LLP Laboratório de Linguagens de Programação

Detecting Logical Errors in Haskell

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UFMG
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DE MINAS GERAIS

Agenda

- Motivation
- Problem Definition
- Goals
- Haskell Grammar Subset
- Fault Localization
- HaskellFL
- Demo
- Test Suite
- Results
- Conclusion

Motivation

Functional Programming

elixir

Functional Programming

- Functional Programming is building software via:
  - Function composition: create new functions by composing others
  - Pure functions: every time it is called, it produces the same result
  - No shared state: no global values
  - Limited side effects: limited iteration with external world
  - Immutability: once a variable is created, its value cannot be changed

Tiobe Index - February 2021

35	Lisp	0.34%
36	Scala	0.34%
37	Lua	0.34%
38	Logo	0.33%
39	Kotlin	0.32%
40	TypeScript	0.29%
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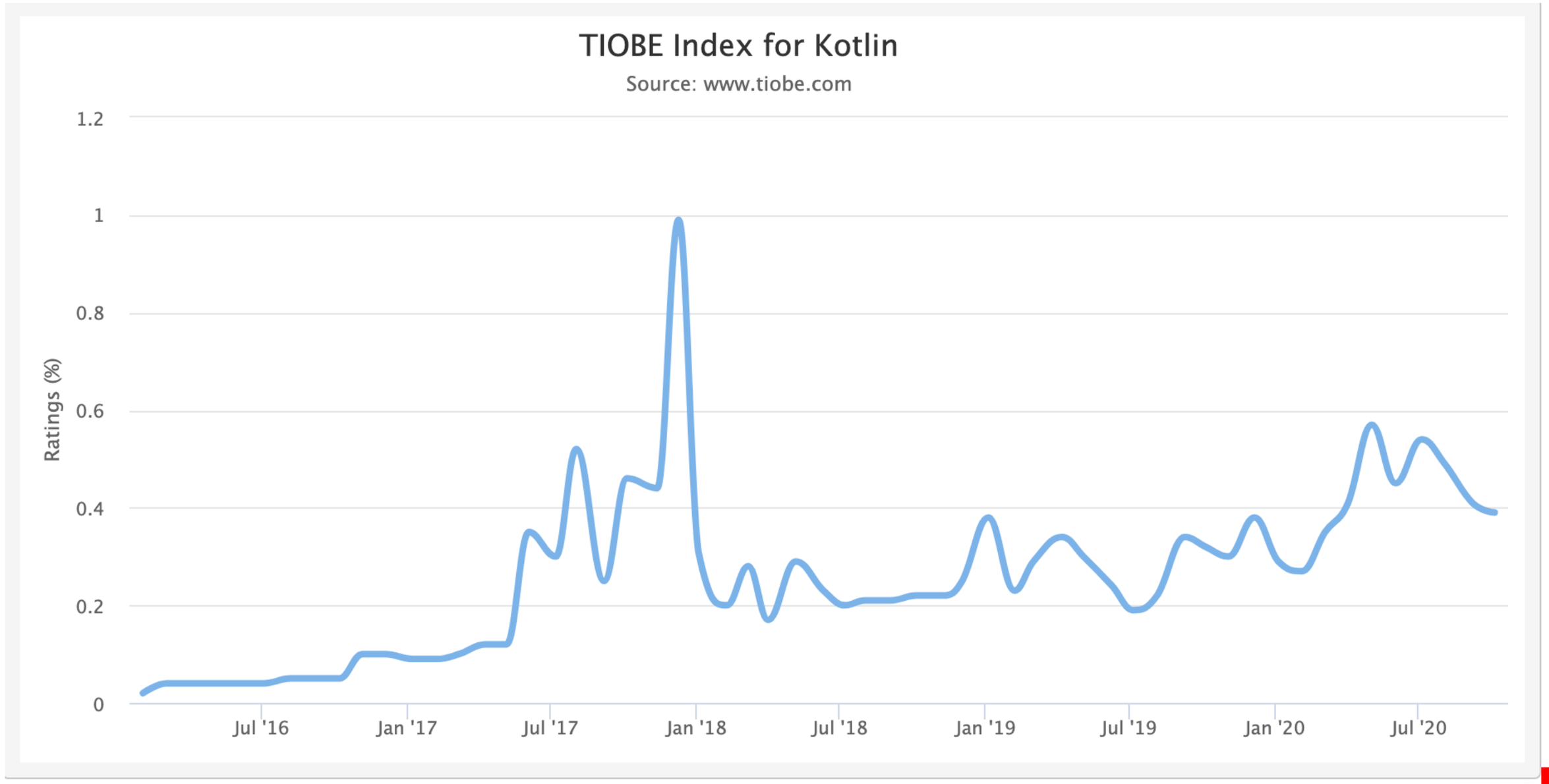
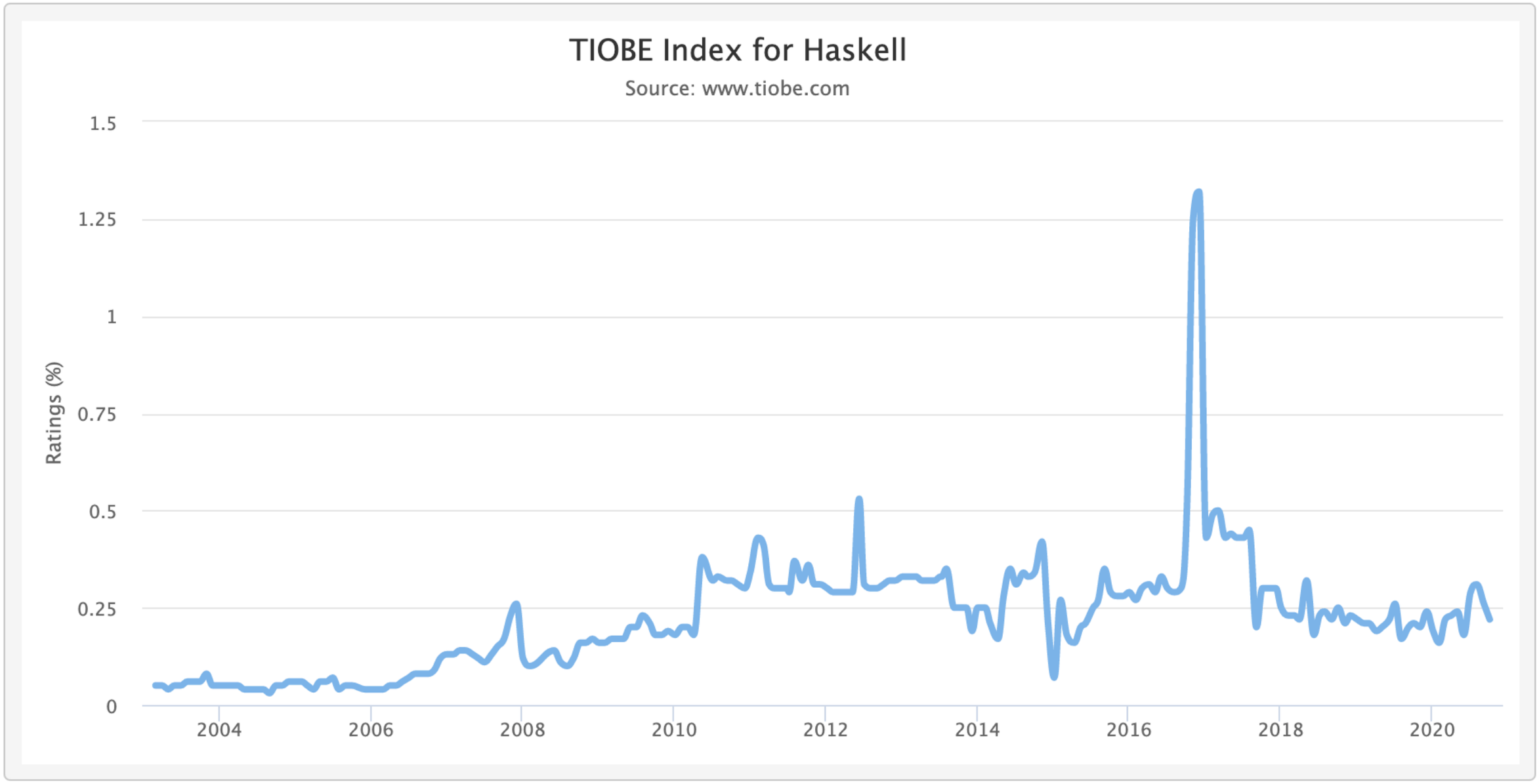
47	Apex	0.23%
48	Elixir	0.22%
49	Alice	0.22%
50	PowerShell	0.21%

Tiobe - Kotlin



Tiobe - Haskell



LLP Laboratório de Linguagens de Programação

GitHub pushes

9	Go	3.728% (-1.048%)	⌄
10	C	3.156% (-0.564%)	⌃
11	C#	2.786% (-1.884%)	⌄
12	Scala	1.071% (+0.008%)	
13	Rust	0.606% (-0.267%)	
14	Swift	0.561% (-0.247%)	
15	Kotlin	0.535% (-0.117%)	
16	Perl	0.476% (-0.053%)	
17	Groovy	0.352% (-0.052%)	⌃
18	Objective-C	0.346% (-0.128%)	⌄
19	Dart	0.338% (+0.056%)	⌃⌃
20	Lua	0.316% (+0.054%)	⌃⌃
21	Vim script	0.250% (-0.083%)	⌄
22	R	0.248% (-0.089%)	⌄
23	Clojure	0.233% (-0.002%)	⌃
24	Haskell	0.232% (-0.037%)	
25	Emacs Lisp	0.218% (-0.090%)	⌄

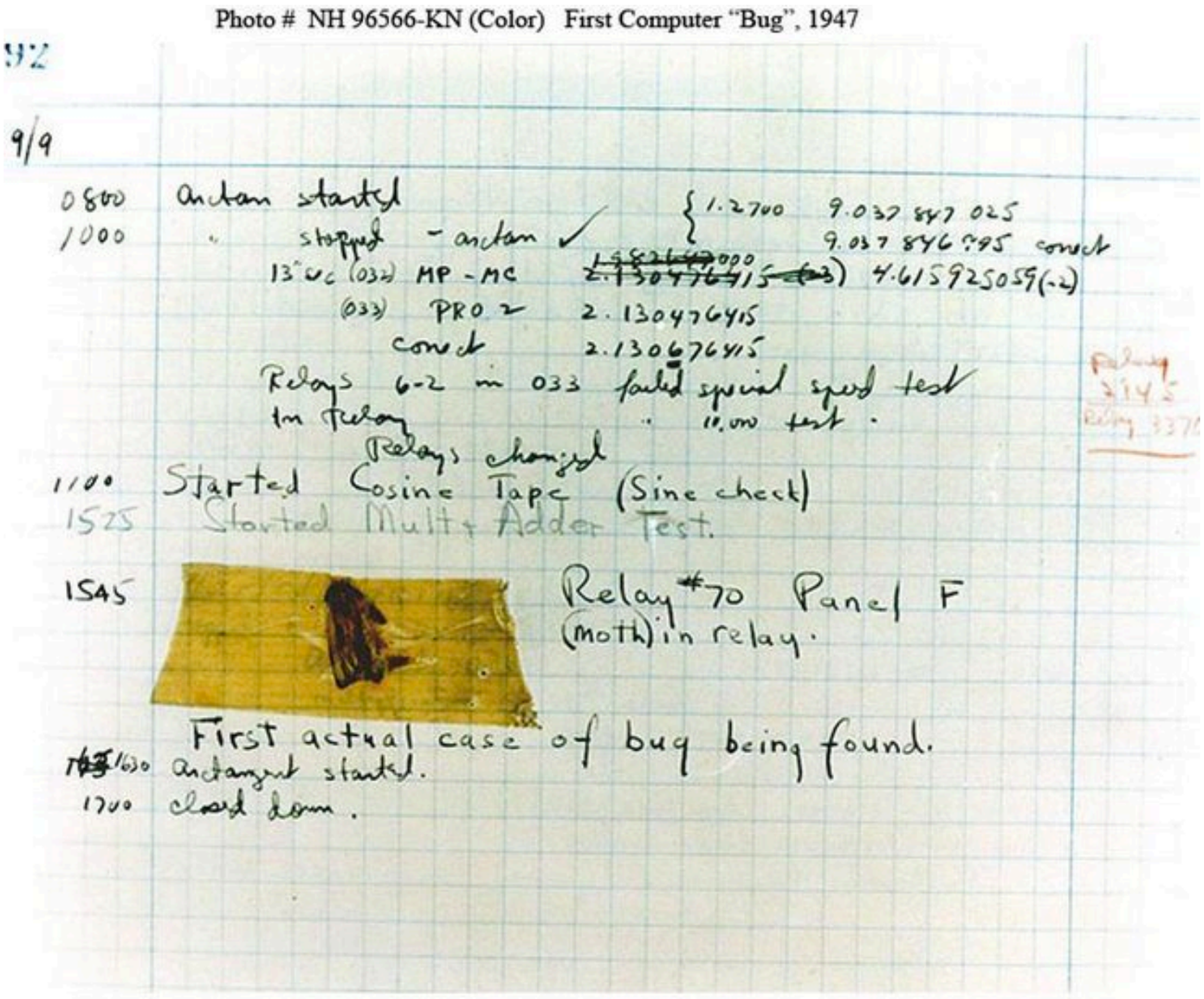
Source: https://madnight.github.io/githut/#/pushes/2020/4

Compilation Errors

```
test.cpp:6:11: error: expected ';' at end of declaration
```

```
test.hs:5:13: error:
    The last statement in a 'do' block must be an expression
      last <- getLine
  |
5 |             last <- getLine
  |             ^^^^^^^^^^^^^^^
Failed, no modules loaded.
```

Bugs



Source: National Geographic

- "After Grace Hopper colleagues at Harvard opened-up some hardware to try and discover what was causing errors in the computer, they were surprised to find the insect trapped in a relay"

Bugs

- Bug is an error, flaw or fault in a program that causes it to produce an unexpected result
- Logical errors: they do not cause the program to crash or simply not work at all, they cause it to return a wrong output

```c
float average(float a, float b)
{
    return a + b / 2;       /* should be (a + b) / 2 */
}
```

Problem Definition

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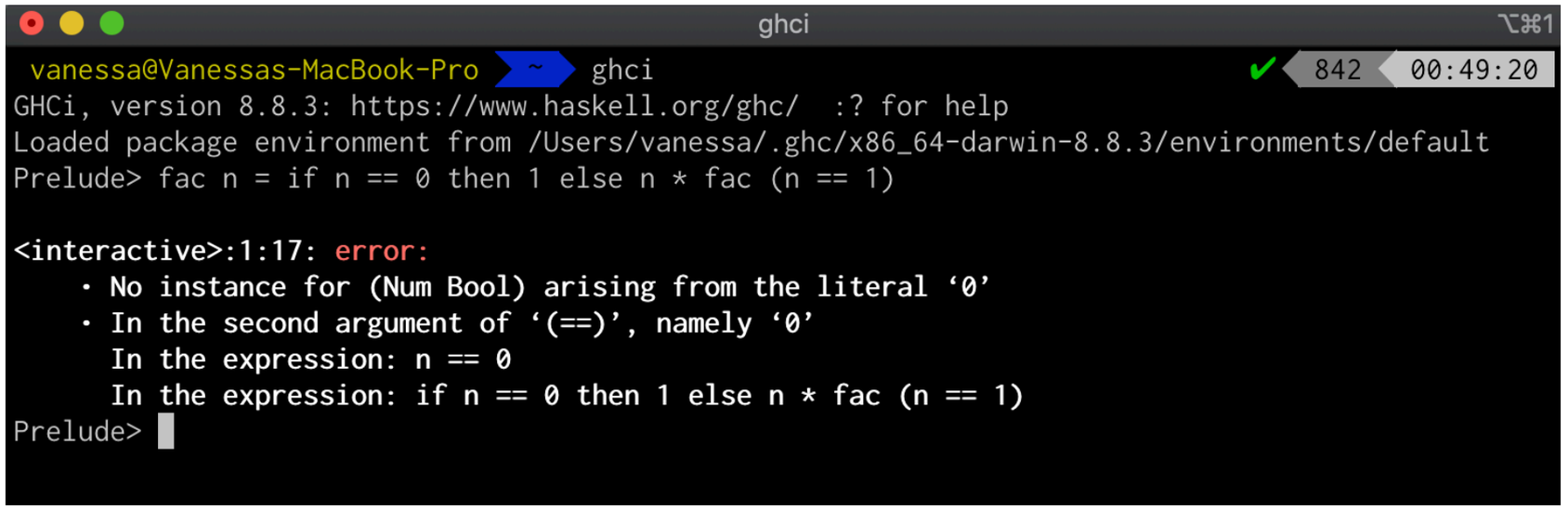
- Challenges in understanding and taking advantage of the functional paradigm
- Much time spent at debugging
- Misleading compiler messages



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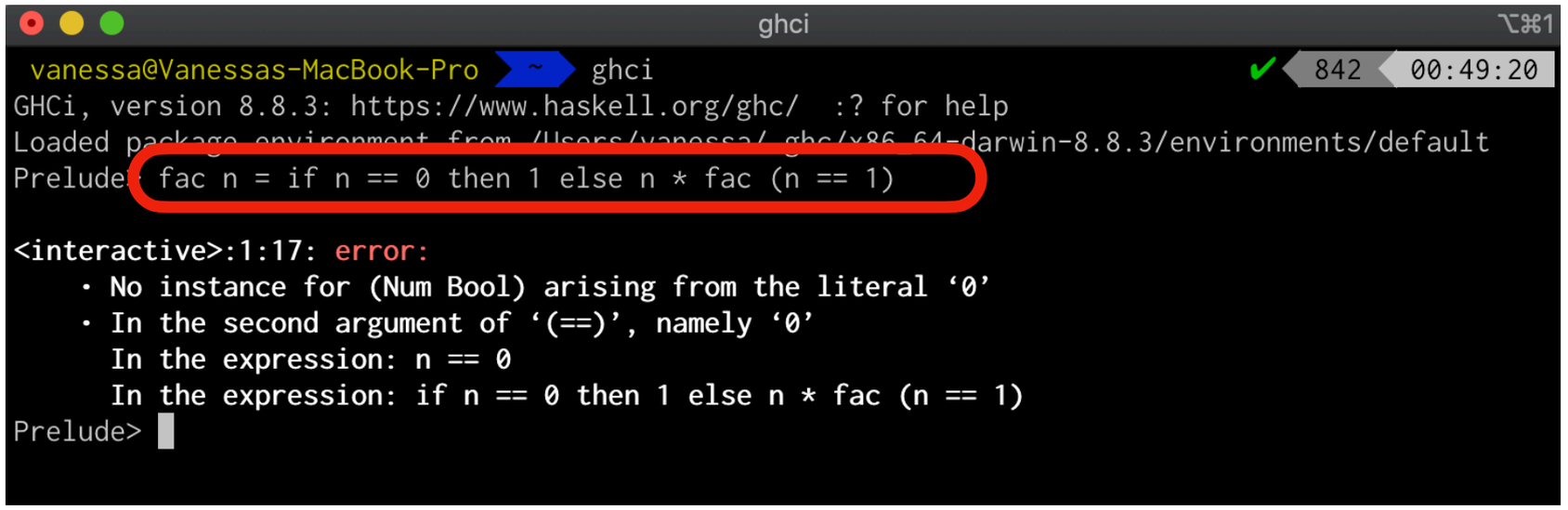

Why Haskell

```
add a b = a + b
```

- Purely functional language
- Pure functions: Haskell, calling add with the same a and b will always return the same value
- Impure functions: C++, moveX modifies pos state

```
class Pos {
    private:
        int x;
        int y;

    public:
        Pos(int x, int y) {
            this->x = x;
            this->y = y;
        }

        void moveX(int inc) {
            this->x = this->x + inc;
        }
};
```

```
Pos pos = Pos(0,0);
pos.moveX(1); // 1 0
pos.moveX(1); // 2 0
pos.moveX(1); // 3 0
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Why Haskell

- Used in functional programming introductory classes
- Several companies use Haskell in internal products or research

Compilers

Compilers

Advertising, Spam Filtering

Finance

Hardware

Goals

Goals

- Project and implement a tool, containing a Haskell interpreter for a subset of Haskell 2010 grammar
- Implement two fault localization techniques
- Build a Haskell test suite covering the chosen Haskell grammar's subset

Haskell Grammar Subset

HaskellFL Grammar Subset

- In: functions, case, if then else, guards, pattern matching, abstract data types, let and where, lambda function
- Out: do notation, list comprehension, type declaration

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greetAndSeeYou :: IO ()
greetAndSeeYou = do name <- nameReturn
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                  | Illegal
                  deriving (Eq, Show)

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filter _ [] = []
filter f (x:xs)
  | f x       = x : (filter f xs)
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Fault Localization

Example 1 - Mid

```
1.module Main where
2.  mid x y z = if y < z
3.    then if x < y
4.           then y
5.           else if x < z
6.                  then y -- BUG
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```
mid 3 3 5 = 3
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mid 5 5 5 = 5
mid 5 3 4 = 4
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Test cases/Lines	1	2	3	4	5	6	7	8	9	10	11	12	P/F
3 3 5		●	●		●	●							P
1 2 3		●	●	●									P
3 2 1		●						●	●				P
5 5 5		●						●		●		●	P
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2 1 3		●	●		●	●							F

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2.  mid x y z = if y < z
3.    then if x < y
4.           then y
5.           else if x < z
6.                  then y -- BUG
7.                  else z
8.    else if x > y
9.           then y
10.          else if x > z
11.                 then x
12.                 else z
```

```
mid 3 3 5 = 3
mid 1 2 3 = 2
mid 3 2 1 = 2
mid 5 5 5 = 5
mid 5 3 4 = 4
mid 2 1 3 = 1
```

Test cases/Lines	1	2	3	4	5	6	7	8	9	10	11	12	P/F
3 3 5		●	●		●	●							P
1 2 3		●	●	●									P
3 2 1		●						●	●				P
5 5 5		●						●		●		●	P
5 3 4		●	●		●		●						P
2 1 3		●	●		●	●							F

Example 1 - Mid

```
1.module Main where
2.  mid x y z = if y < z
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10.          else if x > z
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```

```
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mid 1 2 3 = 2
mid 3 2 1 = 2
mid 5 5 5 = 5
mid 5 3 4 = 4
mid 2 1 3 = 1
```

Test cases/Lines	1	2	3	4	5	6	7	8	9	10	11	12	P/F
3 3 5		●	●		●	●							P
1 2 3		●	●	●									P
3 2 1		●						●	●				P
5 5 5		●						●		●		●	P
5 3 4		●	●		●		●						P
2 1 3		●	●		●	●							F

Example 1 - Mid

```
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```

```
mid 3 3 5 = 3
mid 1 2 3 = 2
mid 3 2 1 = 2
mid 5 5 5 = 5
mid 5 3 4 = 4
mid 2 1 3 = 1
```

Test cases/Lines	1	2	3	4	5	6	7	8	9	10	11	12	P/F
3 3 5		●	●		●	●							P
1 2 3		●	●	●									P
3 2 1		●						●	●				P
5 5 5		●						●		●		●	P
5 3 4		●	●		●		●						P
2 1 3		●	●		●	●							F

Example 1 - Mid

```
1.module Main where
2.  mid x y z = if y < z
3.    then if x < y
4.           then y
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6.                  then y -- BUG
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11.                 then x
12.                 else z
```

```
mid 3 3 5 = 3
mid 1 2 3 = 2
mid 3 2 1 = 2
mid 5 5 5 = 5
mid 5 3 4 = 4
mid 2 1 3 = 1
```

Test cases/Lines	1	2	3	4	5	6	7	8	9	10	11	12	P/F
3 3 5		●	●		●	●							P
1 2 3		●	●	●									P
3 2 1		●						●	●				P
5 5 5		●						●		●		●	P
5 3 4		●	●		●		●						P
2 1 3		●	●		●	●							F

Methods

- **Tarantula**: entities that are primarily executed by failed test cases are more likely to be faulty than those primarily executed by passed test cases

- **Ochiai**: coefficient known from the biology domain, it is more sensitive to potential fault locations in failed runs than to activity in passed runs

$$Tarantula(s) = \frac{\frac{failed(s)}{totalfailed}}{\frac{failed(s)}{totalfailed} + \frac{passed(s)}{totalpassed}}$$

$$Ochiai(s) = \frac{failed(s)}{\sqrt{totalfailed(failed(s) + passed(s))}}$$

Example 1 - Mid

Test cases/Lines	1	2	3	4	5	6	7	8	9	10	11	12	P/F
3 3 5		●	●		●	●							P
1 2 3		●	●	●									P
3 2 1		●						●	●				P
5 5 5		●						●		●		●	P
5 3 4		●	●		●		●						P
2 1 3		●	●		●	●							F
Tarantula	0.00	0.50	0.63	0.00	0.71	**0.83**	0.00	0.00	0.00	0.00	0.00	0.00	
Ochiai	0.00	0.41	0.5	0.00	0.58	**0.71**	0.00	0.00	0.00	0.00	0.00	0.00	

```
1.module Main where
2.  mid x y z = if y < z
3.    then if x < y
4.           then y
5.           else if x < z
6.                then y -- BUG
7.                else z
8.    else if x > y
9.           then y
10.          else if x > z
11.               then x
12.               else z
```

Example 1 - Mid

Test cases/Lines	1	2	3	4	5	6	7	8	9	10	11	12	P/F
3 3 5		●	●		●	●							P
1 2 3		●	●	●									P
3 2 1		●						●	●				P
5 5 5		●						●		●		●	P
5 3 4		●	●		●		●						P
2 1 3		●	●		●	●							F
Tarantula	0.00	0.50	0.63	0.00	0.71	**0.83**	0.00	0.00	0.00	0.00	0.00	0.00	
Ochiai	0.00	0.41	0.5	0.00	0.58	**0.71**	0.00	0.00	0.00	0.00	0.00	0.00	

```
1.module Main where
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5.           else if x < z
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9.           then y
10.          else if x > z
11.               then x
12.               else z
```

Example 1 - Mid

Test cases/Lines	1	2	3	4	5	6	7	8	9	10	11	12	P/F
3 3 5		●	●		●	●							P
1 2 3		●	●	●									P
3 2 1		●						●	●				P
5 5 5		●						●		●		●	P
5 3 4		●	●		●		●						P
2 1 3		●	●		●	●							F
Tarantula	0.00	0.50	0.63	0.00	0.71	**0.83**	0.00	0.00	0.00	0.00	0.00	0.00	
Ochiai	0.00	0.41	0.5	0.00	0.58	**0.71**	0.00	0.00	0.00	0.00	0.00	0.00	

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5.           else if x < z
6.                  then y -- BUG
7.                  else z
8.    else if x > y
9.           then y
10.          else if x > z
11.                 then x
12.                 else z
```

$$totalfailed = 1$$

Example 1 - Mid

Test cases/Lines	1	2	3	4	5	6	7	8	9	10	11	12	P/F
3 3 5		●	●		●	●							P
1 2 3		●	●	●									P
3 2 1		●						●	●				P
5 5 5		●						●		●		●	P
5 3 4		●	●		●		●						P
2 1 3		●	●		●	●							F
Tarantula	0.00	0.50	0.63	0.00	0.71	**0.83**	0.00	0.00	0.00	0.00	0.00	0.00	
Ochiai	0.00	0.41	0.5	0.00	0.58	**0.71**	0.00	0.00	0.00	0.00	0.00	0.00	

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6.                then y -- BUG
7.                else z
8.    else if x > y
9.           then y
10.          else if x > z
11.               then x
12.               else z
```

$totalfailed = 1$ $totalpassed = 5$

Example 1 - Mid

Test cases/Lines	1	2	3	4	5	6	7	8	9	10	11	12	P/F
3 3 5		●	●		●	●							P
1 2 3		●	●	●									P
3 2 1		●						●	●				P
5 5 5		●						●		●		●	P
5 3 4		●	●		●		●						P
2 1 3		●	●		●	●							F
Tarantula	0.00	0.50	0.63	0.00	0.71	**0.83**	0.00	0.00	0.00	0.00	0.00	0.00	
Ochiai	0.00	0.41	0.5	0.00	0.58	**0.71**	0.00	0.00	0.00	0.00	0.00	0.00	

```
1.module Main where
2.  mid x y z = if y < z
3.    then if x < y
4.           then y
5.           else if x < z
6.                then y -- BUG
7.                else z
8.    else if x > y
9.           then y
10.          else if x > z
11.               then x
12.               else z
```

$totalfailed = 1$ $totalpassed = 5$

Example 1 - Mid

Test cases/Lines	1	2	3	4	5	6	7	8	9	10	11	12	P/F
3 3 5		●	●		●	●							P
1 2 3		●	●	●									P
3 2 1		●						●	●				P
5 5 5		●						●		●		●	P
5 3 4		●	●		●		●						P
2 1 3		●	●		●	●							F
Tarantula	0.00	0.50	0.63	0.00	0.71	**0.83**	0.00	0.00	0.00	0.00	0.00	0.00	
Ochiai	0.00	0.41	0.5	0.00	0.58	**0.71**	0.00	0.00	0.00	0.00	0.00	0.00	

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```

$totalfailed = 1$ $totalpassed = 5$

Example 1 - Mid

Test cases/Lines	1	2	3	4	5	6	7	8	9	10	11	12	P/F
3 3 5		●	●		●	●							P
1 2 3		●	●	●									P
3 2 1		●						●	●				P
5 5 5		●						●		●		●	P
5 3 4		●	●		●		●						P
2 1 3		●	●		●	●							F
Tarantula	0.00	0.50	0.63	0.00	0.71	**0.83**	0.00	0.00	0.00	0.00	0.00	0.00	
Ochiai	0.00	0.41	0.5	0.00	0.58	**0.71**	0.00	0.00	0.00	0.00	0.00	0.00	

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7.                else z
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10.          else if x > z
11.               then x
12.               else z
```

$totalfailed = 1$ $totalpassed = 5$

$failed(6) = 1$

Example 1 - Mid

Test cases/Lines	1	2	3	4	5	6	7	8	9	10	11	12	P/F
3 3 5		●	●		●	●							P
1 2 3		●	●	●									P
3 2 1		●						●	●				P
5 5 5		●						●		●		●	P
5 3 4		●	●		●		●						P
2 1 3		●	●		●	●							F
Tarantula	0.00	0.50	0.63	0.00	0.71	**0.83**	0.00	0.00	0.00	0.00	0.00	0.00	
Ochiai	0.00	0.41	0.5	0.00	0.58	**0.71**	0.00	0.00	0.00	0.00	0.00	0.00	

```
1.module Main where
2.  mid x y z = if y < z
3.    then if x < y
4.           then y
5.           else if x < z
6.                then y -- BUG
7.                else z
8.    else if x > y
9.           then y
10.          else if x > z
11.               then x
12.               else z
```

$totalfailed = 1$ $totalpassed = 5$

$failed(6) = 1$ $passed(6) = 1$

Example 1 - Mid

Test cases/Lines	1	2	3	4	5	6	7	8	9	10	11	12	P/F
3 3 5		●	●		●	●							P
1 2 3		●	●	●									P
3 2 1		●						●	●				P
5 5 5		●						●		●		●	P
5 3 4		●	●		●		●						P
2 1 3		●	●		●	●							F
Tarantula	0.00	0.50	0.63	0.00	0.71	**0.83**	0.00	0.00	0.00	0.00	0.00	0.00	
Ochiai	0.00	0.41	0.5	0.00	0.58	**0.71**	0.00	0.00	0.00	0.00	0.00	0.00	

```
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3.    then if x < y
4.           then y
5.           else if x < z
6.                  then y -- BUG
7.                  else z
8.    else if x > y
9.           then y
10.          else if x > z
11.                 then x
12.                 else z
```

$$totalfailed = 1 \qquad totalpassed = 5$$

$$failed(6) = 1 \qquad passed(6) = 1$$

$$Ochiai(6) = \frac{failed(6)}{\sqrt{totalfailed(failed(6) + passed(6))}} = \frac{1}{\sqrt{2}} \approx 0.71$$

Example 1 - Mid

Test cases/Lines	1	2	3	4	5	6	7	8	9	10	11	12	P/F
3 3 5		●	●		●	●							P
1 2 3		●	●	●									P
3 2 1		●						●	●				P
5 5 5		●						●		●		●	P
5 3 4		●	●		●		●						P
2 1 3		●	●		●	●							F
Tarantula	0.00	0.50	0.63	0.00	0.71	**0.83**	0.00	0.00	0.00	0.00	0.00	0.00	
Ochiai	0.00	0.41	0.5	0.00	0.58	**0.71**	0.00	0.00	0.00	0.00	0.00	0.00	

```
1.module Main where
2.  mid x y z = if y < z
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6.                  then y -- BUG
7.                  else z
8.    else if x > y
9.           then y
10.          else if x > z
11.                 then x
12.                 else z
```

$$totalfailed = 1 \qquad totalpassed = 5$$

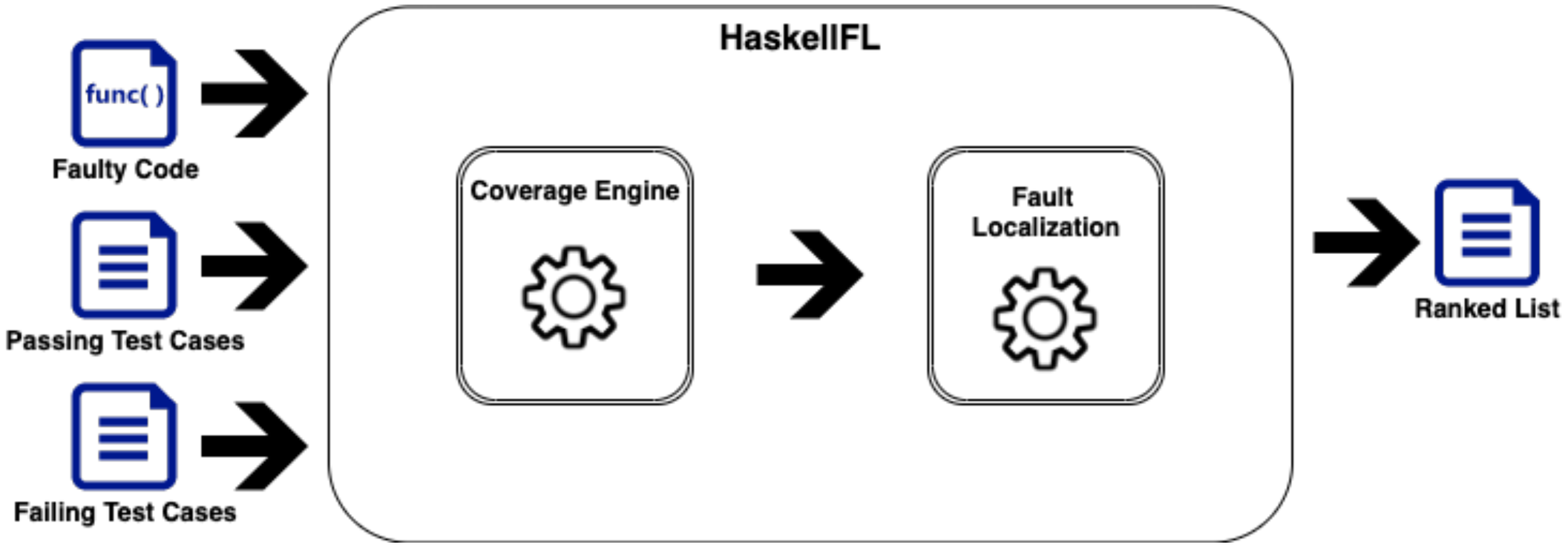
$$failed(6) = 1 \qquad passed(6) = 1$$

$$Ochiai(6) = \frac{failed(6)}{\sqrt{totalfailed(failed(6) + passed(6))}} = \frac{1}{\sqrt{2}} \approx 0.71$$

$$Tarantula(6) = \frac{\frac{failed(6)}{totalfailed}}{\frac{failed(6)}{totalfailed} + \frac{passed(6)}{totalpassed}} = \frac{1}{1 + \frac{1}{5}} = \frac{5}{6} \approx 0.83$$

HaskellFL

HaskellFL Architecture



HaskellFL Input

HaskellFL Input

```
1.  module Main () where
2.
3.      dropWhileClone p [] = []
4.      dropWhileClone p (x:xs)
5.          | p x       = dropWhileClone p xs
6.          | otherwise = x:xs
7.
8.      isSpace s = if s == "" -- BUG
9.          then True
10.         else False
11.
```

HaskellFL Input

```
1.  module Main () where
2.
3.      dropWhileClone p [] = []
4.      dropWhileClone p (x:xs)
5.          | p x       = dropWhileClone p xs
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9.          then True
10.         else False
11.
```

Faulty Code

HaskellFL Input

```
1.  module Main () where
2.
3.      dropWhileClone p [] = []
4.      dropWhileClone p (x:xs)
5.          | p x       = dropWhileClone p xs
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```

Faulty Code

HaskellFL Input

```
1.  module Main () where
2.
3.      dropWhileClone p [] = []
4.      dropWhileClone p (x:xs)
5.          | p x         = dropWhileClone p xs
6.          | otherwise = x:xs
7.
8.      isSpace s = if s == "" -- BUG
9.          then True
10.         else False
11.
```

Faulty Code

```
dropWhileClone isSpace ["v", " "]
dropWhileClone isSpace ["v", ""]
dropWhileClone isSpace ["y"]
dropWhileClone isSpace ["p", "e"]
dropWhileClone isSpace []
```

HaskellFL Input

```
1.  module Main () where
2.
3.      dropWhileClone p [] = []
4.      dropWhileClone p (x:xs)
5.          | p x         = dropWhileClone p xs
6.          | otherwise = x:xs
7.
8.      isSpace s = if s == "" -- BUG
9.          then True
10.         else False
11.
```

Faulty Code

```
dropWhileClone isSpace ["v", " "]
dropWhileClone isSpace ["v", ""]
dropWhileClone isSpace ["y"]
dropWhileClone isSpace ["p", "e"]
dropWhileClone isSpace []
```

tests-pass.txt

HaskellFL Input

```
1.  module Main () where
2.
3.      dropWhileClone p [] = []
4.      dropWhileClone p (x:xs)
5.          | p x         = dropWhileClone p xs
6.          | otherwise = x:xs
7.
8.      isSpace s = if s == "" -- BUG
9.          then True
10.         else False
11.
```

Faulty Code

```
dropWhileClone isSpace ["v", " "]
dropWhileClone isSpace ["v", ""]
dropWhileClone isSpace ["y"]
dropWhileClone isSpace ["p", "e"]
dropWhileClone isSpace []
```

tests-pass.txt

```
dropWhileClone isSpace [" ", "v", " "]
dropWhileClone isSpace [" ", " ", "p"]
dropWhileClone isSpace ["", " ", "p"]
dropWhileClone isSpace [" "]
dropWhileClone isSpace [""]
```

HaskellFL Input

```
1.  module Main () where
2.
3.      dropWhileClone p [] = []
4.      dropWhileClone p (x:xs)
5.          | p x         = dropWhileClone p xs
6.          | otherwise = x:xs
7.
8.      isSpace s = if s == "" -- BUG
9.          then True
10.         else False
11.
```

Faulty Code

```
dropWhileClone isSpace ["v", " "]
dropWhileClone isSpace ["v", ""]
dropWhileClone isSpace ["y"]
dropWhileClone isSpace ["p", "e"]
dropWhileClone isSpace []
```

tests-pass.txt

```
dropWhileClone isSpace [" ", "v", " "]
dropWhileClone isSpace [" ", " ", "p"]
dropWhileClone isSpace ["", " ", "p"]
dropWhileClone isSpace [" "]
dropWhileClone isSpace [""]
```

tests-fail.txt

HaskellFL Engine

Line	Passing Tests	Failing Tests
1	-	-
2	-	-
3	5	5
4	-	-
5	4	5
6	4	4
7	-	-
8	**4**	**5**
9	0	2
10	4	4

```haskell
1.  module Main () where
2.
3.      dropWhileClone p [] = []
4.      dropWhileClone p (x:xs)
5.          | p x       = dropWhileClone p xs
6.          | otherwise = x:xs
7.
8.      isSpace s = if s == "" -- BUG
9.          then True
10.         else False
11.
```

$$Tarantula(8) = \frac{\frac{failed(8)}{totalfailed}}{\frac{failed(8)}{totalfailed} + \frac{passed(8)}{totalpassed}} = \frac{1}{1 + \frac{4}{5}} = \frac{5}{9} \approx 0.556$$

$$Ochiai(8) = \frac{failed(8)}{\sqrt{totalfailed(failed(8) + passed(8))}} = \frac{5}{\sqrt{45}} \approx 0.745$$

HaskellFL Output

```haskell
module Main () where

    dropWhileClone p [] = []
    dropWhileClone p (x:xs)
        | p x       = dropWhileClone p xs
        | otherwise = x:xs

    isSpace s = if s == "" -- BUG
        then True
        else False

```

```
"## HaskellFL ##"
"Tarantula: "
Line = 9, Score = 1.0
Line = 5, Score = 1.0
Line = 8, Score = 0.556
Line = 10, Score = 0.5
Line = 6, Score = 0.5
Line = 3, Score = 0.5
```

```
"## HaskellFL ##"
"Ochiai: "
Line = 8, Score = 0.745
Line = 5, Score = 0.745
Line = 3, Score = 0.707
Line = 10, Score = 0.632
Line = 9, Score = 0.632
Line = 6, Score = 0.632
```

Ranked List

HaskellFL Output

```
1.  module Main () where
2.
3.      dropWhileClone p [] = []
4.      dropWhileClone p (x:xs)
5.          | p x         = dropWhileClone p xs
6.          | otherwise = x:xs
7.
8.      isSpace s = if s == "" -- BUG
9.          then True
10.         else False
11.
```

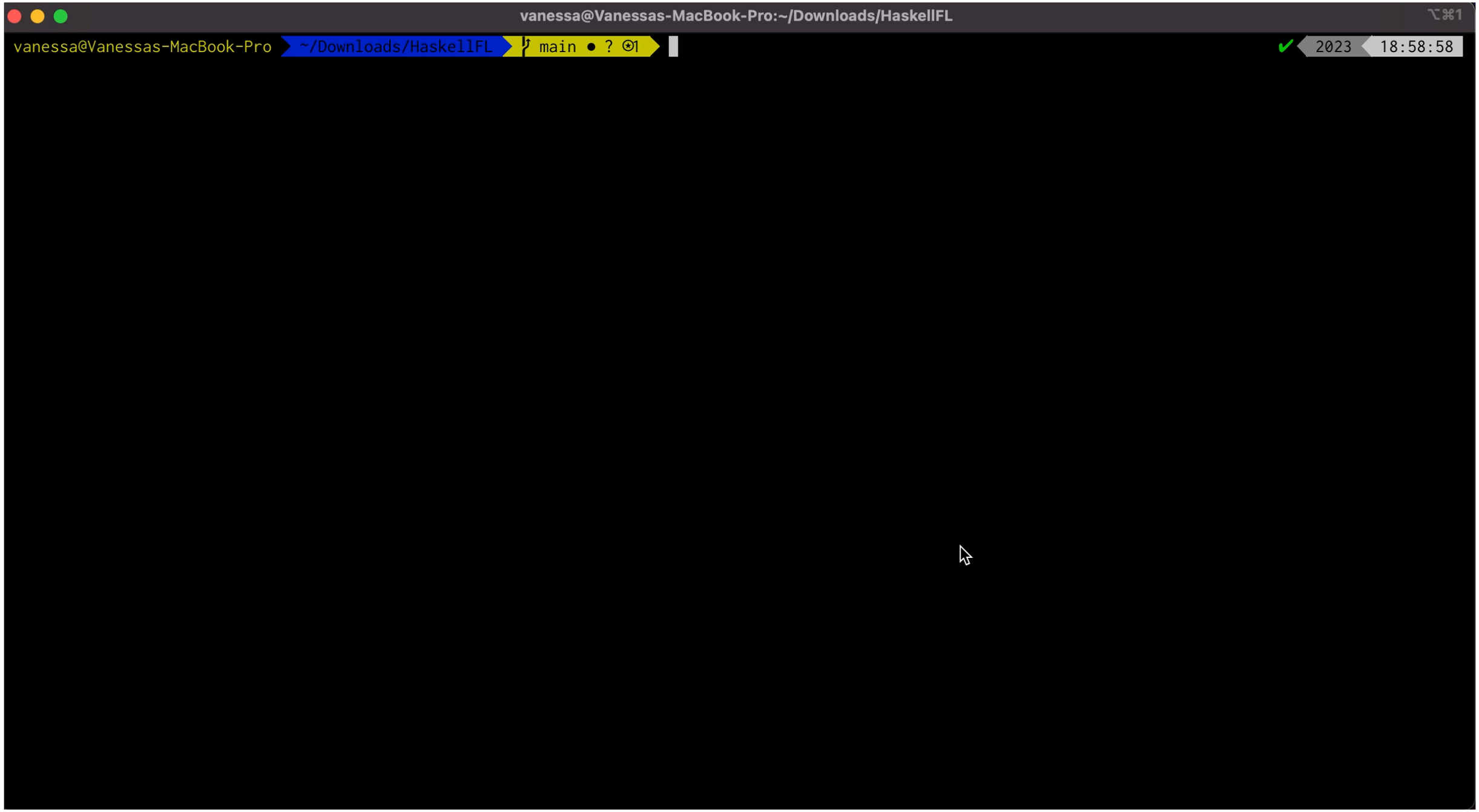
```
"## HaskellFL ##"
"Tarantula: "
Line = 9, Score = 1.0
Line = 5, Score = 1.0
Line = 8, Score = 0.556
Line = 10, Score = 0.5
Line = 6, Score = 0.5
Line = 3, Score = 0.5
```

```
"## HaskellFL ##"
"Ochiai: "
Line = 8, Score = 0.745
Line = 5, Score = 0.745
Line = 3, Score = 0.707
Line = 10, Score = 0.632
Line = 9, Score = 0.632
Line = 6, Score = 0.632
```

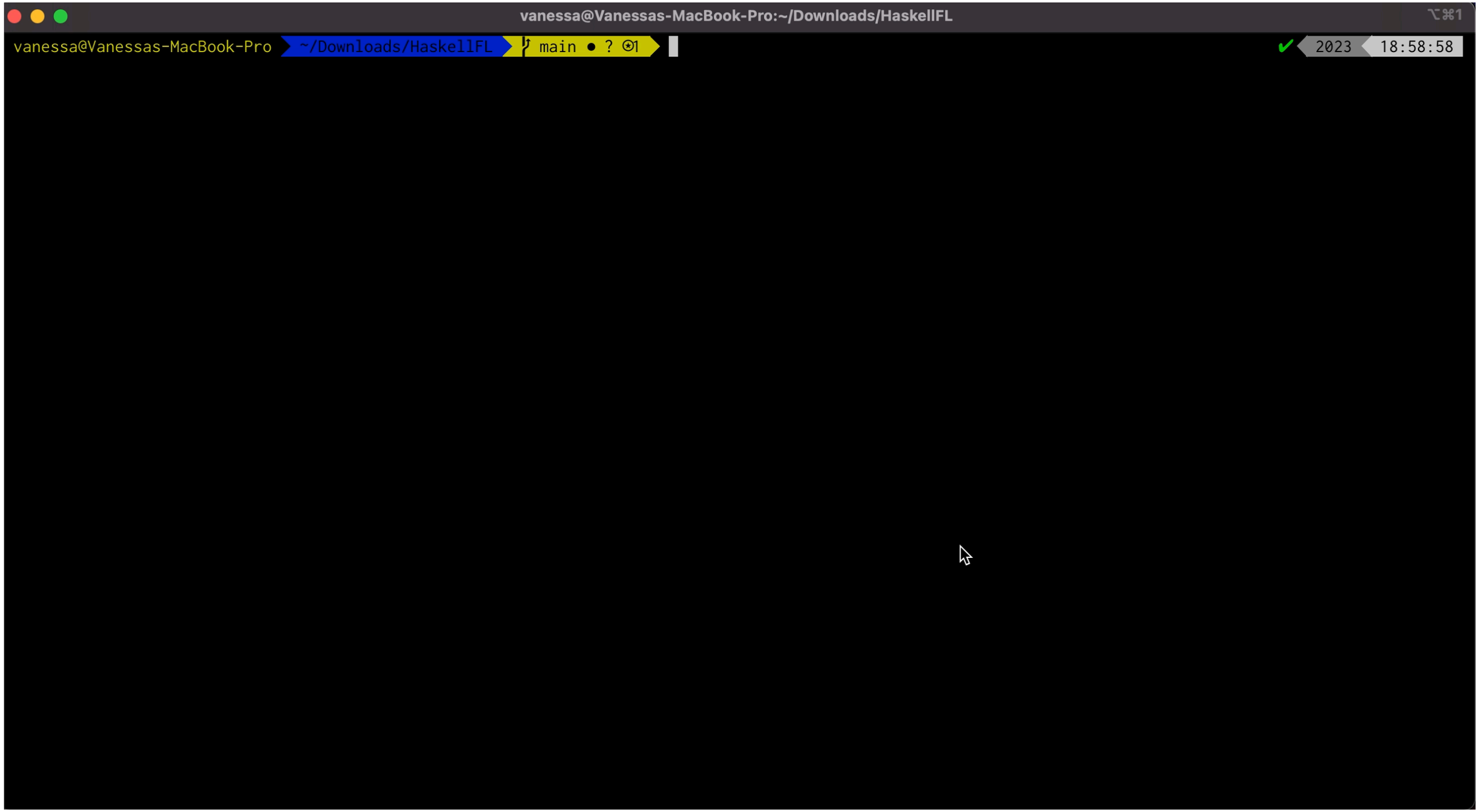
Ranked List

Demo

Demo


vanessa@Vanessas-MacBook-Pro:~/Downloads/HaskellFL
⌥⌘1
vanessa@Vanessas-MacBook-Pro
~/Downloads/HaskellFL
main ● ? ⍟1
2023
18:58:58

Demo


vanessa@Vanessas-MacBook-Pro:~/Downloads/HaskellFL
⌥⌘1
vanessa@Vanessas-MacBook-Pro
~/Downloads/HaskellFL
main ● ? ⍟1
2023
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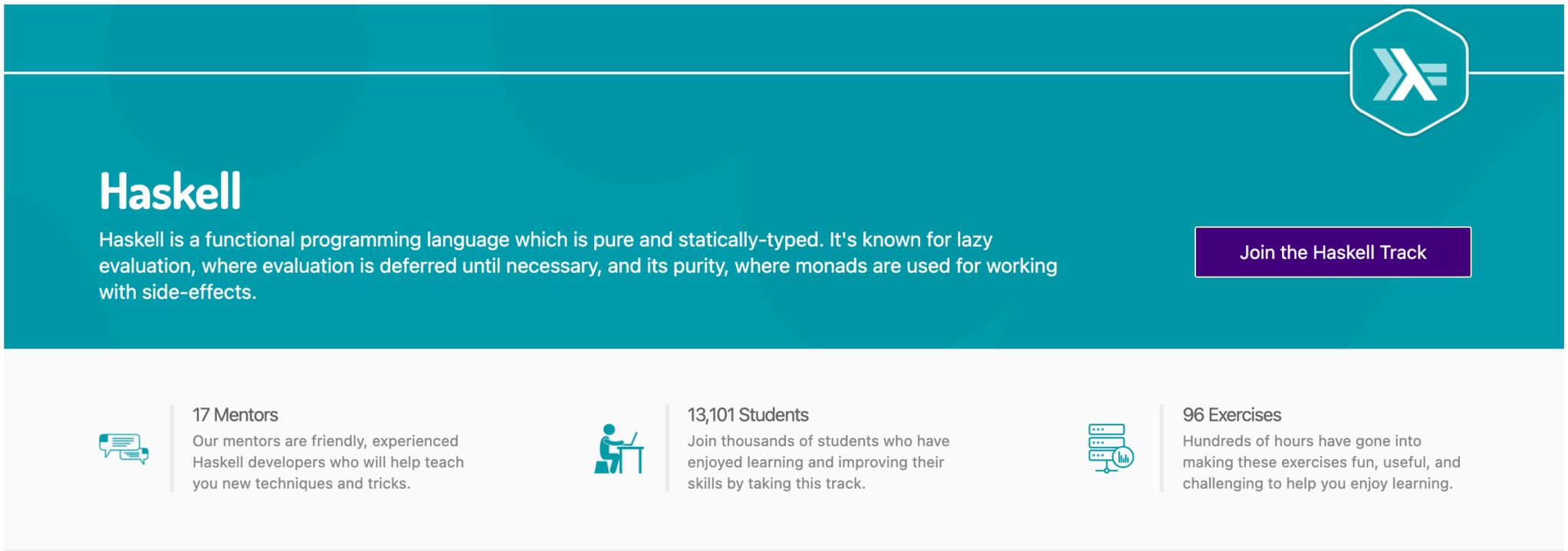
Test Suite

Test Suite

- 24 problems
- Submissions from students in the Functional Programming class at UFMG
- Two versions of mid function
- Submissions for Exercism's Haskell track available on GitHub



Test Suite

Program	#Tests	Ranking	
		Tarantula	Ochiai
mid (Version 1)	6	5	2
mid (Version 2)	6	1	1
dropWhileClone	10	3	1
dropWhile	9	1	1
break (Version 1)	5	1	1
break (Version 2)	8	1	1
toTuples	10	1	1
remdupsReducer	7	1	1
joinr	12	1	1
separateTuplesByType	7	1	1
flip	5	1	1
unzip	3	1	1
maxSumLength	11	1	1
binary-search-tree	8	2	2
grade-school	7	1	1
luhn	6	2	2
raindrops	8	1	1
resistor-color-duo	7	1	1
robot-simulator	9	1	1
roman-numerals	8	1	1
simple-linked-list	6	1	1
space-age	7	1	1
sum-of-multiples	7	3	1
triangle	8	6	5

Results

Results - EXAM Score

- Indicates the percentage of program elements that a developer would have to inspect until finding the bug

```haskell
module Main () where

    dropWhileClone p [] = []
    dropWhileClone p (x:xs)
       | p x       = dropWhileClone p xs
       | otherwise = x:xs

   isSpace s = if s == "" -- BUG
       then True
       else False

```

```
"## HaskellFL ##"
"Ochiai: "
Line = 8, Score = 0.745
Line = 5, Score = 0.745
Line = 3, Score = 0.707
Line = 10, Score = 0.632
Line = 9, Score = 0.632
Line = 6, Score = 0.632
```

Results - EXAM Score

- Indicates the percentage of program elements that a developer would have to inspect until finding the bug

```
1.  module Main () where
2.
3.      dropWhileClone p [] = []
4.      dropWhileClone p (x:xs)
5.          | p x       = dropWhileClone p xs
6.          | otherwise = x:xs
7.
8.      isSpace s = if s == "" -- BUG
9.          then True
10.         else False
11.
```

```
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$$Ochai\ Best = \frac{1}{10} = 10\,\%$$

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$$Ochai\ Best = \frac{1}{10} = 10\,\%$$

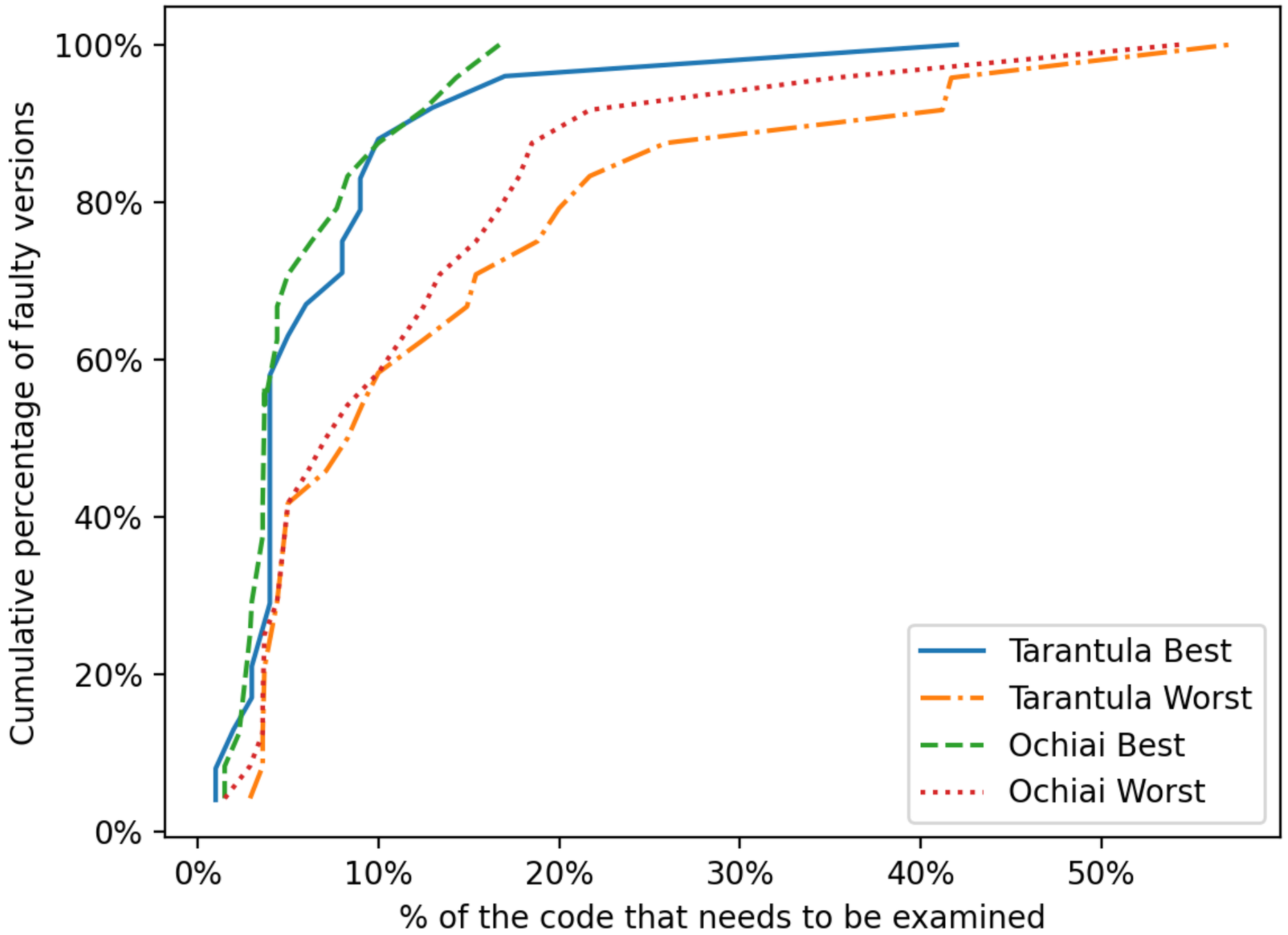
$$Ochai\ Worst = \frac{2}{10} = 20\,\%$$

Results - EXAM Score

- Indicates the percentage of program elements that a developer would have to inspect until finding the bug

EXAM Score	Tarantula Best	Tarantula Worst	Ochiai Best	Ochiai Worst
(0-4.9)%	58.33%	33.33%	66.67%	33.33%
(5-9.9)%	25.00%	20.83%	16.67%	20.83%
(10-14.9)%	8.33%	12.50%	12.50%	16.67%
(15-19.9)%	4.17%	8.33%	4.17%	16.67%
(20-24.9)%	0.00%	8.33%	0.00%	4.17%
(25-29.9)%	0.00%	4.17%	0.00%	0.00%
(30-34.9)%	0.00%	0.00%	0.00%	0.00%
(35-39.9)%	0.00%	0.00%	0.00%	4.17%
(40-44.9)%	4.17%	8.33%	0.00%	0.00%
(45-49.9)%	0.00%	0.00%	0.00%	0.00%
(50-54.9)%	0.00%	0.00%	0.00%	4.17%
(55-59.9)%	0.00%	4.17%	0.00%	0.00%

Results



Conclusion

Contributions

- We created an interpreter for a Haskell grammar subset

- HaskellFL tool and our test suite are available as an open source project at https://github.com/VanessaCristiny/HaskellFL

- HaskellFL located the errors using Tarantula and Ochiai methods examining very few lines for the majority of our test suite

- Our results showed that Ochiai presented better results than Tarantula

- Publication: Detecting Logical Errors in Haskell, to appear in the proceedings of ICTSS 2021

ICTSS 2021: 15. International Conference on Testing Software and Systems

June 03-04, 2021 in New York, United States

Future Work

- Extend the grammar to include do notation and list comprehensions
- Implement mutation-based fault localization algorithms
- Actually repair the code

Detecting Logical Errors in Haskell

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