CS 292C Computer-Aided Reasoning for Software

# Lecture 3: Solver-Aided Programming II

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Fall 2020

# 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.

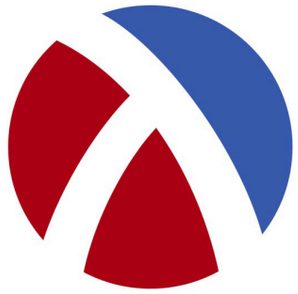
Find code that repairs the program.

# 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)
```

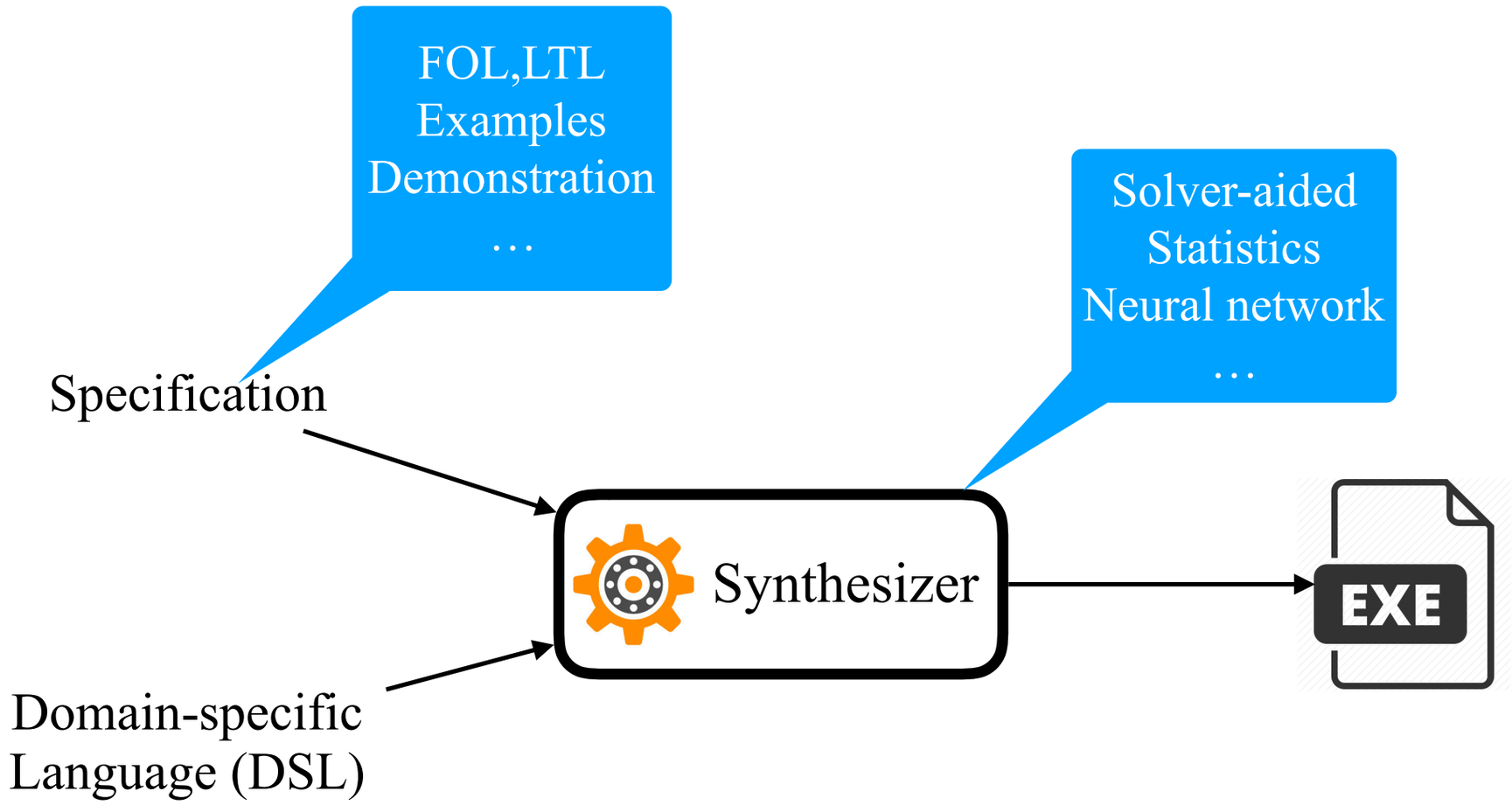
**queries**

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

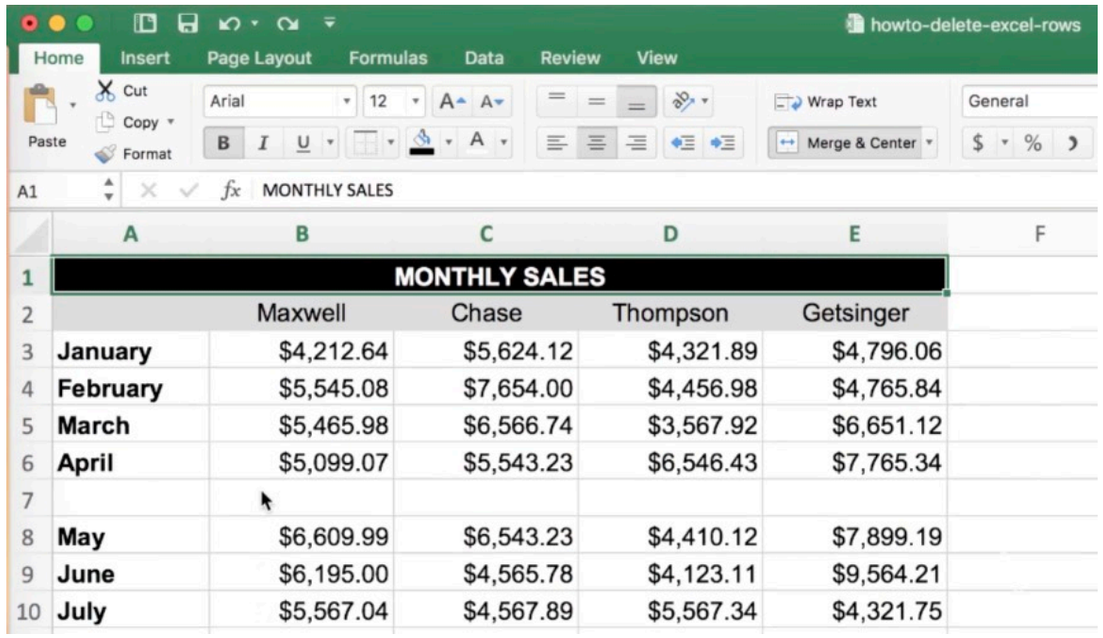
# Outline of this lecture

- 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 | |

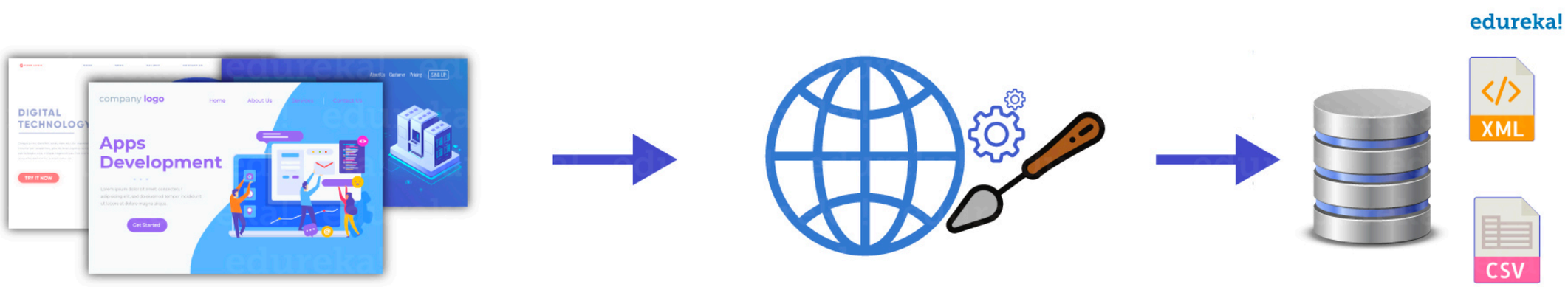
Two minutes tour to the FlashFill system

N Ph.D. students

Sumit Gulwani

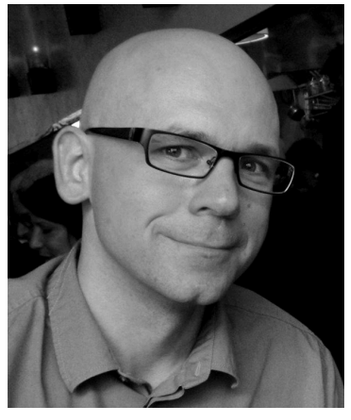
https://www.youtube.com/watch?v=lCVOmWdy1Hc

# 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

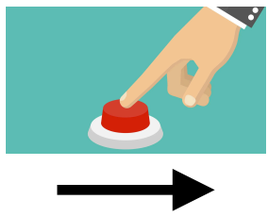

IFTTT

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.

# Program-by-types

```
quickSort(arr[], low, high)
{

}
```



```
quickSort(arr[], low, high)
{
    if (low < high)
    {
        /* pi is partitioning index, arr[pi] is now
           at right place */
        pi = partition(arr, low, high);

        quickSort(arr, low, pi - 1);  // Before pi
        quickSort(arr, pi + 1, high); // After pi
    }
}
```

Five minutes tour to the Hunter system

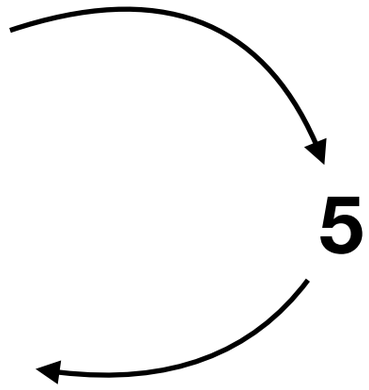
https://fredfeng.github.io/Hunter/

Hunter: Next-Generation Code Reuse for Java. FSE'16

# 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))
…
```



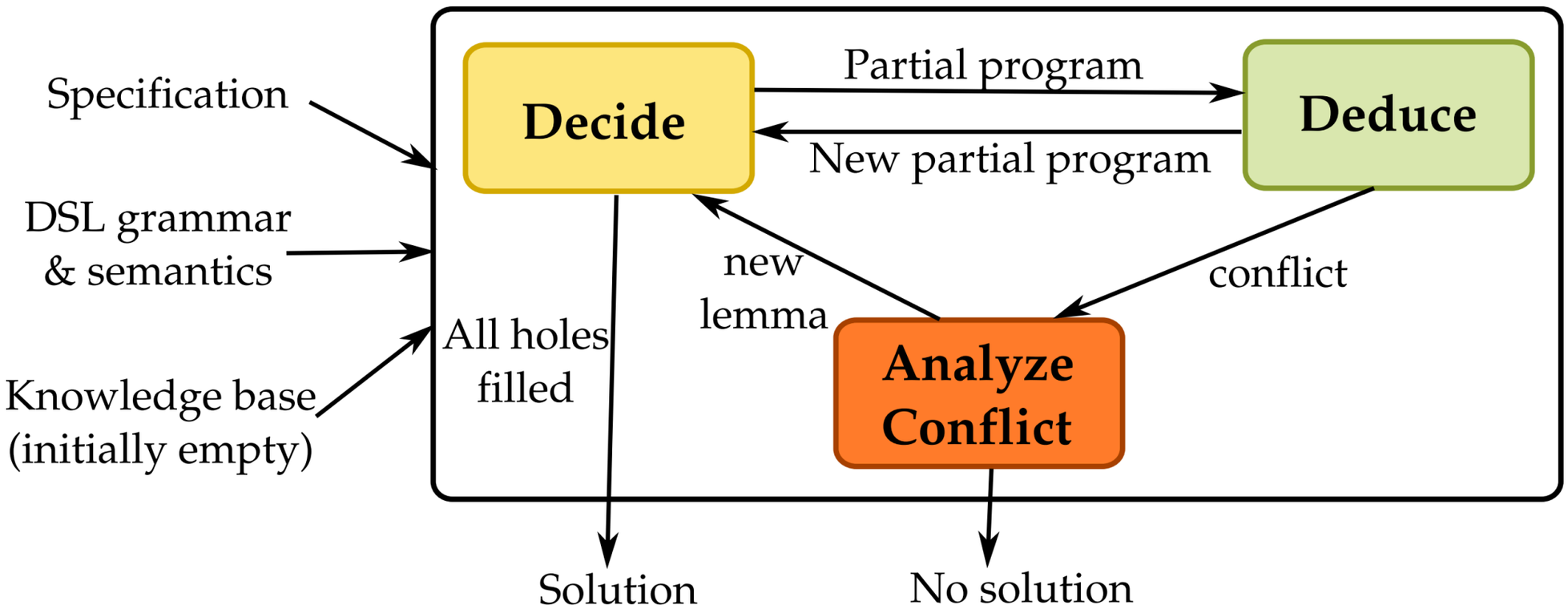

**Enumerate-check**

 Prune invalid candidates (PL)

 Enumerate promising candidates (ML)

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

# Architecture of Neo framework

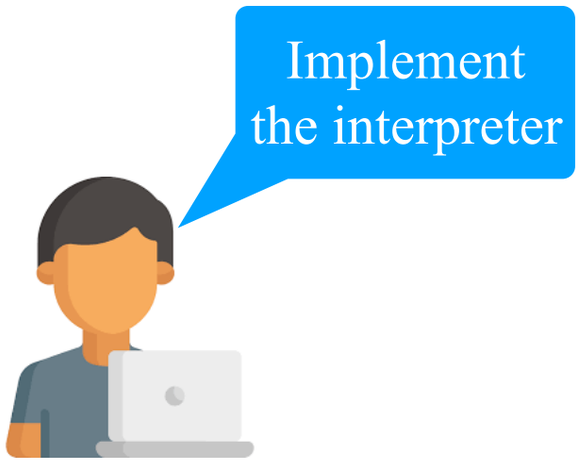



Program synthesis using conflict-driven learning. Yu Feng, Ruben Martins, Osbert Bastani, and Isil Dillig. PLDI'18

# 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 -> Int, Int;
```

# 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!