Delta Debugging Type Errors with a Blackbox Compiler

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Example

Insert an element into an ordered list:

```
1.   insert x [] = [x]
2.   insert x (y:ys) | x > y = y : insert x ys
3.                  | otherwise = x : y : ys
```

Example from : Stuckey, P., Sulzmann, M., Wazny, J. 2004. Improving type error diagnosis.

Example

This code has a type error.

```
1.   insert x [] =  x
2.   insert x (y:ys) | x > y = y : insert x ys
3.                  | otherwise = x : y : ys
```

Example from : Stuckey, P., Sulzmann, M., Wazny, J. 2004. Improving type error diagnosis.

Example

GHC 8.4.3 type error message:

```
Insert.hs:2:27: error:
    • Occurs check: cannot construct the infinite type: a ~ [a]
    • In the expression: y : Main.insert x ys
    In an equation for ‘Main.insert’:
        Main.insert x (y : ys)
        | x > y = y : Main.insert x ys
        | otherwise = x : y : ys
    • Relevant bindings include
    ys :: [a] (bound at Insert.hs:2:13)
    y :: a (bound at Insert.hs:2:11)
    x :: a (bound at Insert.hs:2:8)
    insert :: a -> [a] -> [a] (bound at Insert.hs:1:1)
```

What is the issue?

We all experience type errors, causing hours of frustration…

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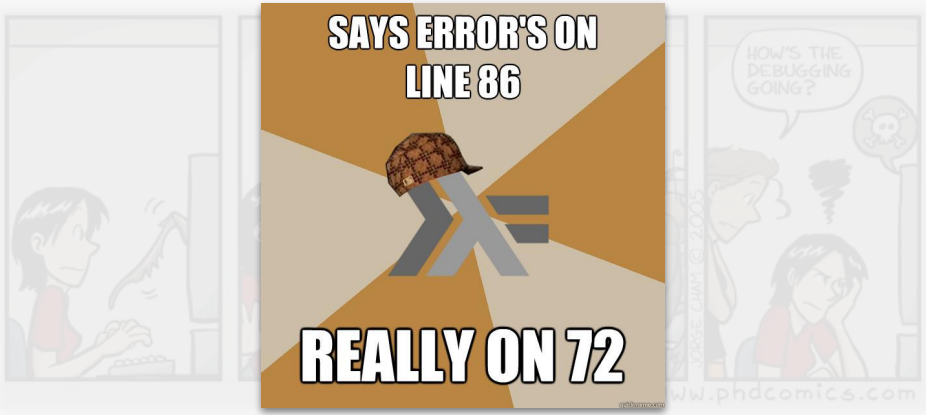
We all experience type errors, causing hours of frustration…

…made worse by the compiler reporting the wrong line...



An illustration of our method

Two programs to work with:

```
1.
2.
3.
```

```
1. insert x [] = x
2. insert x (y:ys) | x > y = y : insert x ys
3.                 | otherwise = x : y : ys
```

An illustration of our method

Add lines to one and remove from the other:

```
1. insert x [] = x
2. insert x (y:ys) | x > y = y : insert x ys
3.
```

```
1.
2.
3.                    | otherwise = x : y : ys
```

An illustration of our method

Type-check the programs:

```
1. insert x [] = x
2. insert x (y:ys) | x > y = y : insert x ys
3.
```

```
1.
2.
3.                    | otherwise = x : y : ys
```

FAIL

An illustration of our method

Type-check the programs:

```
1. insert x [] = x
2. insert x (y:ys) | x > y = y : insert x ys
3.
```

FAIL

```
1.
2.
3.                    | otherwise = x : y : ys
```

UNRESOLVED

An illustration of our method

New base programs to modify:

```
1.
2.
3.
```

```
1. insert x [] = x
2. insert x (y:ys) | x > y = y : insert x ys
3.
```

An illustration of our method

Add and remove line two:

```
1.
2. insert x (y:ys) | x > y = y : insert x ys
3.
```

```
1. insert x [] = x
2.
3.
```

An illustration of our method

Type-check the programs:

```
1.
2. insert x (y:ys) | x > y = y : insert x ys
3.
```

```
1. insert x [] = x
2.
3.
```

PASS

An illustration of our method

Type-check the programs:

```
1.
2. insert x (y:ys) | x > y = y : insert x ys
3.
```

PASS

```
1. insert x [] = x
2.
3.
```

PASS

An illustration of our method

Our new base line programs:

```
1.
2. insert x (y:ys) | x > y = y : insert x ys
3.
```

```
1. insert x [] = x
2. insert x (y:ys) | x > y = y : insert x ys
3.
```

An illustration of our method

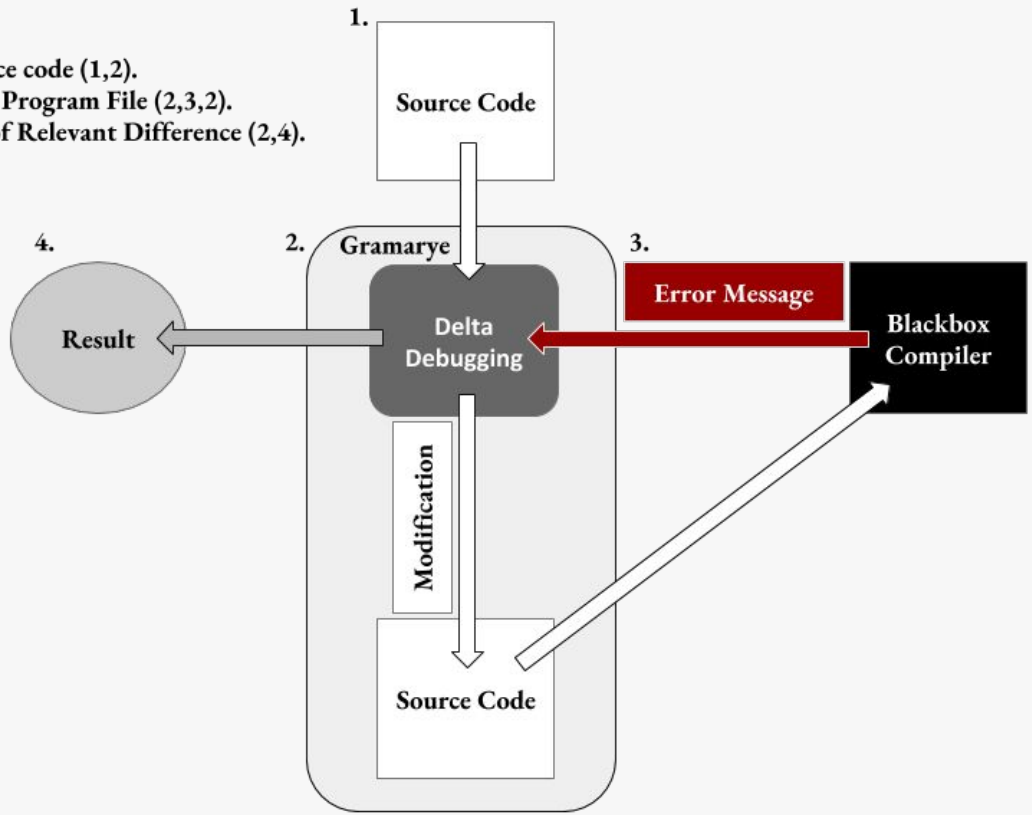
Algorithm terminates:

```
1.
2. insert x (y:ys) | x > y = y : insert x ys
3.
```

```
1. insert x [] = x
2. insert x (y:ys) | x > y = y : insert x ys
3.
```

Relevant difference is line **1**

Input raw source code (1,2).
Recursion over Program File (2,3,2).
Output result of Relevant Difference (2,4).



Isolating Delta Debugging

Andreas Zeller. 2009. Why Programs Fail.

Automates scientific problem solving

- Iterates over two programs - Modifying and Testing
- Binary Chop to provide what to modify
- Isolates the difference between the two

A Black Box Compiler

Accessing standard output from the compiler

- No modification to the existing compiler
- Method allows option of extending to other compilers
- Used only as a type checker

Manipulating Source Code

Directly changing the source of the program

- Adding and Removing whole lines
- No need for our own parser
- Keeps programmers' layout intact

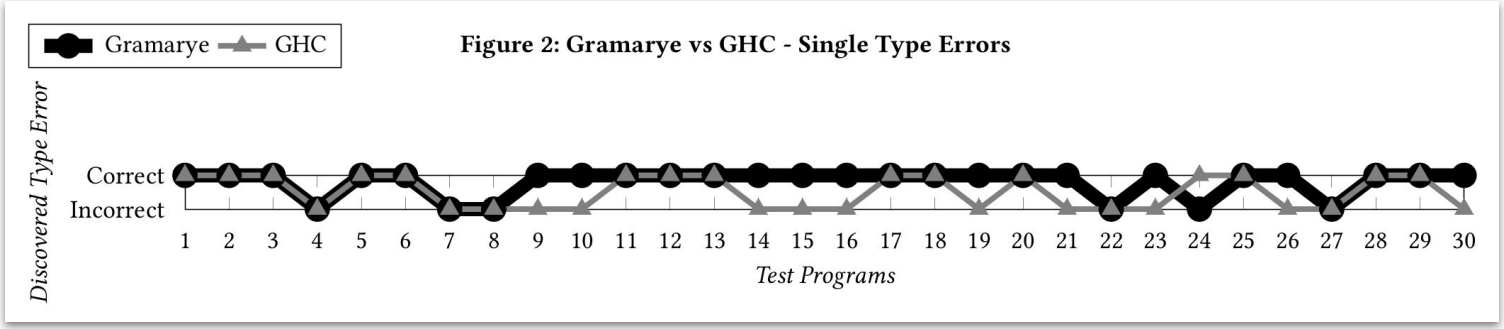
Evaluation

- The inaccurate reporting of the line number of a type error
- Compared the method to the outcome of GHC
- 30 programs with single errors, 870 with multiple errors
  - Collected by Chen and Erwig from previous papers
  - Contain an Oracle - we know the line of the error

Locating Single Type Errors

Show improvement in locating single errors?

- If line number matched oracle, it was accurate
- **80%** success rate vs GHC at **50%**



Locating Multiple Type Errors

Show improvement in locating multiple errors?

- Two non-connected functions containing type errors
- **68%** success rate vs GHC at **71%**

```
addList ls s = if s `elem` ls then ls else s : ls
v5 = addList "a" ["b"]

sumLists = sum2 . map sum2
sum2 [] = []
sum2 (x:xs) = x + sum2 xs
```

Precisely Locating Type Errors

Return a smaller set of locations?

- **53%** accurate on single type errors vs GHC at **40%**
- **43%** accurate on multiple type errors vs GHC at **15%**

Program	Gramarye	GHC	Program	Gramarye	GHC	Program	Gramarye	GHC
1	✓	✓	11	×	✓	21	✓	×
2	×	✓	12	✓	✓	22	×	×
3	✓	×	13	✓	✓	23	✓	×
4	×	×	14	×	×	24	×	×
5	×	✓	15	×	×	25	✓	✓
6	×	✓	16	✓	×	26	✓	×
7	×	×	17	✓	×	27	×	×
8	×	×	18	✓	✓	28	✓	✓
9	✓	×	19	×	×	29	×	✓
10	✓	×	20	✓	✓	30	×	✓

Future Work

- Investigate the outlier for Single Type Errors
- Evaluate the non-determinism of the algorithm’s choices
- Move to larger examples

Thank You

- Type error debugging tool that employs: Delta Debugging, Blackbox compiler, and direct Source Code manipulation.
  - **80%** successful in locating single type errors
  - **68%** successful in locating multiple type errors
  - **53%** and **43%** precise accuracy locating type errors

https://github.com/JoannaSharrad/gramarye