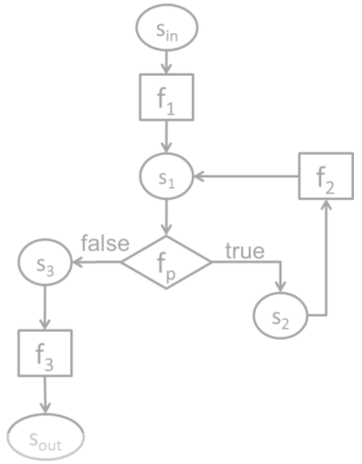
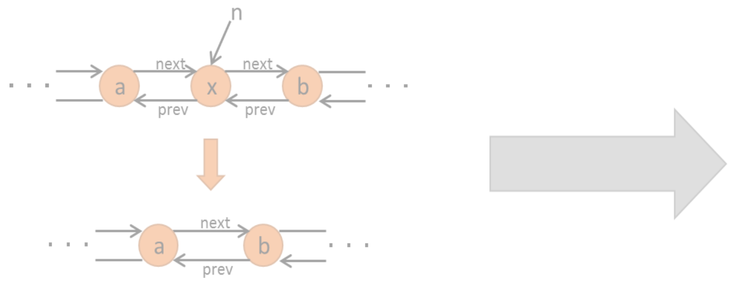
$\exists c \forall in\ Q(c, in)$

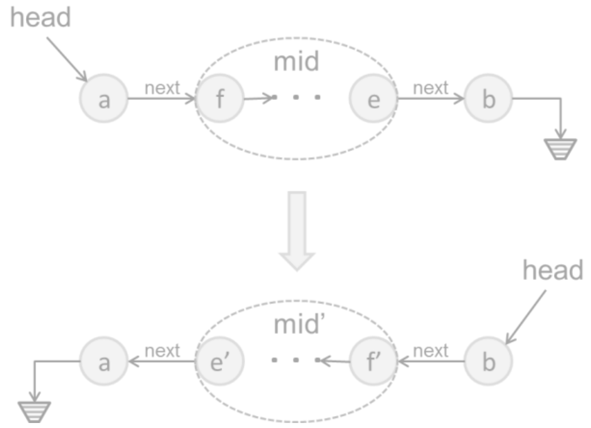
```
/* Average of x and y without using x+y (avoid overflow)*/
int avg(int x, int y){
  int t = expr({x/2, y/2, x%2, y%2, 2 }, {PLUS, DIV});
  assert t == (x+y)/2;
  return t;
}
```

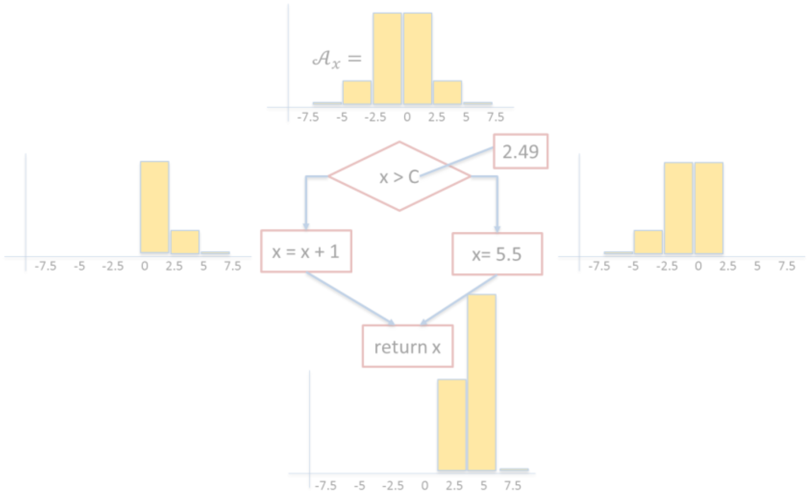




```
{
   s  = n.succ;
   p = n.pred;
   p.succ = s;
   s.pred = p;
}
```

Module III: Advanced Topics





$\varphi(p)$

$Sk[c](in)$

Lecture 14
Human Interaction in Synthesis

Nadia Polikarpova

(with slides from Hila Peleg)

Project Logistics

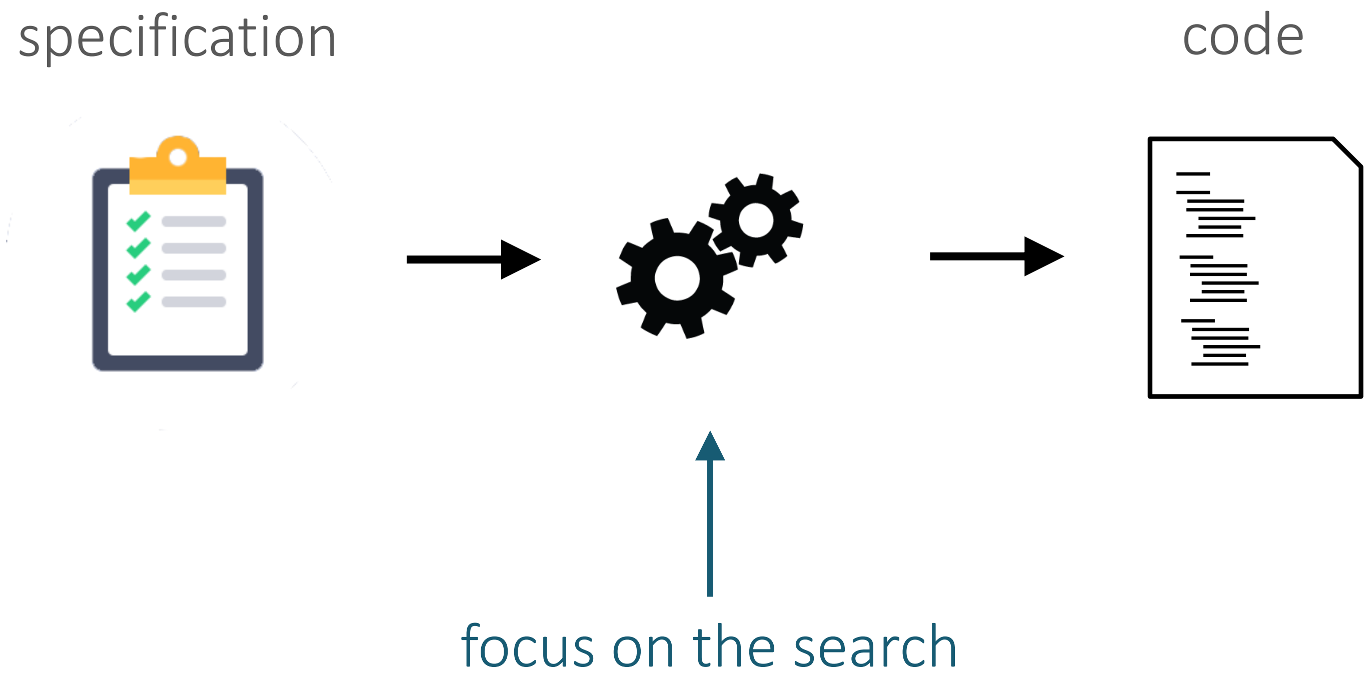
Project presentations

- Tuesday Mar 19, 3-4:20pm
- 20 min per team (15 min presentation + questions)
- Structure: motivation, **demo**, technique, evaluation
- If your slot doesn't work for you, let me know

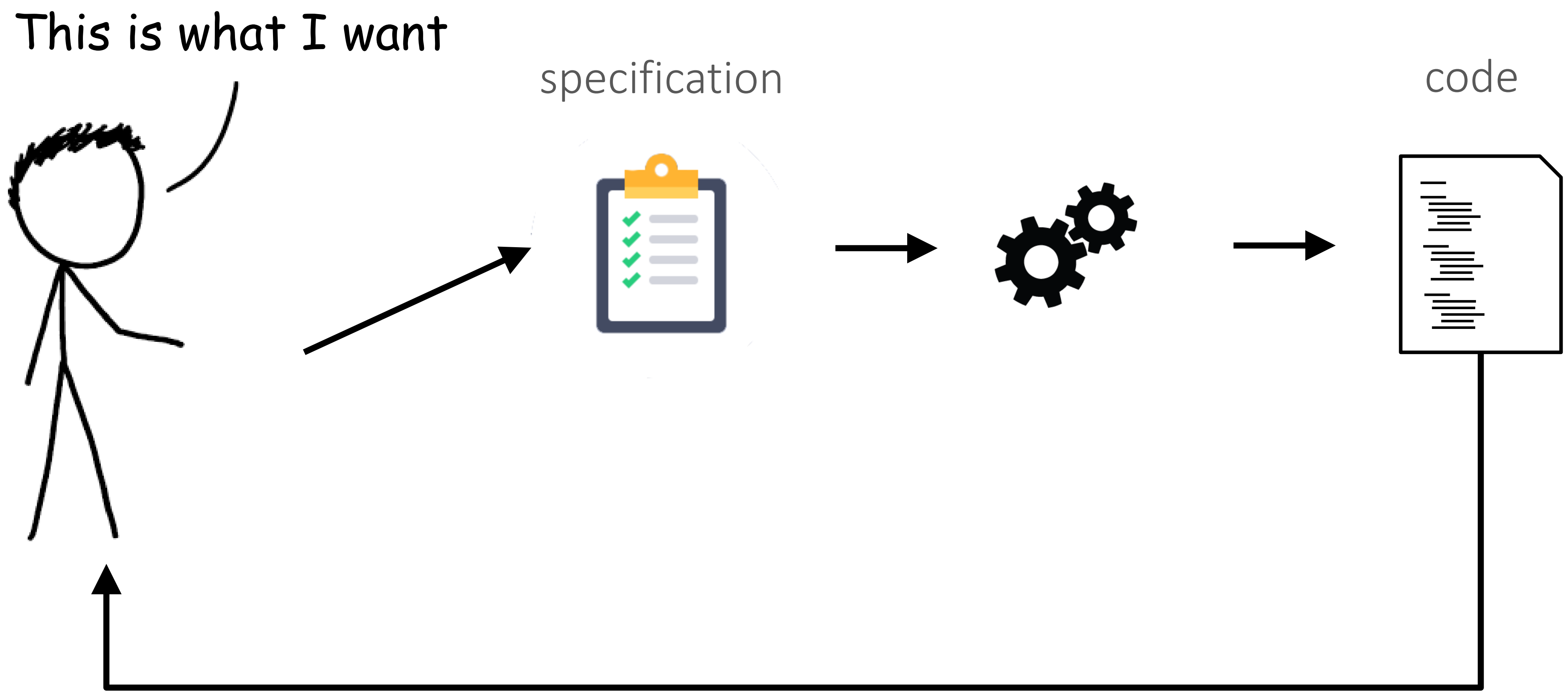
Project reports

- Due on Mar 22 (start early!)
- Format: see course organization page (3-5 pages, ACM format)

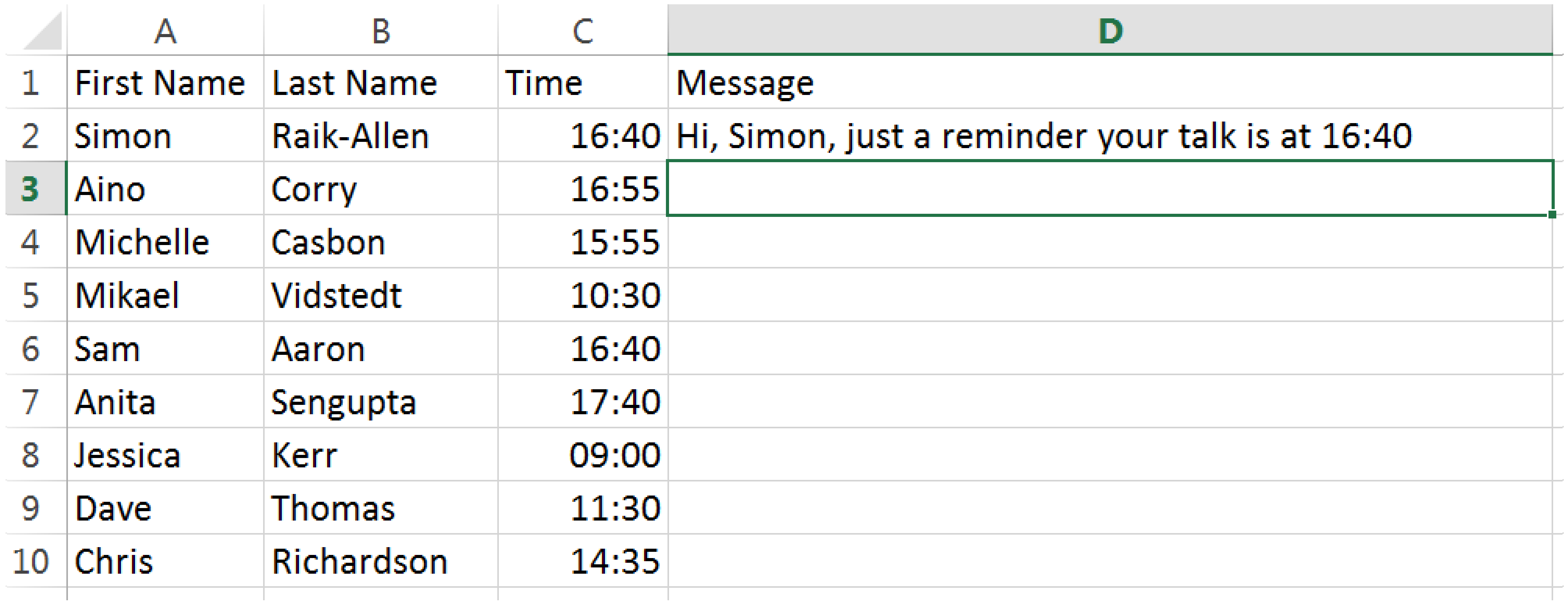
What we've seen so far



The big picture

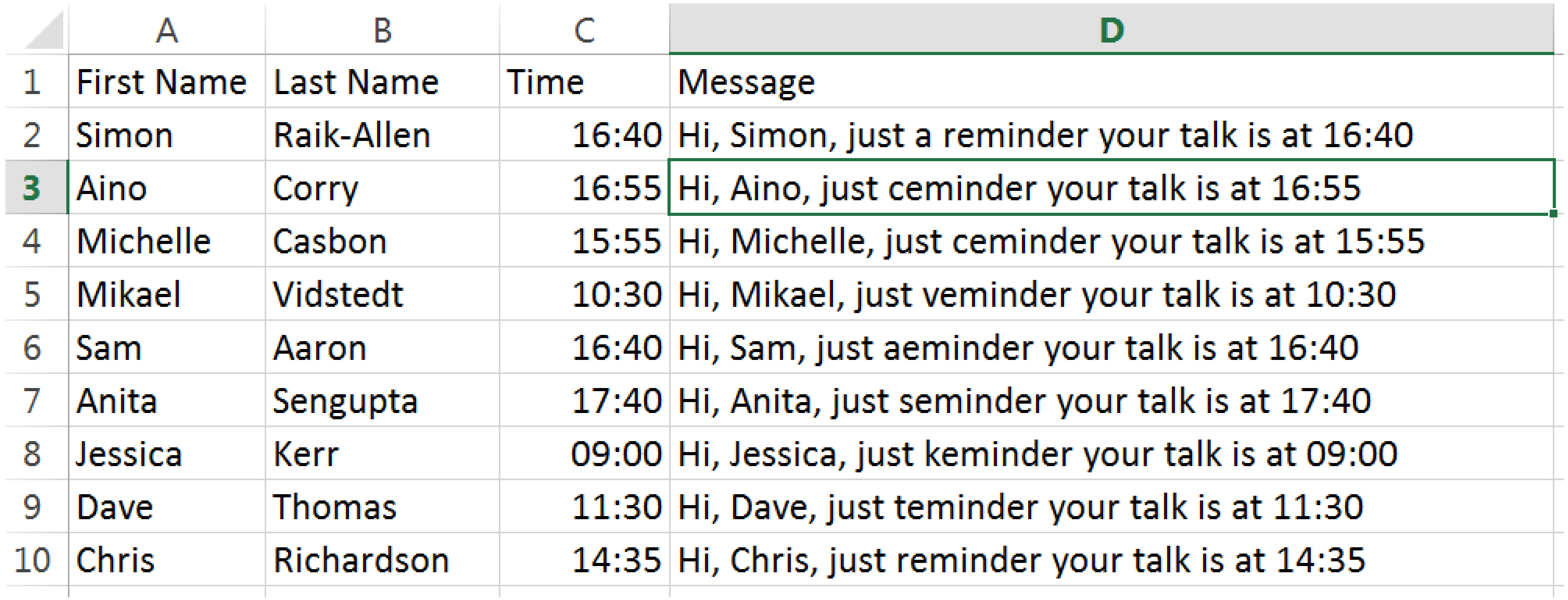


Intent via examples



	A	B	C	D
1	First Name	Last Name	Time	Message
2	Simon	Raik-Allen	16:40	Hi, Simon, just a reminder your talk is at 16:40
3	Aino	Corry	16:55	
4	Michelle	Casbon	15:55	
5	Mikael	Vidstedt	10:30	
6	Sam	Aaron	16:40	
7	Anita	Sengupta	17:40	
8	Jessica	Kerr	09:00	
9	Dave	Thomas	11:30	
10	Chris	Richardson	14:35	

Intent via examples



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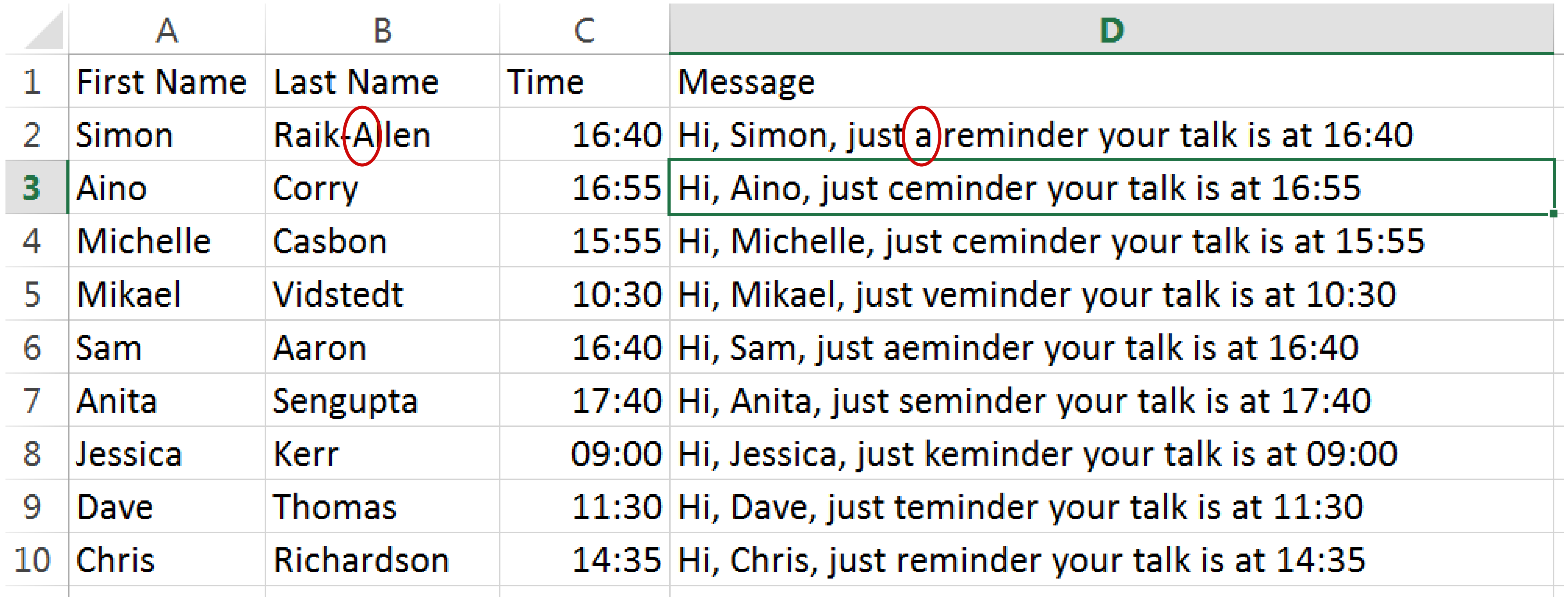
Intent via examples



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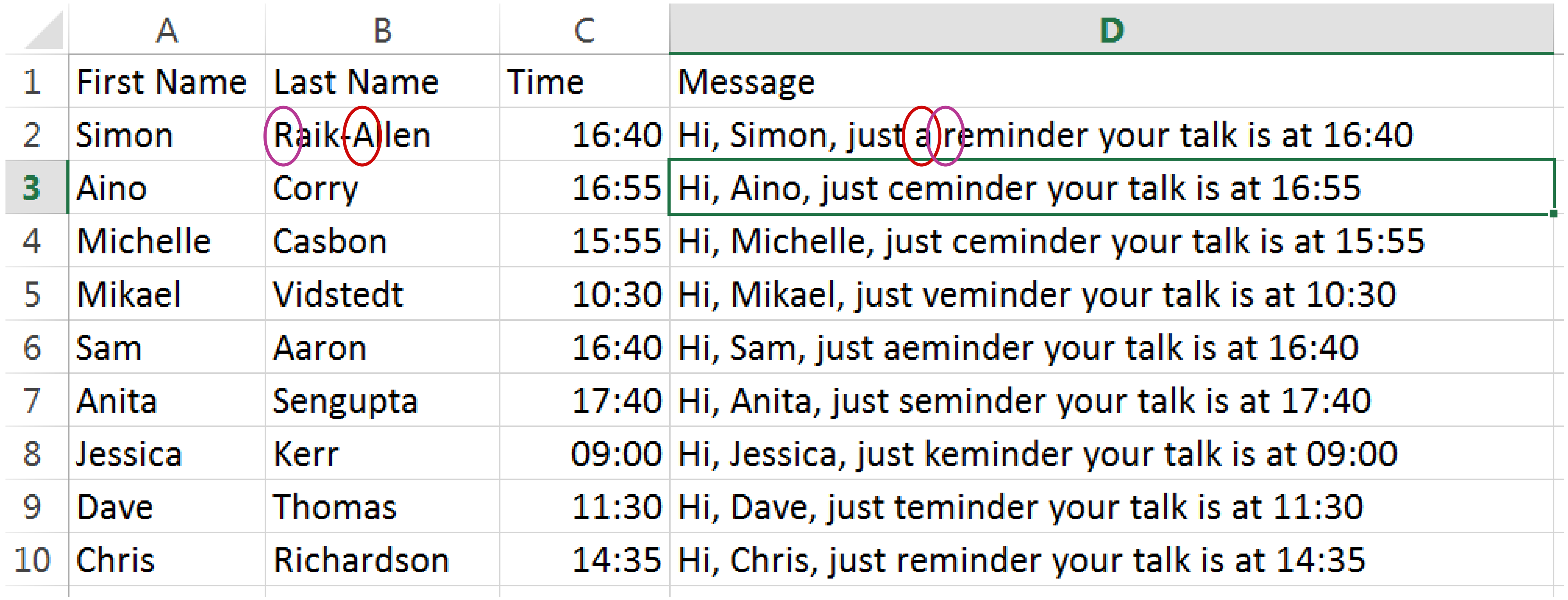
Intent via examples



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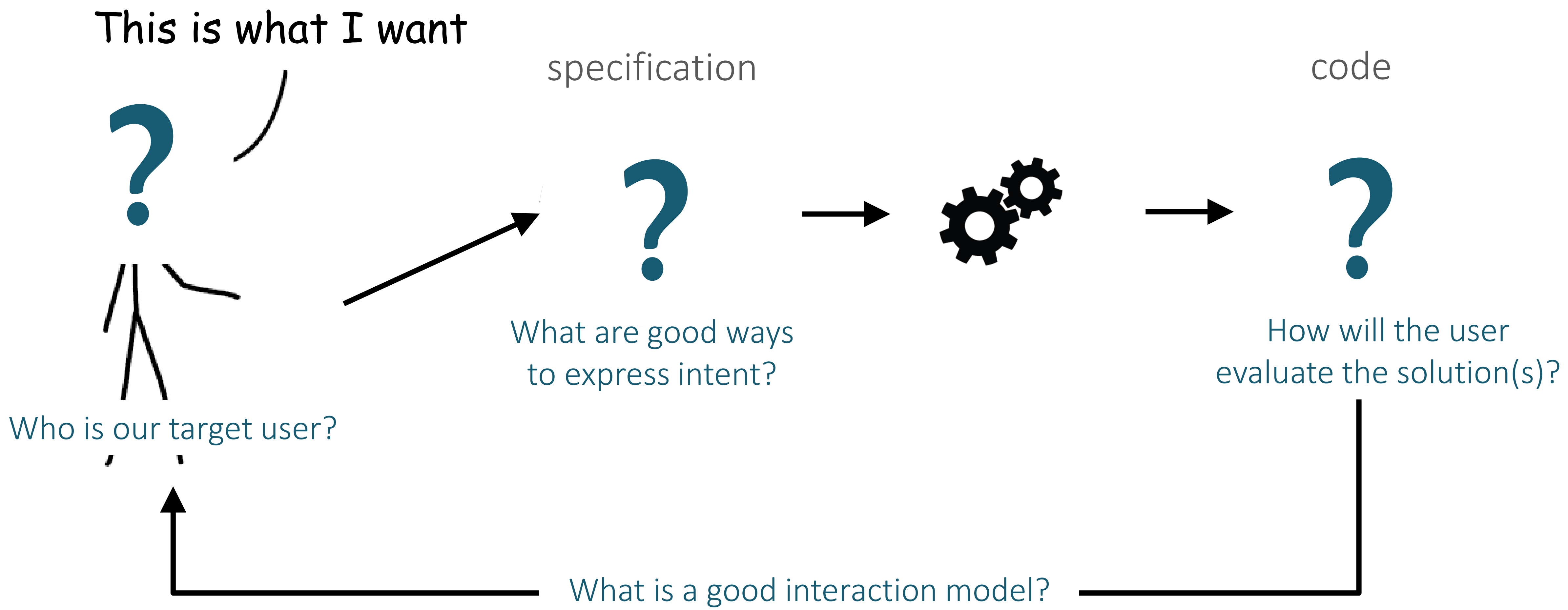
The big picture


This is what I want
specification
code
What are good ways to express intent?
How will the user evaluate the solution(s)?
Who is our target user?
What is a good interaction model?

This week

Today: synthesis for programmers

- Snippy [Ferdowsifard et al, UIST’20; OOPLSA’21]
- Hoogle+ [James et al, OOPSLA’20]
- RESL [Peleg et al, OOPLSA’20; Peleg et al, ICSE’18]

Thursday: synthesis for non-programmers

- Rousillon [Chasins, Meuller, Bodik, UIST’18]
- Wrex [Drosos et al, CHI’20]
- Regae [Zhang et al, UIST’20]

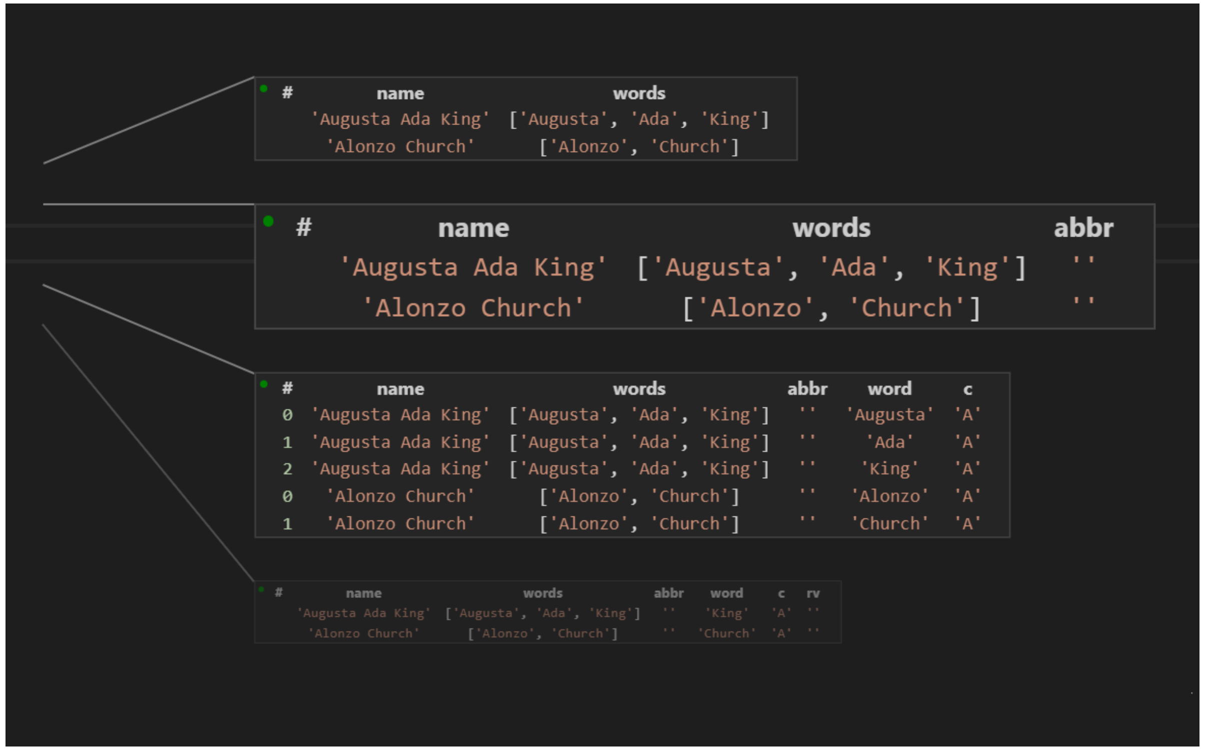
Snippy

[Ferdowsifard et al, UIST'20]

Live Programming + Programming by Example

Live Programming

Visualize program state



#	name	words
	'Augusta Ada King'	['Augusta', 'Ada', 'King']
	'Alonzo Church'	['Alonzo', 'Church']

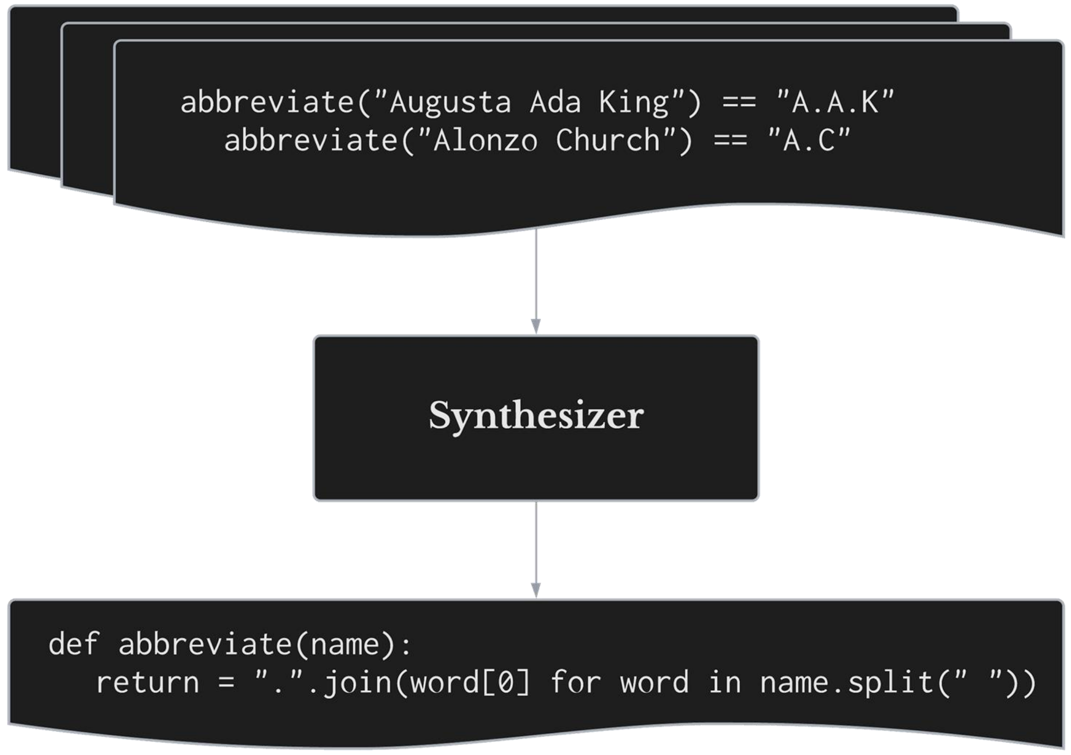
#	name	words	abbr
	'Augusta Ada King'	['Augusta', 'Ada', 'King']	''
	'Alonzo Church'	['Alonzo', 'Church']	''

#	name	words	abbr	word	c
0	'Augusta Ada King'	['Augusta', 'Ada', 'King']	''	'Augusta'	'A'
1	'Augusta Ada King'	['Augusta', 'Ada', 'King']	''	'Ada'	'A'
2	'Augusta Ada King'	['Augusta', 'Ada', 'King']	''	'King'	'A'
0	'Alonzo Church'	['Alonzo', 'Church']	''	'Alonzo'	'A'
1	'Alonzo Church'	['Alonzo', 'Church']	''	'Church'	'A'

#	name	words	abbr	word	c	rv
	'Augusta Ada King'	['Augusta', 'Ada', 'King']	''	'King'	'A'	''
	'Alonzo Church'	['Alonzo', 'Church']	''	'Church'	'A'	''

Programming By Example

Generate programs from examples

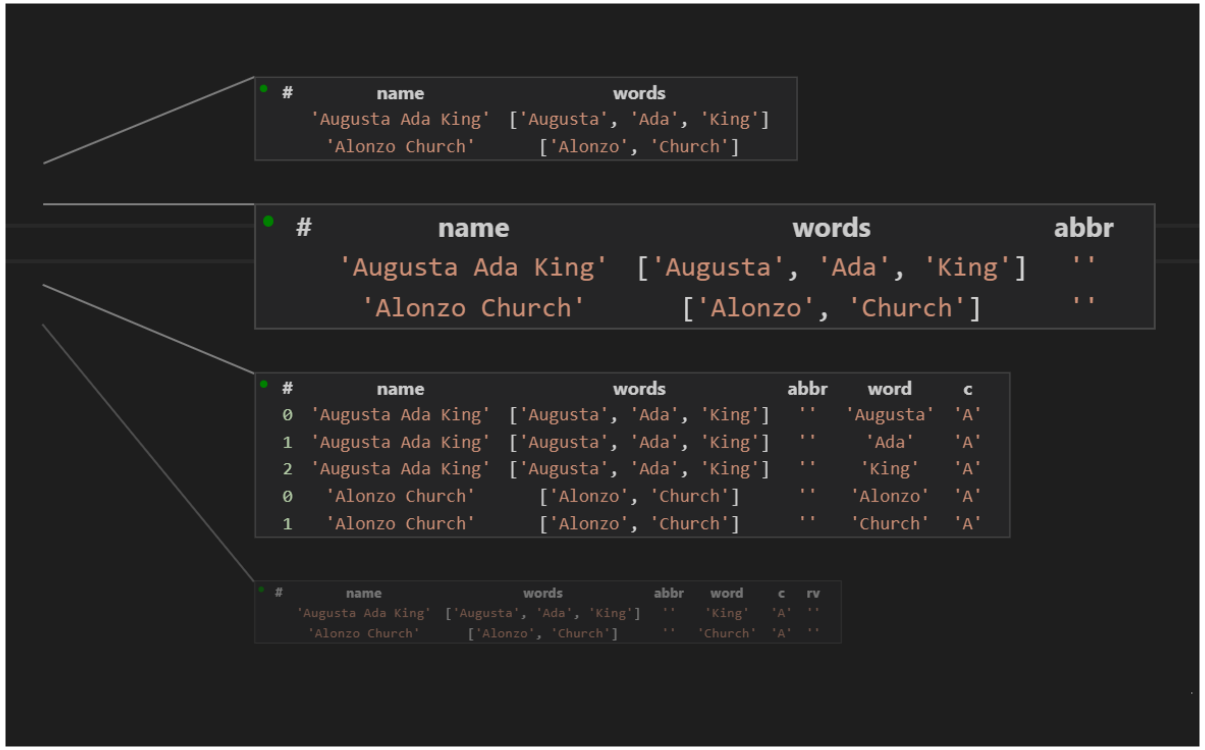


```
abbreviate("Augusta Ada King") == "A.A.K"
  abbreviate("Alonzo Church") == "A.C"
```

```
def abbreviate(name):
   return = ".".join(word[0] for word in name.split(" "))
```

Live Programming

Visualize program state



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	'Alonzo Church'	['Alonzo', 'Church']

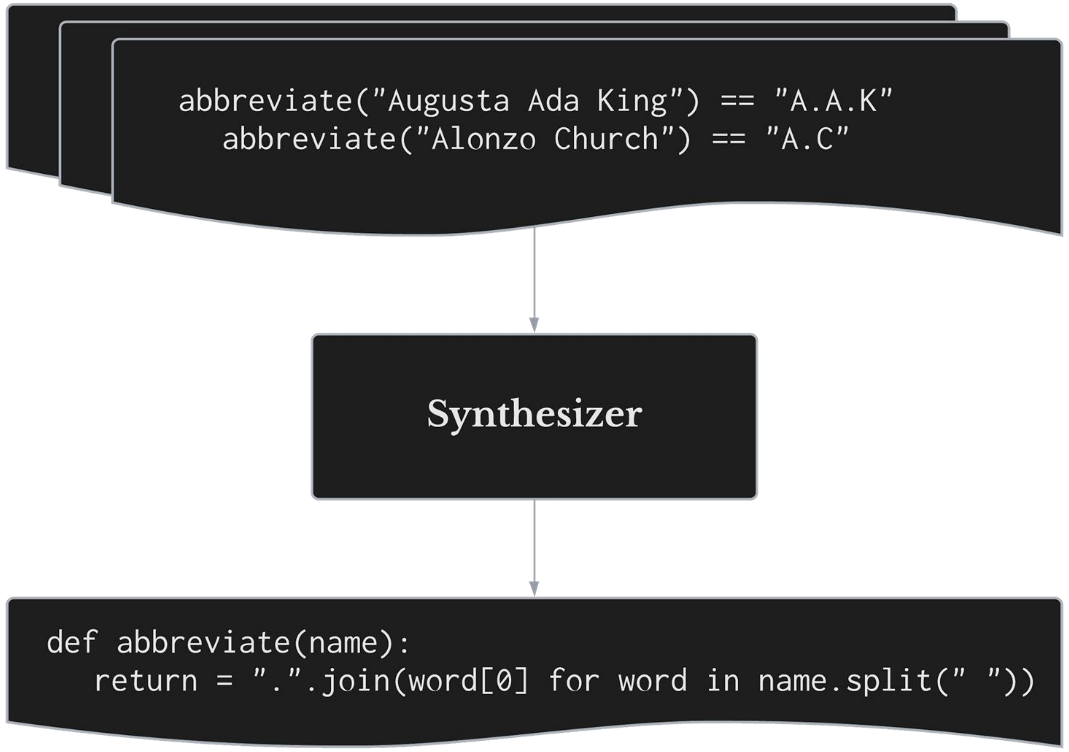
#	name	words	abbr
	'Augusta Ada King'	['Augusta', 'Ada', 'King']	''
	'Alonzo Church'	['Alonzo', 'Church']	''

#	name	words	abbr	word	c
0	'Augusta Ada King'	['Augusta', 'Ada', 'King']	''	'Augusta'	'A'
1	'Augusta Ada King'	['Augusta', 'Ada', 'King']	''	'Ada'	'A'
2	'Augusta Ada King'	['Augusta', 'Ada', 'King']	''	'King'	'A'
0	'Alonzo Church'	['Alonzo', 'Church']	''	'Alonzo'	'A'
1	'Alonzo Church'	['Alonzo', 'Church']	''	'Church'	'A'

#	name	words	abbr	word	c	rv
	'Augusta Ada King'	['Augusta', 'Ada', 'King']	''	'King'	'A'	''
	'Alonzo Church'	['Alonzo', 'Church']	''	'Church'	'A'	''

Programming By Example

Generate programs from examples



```
abbreviate("Augusta Ada King") == "A.A.K"
  abbreviate("Alonzo Church") == "A.C"
```

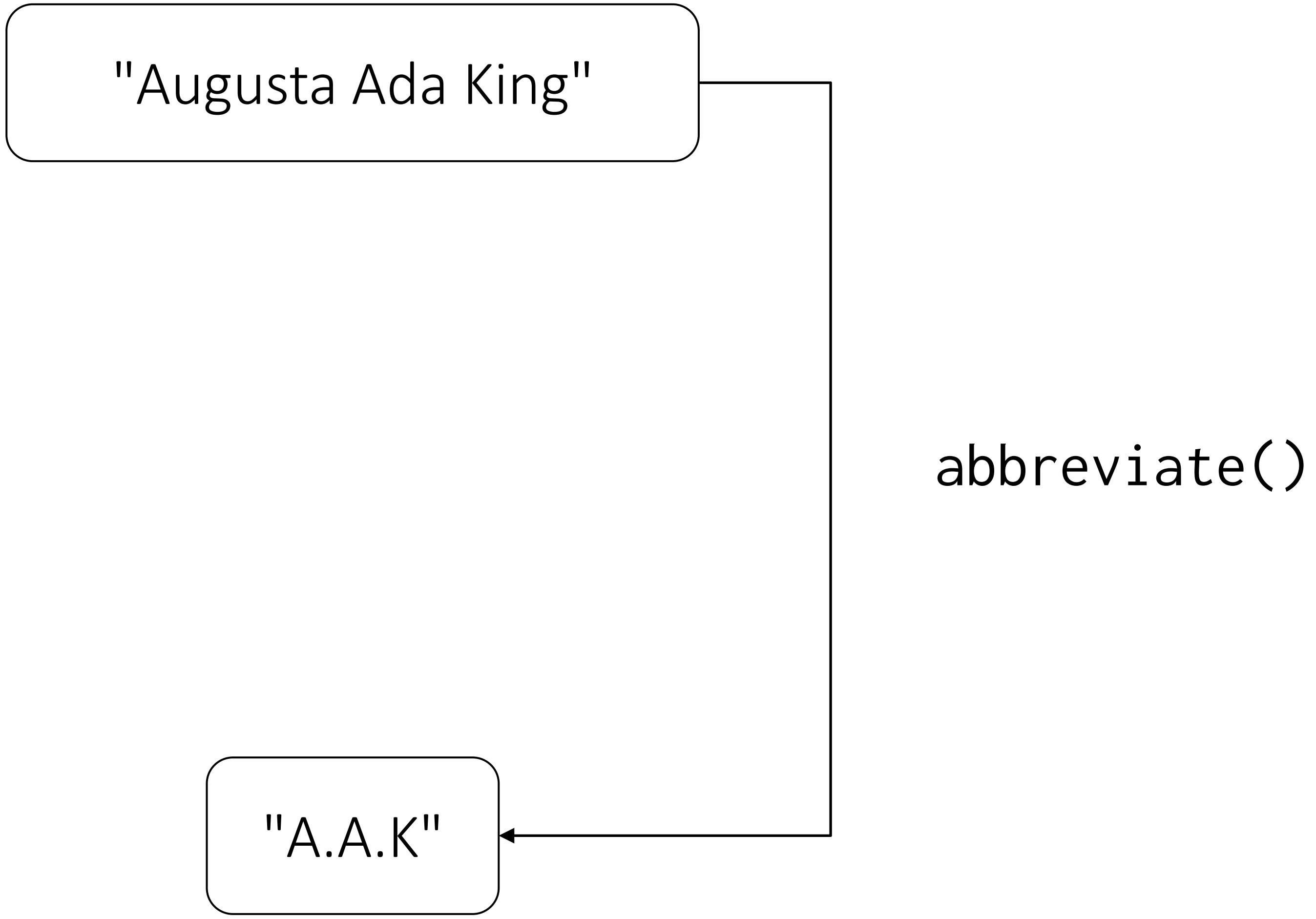
```
def abbreviate(name):
   return = ".".join(word[0] for word in name.split(" "))
```

Snippy

Idea: Live Programming is a great environment for synthesis

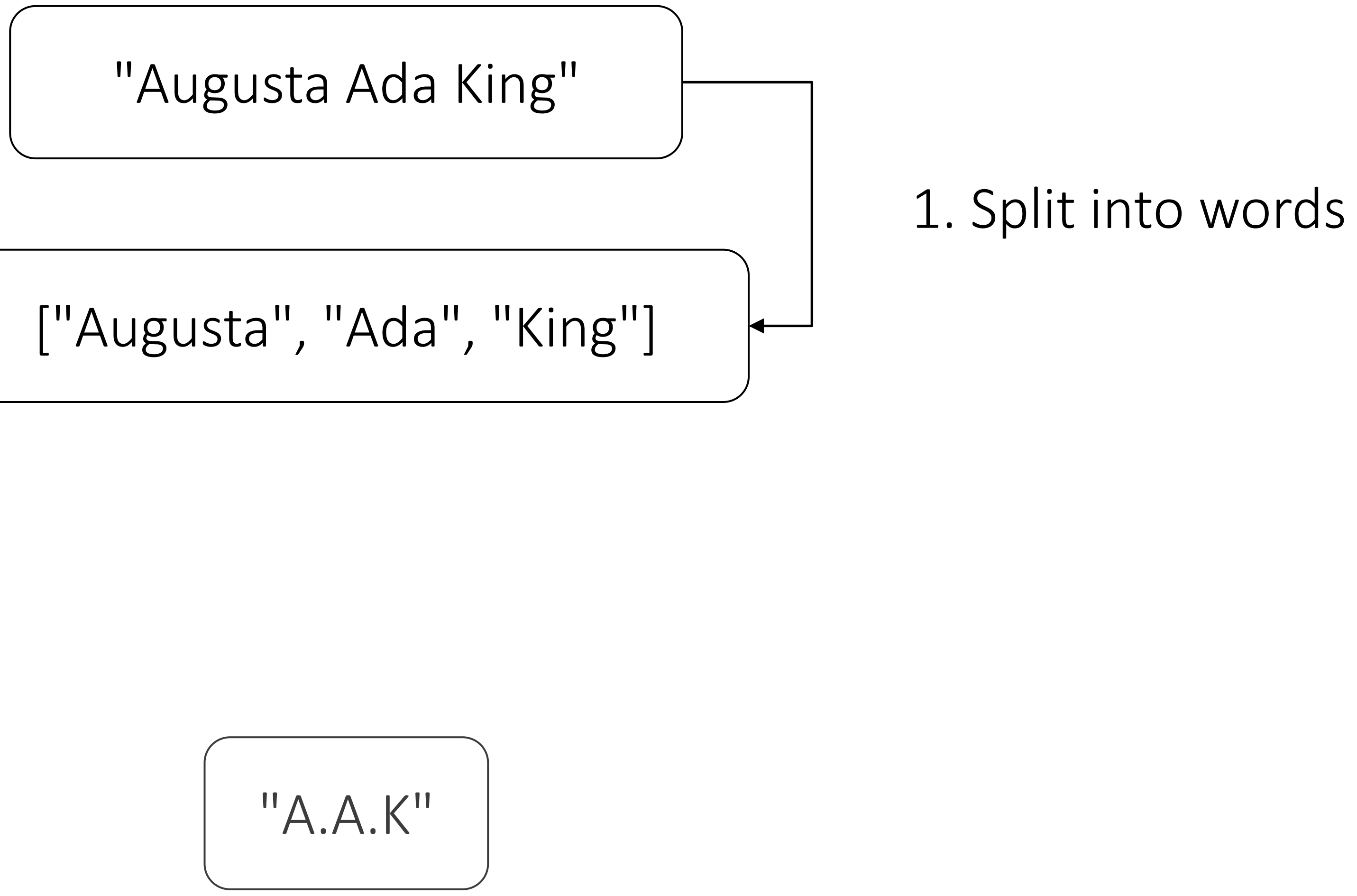
- inputs are already there (only need to add output)
- encourages “small-step” PBE (easier for the synthesizer)

Problem: Abbreviate*



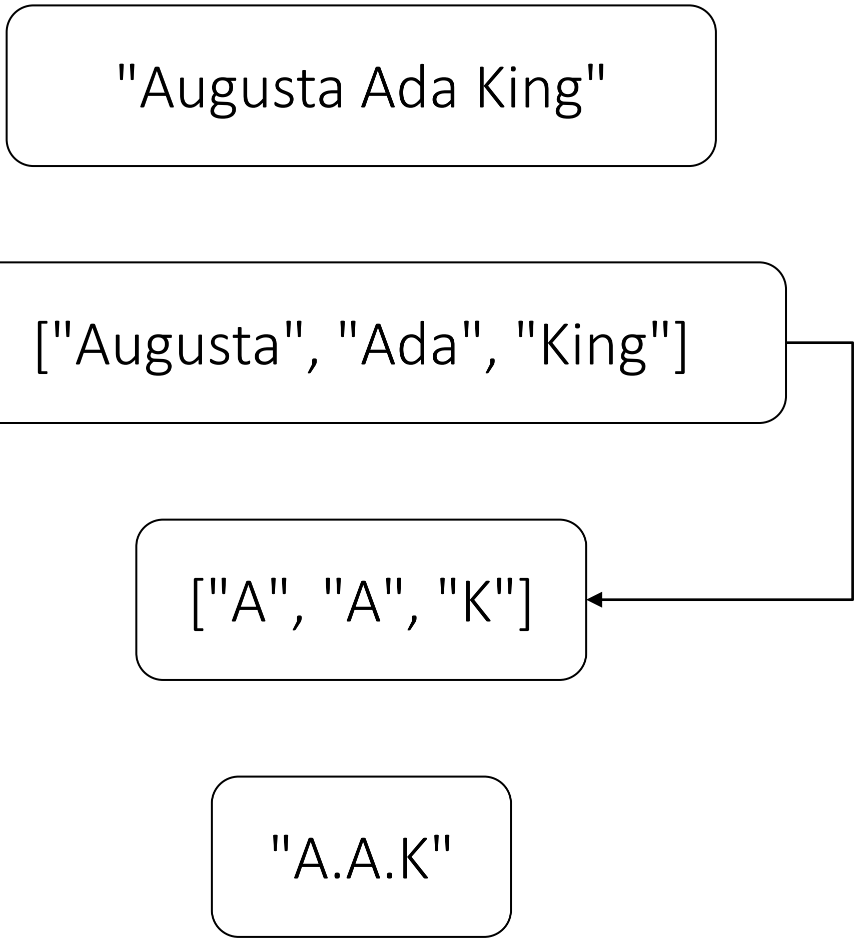
* https://www.codewars.com/kata/57eadb7ecd143f4c9c0000a3

Problem: Abbreviate*



* https://www.codewars.com/kata/57eadb7ecd143f4c9c0000a3

Problem: Abbreviate*

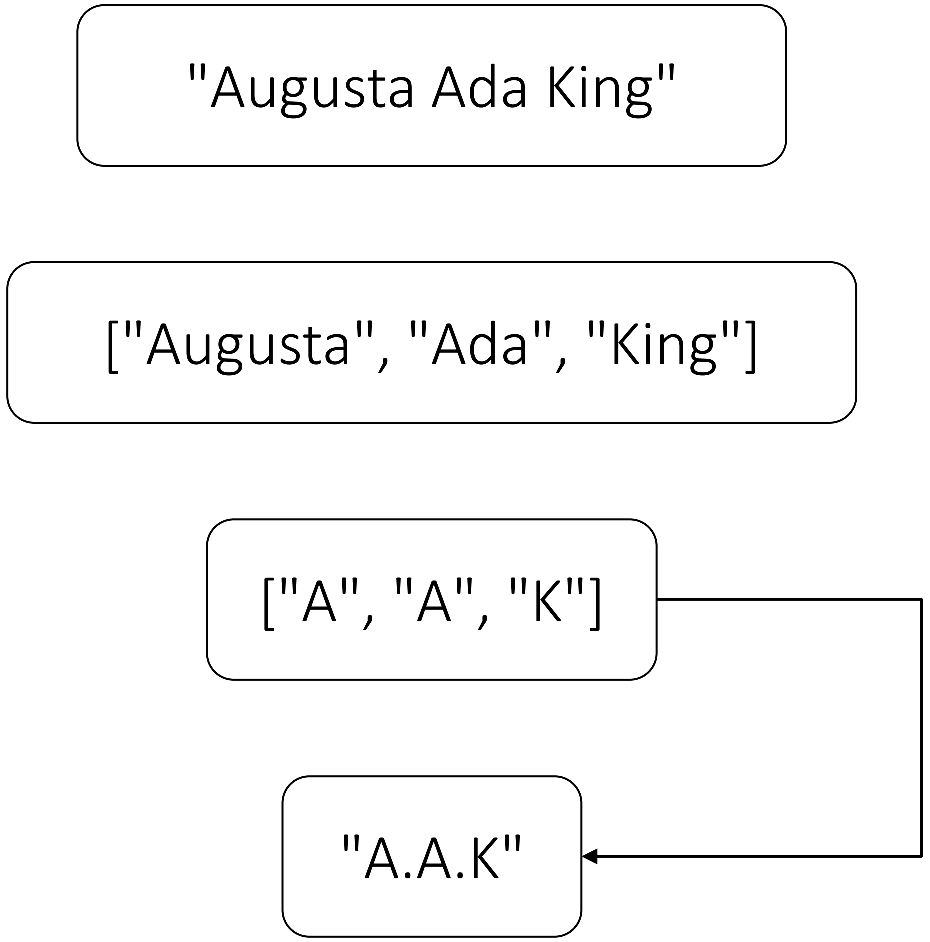


1. Split into words

2. Get the first letter of each

* https://www.codewars.com/kata/57eadb7ecd143f4c9c0000a3

Problem: Abbreviate*



```
"Augusta Ada King"

["Augusta", "Ada", "King"]

["A", "A", "K"]

"A.A.K"
```

1. Split into words

2. Get the first letter of each

3. Put dots in between

* https://www.codewars.com/kata/57eadb7ecd143f4c9c0000a3

Problem: Abbreviate*

"Augusta Ada King"

["Augusta", "Ada", "King"]

["A", "A", "K"]

"A.A.K"

1. Split into words
2. Get the first letter of each
3. Put dots in between

* https://www.codewars.com/kata/57eadb7ecd143f4c9c0000a3

User Study

- Within-subject study of 13 participants
- 4 programming tasks in 2 pairs
- Two groups:
    - SnipPy
    - Projection Boxes + Web Browser

SnipPy vs. The Internet

- More limited

+ Faster

+ Lower cognitive burden

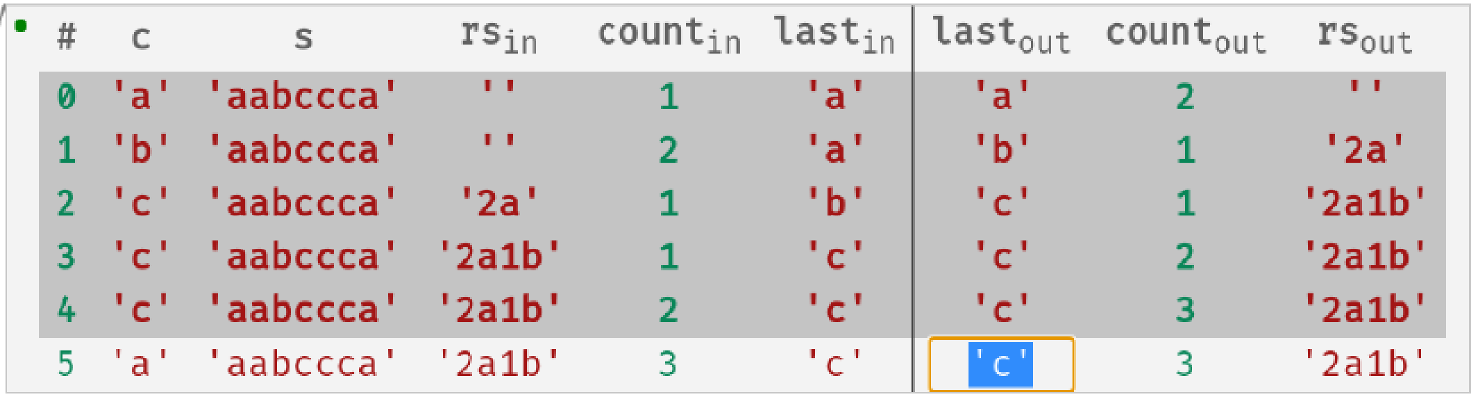
+ More compact solutions

Loopy

[Ferdowsifard et al, OOPSLA’21]

Snippy for loop bodies

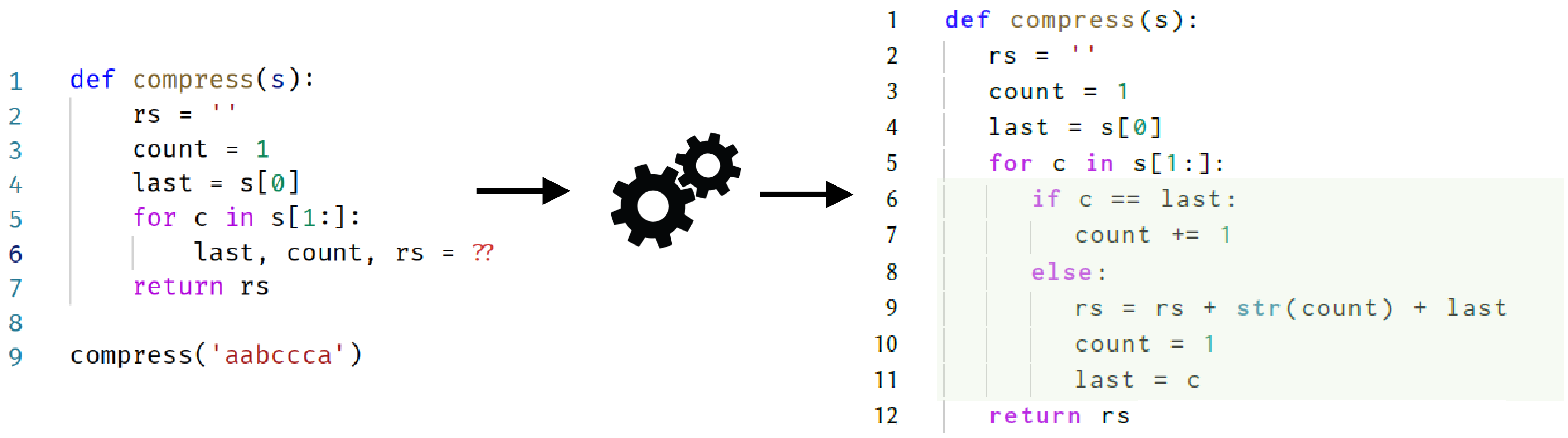
```
def compress(s):
    rs = ''
    count = 1
    last = s[0]
    for c in s[1:]:
        last, count, rs = ??
    return rs

compress('aabccca')
```



#	c	s	rs_{in}	$count_{in}$	$last_{in}$	$last_{out}$	$count_{out}$	rs_{out}
0	'a'	'aabccca'	''	1	'a'	'a'	2	''
1	'b'	'aabccca'	''	2	'a'	'b'	1	'2a'
2	'c'	'aabccca'	'2a'	1	'b'	'c'	1	'2a1b'
3	'c'	'aabccca'	'2a1b'	1	'c'	'c'	2	'2a1b'
4	'c'	'aabccca'	'2a1b'	2	'c'	'c'	3	'2a1b'
5	'a'	'aabccca'	'2a1b'	3	'c'	'c'	3	'2a1b'

Loopy

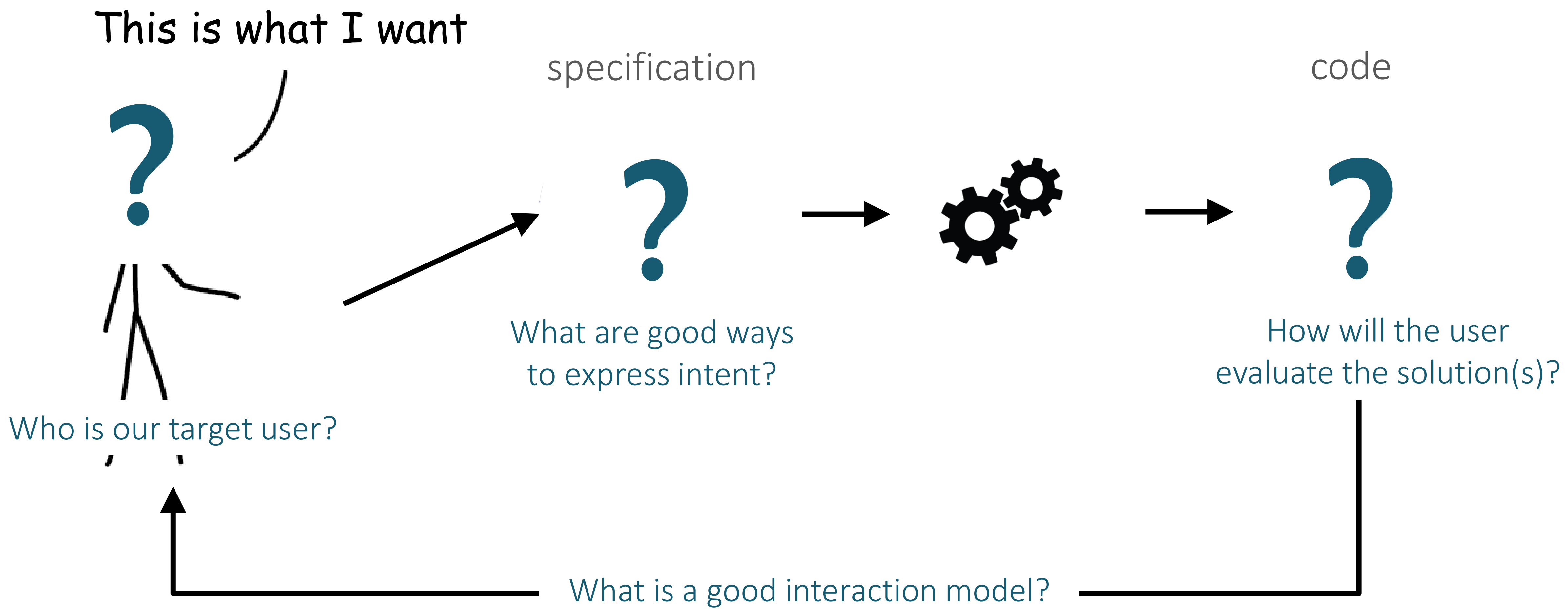
[Ferdowsifard et al, OOPSLA’21]



```python
def compress(s):
    rs = ''
    count = 1
    last = s[0]
    for c in s[1:]:
        last, count, rs = ??
    return rs

compress('aabccca')
```

```python
def compress(s):
    rs = ''
    count = 1
    last = s[0]
    for c in s[1:]:
        if c == last:
            count += 1
        else:
            rs = rs + str(count) + last
            count = 1
            last = c
    return rs
```

The big picture


This is what I want
specification
code
What are good ways to express intent?
How will the user evaluate the solution(s)?
Who is our target user?
What is a good interaction model?

Hoogle+

[James et al, OOPLSA’20]

API discovery for Haskell

Inspiration: Hoogle

Hoogλe

```
Char -> String -> [String]
```

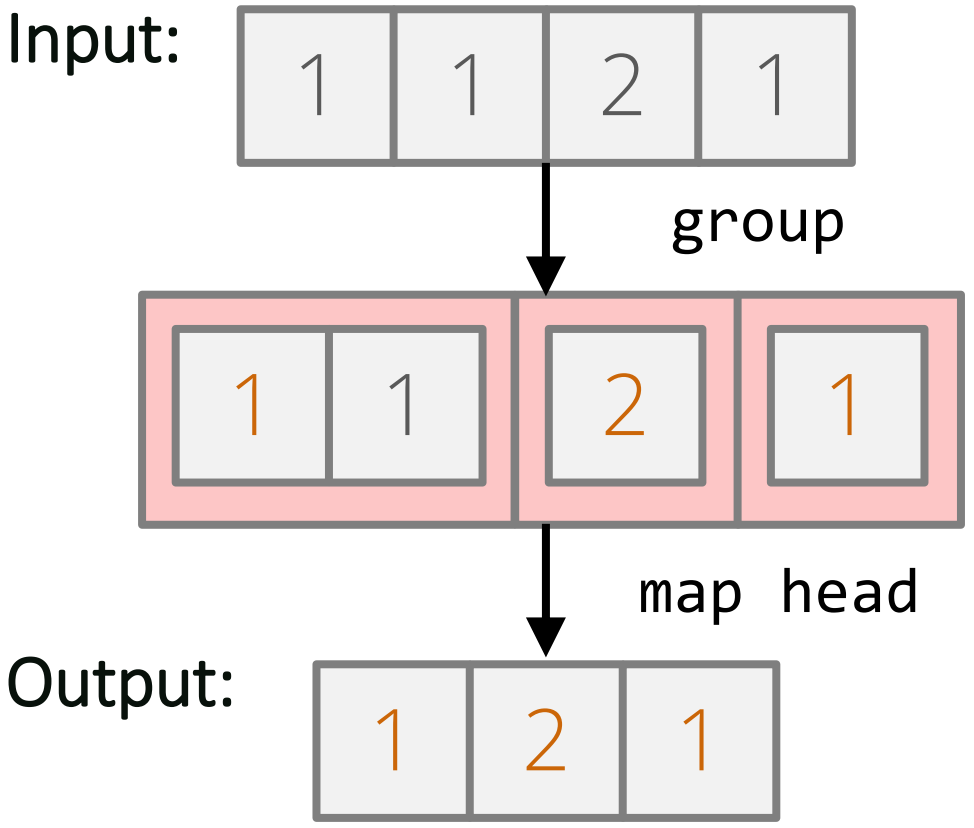
Search

```
split :: Char -> String -> [String]
```

ghc Util

cannot compose functions!

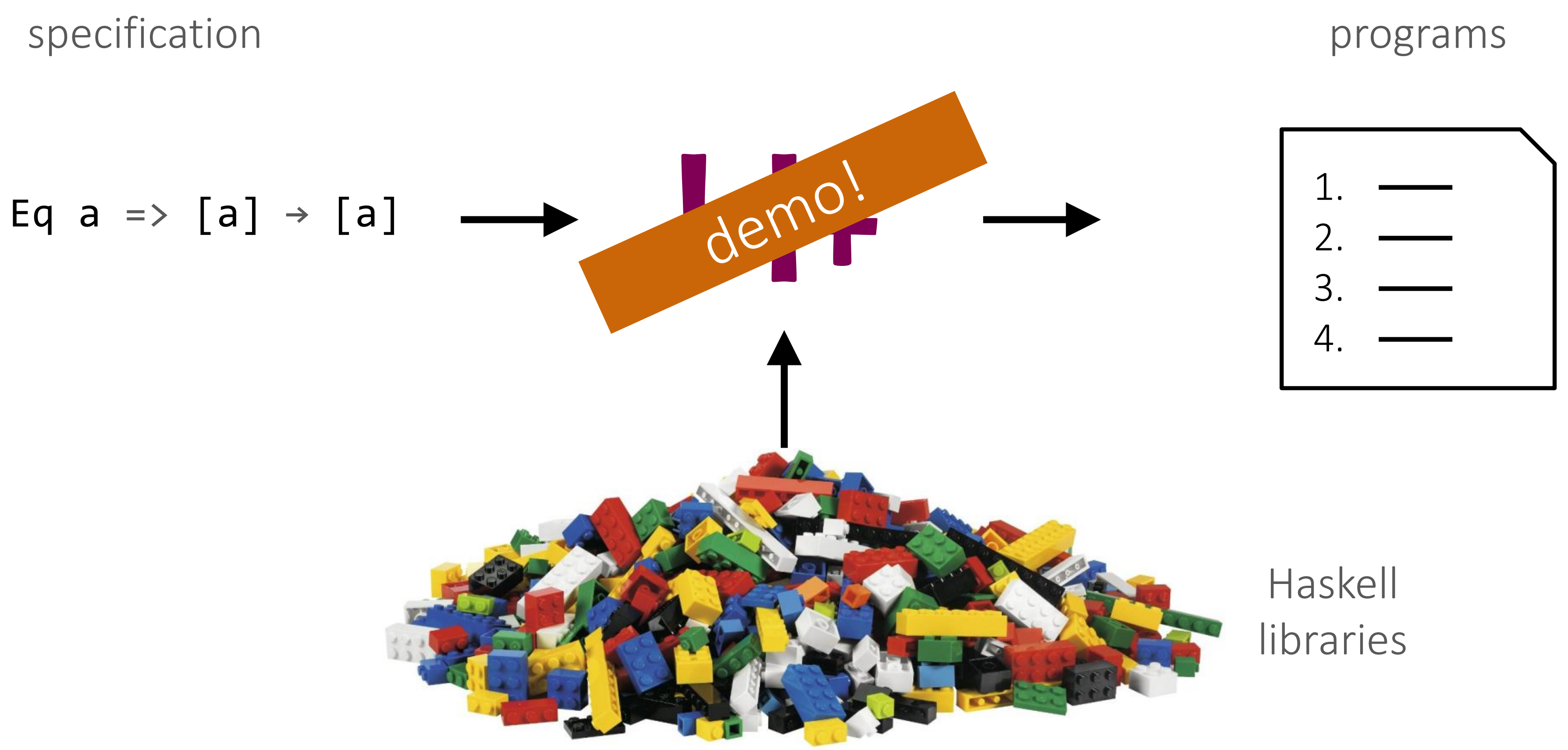
Example: compress a list



Compress: specification

```
compress ::           [a] → [a]
```

Hoogle+


specification
programs
Eq a => [a] → [a]
demo!
1.
2.
3.
4.
Haskell
libraries

Challenges

→ Types are ambiguous

Which solution is the right one?

Helping beginners with types

Too many irrelevant results

Hoogλe+

```
Eq a => [a] → [a]
```

Search

```
\xs -> []
```

❌ ignores the argument!

```
\xs -> xs
```

❌ ignores the type class!

```
\xs -> head []
```

❌ always crashes!

```
\xs -> tail xs
```

❌ ignores the type class!

Too many irrelevant results

Hoogλe+

```
Eq a => [a] → [a]
```

Search

```
\xs -> head (group xs)
```

```
\xs -> init (head (group xs))
```

```
\xs -> tail (head (group xs))
```

❌ duplicate!

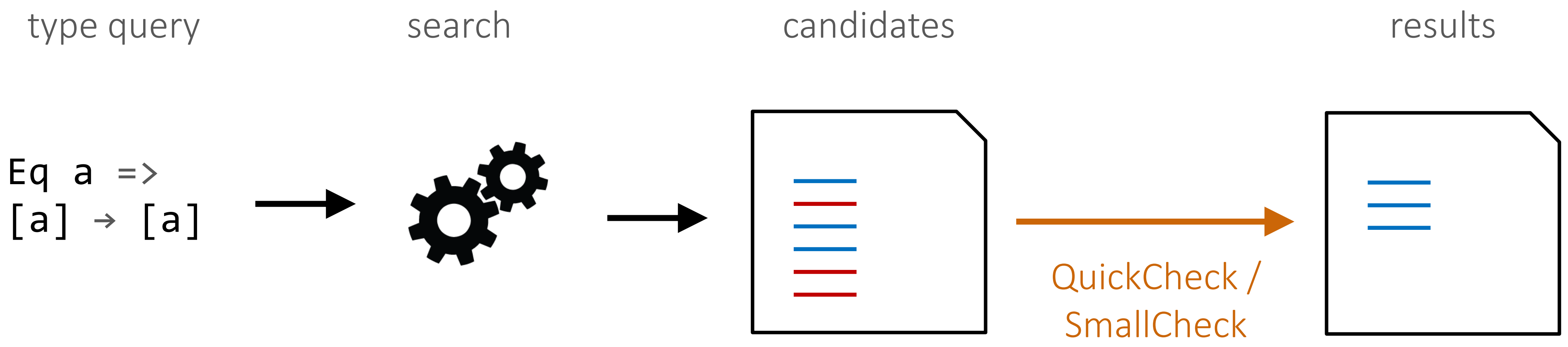
Challenges

→ Types are ambiguous
  - sometimes can fix by asking the use for IO examples
  - but not for all queries, e.g. `Int -> Bytestring`
  - should be able to filter our irrelevant results without user’s help

Which solution is the right one?

Helping beginners with types

Test-based filtering



1. does it crash on all inputs?
2. is the output always the same as another candidate?
3. does the output stay the same when changing an input?

Challenges

Types are ambiguous

→ Which solution is the right one?

Helping beginners with types

Comprehension

Hoogλe+

```
Eq a => [a] → [a]
```

Search

```
\xs -> concat (group xs)
```

```
\xs -> head (group xs)
```

```
\xs -> last (group xs)
```

```
\xs -> map head (group xs)
```

how do I know what these programs do?

Test-based comprehension

Hoogλe+

```
Eq a => [a] → [a]
```

Search

```
\xs -> concat (group xs)
[0,1]    -> [0,1]
[0,0]    -> [0,0]

\xs -> head (group xs)
[0,1]    -> [0]
[0,0]    -> [0,0]

\xs -> last (group xs)
[0,1]    -> [1]
[0,0]    -> [0,0]

\xs -> map head (group xs)    ✓
[0,1]    -> [0,1]
[0,0]    -> [0]
```

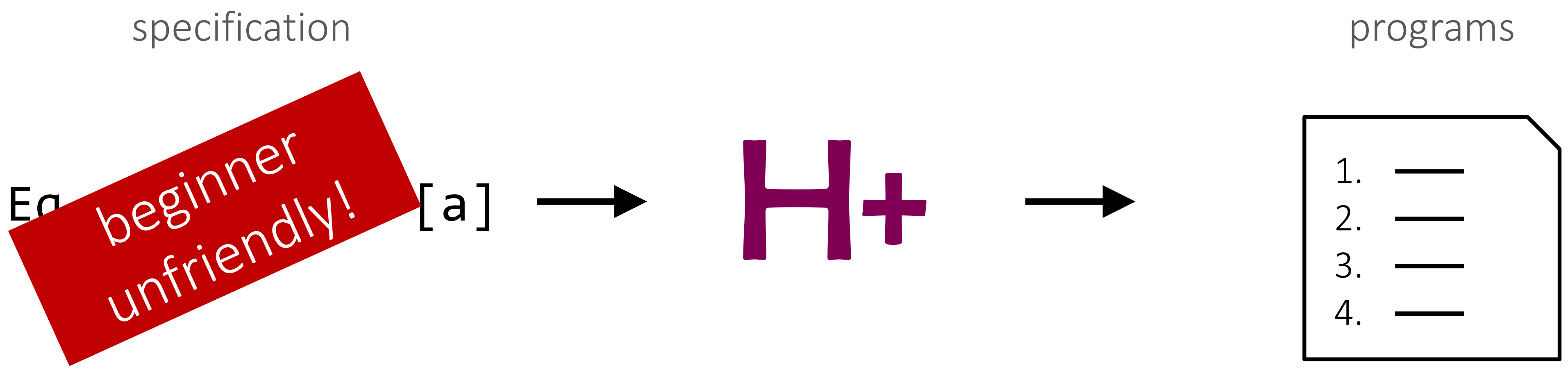
Challenges

Types are ambiguous

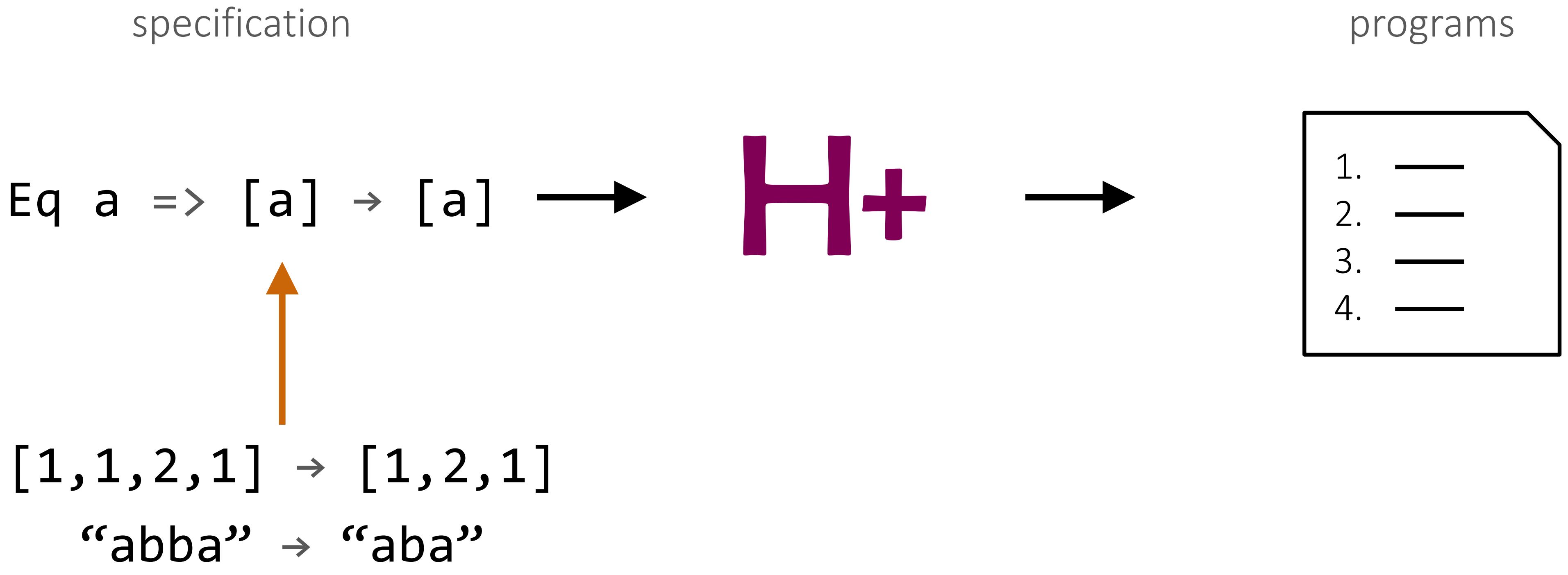
Which solution is the right one?

→ Helping beginners with types

Hoogle+



Can we infer type from tests?



Types from tests

$$\begin{tikzcd}
 & & \texttt{...} \\
\texttt{a} \to \texttt{[b]} & & \texttt{[a]} \to \texttt{b} \arrow[u] \\
 & \texttt{[a]} \to \texttt{[b]} \arrow[ul] \arrow[ur] & \\
 & \texttt{[a]} \to \texttt{[a]} \arrow[u] & \\
 & \texttt{Eq a => [a]} \to \texttt{[a]} \arrow[u] & \\
 & \texttt{Ord a => [a]} \to \texttt{[a]} \arrow[u] & \\
\texttt{[Int]} \to \texttt{[Int]} \arrow[ur] & & \texttt{[Char]} \to \texttt{[Char]} \arrow[ul] \\
\texttt{[1,1,2,1]} \to \texttt{[1,2,1]} \arrow[u, "\text{ghci}"] & & \text{“abba”} \to \text{“aba”} \arrow[u, "\text{ghci}"']
\end{tikzcd}$$

more general types

least common generalization

Types from tests

$$\begin{tikzcd}
 & & \cdots & \\
\cancel{a \to [b]} & & \cancel{[a] \to b} \arrow[u] & \text{generalizes over complex type} \\
 & \cancel{[a] \to [b]} \arrow[ul] \arrow[ur] & & \text{unreachable type variable } \mathbf{b} \\
 & {[a] \to [a]} \arrow[u] & & \\
 & \texttt{Eq a} \Rightarrow [a] \to [a] \arrow[u] & & \\
 & \texttt{Ord a} \Rightarrow [a] \to [a] \arrow[u] & & \\
{[\texttt{Int}] \to [\texttt{Int}]} \arrow[ur] & & {[\texttt{Char}] \to [\texttt{Char}]} \arrow[ul] & \\
{[1,1,2,1] \to [1,2,1]} \arrow[u] & & \text{“abba”} \to \text{“aba”} \arrow[u] &
\end{tikzcd}$$

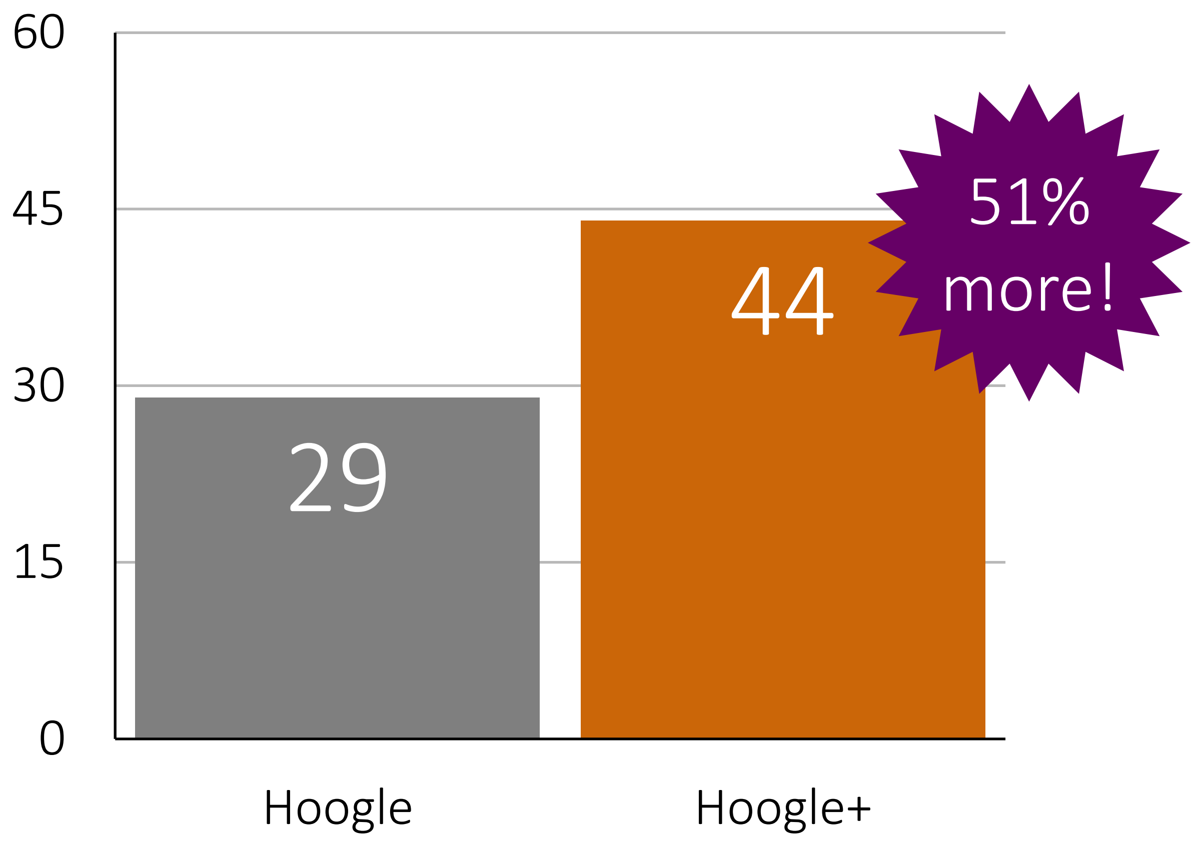
User study

30 participants

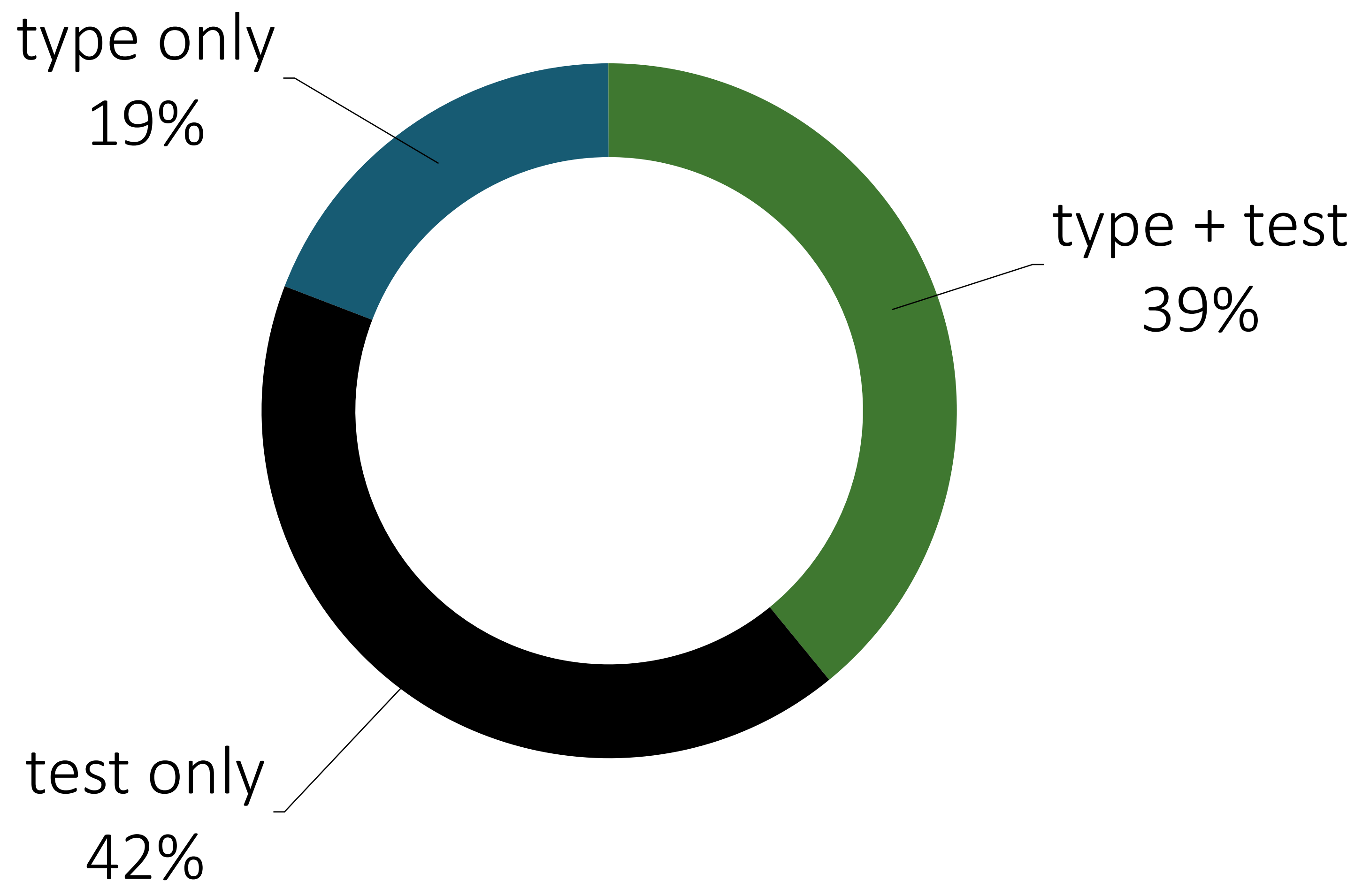
4 tasks

2 with Hoogle, then 2 with Hoogle+

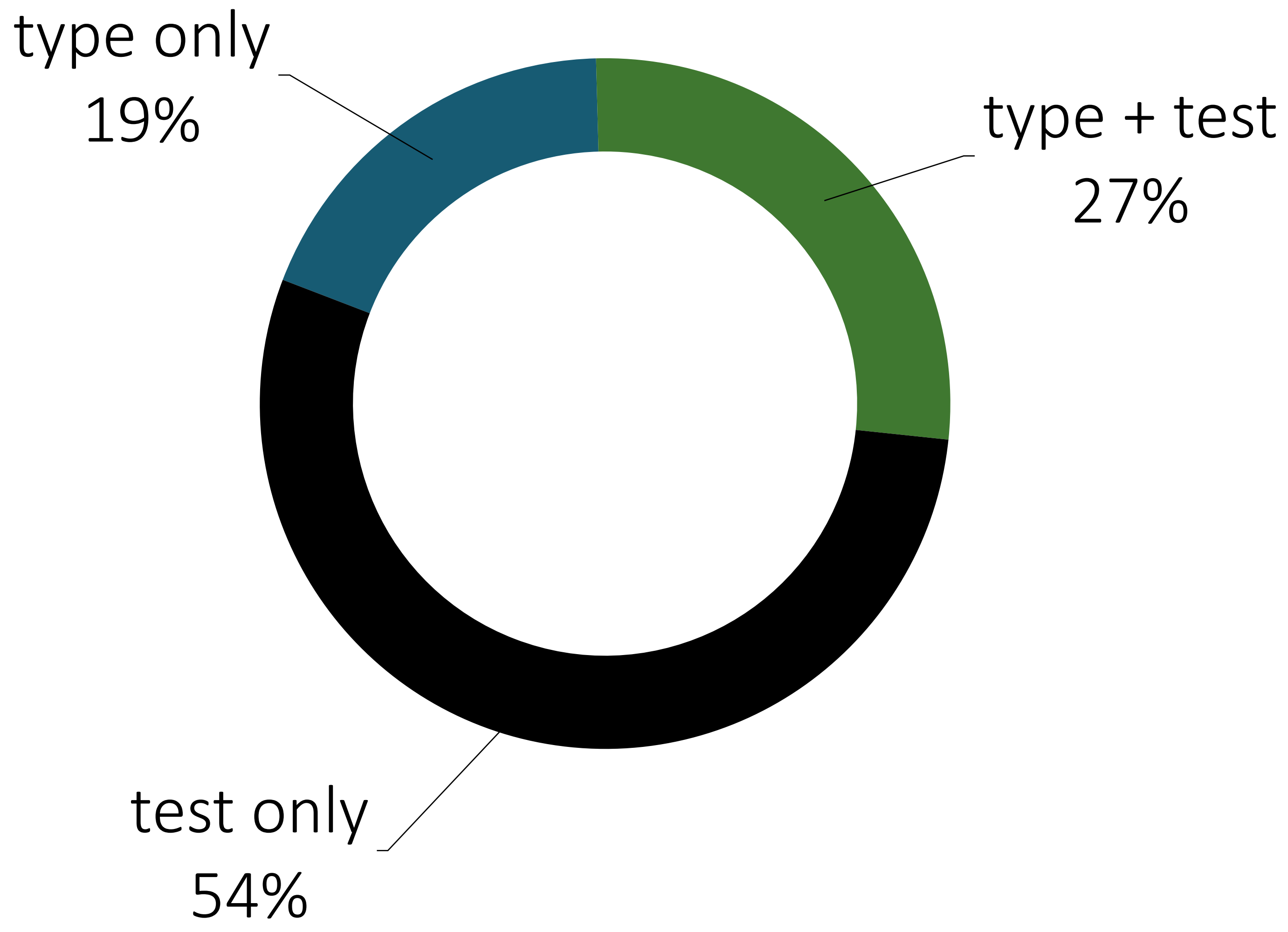
Results: completed tasks



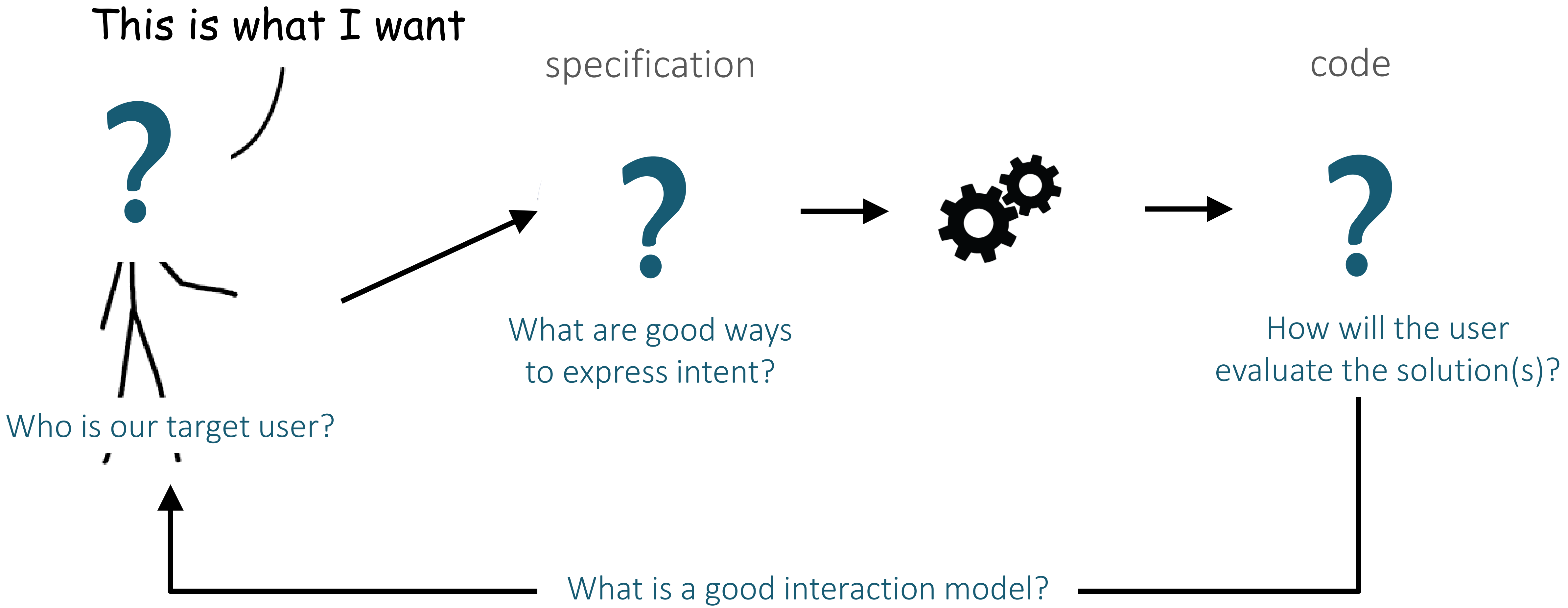
Modes of specification



Modes of specification: beginners



The big picture


This is what I want
specification
code
What are good ways to express intent?
How will the user evaluate the solution(s)?
Who is our target user?
What is a good interaction model?

RESL

[Peleg et al, OOPSLA’20]

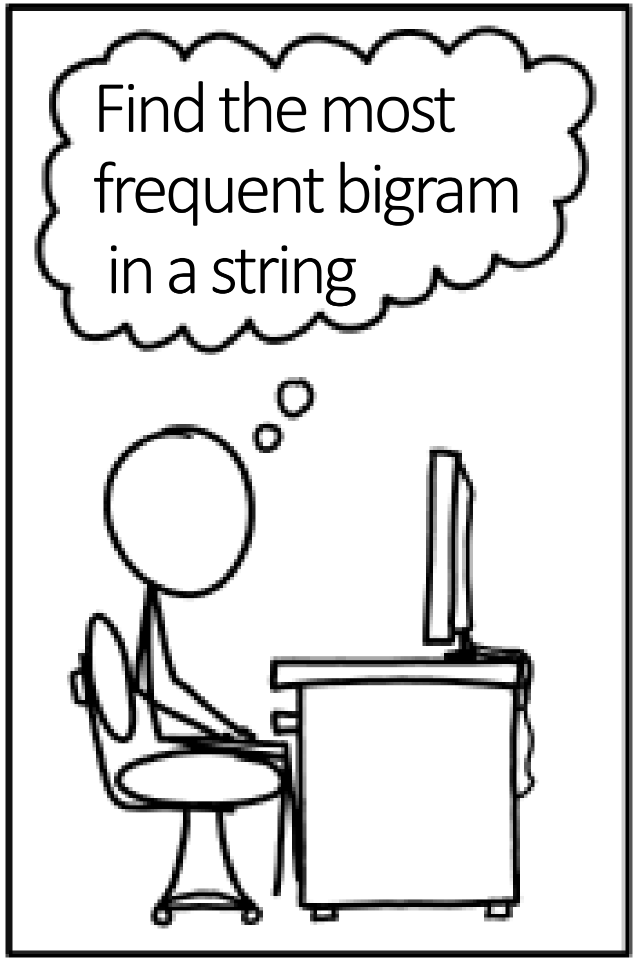
Synthesis embedded into a REPL

→ = syntactic specs (aka granular interaction model)

+ sketching

+ debugger

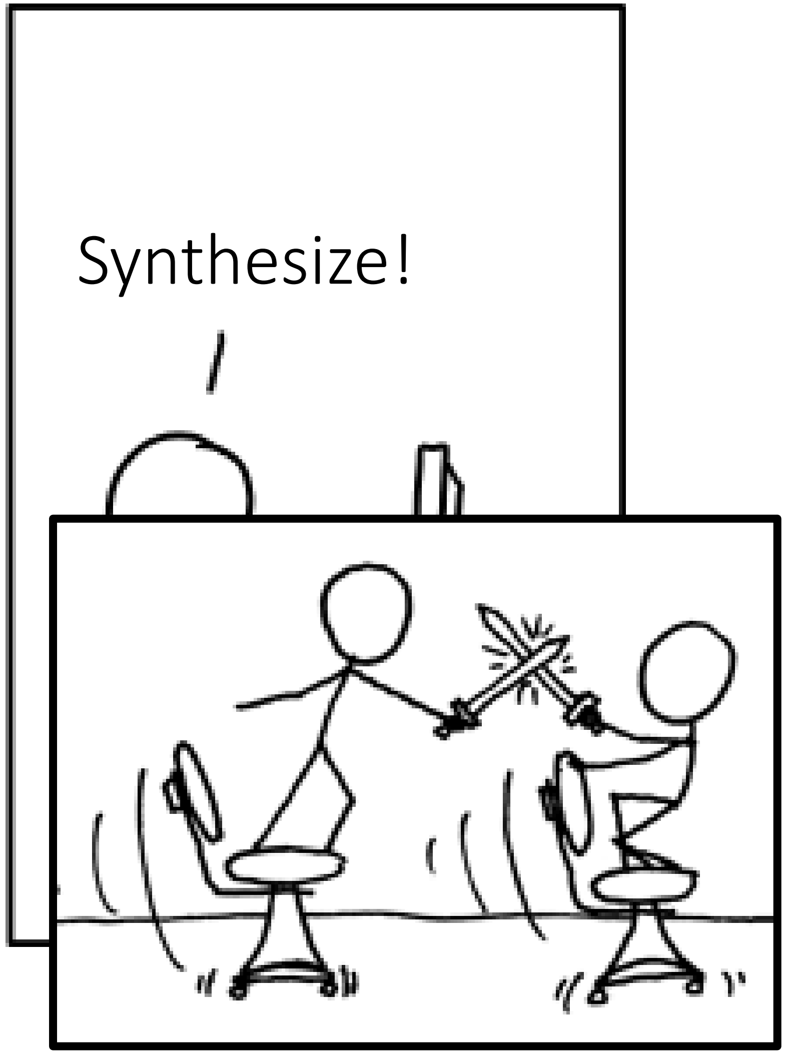
Programming by Example



An example of the desired behavior:

Input:
"a**bd**fibfcfde**bd**fd
e**bd**ihgfkjfde**bd**"

Output: "bd"

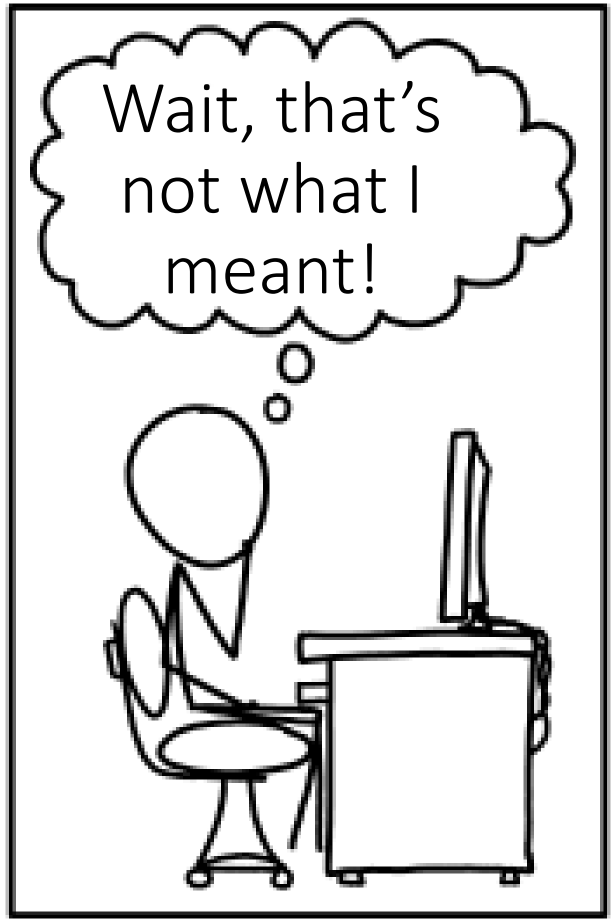


Examples are ambiguous

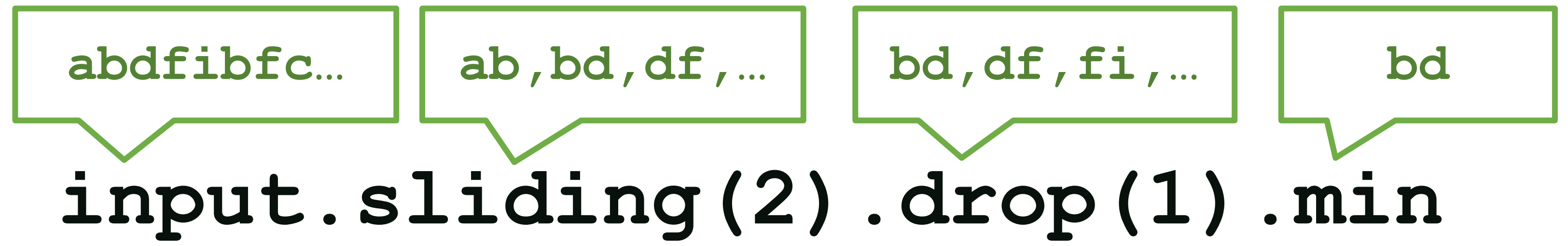
Input:
`"abdfibfcfdebdfd`
`ebdihgfkjfdebd"`

Output: `"bd"`

```
input
.takeRight(2)
```

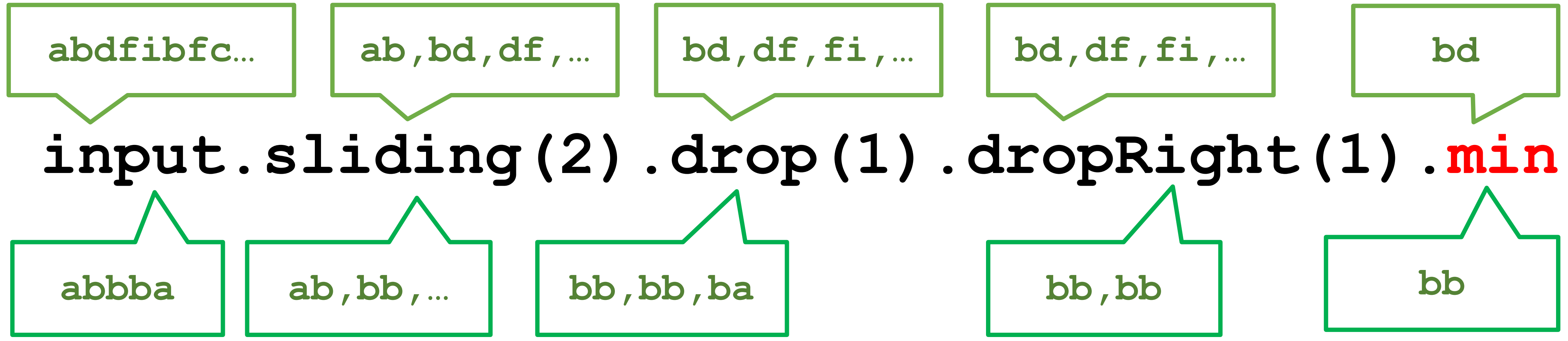


Problem with examples



```
input.sliding(2).drop(1).min
```

Input: "abbba", Output: "bb"



```
input.sliding(2).drop(1).dropRight(1).min
```

Granular Interaction Model (GIM)

[Peleg et al, ICSE’18]

Idea: Programmers understand code

- they can give syntactic feedback about the candidate solution

Granular Interaction Model (GIM)

```
input
//ab,bd,df,…
.sliding(2)
//bd,df,fi,…
.drop(1)
//bd
.min
```

That looks right

Those are wrong

Granular feedback

Exclude

`exclude(f.g.h)`: never show programs of the form `input.….f.g.h.…`

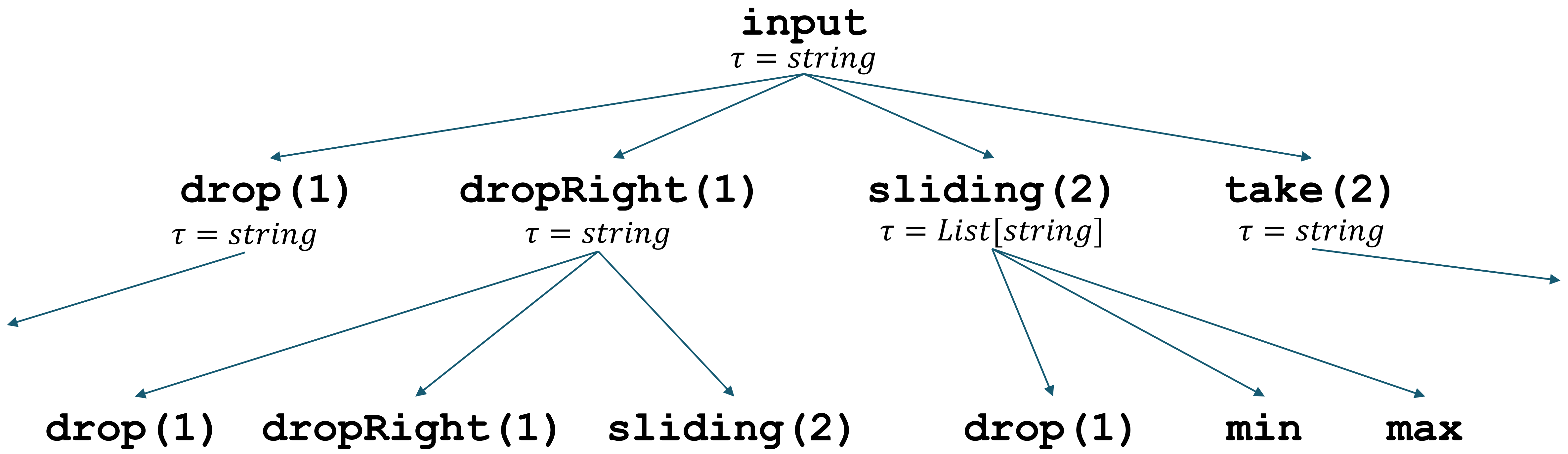
Retain

`retain(f.g.h)`: only show programs of the form `input.….f.g.h.…`

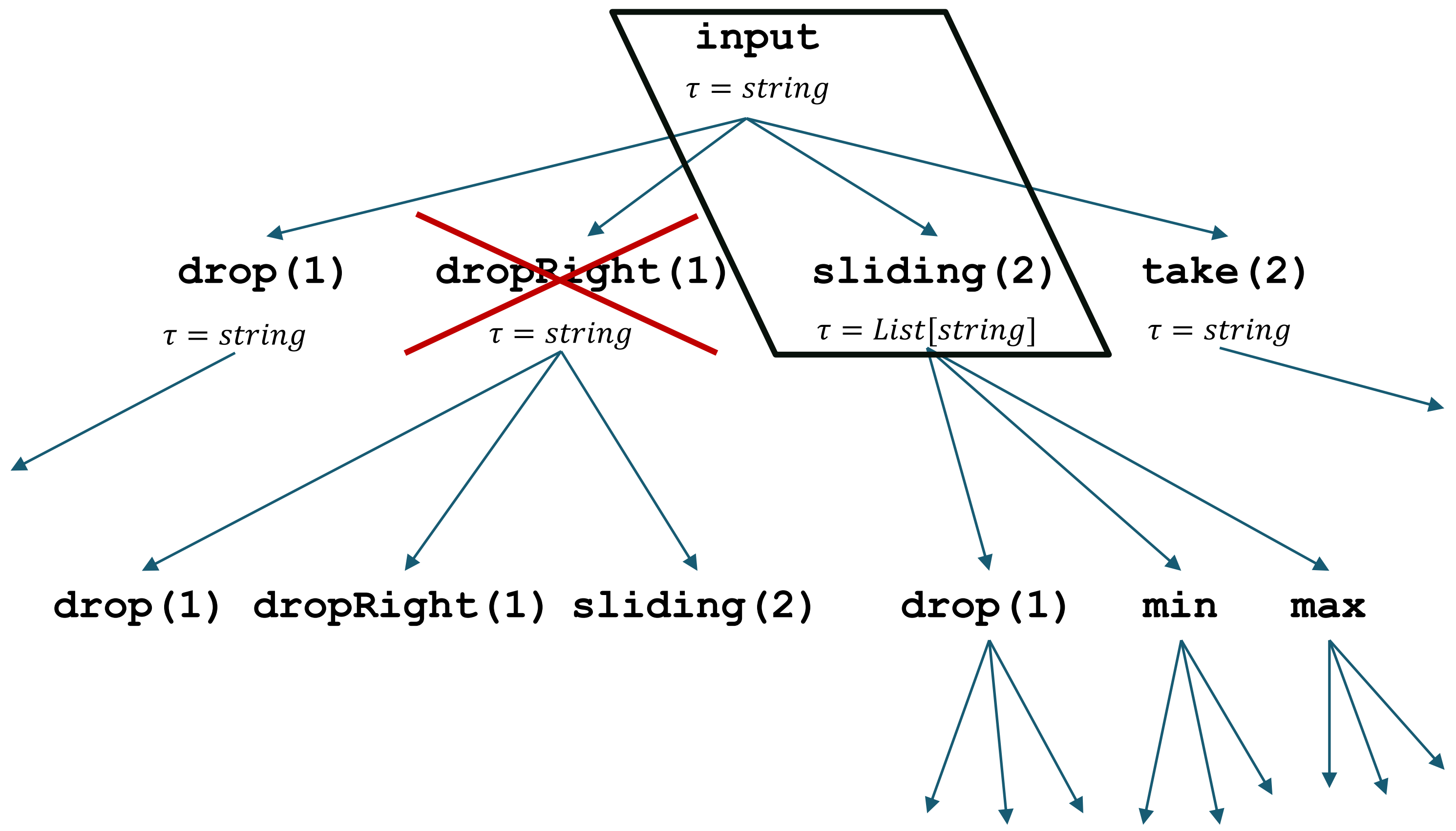
Affix

`affix(f.g.h)`: only show programs of the form `input.f.g.h.…`

Program space



Program space pruning



RESL

[Peleg et al, OOPSLA'20]

Synthesis embedded into a REPL
= syntactic specs (aka granular interaction model)
+ sketching
+ debugger

Running example

All prefixes of printed number

```
420
 ↓
[‘4’, ‘42, ‘420’]
```

RESL

demo

User study

19 participants

- industry programmers with no JS experience

4 tasks

Control: REPL + docs

Treatment: RESL

User study

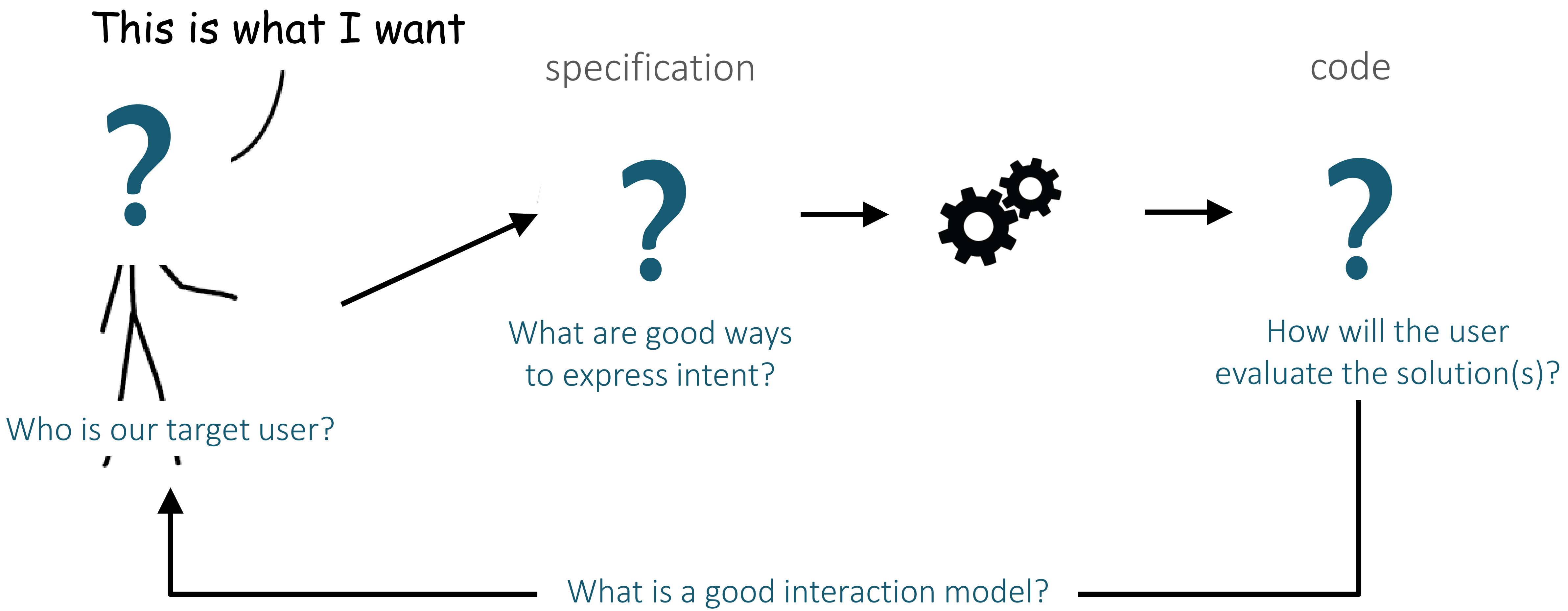
RQ1: Does RESL reduce editing load?

- In 3 out of 4 tasks big reduction in edit iterations
- In 2 out of 4 tasks, over 50% of the code was synthesized

RQ2: Does RESL reduce programmer frustration?

- No RESL user abandoned the task while some REPL users did

The big picture


This is what I want
specification
code
Who is our target user?
What are good ways to express intent?
How will the user evaluate the solution(s)?
What is a good interaction model?

This week

Tuesday: synthesis for programmers

- Snippy [Ferdowsifard et al, UIST'20; OOPLSA'21]
- Hoogle+ [James et al, OOPSLA'20]
- RESL [Peleg et al, OOPLSA'20; Peleg et al, ICSE'18]

Thursday: synthesis for non-programmers

- Rousillon [Chasins, Meuller, Bodik, UIST'18]
- Wrex [Drosos et al, CHI'20]
- Regae [Zhang et al, UIST'20]

Rousillon / Helena

[Chasins, Meuller, Bodik, UIST’18]

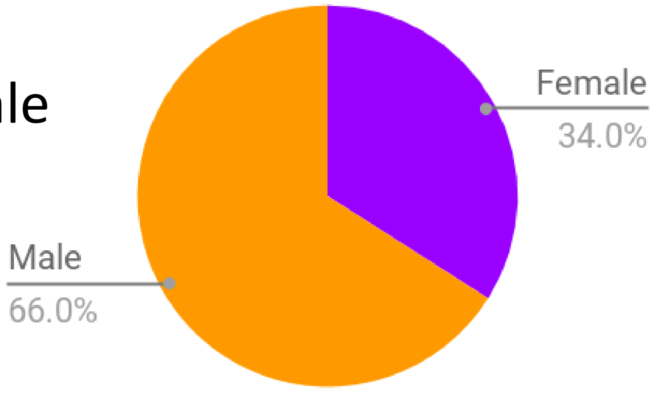
Web scraping for social scientists

The web: a rich source of data!

2008: Google indexed **1 trillion** pages
Now: indexes > **60 trillion** pages
→ lots of content out there

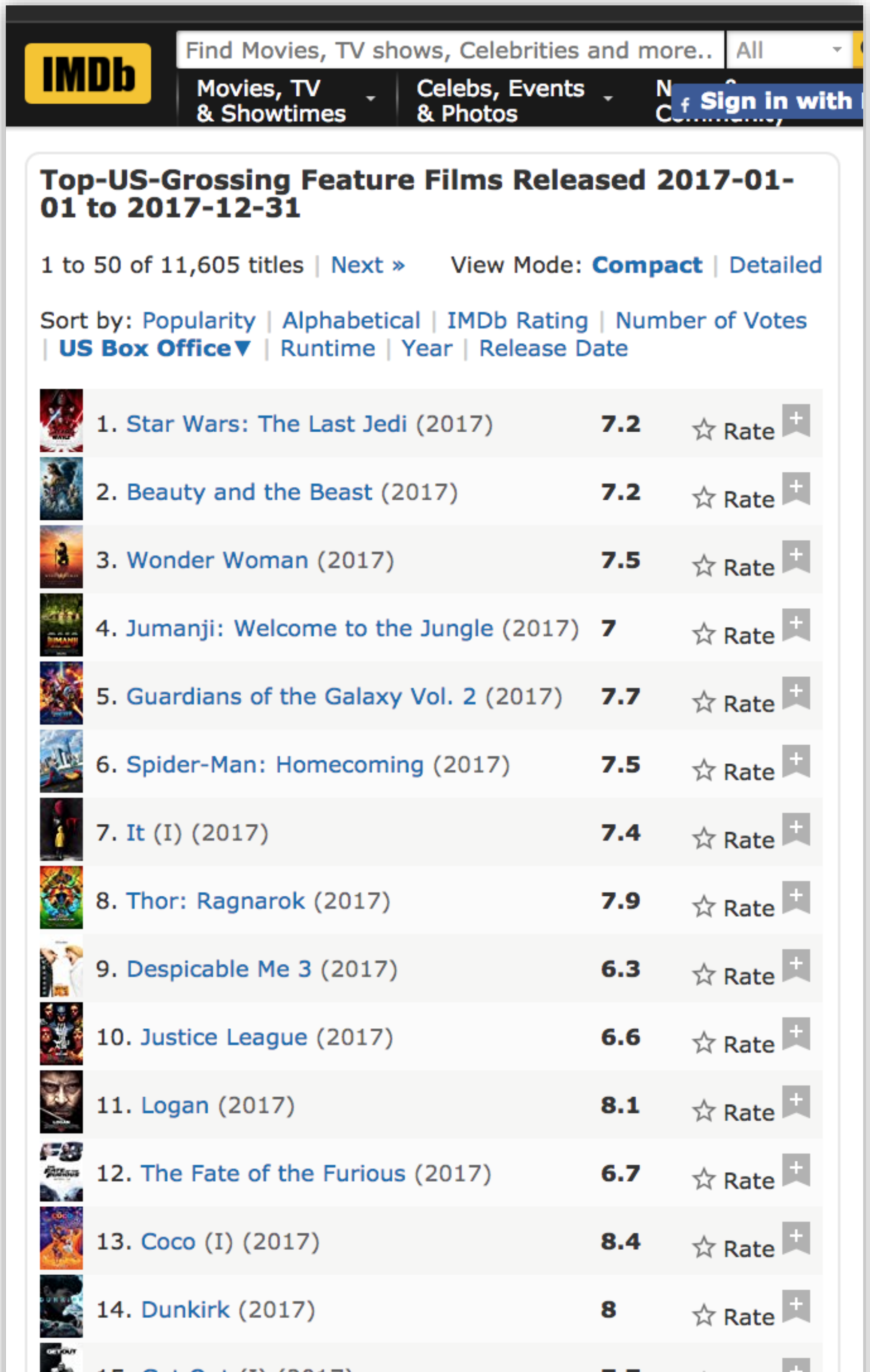
Have you written a scraper?

Percentages of Female and Male Speaking Characters - Top 100 Films of 2017



Woman director or writer: 42% female speaking roles
Only male directors, writers: 32% female speaking roles

Martha M. Lauzen. 2018. It's a Man's (Celluloid) World: Portrayals of Female Characters in the 100 Top Films of 2017



Top-US-Grossing Feature Films Released 2017-01-01 to 2017-12-31

1 to 50 of 11,605 titles | Next » View Mode: **Compact** | Detailed

Sort by: Popularity | Alphabetical | IMDb Rating | Number of Votes | **US Box Office▼** | Runtime | Year | Release Date

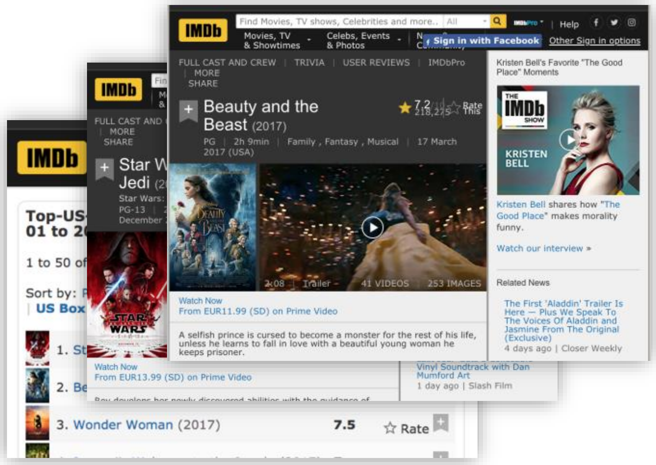
1. Star Wars: The Last Jedi (2017)	7.2	☆ Rate
2. Beauty and the Beast (2017)	7.2	☆ Rate
3. Wonder Woman (2017)	7.5	☆ Rate
4. Jumanji: Welcome to the Jungle (2017)	7	☆ Rate
5. Guardians of the Galaxy Vol. 2 (2017)	7.7	☆ Rate
6. Spider-Man: Homecoming (2017)	7.5	☆ Rate
7. It (I) (2017)	7.4	☆ Rate
8. Thor: Ragnarok (2017)	7.9	☆ Rate
9. Despicable Me 3 (2017)	6.3	☆ Rate
10. Justice League (2017)	6.6	☆ Rate
11. Logan (2017)	8.1	☆ Rate
12. The Fate of the Furious (2017)	6.7	☆ Rate
13. Coco (I) (2017)	8.4	☆ Rate
14. Dunkirk (2017)	8	☆ Rate

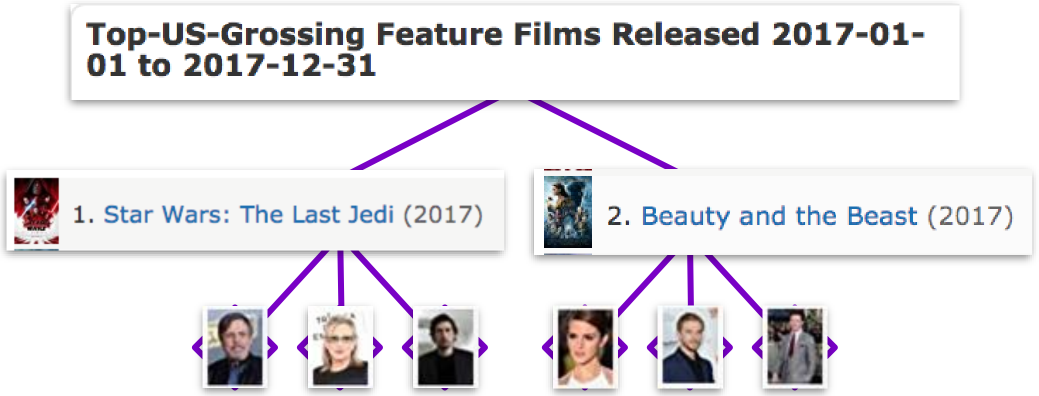
Let’s automate!

We’ve got some libraries…

common thread: users must reverse engineer target webpages

Formative Study: What kinds of web data?


IMDb
Beauty and the Beast (2017)
PG | 2h 9min | Family , Fantasy , Musical | 17 March 2017 (USA)
Watch Now
From EUR11.99 (SD) on Prime Video
A selfish prince is cursed to become a monster for the rest of his life, unless he learns to fall in love with a beautiful young woman he keeps prisoner.
Related News
Star Wars: The Last Jedi
3. Wonder Woman (2017) 7.5 Rate


Top-US-Grossing Feature Films Released 2017-01-01 to 2017-12-31
1. Star Wars: The Last Jedi (2017)
2. Beauty and the Beast (2017)

distributed

must navigate between pages - e.g., click, use forms + widgets

hierarchical

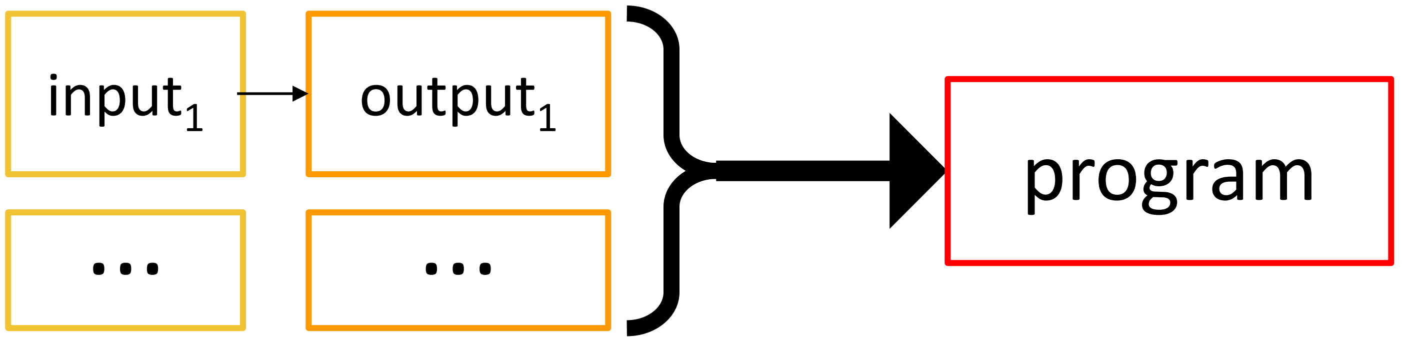
must traverse and collect tree-structured data

Formative Study: Can social scientists use...

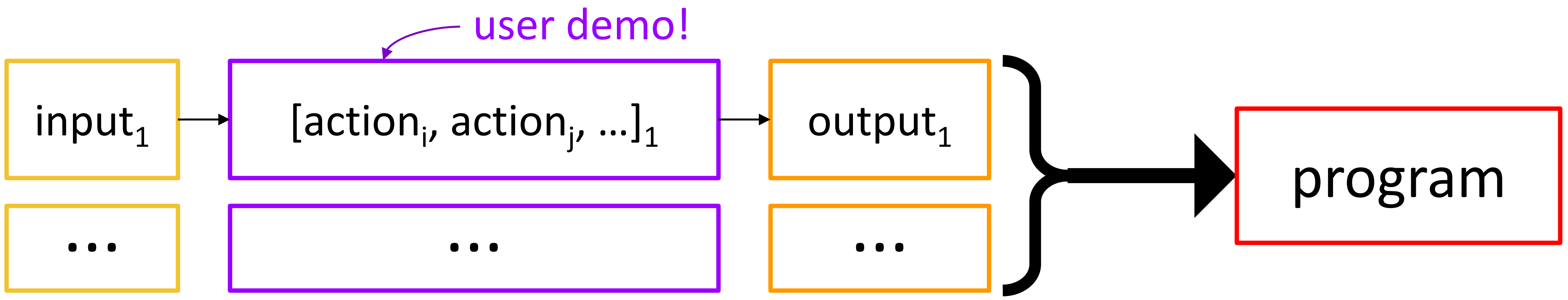
Traditional programming?	Manual collection?	Programming by demonstration?
Skills:	Skills:	Skills:
Basic programming	Browser use	Browser use
Web DSL	But	But
DOM	Slow	Can’t collect distributed, hierarchical datasets
~~JavaScript~~	Tedious	
~~Server interaction~~	Small-scale data	
✖	✖ / 😃	✖

What's Programming by Demonstration (PBD)?

Closely related to Programming by Example (PBE) (e.g., FlashFill)



But PBD (e.g., SMARTedit) gets to see the input being transformed into the output:



Design goals

D1: Expertise – do not require knowledge of HTML, DOM trees, etc.
D2: Distributed hierarchical data – handle realistic datasets
D3: Learnability – prioritize learnability by novices over usability by tool experts

The Interaction Model

user demonstrates how to collect one joined row

start recording

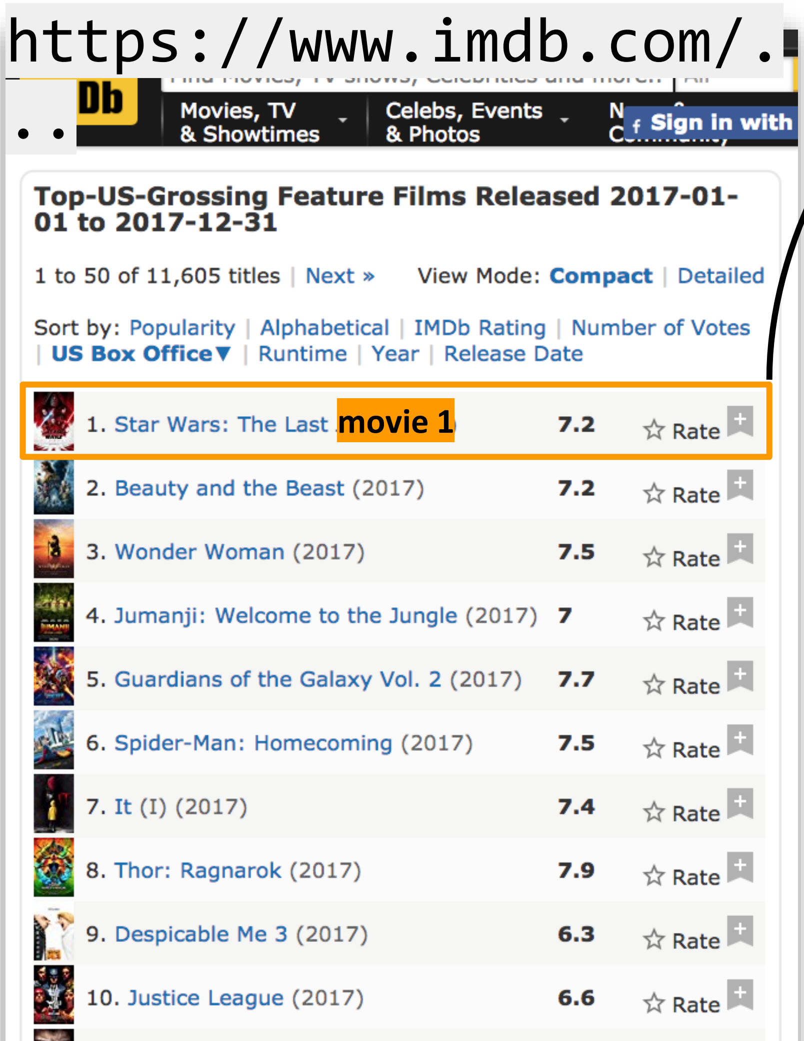
load www.imdb.com...

collect	**movie 1**
click	**movie 1**
collect	**actor 1**

end recording

load

`https://www.imdb.com/...`



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1. Star Wars: The Last **movie 1**	7.2	☆ Rate
2. Beauty and the Beast (2017)	7.2	☆ Rate
3. Wonder Woman (2017)	7.5	☆ Rate
4. Jumanji: Welcome to the Jungle (2017)	7	☆ Rate
5. Guardians of the Galaxy Vol. 2 (2017)	7.7	☆ Rate
6. Spider-Man: Homecoming (2017)	7.5	☆ Rate
7. It (I) (2017)	7.4	☆ Rate
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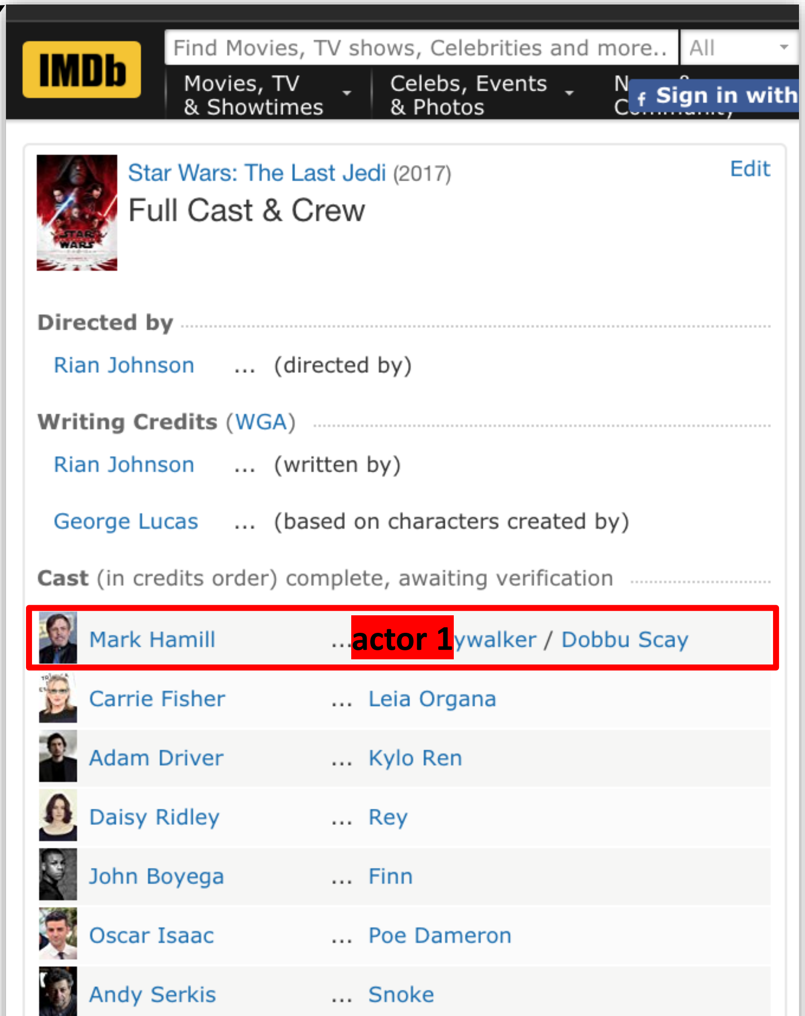


Star Wars: The Last Jedi (2017)

Full Cast & Crew

Directed by

Rian Johnson ... (directed by)

Writing Credits (WGA)

Rian Johnson ... (written by)

George Lucas ... (based on characters created by)

Cast (in credits order) complete, awaiting verification

Mark Hamill	... **actor 1**ywalker / Dobbu Scay
Carrie Fisher	... Leia Organa
Adam Driver	... Kylo Ren
Daisy Ridley	... Rey
John Boyega	... Finn
Oscar Isaac	... Poe Dameron
Andy Serkis	... Snoke

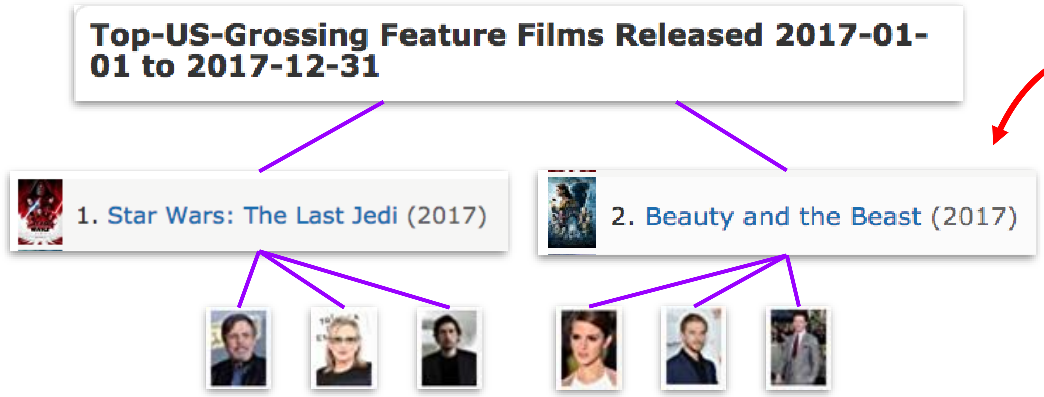
Technical Challenges

Hierarchical Data: Synthesis of nested loops - needed for hierarchical data - is a long-standing open problem.

Relation Ambiguity: Single row is an ambiguous demo. Which relation did the user intend to select?

Readability: For robust automation, must run 100s of low-level, unreadable DOM events.

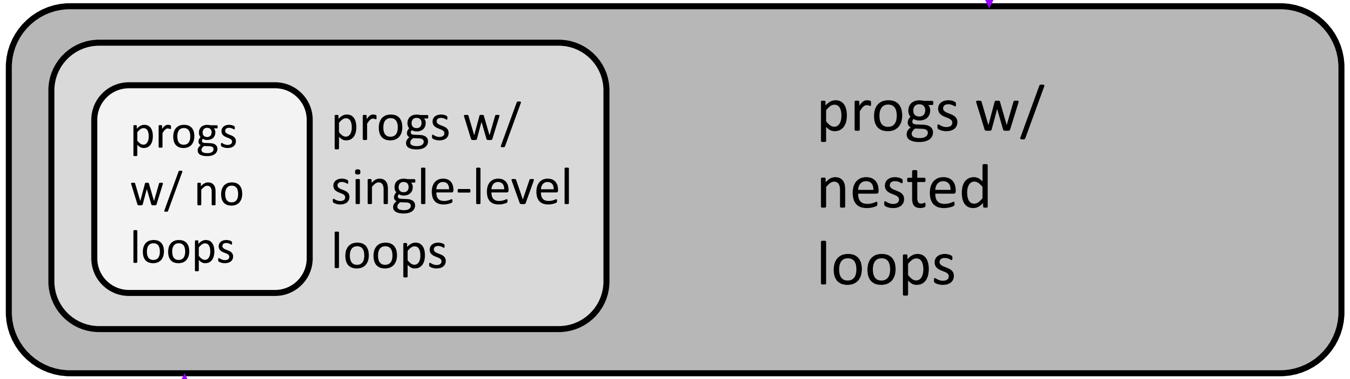
Problem 1: Hierarchical Data


Top-US-Grossing Feature Films Released 2017-01-01 to 2017-12-31
1. Star Wars: The Last Jedi (2017)
2. Beauty and the Beast (2017)

```
for movie in movie_list:
    // scrape movie data
    for actor in actor_list:
        // scrape actor data
```

hierarchical data → nested loops

The issue:
Nested loop synthesis is an open problem.



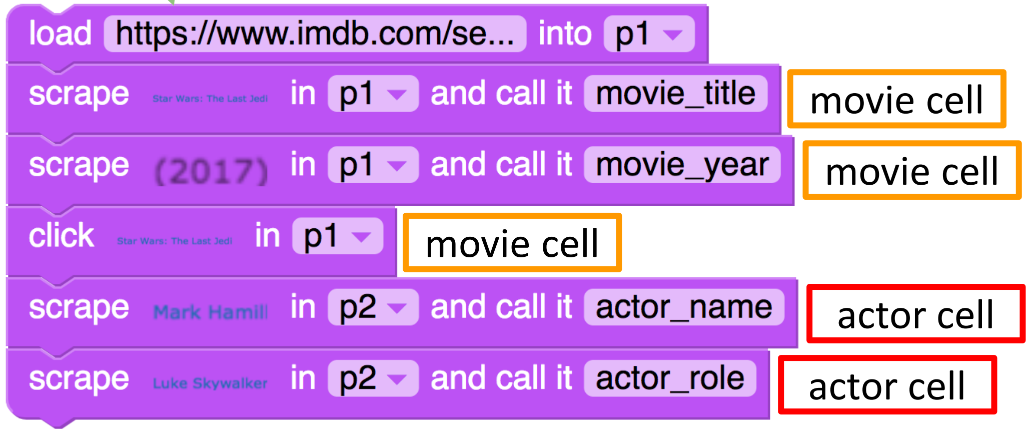
Past solutions:
In web automation, none. In other domains, manually marking loop boundaries.

The space of possible programs is just too big. To pick among all these, our spec is ambiguous.

Problem 1: Hierarchical Data

Solution:
Design user interaction to make search tractable

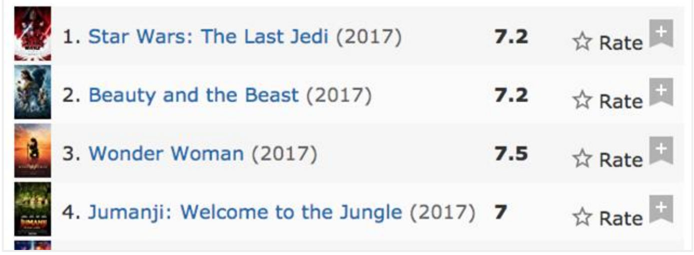
Contract w/ user: perform one iteration of each loop, ordered from outer to inner



```
load https://www.imdb.com/se... into p1
scrape Star Wars: The Last Jedi in p1 and call it movie_title    movie cell
scrape (2017) in p1 and call it movie_year    movie cell
click Star Wars: The Last Jedi in p1    movie cell
scrape Mark Hamill in p2 and call it actor_name    actor cell
scrape Luke Skywalker in p2 and call it actor_role    actor cell
```

Label uses of relation cells

movie relation



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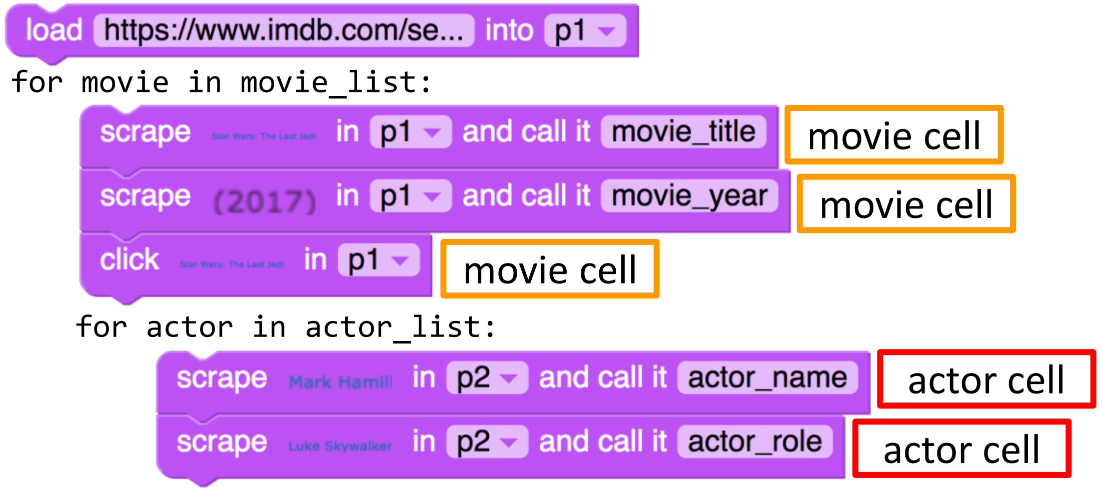
2. Beauty and the Beast (2017)	7.2	☆ Rate	
3. Wonder Woman (2017)	7.5	☆ Rate	
4. Jumanji: Welcome to the Jungle (2017)	7	☆ Rate	

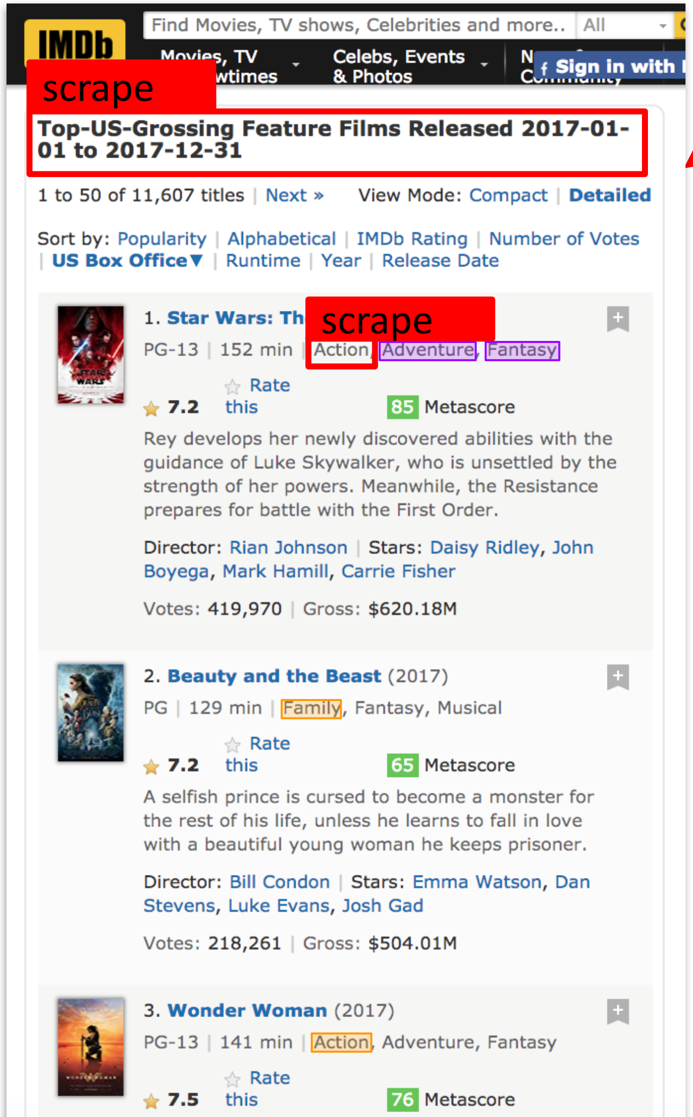
PBD takeaway:
To add loops efficiently, first find objects that should be treated together.

One loop per relation, start before cell use



```
load https://www.imdb.com/se... into p1
for movie in movie_list:
    scrape Star Wars: The Last Jedi in p1 and call it movie_title    movie cell
    scrape (2017) in p1 and call it movie_year    movie cell
    click Star Wars: The Last Jedi in p1    movie cell
    for actor in actor_list:
        scrape Mark Hamill in p2 and call it actor_name    actor cell
        scrape Luke Skywalker in p2 and call it actor_role    actor cell
```

Problem 2: Relation Ambiguity



Top-US-Grossing Feature Films Released 2017-01-01 to 2017-12-31

1 to 50 of 11,607 titles | Next » View Mode: Compact | Detailed

Sort by: Popularity | Alphabetical | IMDb Rating | Number of Votes | US Box Office ▾ | Runtime | Year | Release Date

1. Star Wars: Th
PG-13 | 152 min | Action, Adventure, Fantasy
7.2 Rate this 85 Metascore
Rey develops her newly discovered abilities with the guidance of Luke Skywalker, who is unsettled by the strength of her powers. Meanwhile, the Resistance prepares for battle with the First Order.
Director: Rian Johnson | Stars: Daisy Ridley, John Boyega, Mark Hamill, Carrie Fisher
Votes: 419,970 | Gross: $620.18M

2. Beauty and the Beast (2017)
PG | 129 min | Family, Fantasy, Musical
7.2 Rate this 65 Metascore
A selfish prince is cursed to become a monster for the rest of his life, unless he learns to fall in love with a beautiful young woman he keeps prisoner.
Director: Bill Condon | Stars: Emma Watson, Dan Stevens, Luke Evans, Josh Gad
Votes: 218,261 | Gross: $504.01M

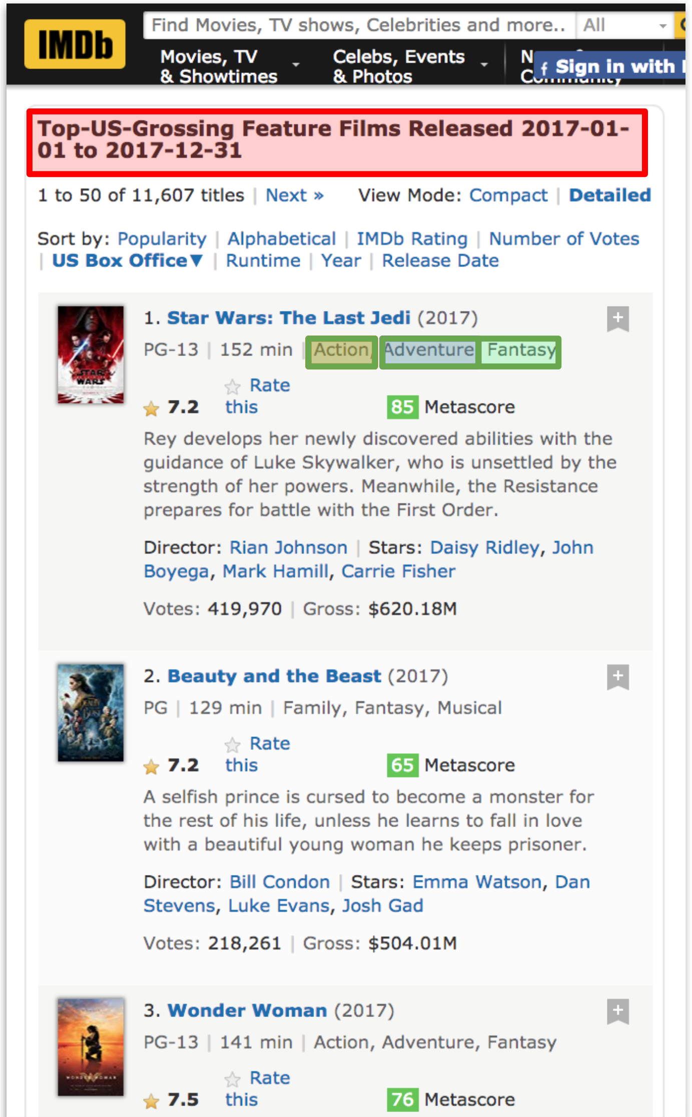
3. Wonder Woman (2017)
PG-13 | 141 min | Action, Adventure, Fantasy
7.5 Rate this 76 Metascore

Given this demo, what's the right relation? Is node 1 included? If not, do we want purple or orange cells in rows 2 and 3? Maybe purple + orange + unhighlighted?

The issue:
Can extract many relations from one page. Set of interacted nodes → 1 chosen relation?

Past solutions:
Have user label multiple rows.

Problem 2: Relation Ambiguity


IMDb
Find Movies, TV shows, Celebrities and more.. | All
Movies, TV & Showtimes | Celebs, Events & Photos | Sign in with

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7.5 Rate this 76 Metascore

Solution:
Take advantage of domain-specific patterns (e.g, web design best practices) to find objects we should treat together

siblingWithShape([n1,n2], s) → Ø

siblingWithShape([n2], s) → n3

relation → [n2, n3, n4]

User Study:

PBD vs. traditional programming

Setup:

Within-subject study, 15 CS PhD students

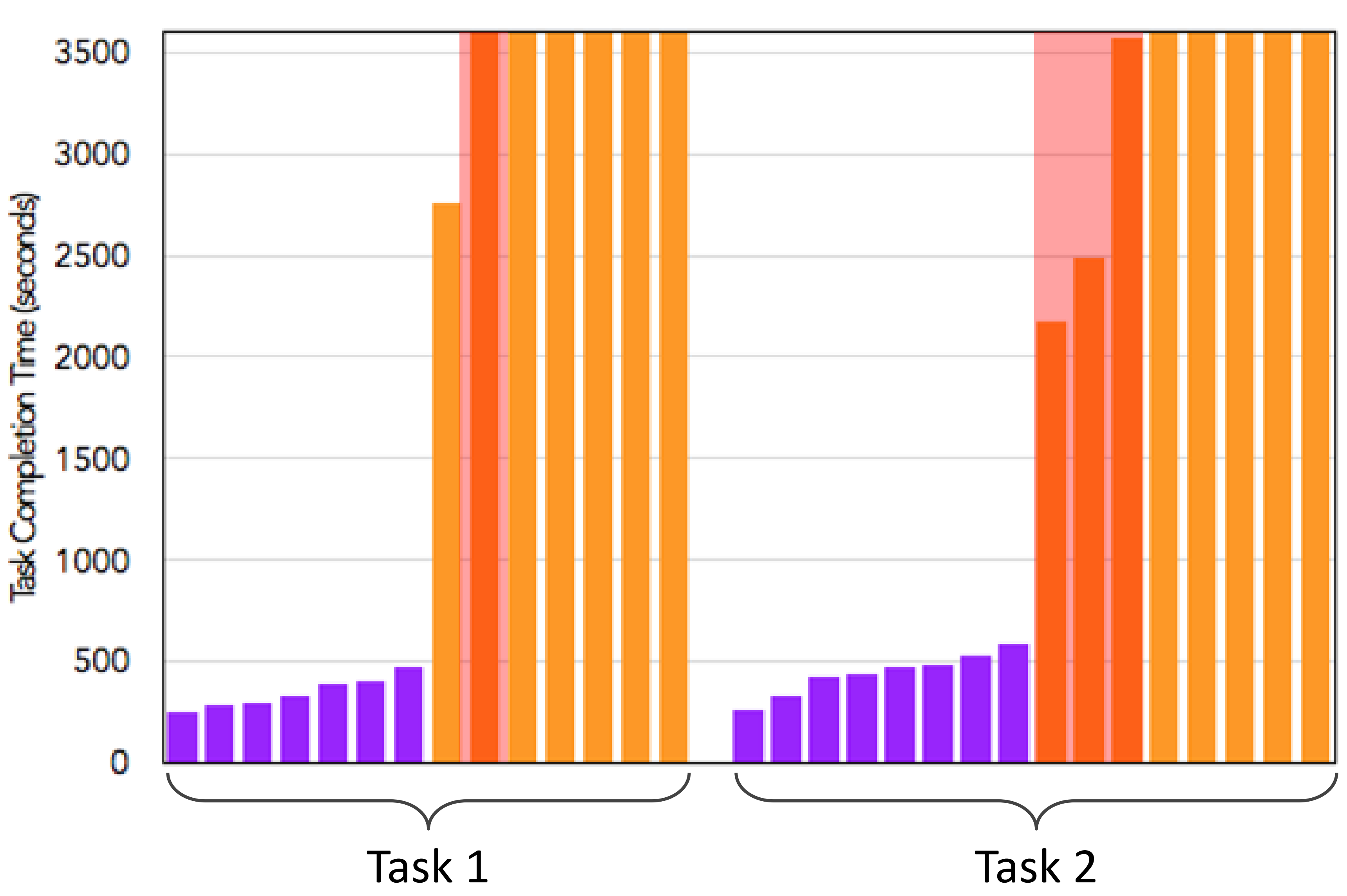
2 tasks: Authors-Papers and Foundations-Tweets

2 tools: Helena then Selenium OR Selenium then Helena

9/15 prior scraping experience

4/15 prior Selenium experience

Q1: Can users learn PBD faster?



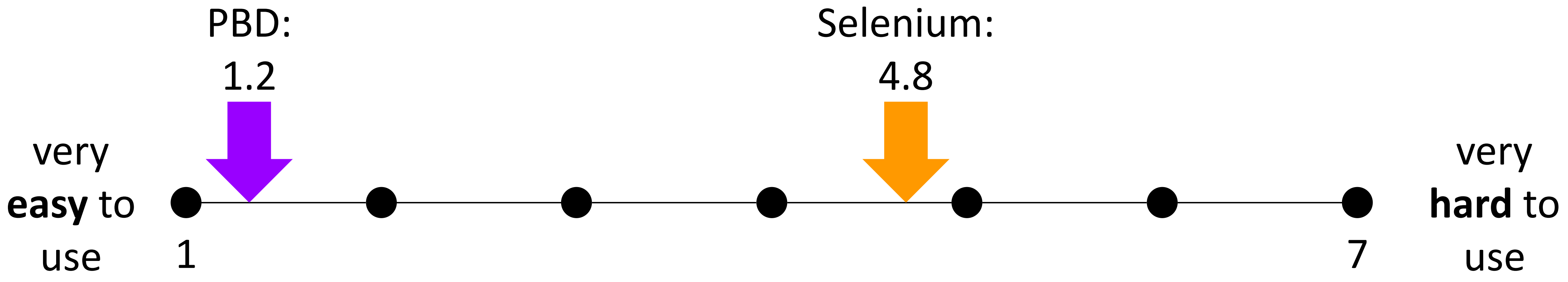
🟪 Helena

🟧 Selenium

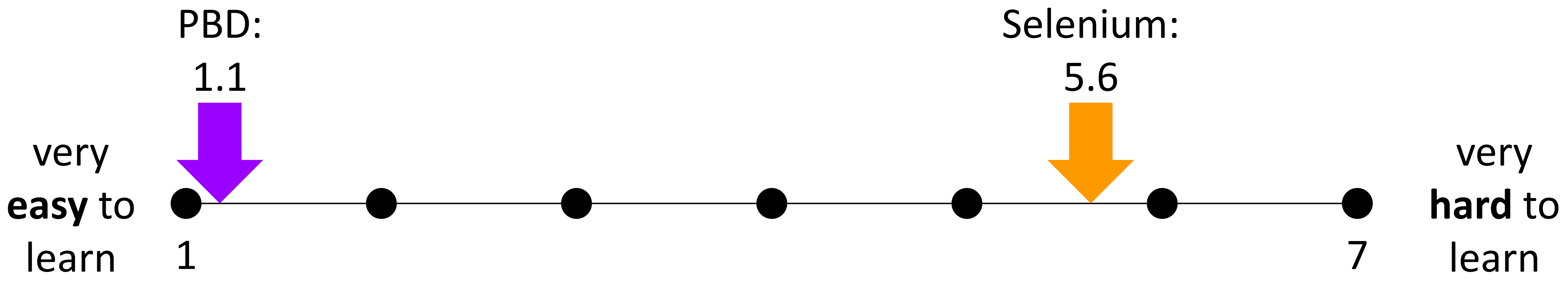
Completion rate with Helena: 100%
Completion rate with Selenium: 26.7%

Lower bound on time savings is 47 mins for task 1, 52 mins for task 2

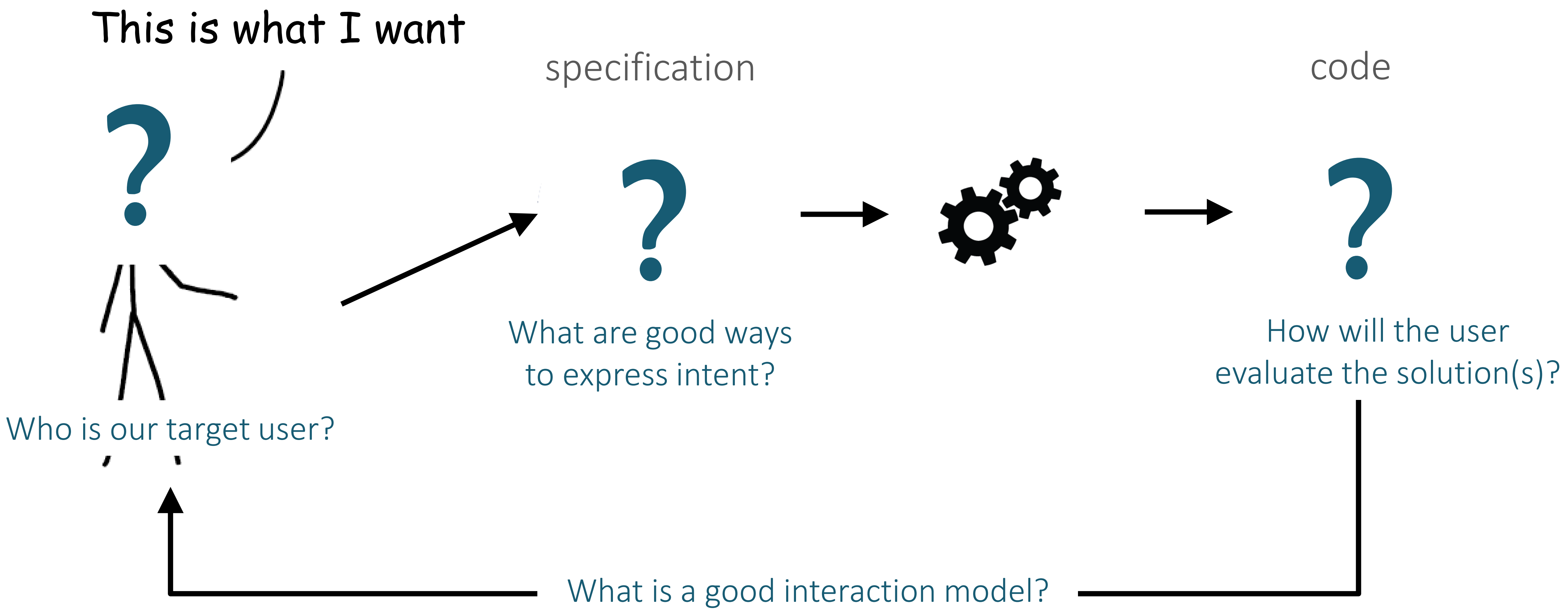
Q2: Do users perceive PBD as more usable?



Q3: Do users perceive PBD as more learnable?



The big picture


This is what I want
specification
code
What are good ways to express intent?
How will the user evaluate the solution(s)?
Who is our target user?
What is a good interaction model?

Wrex

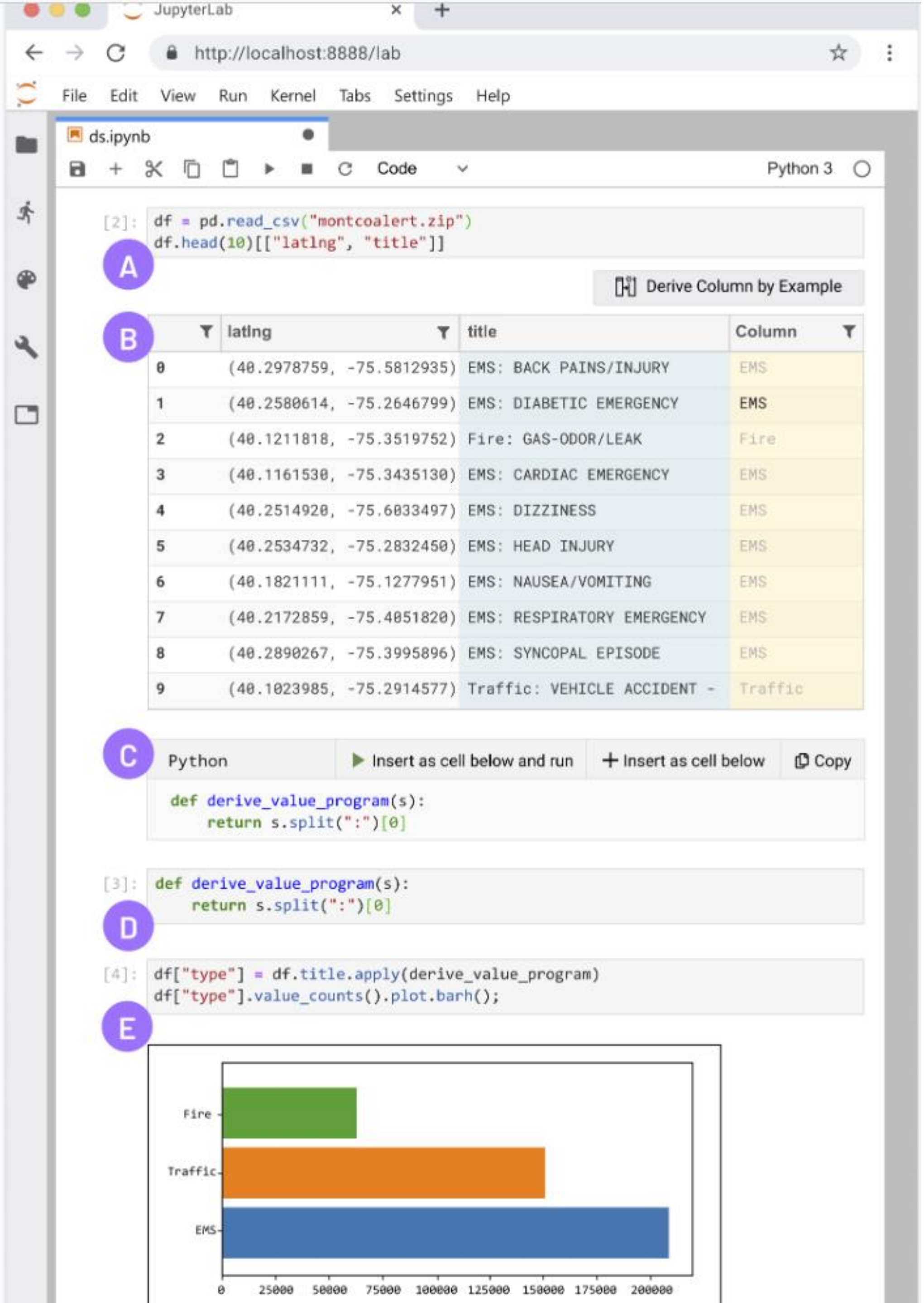
[Drosos, Barik, Guo, DeLine, Gulwani, CHI’20]

Data wrangling for data scientists

Design goals

Formative study with data scientists identified following goals:

1. Must be available where the data scientist works—within their notebooks
2. Must generate Python or R code they can inspect/modify



```
[2]: df = pd.read_csv("montcoalert.zip")
     df.head(10)[["latlng", "title"]]
```

	latlng	title	Column
0	(40.2978759, -75.5812935)	EMS: BACK PAINS/INJURY	EMS
1	(40.2580614, -75.2646799)	EMS: DIABETIC EMERGENCY	EMS
2	(40.1211818, -75.3519752)	Fire: GAS-ODOR/LEAK	Fire
3	(40.1161530, -75.3435130)	EMS: CARDIAC EMERGENCY	EMS
4	(40.2514920, -75.6033497)	EMS: DIZZINESS	EMS
5	(40.2534732, -75.2832450)	EMS: HEAD INJURY	EMS
6	(40.1821111, -75.1277951)	EMS: NAUSEA/VOMITING	EMS
7	(40.2172859, -75.4051820)	EMS: RESPIRATORY EMERGENCY	EMS
8	(40.2890267, -75.3995896)	EMS: SYNCOPAL EPISODE	EMS
9	(40.1023985, -75.2914577)	Traffic: VEHICLE ACCIDENT -	Traffic

```
def derive_value_program(s):
    return s.split(":")[0]
```

```
[3]: def derive_value_program(s):
         return s.split(":")[0]
```

```
[4]: df["type"] = df.title.apply(derive_value_program)
     df["type"].value_counts().plot.barh();
```

A. Users create a data frame with their dataset and sample it.

B. WREX's interactive grid where users can derive a new column and give data transformation examples.

C. WREX's code window containing synthesized code generated from grid interactions.

D. Synthesized code inserted into a new input cell.

E. Applying synthesized code to full data frame and plotting results.

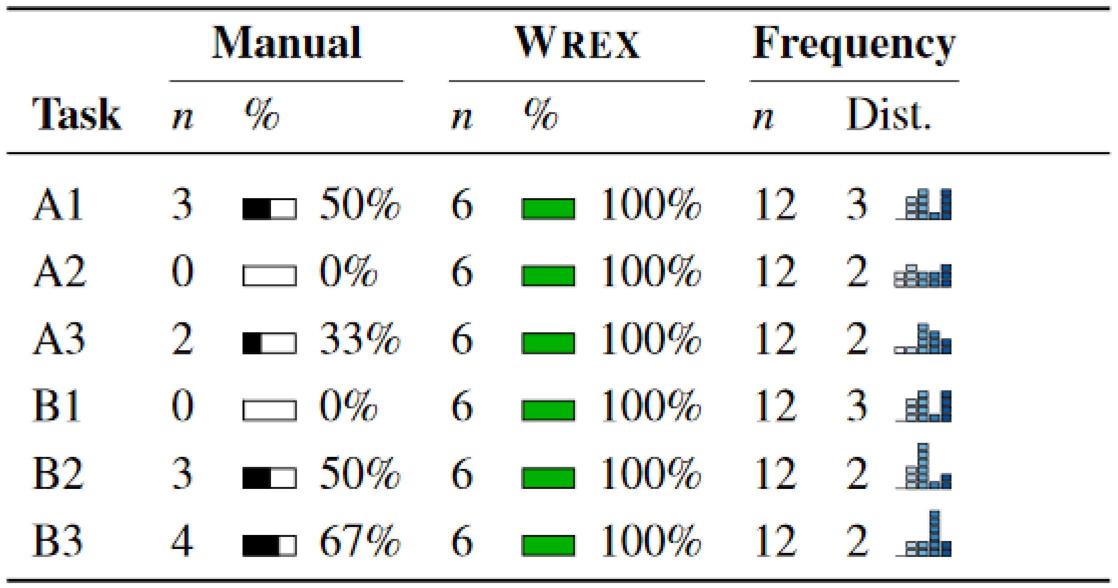
User study

12 participants (data scientists)

6 tasks with two datasets

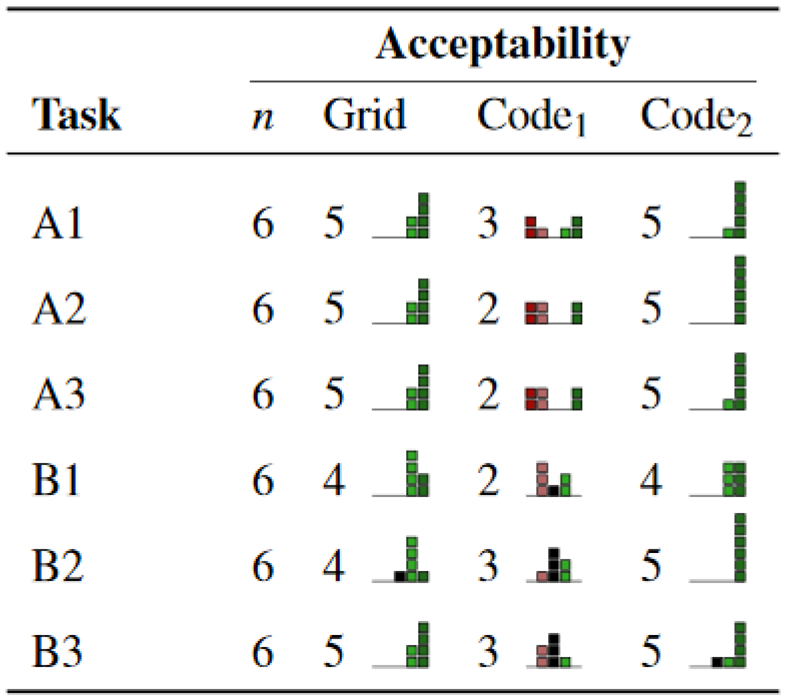
- string extractions, transformation, formatting

Study results



Task	Manual		WREX		Frequency	
	n	%	*n*	%	*n*	Dist.
A1	3	50%	6	100%	12	3
A2	0	0%	6	100%	12	2
A3	2	33%	6	100%	12	2
B1	0	0%	6	100%	12	3
B2	3	50%	6	100%	12	2
B3	4	67%	6	100%	12	2

Table 2: Participant task completion under WREX and manual data wrangling conditions. Participant reported frequency of tasks in day-to-day work. Participants were given five minutes to complete each task. Rating scale for task frequency from left-to-right: □ Never (1), ■ Rarely (2), ■ Occasionally (3), ■ Moderately (4), ■ A great deal (5). Median values precede each distribution.



Task	Acceptability			
	n	Grid	Code$_1$	Code$_2$
A1	6	5	3	5
A2	6	5	2	5
A3	6	5	2	5
B1	6	4	2	4
B2	6	4	3	5
B3	6	5	3	5

Table 4: How acceptable was the grid experience and the corresponding synthesized code snippet? Rating scale from left-to-right: 🟥 Unacceptable (1), 🟥 Slightly unacceptable (2), ⬛ Neutral (3), 🟩 Slightly acceptable (4), and 🟩 Acceptable (5). Code$_1$ are the ratings from the code synthesized in the in-lab study. Code$_2$ are the ratings after incorporating the participants' feedback. Median values precede each distribution.

Regae

[Zhang, Lowmanstone, Wang, Glassman, UIST’20]

Better UI for a regex synthesizer

Regae: questions

Behavioral constraints? Structural constraints? Search strategy?

- IO examples
- Built-in DSL
- Top-down enumerative search

Regae: questions

Does semantic augmentation contribute to behavioral or structural constraints, or something else?

- Structural because it affects the search space

What about data augmentation?

- Directly contributes only to result comprehension
- Indirectly to behavioral because users can use those examples as input

Why is it important to randomize the order of control and treatment?

- learning effects / fatigue effects

Regae: questions

When can we soundly reject the sketch `concat(<num>, e)`?

- Can we:
  - reject when there's a **negative** example that **starts** with a number?
  - reject when there's a **positive** example that **doesn't start** with a number?
- More generally, replace `e` with `star(<any>)` and check whether all positives can be parsed!
  - if under `not`, then replace with an empty-language regex
- Another idea is define equivalence on regexes, e.g. `optional(star(e))` is equivalent to `star(e)`

Regae: contributions

Novel way to express intent: semantics augmentation

Novel way to explain synthesis results to user: data augmentation

Automata-theoretic algorithms to generate explanatory examples

- familiar examples with different output, corner cases, distinguishing examples

Usability confirmed by user study

- Completion rate: 12/12 vs 4/12; twice more confident; less cognitive load

Regae: limitations

Limited to regexes

Which parts are generalizable and which not?

Marking as general affects completeness

Not tolerant to user mistakes

User study participants might not be representative