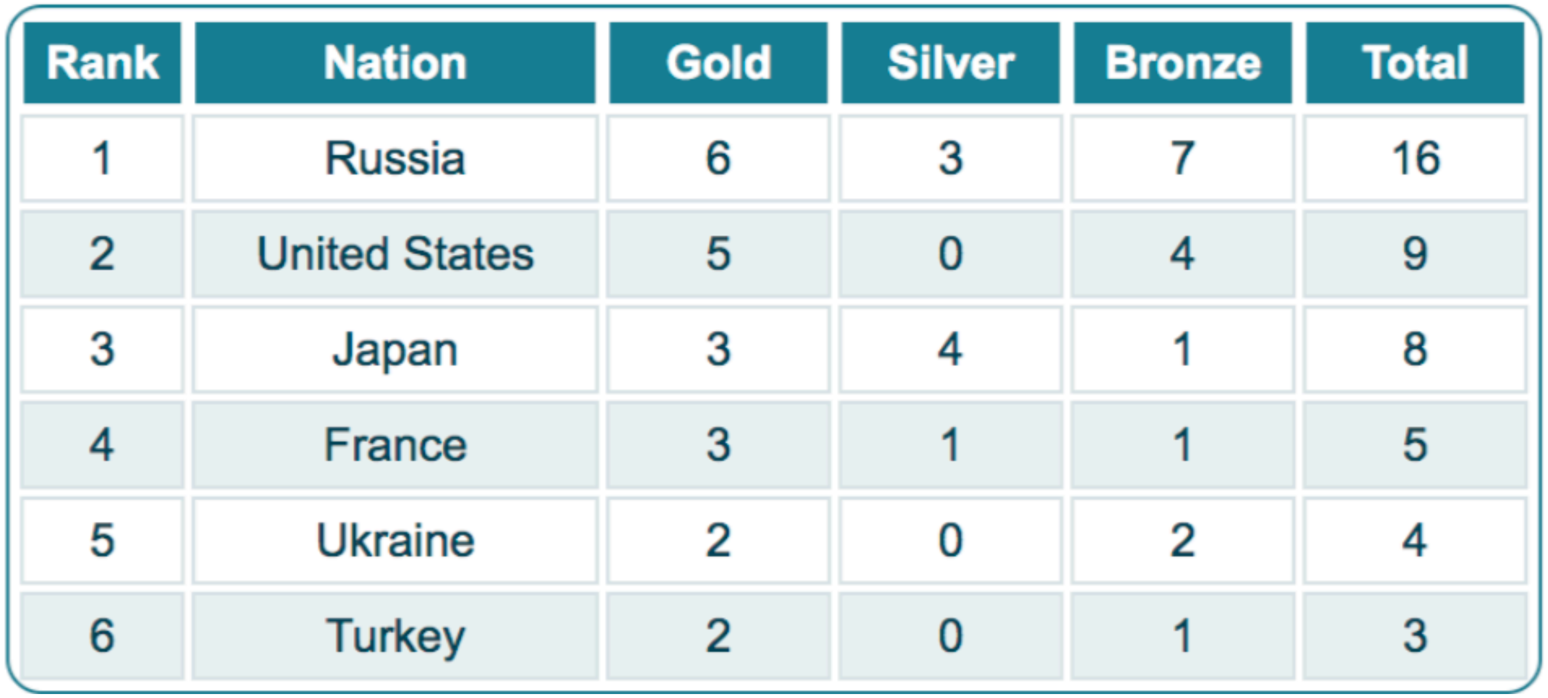

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Consistent Programs = Spurious Programs + Correct Programs

select([nation =“Turkey”], silver) → 0 ✓

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select(argmin([all_rows], silver))), silver) → 0 ✓

Spurious Programs

Learning Objective:

p_θ**(Consistent Programs | Question, Context)**

||

p_θ **(Spurious Programs|…)** **+** p_θ **(Correct Programs|…)**

Spurious Programs

Learning Objective:

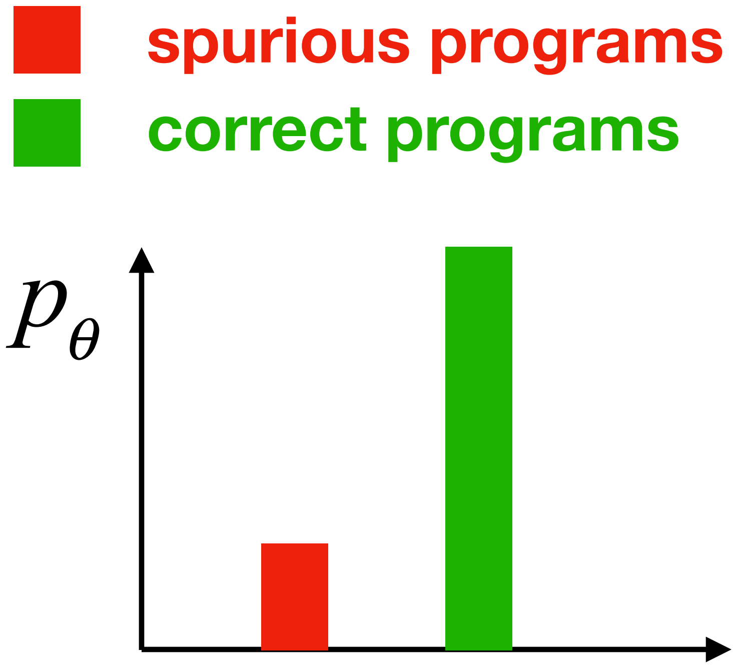
$$p_\theta(\textbf{Consistent Programs} \mid \textbf{Question, Context})$$

$$\parallel$$

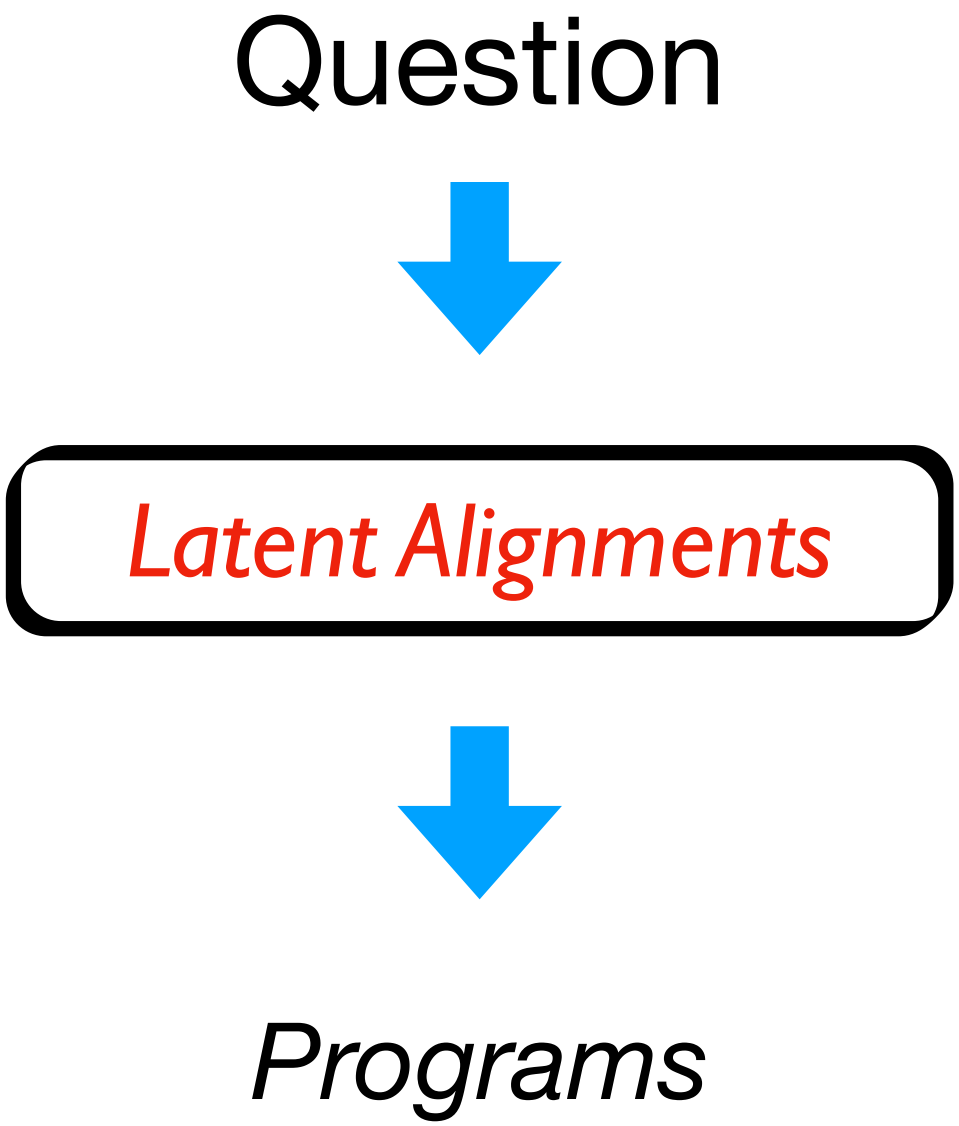
$$\underbrace{p_\theta(\textbf{Spurious Programs}|\ldots)}_{\textit{harmful !}} + p_\theta(\textbf{Correct Programs}|\ldots)$$

Our Approach

Inductive Bias



Latent Alignments

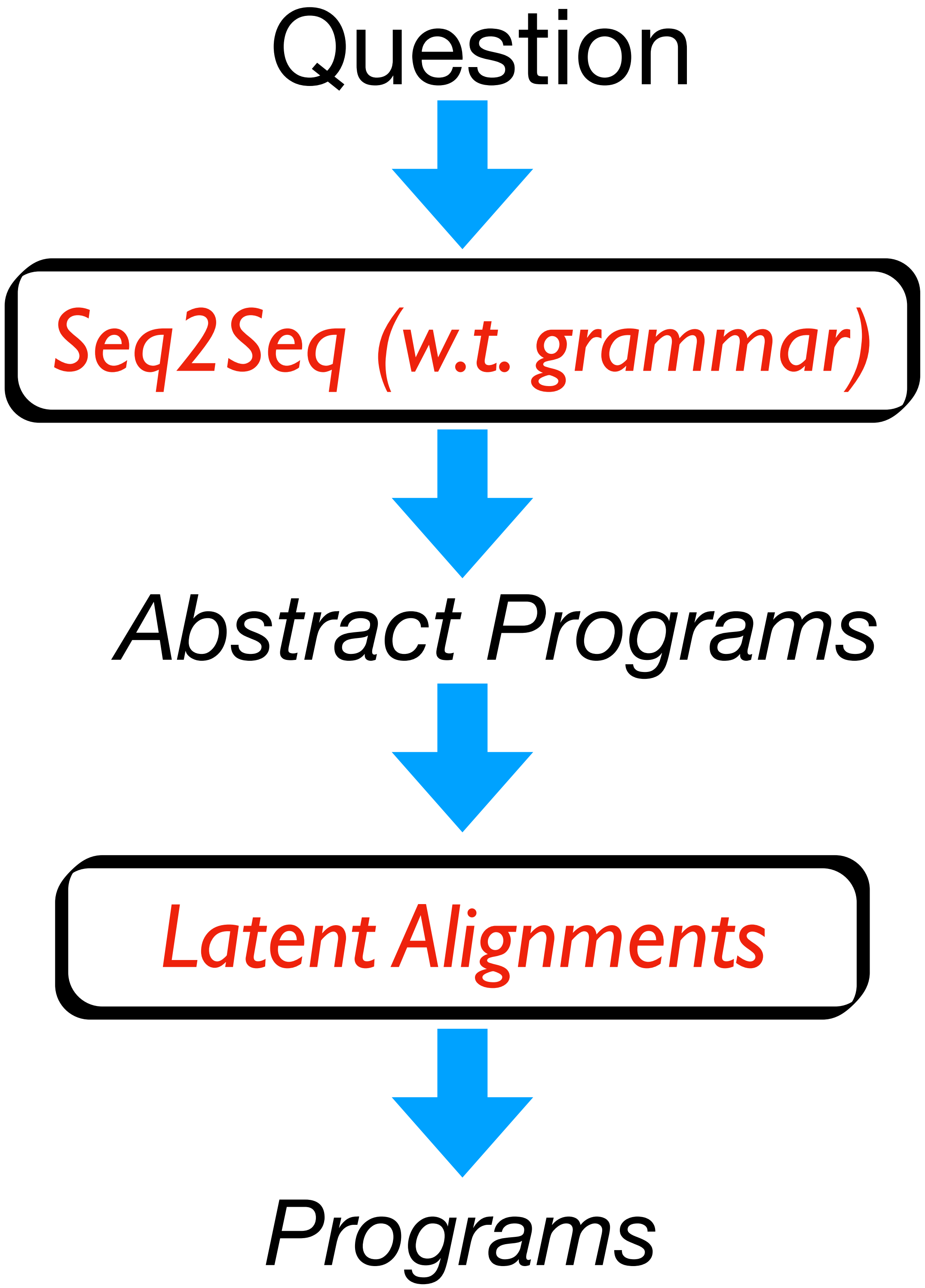


Question

Latent Alignments

Programs

Two-Stage Search



Question

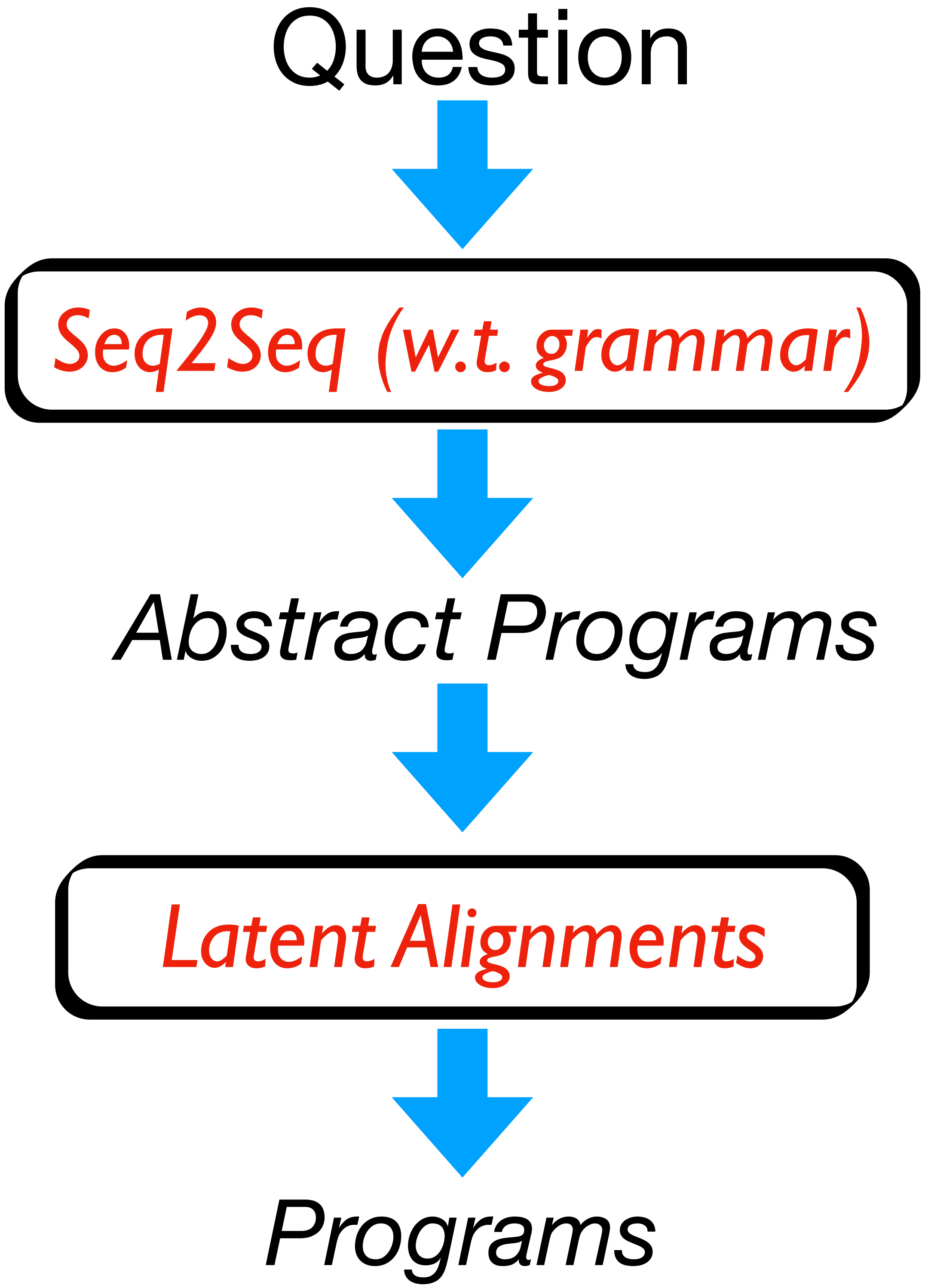
Seq2Seq (w.t. grammar)

Abstract Programs

Latent Alignments

Programs

Two-Stage Search



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Programs

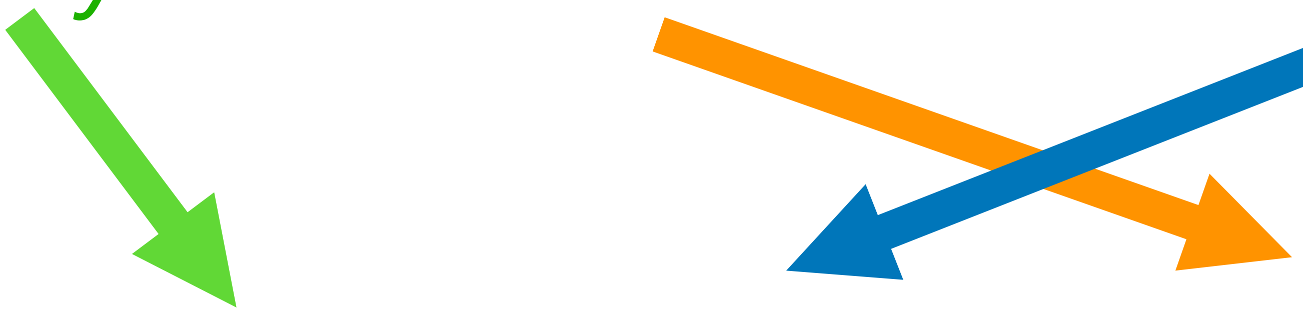
how many silver medals did the nation of Turkey win?

e.g. **select(***#rows***),** *#column***)**

e.g. **select([nation ="Turkey"], silver)**

Observation: Need Alignments

One-to-one alignment



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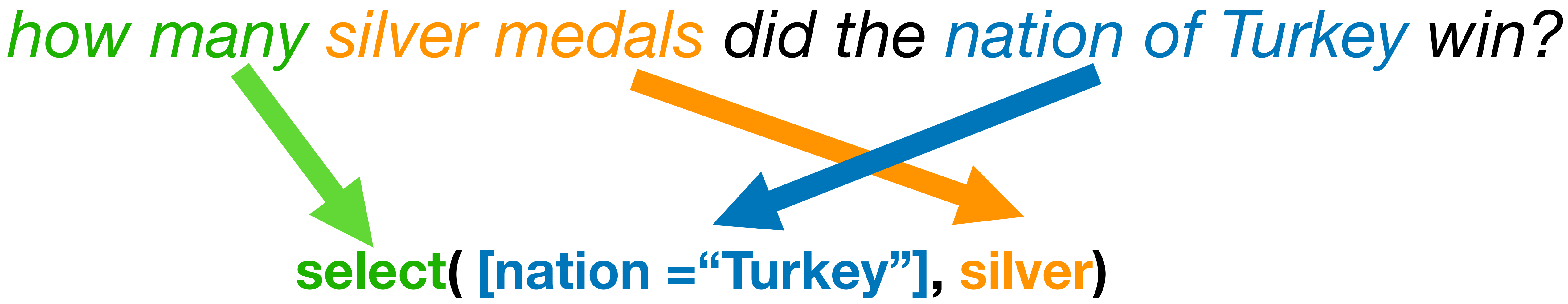

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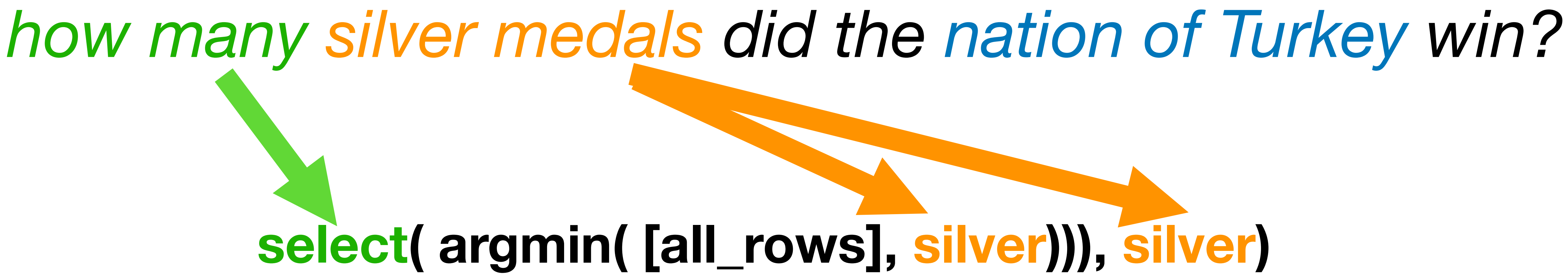

how many silver medals did the nation of Turkey win?

select(argmin([all_rows], silver))), silver)

Alignment

SCFG [Wong and Mooney, 2007]
CCG [Zettlemoyer & Collins, 2007]
Hybrid Tree [Lu et al., 2008]

- Cover alignments
- Full correspondence are expensive to model

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- No structural alignments
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Get the best of both worlds?

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Get the best of both worlds?

Only consider alignments of low-level operations

Decomposition

Program:

Abstract Program + *Instantiation*

(high-level operations and slots)

(low-level operations)

select(*#rows***,** *#column***)**

select([rank = 2], total)

select([nation =“Turkey”], silver)

select([nation =“United States”], gold)

Abstract Programs

```
select(#rows, #column)

select(argmax( #rows),
  #column), #column)
select(argmin( #rows),
  #column), #column)

⋮
```

- Retain high-level operations
- Generalise across different context

[Dong and Lapata, 2018; Catherine Finegan-Dollak and Radev, 2018; Goldman et al., 2018; Herzig and Berant, 2018; Nye et al., 2019]

Abstract Programs

select(*#rows***,** *#column***)**

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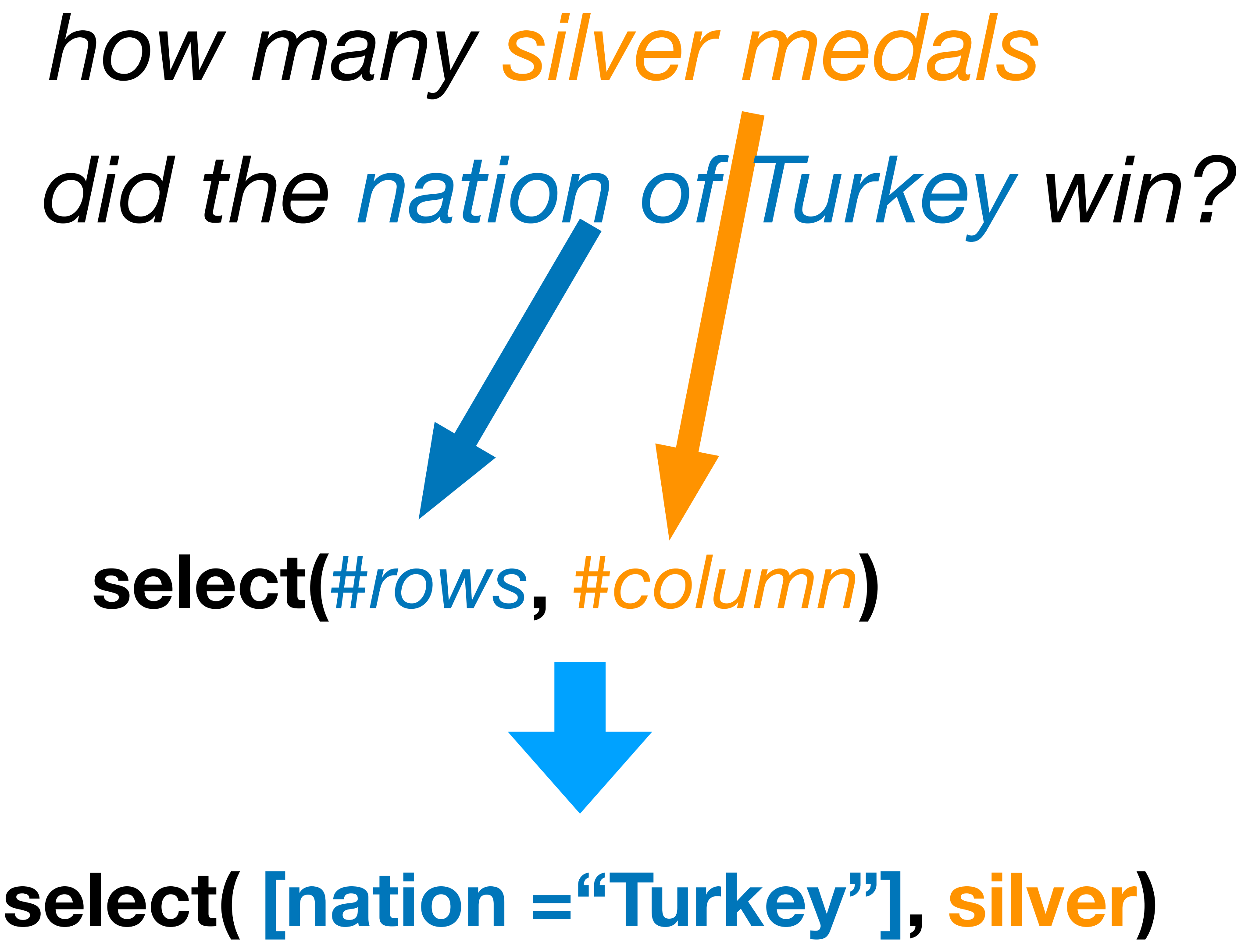
⋮

- Retain high-level operations
- Generalise across different context
- Facilitate tractable probabilistic alignment model

[Dong and Lapata, 2018; Catherine Finegan-Dollak and Radev, 2018; Goldman et al., 2018; Herzig and Berant, 2018; Nye et al., 2019]

Model Alignments



Question

how many silver medals did the nation of Turkey win?

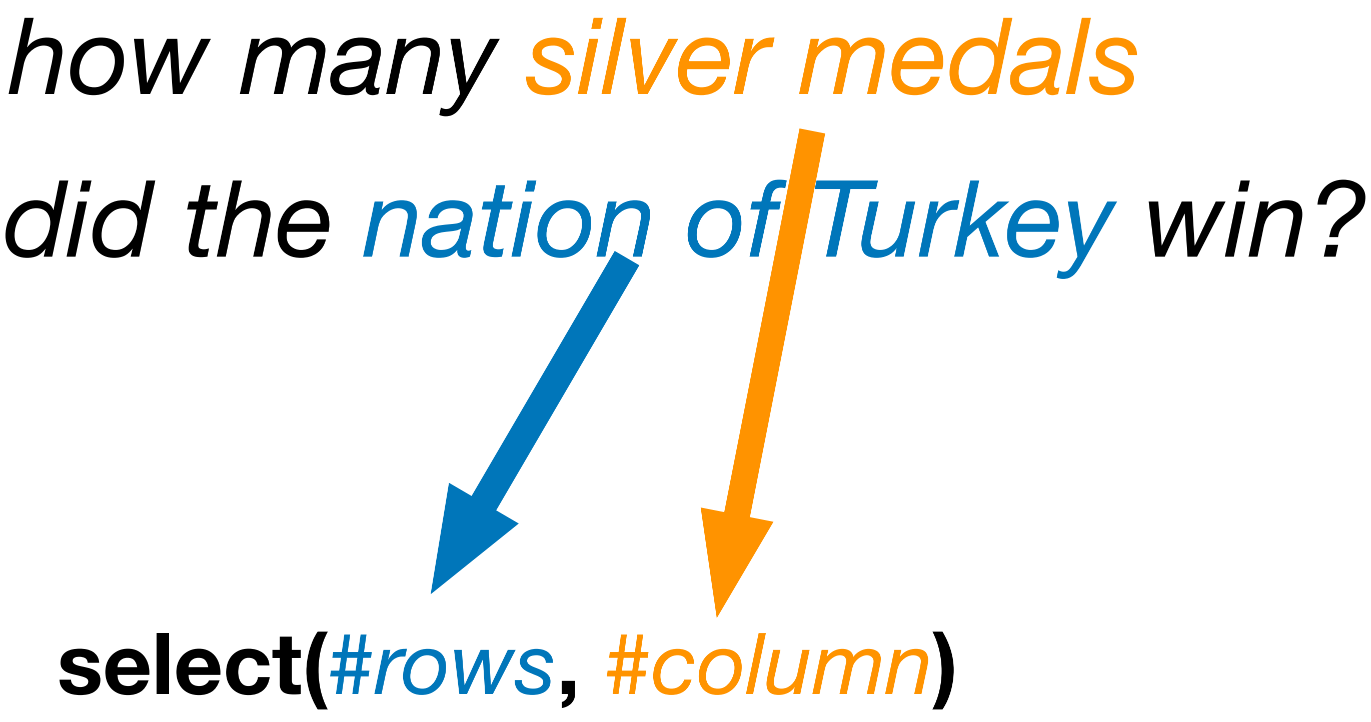
Abstract Program

select(*#rows*, *#column***)**

Program

select([nation =“Turkey”], silver)

Structural Alignment



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select(*#rows***,** *#column***)**

- One-to-one alignments between spans and slots
- Marginal probability can be computed with dynamic programming [Tackstrom et al. 2015]

Structural Alignment

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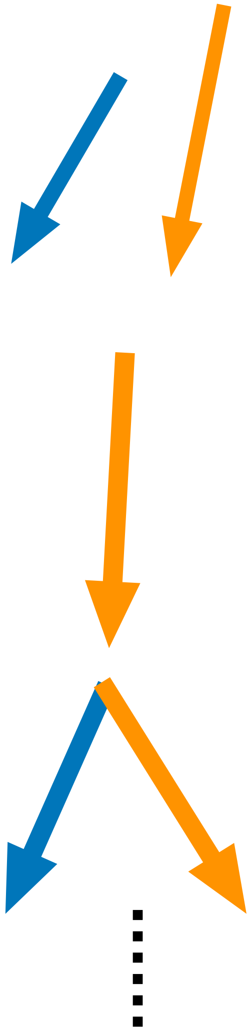

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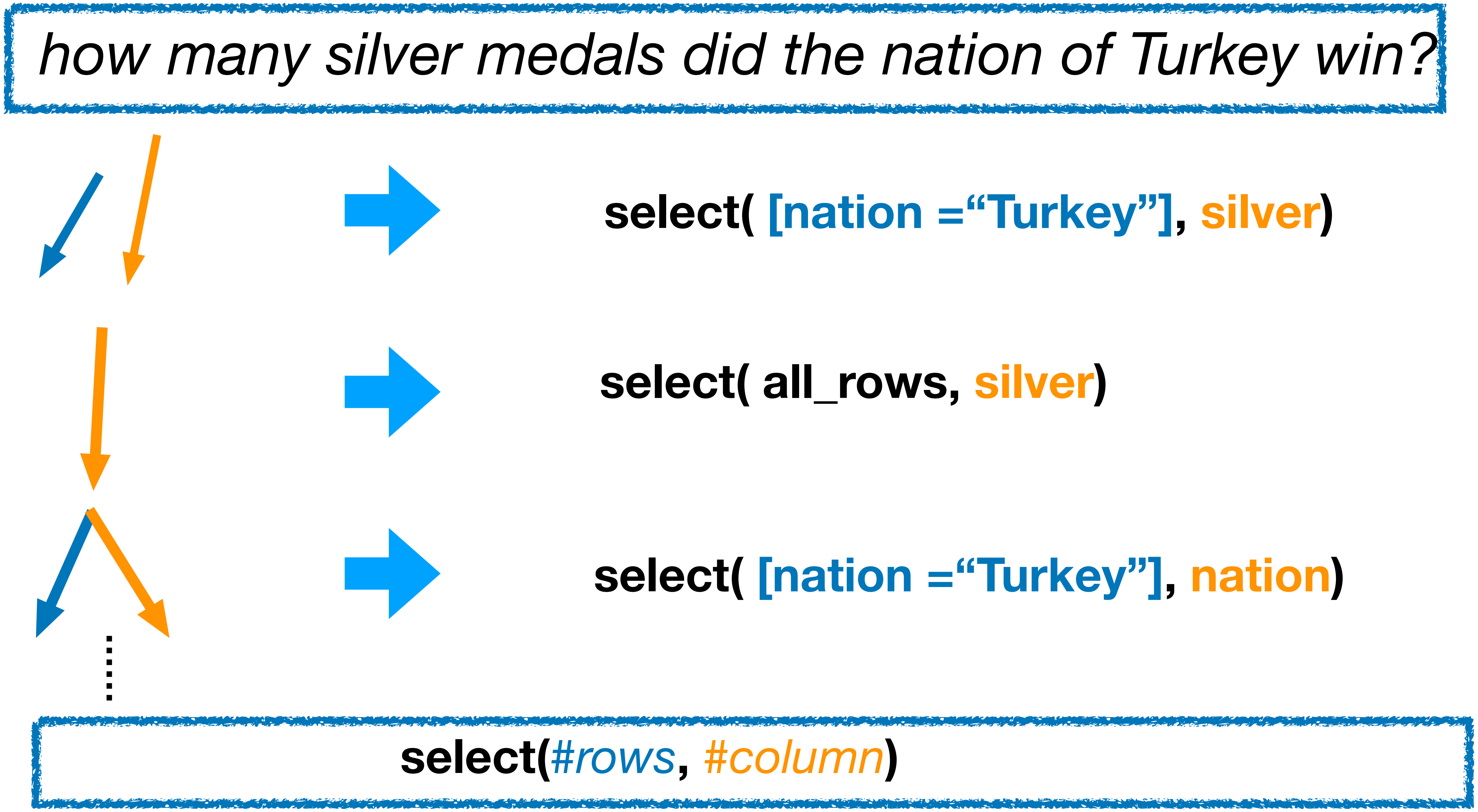


how many silver medals did the nation of Turkey win?

select([nation =“Turkey”], silver)

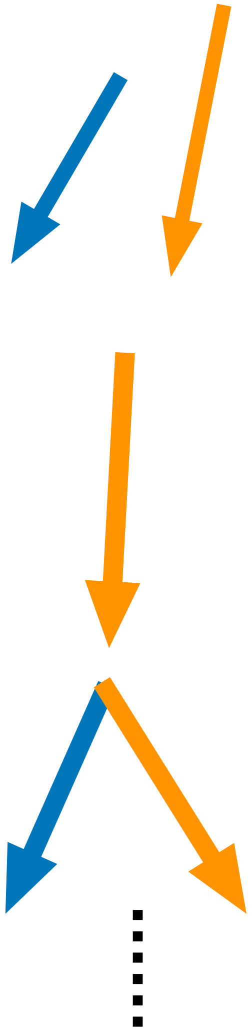
select(all_rows, silver)

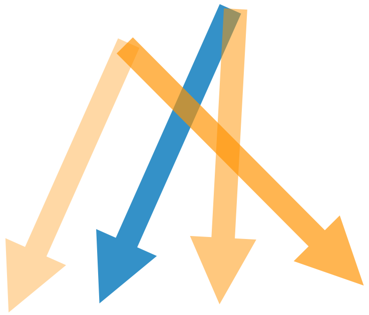
select([nation =“Turkey”], nation)

select(*#rows*, *#column*)

Structural Alignment

how many silver medals did the nation of Turkey win?





Expected Alignment
(Continuous)

select([nation =“Turkey”],
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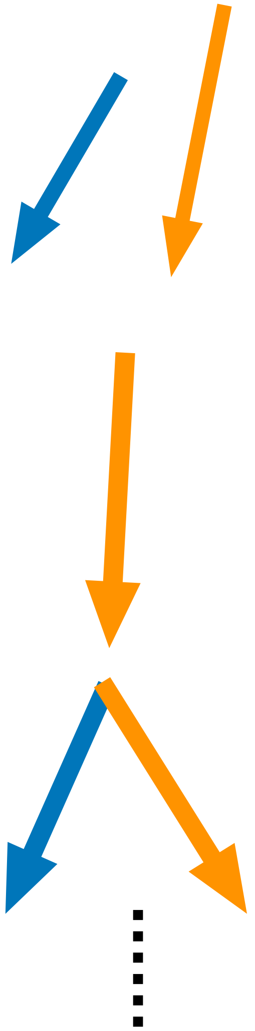
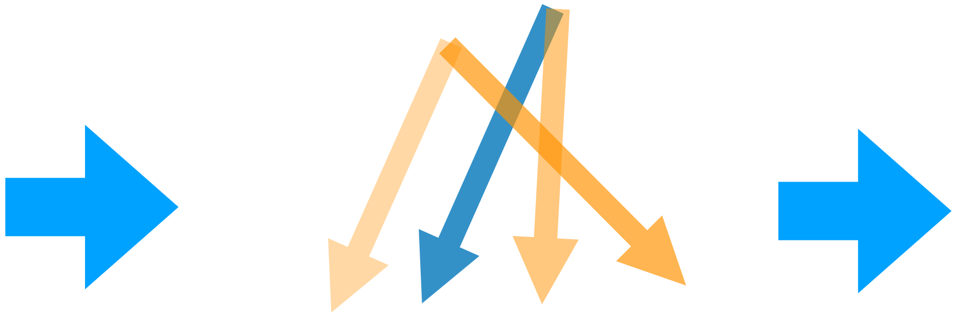
select(*#rows*, *#column*)

Structural Alignment

how many silver medals did the nation of Turkey win?





select(**[nation =“Turkey”],**
silver)

Expected Alignment (Continuous)

structured attention [Kim et al., 2017]

select(*#rows*, *#column*)

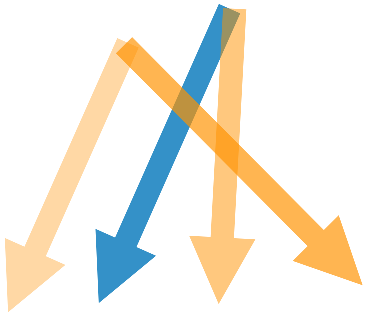
Summary

- A two-stage approach that incorporates:

1. abstract programs

select(*#rows*, *#column*)

2. (expected) structured alignments



Experiments

Datasets

	WikiTableQuestions	WikiSQL
# of question-denotation pairs	18,496	80,654
# of tables	2,018	24,241

- Questions involve a variety of operations
- Unseen tables at ***test*** time

Consistent Programs

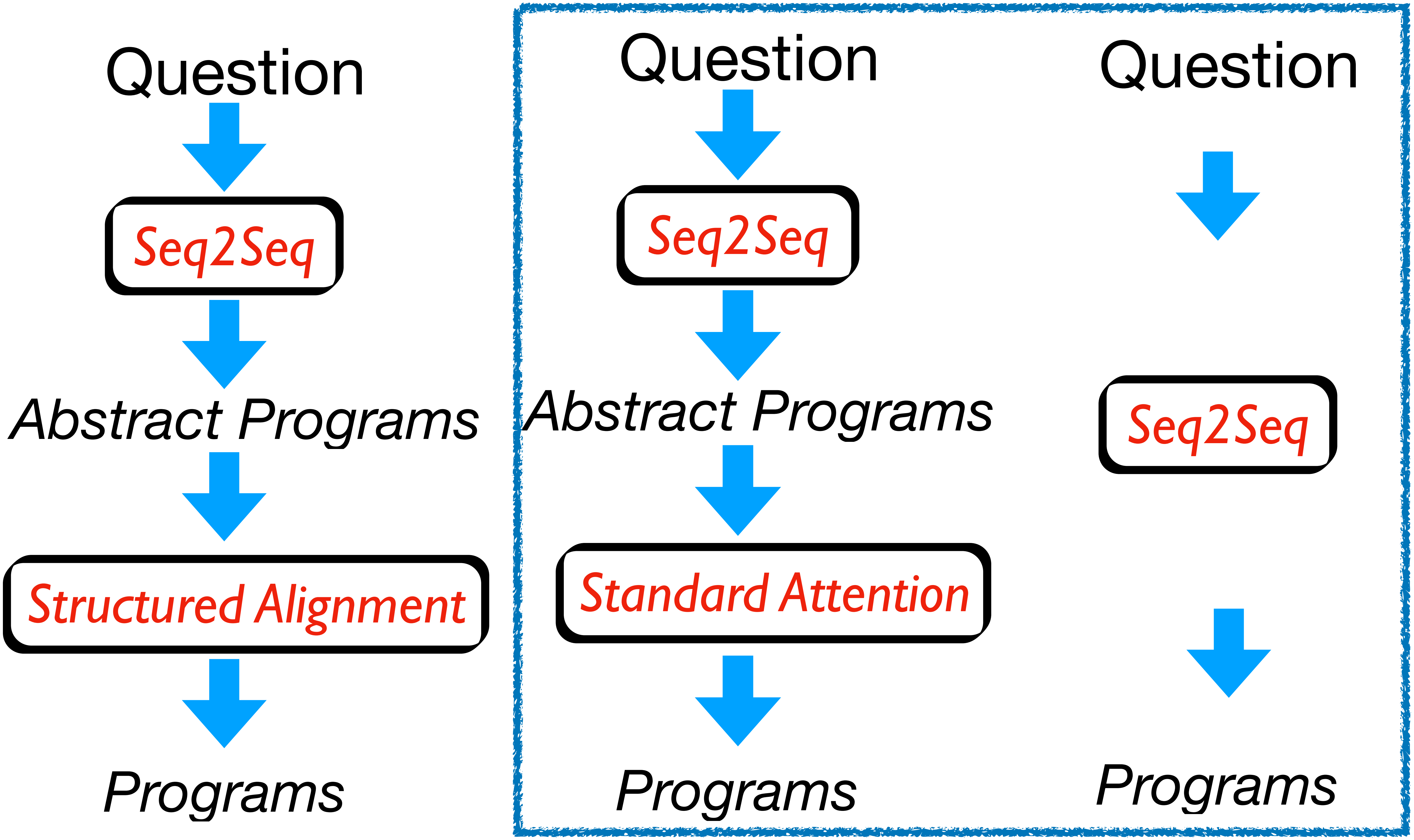
	WikiTableQuestions	WikiSQL
# of consistent programs per question	200	84

Most consistent programs are spurious!

Training and Inference

- Train: ***marginal probability*** of consistent programs
- Inference: ***beam search*** (for abstract programs)
- Evaluation: ***execution accuracy***

Baselines



Question

Seq2Seq

Abstract Programs

Structured Alignment

Programs

Question

Seq2Seq

Abstract Programs

Standard Attention

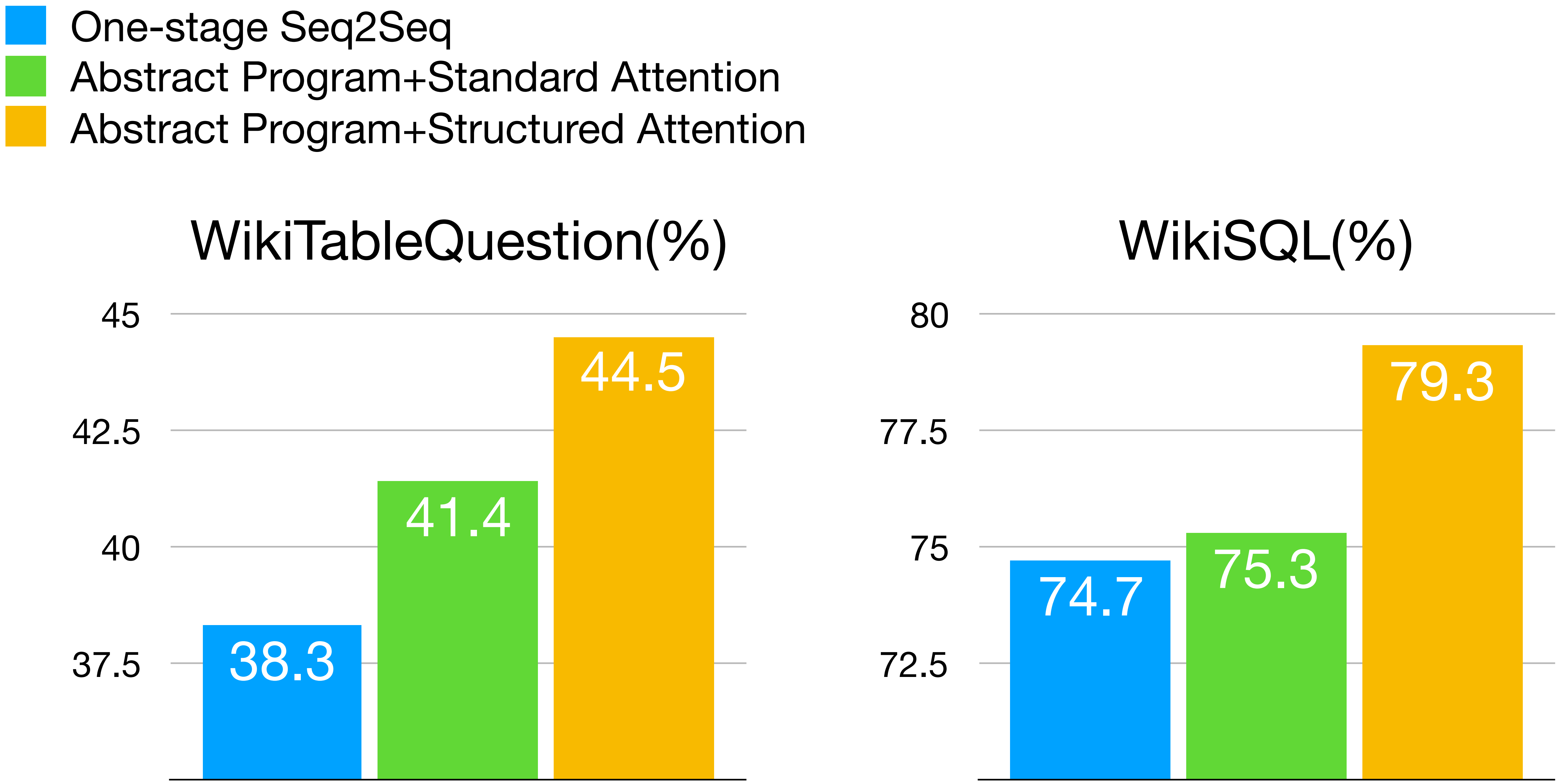
Programs

Question

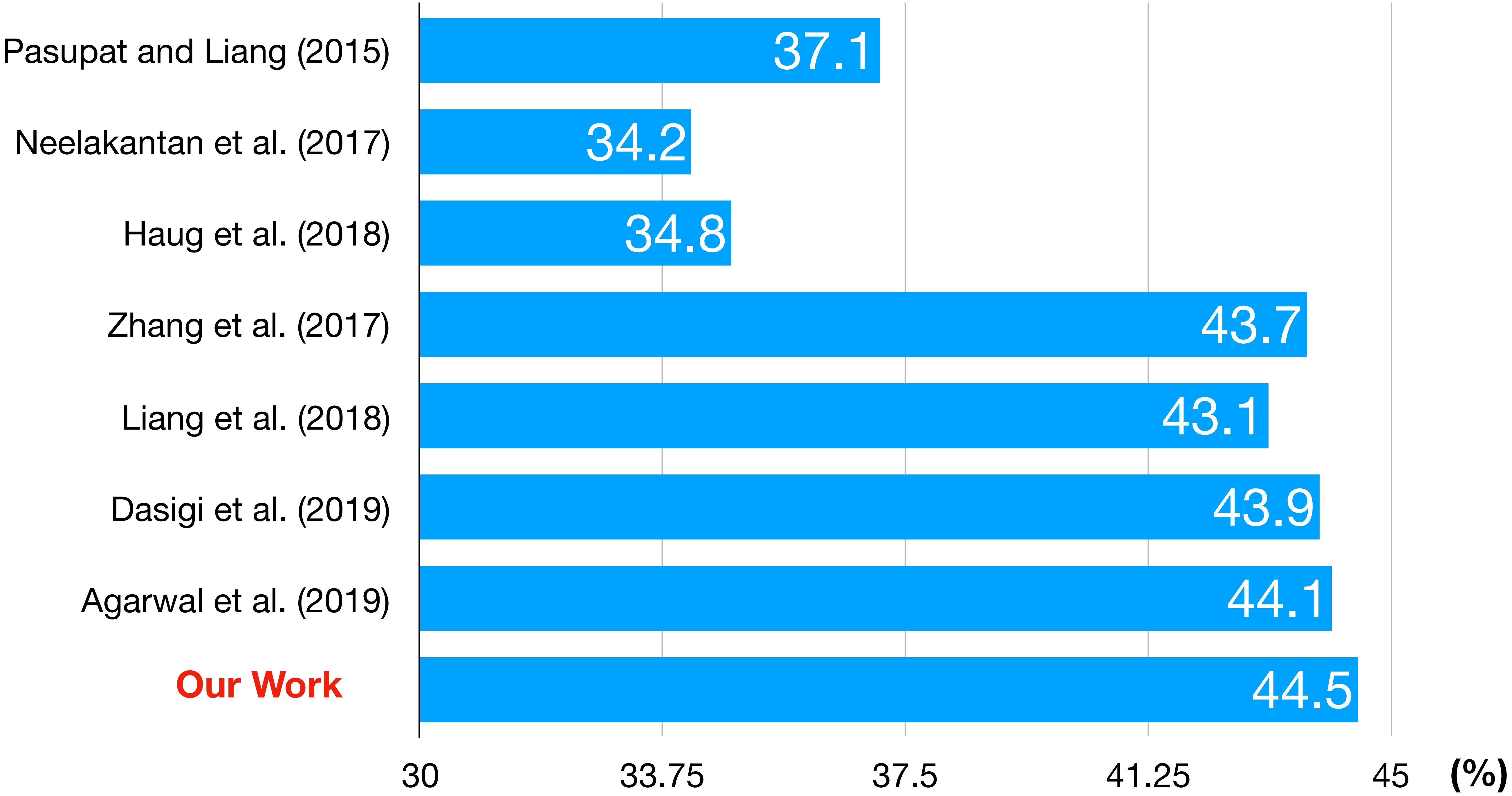
Seq2Seq

Programs

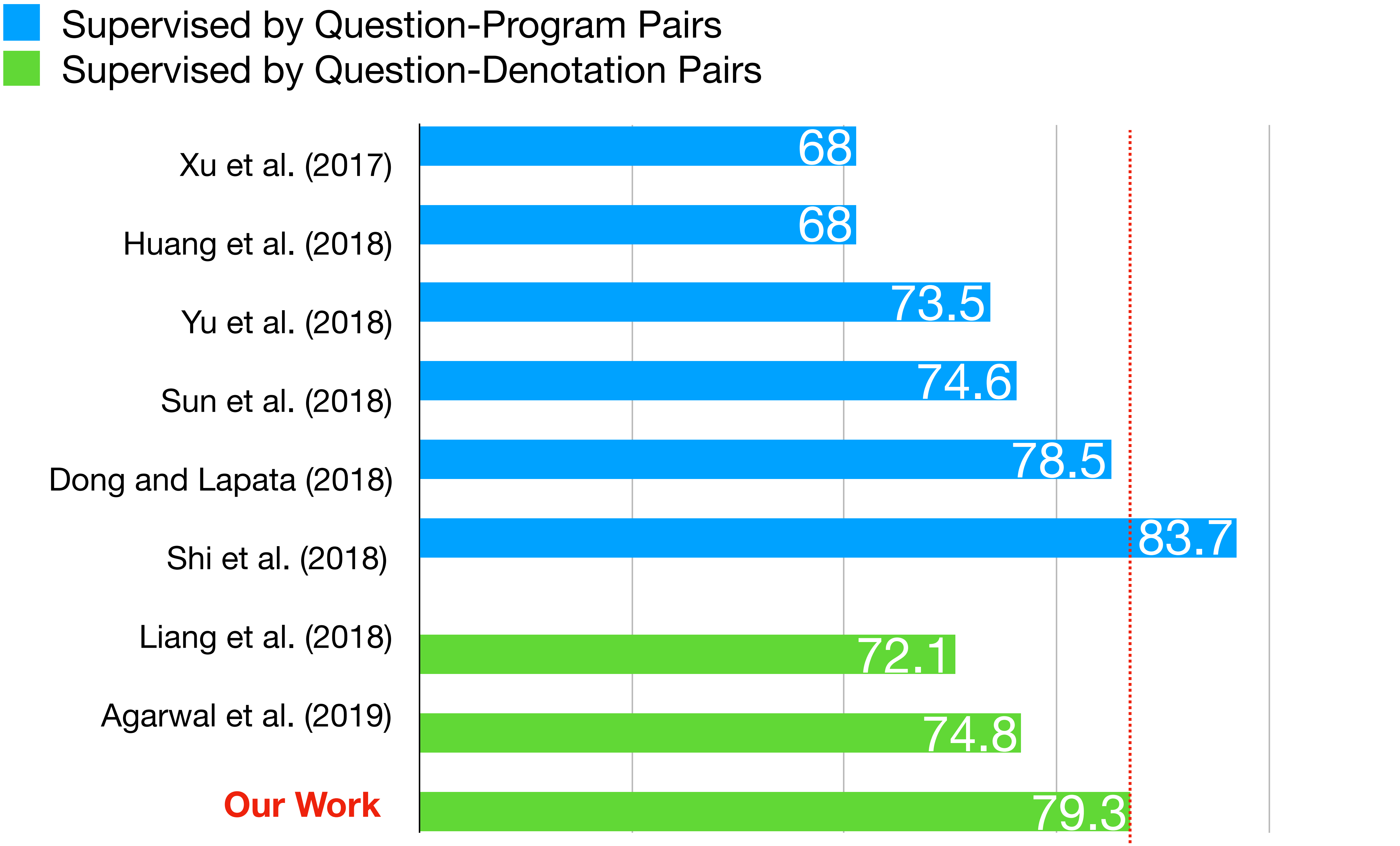
Compared with Baselines



Results on WikiTableQ



Results on WikiSQL



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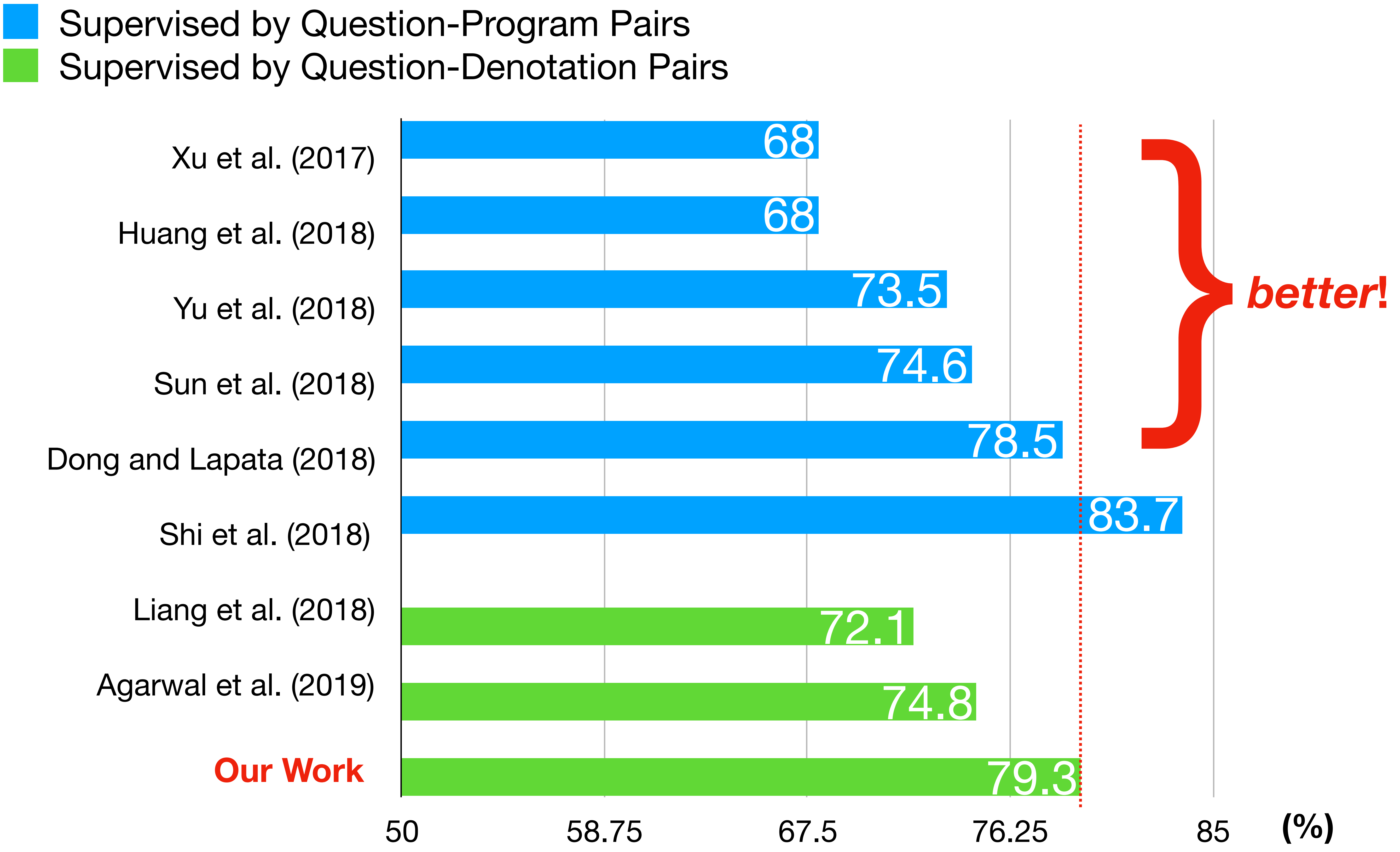


Does it really handle spuriousness?

Expectation:

p_θ(**Spurious Programs**|...) < p_θ(**Correct Programs**|...)

Does it really handle spuriousness?

Expectation:

p_θ(**Spurious Programs**|...) **<** p_θ(**Correct Programs**|...)

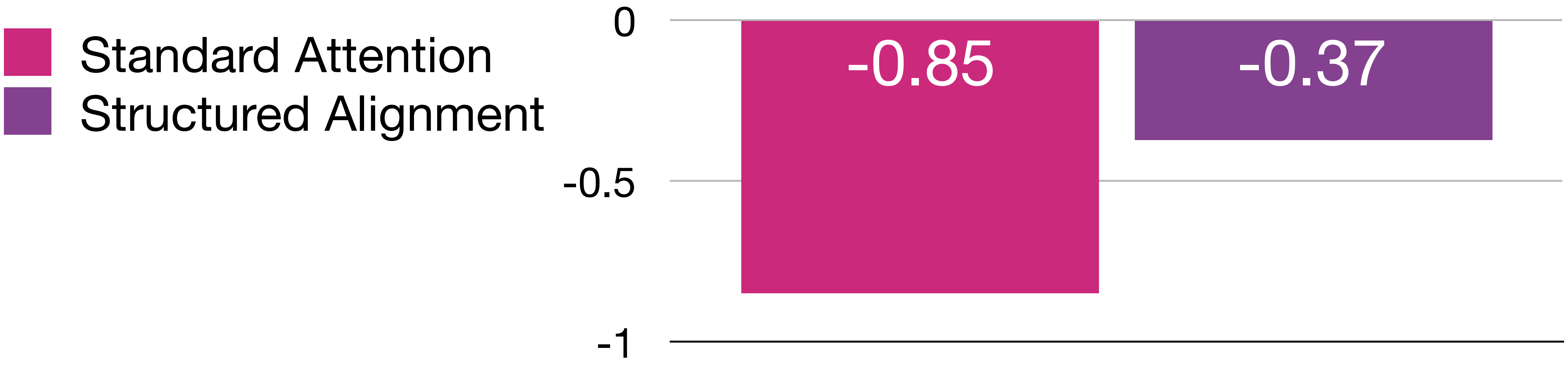
p_θ(**Correct Program**|**Consistent Programs**)

Does it really handle spuriousness?

Expectation:

p_θ(**Spurious Programs**|...) < p_θ(**Correct Programs**|...)

log p_θ(**Correct Program**|**Consistent Programs**)



Generalization

General Form of Two-Stage Framework

Abstract Programs + Probabilistic Alignment

domain specific language

logical forms

SQL/Python

⋮

+

one-to-one

monotonicity

bijectivity

sparsity

⋮

Summary

- We propose a semantic parser that features abstract programs and latent structured alignments.
- State-of-the-art performance on two benchmarks.
- Inductive bias introduced really help handle spuriousness.
- Code available: https://github.com/berlino/weaksp_em19

erc European Research Council

ERC Starting Grant BroadSem