Utrecht University

Efficient Structural Differencing

… and the lessons learned from it

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Intro

Contributions

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- Efficient Algorithm for structured diffing (and merging)
    - Think of `UNIX` diff, over AST's.

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    - Think of `UNIX` diff, over AST's.
- Wrote it in Haskell, generically
- Tested against dataset from GitHub
    - mined Lua repositories

Line-by-Line Differencing

The UNIX diff

Compares files line-by-line, outputs an *edit script*.

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type checker: "You fool!
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rethink your bad code."
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UNIX diff outputs:

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Computes changes by enumeration.

```
diff :: [String] -> [String] -> Patch
diff x y = head $ sortBy mostCopies $ enumerate_all x y
```

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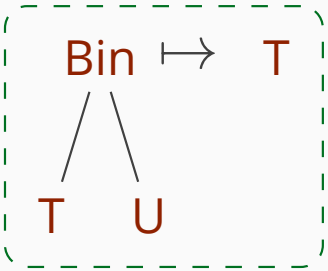

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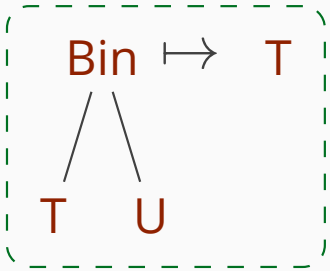

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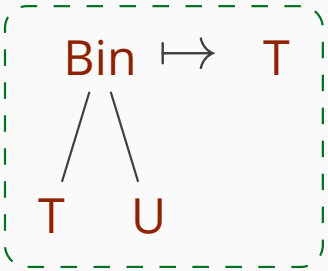

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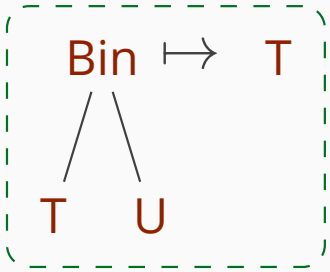

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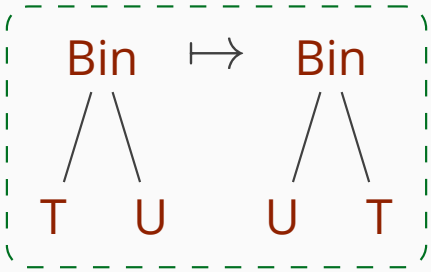

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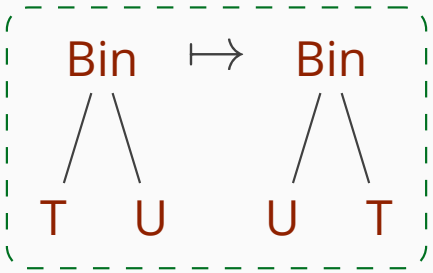

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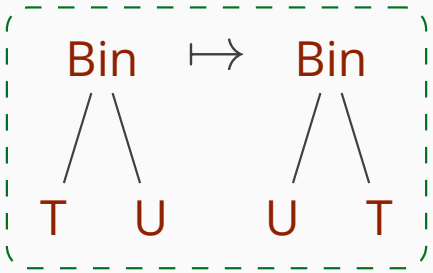

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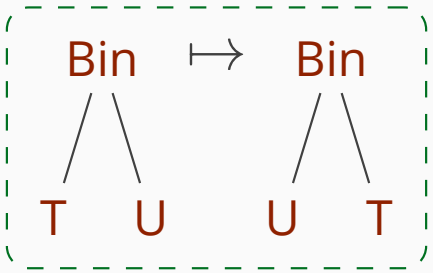

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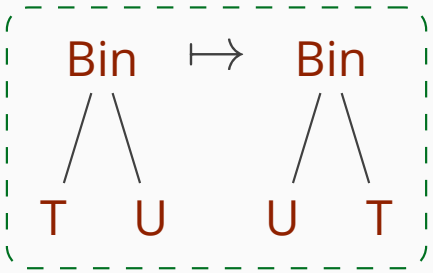

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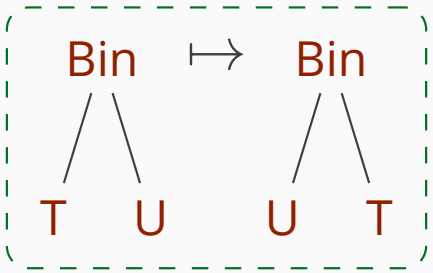

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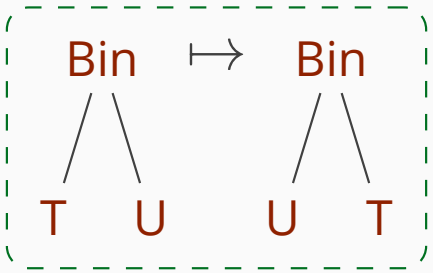

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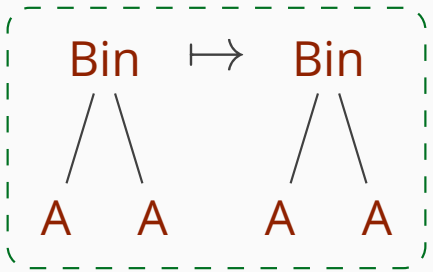

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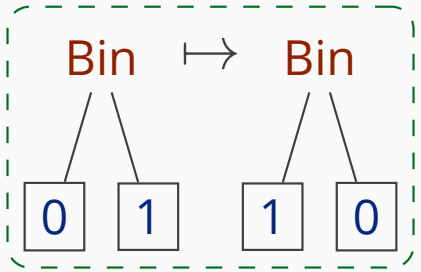
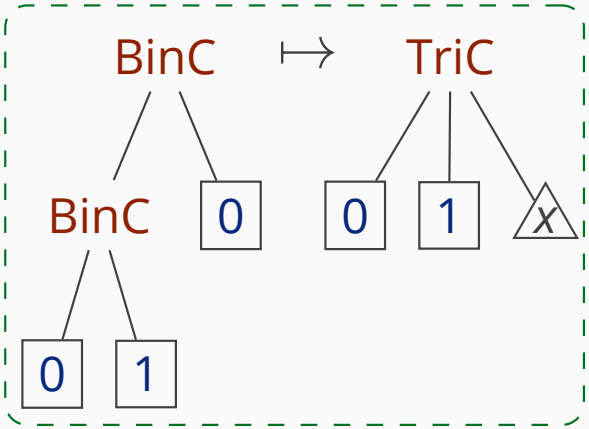
Solution: Detach from *edit-scripts*



New Structure for Changes

Changes

```
diff (Bin (Bin t u) t) (Tri t u x) =
```



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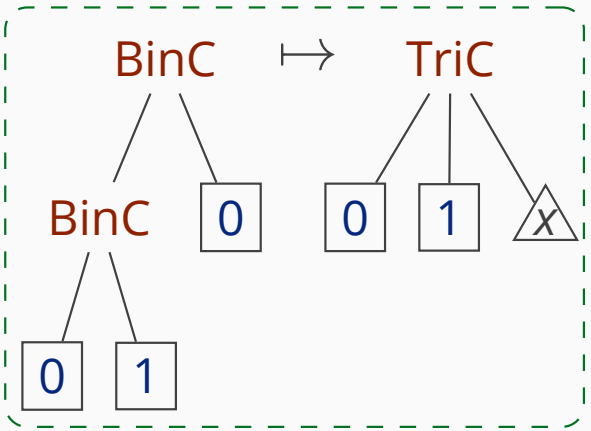

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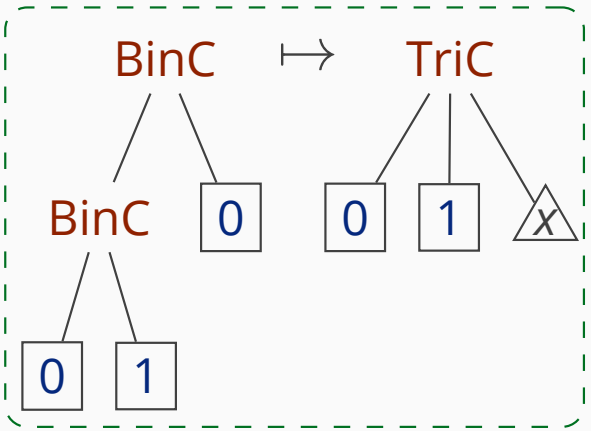

- Arbitrary duplications, contractions, permutations
  - Can explore all copy opportunities
- Faster to compute
  - Our `diff x y` runs in $\mathcal{O}(\text{size x} + \text{size y})$

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Two *contexts*

- deletion: matching
- insertion: instantiation

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data Tree = Leaf
          | Bin Tree Tree
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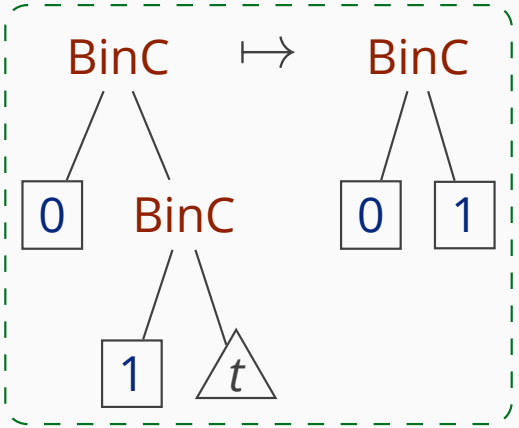
```
data TreeC h = LeafC
             | BinC TreeC TreeC
             | TriC TreeC TreeC TreeC
             | Hole h


type Change = (TreeC MetaVar , TreeC MetaVar)
```

Applying Changes



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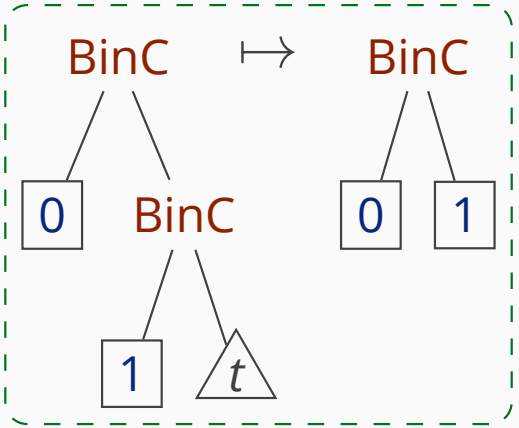

Call it c,

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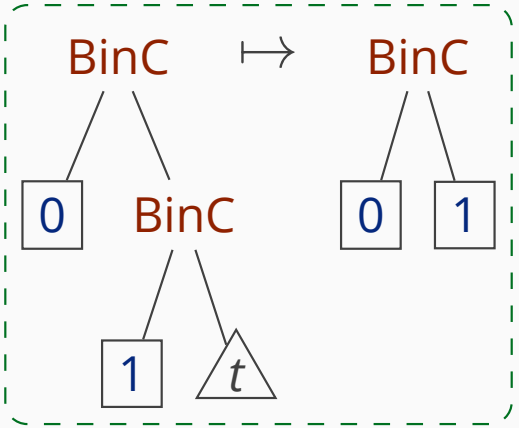

Call it `c`, application function sketch:

```
apply c = \x -> case x of
   Bin a (Bin b c) -> if c == t then Just (Bin a b) else Nothing
   _               -> Nothing
```

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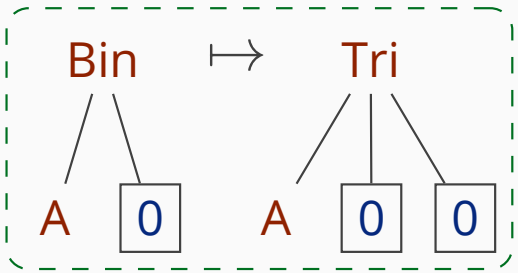

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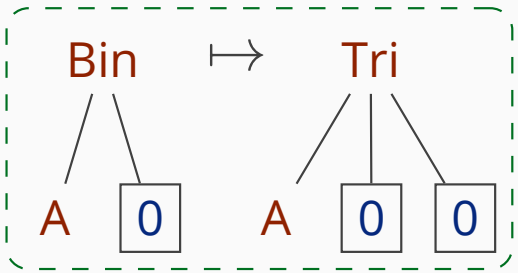

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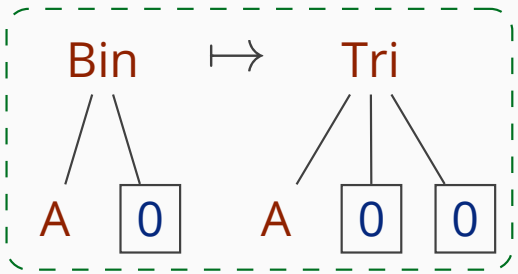

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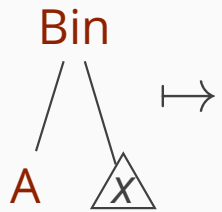


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Consequence of definition of `Change`

Postpone the *hard* part for now

- Oracle: `wcs :: Tree -> Tree -> (Tree -> Maybe MetaVar)`
  - stands for *which common subtree*

Computing Changes: The Easy Part

Extracting the context:

```
extract :: (Tree -> Maybe MetaVar) -> Tree -> TreeC
extract f x = maybe (extract' x) Hole $ f x
  where
    extract' (Bin a b) = BinC (extract f a) (extract f b)
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Runs in amortized $\mathcal{O}(1)$

Experiments

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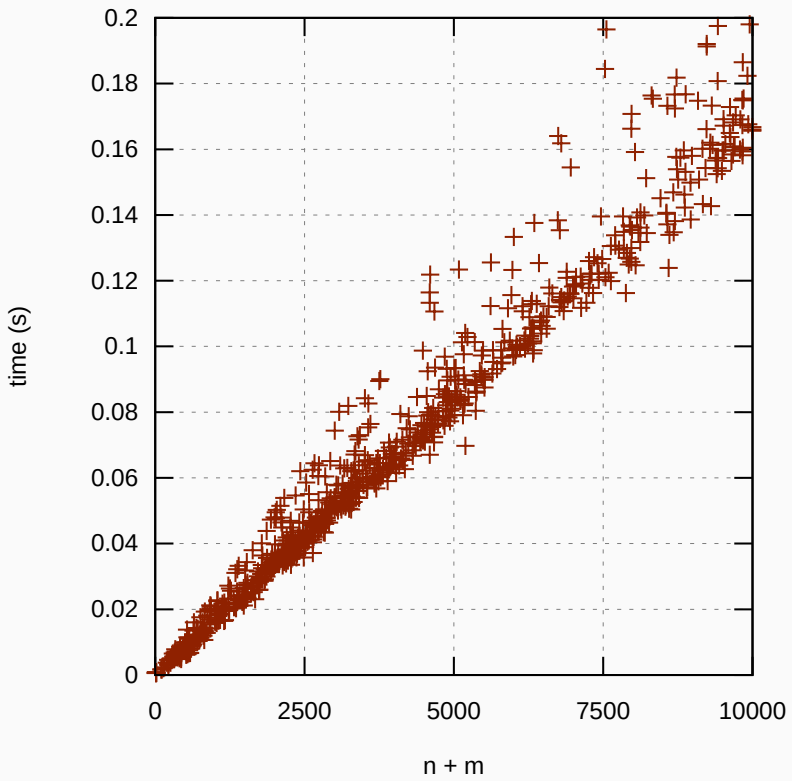

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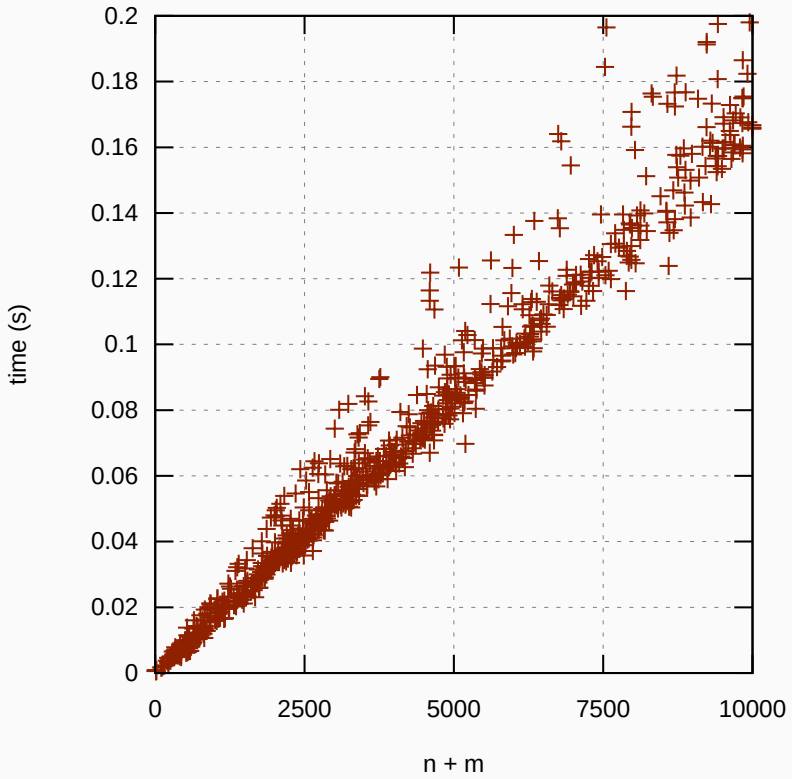

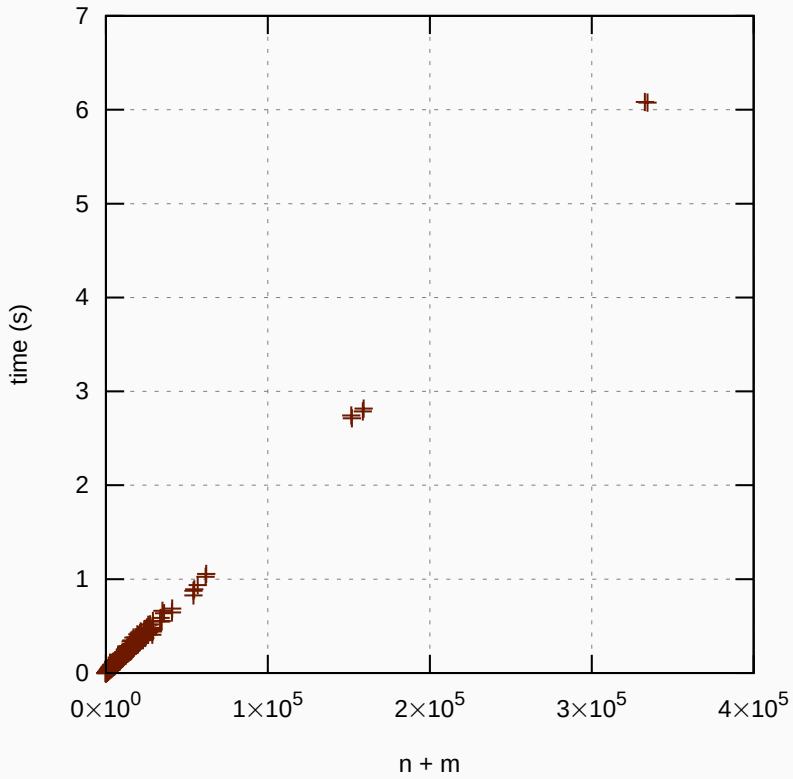

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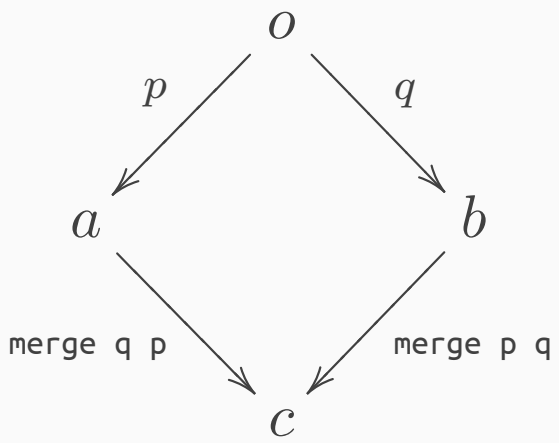

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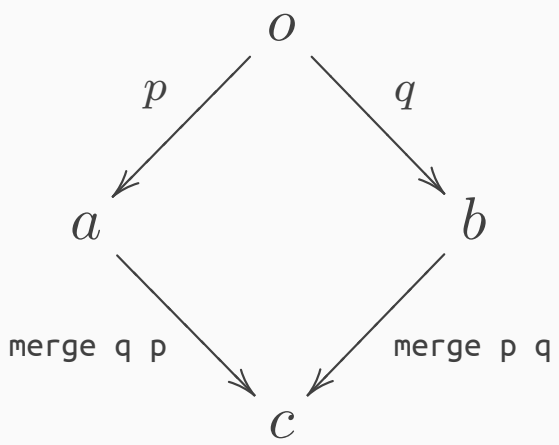

11% of mined merge commits could be *merged*

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We have learned:

1. Generalizations can break specs
2. More expressiveness does not mean higher complexity
3. Thinking extensionally is very helpful

In Greater Depth

In Depth: The Efficient Oracle

Recall,

```
wcs :: Tree -> Tree -> Tree -> Maybe MetaVar
wcs s d x = elemIndex x (subtrees s `intersect` subtrees d)
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- Comparing trees for equality

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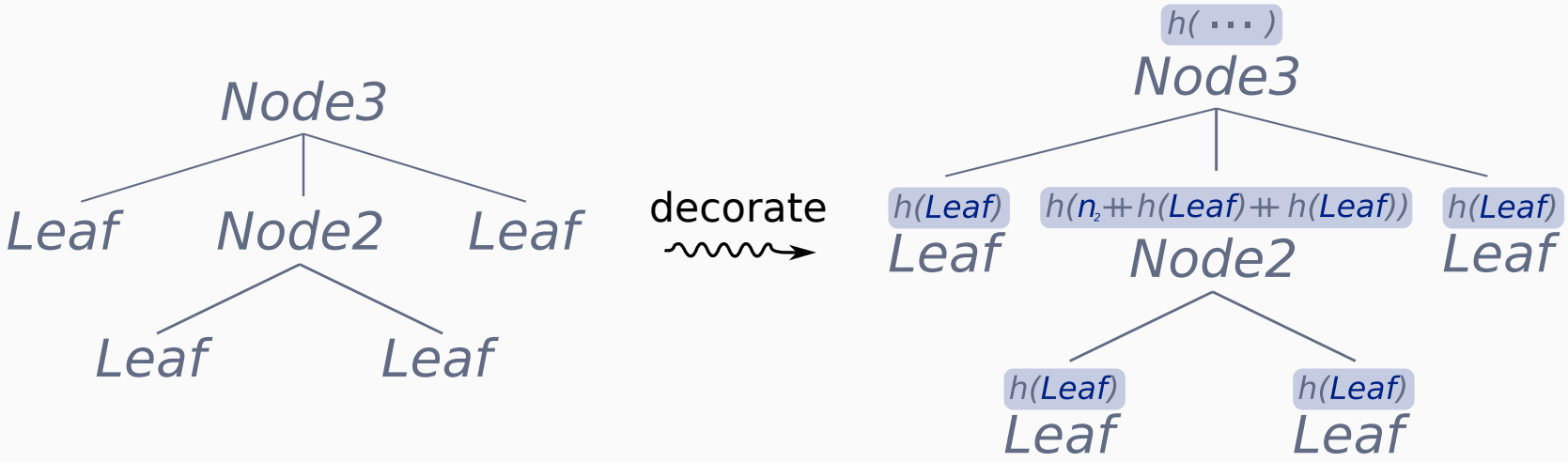
Two inefficiency points:

- Comparing trees for equality
- Searching for a subtree in all enumerated subtrees

In Depth: The Efficient Oracle (Inefficiency #1)



In Depth: The Efficient Oracle (Merkle Trees)

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Annotate Trees with `Digests`:

```
decorate :: Tree -> TreeH
data TreeH = LeafH
           | BinH (TreeH, Digest) (TreeH, Digest)
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root LeafH                      = hash "leaf"
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Compare roots:

```
instance Eq TreeH where
  t == u = root t == root u
```

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tr :: Trie -> TreeH -> Trie
tr db t = insert (root t)
        $ case t of
            LeafH                  -> db
            BinH (x , _) (y , _) -> tr (tr db x) y
            ...
```

In Depth: The Efficient Oracle: The `diff` function

One could write:

```
diff :: Tree -> Tree -> Change
diff s d = let s' = decorate s; d' = decorate d
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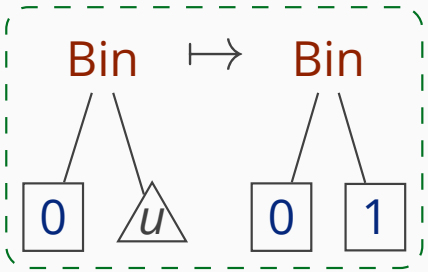

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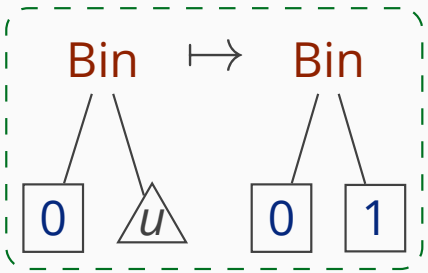

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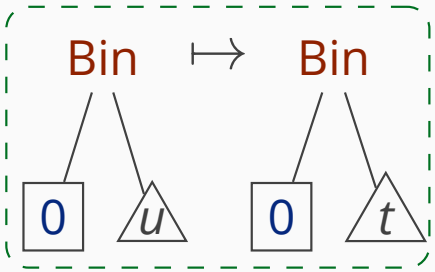

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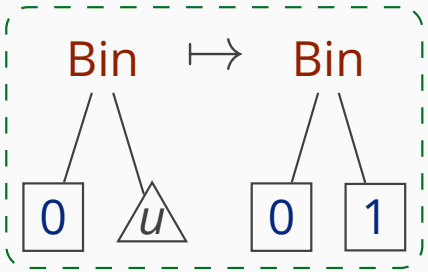

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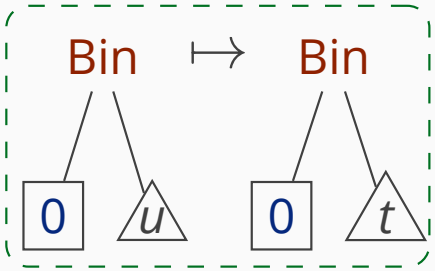
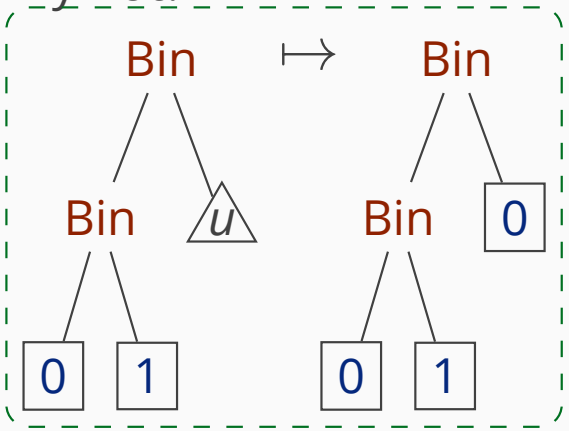


Why not?



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This makes a preorder (reflexive; transitive)

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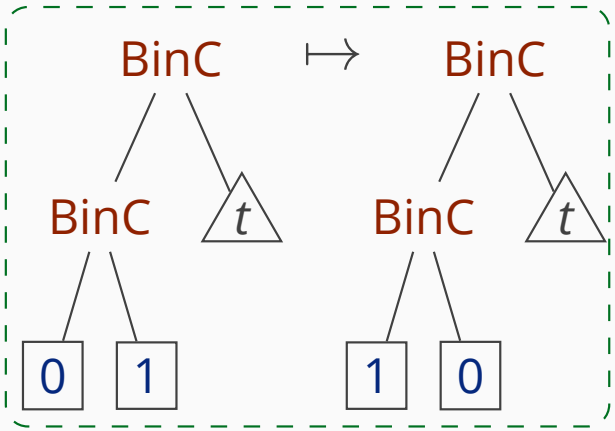

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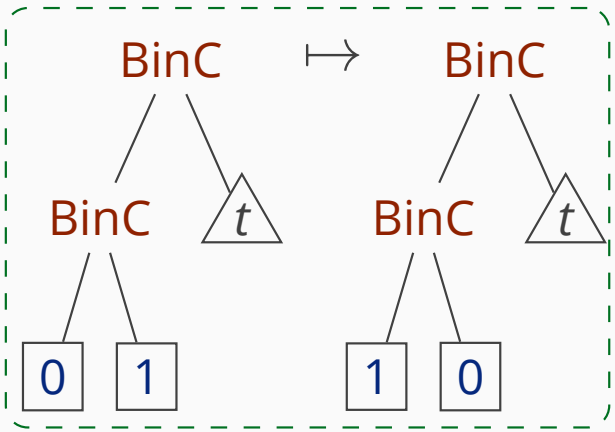

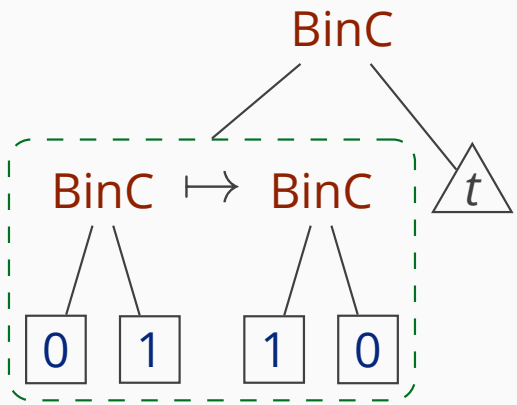

In Depth: Merging and Anti-unification

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Extract the *greatest common prefix* from two `TreeC`:

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gcp :: TreeC a -> TreeC b -> TreeC (TreeC a , TreeC b)
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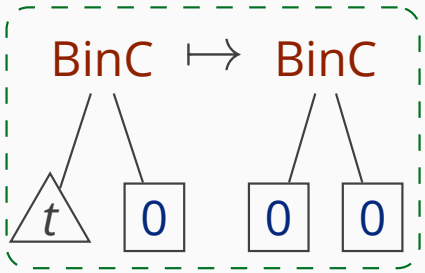

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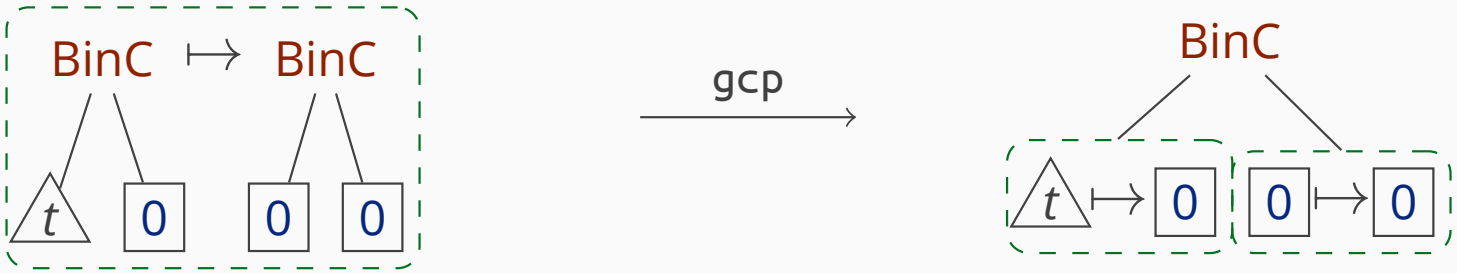

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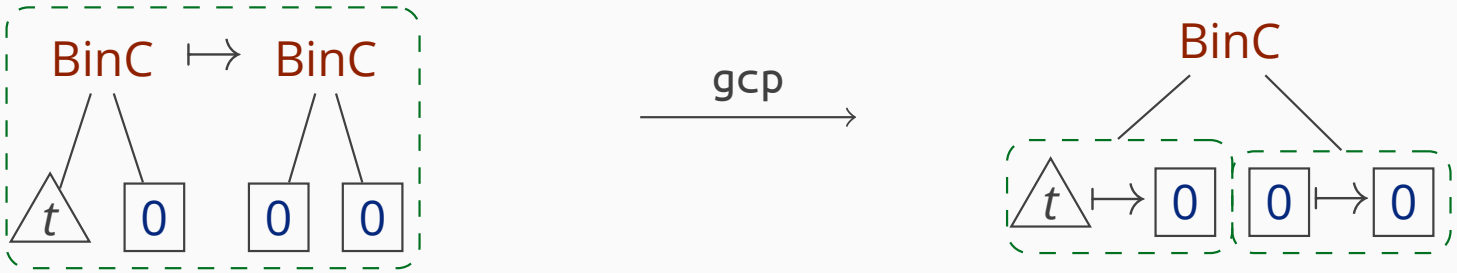

Define `closure :: Patch -> Patch` to fix scopes.

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Performance of structural diffing:

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Utrecht University

Efficient Structural Differencing

… and the lessons learned from it

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