Signature Inference for Functional Property Discovery

or: How never to come up with tests manually anymore(*)

Tom Sydney Kerckhove

ETH Zurich
https://cs-syd.eu/
https://github.com/NorfairKing

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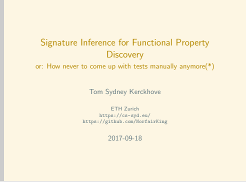
2017-09-21

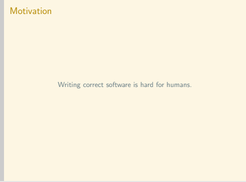
Signature Inference for Functional Property Discovery



1. The presentation should take about thirty minutes.
2. I have been working on this for the last six months, so if I forget to explain anything, please ask me immediately.

Motivation

Writing correct software is hard for humans.

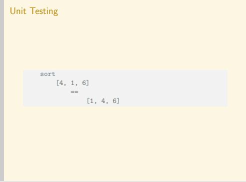

Motivation

Writing correct software is hard for humans.

1. So why would we want to not want to come up with tests manually?

Unit Testing

```
    sort
        [4, 1, 6]
            ==
                [1, 4, 6]
```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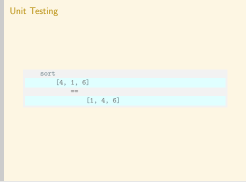

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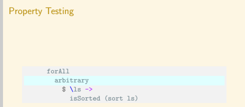
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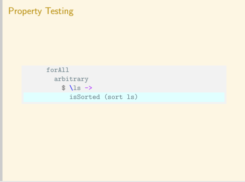
└─Motivation
└─Property Testing



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Property Discovery

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Property Discovery with QuickSpec

Property Discovery with QuickSpec

Example Code

```haskell
module MySort where

mySort :: Ord a => [a] -> [a]
mySort [] = []
mySort (x:xs) = insert (mySort xs)
  where
    insert [] = [x]
    insert (y:ys)
        | x <= y = x : y : ys
        | otherwise = y : insert ys

myIsSorted :: Ord a => [a] -> Bool
myIsSorted [] = True
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myIsSorted (x:y:ls) = x <= y && myIsSorted (y : ls)
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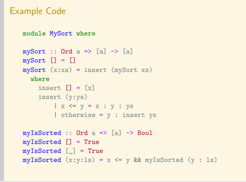
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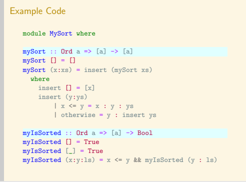
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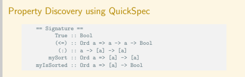
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1. Explain how would you use this
2. Before I go on:
3. This is Really cool!
4. Really good at what it does
5. Great foundation for what comes next

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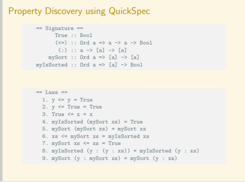
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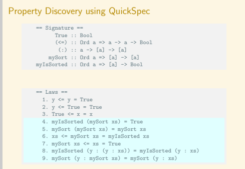
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QuickSpec Code

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module MySortQuickSpec where

import Control.Monad
import MySort
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main :: IO ()
main =
    void $
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        signature
        { constants =
              [ constant "True" (True :: Bool)
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Problems with QuickSpec: Monomorphisation

Only for monomorphic functions

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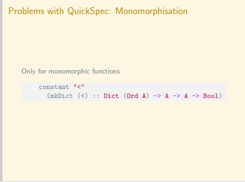
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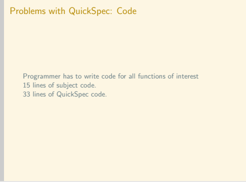
15 lines of subject code.
33 lines of QuickSpec code.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Problems with QuickSpec: Speed

Dumb version of the QuickSpec approach:

1. Generate all possible terms
2. Generate all possible equations (tuples) of terms
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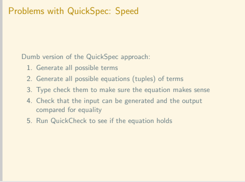
4. Check that the input can be generated and the output compared for equality
5. Run QuickCheck to see if the equation holds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Property Discovery with EasySpec

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A QuickSpec Signature

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  Signature {
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```
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Signature Inference for Functional Property Discovery
└─Automation
  └─A QuickSpec Signature

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Signature Expression Generation

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filter :: (a -> Bool) -> [a] -> [a]
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└─Automation
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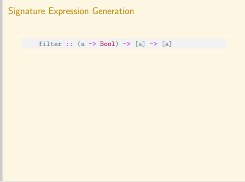
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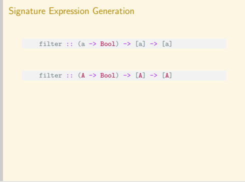

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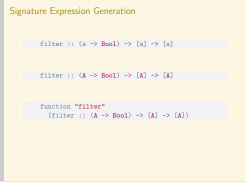

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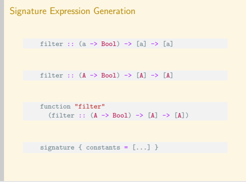
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Current Situation

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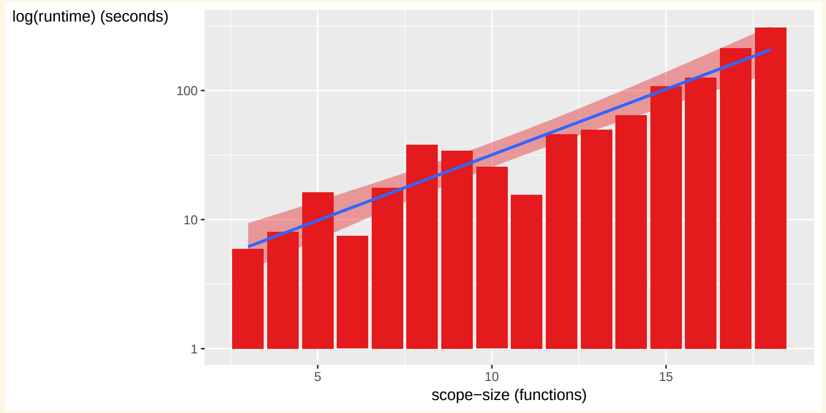
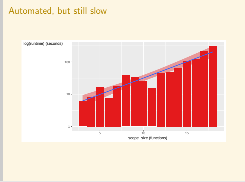
Automated, but still slow





1. Now we have automated QuickSpec, but it still slow

Definition: Property

Example:

```
    reverse (reverse ls) = ls
```

Short for:

```
    (\ls -> reverse (reverse ls)) = (\ls -> ls)
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In general:

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    (f :: A -> B) = (g :: A -> B)
    for some A and B with
    instance Arbitrary A
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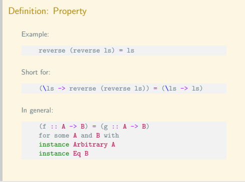
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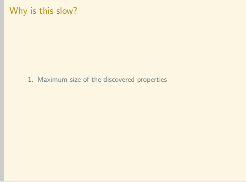
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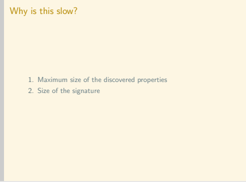
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Idea

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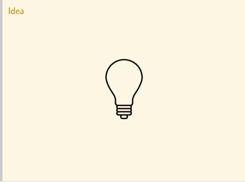
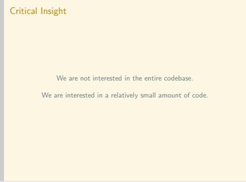
Signature Inference for Functional Property Discovery
└─Signature Inference
└─Idea



Critical Insight

We are not interested in the entire codebase.

We are interested in a relatively small amount of code.


Critical Insight

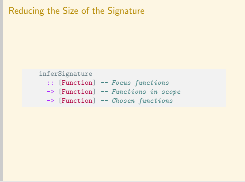
We are not interested in the entire codebase.

We are interested in a relatively small amount of code.

1. This means that we have an entirely different goal than QuickSpec.
2. Comparisons with QuickSpec are not really fair, but we have nothing else to compare to.

Reducing the Size of the Signature

```
inferSignature
  :: [Function] -- Focus functions
  -> [Function] -- Functions in scope
  -> [Function] -- Chosen functions
```


Reducing the Size of the Signature

```
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  :: [Function] -- Focus functions
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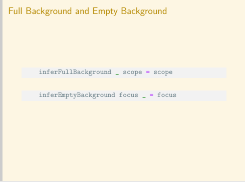
Full Background and Empty Background

```
    inferFullBackground _ scope = scope
```

```
    inferEmptyBackground focus _ = focus
```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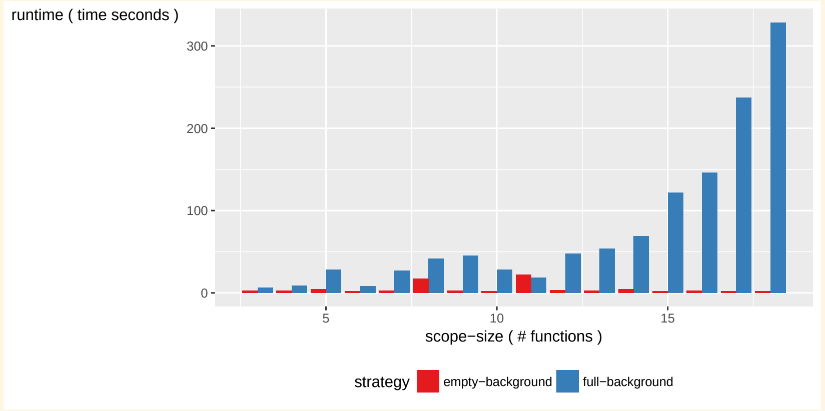

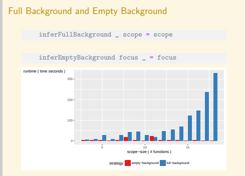

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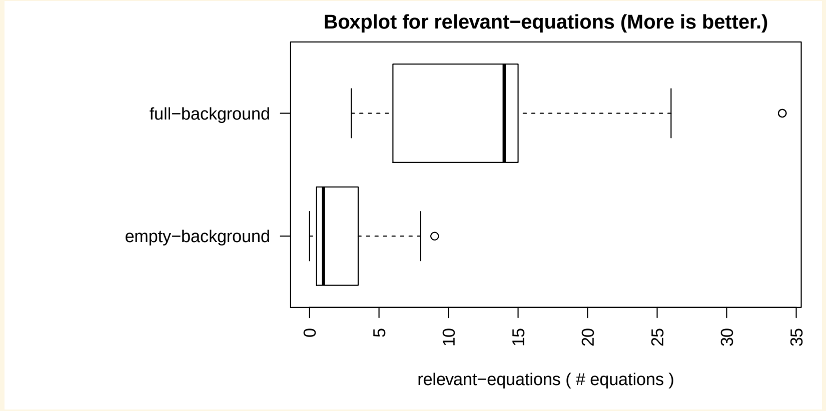
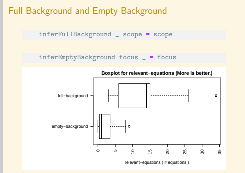
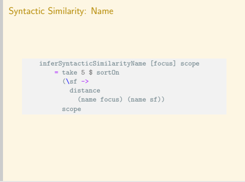




Syntactic Similarity: Name

```haskell
inferSyntacticSimilarityName [focus] scope
    = take 5 $ sortOn
      (\sf ->
        distance
          (name focus) (name sf))
      scope
```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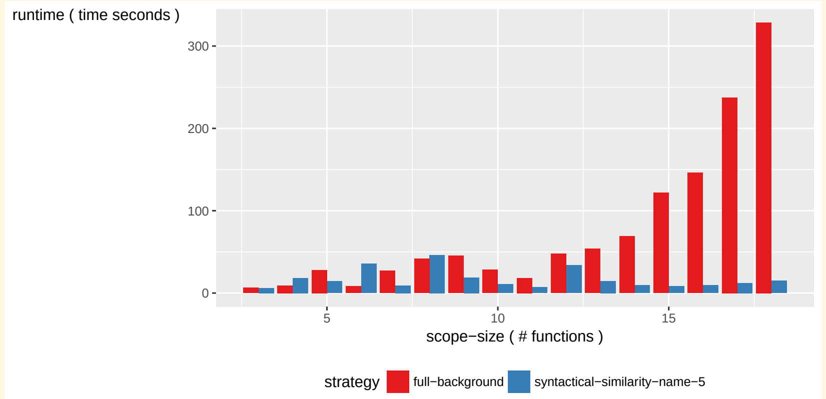

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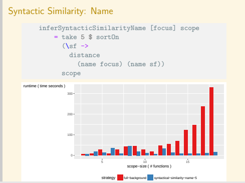
Signature Inference for Functional Property Discovery
└─Signature Inference
└─Syntactic Similarity: Name



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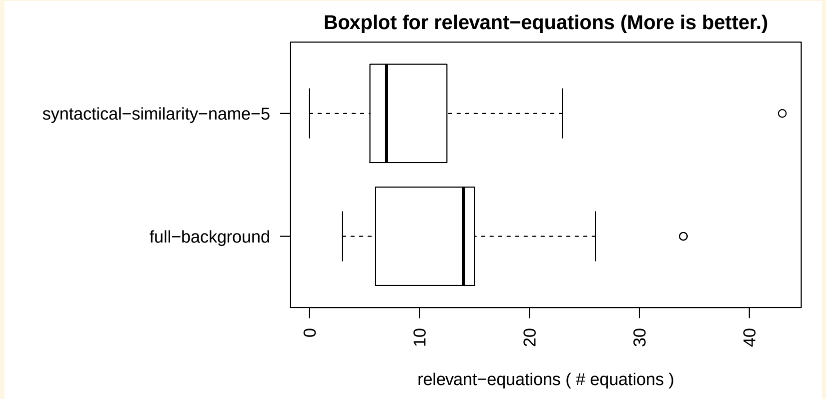

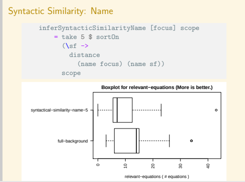
Syntactic Similarity: Name

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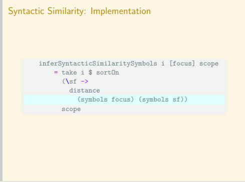
```

Syntactic Similarity: Implementation

```
    inferSyntacticSimilaritySymbols i [focus] scope
        = take i $ sortOn
          (\sf ->
            distance
              (symbols focus) (symbols sf))
          scope
```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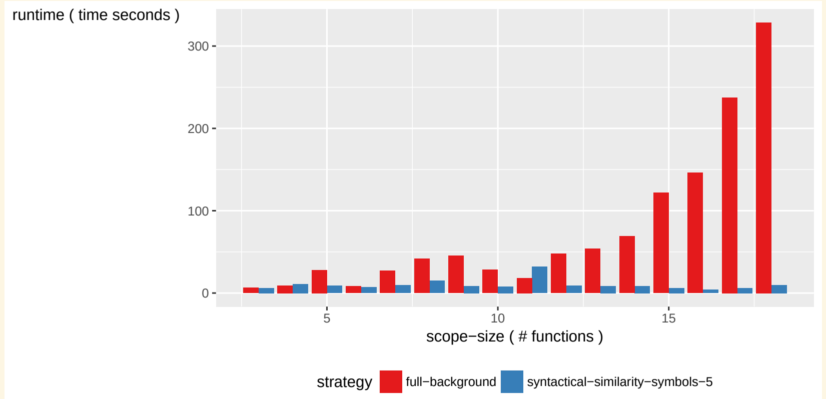

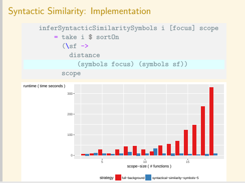
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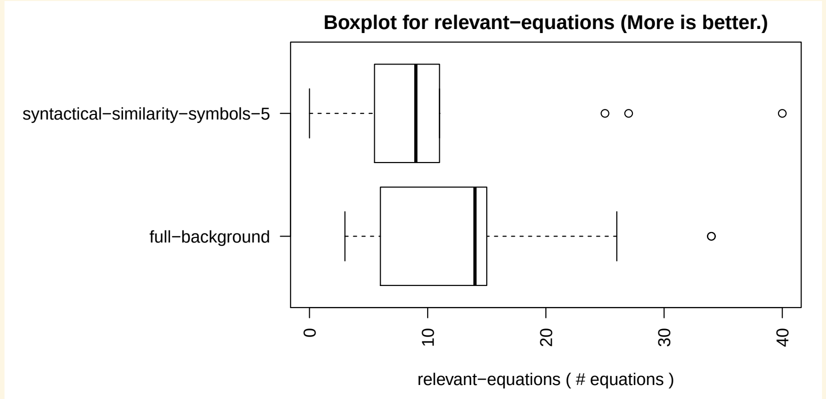

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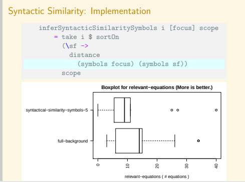
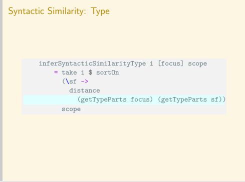
Signature Inference for Functional Property Discovery
└─Signature Inference

└─Syntactic Similarity: Implementation



Syntactic Similarity: Type

```
inferSyntacticSimilarityType i [focus] scope
    = take i $ sortOn
      (\sf ->
        distance
          (getTypeParts focus) (getTypeParts sf))
      scope
```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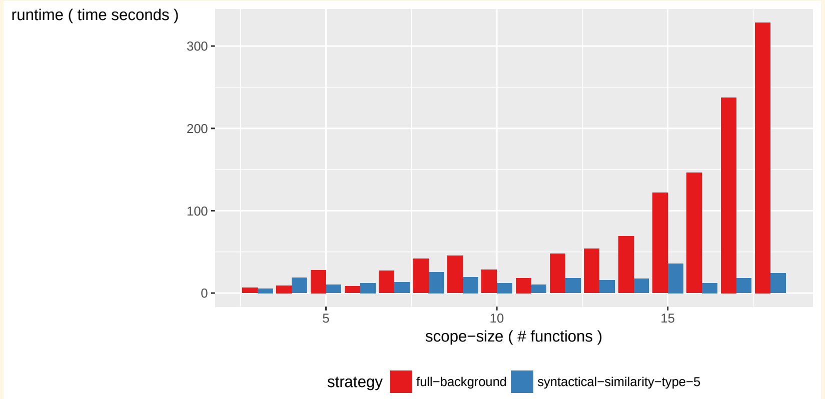

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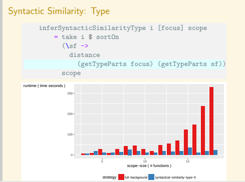
Signature Inference for Functional Property Discovery
└─Signature Inference
└─Syntactic Similarity: Type



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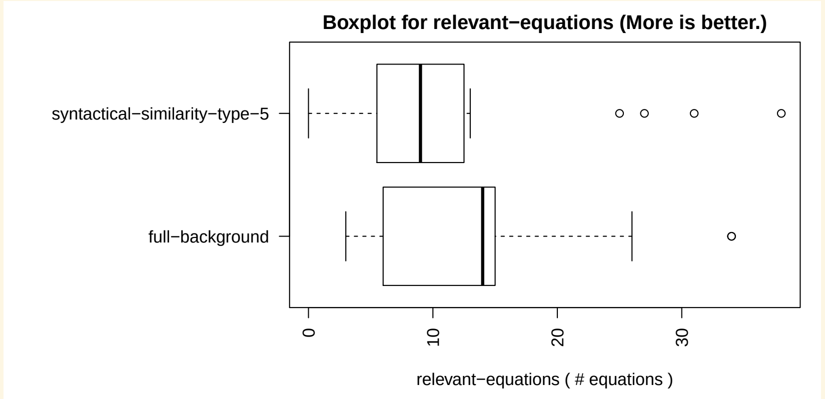

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Signature Inference for Functional Property Discovery
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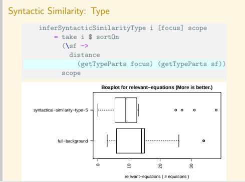
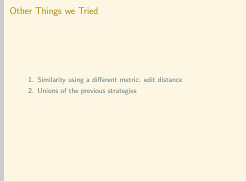


Other Things we Tried

1. Similarity using a different metric: edit distance
2. Unions of the previous strategies


Other Things we Tried

1. Similarity using a different metric: edit distance
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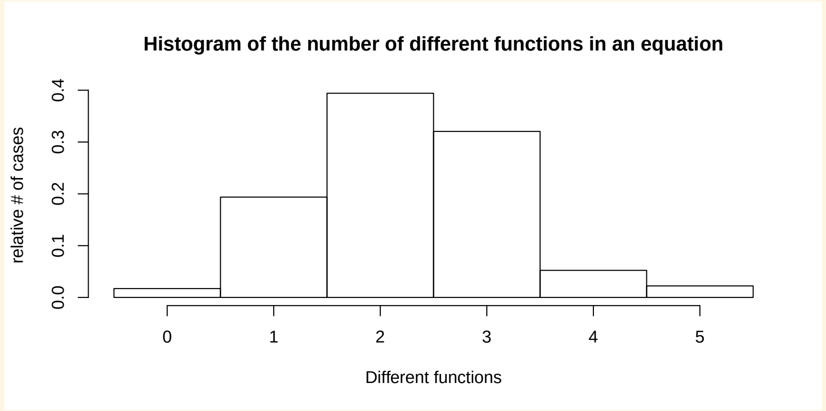
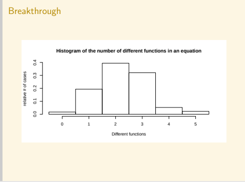
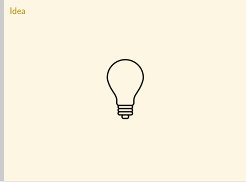
Breakthrough





Idea


Idea

We can run QuickSpec more than once!

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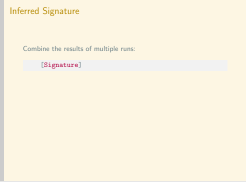
Inferred Signature

Combine the results of multiple runs:

```
    [Signature]
```

2017-09-21

Signature Inference for Functional Property Discovery
└─Signature Inference
    └─Inferred Signature


Inferred Signature

Combine the results of multiple runs:

[Signature]

Inferred Signature

Combine the results of multiple runs:

```
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```

User previous results as background properties:

```
    Forest Signature
```

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Signature Inference for Functional Property Discovery
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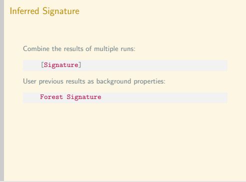
    └─Inferred Signature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Inferred Signature

Combine the results of multiple runs:

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[Signature]
```

User previous results as background properties:

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Share previous runs:

```
DAG Signature
```

Inferred Signature

Combine the results of multiple runs:

[Signature]

User previous results as background properties:

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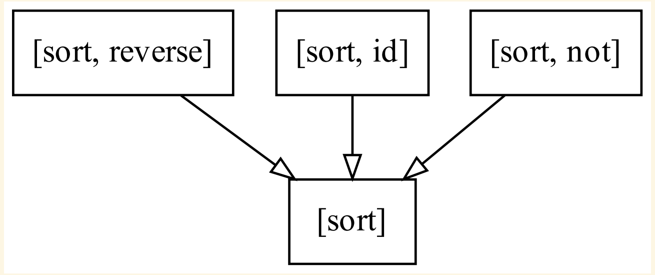
Share previous runs:

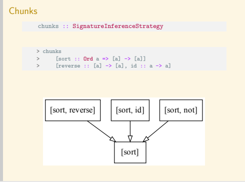
DAG Signature

Chunks

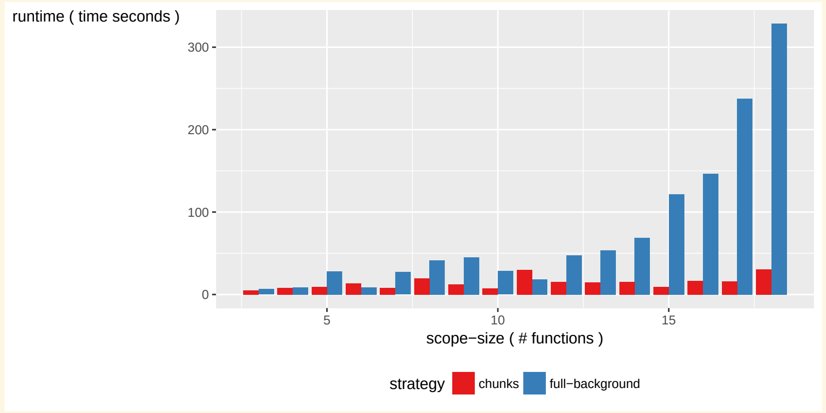
```
chunks :: SignatureInferenceStrategy
```

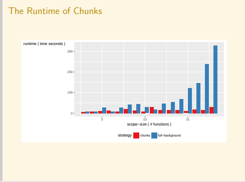
```
> chunks
>     [sort :: Ord a => [a] -> [a]]
>     [reverse :: [a] -> [a], id :: a -> a]
```



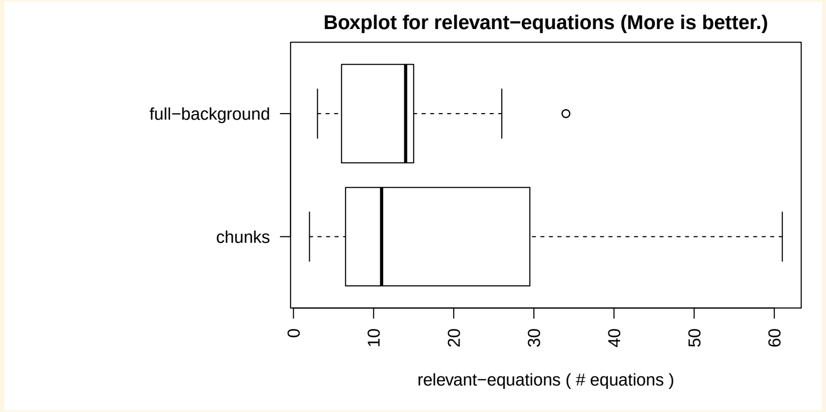


The Runtime of Chunks





The Outcome of Chunks: Relevant equations



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Signature Inference for Functional Property Discovery
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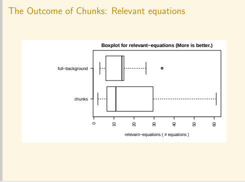
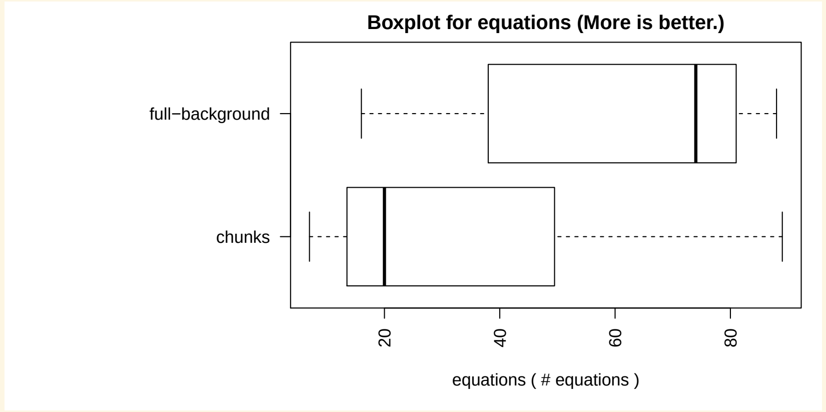
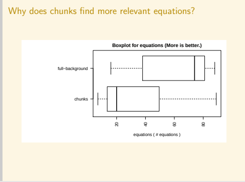


Why does chunks find more relevant equations?





Why does chunks find more relevant equations?

Scope:

```
    a = (+ 1)
    b = (+ 2)
    c = (+ 3)
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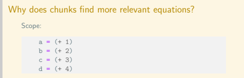
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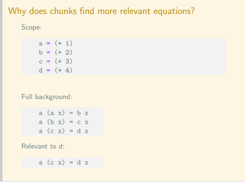
Full background:

```
a (a x) = b x
a (b x) = c x
a (c x) = d x
```

Relevant to d:

```
a (c x) = d x
```



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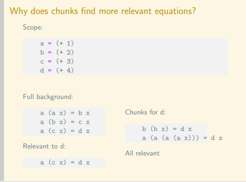
Relevant to d:

```
a (c x) = d x
```

Chunks for d:

```
b (b x) = d x
a (a (a (a x))) = d x
```

All relevant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All relevant

Inferred Signature

```
type SignatureInferenceStrategy
    = [Function] -> [Function] -> InferredSignature



type InferredSignature =
    DAG ([(Signature, [Equation])] -> Signature)
```

Inferred Signature

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type InferredSignature =
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```

Inferred Signature

```
type SignatureInferenceStrategy
    = [Function] -> [Function] -> InferM ()

data InferM a where
    InferPure :: a -> InferM a
    InferFmap :: (a -> b) -> InferM a -> InferM b
    InferApp :: InferM (a -> b) -> InferM a -> InferM b
    InferBind :: InferM a -> (a -> InferM b) -> InferM b

    InferFrom
        :: Signature
        -> [OptiToken]
        -> InferM (OptiToken, [Equation])
```

Inferred Signature

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type SignatureInferenceStrategy
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        -> InferM (OptiToken, [Equation])
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Chunks Plus

```
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```

```
> chunksPlus
>     [sort :: Ord a => [a] -> [a]]
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```
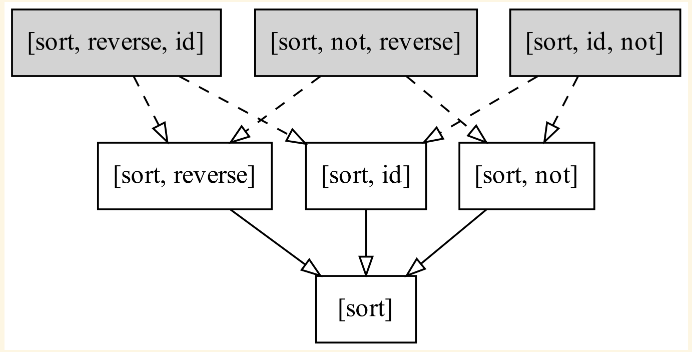
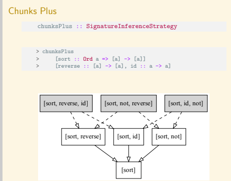
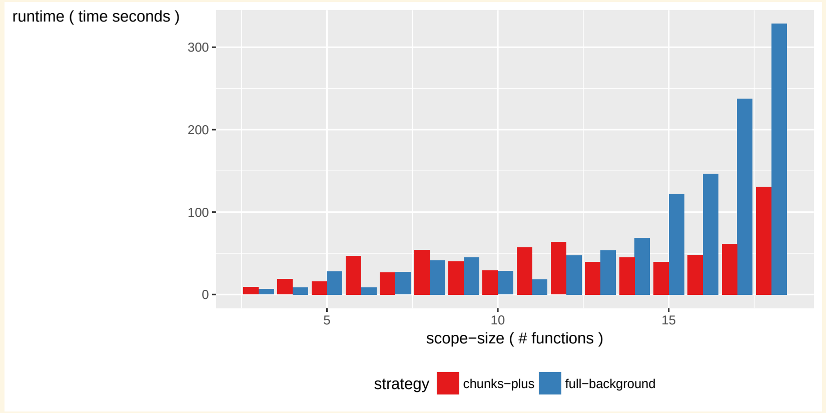





The runtime of chunks plus



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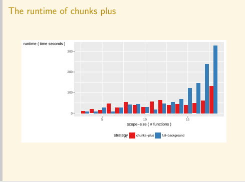
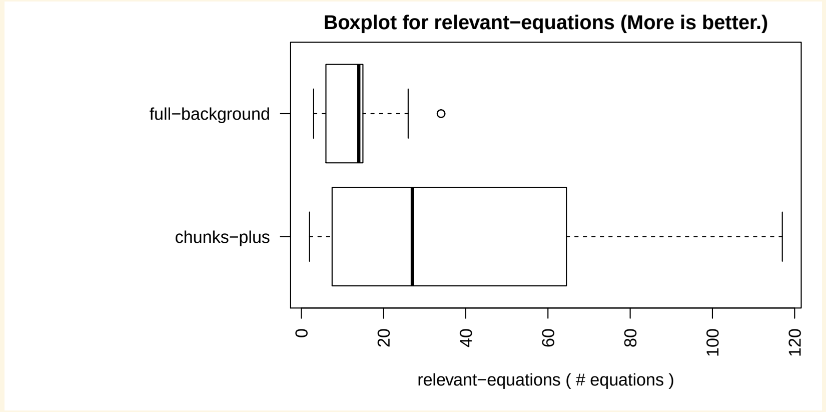
Signature Inference for Functional Property Discovery
└─Signature Inference
└─The runtime of chunks plus



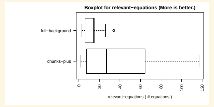
The outcome of chunks plus: Relevant equations



Signature Inference for Functional Property Discovery
└─Signature Inference
└─The outcome of chunks plus: Relevant equations

2017-09-21

The outcome of chunks plus: Relevant equations

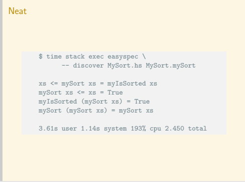


Neat

```
$ time stack exec easyspec \
      -- discover MySort.hs MySort.mySort

xs <= mySort xs = myIsSorted xs
mySort xs <= xs = True
myIsSorted (mySort xs) = True
mySort (mySort xs) = mySort xs

3.61s user 1.14s system 193% cpu 2.450 total
```



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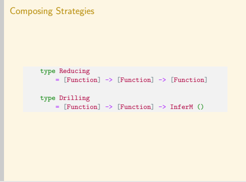
Composing Strategies

```
    type Reducing
        = [Function] -> [Function] -> [Function]

    type Drilling
        = [Function] -> [Function] -> InferM ()
```

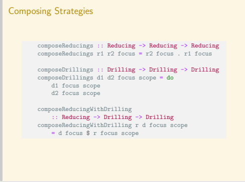


Composing Strategies

```
composeReducings :: Reducing -> Reducing -> Reducing
composeReducings r1 r2 focus = r2 focus . r1 focus

composeDrillings :: Drilling -> Drilling -> Drilling
composeDrillings d1 d2 focus scope = do
    d1 focus scope
    d2 focus scope

composeReducingWithDrilling
    :: Reducing -> Drilling -> Drilling
composeReducingWithDrilling r d focus scope
    = d focus $ r focus scope
```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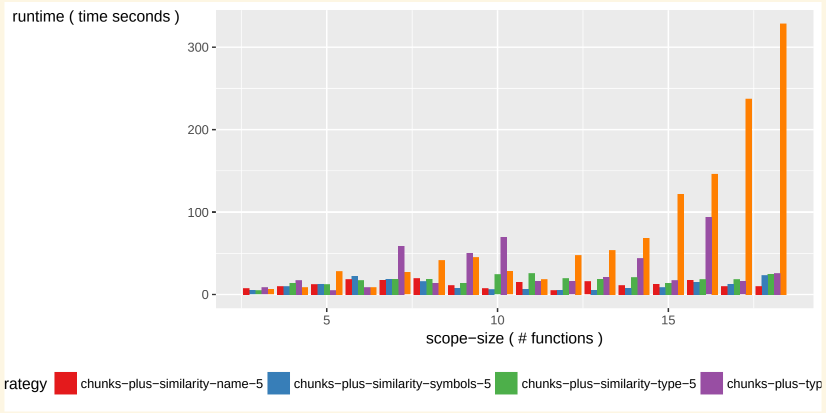
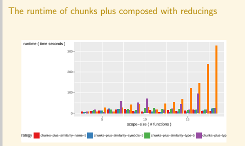
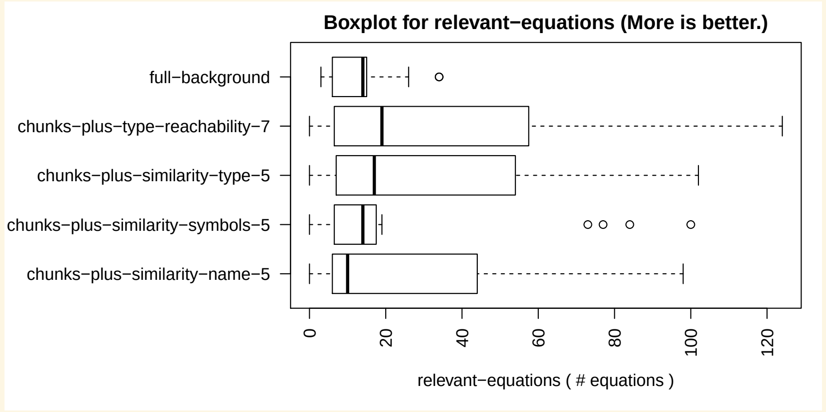
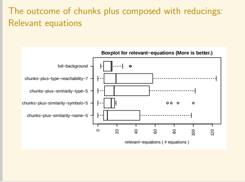
The runtime of chunks plus composed with reducings



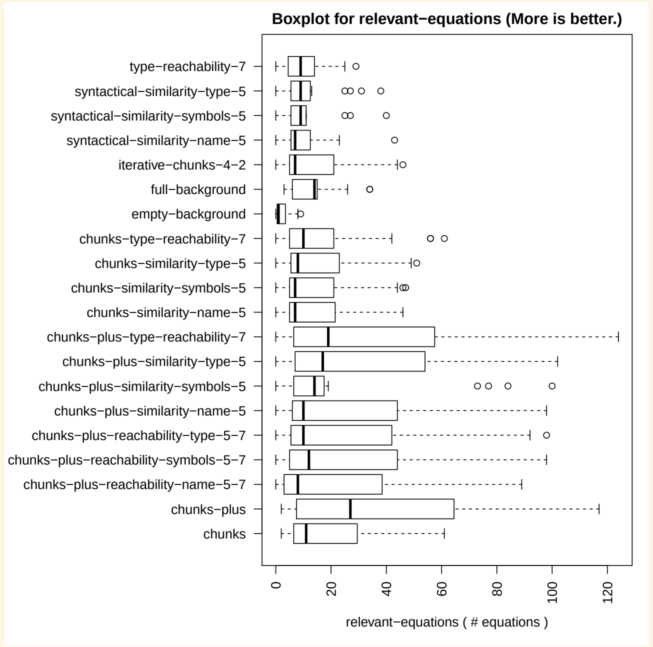


The outcome of chunks plus composed with reducings: Relevant equations



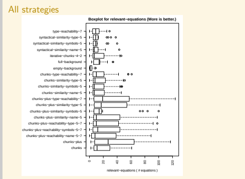


All strategies



2017-09-21

Signature Inference for Functional Property Discovery
└─Signature Inference
└─All strategies



Great promise, but ...

2017-09-21

Signature Inference for Functional Property Discovery
└─Signature Inference
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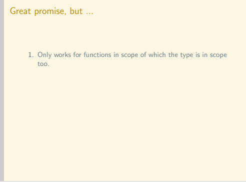
1. Only works for functions in scope of which the type is in scope too.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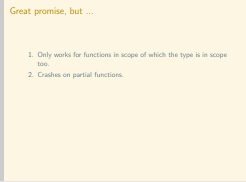
2. Crashes on partial functions.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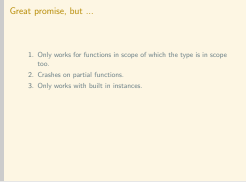
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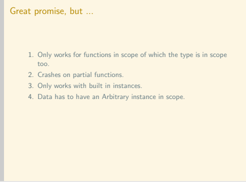
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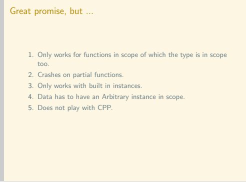
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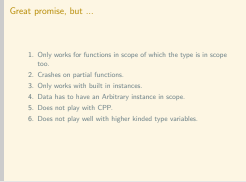
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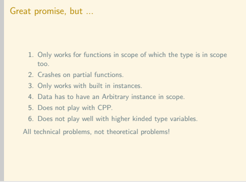
All technical problems, not theoretical problems!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Further Research

1. Can we go faster?

2017-09-21

Signature Inference for Functional Property Discovery
└─Signature Inference
  └─Further Research

Further Research

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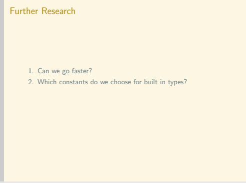
Further Research

1. Can we go faster?
2. Which constants do we choose for built in types?


Further Research

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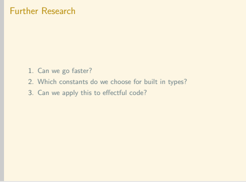
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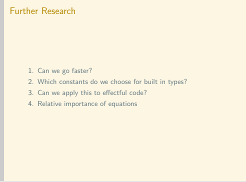
4. Relative importance of equations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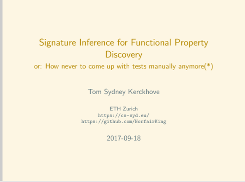
Signature Inference for Functional Property Discovery

or: How never to come up with tests manually anymore(*)

Tom Sydney Kerckhove

ETH Zurich
https://cs-syd.eu/
https://github.com/NorfairKing

2017-09-18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