CS 292C Computer-Aided Reasoning for Software

Lecture 3: Solver-Aided Programming II

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Fall 2019

Summary of previous lecture

- The first homework is out
- The first paper review is out
- The classical way for using solvers
- Solver-aided programming I
- Rosette constructs

A programming model that integrates solvers into the language, providing constructs for program verification, synthesis, and debugging.

Solver-aided programming

```
p(x) {
  v = 12
```

```
p(x) {
  v = ??
  …
}
assert safe(x, p(x))
```

Find an input on which the program fails.

Localize bad parts of the program.

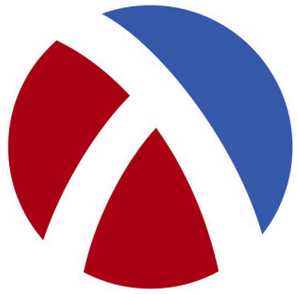
Find values that repair the failing run.

Find code that repairs the program.

Rosette constructs

Rosette

=



Racket

+

```
(define-symbolic id type)
(define-symbolic* id type)
```

symbolic values

```
(assert expr)
```

assertions

```
(verify expr)
(debug [type ...+] expr)
(solve expr)
(synthesize
  #:forall expr
  #:guarantee expr)
```

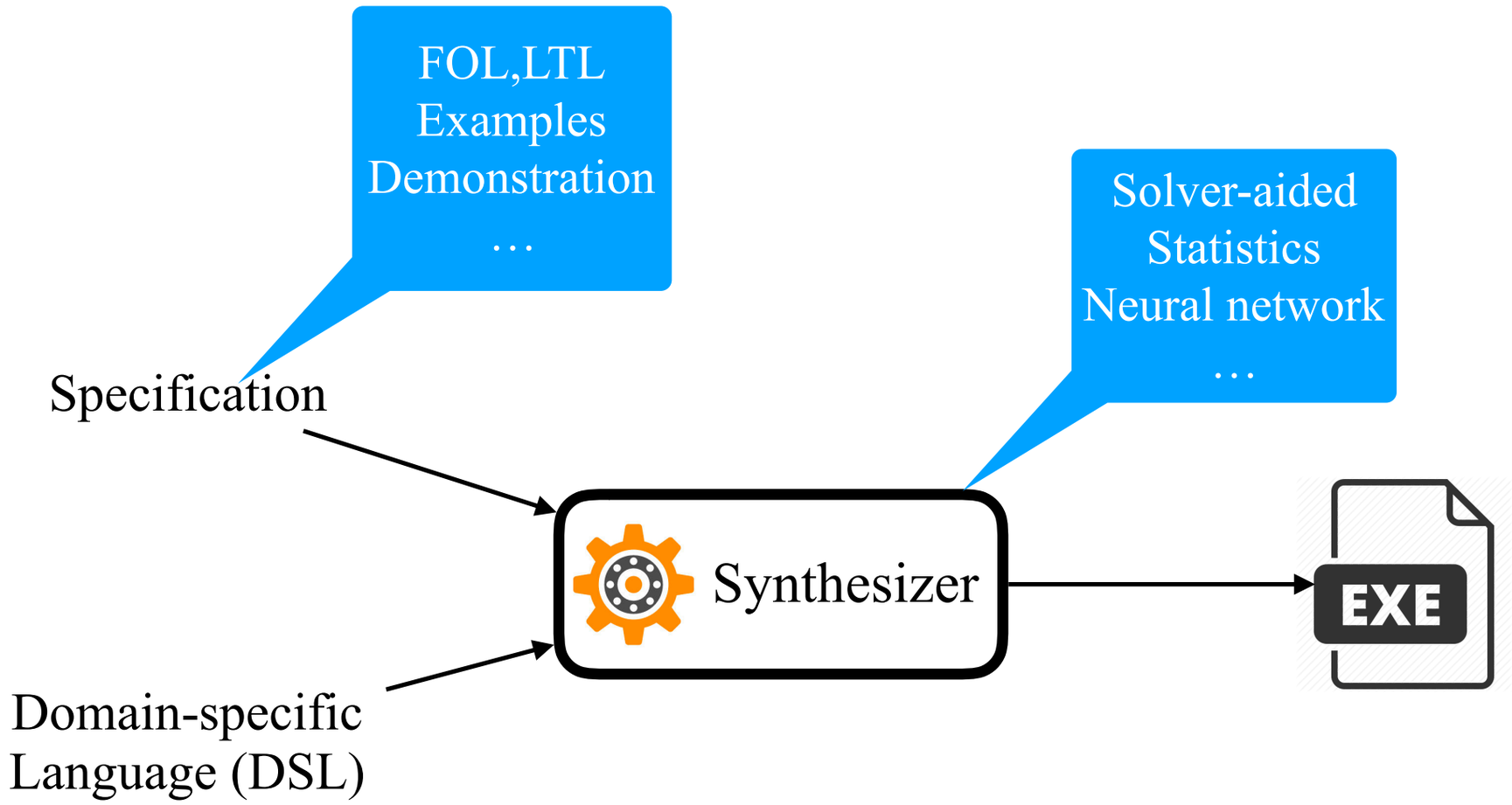
queries

A Lightweight Symbolic Virtual Machine for Solver-Aided Host Languages. Emina Torlak and Rastislav Bodik. PLDI'14

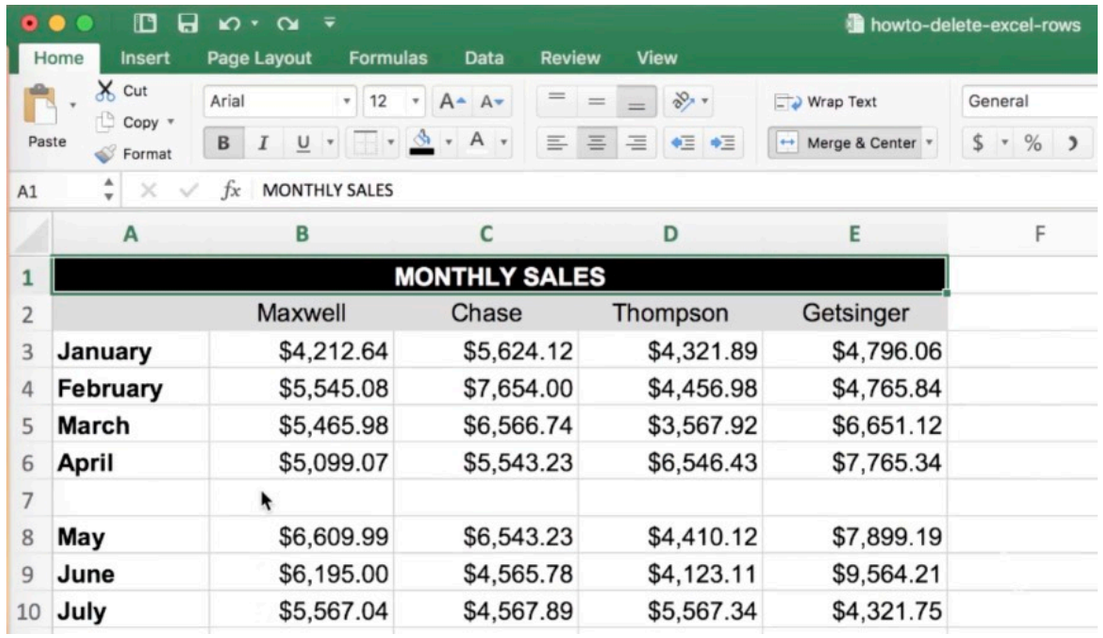
Outline of this lecture

- The spectrum of program synthesis
- Solver-aided programming II (synthesis)
- Program synthesis via conflict-driven learning

What is program synthesis



Program-by-example



	A	B	C	D	E	F
1	MONTHLY SALES					
2		Maxwell	Chase	Thompson	Getsinger	
3	January	$4,212.64	$5,624.12	$4,321.89	$4,796.06	
4	February	$5,545.08	$7,654.00	$4,456.98	$4,765.84	
5	March	$5,465.98	$6,566.74	$3,567.92	$6,651.12	
6	April	$5,099.07	$5,543.23	$6,546.43	$7,765.34	
7						
8	May	$6,609.99	$6,543.23	$4,410.12	$7,899.19	
9	June	$6,195.00	$4,565.78	$4,123.11	$9,564.21	
10	July	$5,567.04	$4,567.89	$5,567.34	$4,321.75	

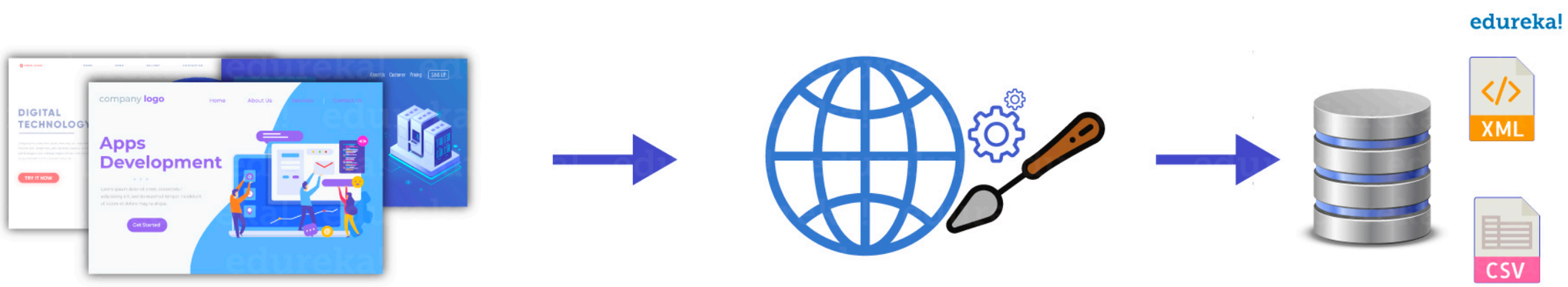
Two minutes tour to the FlashFill system

N Ph.D. students

Sumit Gulwani

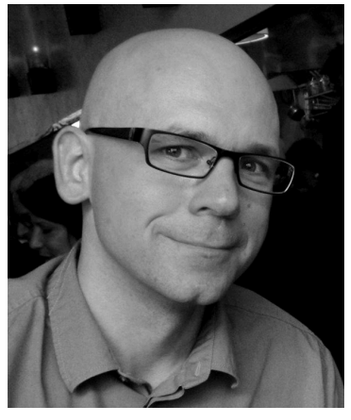
https://www.youtube.com/watch?v=lCVOmWdy1Hc

Program-by-demonstration



One minute tour to the Helena system

Sarah Chasins



Ras Bodik

https://tinyurl.com/y35936gr

http://helena-lang.org/

Program-by-natural-language

Amazon Alexa

SQLizer

IFTTT

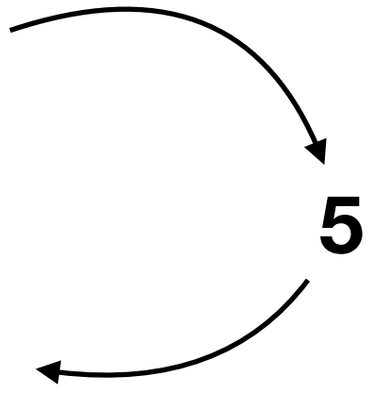
Yaghmazadeh, Navid, et al. SQLizer: query synthesis from natural language. OOPSLA 2017.

Quirk, Chris, Raymond Mooney, and Michel Galley. "Language to code: Learning semantic parsers for if-this-then-that recipes." ACL 2015.

A general synthesizer

```
func const: Int -> 0 | 1 | 2 | 3;
func plus: Int -> Int, Int;
func minus: Int -> Int, Int;
func mult: Int r -> Int, Int;
```

```
0,
plus(1,2)
minus(3,1)
plus(1,minus(3,1))
…
```



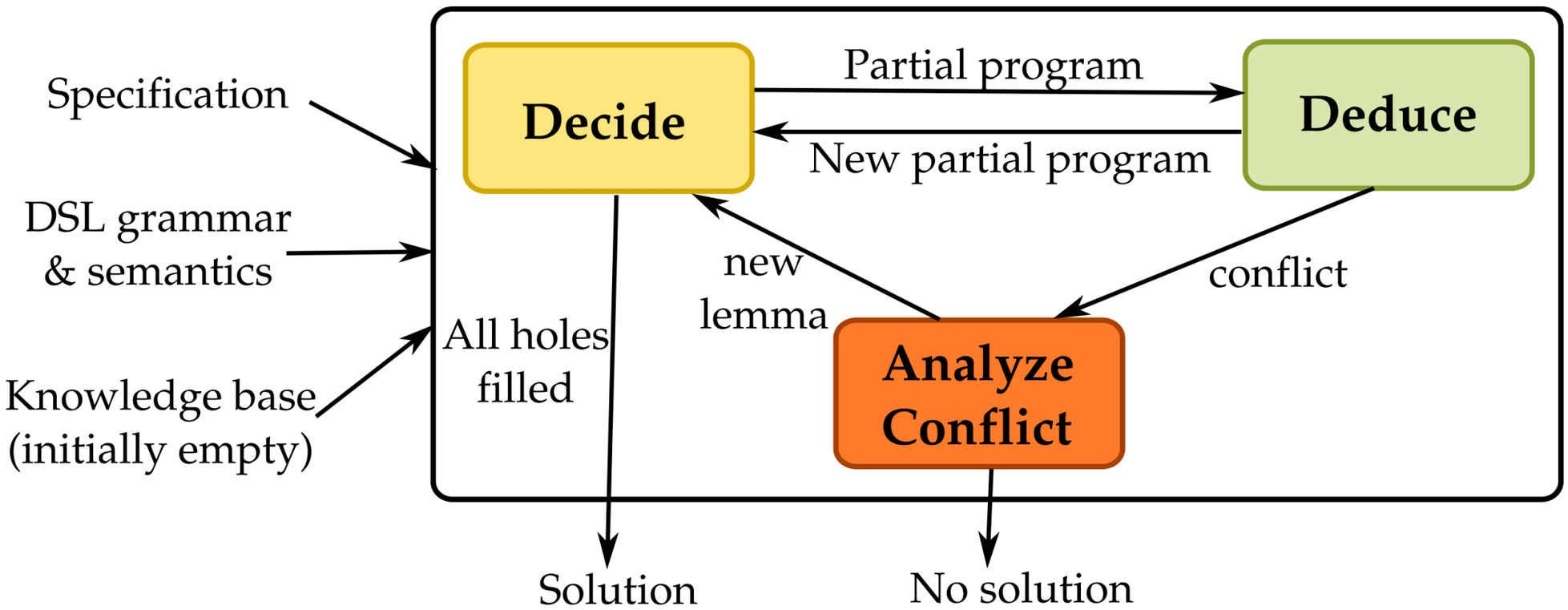
Enumerate-check


Prune invalid candidates (PL)


Enumerate promising candidates (ML)

Alur, Rajeev, et al. "Syntax-guided synthesis." FMCAD 2013.

Architecture of Neo framework

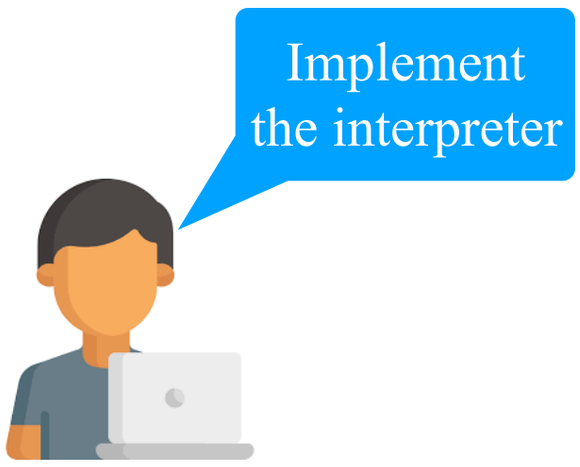


Program synthesis using conflict-driven learning. Yu Feng, Ruben Martins, Osbert Bastani, and Isil Dillig. PLDI'18

Neo in action: step 1


```
# First, specify the types that will be used

enum SmallInt {"0", "1", "2", "3"}

# Finally, specify the production rules

func const: Int -> SmallInt;

func plus: Int -> Int, Int;

func minus: Int -> Int, Int;

func mult: Int r -> Int a, Int b {
   is_positive(a) && is_positive(b) ==> is_positive(r);
     !is_positive(a) && !is_positive(b) ==> !is_positive(r);
}

predicate occurs(plus, 0.5);
predicate is_parent_of(minus, const, 0.6);
```

Neo in action: step 2




```
class ToyInterpreter(PostOrderInterpreter):

    def eval_SmallInt(self, v):
        return int(v)

    def eval_const(self, node, args):
        return args[0]

    def eval_plus(self, node, args):
        return args[0] + args[1]

    def eval_minus(self, node, args):
        return args[0] - args[1]

    def eval_mult(self, node, args):
        return args[0] * args[1]
```

Neo in action: step 3


```
synthesizer = Synthesizer(
    enumerator=SmtEnumerator(spec, depth=3, loc=2),
    decider=ExampleConstraintDecider(
        spec=spec,
        interpreter=ToyInterpreter(),
        examples=[
          Example(input=[4, 3], output=3),
            Example(input=[6, 3], output=9),
            Example(input=[1, 2], output=-2),
            Example(input=[1, 1], output=0),
        ]
    )
)
```

TODOs by next lecture

- 1st Paper review is due
- Install Rosette and Neo
  - Install Rosette: https://docs.racket-lang.org/rosette-guide/ch_getting-started.html
  - Install Neo: https://github.com/fredfeng/Trinity
- Discuss your final project during the office hour!