Natural Language Interfaces for Semi-Structured Web Pages

University Oral Examination Ice Pasupat





environment



environment

utterance

Alexa, play Despacito





utterance

Alexa, play Despacito

actions











natural language interface to database

[Hendrix et al., 1978 / Androutsopoulos et al., 1995 / Popescu et al., 2003 / ...]





natural language interface to database

smart search engines

Goal: Extend the capability of these systems along two axes:

- •
- ▶

>
>
...



Goal: Extend the capability of these systems along two axes:

Scope of the environment (breadth)

How much is a Steak Burrito at Ray's Grill?



Goal: Extend the capability of these systems along two axes:

?????

Scope of the environment (breadth)







most virtual assistants

database / apps limited schema



Scope of the environment (breadth)

[Zelle + Mooney, 1996 / Zettlemoyer + Collins, 2007 / Liang et al., 2011 / ...]



most virtual assistants

database / apps limited schema semantic parsing on knowledge bases

knowledge base still limited schema





Freebase

Scope of the environment (breadth)

[Cai + Yates, 2013 / Berant et al., 2013 / Kwiatkowski et al., 2013 / Bordes et al., 2015 / ...]



Scope of the environment (breadth)

[Robertson et al., 19xx / Hearst, 1992 / Richardson et al., 2013 / Rajpurkar et al., 2016 / ...]

Goal: Extend the capability of these systems along two axes:

?????

Scope of the environment (breadth)





Goal: Extend the capability of these systems along two axes:

\$8.50

Scope of the environment (breadth)





\$7.5



Goal: Extend the capability of these systems along two axes:

\$8.50

- Scope of the environment (breadth)
- Task complexity (depth)





Goal: Extend the capability of these systems along two axes:

- Scope of the environment (breadth)
- Task complexity (depth)

What's the cheapest burrito with chicken?



Goal: Extend the capability of these systems along two axes:

- Scope of the environment (breadth)
- Task complexity (depth)

What's the cheapest burrito with chicken?



Goal: Extend the capability of these systems along two axes:

- Scope of the environment (breadth)
- Task complexity (depth)



Task Complexity (depth)



surface form matching

Task Complexity (depth)

How much is a steak burrito?

1-2 step reasoning

Find pages with "burrito"

surface form matching

Task Complexity (depth)

What's the cheapest burrito with chicken?	multi-step reasoning
How much is a steak burrito?	1-2 step reasoning
Find pages with "burrito"	surface form matching

Task Complexity (depth)





Task Complexity (depth) web pages multi-step reasoning semantic parsing on databases most virtual semantic parsing on question answering knowledge bases assistants on paragraphs web scraping web search

Scope of the environment (breadth)

Task Complexity (depth)



Scope of the environment (breadth)

interact with HTML elements based on the queries

follow on facebook

appleinsider



[P., Allan Jiang, Evan Liu, Kelvin Guu, Percy Liang, 2018]

interact with HTML elements based on the queries

follow on facebook

appleinsider



[P., Allan Jiang, Evan Liu, Kelvin Guu, Percy Liang, 2018]

interact with HTML elements based on the queries

follow on facebook

appleinsider



Tuesday, May 28, 2019

Video 2019 iPod touch: Everything you need to know

Apple has just updated the last remaining iPod, the iPod touch, for 2019 with an A10 Fusion processor and storage boost. Here is everything you need to know about Tuesday's release.

[P., Allan Jiang, Evan Liu, Kelvin Guu, Percy Liang, 2018]

extracting a list of entities from the web page

hiking trails in baltimore

Every Trail

HOME | EXPLORE | MOBILE APPS | CREATE TRIP | MY EVERYTRAIL

Hiking near Baltimore, Maryland

Guides



Avalon Super Loop - Patapsco State Park

Patapsco State Park, Maryland, United States (7.5 miles away)

Difficult: 12.7 miles, Full day lots of ruins, waterfalls, trains, and river views

Do the entire Avalon Patapsco state park in 1 day! This loop covers the majority of the Avalon area, with multiple ruins, waterfalls and other artifacts to find along the way. Starting at the parking lot, you hike up the road a ways to the Ridge trail sign. The next leg is the maintenace loop which has an old old tractor to look at and some...



- D

Patapsco Valley State Park - Hilton Area 8 Miles/Moderate

Catonsville, Maryland, United States (7.7 miles away)

Moderate: 7.8 miles, Half day 8 mile circuit hike including sections in the Avalon, Orange Grove and Glen Artney areas of PVSP.

[P. and Liang, 2014]

interact with HTML elements based on the queries

follow on facebook

appleinsider



Apple has just updated the last remaining iPod, the iPod touch, for 2019 with an A10 Fusion processor and storage boost. Here is everything you need to know about Tuesday's release.

[P., Allan Jiang, Evan Liu, Kelvin Guu, Percy Liang, 2018]

extracting a list of entities from the web page

hiking trails in baltimore

Every Trail

HOME | EXPLORE | MOBILE APPS | CREATE TRIP | MY EVERYTRAIL

Hiking near Baltimore, Maryland



Avalon Super Loop - Patapsco State Park

Difficult: 12.7 miles, Full day lots of ruins, waterfalls, trains, and river views

Do the entire Avalon Patapsco state park in 1 day! This loop covers the majority of the Avalon area, with multiple ruins, waterfalls and other artifacts to find along the way. Starting at the parking lot, you hike up the road a ways to the Ridge trail sign. The next leg is the maintenace loop which has an old old tractor to look at and some...



Patapsco Valley State Park - Hilton Area 8 Miles/Moderate

Moderate: 7.8 miles, Half day

8 mile circuit hike including sections in the Avalon, Orange Grove and Glen Artney areas of PVSP.

[P. and Liang, 2014]

Structures such as tables have potential for **complex reasoning**!

Structures such as tables have potential for complex reasoning!

list of hedge funds in new york

Rank \$	Firm +	Headquarters +
1	Bridgewater Associates	Westport, CT
2	Man Group	E London
3	J.P. Morgan Asset Management	New York
4	Brevan Howard Asset Management	E London
5	Och-Ziff Capital Management Group	Mew York
6	Paulson & Co.	New York
7	BlackRock Advisors	New York





Outline

- Motivation
- Task: Answering complex questions on web tables
- Approach: Semantic parsing with distant supervision
- Improvement 1: Make it faster
- Improvement 2: Convert to direct supervision
Piotr Kędzia

Competition record

Year +	Competition +	Venue +	Position +	Event +	Notes +
		Representing 📥 Poland			
	World Youth Championships	Debracan Hundany	2nd	400 m	47.12
2001	wond four championships	Debrecen, Hungary	1st	Medley relay	1:50.46
	European Junior Championships	Grosseto, Italy	1st	4x400 m relay	3:06.12
2002	Furnan Iuniar Championshing	Transara Cialand	3rd	400 m	46.69
2003	European Junior Championships	lampere, Finiand	2nd	4x400 m relay	3:08.62
	European U23 Championships	Erfurt, Germany	11th (sf)	400 m	46.62
			1st	4x400 m relay	3:04.41
2005	Universiade	Izmir, Turkey	7th	400 m	46.89
			1st	4x400 m relay	3:02.57
2005	World Indoor Championships	Moscow, Russia	2nd (h)	4x400 m relay	3:06.10
2006	European Championships	Gothenburg, Sweden	3rd	4x400 m relay	3:01.73
	European Indoor Championships	Birmingham, United Kingdom	3rd	4x400 m relay	3:08.14
2007	(and the stand of	Provide the The Hand	7th	400 m	46.85
	Universiade	Bangkok, Thailand	1st	4x400 m relay	3:02.05
2000	World Indoor Championships	Valencia, Spain	4th	4x400 m relay	3:08.76
2008	Olympic Games	Beijing, China	7th	4x400 m relay	3:00.32
2009	Universiade	Belgrade, Serbia	2nd	4x400 m relay	3:05.69

Piotr Kędzia

Competition record

Year +	Competition +	Venue +	Position +	Event +	Notes +
		Representing 📥 Poland			
	World Youth Championships	Debracan Hundany	2nd	400 m	<mark>47.12</mark>
2001	wond fould championships	Debrecen, Hungary	1st	Medley relay	1:50.46
	European Junior Championships	Grosseto, Italy	1st	4x400 m relay	3:06.12
2002	European Junior Championshins	Tampara Finland	3rd	400 m	46.69
2003	European Junior Championships	lampere, riniano	2nd	4x400 m relay	3:08.62
2005	European U23 Championships	Erfurt, Germany	11th (sf)	400 m	46.62
			1st	4x400 m relay	3:04.41
	Universiade	Izmir, Turkey	7th	400 m	46.89
			1st	4x400 m relay	3:02.57
2005	World Indoor Championships	Moscow, Russia	2nd (h)	4x400 m relay	3:06.10
2006	European Championships	Gothenburg, Sweden	3rd	4x400 m relay	3:01.73
	European Indoor Championships	Birmingham, United Kingdom	3rd	4x400 m relay	3:08.14
2007	Universited	Danskels Thailand	7th	400 m	46.85
	Universidde	Bangkok, Thanand	1st	4x400 m relay	3:02.05
2000	World Indoor Championships	Valencia, Spain	4th	4x400 m relay	3:08.76
2008	Olympic Games	Beijing, China	7th	4x400 m relay	3:00.32
2009	Universiade	Belgrade, Serbia	2nd	4x400 m relay	3:05.69

In what city did Piotr's last 1st place finish occur?

A new dataset of Wikipedia tables, complex questions, and answers

- ► 22K examples
- ► 2K tables

Task Complexity (depth):

Year +	Competition +	Venue +	Position +	Event +	Notes +
		Representing 📥 Poland			
		Debracen Humany	2nd	400 m	<mark>47.12</mark>
2001	world touch Championships	Debrecen, Hungary	1st	Medley relay	1:50.46
	European Junior Championships	Grosseto, Italy	1st	4x400 m relay	3:06.12
2002	European Iunian Championshine	Transact Cirland	3rd	400 m	46.69
2003	European Junior Championships	Tampere, Finiand	2nd	4x400 m relay	3:08.62
2005	European U23 Championships	Erfurt, Germany	11th (sf)	400 m	46.62
			1st	4x400 m relay	3:04.41
	Universiade	Izmir, Turkey	7th	400 m	46.89
			1st	4x400 m relay	3:02.57
2005	World Indoor Championships	Moscow, Russia	2nd (h)	4x400 m relay	3:06.10
2006	European Championships	Gothenburg, Sweden	3rd	4x400 m relay	3:01.73
	European Indoor Championships	Birmingham, United Kingdom	3rd	4x400 m relay	3:08.14
2007			7th	400 m	46.85
	Universiade	Bangkok, Inaliand	1st	4x400 m relay	3:02.05
2000	World Indoor Championships	Valencia, Spain	4th	4x400 m relay	3:08.76
2008	Olympic Games	Beijing, China	7th	4x400 m relay	3:00.32
2009	Universiade	Belgrade, Serbia	2nd	4x400 m relay	3:05.69

How long did it take this competitor to finish the <u>4x400</u> meter relay at <u>Universiade</u> in <u>2005</u>?

Task Complexity (depth):

Year +	Competition +	Venue +	Position +	Event +	Notes +
		Representing <u>Poland</u>			
		Debrasen Humany	2nd	400 m	47.12
2001	world touch Championships	Debrecen, Hungary	1st	Medley relay	1:50.46
	European Junior Championships	Grosseto, Italy	1st	4x400 m relay	3:06.12
2002	European Iunion Championshine	Tanaan Caland	3rd	400 m	46.69
2003	European Junior Championships	lampere, Finland	2nd	4x400 m relay	3:08.62
	European U23 Championships	Erfurt, Germany	11th (sf)	400 m	46.62
			1st	4x400 m relay	3:04.41
2005	Universiade	Izmir, Turkey	7th	400 m	46.89
			1st	4x400 m relay	3:02.57
2005	World Indoor Championships	Moscow, Russia	2nd (h)	4x400 m relay	3:06.10
2006	European Championships	Gothenburg, Sweden	3rd	4x400 m relay	3:01.73
	European Indoor Championships	Birmingham, United Kingdom	3rd	4x400 m relay	3:08.14
2007		Bangkok, Thailand	7th	400 m	46.85
	Universiade		1st	4x400 m relay	3:02.05
	World Indoor Championships	Valencia, Spain	4th	4x400 m relay	3:08.76
2008	Olympic Games	Beijing, China	7th	4x400 m relay	3:00.32
2009	Universiade	Belgrade, Serbia	2nd	4x400 m relay	3:05.69

How long did it take this competitor to finish the <u>4x400</u> meter relay at <u>Universiade</u> in <u>2005</u>?

Where was the competition held immediately <u>before</u> the one in Turkey?

Task Complexity (depth):

Year +	Competition +	Venue +	Position +	Event +	Notes +
		Representing <u>Poland</u>			
	World Youth Championships	Debracen Humann	2nd	400 m	47.12
2001	wond fourth championships	Debrecen, Hungary	1st	Medley relay	1:50.46
	European Junior Championships	Grosseto, Italy	1st	4x400 m relay	3:06.12
2002	European Junior Championshins	Tampara Finland	3rd	400 m	46.69
2003	European Junior Championships	Tampere, Finiand	2nd	4x400 m relay	3:08.62
	European U23 Championships	Erfurt, Germany	11th (sf)	400 m	46.62
			1st	4x400 m relay	3:04.41
2005	Universiade	Izmir, Turkey	7th	400 m	46.89
			1st	4x400 m relay	3:02.57
2006	World Indoor Championships	Moscow, Russia	2nd (h)	4x400 m relay	3:06.10
2006	European Championships	Gothenburg, Sweden	3rd	4x400 m relay	3:01.73
	European Indoor Championships	Birmingham, United Kingdom	3rd	4x400 m relay	3:08.14
2007	(and a second se	Barrelah Thelland	7th	400 m	46.85
	Universiade	Bangkok, Thailand	1st	4x400 m relay	3:02.05
2000	World Indoor Championships	Valencia, Spain	4th	4x400 m relay	3:08.76
2008	Olympic Games	Beijing, China	7th	4x400 m relay	3:00.32
2009	Universiade	Belgrade, Serbia	2nd	4x400 m relay	3:05.69

How long did it take this competitor to finish the <u>4x400</u> meter relay at <u>Universiade</u> in <u>2005</u>?

Where was the competition held immediately <u>before</u> the one in Turkey?

<u>How many times</u> has this competitor placed 5th <u>or better</u> in competition?

Scope of the environment (breadth):

• Diverse data types: 4K different column headers among 2K tables

Year	Division	League	Regular Season	Playoffs	Open Cup	Avg. Attendance
2001	2	USL A-League	4th, Western	Quarterfinals	Did not qualify	7,169
2002	2	USL A-League	2nd, Pacific	1st Round	Did not qualify	6,260
2003	2	USL A-League	3rd, Pacific	Did not qualify	Did not qualify	5,871
2004	2	USL A-League	1st, Western	Quarterfinals	4th Round	5,628
2005	2	USL First Division	5th	Quarterfinals	4th Round	6,028
2006	2	USL First Division	11th	Did not qualify	3rd Round	5,575
2007	2	USL First Division	2nd	Semifinals	2nd Round	6,851
2008	2	USL First Division	11th	Did not qualify	1st Round	8,567
2009	2	USL First Division	1st	Semifinals	3rd Round	9,734
2010	2	USSF D-2 Pro League	3rd, USL (3rd)	Quarterfinals	3rd Round	10,727

Year +	Competition +	Venue +	Position +	Event +	Notes a
		Representing 📥 Poland			
	Weeklehren ander eine besetelten	Debuser Horses	2nd	400 m	47.12
2001	world routh Championships	Debrecen, Hungary	1st	Medley relay	1:50.46
	European Junior Championships	Grosseto, Italy	1st	4 × 400 m relay	3:06.12
2002	World Junior Championships	Kingston, Jamaica	4th	4 × 400 m relay	3:06.25
2002	Frankrike Karley Okamala aktor	Transford Fisherd	3rd	400 m	46.69
2003	European Junior Championships	nips Tampere, Finland	2nd	4 × 400 m relay	3:08.62
	European U23 Championships Universiade	Erfurt, Germany Izmir, Turkey	11th (sf)	400 m	46.62
			1st	4 × 400 m relay	3:04.41
2005			7th	400 m	46.89
			1st	4 × 400 m relay	3:02.57
2000	World Indoor Championships	Moscow, Russia	2nd (h)	4 × 400 m relay	3:06.10
2006	European Championships	Gothenburg, Sweden	3rd	4 × 400 m relay	3:01.73
	European Indoor Championships	Birmingham, United Kingdom	3rd	4 × 400 m relay	3:08.14
2007	the first sector de la	Departure The land	7th	400 m	46.85
	Universiade	Bangkok, Thailand	1st	4 × 400 m relay	3:02.05
2000	World Indoor Championships	Valencia, Spain	4th	4 × 400 m relay	3:08.76
2008	Olympic Games	Beijing, China	6th	4 × 400 m relay	3:00.32
2009	Universiade	Belgrade, Serbia	2nd	4 × 400 m relay	3:05.69

	Team	County	Wins	Years won
	Two Mile House	Kildare	1	2018
	Kilanerin–Ballyfad	Wexford	1	2017
	St. Colmcille's	Meath	1	2016
	Ratoath	Meath	1	2015
	Seán O'Mahonys	Louth	1	2014
	Geraldines	Louth	1	2013
	Monasterevin	Kildare	1	2012
	Éire Óg Greystones	Wicklow	1	2011
	Ballymore Eustace	Kildare	1	2010
	Maynooth	Kildare	1	2009
	Ballyroan Abbey	Laois	1	2008
	Fingal Ravens	Dublin	1	2007
	Confey	Kildare	1	2006
	Crettyard	Laois	1	2005
	Wolfe Tones	Meath	1	2004
k Gaels	Louth	1	2003	

Rank	City	Passengers	Ranking	Airline
1	United States, Los Angeles	15,383	-	Alaska Airlines
2	eanada, Calgary	9,279	-	WestJet
3	Canada, Toronto	2,241	▲ 3	Sunwing Airlines
4	United States, Houston	1,730	1	United Express
5	United States, Minneapolis	1,279	1	Sun Country Airlines
6	United States, Phoenix-Sky Harbor	821	A 2	American Airlines

Dundal

15 August 1987Derby CountyAway0-117,204———118 August 1987Coventry CityHome0-19,303——122 August 1987West Han UnitedHome2-28,073Harford 2)123 August 1987ChelseaAway1016,075—131 August 1987ArsenalHome2-26,804Breacker, Harford, Hill, Nwajiobi, B. Stein115 September 1987EvertonHome2-16,8124Hill, B. Stein115 September 1987EvertonHome2-111,175—125 September 1987Queens Park RangerAway0-111,275—126 September 1987Outens Park RangerAway1-312,391Harford (pen)110 October 1987MinbledonHome1-312,391B. Stein, M. Stein (D117 October 1987WimbledonHome2-07,018B. Stein, M. Stein (D117 October 1987WimbledonHome2-010,991Allinson, M. Stein (D114 November 1987Steinfled WednesdayAway2-010,991Allinson, M. Stein (D114 November 1987Norwich CityHome2-010,991Allinson (A. Stein115 December 1987Norwich CityHome2-010,991Allinson (M. Stein116 December 1987Norwich CityHome2-012,125Foster1 <th>Date</th> <th>Opponent</th> <th>Venue</th> <th>Result</th> <th>Attendance</th> <th colspan="2">Scorers</th>	Date	Opponent	Venue	Result	Attendance	Scorers	
18 August 1987 Coventry City Home 0-1 9,380 — — () 22 August 1987 Vest Ham United Home 2-2 8.073 Harford 2) () 23 August 1987 Chelsea Away 0.3 10.00 — .	15 August 1987	Derby County	Away	0-1	17,204	_	
22 August 1987 Vest Ham United Home 2-2 8,07.3 Hardrof (2) 1 23 August 1987 Chelsa Away 5.3 G.6.75 G.M.G.M.G.M.M.M.M.M.M.M.M.M.M.M.M.M.M.M	18 August 1987	Coventry City	Home	0-1	9,380	_	
29 August 1987 Chelsea Away 0-3 16,075 ————————————————————— 31 August 1987 Arsenal Home 1-1 8,745 Wilson (pen) Image 5 September 1987 Oxford United Away 5-2 6,804 Breacker, Harford, Hill, B.Stein Image 12 September 1987 Chrotn Athletic Away 5-2 8,124 Hill, B.Stein Image 13 September 1987 Chrotn Athletic Away 5-2 11,175 Genes Park Ranges Away 5-2 11,175 ————————————————————————— 13 October 1987 Manchester United Home 1-1 9,137 Harford Mendon Image 14 October 1987 Minbedon Home 4-1 11,997 —— Image 24 October 1987 Winbedon Home 1-1 11,997 —— Image 24 October 1987 Winbedones Mange 1-0 11,997 — Image 24 October 1987 Kencastle United Home 1-0 16,990 Allinson,	22 August 1987	West Ham United	Home	2-2	8,073	Harford (2)	
31 August 1987 Arsenal Home 1-1 8, 7, 4 Wilson (pen) I 5 September 198 Oxford United Away 5-2 6, 6, 40 Breacker, Harford, Hill, Nangibab, Stein I 12 September 198 Evenon Mome 2.0 8, 12.0 Arreaker, Harford, Hill, Nangibab, Stein I 13 September 198 Evenon Mome 7.0 Sectore - - 2 September 30 Genes Park Ranges Away 5.2 11,175 - <t< td=""><td>29 August 1987</td><td>Chelsea</td><td>Away</td><td>0-3</td><td>16,075</td><td>—</td><td></td></t<>	29 August 1987	Chelsea	Away	0-3	16,075	—	
S September 1987 Oxford United Away S-2 6,804 Breacker, Harford, Hill, Nwajiobi, B. Stein I 12 September 1987 Everon Home 2-1 8,124 Hill, B. Stein I 13 September 1987 Everon Maway 0-0 50.00 — Mail I 26 September 1987 Manch Athletic Home 11,175 — — I 3 October 1987 Mancheser United Home 4.03 12,391 Harford (pen) I I 10 October 1987 Winbledon Home 4.04 7.038 B. Stein, Wilson I 24 October 1987 Winbledon Home 4.00 7.038 Navajobj, B. Stein, M. Stein (2) I 7 Noember 1987 Newsche United Home 4.00 7.038 Navajobj, B. Stein, M. Stein (2) I 14 November 1987 Suthampton Home 4.0 1.00 A.00 A.00 I I I I I I I I I I	31 August 1987	Arsenal	Home	1-1	8,745	Wilson (pen)	
12 September 1987 Verton Home 2-1 8,124 Hill, B. Stein I 19 September 1987 Charlton Athleici Away 0-1 5,002 — — 2 26 September 1987 Ouens Park Ranges Away 0-2 11,105 — — 2 1 1 3 3 1 9,137 Harford 1 1 0 1 1 9,137 1<	5 September 1987	Oxford United	Away	5-2	6,804	Breacker, Harford, Hill, Nwajiobi, B. Stein	
19 September 1989 Charlton Athletic Away 0-10 5,002 — — 1 26 September 1987 Queens Park Ranges Away 0-20 11,175 — — 1 3 October 1987 Manchester United Home 1-21 9,133 Harford Part Athlerond 1 10 October 1987 Manchester United Home 2-0 7,013 Bestein, Wilson 1 10 October 1987 Werpool Home 2-0 7,038 Bestein, Wilson 1 24 October 1987 Merosate United Home 2-0 7,038 Stein, M.Stein (2) 1 24 October 1987 Steffield Wednesby May 2-0 16,960 Athlinson, M.Stein (2) 1 21 November 1987 Steffield Wednesby Home 2-0 7,020 Bestein 1 21 November 1987 Steffield Wednesby Home 2-0 7,020 Bestein 1 21 November 1987 Steffield Wednesby Home 2-0 7,020 Bestein 1 <td>12 September 1987</td> <td>Everton</td> <td>Home</td> <td>2-1</td> <td>8,124</td> <td>Hill, B. Stein</td> <td></td>	12 September 1987	Everton	Home	2-1	8,124	Hill, B. Stein	
28 September 1987 Queens Park Ranges Away 0-2 11,175 — — () 3 October 1987 Manchester United Home 1-1 9,137 Harford (Pan) () 10 October 1987 Portsmouth Away 1-3 9,137 Harford (Pan) () 10 October 1987 Portsmouth Home 2-0 7,018 B. Stein, Wilson () 24 October 1987 Liverool Home 0-1 11,997 — () () 24 October 1987 Newcastle United Home 0-0 16,960 Allinson, M. Stein (2) () 24 November 1987 Steffield Wednesday Away 2-0 16,960 Allinson, M. Stein (2) () 21 November 1987 Totenham Hötspur Home 2-0 16,910 Allinson (2) () 21 November 1987 Natroic City Home 2-0 16,910 Allinson (2) () 21 December 1987 Natroic City Home 2-0 12,152 Foster) <td>19 September 1987</td> <td>Charlton Athletic</td> <td>Away</td> <td>0-1</td> <td>5,002</td> <td>-</td> <td></td>	19 September 1987	Charlton Athletic	Away	0-1	5,002	-	
3 October 1987 Manchester United Home 1-1 9,137 Harford (pen) I 10 October 1987 Potsmouth Away 1-3 12,391 Harford (pen) I 17 October 1987 Vimbledon Home 2-0 7.018 B.Stein Wilson I 24 October 1987 Vimbledon Home 2-0 7.038 Awayiobi, B.Stein, M.Stein (2) I 7 November 1987 Neesde United Home 2-0 16.960 Allinson, M.Stein (2) I 14 November 1987 Tottenham Hötspur Home 2-0 16.960 Allinson, M.Stein (2) I 25 December 1987 Nordch City Home 2-0 16.910 Allinson (2) I 26 December 1987 Storthon Athletic Home 2-0 6.618 Harford, McDonough I 28 December 1987 Carton Athletic Home 2-0 6.618 Admot, M.Stein I 29 January 1988 Derstro Mathletic Home 2-0 7.743 Mulson I	26 September 1987	Queens Park Rangers	Away	0-2	11,175	_	
10 October 1987 Portsmouth Away 1-3 12,391 Harford (pen) I 17 October 1987 Wimbledon Home 2-0 7,018 B.Stein, Wilson I 24 October 1987 Wimbledon Home 2-0 7,018 B.Stein, Wilson I 24 October 1987 Userpool Home 4-0 1,09 B.Stein, M.Stein (2) I 7 November 1987 Newsdie United Home 4-0 7,638 Nawajoh, B.Stein, M.Stein (2) I 14 November 1987 Soffeld Wednesday Away 2-0 16,060 Allinson, M.Stein (2) I 5 December 1987 Nowich City Home 2-2 6,618 Harford (McDonough (1) I 18 December 1987 Soutampton Home 2-2 6,618 Harford McDonough (1) I 18 December 1987 Soutampton Home 2-0 7,243 MWilson I 19 January 1988 Charton Athletic Home 1-0 7,175 McDonough I 19	3 October 1987	Manchester United	Home	1-1	9,137	Harford	
17 October 1987 Wimbledon Home 2-0 7,018 B. Stein, Wilson I 24 October 1987 Iverpool Home 0-1 17,979 G. Stein, Wilson I 7 November 1980 Newcastle Under Home 4-0 7,039 Nawajobi, B. Stein, Milson I 7 November 1987 Steffeld Wednesday Away 2-0 16,960 Allinson, M. Stein I 14 November 1987 Steffeld Wednesday Home 2-0 10,091 Allinson, M. Stein I 15 November 1987 Nordrich City Home 2-0 10,091 Allinson (2) I 15 December 1987 Nordrich City Home 4-0 7,243 Mardrof, M. Stein I 16 December 1987 Stofthard Method Home 2-0 2,122 G. Harford, M. Stein I 26 December 1987 Korton Home 1-0 2,123 G. Harford, M. Stein I 21 January 1988 Chelsea Home 1-0 7,473 Mullson I 21 January 1988 Korto Authietic Home 1-0 7,473 Mullson I 16 January 1988 Korto Mullson Home 1-0 7,473 Mullson Mullson	10 October 1987	Portsmouth	Away	1-3	12,391	Harford (pen)	
24 October 1980 Userpoid Home 0-1 11,997 — — () 7 November 1980 Newcastle United Home 4-0 7,638 Nwajiobi, B. Stein, M. Stein (2) I 14 November 1980 Sheffield Wednessay Rawy 2-0 7,638 OMalinson, M. Stein (2) I 14 November 1980 Sheffield Wednessay Rawy 2-0 10,001 Allinson, M. Stein (2) I 21 November 1980 Steffield Wednessay Rawy 2-0 10,001 Allinson, M. Stein (2) I 5 Docember 1980 North City Mawy 2-7 7,002 G. Stein (2) I 25 Docember 1987 Katford Mawy 1-0 12,152 Foster I I 26 Docember 1987 Katford N. Stein Mawy 1-2 32,128 I I 21 January 1988 Chathan Athletic Mawy 1-2 32,128 Mindon Mathletic I I I I I I I I	17 October 1987	Wimbledon	Home	2-0	7,018	B. Stein, Wilson	
Newcastle United Home 4-0 7,638 Nwajiobi, B. Stein, M. Stein (2) (1) 14 November 1987 Sheffield Wednesday Away 2-0 16,660 Allinson, M. Stein (2) (1) 21 November 1987 Tottenham Hotspur Home 2-0 16,960 Allinson, M. Stein (2) (1) 21 November 1987 Tottenham Hotspur Home 2-0 10,091 Allinson, M. Stein (2) (1) 5 December 1987 Vardor (1) Home 2-0 7,002 B. Stein (2) (1) 12 December 1987 Vardor (2) Maway 1-0 12,152 Foster (2) (1) (1) 26 December 1987 Vardon Athletic Home 2-2 6,618 Harford, M. Stein (2) (1) (1) 21 January 1988 Charlon Athletic Home 1-0 7,175 Mitonough, S. Stein, M. Stein (3) (1) 21 January 1988 Orby County Home 1-0 7,175 McDonough, S. Stein, M. Stein (3) (1) 21 January 1984 Arenal (1) Mawa 1-2	24 October 1987	Liverpool	Home	0-1	11,997	_	
14 November 1987 Sheffield Wednesday Away 2-0 16,960 Allinson, M. Stein I 21 November 1987 Totenham Hotspur Home 2-0 10,910 Allinson (2) I 5 December 1987 Norkic Kity Home 2-0 7,002 B. Stein I 12 December 1987 Norkic Kity Home 2-0 12,152 Froster I 12 December 1987 Sudhampton Home 2-2 6.618 Harford, McDonough I I 26 December 1987 Charlton Athletic Home 1-0 7,243 Wilson I I 21 January 1988 Chelsea Home 1-0 7,175 McDonough I	7 November 1987	Newcastle United	Home	4-0	7,638	Nwajiobi, B. Stein, M. Stein (2)	
21 November 1987 Tottenham Hotspur Home 2-0 10.091 Allinson (2) Allinson (2) 5 December 1980 Nowich City Home 2-2 7.002 B. Stein Allinson (2) 12 December 1980 Watford Away 2-0 7.012 Foster Allinson (2) 12 December 1987 Suthampton Home 2-2 6.618 Harford, McDonough Allinson (2) 12 December 1987 Suthampton Away 0-2 32,128 — — Allinson (2) Milson 26 December 1987 Charbon Athletic Home 1-0 7.243 Milson — 1 21 January 1988 Dethy County Home 1-0 7.243 McDonough Milson 13 January 1988 Derly County Home 1-0 7.175 McDonough Milson 13 January 1988 Oxford United Home 1-2 2.6,012 McDonough, B.Stein, M.Stein McLinson 13 February 1988 Arsenal Away 1-2 2.6,012 McStein McStein McLinson 13 February 1988 Arsenal Away 1-2 2.6,012 McStein McStein, M.Stein McLinson 13 Harber 1988 Korsenal Away 1-	14 November 1987	Sheffield Wednesday	Away	2–0	16,960	Allinson, M. Stein	
5 December 1987 Nowich City Home 1-2 7,002 B. Stein Interpret 1 12 December 1987 Vatford Away 1-0 12,152 Foster Interpret 1 18 December 1987 Southampton Home 2-2 6.618 Harford, McDonough Interpret 1 26 December 1987 Southampton Away 0-2 32,128 Interpret 1 Interpret 1 28 December 1987 Kerton Home 3-0 7,243 Witison Interpret 1 1 January 1988 Chese Home 3-0 8,018 Harford, B. Stein, M. Stein Interpret 1 1 January 1988 Oxford United Home 3-0 7,175 McDonough, B.Stein, M.Stein 0 Interpret 1 1 January 1988 Oxford United Home 7-4 8,063 Harford (2), McDonough, B.Stein, M.Stein 0 Interpret 1 1 January 1988 Oxford United Home 7-4 8,063 Harford (2), McDonough, B.Stein, M.Stein 0 Interpret 1 1 Janes 1 January 1988 Oxford United Home 7-0 22,612 McMeino Interpret 1 1 Janes 1 Janes 1 Janes 1 March 1 Janes 1 Janes 1 Janes 1 Janes 1 Janes 1 1 Janes 1 Janes 1 <t< td=""><td>21 November 1987</td><td>Tottenham Hotspur</td><td>Home</td><td>2-0</td><td>10,091</td><td>Allinson (2)</td><td></td></t<>	21 November 1987	Tottenham Hotspur	Home	2-0	10,091	Allinson (2)	
12 December 1987 Watford Away 1-0 12,152 Foster I 18 December 1987 Southampton Home 2-2 6.618 Harford, McDonough I 26 December 1987 Eveton Away 0-2 32,128 I I 28 December 1987 Eveton Away 0-2 32,128 I I I 28 December 1987 Charton Athletic Home 1-0 32,128 I I I 1 January 1988 Cherton Athletic Home 3-0 8,018 Harford, B. Stein, M. Stein I 2 January 1988 Vest Ham United Away 1-1 16,716 McDonough, B.Stein, M.Stein (I) I 3 February 1988 Oxford United Home 7-4 8,063 Harford (2), McDonough, B.Stein, M.Stein (I) I 3 Harch 1988 Nimbedon Away 1-2 22,612 MtStein I 5 March 1988 Vimbedon Away 1-2 22,612 MtStein I 5 March 1988 Vimbedon Away 1-2 22,612 MtStein I 5 March 1988 Vimbedon Away 1-2 22,612 MtStein I 5 March 1988 Vi	5 December 1987	Norwich City	Home	1-2	7,002	B. Stein	
18 December 1987 Southampton Home 2-2 6,618 Harford, McDonough I 26 December 1987 Everton Away 0-2 32,128 — — 28 December 1987 Everton Home 1-0 7,248 Million Million 19 January 1988 Chalton Athletic Home 1-0 7,248 Marford, B. Stein, M. Stein Million 19 January 1988 Metham United Away 1-0 16,716 McDonough Million 16 January 1988 Orby County Home 1-0 7,175 McDonough, B.Stein, M.Stein Million 13 February 1988 Arsenal Home 1-2 22,612 McStein Million 5 March 1988 Winbledon Away 1-2 22,612 McStein McStein 13 February 1988 Konstruction Away 1-2 22,612 McStein McStein 5 March 1988 Winbledon Away 5-2 24,612 McStein McStein McStein 13 February 1988 Konstruction Away 5-2 24,612 McStein McStein McStein 13 Harch 1988 Vinbledon Away 5-2 43,873 3- - -	12 December 1987	Watford	Away	1-0	12,152	Foster	
26 December 1987 Verton Away 0-2 32,128 — — (1) 28 December 1987 Charlton Athletic Home 1-0 7,243 Wilson 1 1 January 1988 Chelsea Home 3-0 8,081 Harford, 8, Stein, M, Stein 1 1 January 1988 Vest Ham United Home 1-0 16,716 McDonough 1 1 January 1988 Vest Ham United Home 1-0 7,715 McDonough 1 1 January 1988 Oxford United Home 1-0 7,175 McDonough, 8,5tein, M,Stein (3) 1 1 February 1988 Arsenal Away 1-2 22,612 McStein 1 5 March 1988 Kinschan Away 1-2 22,612 McStein 1 1 S March 1988 Coentry City Away 1-2 24,612 McStein 1 1 S March 1988 Coentry City Away 1-2 3,717 McStein, MStein, Wilson, own goal 1	18 December 1987	Southampton	Home	2-2	6,618	Harford, McDonough	
28 December 1987 Charlton Athletic Home 1-0 7,243 Wilson Mome 1 1 January 1988 Chelsea Home 3-0 8,018 Harford, B. Stein, M. Stein 1 2 January 1988 West Ham United Away 1-1 16,713 M. Stein, M. Stein 1 16 January 1988 Derby County Home -0 7,175 McDonough 1 16 February 1988 Oxford United Home -0 7,475 McDonough, B. Stein, M. Stein, M. Stein 1 13 February 1988 Arsenal Away 1-2 22,612 M.Stein 1 5 March 1988 Winbledon Away 0-2 4,854 1 15 March 1988 Coventry City Away 0-3 13,711 2 29 March 1988 Portsmuth Home 4-0 6,740 B. Stein, M.Stein, Wilson, own goal 1	26 December 1987	Everton	Away	0-2	32,128	-	
1 January 1988 Chelsea Home 3-0 8,018 Harford, B. Stein, M. Stein 9 2 January 1988 West Ham United Away 1-1 16,716 M. Stein 1 16 January 1988 Derby County Home 1-0 7,175 McDonough 1 6 February 1988 Oxford United Home 7-4 8,063 Harford (2), McDonough, B.Stein, M.Stein (3) 1 13 February 1988 Arsenal Away 1-2 22,012 M.Stein 1 5 March 1988 Wimbledom Away 0-2 4,854 1 15 March 1988 Coventry City Away 0-4 13,711 1 29 March 1988 Portsmutht Home 4-1 6,740 B.Stein, M.Stein, Wilson, own goal 1	28 December 1987	Charlton Athletic	Home	1-0	7,243	Wilson	
2 January 1988 West Ham United Away 1-1 16,716 M.Stein Inclusion 16 January 1988 Deby County Home 1-0 7,175 McDonough Inclusion	1 January 1988	Chelsea	Home	3-0	8,018	Harford, B. Stein, M. Stein	
16 January 1988 Derby County Home 1-0 7,175 McDonough 6 February 1988 Oxford United Home 7-4 8,063 Harford (2), McDonough, B.Stein, M.Stein (3) 13 February 1988 Arsenal Away 1-2 22,612 M.Stein 5 March 1988 Wimbledom Away 0-2 24,612 — — 15 March 1988 Coventry City Away 0-2 4,843 — — 29 March 1988 Portsmouth Home 4-1 6,740 B.Stein, M.Stein, Wilson, own goal —	2 January 1988	West Ham United	Away	1-1	16,716	M. Stein	
6 February 1988 Oxford United Home 7-4 8,063 Harford (2), McDonough, 8.Stein, M.Stein (3) 13 February 1988 Arsenal Away 1-2 22,612 M.Stein 5 March 1988 Vimbledon Away 0-2 4,85 — — 15 March 1988 Coventry City Away 0-4 13,711 —	16 January 1988	Derby County	Home	1-0	7,175	McDonough	
13 February 1988 Arsenal Away 1-2 22,612 M.Stein 5 March 1988 Wimbledon Away 0-2 4,854 15 March 1988 Coventry City Away 0-4 13,711 29 March 1988 Portsmouth Home 4-1 6,740 B.Stein, M.Stein, Wilson, own goal	6 February 1988	Oxford United	Home	7-4	8,063	Harford (2), McDonough, B.Stein, M.Stein (3)	
5 March 1988 Wimbledon Away 0-2 4,854 — 15 March 1988 Coventry City Away 0-4 13,711 — 29 March 1988 Portsmouth Home 4-1 6,740 B.Stein, M.Stein, Wilson, own goal	13 February 1988	Arsenal	Away	1-2	22,612	M.Stein	
15 March 1988 Coventry City Away 0-4 13,711 — — — — — 2 29 March 1988 Portsmouth Home 4-1 6,740 B.Stein, M.Stein, Wilson, own goal — …	5 March 1988	Wimbledon	Away	0-2	4,854	_	
29 March 1988 Portsmouth Home 4–1 6,740 B.Stein, M.Stein, Wilson, own goal	15 March 1988	Coventry City	Away	0-4	13,711	_	
	29 March 1988	Portsmouth	Home	4-1	6,740	B.Stein, M.Stein, Wilson, own goal	

Scope of the environment (breadth):

- Diverse data types: 4K different column headers among 2K tables
- Only ~20% can be answered by Freebase (a large knowledge base)

Scope of the environment (breadth):

- Diverse data types: 4K different column headers among 2K tables
- Only ~20% can be answered by Freebase (a large knowledge base)

We ensure that tables in the test set do not appear in the training data

• This tests the model's ability to generalize to unseen data schema

Outline

- Motivation
- Task: Answering complex questions on web tables
- Approach: Semantic parsing with distant supervision
- Improvement 1: Make it faster
- Improvement 2: Convert to direct supervision

Idea: Parse the utterance into an executable logical form

Where did the last 1st place finish occur?

Year	Venue	Position	Time
2003	Finland	1st	47.12
2005	Germany	5th	46.62
2007	Thailand	1st	53.13

Idea: Parse the utterance into an executable logical form

Where did the last 1st place finish occur?

Year	Venue	Position	Time
2003	Finland	1st	47.12
2005	Germany	5th	46.62
2007	Thailand	1st	53.13

Idea: Parse the utterance into an executable logical form

Where did the last 1st place finish occur?

Year	Venue	Position	Time
2003	Finland	1st	47.12
2005	Germany	5th	46.62
2007	Thailand	1st	53.13

Idea: Parse the utterance into an executable logical form

Where did the last 1st place finish occur?

Year	Venue	Position	Time
2003	Finland	1st	47.12
2005	Germany	5th	46.62
2007	Thailand	1st	53.13

Idea: Parse the utterance into an executable logical form

Where did the last 1st place finish occur?

Year	Venue	Position	Time
2003	Finland	1st	47.12
2005	Germany	5th	46.62
2007	Thailand	1st	53.13

Idea: Parse the utterance into an executable logical form

Where did the last 1st place finish occur?

Year	Venue	Position	Time
2003	Finland	1st	47.12
2005	Germany	5th	46.62
2007	Thailand	1st	53.13
"denotation"			

Where ?				









Learning from Denotations





Learning from Denotations



[Clark et al., 2010 / Liang et al., 2011 / Berant et al., 2013 / ...]

Learning from Denotations



Parser





VenueOf.argmax(HasPosition.1st, Index)

Year	Venue	Position	Time
2003	Finland	1st	47.12
2005	Germany	5th	46.62
2007	Thailand	1st	53.13

Where did the last 1st place finish occur?





Year	Venue	Position	Time
2003	Finland	1st	47.12
2005	Germany	5th	46.62
2007	Thailand	1st	53.13





Year	Venue	Position	Time
2003	Finland	1st	47.12
2005	Germany	5th	46.62
2007	Thailand	1st	53.13

Where did the last 1st place finish occur?





Year	Venue	Position	Time
2003	Finland	1st	47.12
2005	Germany	5th	46.62
2007	Thailand	1st	53.13

Where did the last 1st place finish occur?





Year	Venue	Position	Time
2003	Finland	1st	47.12
2005	Germany	5th	46.62
2007	Thailand	1st	53.13

Floating Parser

Allows LF parts to be generated from other sources than the utterance



Where did the last 1st place finish occur?

Floating Parser

Allows LF parts to be generated from other sources than the utterance

The **scorer** is responsible for capturing the relationship between "Venue" and words in the utterance



Where did the last 1st place finish occur?

Floating Parser

Most neural decoders today generate tokens in a floating fashion (with a soft guidance from attention)



Results

	Test Accuracy
Tiny rule set (cell lookup + counting)	24.3
Small rule set (sum, argmax, next/prev row, subtraction, etc.)	37.1
Large rule set (fuzzy string matching, advanced argmax, etc.)	42.7

Results

	Test Accuracy
Tiny rule set (cell lookup + counting)	24.3
Small rule set (sum, argmax, next/prev row, subtraction, etc.)	37.1
Large rule set (fuzzy string matching, advanced argmax, etc.)	42.7
Upper bound (Ice writes a logical form)	(84.0)

Results

	Test Accuracy	Runtime
Tiny rule set (cell lookup + counting)	24.3	
Small rule set (sum, argmax, next/prev row, subtraction, etc.)	37.1	~ 4 hours
Large rule set (fuzzy string matching, advanced argmax, etc.)	42.7	~ 11 hours
Upper bound (Ice writes a logical form)	(84.0)	

Slow runtime prevents us from increasing coverage!
Outline

- Motivation
- ► Task: Answering complex questions on web tables
- Approach: Semantic parsing with distant supervision
- Improvement 1: Make it faster
- Improvement 2: Convert to direct supervision

For each training example:

Who took office right after Uriah Forrest?

For each training example:

 Fetch previously processed examples with similar utterances (Levenshtein distance)

<u>Who</u> took office <u>right after</u> Uriah Forrest?

<u>Who</u> ranked <u>right after</u> Turkey?

NationOf.NextOf.HasNation.Turkey

For each training example:

 Fetch previously processed examples with similar utterances (Levenshtein distance)





For each training example:

- Fetch previously processed examples with similar utterances
- During search, try creating logical forms from macros found in those examples first



	Dev	Time (ms/example)	
	Accuracy	Train	Predict
Large rule set	40.6	1117	1150
+ Macros	40.4	99	70

11× speedup! 16× speedup!

	Test Acc.	+Ensemble
Small rule set	37.1	-
Neural Programmer (Neelakantan et al., 2016)	34.2	37.7
Neural Multi-Step Reasoning (Haug et al., 2017)	34.8	38.7
Large rule set	42.7	-
+ Macros	43.7	-
Upper bound (Ice writes a logical form)	(84.0)	-

Outline

- Motivation
- ► Task: Answering complex questions on web tables
- Approach: Semantic parsing with distant supervision
- Improvement 1: Make it faster
- Improvement 2: Convert to direct supervision





81



During training:

Correct answer



Pros:

- Collecting answers is easier than collecting LFs for each question
- The dataset is not tied to a specific LF formalism

Pros:

- Collecting answers is easier than collecting LFs for each question
- The dataset is not tied to a specific LF formalism

Cons:

- Need to do search (both at training and test time)
 - Slow (macros helped a bit)
 - ▷ Two more problems during training: ...





Parser uses **beam search** to make search tractible

 For each parsing state, only keep up to B = 100 highest-scoring partial LFs and discard the rest





Some LFs are **spurious** (right for wrong reasons)

Where did the last 1st place finish occur?

VenueOf.argmax(HasPosition.1st, Index)

Year	Venue	Position	Time
2003	Finland	1st	47.12
2005	Germany	5th	46.62
2007	Thailand	1st	53.13

Some LFs are **spurious** (right for wrong reasons)

Where did the last 1st place finish occur?



VenueOf.argmax(HasPosition.1st, <u>Time</u>)

Year	Venue	Position	Time
2003	Finland	1st	47.12
2005	Germany	5th	46.62
2007	Thailand	1st	53.13



Pros:

- Collecting answers is easier than collecting LFs for each question
- ► The dataset is not tied to a specific LF formalism

Cons:

- Need to do search
 - ▷ Slow
 - \triangleright Cannot find consistent LFs \rightarrow cannot learn
 - ▷ Find spurious LFs \rightarrow bad updates

Let's avoid search during training altogether!

Let's avoid search during training altogether!

 For each training example (utterance, table, answer), augment it with LFs

Use (utterance, table, LFs) for supervised training

Let's avoid search during training altogether!

 For each training example (utterance, table, answer), augment it with LFs

 \triangleright

 \triangleright

► Use (utterance, table, LFs) for supervised training

Let's avoid search during training altogether!

- For each training example (utterance, table, answer), augment it with LFs
 - Enumerate all LFs consistent with the correct answer
 - \triangleright
- ► Use (utterance, table, LFs) for supervised training

all logical forms



Let's avoid search during training altogether!

- For each training example (utterance, table, answer), augment it with LFs
 - Enumerate all LFs consistent with the correct answer
 - \triangleright
- ► Use (utterance, table, LFs) for supervised training

all logical forms



Let's avoid search during training altogether!

- For each training example (utterance, table, answer), augment it with semantically correct LFs
 - Enumerate all LFs consistent with the correct answer
 - Filter out spurious LFs
- Use (utterance, table, LFs) for supervised training

all logical forms

semantically correct

Let's avoid search during training altogether!

- For each training example (utterance, table, answer), augment it with semantically correct LFs
 - Enumerate all LFs consistent with the correct answer
 - **Filter out** spurious LFs
- Use (utterance, table, LFs) for supervised training

all logical forms



Enumerating consistent LFs

Beam search controls the search space, but can **discard crucial LF parts** \rightarrow low coverage!

If we have access to the **correct answer**, is there a better way to control the search space?

Year	Venue	Position	Time
2003	Finland	1st	47.12
2005	Germany	5th	46.62
2007	Thailand	1st	53.13

HasIndex.2

HasPosition.5th

HasVenue.Germany

Year	Venue	Position	Time	
2003	Finland	1st	47.12	
2005	Germany	5th	46.62	r
2007	Thailand	1st	53.13	

TimeOf.	HasIndex.2
TimeOf.	HasPosition.5th
TimeOf.	HasVenue.Germany

Year	Venue	Position	Time
2003	Finland	1st	47.12
2005	Germany	5th	46.62
2007	Thailand	1st	53.13

Group LFs with the same denotation together during search



Year	Venue	Position	Time
2003	Finland	1st	47.12
2005	Germany	5th	46.62
2007	Thailand	1st	53.13

Phase 1: Group LFs with the same denotation together during search



Phase 1: Group LFs with the same denotation together during search



Phase 1: Group LFs with the same denotation together during search

Remove paths that do not give the correct answer


Dynamic Programming on Denotations

Phase 2: Search over LFs, but only on the paths found in Phase 1



Testing coverage:

- Annotate each example with a semantically correct LF
- Test whether the algorithm can generate the annotated LF



Testing coverage:

- Annotate each example with a semantically correct LF
- Test whether the algorithm can generate the annotated LF



Success rate: 53.7%

Testing coverage:

- Annotate each example with a semantically correct LF
- Test whether the algorithm can generate the annotated LF



Success rate: 53.7%

Testing coverage:

- Annotate each example with a semantically correct LF
- Test whether the algorithm can generate the annotated LF



Let's avoid search during training altogether!

- For each training example (utterance, table, answer), augment it with semantically correct LFs
 - Enumerate all LFs consistent with the correct answer
 - **Filter out** spurious LFs
- Use (utterance, table, LFs) for supervised training

all logical forms



Let's avoid search during training altogether!

- For each training example (utterance, table, answer), augment it with semantically correct LFs
 - Enumerate all LFs consistent with the correct answer
 - Filter out spurious LFs
- Use (utterance, table, LFs) for supervised training

all logical forms



Let's avoid search during training altogether!

- For each training example (utterance, table, answer), augment it with semantically correct LFs
 - Enumerate all LFs consistent with the correct answer
 - Filter out spurious LFs
- Use (utterance, table, LFs) for supervised training

all logical forms



Filtering out Spurious LFs

Year	Venue	Position	Time
2003	Finland	1st	47.12
2005	Germany	5th	46.62
2007	Thailand	1st	53.13



Filtering out Spurious LFs

Year	Venue	Position	Time
2003	Germany	1st	53.13
2005	Finland	1st	47.12
2007	Thailand	5th	46.62

Randomize cells in each column

Where did the last 1st place finish occur?HumanFinlandCorrect LFFinlandSpurious LFGermany

Generate fictitious tables and execute the logical forms on them

Original Table

	Thailand
LF1	Thallanu

- LF 2 Thailand
- LF 3 Thailand
- LF 4 Thailand
- LF 5 Thailand

Human Thailand

Generate fictitious tables and execute the logical forms on them

	Original Table	Fictitious Table 1
LF 1	Thailand	Finland
LF 2	Thailand	Thailand
LF 3	Thailand	Finland
LF 4	Thailand	Finland
LF 5	Thailand	Germany
Human	Thailand	Finland

Generate fictitious tables and execute the logical forms on them

	Original Table	Fictitious Table 1
LF 1	Thailand	Finland
	Thailand	Thailand
LF 3	Thailand	Finland
LF 4	Thailand	Finland
	Thailand	Germany
Human	Thailand	Finland

Generate fictitious tables and execute the logical forms on them

We also propose a way to select the **most informative** fictitious tables

	Original Table	Fictitious Table 1	Fictitious Table 2
LF 1	Thailand	Finland	Germany
	Thailand	Thailand	Germany
	Thailand	Finland	Thailand
LF 4	Thailand	Finland	Germany
	Thailand	Germany	Finland
Human	Thailand	Finland	Germany

Results:

- Accidentally pruned correct LFs in 20% of the examples
 - because randomizing cells can create nonsensical tables
- But for the remaining examples, pruned out 92.1% of spurious LFs

Relax assumption: Only filter LFs disagreeing with humans > once

- Accidentally pruned correct LFs in 20% of the examples
 - because randomizing cells can create nonsensical tables
- But for the remaining examples, pruned out 92.1% of spurious LFs 78%

Let's avoid search during training altogether!

- For each training example (utterance, table, answer), augment it with semantically correct LFs
 - Enumerate all LFs consistent with the correct answer
 - Filter out spurious LFs
- Use (utterance, table, LFs) for supervised training

all logical forms

semantically correct

Let's avoid search during training altogether!

- For each training example (utterance, table, answer), augment it with semantically correct LFs
 - **Enumerate** all LFs consistent with the correct answer
 - Filter out spurious LFs
- Use (utterance, table, LFs) for supervised training

all logical forms

semantically correct

Using macros to make search faster

	Test Acc.	+Ensemble
Small rule set	37.1	-
Neural Programmer (Neelakantan et al., 2016)	34.2	37.7
Neural Multi-Step Reasoning (Haug et al., 2017)	34.8	38.7
Large rule set	42.7	-
+ Macros	43.7	-

Krishnamurthy et al., 2017 uses 100 shortest LFs we generated to train a neural parser (top-down tree generation)

Using macros to make search faster

	Test Acc.	+Ensemble
Small rule set	37.1	-
Neural Programmer (Neelakantan et al., 2016)	34.2	37.7
Neural Multi-Step Reasoning (Haug et al., 2017)	34.8	38.7
Large rule set	42.7	-
+ Macros	43.7	-
Neural Parser trained on consistent LFs (DPD; no filtering)	36.3	

Krishnamurthy et al., 2017 uses 100 shortest LFs we generated to train a neural parser (top-down tree generation)

Using macros to make search faster

	Test Acc.	+Ensemble
Small rule set	37.1	-
Neural Programmer (Neelakantan et al., 2016)	34.2	37.7
Neural Multi-Step Reasoning (Haug et al., 2017)	34.8	38.7
Large rule set	42.7	-
+ Macros	43.7	-
Neural Parser trained on consistent LFs (DPD; no filtering)	36.3	
Neural Parser trained on correct LFs (DPD + filtering)	43.3	45.9

Krishnamurthy et al., 2017 uses 100 shortest LFs we generated to train a neural parser (top-down tree generation)

Summary

Task Complexity (depth)

database / apps

knowledge base

Freebase[®]

web pages

Piotr Kedzia

any texts

The Lacey Act of 1900 was the first federal law that regulated commercial animal markets. It prohibited interstate commerce of animals killed in violation of state game laws, and covered all fish and wildlife and their parts or products, as well as plants. Other legislation followed, including the Migratory Bird Conservation Act of 1929, a 1937 treaty prohibiting the hunting of right and gray whales, and the Bald Eagle Protection Act of 1940. These later laws had a low cost to society-the species were relatively rare-and little opposition was raised.^[9]

Scope of the environment (breadth)

Summary

Task Complexity (depth)



Scope of the environment (breadth)

Summary



Future Directions

Task Complexity (depth)



Scope of the environment (breadth)

Future Directions

Task Complexity (depth)

- Learn implicit columns
 ("<u>What</u> is?" → which column?)
- Detect if the question cannot be answered by the table
- More complex reasoning (e.g., "consecutive")
- Better table understanding
 (^J °□°)^J ~ ⊥ ⊥ ⊥

answering complex questions on web tables

Scope of the environment (breadth)



Task Complexity (depth)

Alaska. **Book a flight** One-way Use miles From $\times \bigcirc$ × () Return Depart titi) Number of passengers Child traveling alone? V More search options View results on low-fare calendar **FIND FLIGHTS** FAQ Full site Contact us Legal Privacy

multi-step web interaction

answering complex questions on web tables

Scope of the environment (breadth)

[PLOW (Allen et al., 2007) / Branavan et al., 2010 / World of Bits (Shi et al., 2017 / Liu et al., 2018 / Gur et al., 2019) / ...]



Task Complexity (depth)



Scope of the environment (breadth)

[QALD shared tasks / Spider (Yu et al., 2018) / HotpotQA (Yang et al., 2018) / DROP (Dua et al., 2019) / ...]

Thank you!