

Bridging the Language-Action Gap

Percy Liang



RoboNLP Workshop — August 3, 2017

The dream



The dream



move the fruits to the fridge

The dream



move the fruits to the fridge

Challenges

operate in the physical world



perception, navigation, manipulation

Challenges

operate in the physical world



map intents to actions

move the fruits to the fridge

perception, navigation, manipulation

Challenges

operate in the physical world



perception, navigation, manipulation

map intents to actions

move the fruits to the fridge

1. go to table
2. pick up fruits
3. go to fridge
4. open fridge door
5. put fruits in fridge
6. close fridge door

Challenges

operate in the physical world



perception, navigation, manipulation

map intents to actions

move the fruits to the fridge

1. go to table
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parsing — planning

Challenges

operate in the physical world



perception, navigation, manipulation

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move the fruits to the fridge

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parsing planning

Language to logical forms

[world]

Pick up the largest red block

Language to logical forms

[world]

Pick up the largest red block



semantic parsing

Red Blocks

Language to logical forms

[world]

Pick up the largest red block



semantic parsing

HasColor(Red) Blocks

Language to logical forms

[world]

Pick up the largest red block



semantic parsing

HasColor(Red) \cap Blocks

Language to logical forms

[world]

Pick up the largest red block



semantic parsing

$\text{argmax}(\text{HasColor(Red)} \cap \text{Blocks}, \text{Size})$

Language to logical forms

[world]

Pick up the largest red block



semantic parsing

`PickUp(argmax(HasColor(Red) ∩ Blocks, Size))`

Language to logical forms

[world]

Pick up the largest red block



semantic parsing



`PickUp(argmax(HasColor(Red) ∩ Blocks, Size))`

execute

[actions]

Language to logical forms

[world]

Pick up the largest red block



semantic parsing



`PickUp(argmax(HasColor(Red) ∩ Blocks, Size))`

execute

[actions]

good alignment between words and primitives



[database]

Language to programs

Pick up the largest red block



[database]

Language to programs

Pick up the largest red block



"semantic parsing"

`PickUp(argmax(HasColor(Red) ∩ Blocks, Size))`



Language to programs

[database]

Pick up the largest red block



"semantic parsing"

MoveToTable(); PickUp(argmax(HasColor(Red) \cap Blocks, Size))



[database]

Language to programs

Pick up the largest red block



"semantic parsing"

MoveToTable(); MoveTo(argmax(HasColor(Red) \cap Blocks, Size)); PickUp(objects[-1])



Language to programs

[database]

Pick up the largest red block



"semantic parsing"

MoveToTable(); MoveTo(argmax(HasColor(Red) ∩ Blocks, Size)); PickUp(objects[-1])



execute

[actions]



Language to programs

[database]

Pick up the largest red block



"semantic parsing"

MoveToTable(); MoveTo(argmax(HasColor(Red) ∩ Blocks, Size)); PickUp(objects[-1])

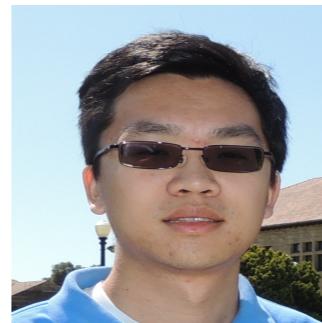


execute

[actions]

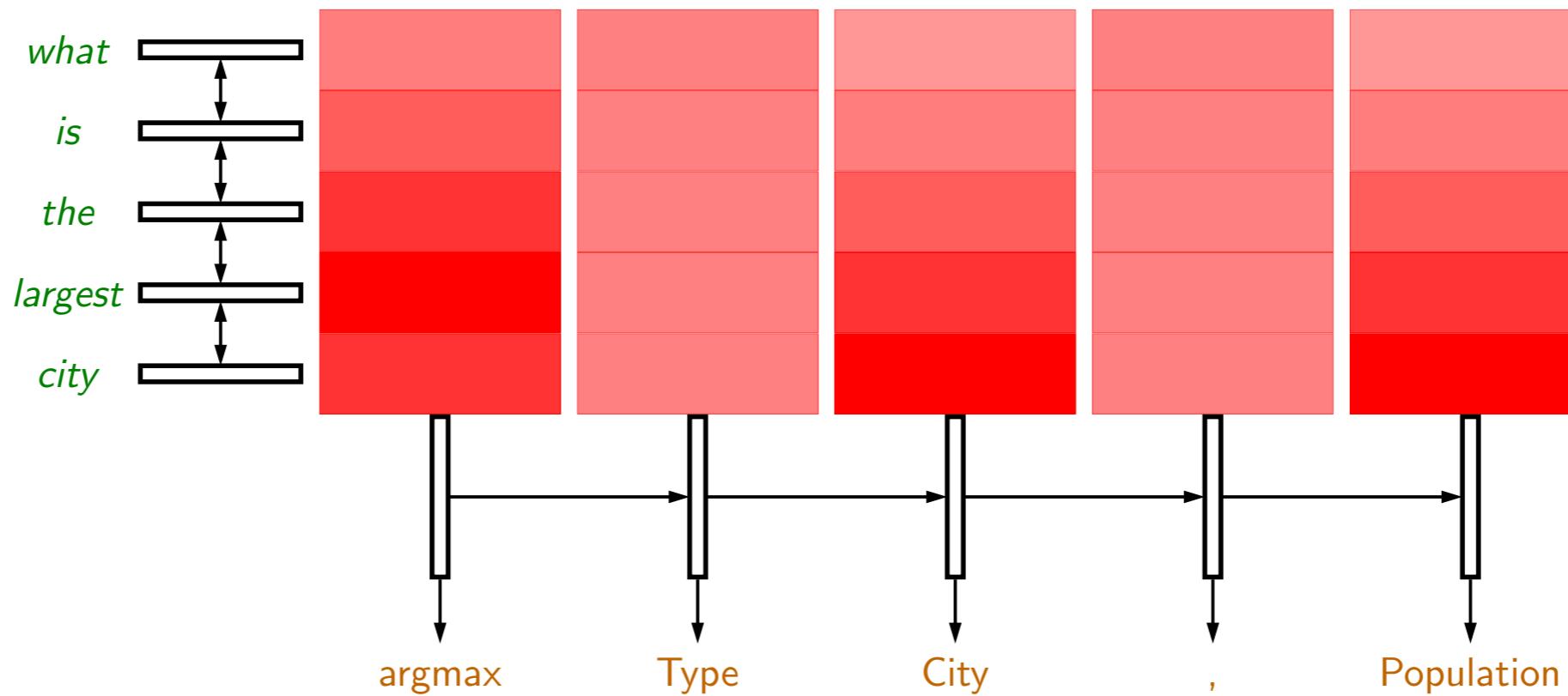
gap between words and primitives — **key problem!**

1. Simplifying the mapping from language to programs (ACL 2016)

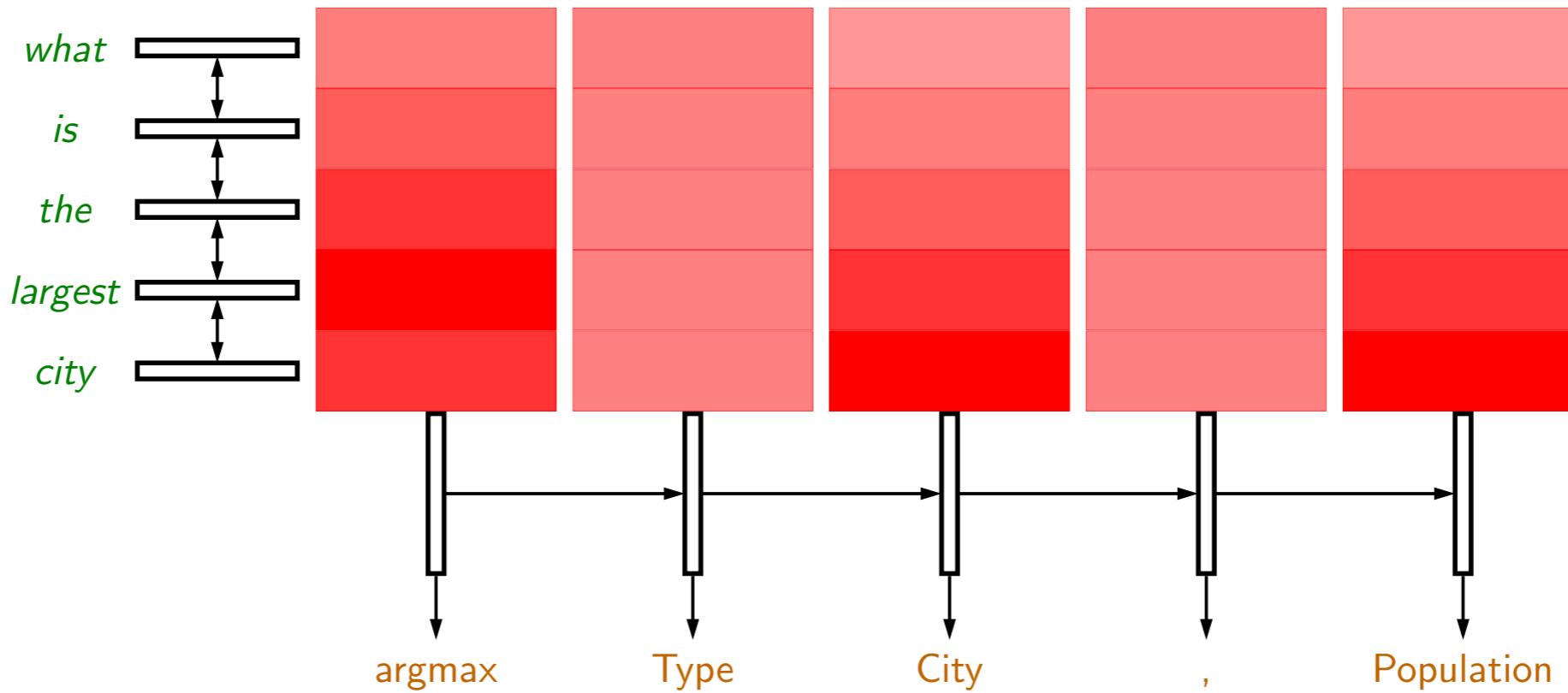


Robin Jia

Attention-based RNN



Attention-based RNN

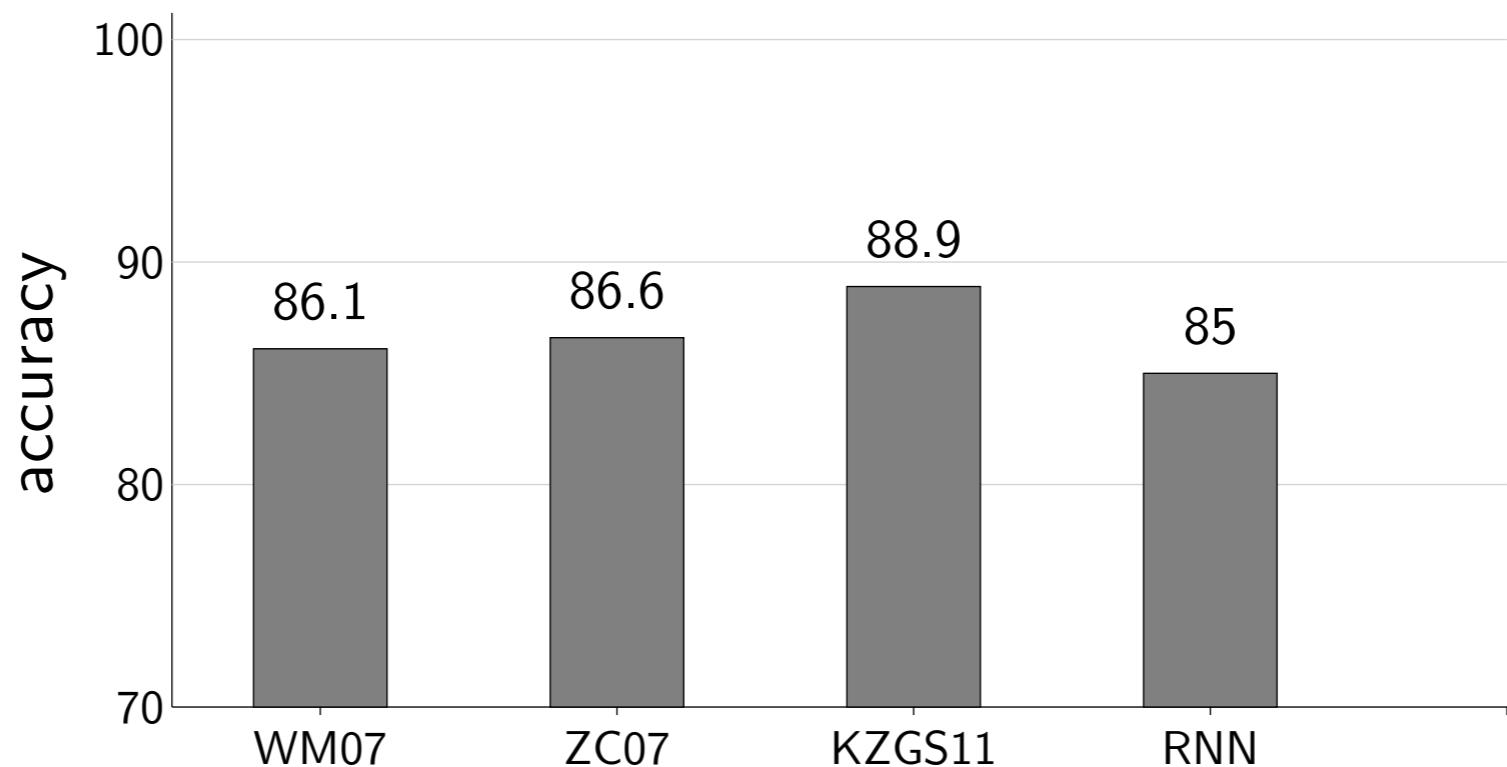


Attention replaces discrete latent variables for derivation/alignment

Results

Dataset: US Geography dataset (Zelle & Mooney, 1996)

What is the highest point in Florida?



Data recombination

Original dataset:

what's the capital of Germany? CapitalOf(Germany)

what countries border France? Borders(France)

Data recombination

Original dataset:

what's the capital of Germany? CapitalOf(Germany)

what countries border France? Borders(France)

Add new examples:

what's the capital of France? CapitalOf(France)

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Data recombination

Original dataset:

what's the capital of Germany? CapitalOf(Germany)

what countries border France? Borders(France)

Add new examples:

what's the capital of France? CapitalOf(France)

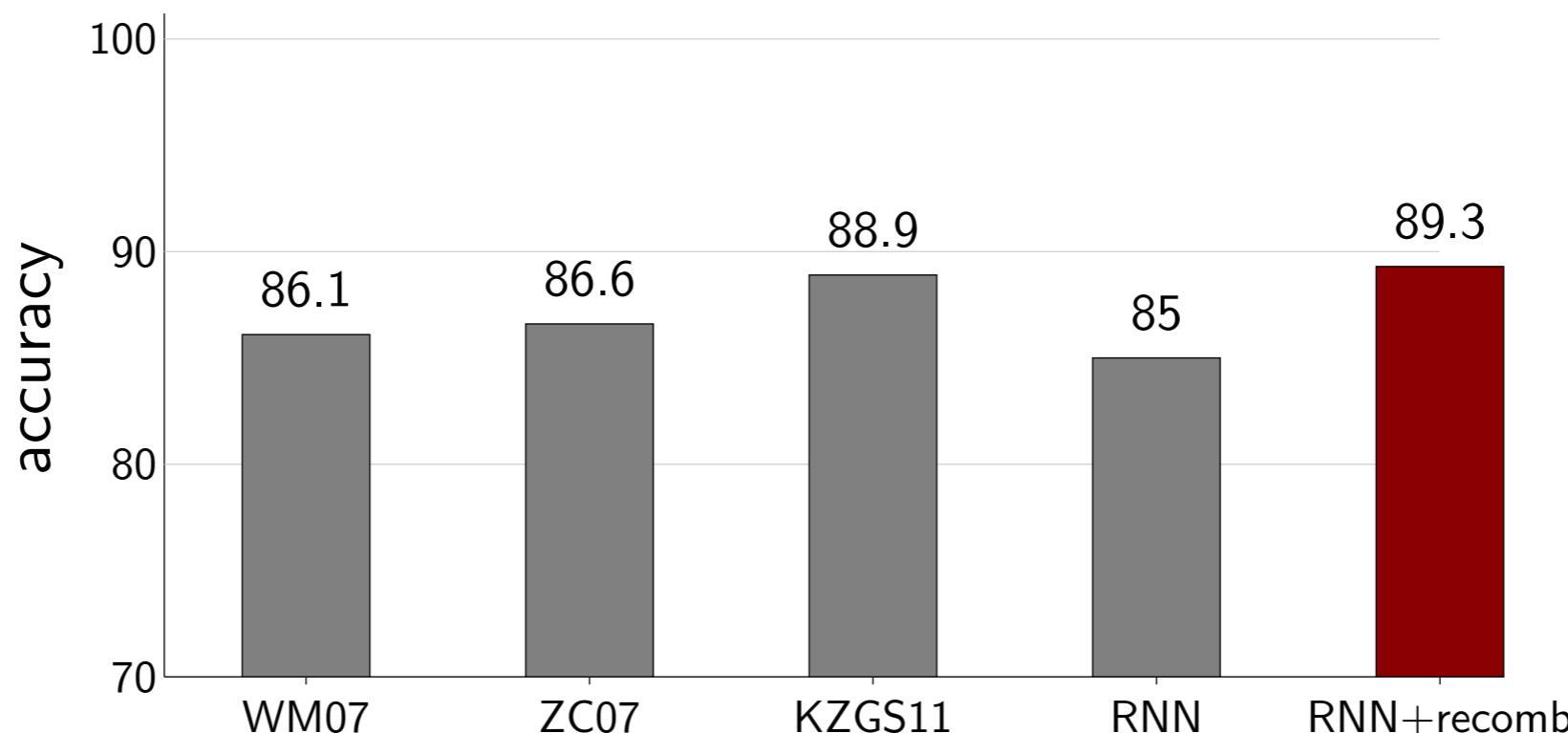
what countries border Germany? Borders(Germany)

Encode compositionality through **data recombination**

Results

Dataset: US Geography dataset (Zelle & Mooney, 1996)

What is the highest point in Florida?



state-of-the-art, simpler

If no annotated logical forms...

Greece held its last Summer Olympics in which year?

?

2004

Year	City	Country	Nations
1896	Athens	Greece	14
1900	Paris	France	24
1904	St. Louis	USA	12
...
2004	Athens	Greece	201
2008	Beijing	China	204
2012	London	UK	204

If no annotated logical forms...

Greece held its last Summer Olympics in which year?

R[Index].Country.Greece

2004

Year	City	Country	Nations
1896	Athens	Greece	14
1900	Paris	France	24
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If no annotated logical forms...

Greece held its last Summer Olympics in which year?

R[Nations].Country.Greece

2004

Year	City	Country	Nations
1896	Athens	Greece	14
1900	Paris	France	24
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...
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If no annotated logical forms...

Greece held its last Summer Olympics in which year?

$\text{argmax}(\text{Country.Greece}, \text{Nations})$

2004

Year	City	Country	Nations
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If no annotated logical forms...

Greece held its last Summer Olympics in which year?

... (thousands of logical forms later) ...

2004

Year	City	Country	Nations
1896	Athens	Greece	14
1900	Paris	France	24
1904	St. Louis	USA	12
...
2004	Athens	Greece	201
2008	Beijing	China	204
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If no annotated logical forms...

Greece held its last Summer Olympics in which year?

R[Date].R[Year].argmax(Country.Greece, Index)

2004

Year	City	Country	Nations
1896	Athens	Greece	14
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1904	St. Louis	USA	12
...
2004	Athens	Greece	201
2008	Beijing	China	204
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2. Simplifying the target programs (ACL 2016)



Reggy Long



Panupong Pasupat

Context-dependent semantic parsing



pour the last green beaker
into beaker two



then into the first



mix



Context-dependent semantic parsing

TANGRAMS



delete the second object from the left



bring it back as the first figure



undo that



redo step two

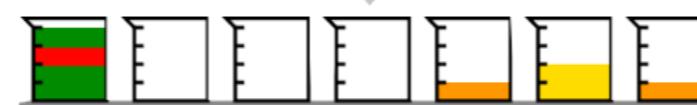
ALCHEMY



pour the last green beaker into beaker two



then into the first



mix



SCENE



the man in the purple hat takes a step to the right



he's joined on his left by a person wearing a purple shirt and no hat

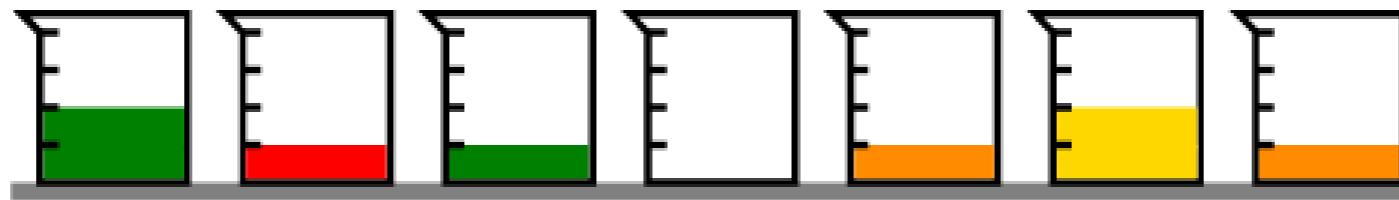


they move to the left end



another hatless person, this time in a blue shirt, arrives at his left where the other person had been

Simpler logical forms



`pour(3, 2)`

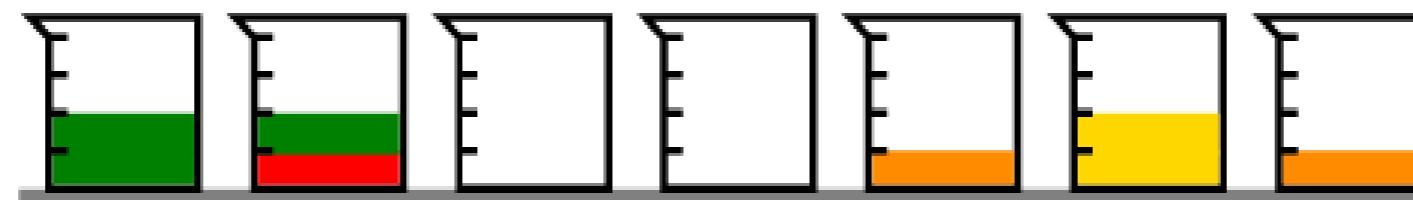
`pour(hasColor(green)[-1], 2)`

`pour(hasColor(green)[1], 2)`

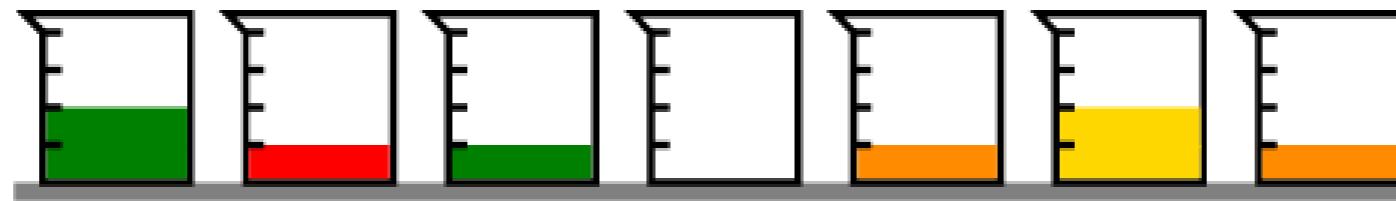
`pour(3, hasColor(red))`

`pour(hasColor(green)[-1], hasColor(red))`

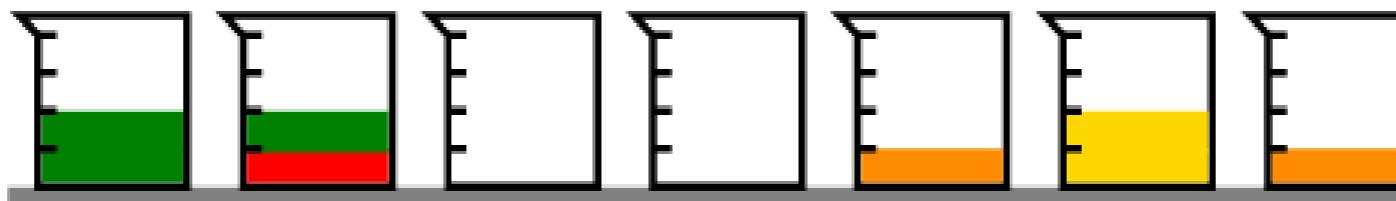
`pour(hasColor(green)[1], hasColor(red))`



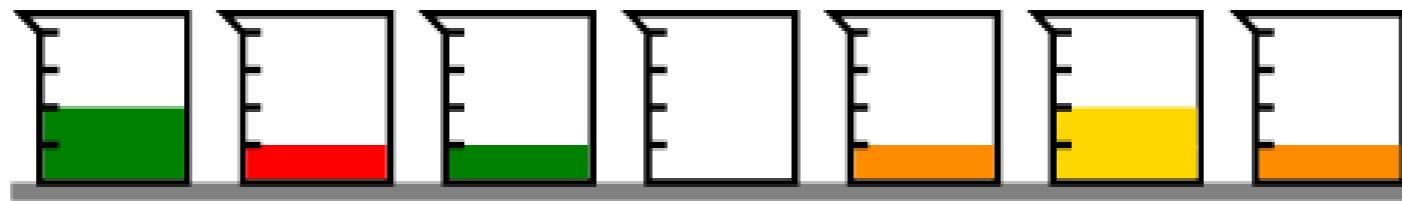
Simpler logical forms



`pour(3, 2)`

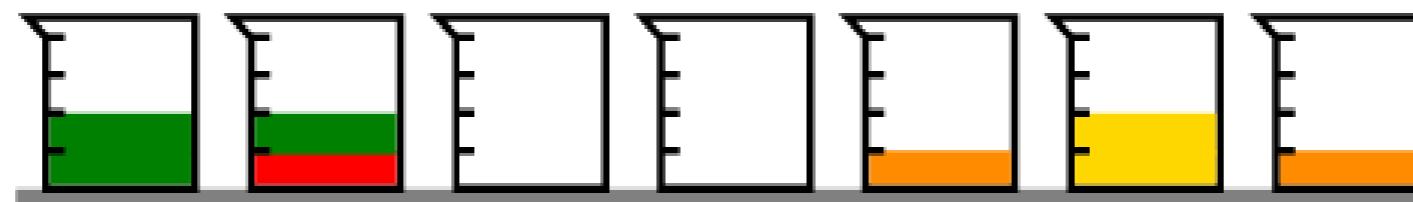


Simpler logical forms

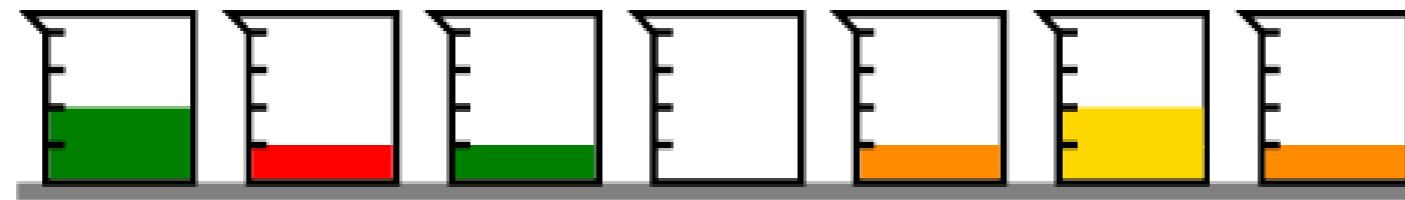


pour(3, 2)

- featurize objects with properties (green)
- can fake conjunction/disjunction/superlatives: *last*
- harder: *second orange beaker*

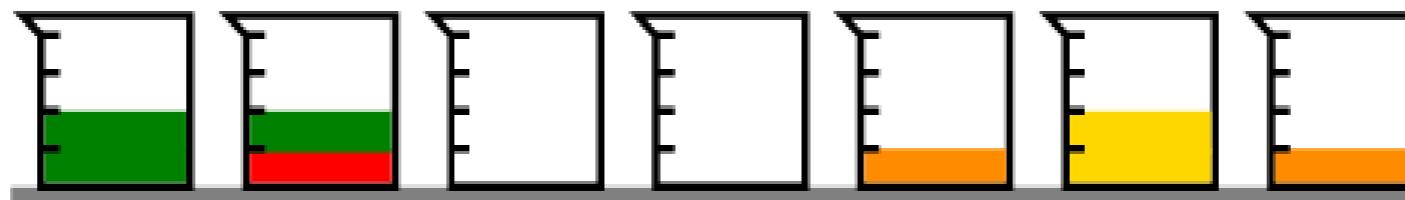


Simpler logical forms



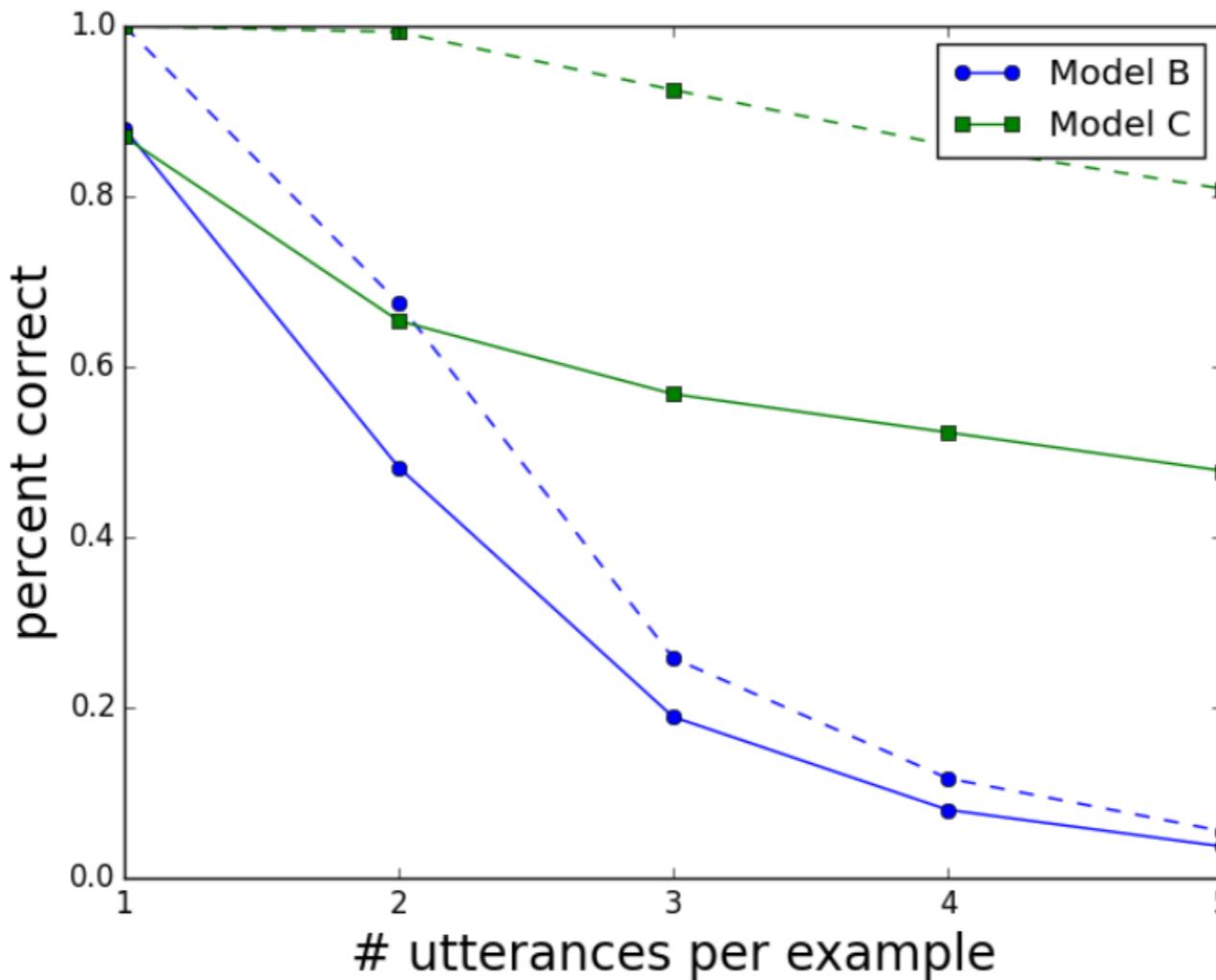
pour(3, 2)

- featurize objects with properties (green)
- can fake conjunction/disjunction/superlatives: *last*
- harder: *second orange beaker*



approximate logic with features

Results



simpler logical forms can work better

3. Better search over programs (ACL 2017)



Kelvin Guu

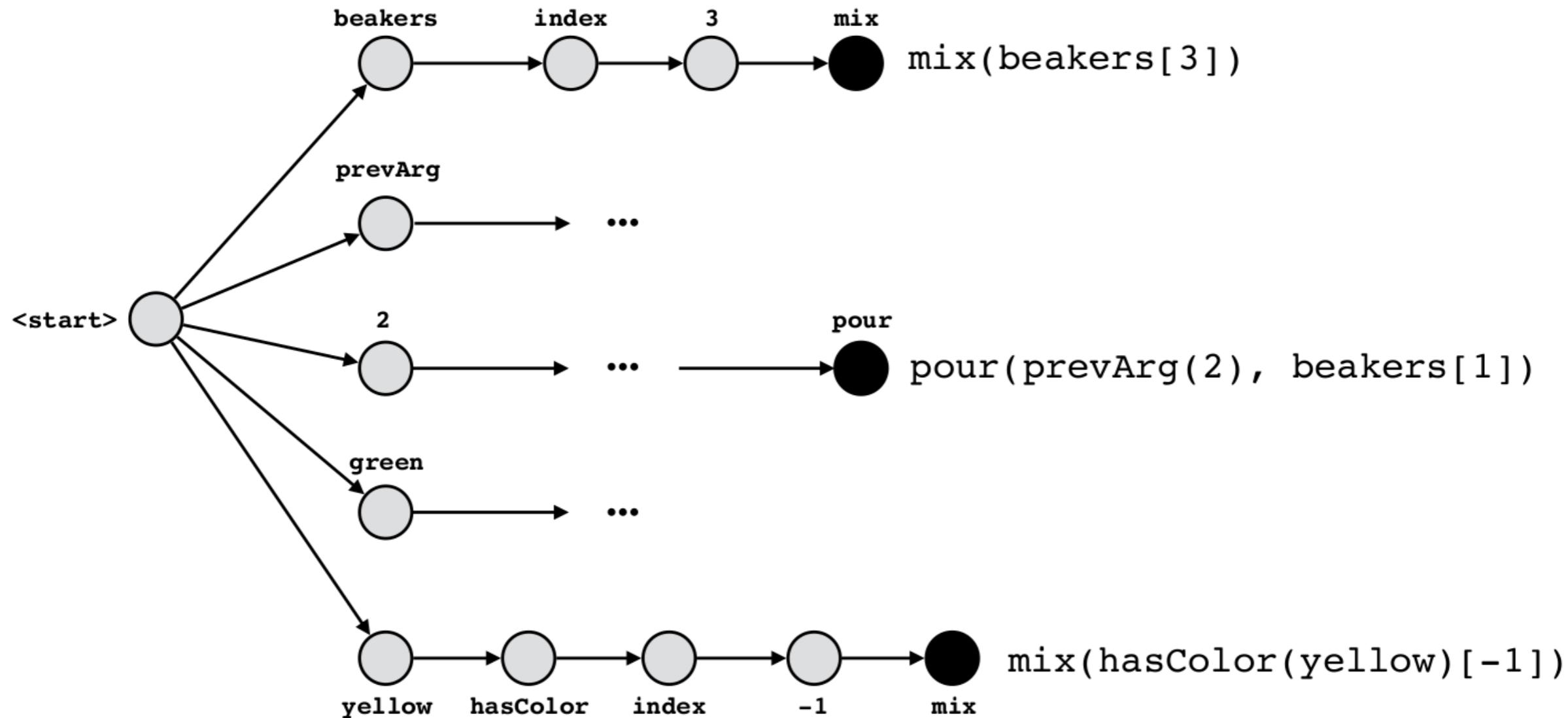


Panupong Pasupat



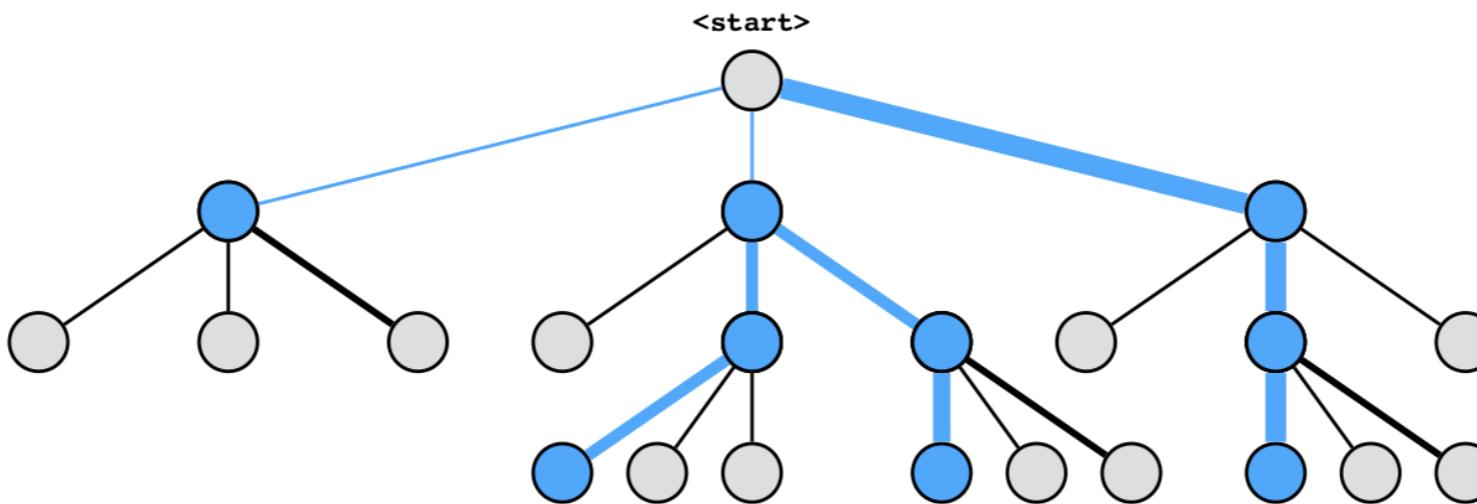
Evan Liu

Search tree over programs

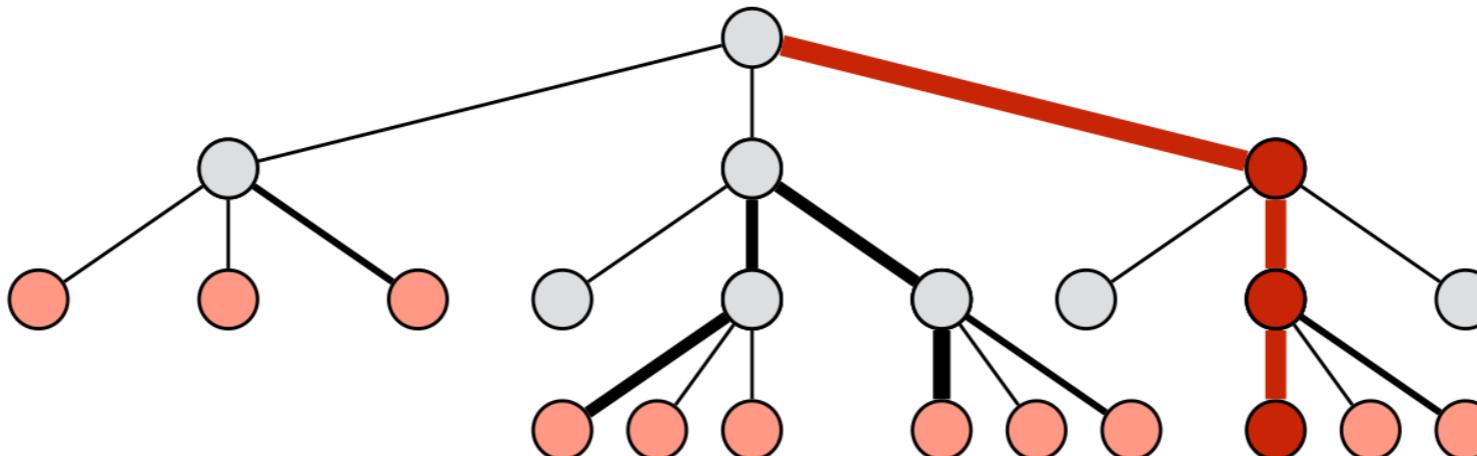


Maximum likelihood versus REINFORCE

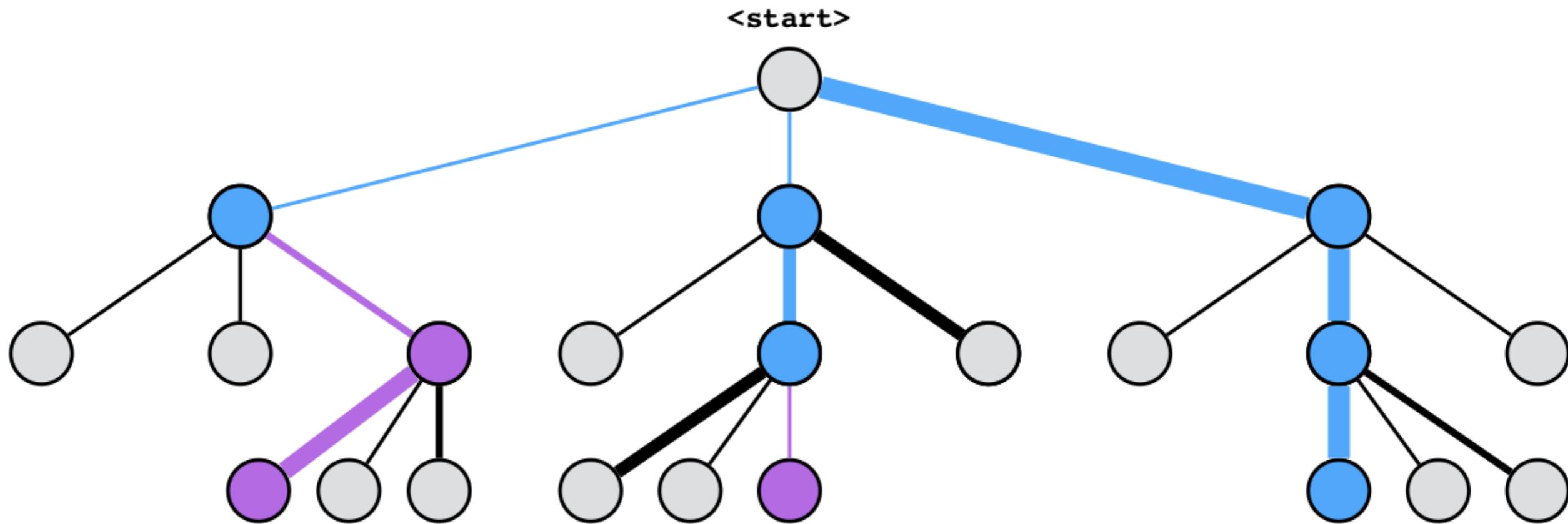
Beam search (beam_size = 3)



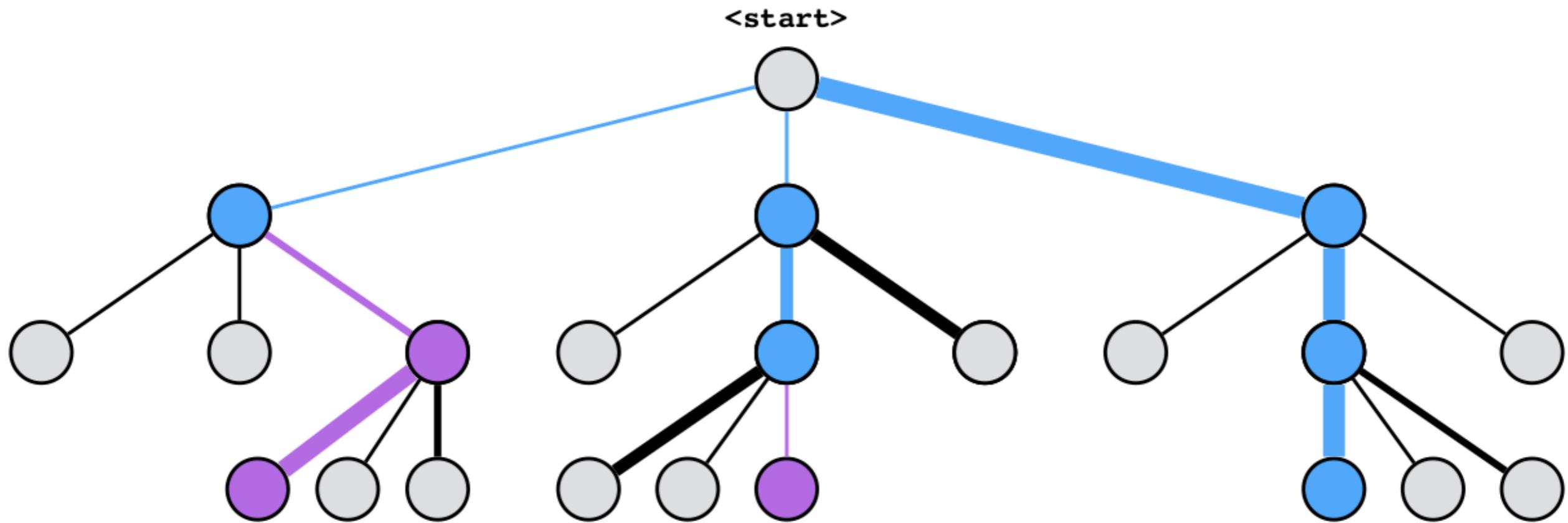
REINFORCE + epsilon greedy



Hybrid: randomized beam search

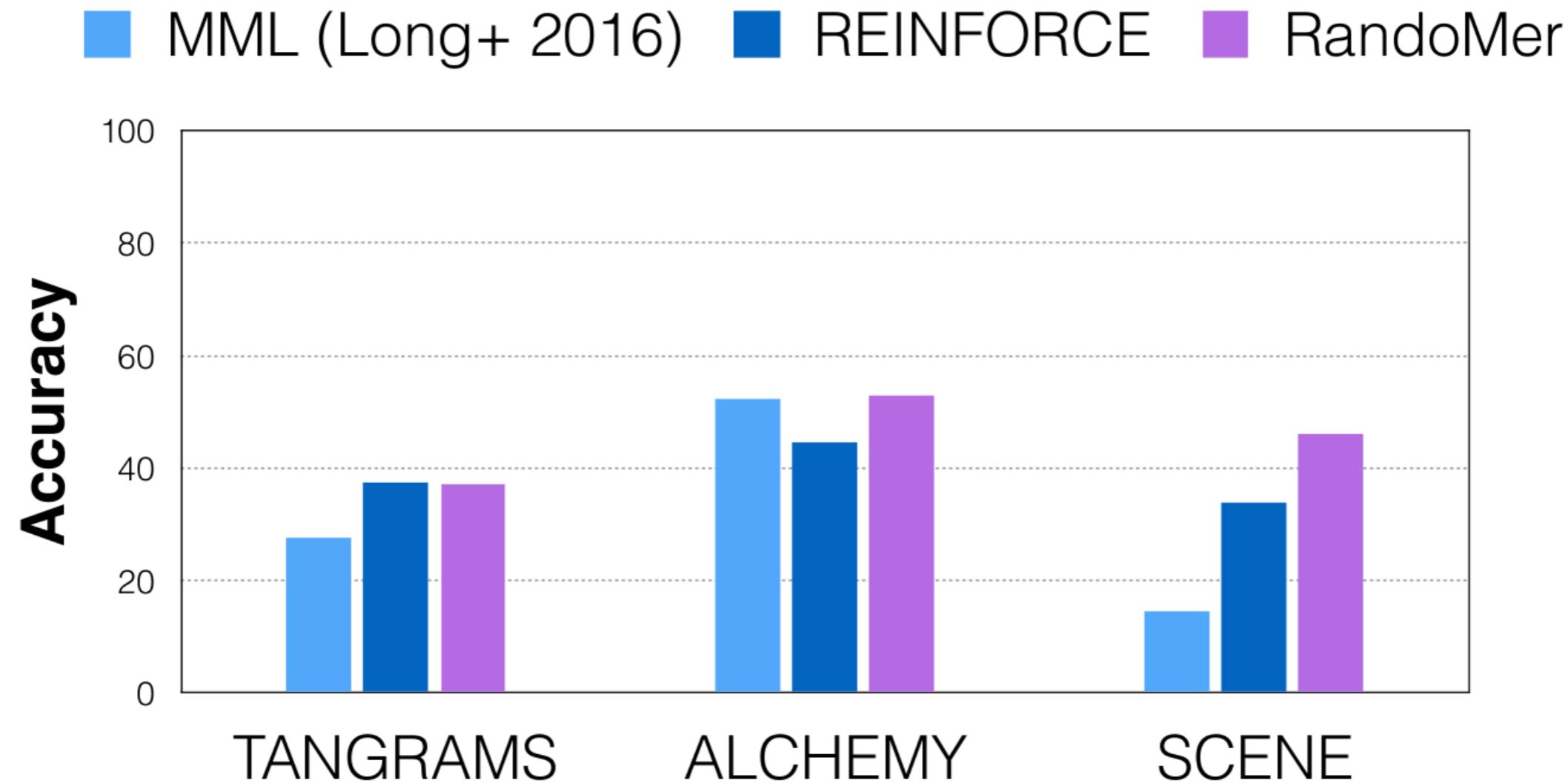


Hybrid: randomized beam search



combine systematic + random exploration

Results



No recourse on failures



*4. How do we develop systems that **improve with use**? (ACL 2016)*



Sida Wang



Chris Manning

Language games

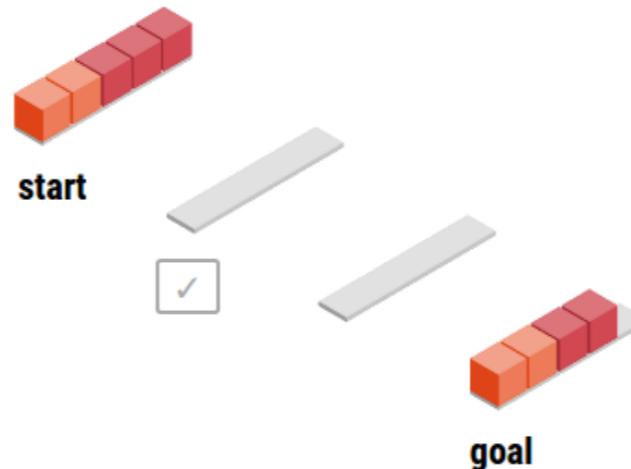


Wittgenstein (1953):

Language derives its meaning from use.



SHRDLURN



sees goal

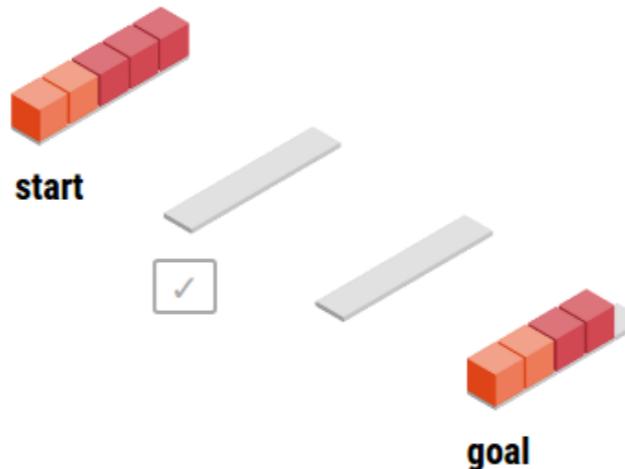
has language



perform actions

no language

SHRDLURN



remove red

sees goal

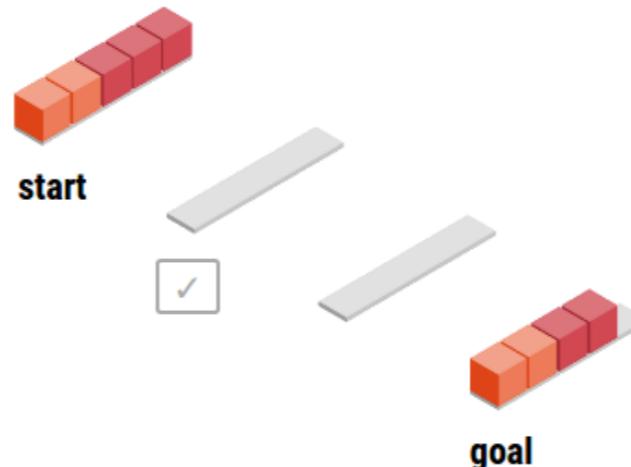
has language



perform actions

no language

SHRDLURN



sees goal

has language

remove red

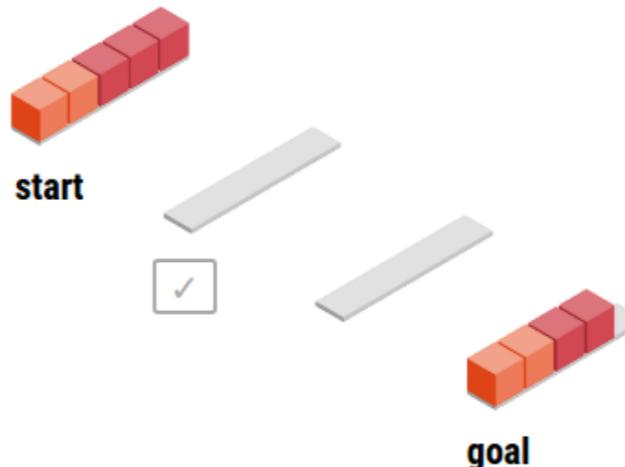
add(hascolor(red))
add(hascolor(brown))
remove(hascolor(red))
remove(hascolor(brown))



perform actions

no language

SHRDLURN



remove red

sees goal

has language

add(hascolor(red))
add(hascolor(brown))
remove(hascolor(red))
remove(hascolor(brown))



perform actions

no language

Real users (June-Sept 2016)

10,000+ utterances

*add brown on the top unless the rightmost
not(red)*

*pick up blue blocks
+ 1 2 3 4 5 r*

Not the brown block!, The orange block!

add blo 1 bro

rem ora blo

add blo 6 pin

add blo 134 bl

去掉最后一块

在蓝色块上面加一层橙色块

smaz 1 a 2 a 3 a 5 jednou

retire les blocs bleus

move all blocks but middle

- 1 br - 4 br - 6 br

一番奥にオレンジを置く, 一番右の赤を消す

add red one on the first

lift 1 3 5

add one orange block on top of each orange

去掉 蓝色 方块

smaz 1 a 2 a 3 a 5

quita el bloque marrón

quita el primer bloque por la derecha

drop orange not left not right

add brown on all blue in line 2 in line 3

Add x x o x o x red block

只保留桔黄色的方块

quitar cubo rojo, quitar ultimo cubo rojo

System learns language from scratch through interaction!

5. Scaling up using definitions (ACL 2017)



Sida Wang

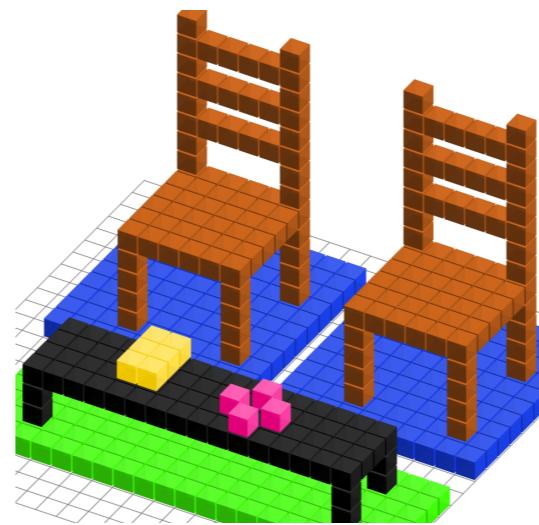


Sam Ginn



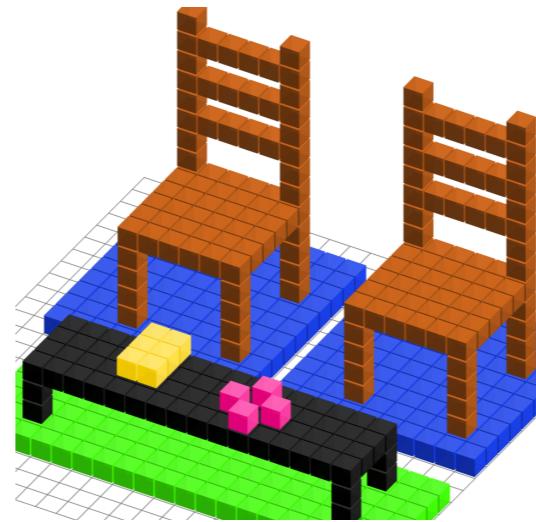
Chris Manning

Voxelurn



add two chairs 5 spaces apart

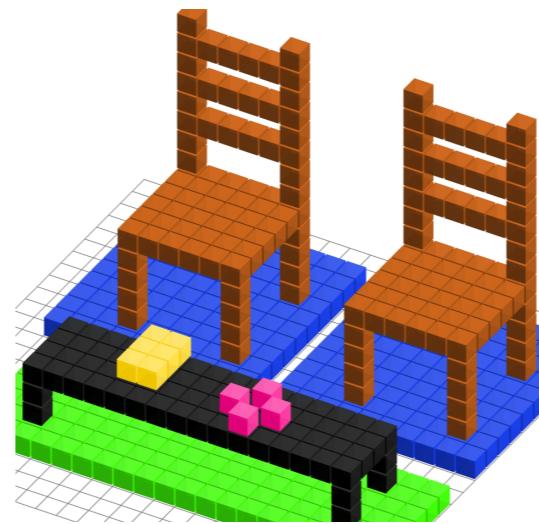
Voxelurn



add two chairs 5 spaces apart

```
(:s (:s (:blk (:loop (number 3) (:s (: add brown here) (:for (call adj top this) (: select)))) (:loop (number 3) (:for (call adj bot this) (: select)))) (:loop (number 3) (:for (call adj left this) (: select)))) (:s (:s (:blk (:loop (number 3) (:s (: add brown here) (:for (call adj top this) (: select)))) (:loop (number 3) (:for (call adj bot this) (: select)))) (:loop (number 3) (:for (call adj back this) (: select)))) (:blk (:loop (number 3) (:s (: add brown here) (:for (call adj top this) (: select)))) (:loop (number 3) (:for (call adj bot this) (: select)))) (:loop (number 3) (:for (call adj right this) (: select)))) (:blk (:loop (number 3) (:s (: add brown here) (:for (call adj top this) (: select)))) (:loop (number 3) (:for (call adj bot this) (: select)))))
```

Voxelurn



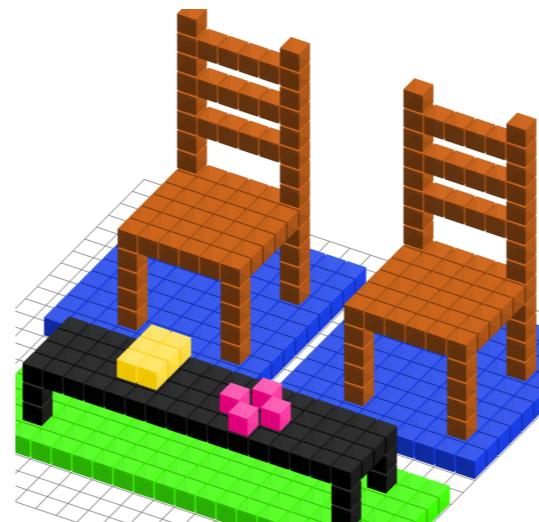
add two chairs 5 spaces apart

Learn from definitions using grammar induction:

add chair, move 5 left, add chair

```
(:s (:s (:blk (:loop (number 3) (:s (: add brown here) (:for (call adj top this) (: select)))) (:loop (number 3) (:for (call adj bot this) (: select)))) (:loop (number 3) (:for (call adj left this) (: select)))) (:s (:s (:blk (:loop (number 3) (:s (: add brown here) (:for (call adj top this) (: select)))) (:loop (number 3) (:for (call adj bot this) (: select)))) (:loop (number 3) (:for (call adj back this) (: select)))) (:blk (:loop (number 3) (:s (: add brown here) (:for (call adj top this) (: select)))) (:loop (number 3) (:for (call adj bot this) (: select)))) (:loop (number 3) (:for (call adj right this) (: select)))) (:blk (:loop (number 3) (:s (: add brown here) (:for (call adj top this) (: select)))) (:loop (number 3) (:for (call adj bot this) (: select)))))
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Voxelurn



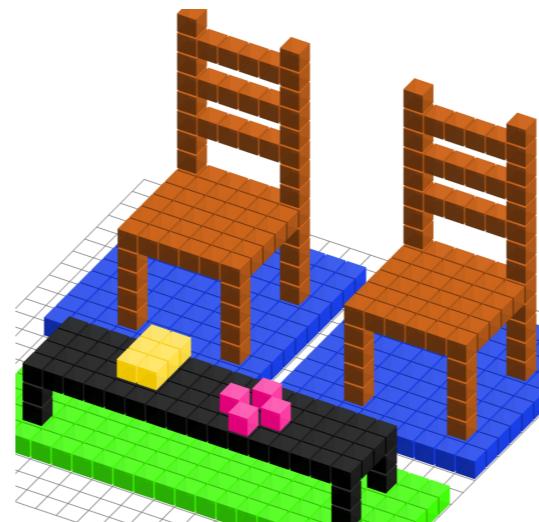
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Voxelurn



add two chairs 5 spaces apart

Learn from definitions using grammar induction:

add 4 legs, add chair base, add chair back, ...

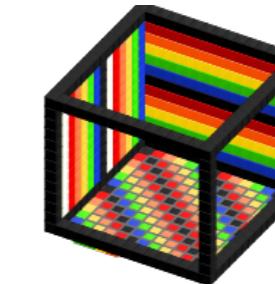
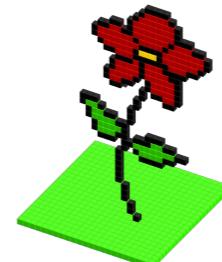
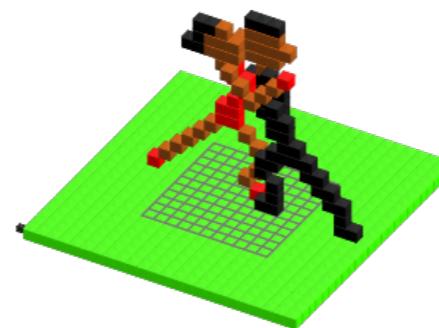
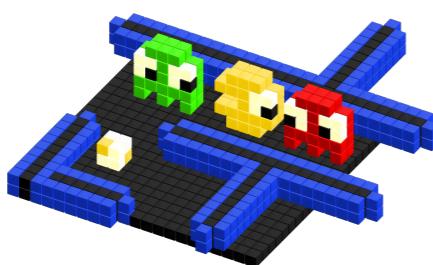
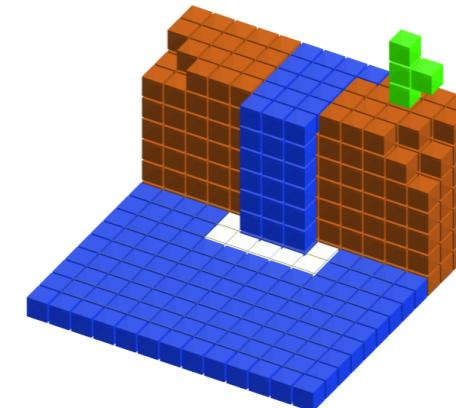
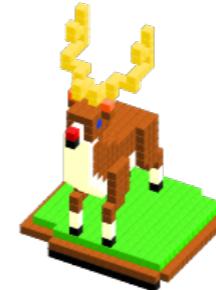
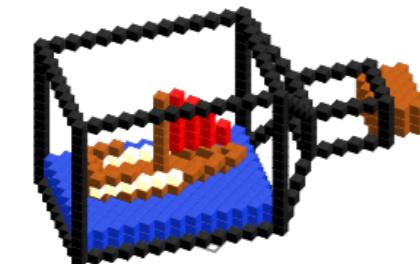
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(:s (:s (:blk (:loop (number 3) (:s (: add brown here) (:for (call adj top this) (: select)))) (:loop (number 3) (:for (call adj bot this) (: select)))) (:loop (number 3) (:for (call adj left this) (: select)))) (:s (:s (:blk (:loop (number 3) (:s (: add brown here) (:for (call adj top this) (: select)))) (:loop (number 3) (:for (call adj bot this) (: select)))) (:loop (number 3) (:for (call adj back this) (: select)))) (:blk (:loop (number 3) (:s (: add brown here) (:for (call adj top this) (: select)))) (:loop (number 3) (:for (call adj bot this) (: select)))) (:loop (number 3) (:for (call adj right this) (: select)))) (:blk (:loop (number 3) (:s (: add brown here) (:for (call adj top this) (: select)))) (:loop (number 3) (:for (call adj bot this) (: select)))))
```

Voxelurn

3 days, 42 users, 230 structures, 64075 utterances, 2495 definitions

add chair, move 5 left, add chair

add 4 legs, add chair base, add chair back, ...



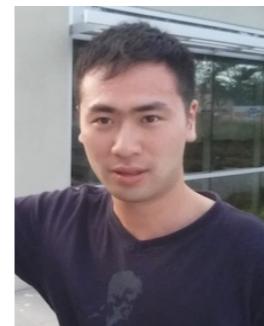
6. A virtual environment (ICML 2017)



Tianlin Shi



Andrej Karpathy



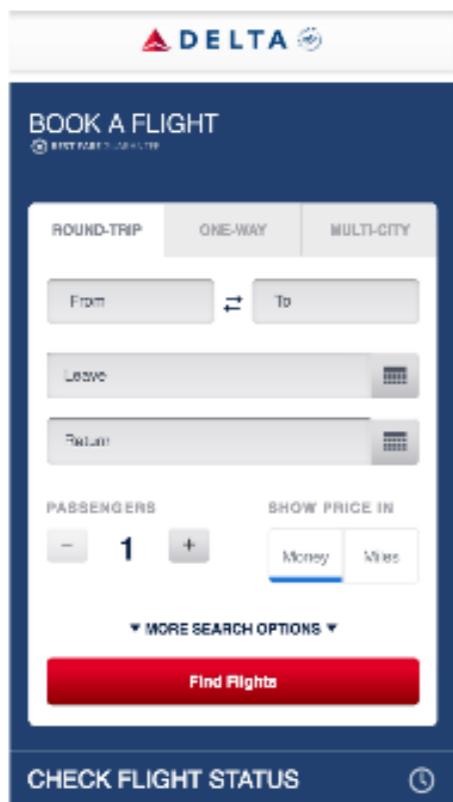
Jim Fan



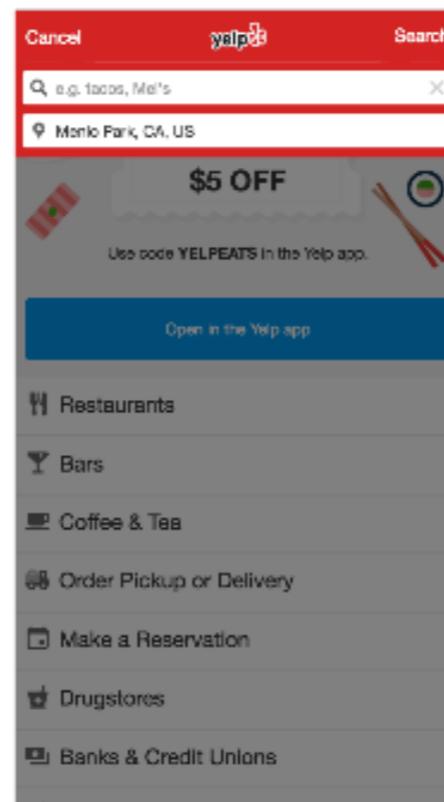
Jonathan Hernandez

World of Bits

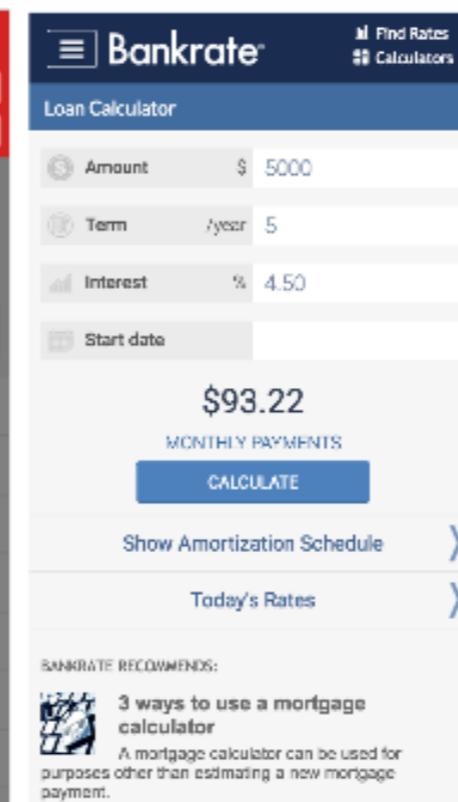
Query: Can you book a flight from San Francisco to New York?



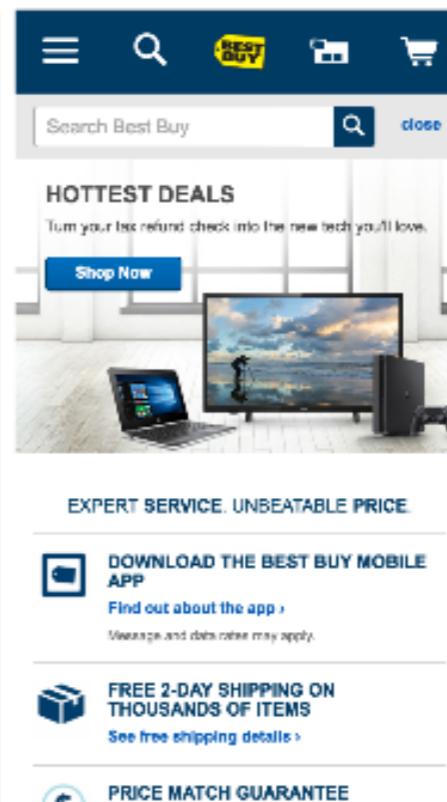
Query: What are the top rated place to eat Korean food in SF?



Query: What is the monthly payment for \$2000 with a term of 2 years at today's rates?



Query: How much is an iPhone 7 Plus in Indiana?



open-domain realism (NLP, vision)

Proxy

Collect Data



Training



Deploy



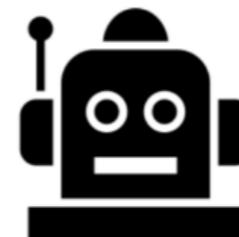
HTTP



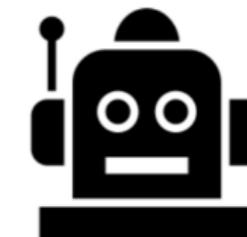
HTTP



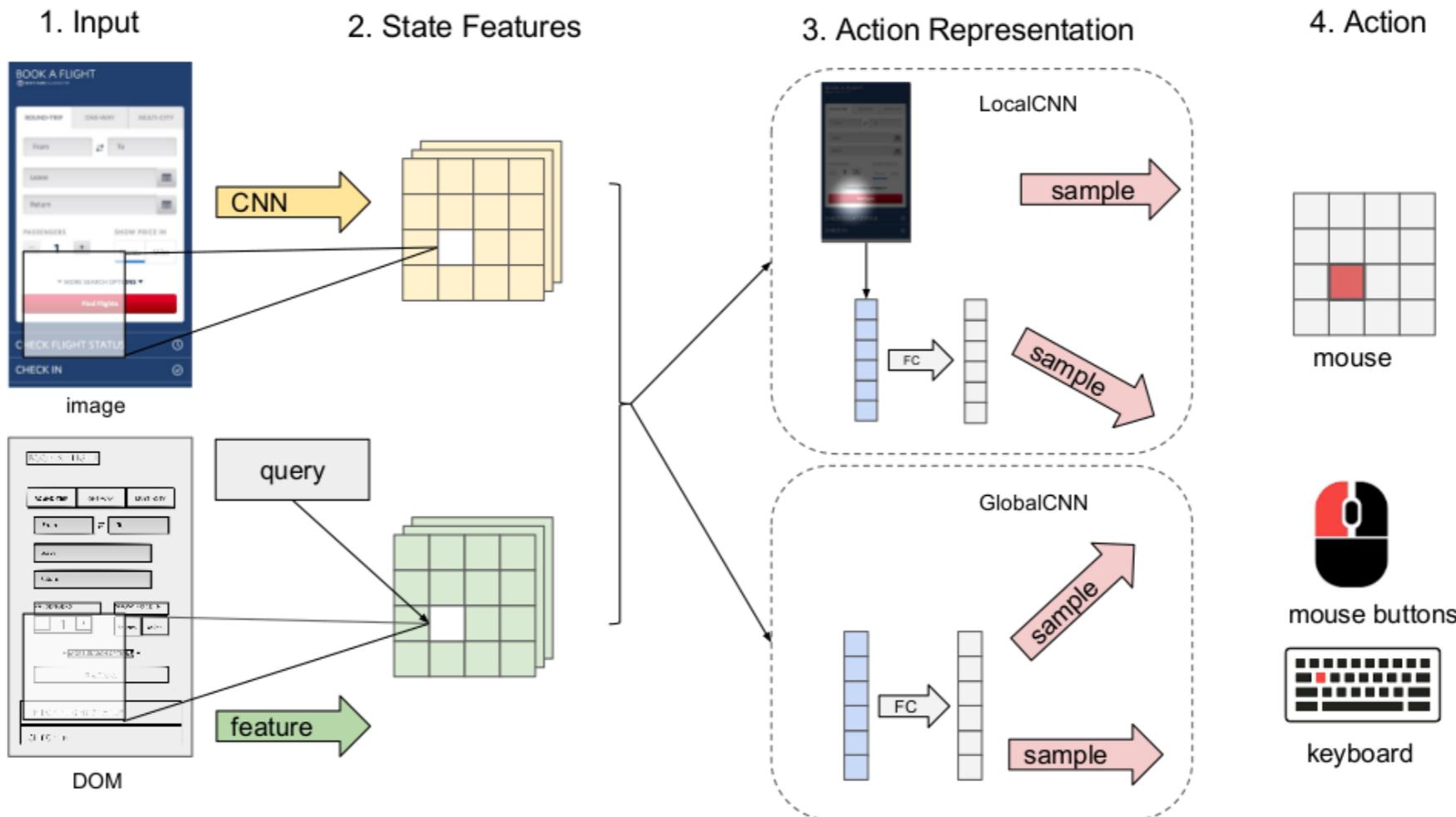
HTTP



HTTP



Model



behavioral cloning + reinforcement learning

Conclusions

add two chairs 5 spaces apart

```
(:s (:s (:blk (:loop (number 3) (:s (: add brown here) (:for (call adj top this) (: select)))) (:loop (number 3) (:for (call adj bot this) (: select)))) (:loop (number 3) (:for (call adj left this) (: select)))) (:s (:s (:s (:blk (:loop (number 3) (:s (: add brown here) (:for (call adj top this) (: select)))) (:loop (number 3) (:for (call adj bot this) (: select)))) (:loop (number 3) (:for (call adj back this) (: select)))) (:blk (:loop (number 3) (:s (: add brown here) (:for (call adj top this) (: select)))) (:loop (number 3) (:for (call adj bot this) (: select)))) (:loop (number 3) (:for (call adj right this) (: select)))) (:blk (:loop (number 3) (:s (: add brown here) (:for (call adj top this) (: select)))) (:loop (number 3) (:for (call adj bot this) (: select)))))))
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Conclusions

add two chairs 5 spaces apart

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Representation / model?

- Simplify mapping from language to programs

Conclusions

add two chairs 5 spaces apart

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Representation / model?

- Simplify mapping from language to programs

Supervision?

- Indirect supervision (randomized + systematic exploration)
- Interactive language learning (from definitions)

Conclusions

add two chairs 5 spaces apart

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```

Representation / model?

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Task?

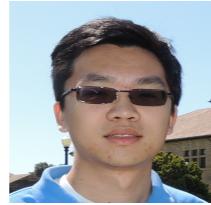
- Open-ended actions on the web



Kelvin Guu



Jonathan Hernandez



Robin Jia



Andrej Karpathy



Evan Liu



Chris Manning



Sam Ginn



Tianlin Shi



Sida Wang

DARPA

NSF

Microsoft

Tencent

Thank you!