SEMPRE: Semantic Parsing with Execution

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CS224U

May 18, 2015

Goals

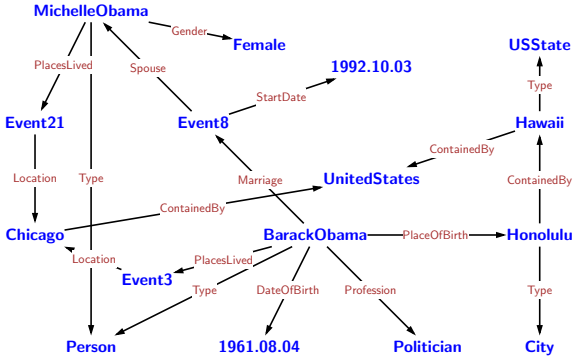
- Show how you can use SEMPRE for question answering on Freebase.

- Highlight the many applications of SEMPRE.

Outline

Review of semantic parsing

Using SEMPRE for Freebase QA



Other applications

Year	Competition	Venue	Position	Event	Notes
Representing Poland					
2001	World Youth Championships	Debrecen, Hungary	2nd	400 m	47.12
			1st	Medley relay	1:50.46
	European Junior Championships	Grosseto, Italy	1st	4x400 m relay	3:06.12
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	Olympic Games	Beijing, China	7th	4x400 m relay	3:00.32
2009	Universiade	Belgrade, Serbia	2nd	4x400 m relay	3:05.69

Question answering via semantic parsing

Which states' capitals are also their largest cities?

Question answering via semantic parsing

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semantic parsing

$\mu x.\text{Type.USState} \sqcap \text{Capital.argmax}(\text{Type.City} \sqcap \text{ContainedBy}.x, \text{Area})$

Question answering via semantic parsing

Which states' capitals are also their largest cities?

semantic parsing

μx.Type.USState $\sqcap$ Capital.argmax(Type.City $\sqcap$ ContainedBy.x, Area)

execute

`Arizona,Hawaii,Idaho,Indiana,Iowa,Oklahoma,Utah`

Question answering via semantic parsing

Which states' capitals are also their largest cities?

semantic parsing

execute

`Arizona,Hawaii,Idaho,Indiana,Iowa,Oklahoma,Utah`

General framework

[utterance: user input]

semantic parsing

[program]

execute

`[behavior: user output]`

Semantics?

Percy teaches at Stanford.

teachesAt(Percy, Stanford)

Semantics?

Semantic parsing is fundamentally a **translation** task...

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How many people live in Seattle?

count(Type.Person ⊓ LiveIn.Seattle)

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$\mathbf{R}$[Population].Seattle

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How many people live in Seattle?

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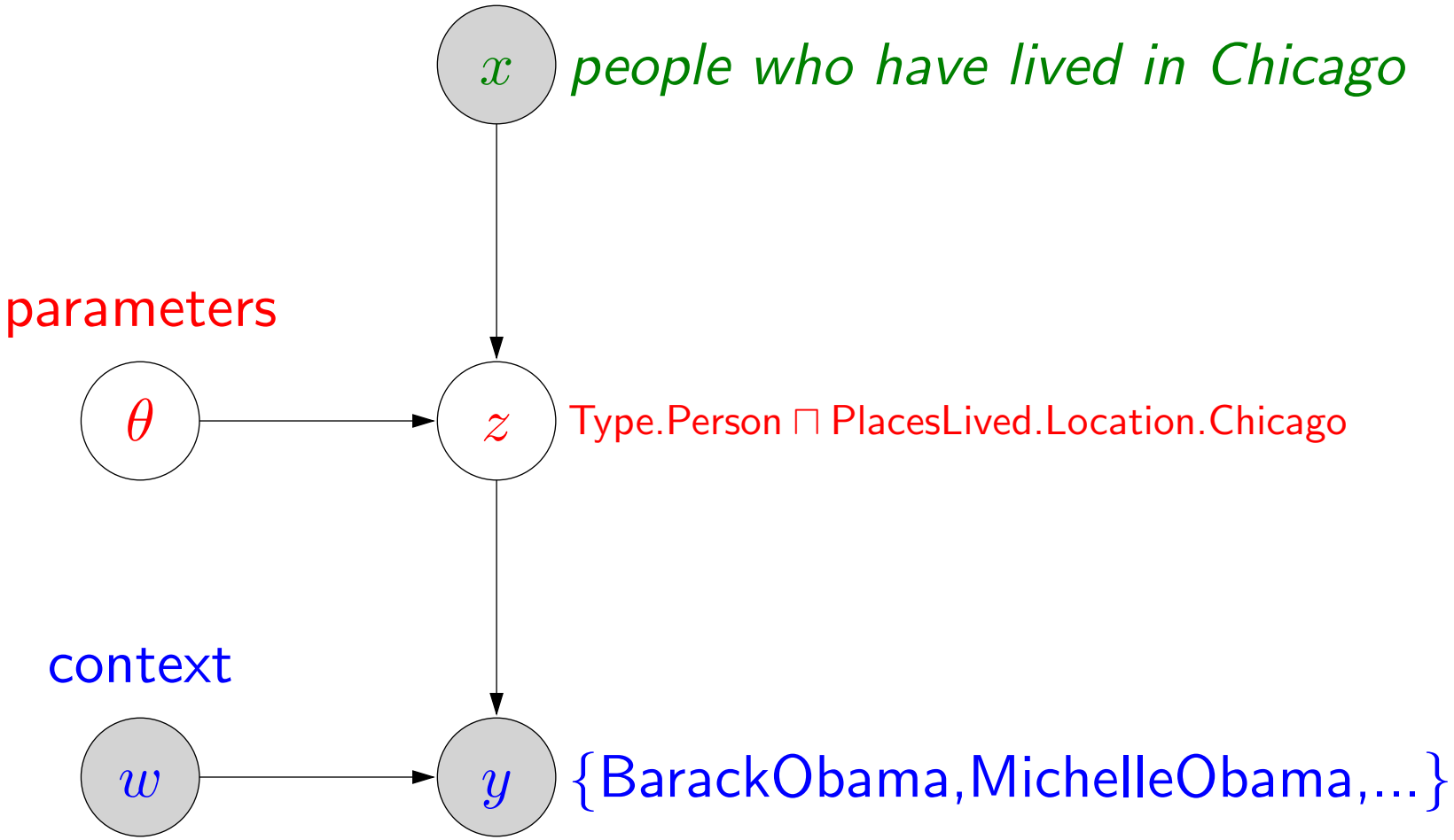
...into a low-level language.

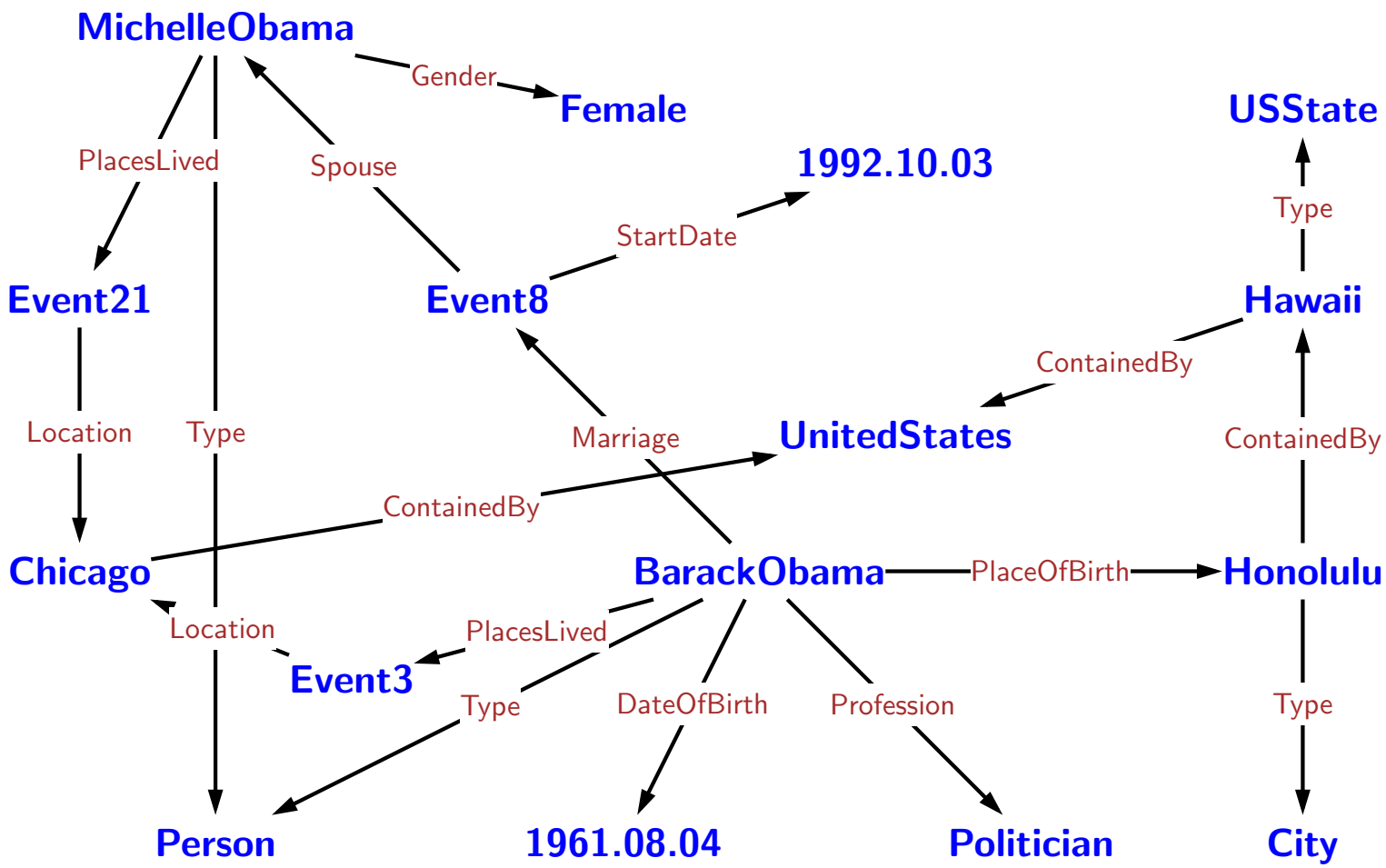
Probabilistic framework



[Bollacker, 2008; Google, 2013]

Freebase

100M entities (nodes) 1B assertions (edges)



[Liang, 2013]

Logical forms: lambda DCS

Type.Person ⊓ PlacesLived.Location.Chicago

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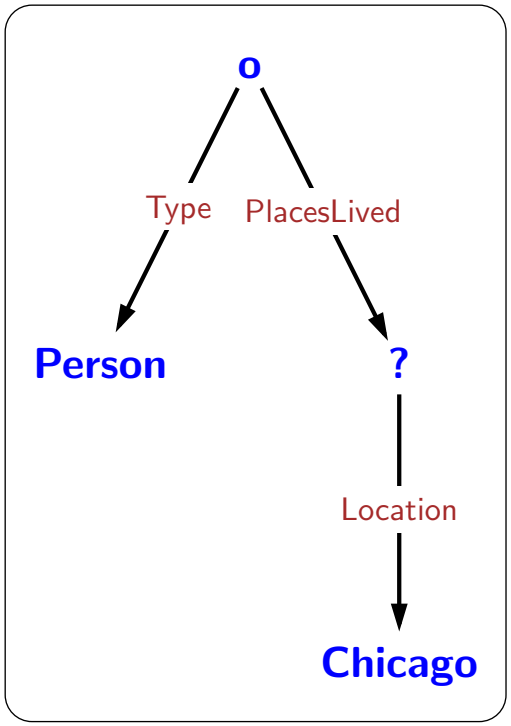

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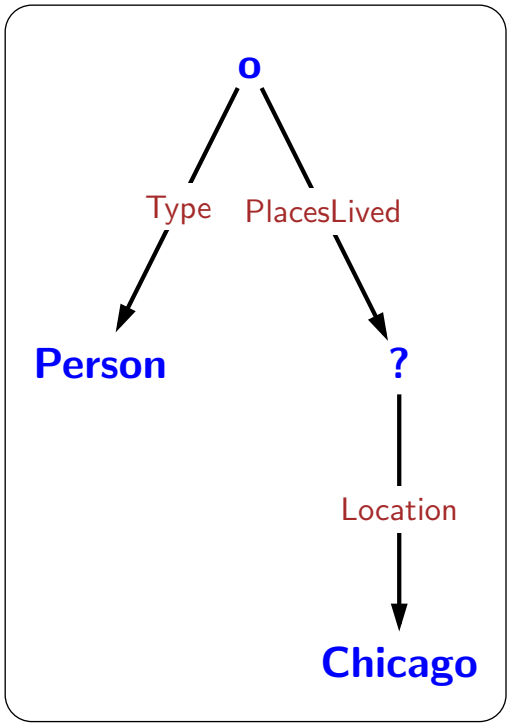

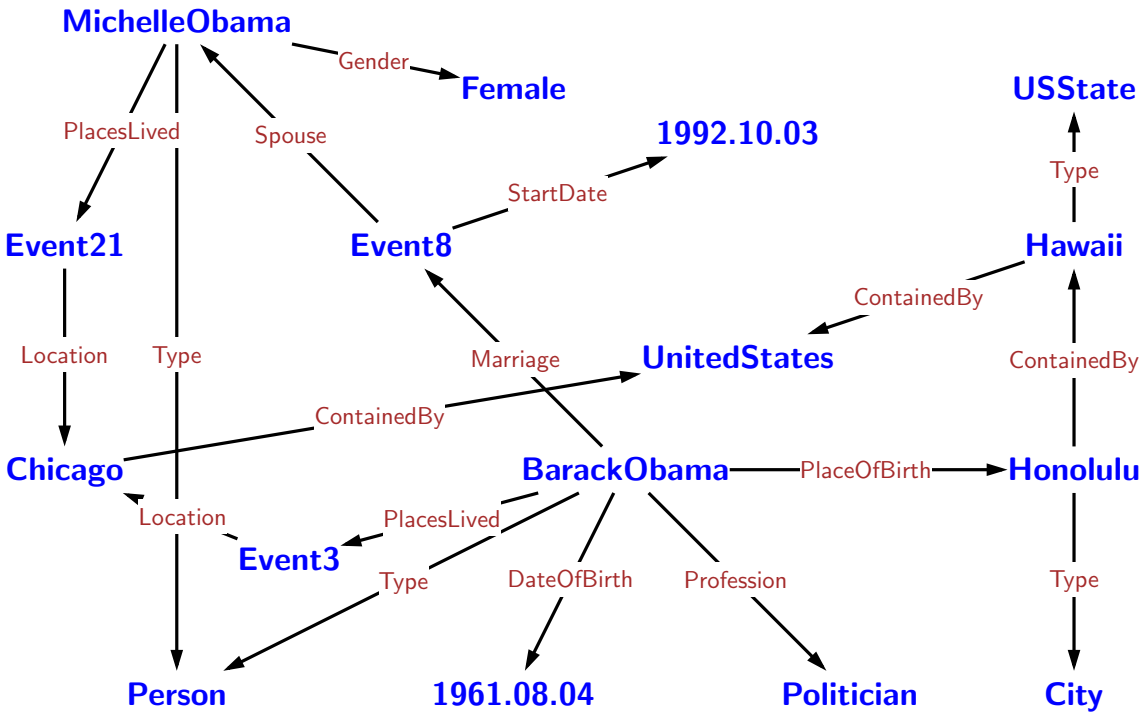

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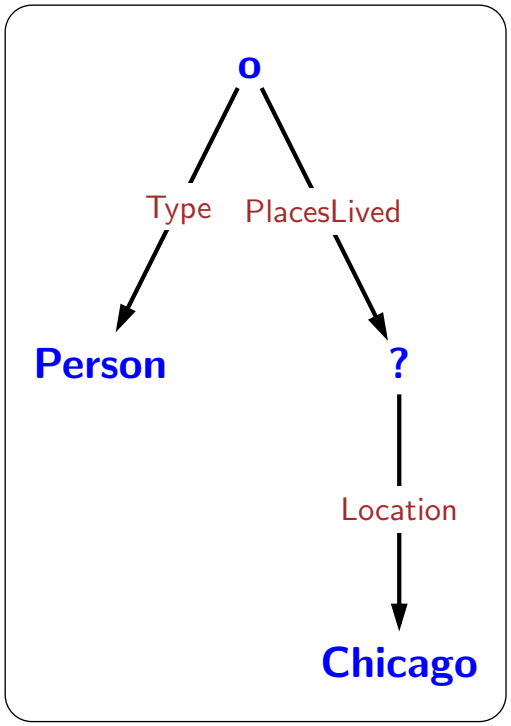

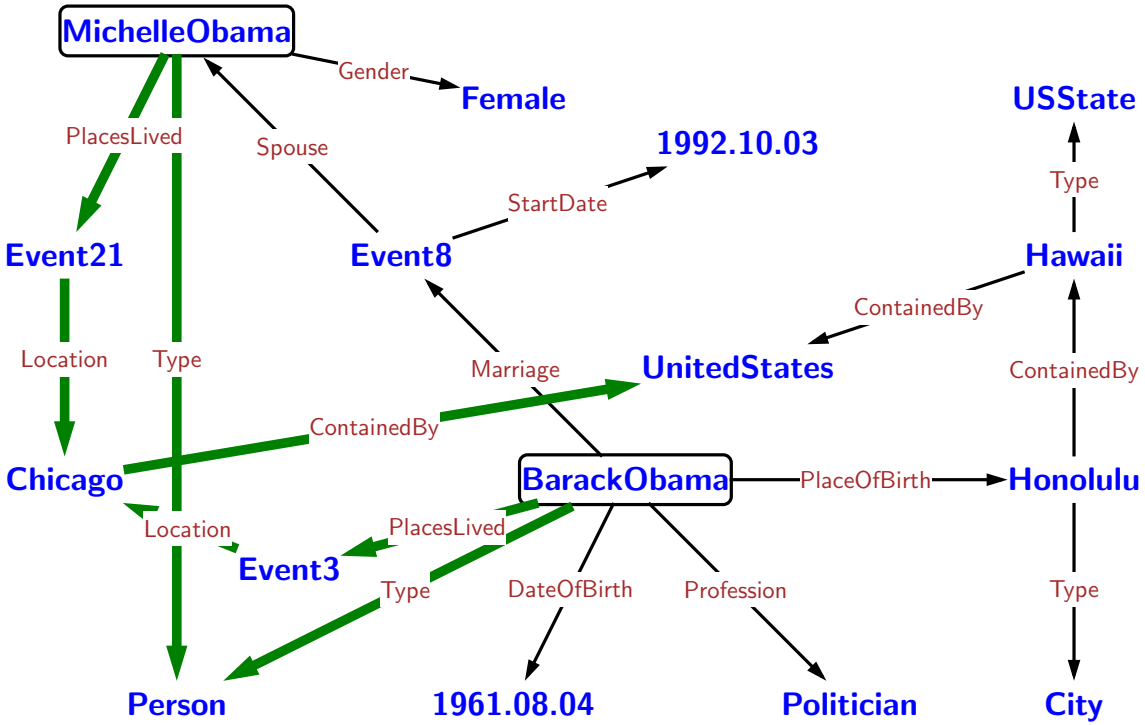

Lambda DCS

Entity

Chicago

Lambda DCS

Entity

Chicago

Join

PlaceOfBirth.Chicago

Lambda DCS

Entity

Chicago

Join

PlaceOfBirth.Chicago

Intersect

Type.Person⊓PlaceOfBirth.Chicago

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Superlative

argmin(Type.Person ⊓ PlaceOfBirth.Chicago, DateOfBirth)

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Anaphora

μx.Type.Person ⊓ Children.Influence.x

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Variable

argmax(Type.Person, $\mathbf{R}[\lambda x$.count(Parent.Parent.$x)]$)

Comparison to lambda calculus

Lambda calculus

$$\lambda x.\mathsf{Type}(x, \mathsf{Person}) \wedge \exists e.\mathsf{PlacesLived}(x, e) \wedge \mathsf{Location}(e, \mathsf{Chicago})$$

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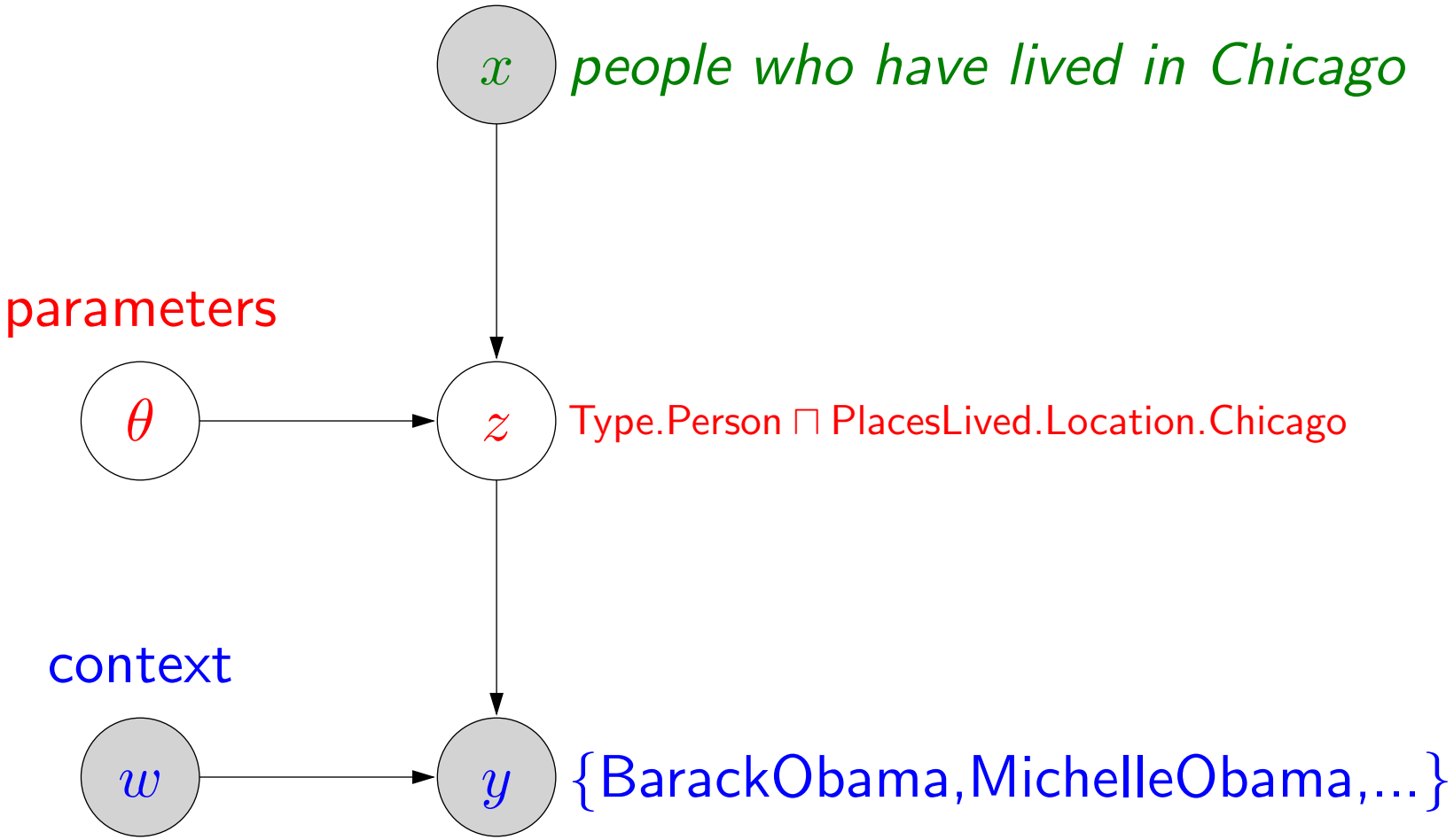
Lambda calculus

$$\lambda x.\mathsf{Type}(x, \mathsf{Person}) \wedge \exists e.\mathsf{PlacesLived}(x, e) \wedge \mathsf{Location}(e, \mathsf{Chicago})$$

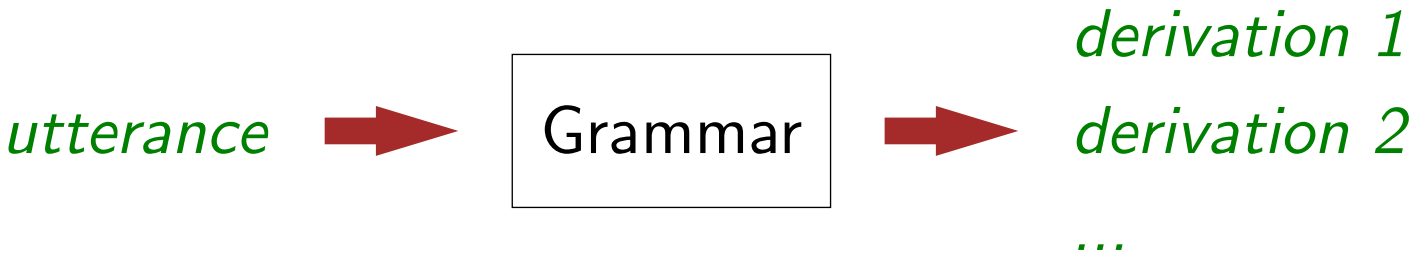
Lambda dependency-based compositional semantics (DCS)

$$\mathsf{Type.Person} \sqcap \mathsf{PlacesLived.Location.Chicago}$$

Probabilistic framework



(Over)-generating derivations



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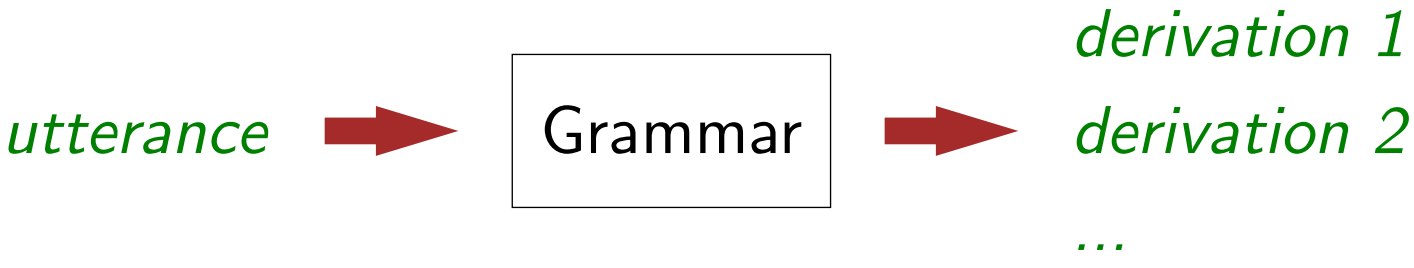


A Real Dumb Grammar

(lexicon) *Chicago* $\Rightarrow$ E : Chicago

(lexicon) *people* $\Rightarrow$ E : Type.Person

(lexicon) *live* $\Rightarrow$ E $\times$ E : PlacesLived

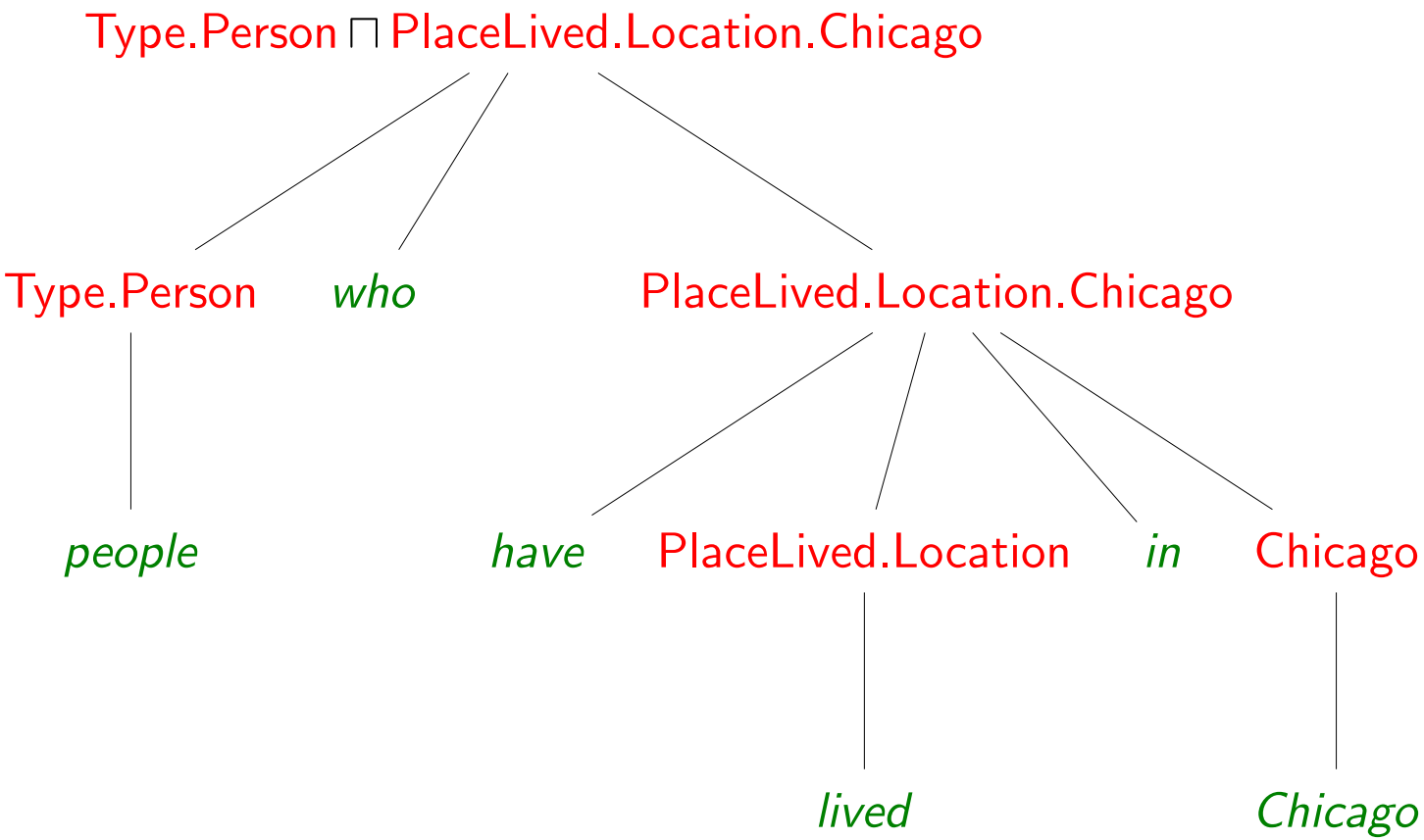
...

(join) E $\times$ E : b E : u $\Rightarrow$ E : $b.u$

(intersect) E : u E : v $\Rightarrow$ E : $u \sqcap v$

Derivations

Derivation: construction of logical form given utterance



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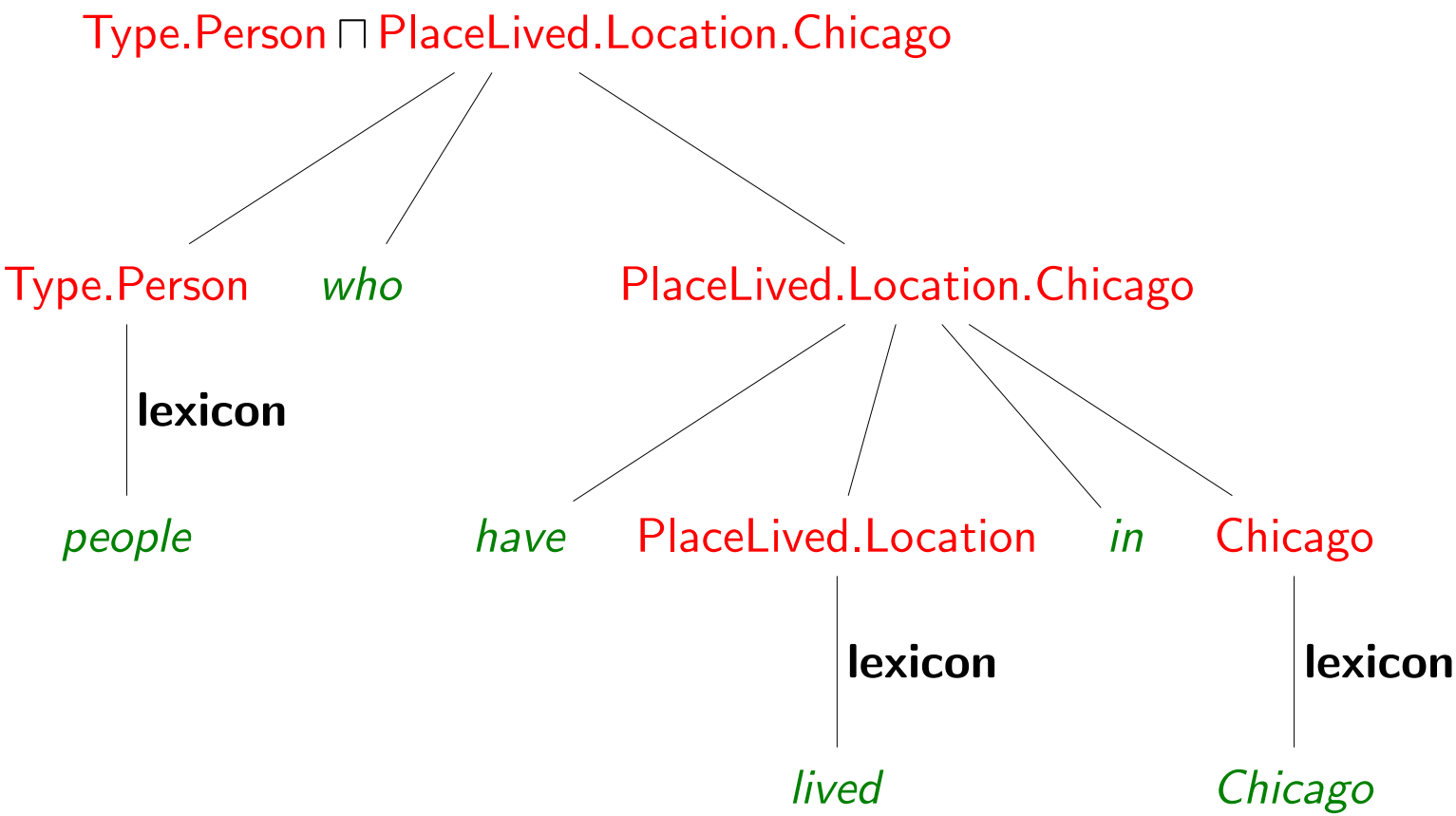

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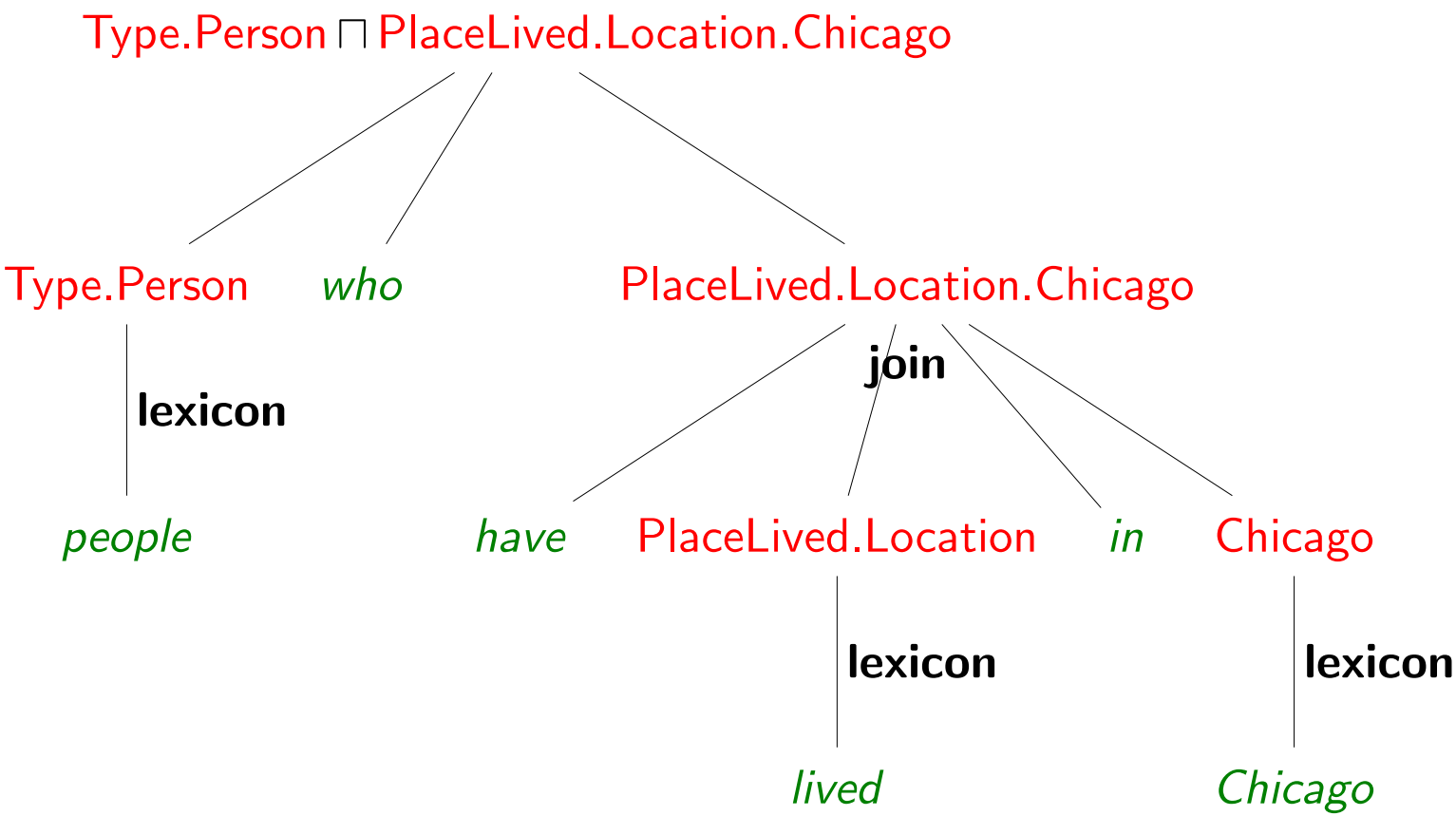

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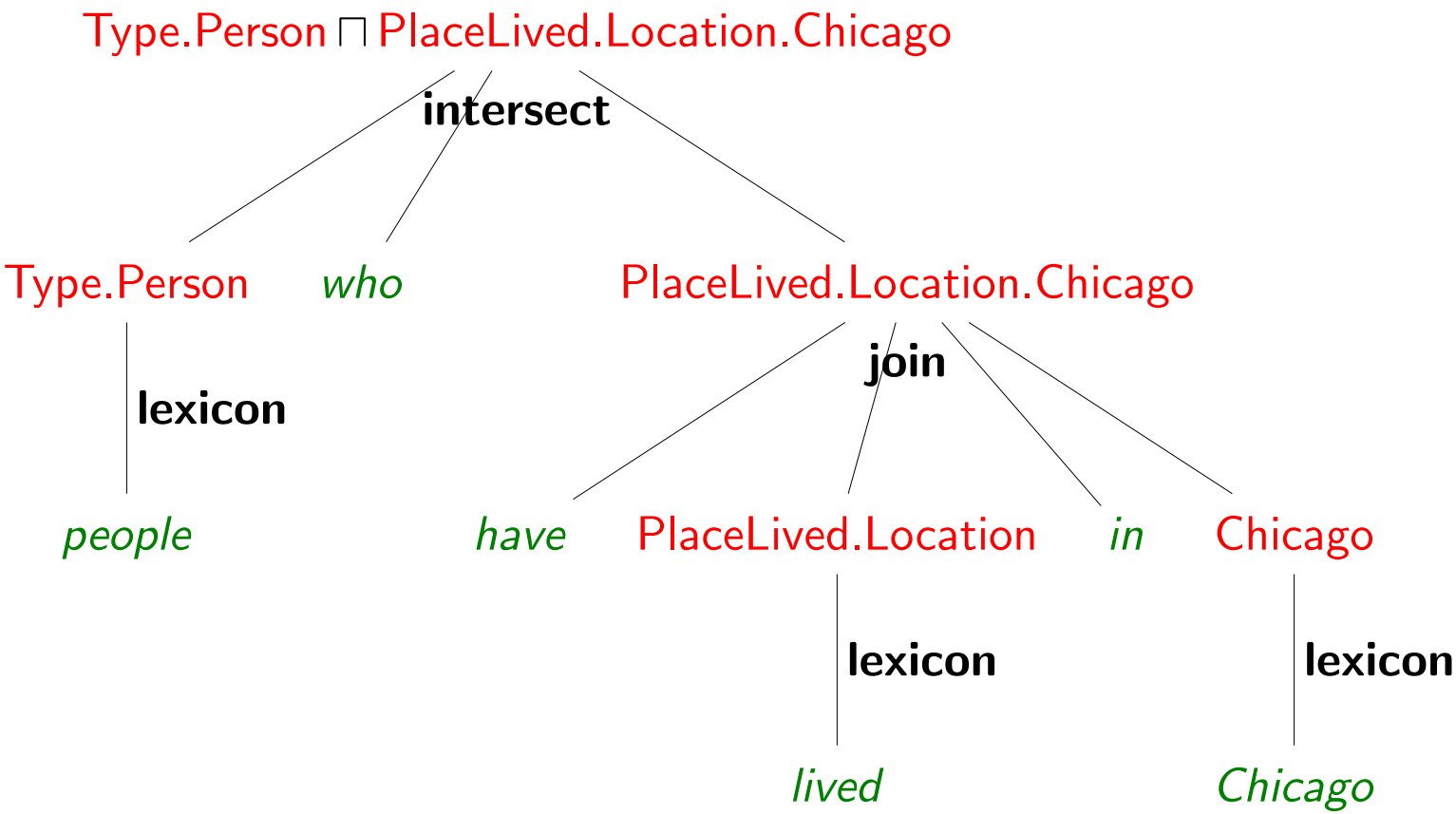
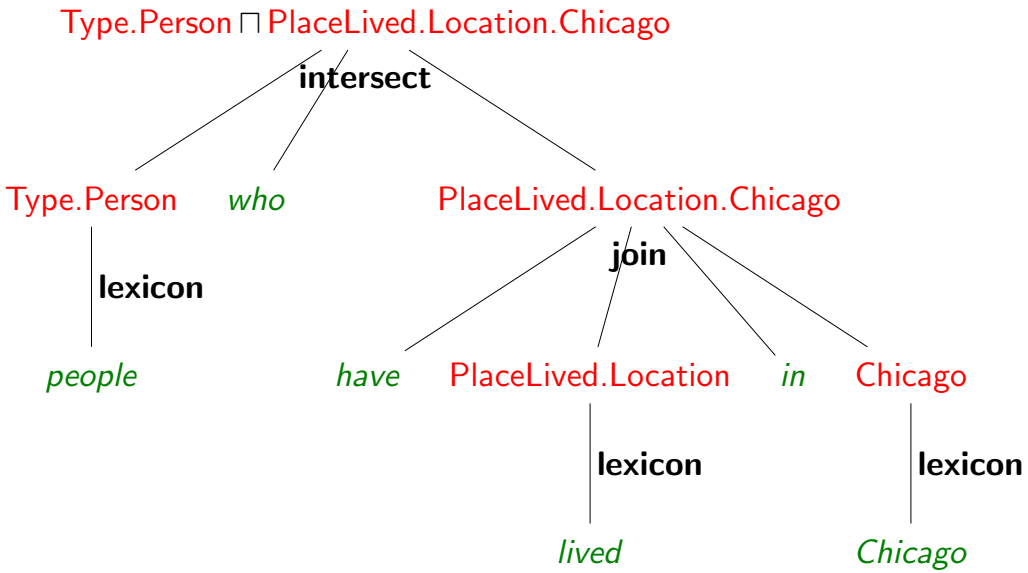


Floating parsers



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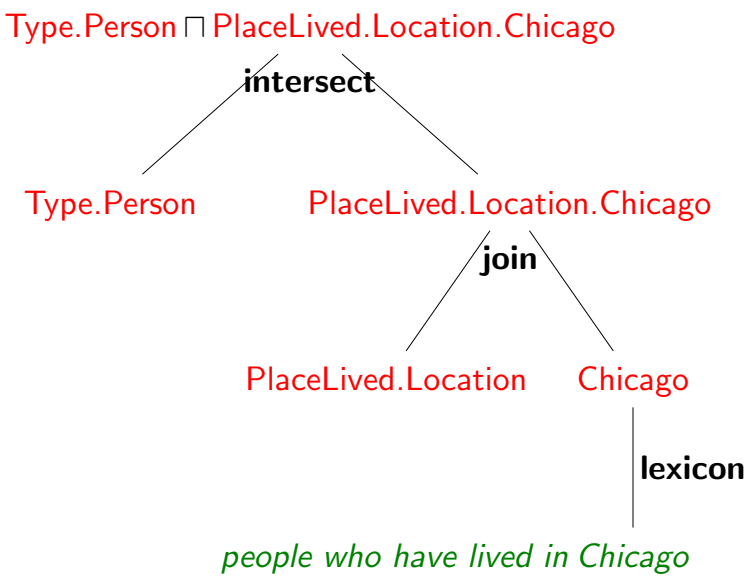

Key idea: detach logical form from sentence

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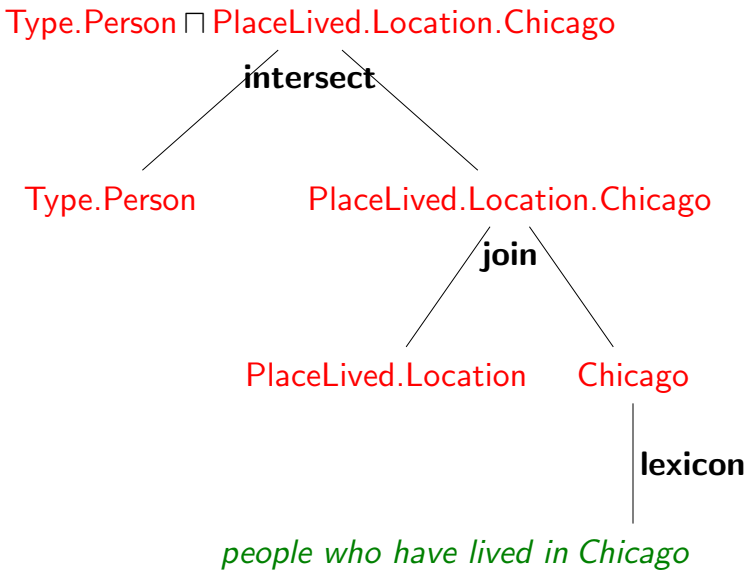

Key idea: detach logical form from sentence

Pruning: use world knowledge / pragmatics — avoid empty sets, type errors, redundant operations

Many possible derivations!

$x =$ *people who have lived in Chicago*

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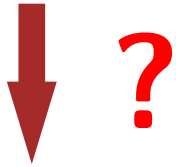

set of candidate derivations $\mathcal{D}(x)$

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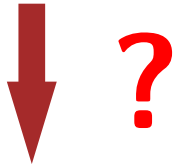

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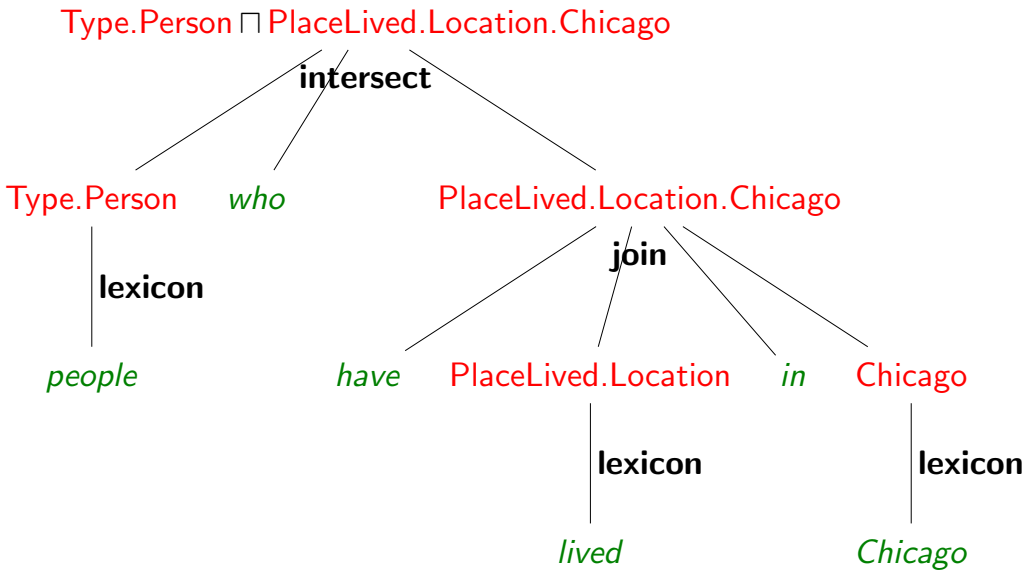

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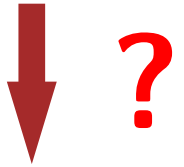

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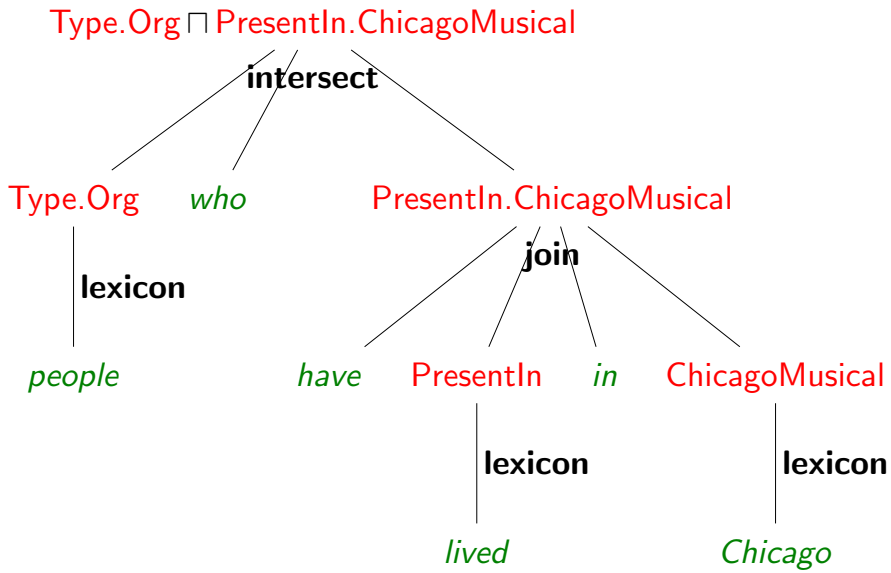
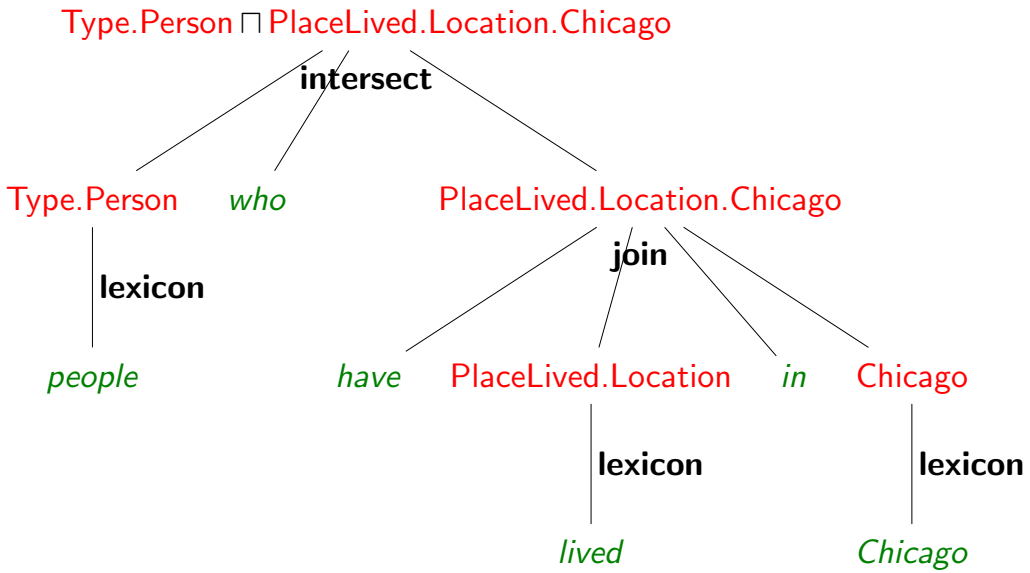


x: utterance

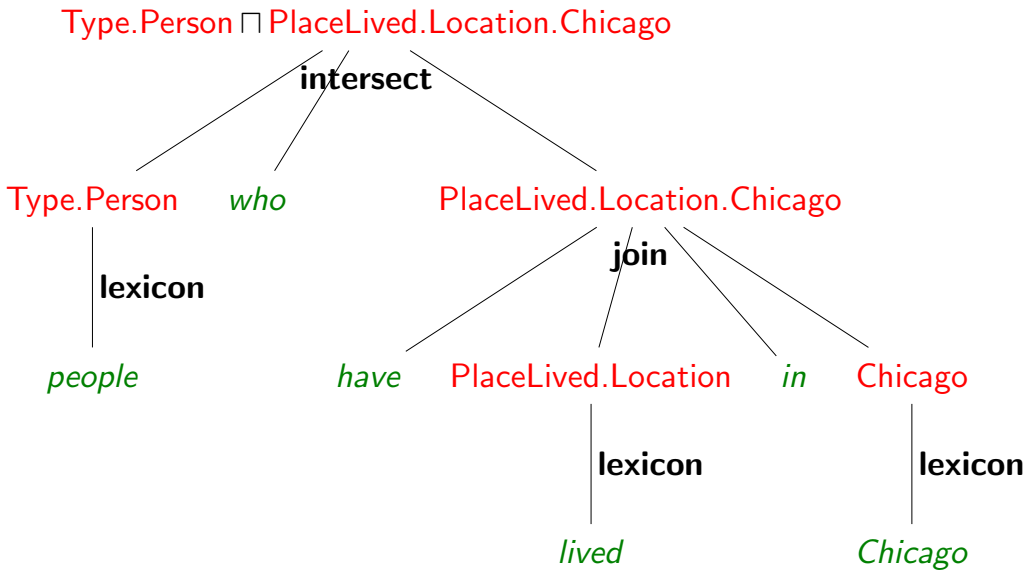
d: derivation



Feature vector $\phi(x, d) \in \mathbb{R}^F$:

x: utterance

d: derivation



Feature vector $\phi(x, d) \in \mathbb{R}^F$:

apply join	1
apply intersect	1
apply lexicon	3
skipped IN	1
skipped NN	0
lived maps to PlacesLived.Location	1
lived maps to PlaceOfBirth	0
alignmentScore	1.52
denotation-size=1	1
...	...

Scoring derivations

Feature vector: $\phi(x, d) = [1.3, 2, 0, 1, 0, 0, \ldots] \in \mathbb{R}^F$

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Scoring function:

$$\text{Score}_\theta(x, d) = \phi(x, d) \cdot \theta = \sum_{j=1}^{F} \theta_j \phi_j(x, d)$$

Log-linear model

Candidate derivations (defined by grammar): $\mathcal{D}(x)$

Log-linear model

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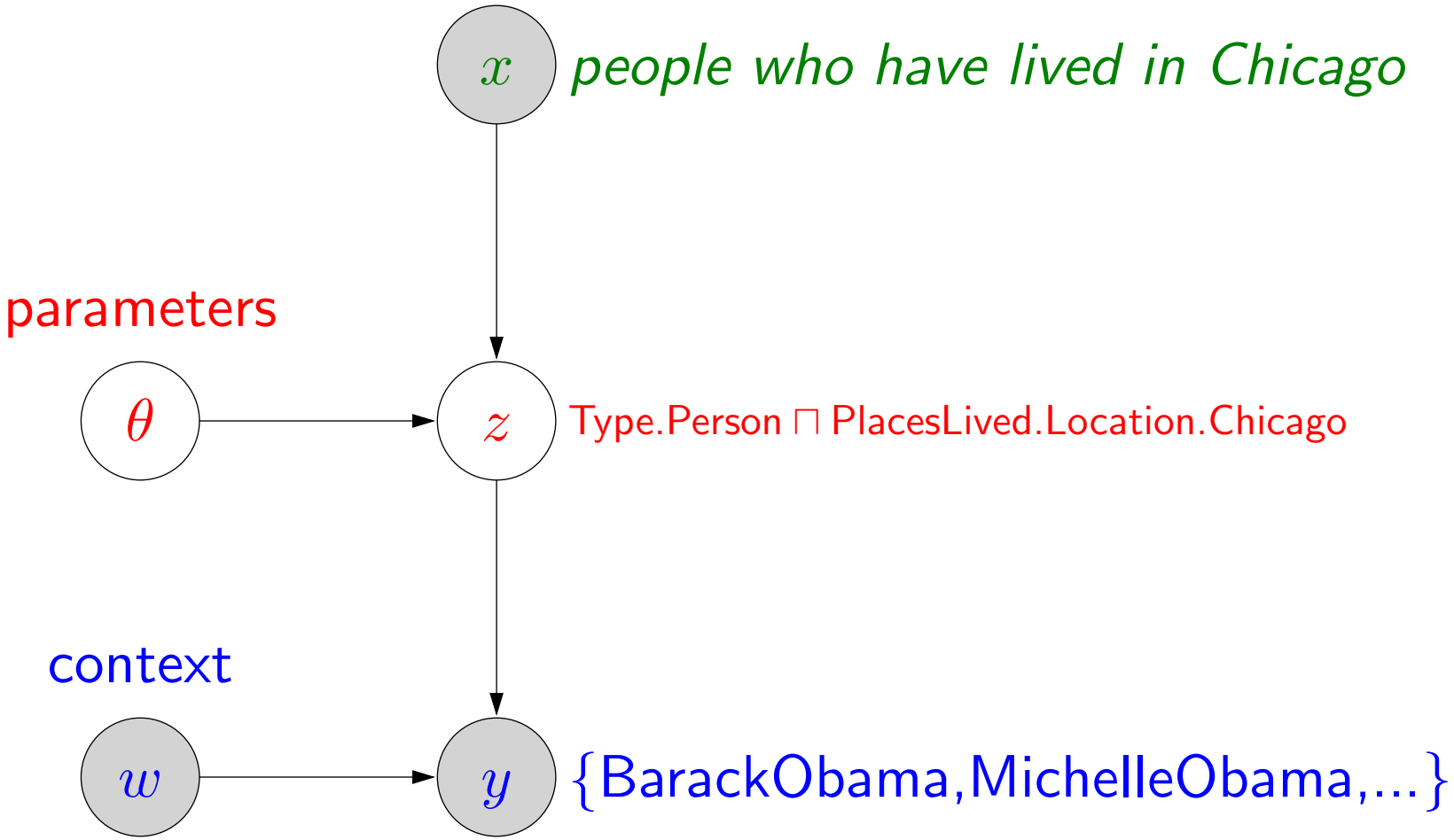
Model: distribution over derivations d given utterance x

$$p(d \mid x, \theta) = \frac{\exp(\text{Score}_\theta(x,d))}{\sum_{d' \in \mathcal{D}(x)} \exp(\text{Score}_\theta(x,d'))}$$

Probabilistic framework



Learning

Training data:

What's Bulgaria's capital?

`Sofia`

What movies has Tom Cruise been in?

`TopGun,VanillaSky,...`

...

+grammar, +features

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Algorithm:

AdaGrad (stochastic gradient with per-feature step size)

Training intuition

Where did Mozart tupress?

Vienna

Training intuition

Where did Mozart tupress?

`PlaceOfBirth.WolfgangMozart`

`PlaceOfDeath.WolfgangMozart`

`PlaceOfMarriage.WolfgangMozart`

Vienna

Training intuition

Where did Mozart tupress?

`PlaceOfBirth.WolfgangMozart`	$\Rightarrow$ Salzburg
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Vienna

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Where did Hogarth tupress?

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Where did Hogarth tupress?

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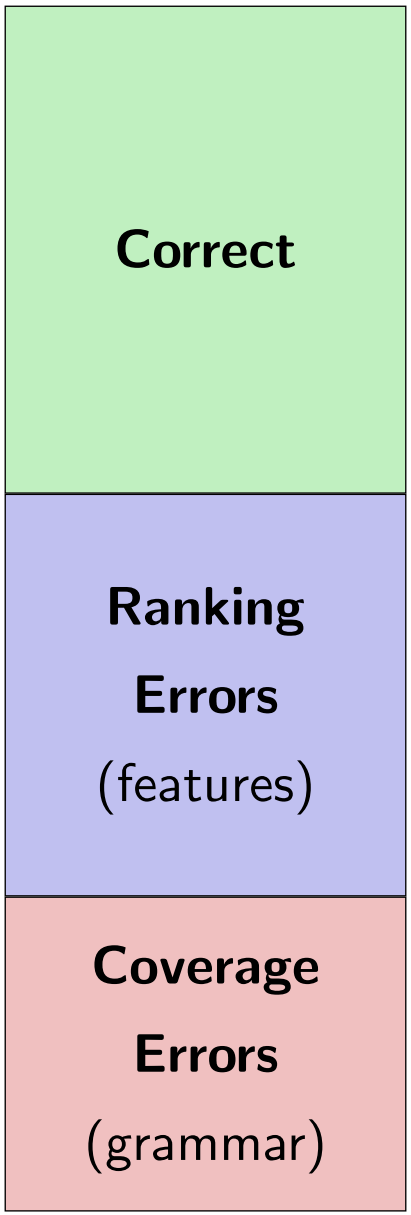
Two types of errors



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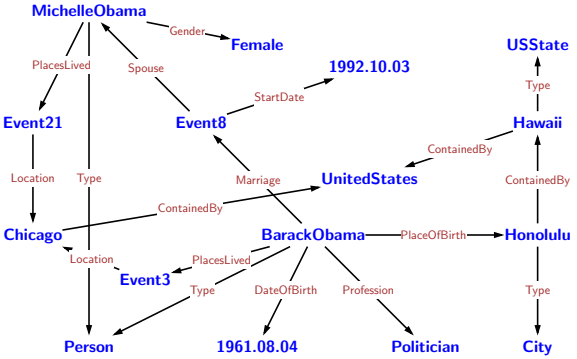

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2009	Universiade	Belgrade, Serbia	2nd	4x400 m relay	3:05.69

Setting up SEMPRE

git clone https://github.com/percyliang/sempre

cd sempre

./pull-dependencies core corenlp freebase

make module-classes freebase

Freebase players

Entities:

fb:en.barack_obama

Types:

fb:people.person

Properties:

fb:people.person.place_of_birth

Freebase players

Entities:

fb:en.barack_obama

: (union fb:people.person fb:biology.animal_owner ...)

Types:

fb:people.person

: fb:type.type

Properties:

fb:people.person.place_of_birth

: (-¿ fb:location.location fb:people.person)

Running SEMPRE

Browse Freebase:

freebase/scripts/fbshell.rb

Interactive prompt:

./run @mode=simple-freebase -Grammar.inPaths cs224u.grammar

Grammar rules

three plus four hundred

```
(rule $Number ($PHRASE) (NumberFn))

(rule $Number ($Number plus $Number)
    (lambda x (lambda y (call + (var x) (var y)))))
```

How a rule works:

- Match RHS to produce input derivations
- Call **semantic function** (SemanticFn) on input derivations to produce zero or more output derivations

SEMPRE components

- `Formula`: logical form (Java program or lambda DCS)
- `Value`: denotation (Java object)

SEMPRE components

- `Formula`: logical form (Java program or lambda DCS)
- `Value`: denotation (Java object)
- `Executor`: maps logical forms to denotations (`JavaExecutor` or `SparqlExecutor`)
- `Parser`: maps utterances to logical forms (`BeamParser` or `FloatingParser`)
- `Learner`: maps examples to parameters

Creating a simple grammar

[demo]

SEMPRE highlights

- Integrates rule-based and statistical methods
- Agnostic to grammar (CFG, CCG, loose or tight)
- Agnostic to logical form (lambda DCS, lambda calculus, Java, AMR)
- Agnostic to answer (any Java object)
- Grammar: SemanticFn, built on CoreNLP
- Learning: online feature-rich discriminative training with embedded execution

Pointers

Issues/questions:

https://github.com/percyliang/sempre/issues

Pointers

Issues/questions:

https://github.com/percyliang/sempre/issues

Internal repository on NLP machines (ask Percy for permissions):

```
git clone jamie:/user/psl/git/semparse.git
```

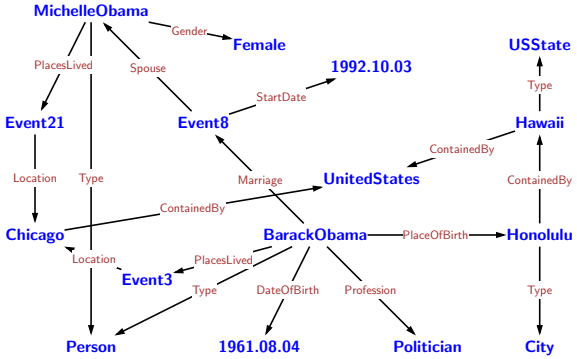
Internal mailing list:

```
stanford-sempre@googlegroups.com
```

Outline

Review of semantic parsing

Using SEMPRE for Freebase QA



Other applications

Year	Competition	Venue	Position	Event	Notes
Representing Poland					
2001	World Youth Championships	Debrecen, Hungary	2nd	400 m	47.12
			1st	Medley relay	1:50.46
	European Junior Championships	Grosseto, Italy	1st	4x400 m relay	3:06.12
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			1st	4x400 m relay	3:04.41
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[Angel Chang, Will Monroe, Chris Potts, Chris Manning]

Text-to-scene generation

There is a room with a chair and a computer.

[with Robin Jia (Lev/MacCartney/Manning/Levy's dataset)]

Solving LSAT logic puzzles

Exactly six of seven jugglers–G, H, K, L, N, P, and Q–are each assigned to exactly one of three positions–front, middle, and rear–on one of two teams–team 1 and team 2.

For each team, exactly one juggler must be assigned to each position according to the following conditions:

- *If either G or H or both are assigned to teams, they are assigned to front positions.*
- ...

[with Robin Jia (Lev/MacCartney/Manning/Levy's dataset)]

Solving LSAT logic puzzles

Exactly six of seven jugglers–G, H, K, L, N, P, and Q–are each assigned to exactly one of three positions–front, middle, and rear–on one of two teams–team 1 and team 2.

For each team, exactly one juggler must be assigned to each position according to the following conditions:

- *If either G or H or both are assigned to teams, they are assigned to front positions.*
- ...

Which one of the following is an acceptable list of assignments of jugglers to team 2?

- *front: Q; middle: K; rear: N*
- ...

[with Ice Pasupat; ACL 2015]

Compositionality on web tables

Year	Competition	Venue	Position	Event	Notes
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In what city did Piotr's last 1st place finish occur?

[with Ice Pasupat; ACL 2015]

Compositionality on web tables

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2009	Universiade	Belgrade, Serbia	2nd	4x400 m relay	3:05.69

How many times has this competitor placed 5th or better in competition?

[with Reggy Long and Ice Pasupat]

Context-dependent semantic parsing

abc ijk xyz

add an "s" to the end of the first group

abcs ijk xyz

add another to the end of the second

abcs ijks xyz

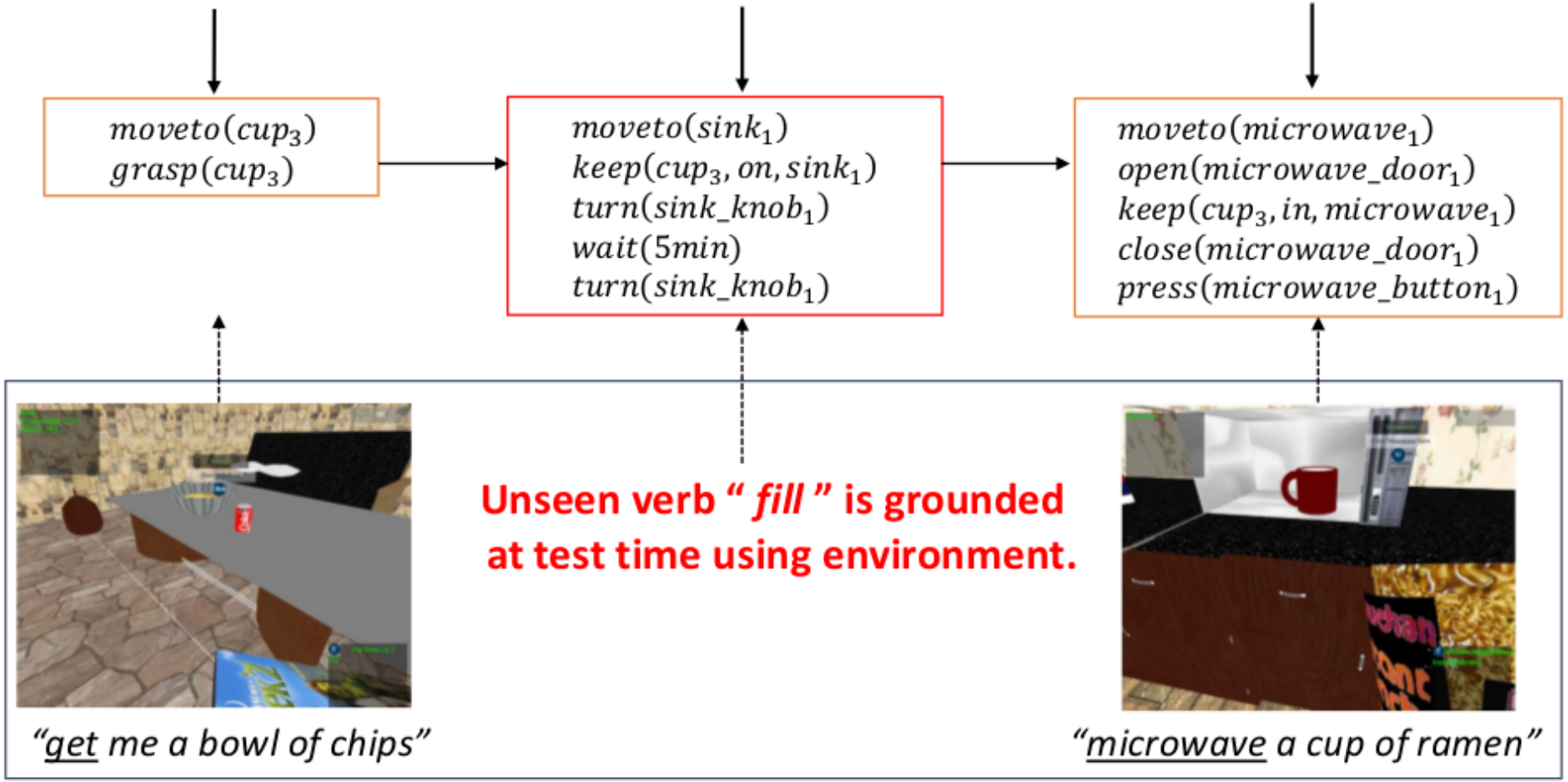
and the third

abcs ijks xyzs

[with Dipendra Misra, Kejia Tao, Ashutosh Saxena, ACL 2015]

Interpreting high-level instructions

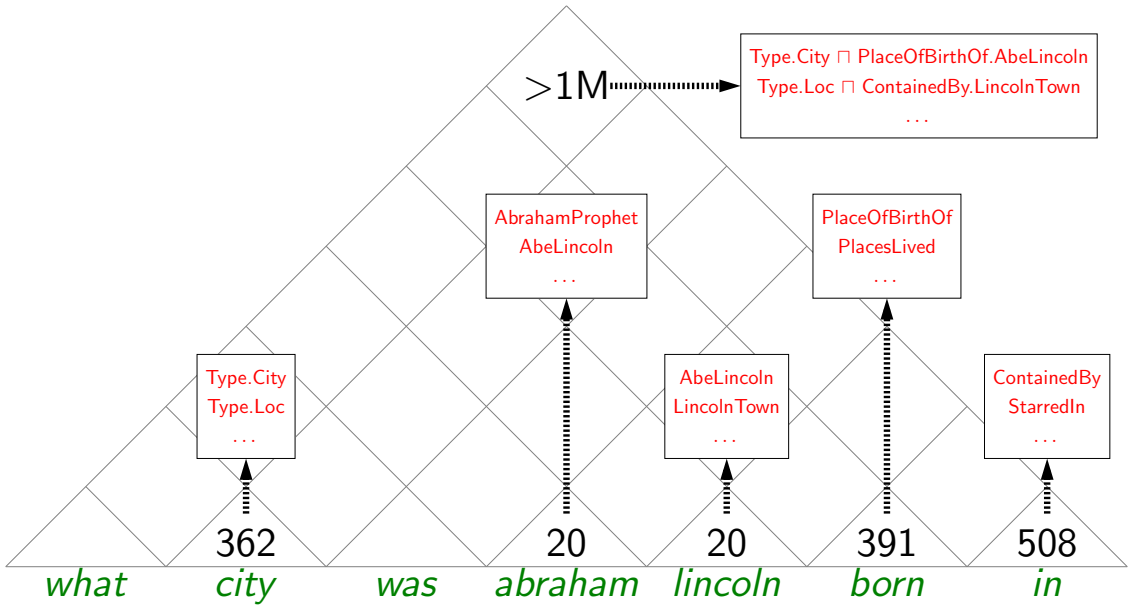
Text: *"get the cup, fill it with water and then microwave the cup"*

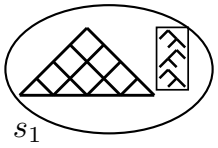


Lexicon Λ from training

[with Jonathan Berant, in submission]

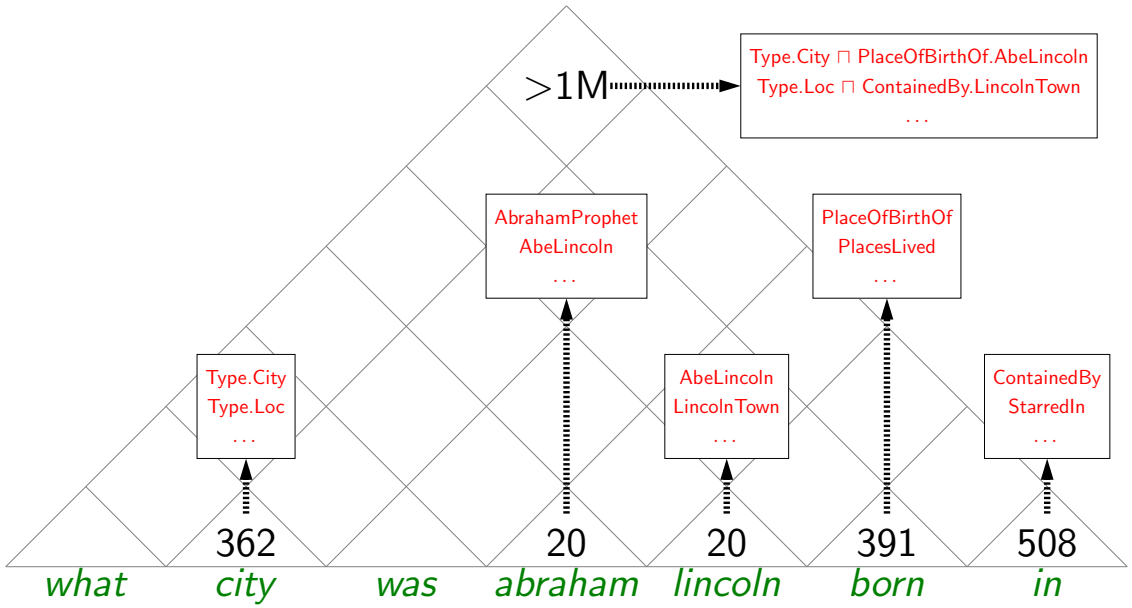
Agenda-based semantic parsing

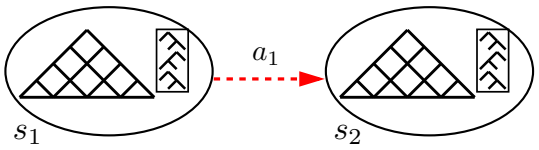




[with Jonathan Berant, in submission]

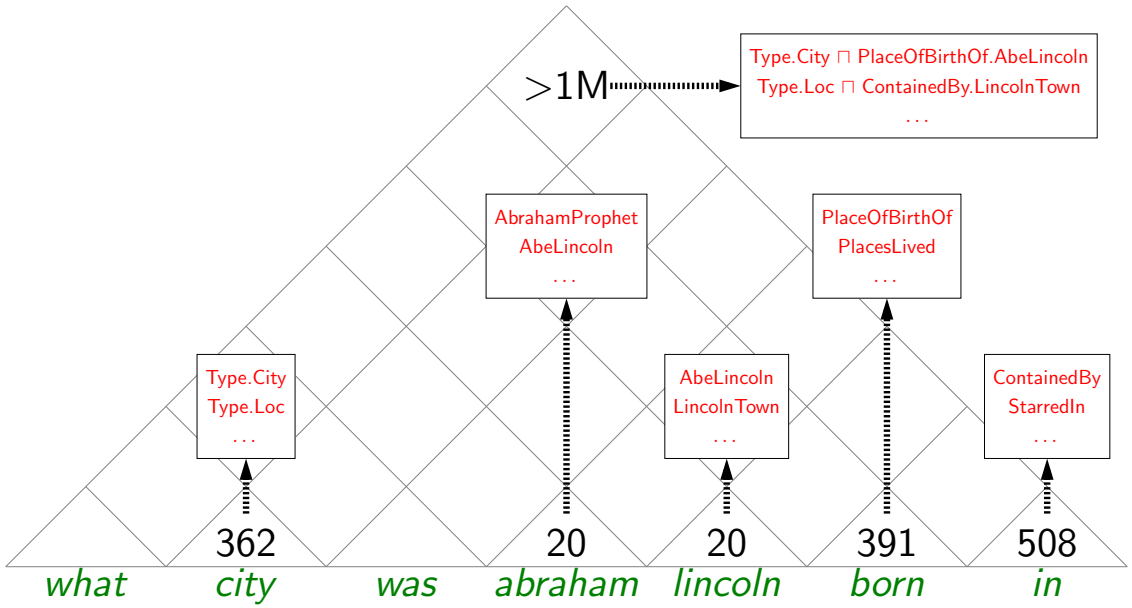
Agenda-based semantic parsing

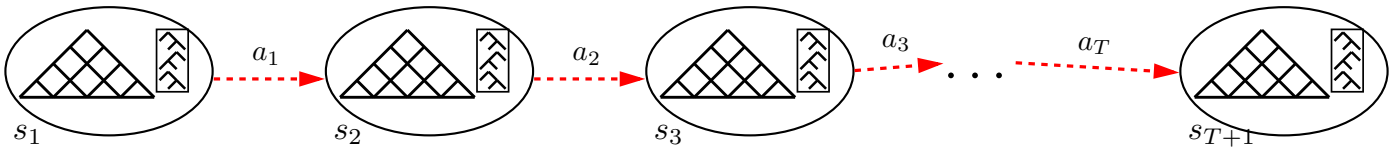




[with Jonathan Berant, in submission]

Agenda-based semantic parsing





[with Jonathan Berant, in submission]

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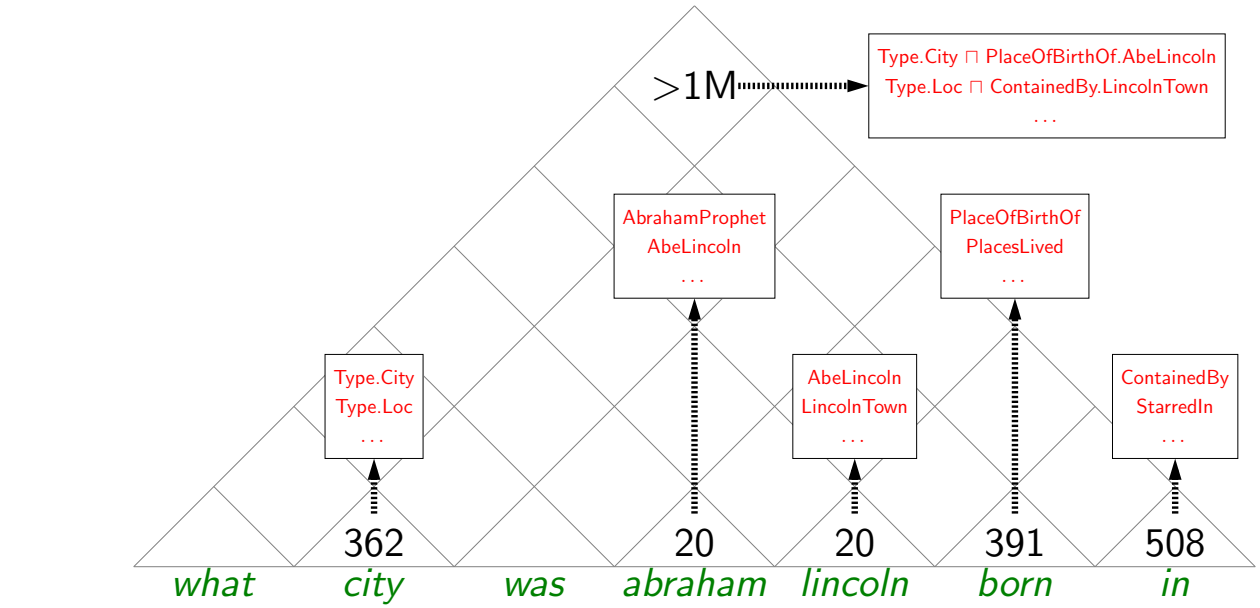

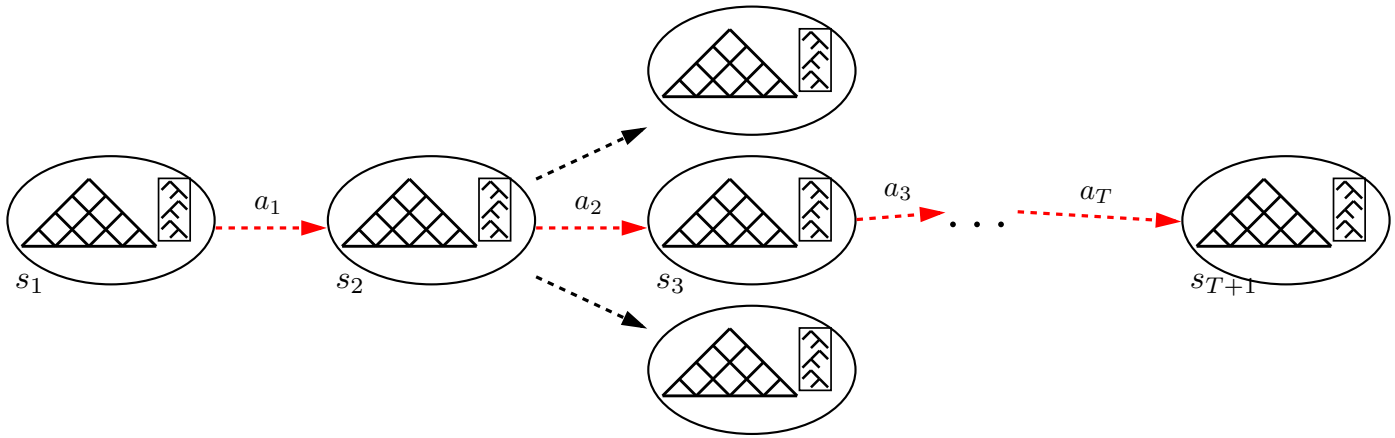

[with Jonathan Berant, in submission]

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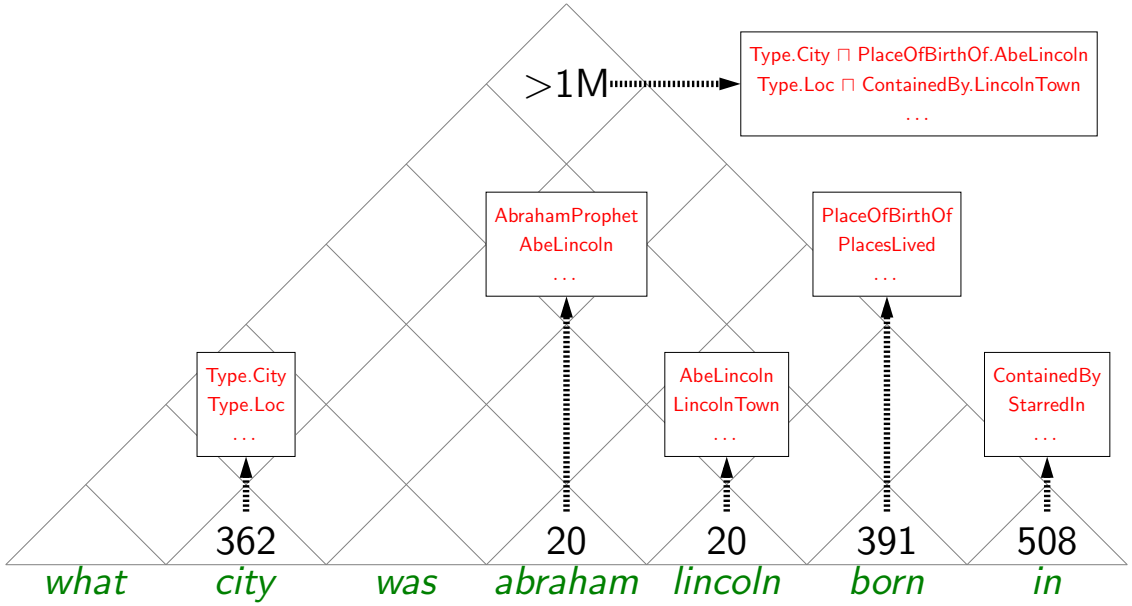
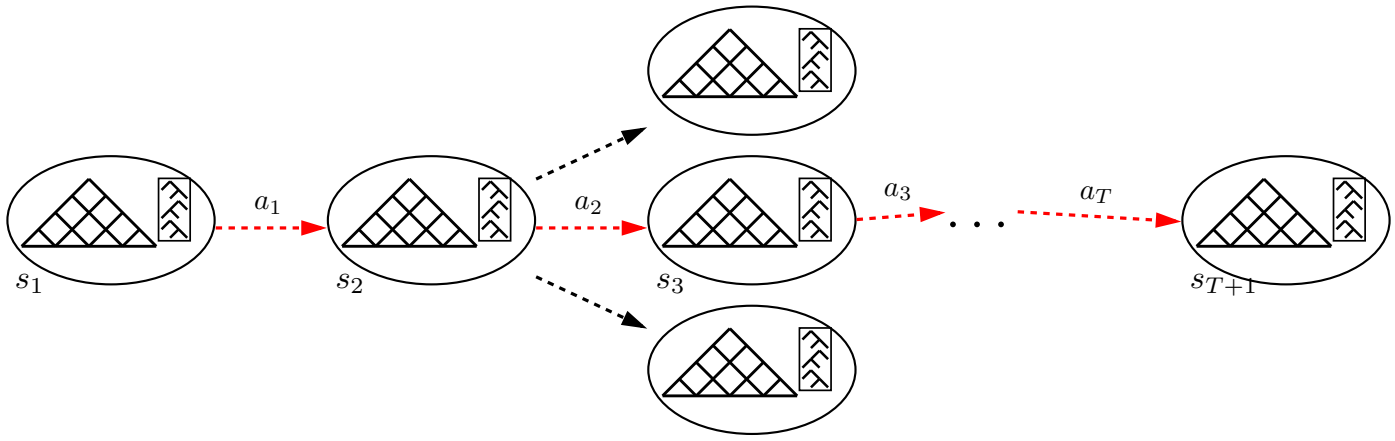




Learn which derivations to try first ⇒ 8x speedup

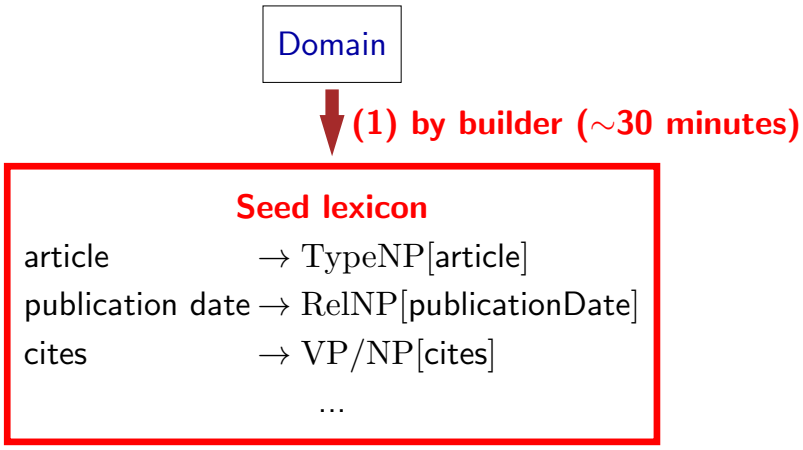
[with Yushi Wang, Jonathan Berant, ACL 2015]

Overnight semantic parsing

Domain

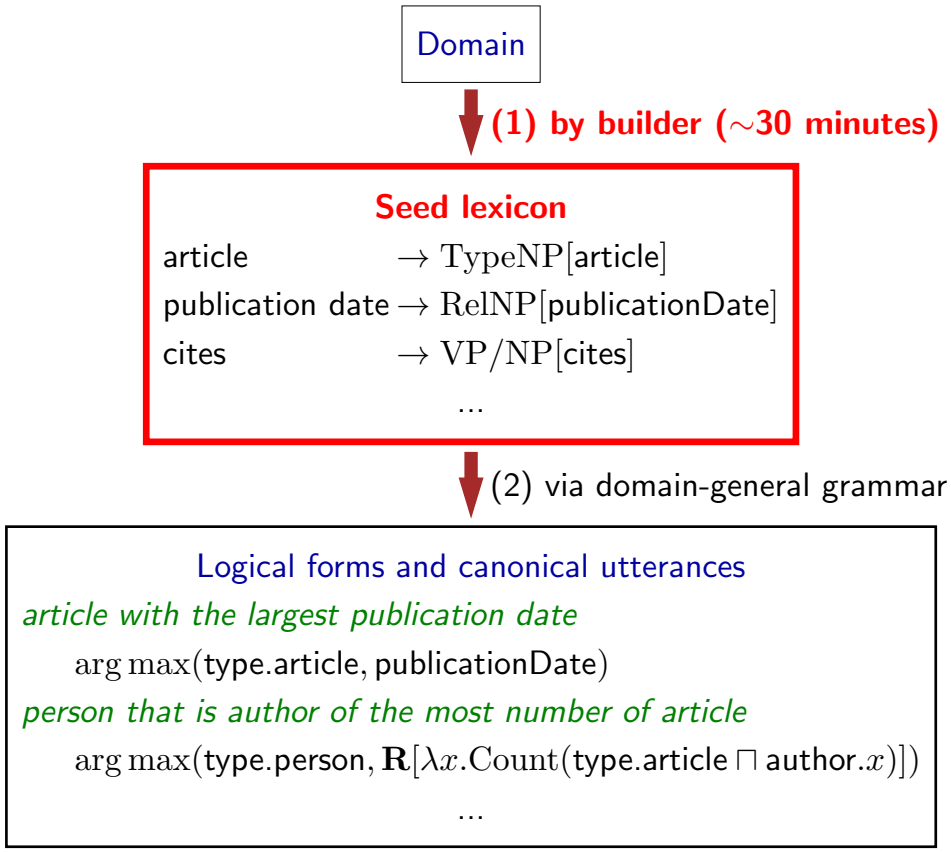
[with Yushi Wang, Jonathan Berant, ACL 2015]

Overnight semantic parsing



[with Yushi Wang, Jonathan Berant, ACL 2015]

Overnight semantic parsing



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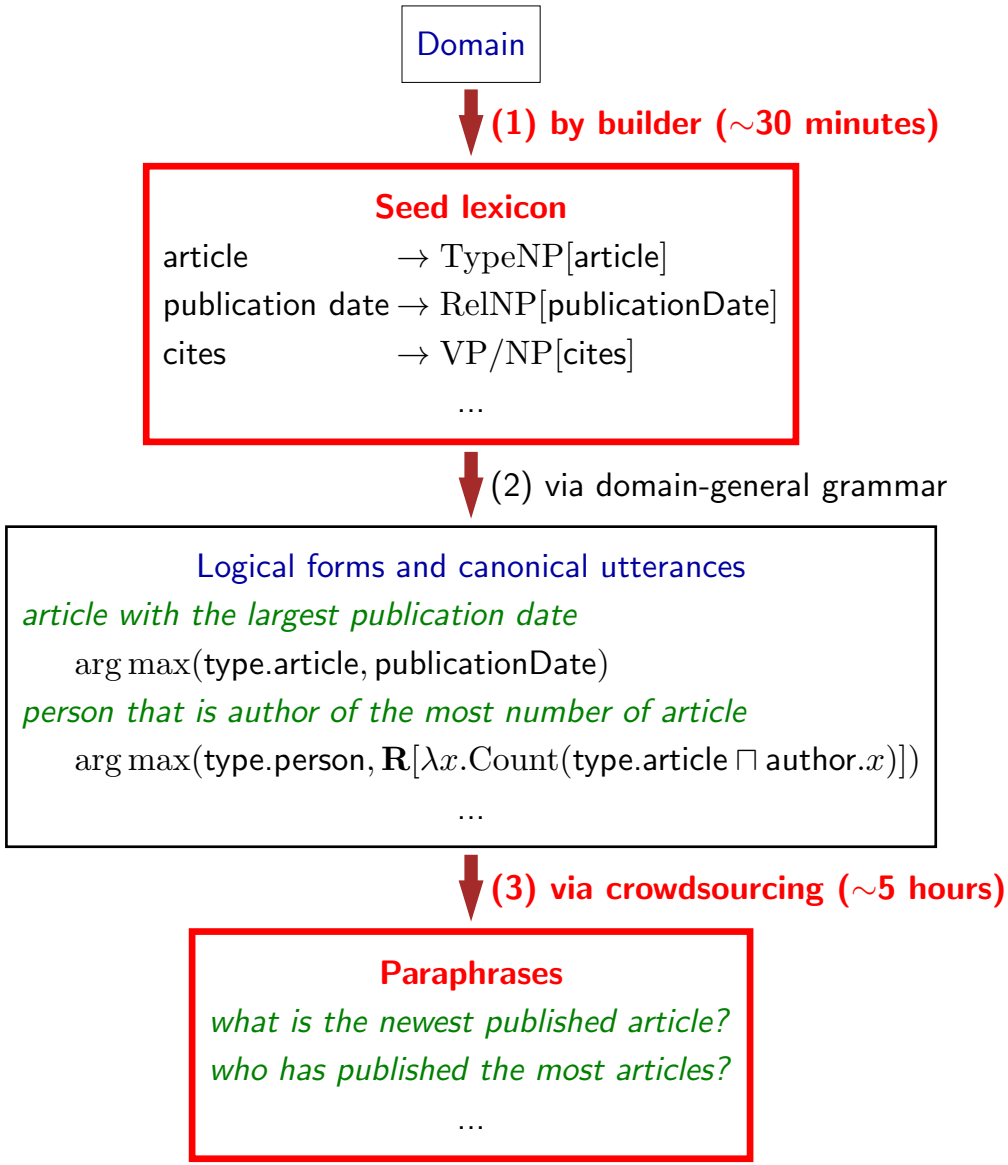
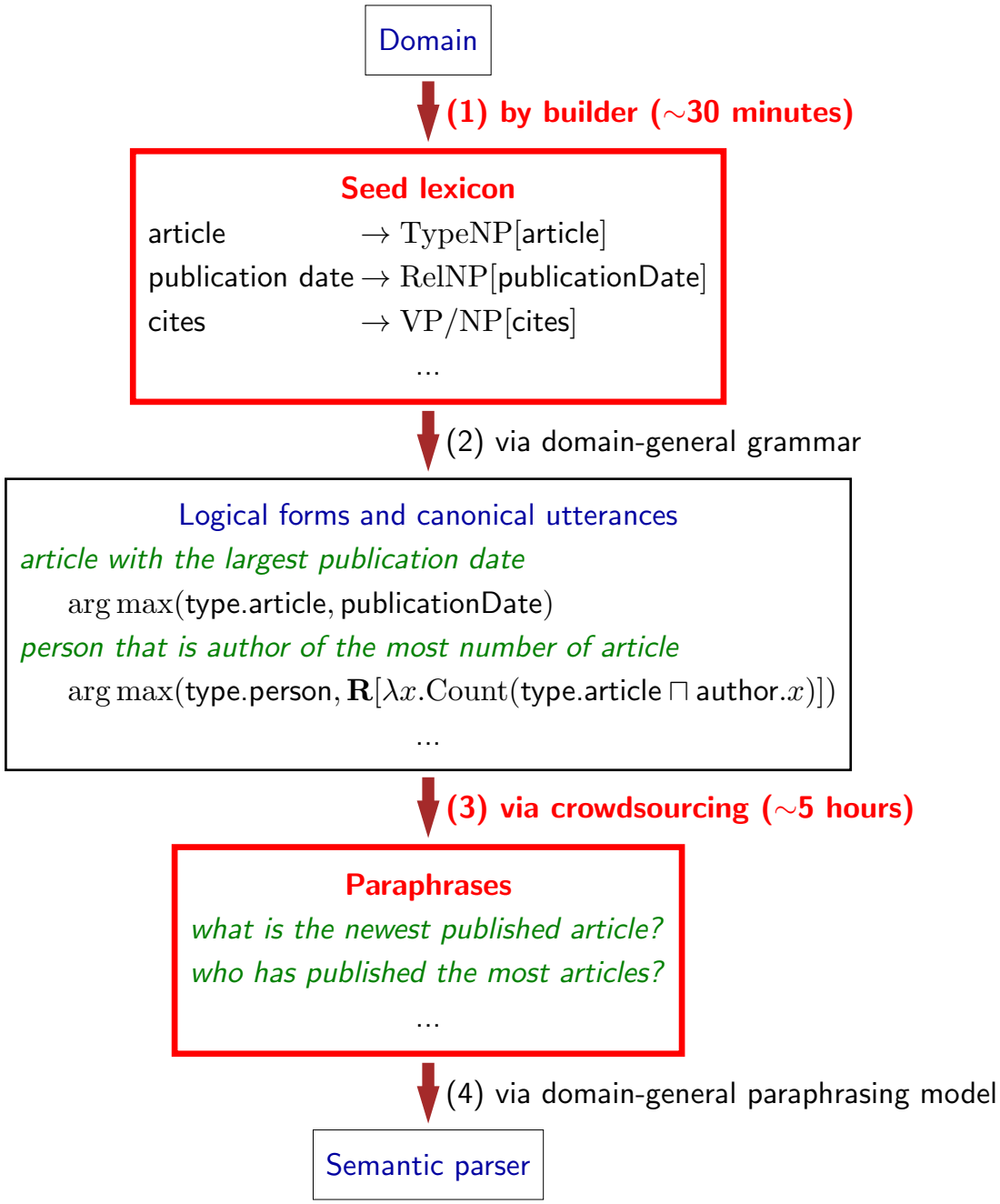
Overnight semantic parsing



[with Yushi Wang, Jonathan Berant, ACL 2015]

Overnight semantic parsing



Answering macro questions

Carbon Dioxide emissions by country
Click heading to sort. Download this data

Table id	Rank, 2009	Country or region	2008, mil tonnes	2009, TOTAL, mil tonnes	2009, per capita, tonnes	% change, 2008 to 2009
225		**World**	**30,493.23**	**30,398.42**	**4.49**	**-0.3**
179		**Asia & Oceania**	**12,338.41**	**13,264.09**	**3.53**	**7.5**
188	**1**	China	6,803.92	**7,710.50**	**5.83**	13.3
1		**North America**	**6,885.07**	**6,410.54**	**14.19**	**-6.9**
7	**2**	United States	5,833.13	**5,424.53**	**17.67**	-7
54		**Europe**	**4,628.98**	**4,310.30**	**7.14**	**-6.9**
91		**Eurasia**	**2,595.86**	**2,358.03**	**8.32**	**-9.2**
107		**Middle East**	**1,658.55**	**1,714.09**	**8.22**	**3.3**
194	**3**	India	1,473.73	**1,602.12**	**1.38**	8.7
102	**4**	Russia	1,698.38	**1,572.07**	**11.23**	-7.4
8		**Central & South America**	**1,228.65**	**1,219.78**	**2.57**	**0.7**

By John McGarrity

Tokyo will meet carbon reduction targets without the need to use carbon credits in its emissions trading scheme, mainly as a result of increased energy efficiency after the 2011 Fukushima nuclear disaster threatened a crunch in power supply.

Japan's capital, one of the world's largest cities, became the first urban area in Asia to impose emissions caps and carbon trading at the start of the decade, blazing a trail for other cities that are using the market to control climate-changing gases.

But big cuts in emissions through energy efficiency – spurred by a 2011 catastrophic Tsunami and subsequent meltdown of a nuclear reactor – is a timely reminder of how random events and changing government priorities can blunt the effectiveness of emissions trading schemes.

"Setting an ambitious cap for emissions schemes is crucial. Carbon markets should really take the lead in reducing emissions at least cost, but also work in parallel with other policies rather than compete with them" said Sarah Deblock, European Policy Director with the International Emissions Trading Association.

Report: Fukushima to use 100% renewable energy by 2040
Report: Japan proposes huge smart meter roll-out to cut emissions

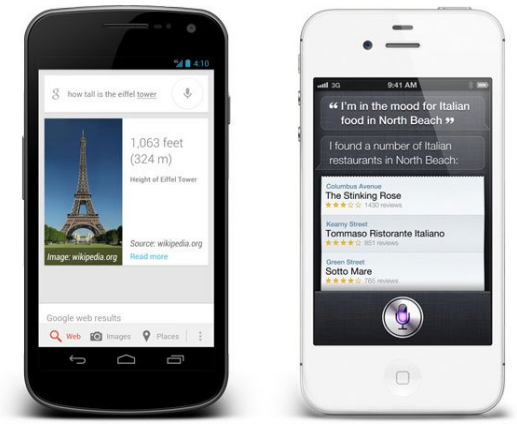
By 2015 EU member states are likely to agree how energy efficiency measures, potentially binding renewables targets and a 40%

Which country has the highest CO2 emissions?

Which had the highest increase since last year?

What fraction is from the five countries with highest GDP?

Natural language interfaces



Which restaurants have my friends been to in the last week?

Which restaurants will still be open Sunday at 10pm?

On Friday night, leave the front light on.

Code and data

http://www-nlp.stanford.edu/software/sempre/

http://www.codalab.org

Collaborators

Jonathan Berant

Andrew Chou

Roy Frostig

Ice Pasupat

Yushi Wang

Robin Jia

Reggy Long

Funding

Google

Microsoft

DARPA

Thank you!