Hoogλe

Finding Functions from Types

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haskell.org/hoogle

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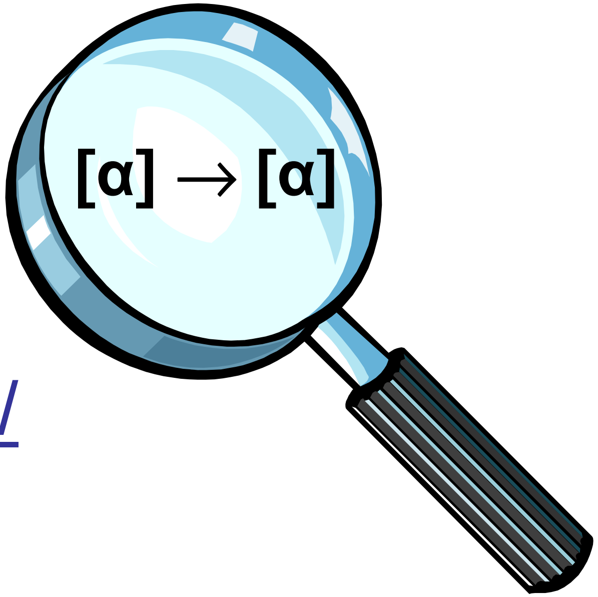


Hoogle Synopsis

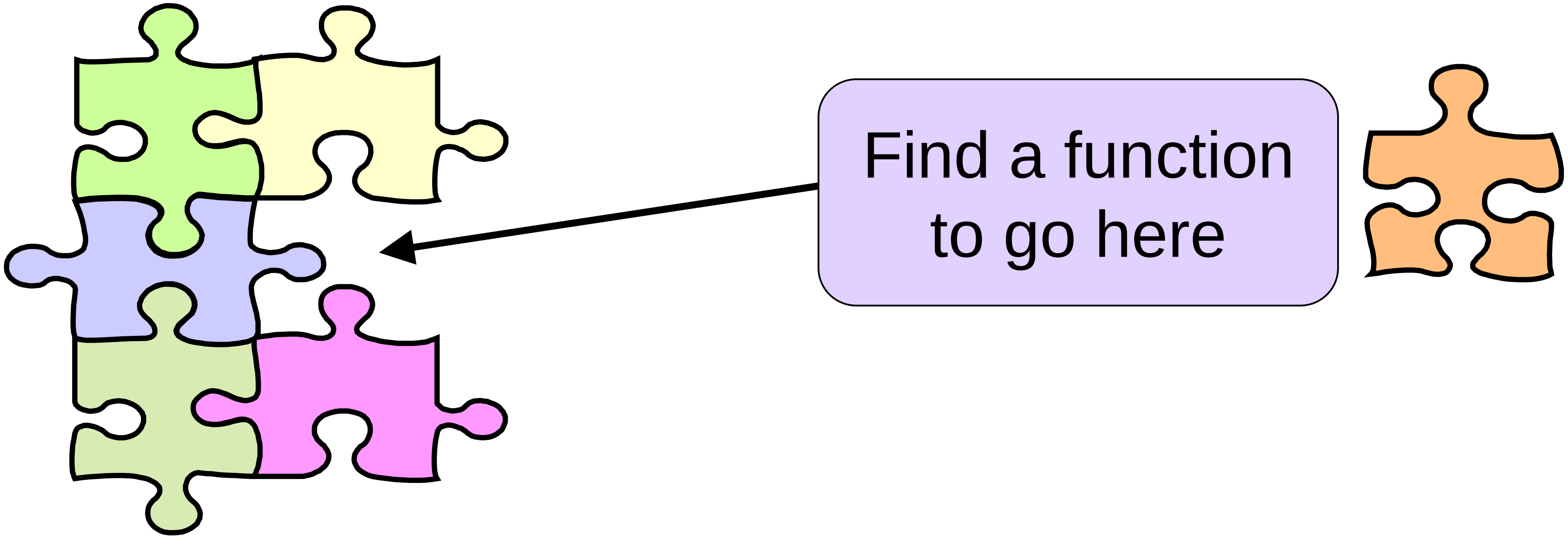
> “Hoogle is a Haskell API search engine, which allows you to search many standard Haskell libraries by either function name, or by approximate type signature.”

Or, Google for Haskell libraries

Solving the Jigsaw

> “static typing is … putting pieces into a jigsaw puzzle”

Real World Haskell

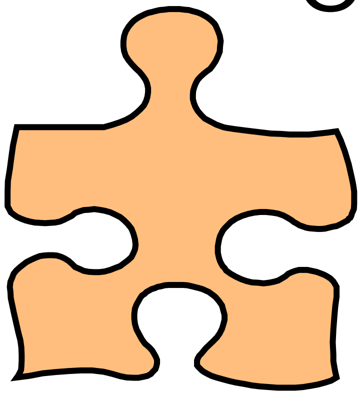


Find a function to go here

Which function do we want?

1 a → [(a,b)] → b

Ord a ⇒ [a] → [a] 4



2 [Int] → String

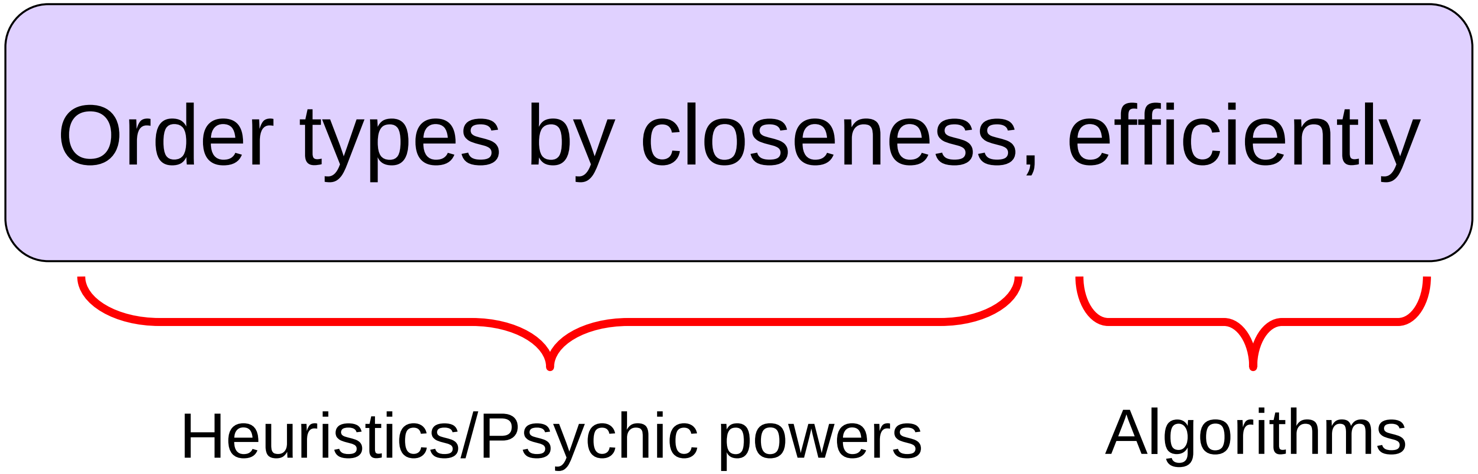
Char → Bool 5

3 Set a → a → Bool

(a → b) → [a] → [b] 6

The Problem

Given a type signature, rank a set of functions with types by appropriateness



Order types by closeness, efficiently

Heuristics/Psychic powers

Algorithms

String: Ordering by closeness

- Equality, perhaps case insensitive
- Prefix/Suffix/Substring matching
- Levenshtein/edit distance

- Tries, KMP, FSA, Baeza-Yates…

search :: [(String,φ)] → (String → [φ])

String: Edit Distance

- How many “steps”
  - – Insertion or deletion
  - – Substitution (just a cheap insert and delete?)

Hello ≈ Hell

Hell ≈ Sell

- *O(nm)*, result is bounded by *max(n,m)*

Type: Ordering by closeness

Ignoring performance, we can write:

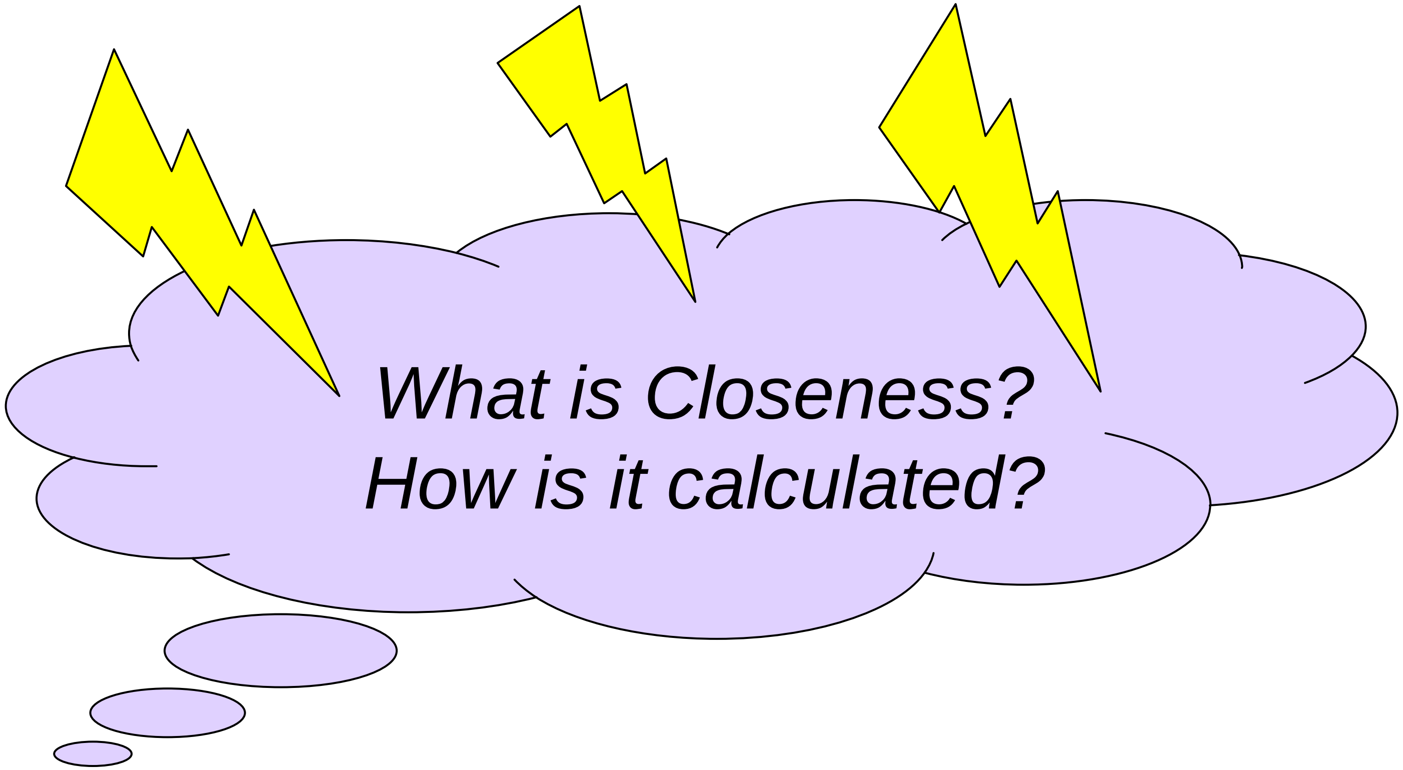
```
match :: Type → Type → Maybe Closeness
```

How “close” are two Type values?

(May not be commutative)

Brainstorm

match :: Type → Type → Maybe Closeness



What is Closeness?
How is it calculated?

Ideas

- Alpha equality (Hoogle 1)
- Isomorphism (Rittri, Runciman - 1980’s)
- Textual type searching (Hayoo!)
- Unification (Hoogle 2)
- Edit distance (Hoogle 3)
- Full edit distance (Hoogle 3.5)
- Structural edit distance (Hoogle 4)
- Result indexed edit distance (Hoogle 5)

Alpha equality

- Take a type signature, and “normalise” it
- Rename variables to be sequential
- Then do an exact text match

- k → v → Map k v
- a → b → Map a b

No psychic powers

Isomorphism

- Only match types which are isomorphic
  - Long before type classes
- Ismorphism is about equal structure
  - $a \to b \to c \;\equiv\; (a, b) \to c$

```
uncurry :: (a → b → c) → (a, b) → c
        :: (a → b → c) → a → b → c
```

Less useful for modern code

Textual Type Searching

- Alpha normalise + strength reduced alpha normalisation

- k → v → Map k v
- a → b → Map a b & a → b → c a b

- Plus substring searching

A neat hack,
build on text search

Unification

- Unify against each result, like a compiler
- The lookup problem:
  - $a \to [(a,b)] \to b \neq a \to [(a,b)] \to \text{Maybe } b$
- Works OK, but not great, in practice
  - More general is fine, what about less general?
  - $a \equiv$ everything?
  - is undefined really the answer?

Not what humans want

Edit Distance

- What changes do I need to make to equalise these types
- Each change has a cost

$$a \rightarrow [(a,b)] \rightarrow b$$

box

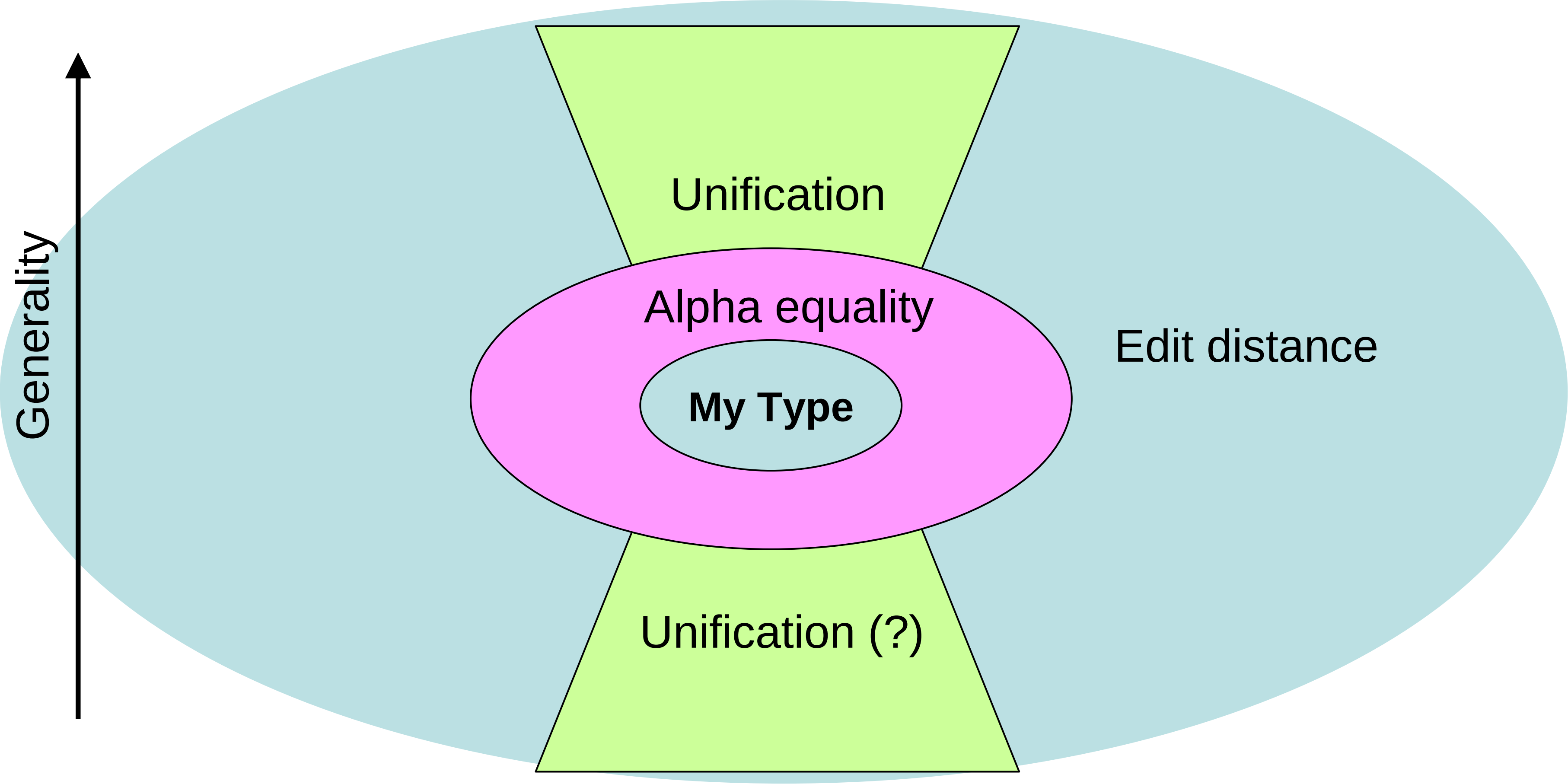
$$a \rightarrow [(a,b)] \rightarrow \text{Maybe } b$$

context

$$\text{Eq } a \Rightarrow a \rightarrow [(a,b)] \rightarrow \text{Maybe } b$$

A nice start,
lots of details left

Ideas Compared



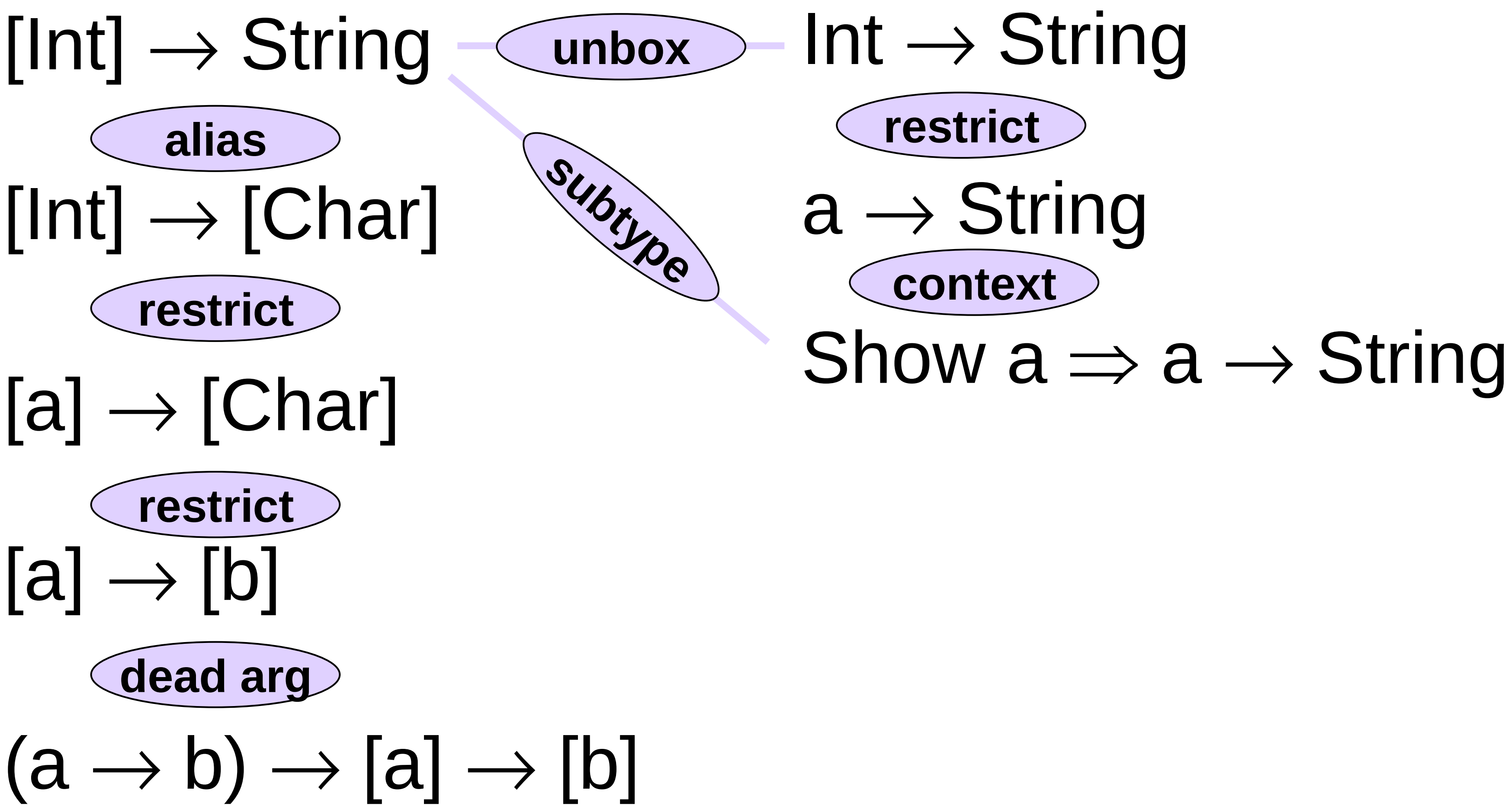
Textual search = superset of alpha equality

All but Textual search can have argument reordering added

Edit Distance Costs

- Alias following (String $\leftrightarrow$ [Char])
- Instances (Ord a $\Rightarrow$ a $\leftrightarrow$ a)
- *Subtyping* (Num a $\Rightarrow$ a $\leftrightarrow$ Int)
- *Boxing* (a $\leftrightarrow$ m a , a $\leftrightarrow$ [a])
- Free variable duplication ((a,b) $\leftrightarrow$ (a,a))
- Restriction ([a] $\leftrightarrow$ m a , Bool $\leftrightarrow$ a)
- Argument deletion (a $\rightarrow$ b $\rightarrow$ c $\leftrightarrow$ b $\rightarrow$ c)
- Argument reordering

Edit Distance Examples



[Int] → String

alias

[Int] → [Char]

restrict

[a] → [Char]

restrict

[a] → [b]

dead arg

(a → b) → [a] → [b]

unbox

Int → String

restrict

a → String

context

Show a ⇒ a → String

subtype

A note on “subtype”

$\text{Num a} \Rightarrow \text{a} \to \text{a}$

$\text{Double} \to \text{Double}$

$\text{a} \to \text{a}$

Given instance Num Double:

$\text{Double} \subset (\text{Num a} \Rightarrow \text{a}) \subset \text{a}$

A note on “boxing”

🔍 $\text{Eq a} \Rightarrow \text{a} \rightarrow \text{[a]} \rightarrow \text{Int}$

$\text{Eq a} \Rightarrow \text{a} \rightarrow \text{[a]} \rightarrow \text{Maybe Int}$

$\text{Eq a} \Rightarrow \text{a} \rightarrow \text{[a]} \rightarrow \text{[Int]}$

Most boxes add a little info:

- Maybe - this might fail/optional arg
- List - may be multiple results
- IO - you need to be in the IO monad

Edit Distances

- Which types of edits should be used?
  - Lots of scope for experimentation
- Can the edits be implemented efficiently?
- What environment do we need?
  - Aliases? Instances?

Ordering Closeness

```
type Closeness = [Edit]

compare ::
    Closeness → Closeness → Ordering

compare = compare `on` score
score :: Closeness → Double

score = sum . map rank
rank :: Edit → Double
```

Throw away choices

Ranking Edits

- Initial attempt: Make up numbers manually
  - Did not scale at all, hard to get right, like solving a large constraint problem in your head

- Solution: Constraint solver!

Ranking Examples

- Keep a list of example searches, with ordered results
- When someone complains, add their complaint to this list

- Generate a set of constraints, then solve
  - I use the ECLiPSe constraint solver

Performance Target:

As-you-type searches
against all current versions
of all Haskell libraries

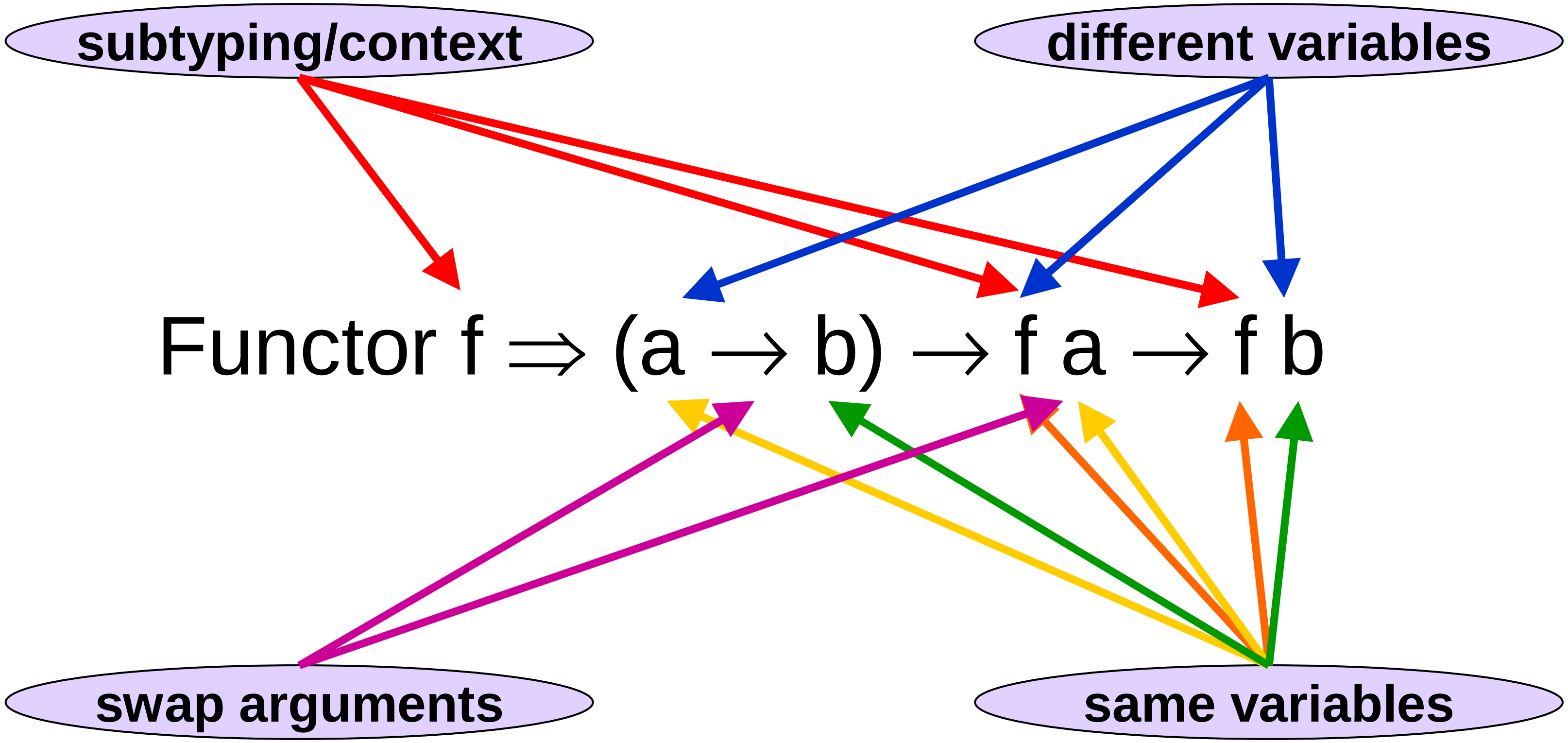
Naive Edit Distance

```
[x| (t, x)  ← database
  , Just c ← [match user t]
  , order by c]
```

- let n = length database
  - $\Theta(n)$ to search all items (ignoring sort)
  - $\Theta(n)$ to find the best result

n = 27,396 today
(target of 296,871)

Decomposing Edit Distance



Interactive Lists

data Barrier o α = Value o α | Barrier o

Given (Barrier o_1:xs),

$\forall$Value o_2 x $\in$ xs, $o_1 < o_2$

bsort :: Ord o $\Rightarrow$ [Barrier o α] $\rightarrow$ [α]

Per Argument Searching

- The idea: Search for each argument separately, combine the results

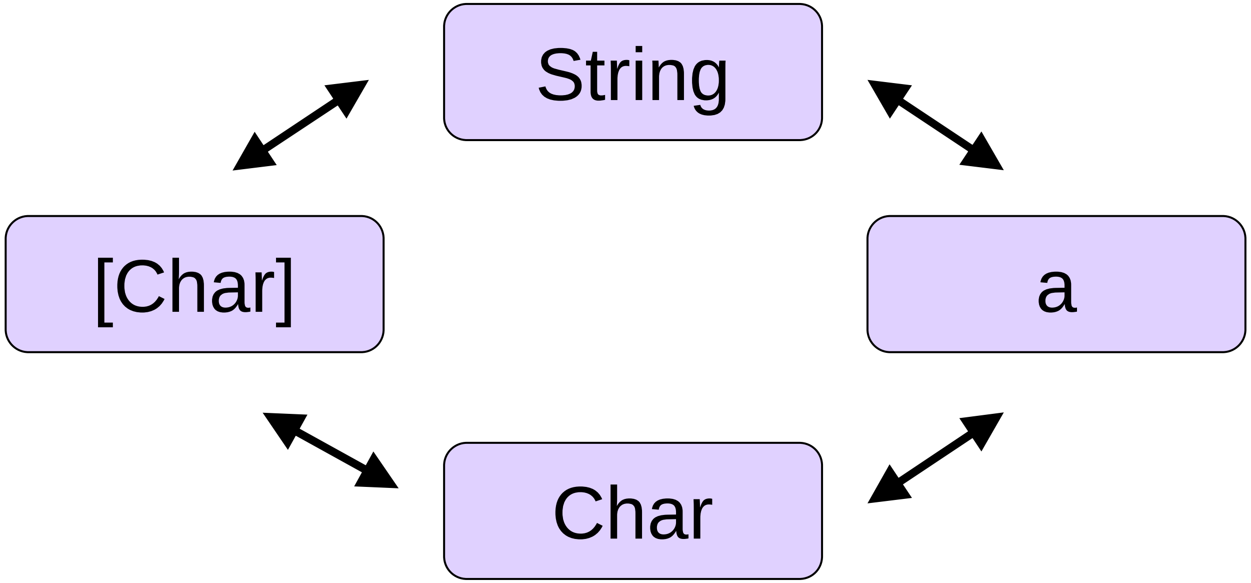
🔍 a → b → c

-
  ```
  combine $ search arguments a `merge`
            search arguments b `merge`
            search results c
  ```

Use interactive lists
for search/combine

Implementing Search

- Have type graphs, annotated with costs
  - Dijkstra's graph search algorithm



Implementing Combine

- Combine is fiddly
- Needs to apply costs such as instances, variable renaming, argument deletion
- Check all arguments are present
- Ensure no duplicate answers

- Fast to search for the best matches

The Problem

- Finds the first result quickly
- Graphs may be really big
- But a particular search may match many results in many ways
  - Finding all results can take some time
  - 5000 functions, ~5 seconds
- Need to be more restrictive with matching

Structure Matching

- We can decompose any type into a structure and a list of terms

  Either (Maybe a) (b,c)

  ≡ ? (? ?) (? ? ?) + Either Maybe a (,) b c

- Can now find types quickly
  - 22 distinct argument structures in base library
  - Very amenable to hashing/interning
  - Not as powerful as edit distance

Structure + Aliases

String ≈ [Char]

? + String ≠ ? ? + [] Char

- Solution: Expand out all aliases
  - Penalise for all mismatched aliases used
  - i.e. left uses String, but right doesn’t
  - Imprecise heuristic

Structure + Boxing

Maybe a ≈ a

? ? + Maybe a ≠ ? + a

- Solution: Only allow top-level boxes
  - – Maybe [a] ≠ Maybe a
  - – Now have at most 3 structure lookups

Boxing is
3x expensive

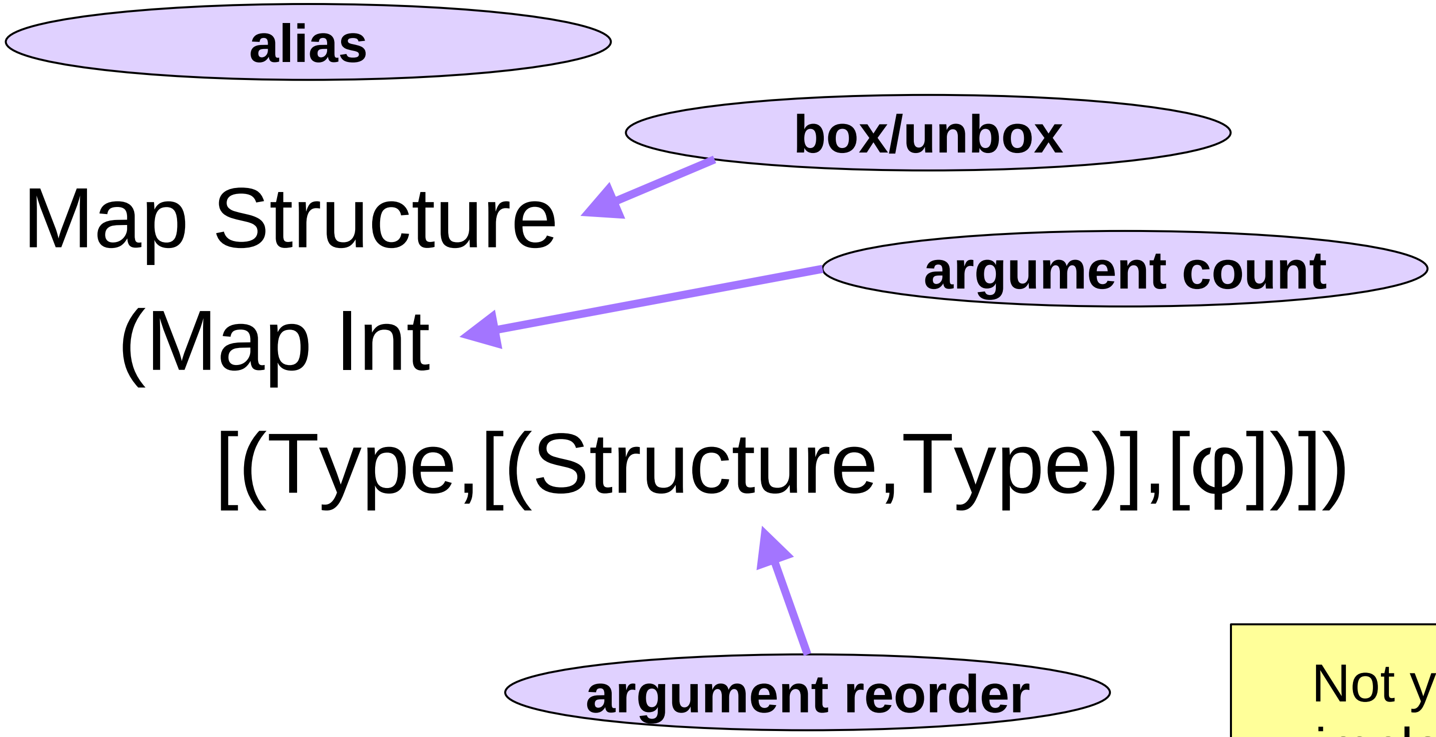
Step 1: Restrict Search

- Use structure for type search
- Many fewer answers
  - 5,000 types, ~0.5 seconds

- Target: 300,000 types, ~0.1 seconds

Step 2: Restrict Combine

- Start by looking at the *result* first



alias

box/unbox

Map Structure

argument count

(Map Int

[(Type,[(Structure,Type)],[φ])])

argument reorder

Not yet finished implementation

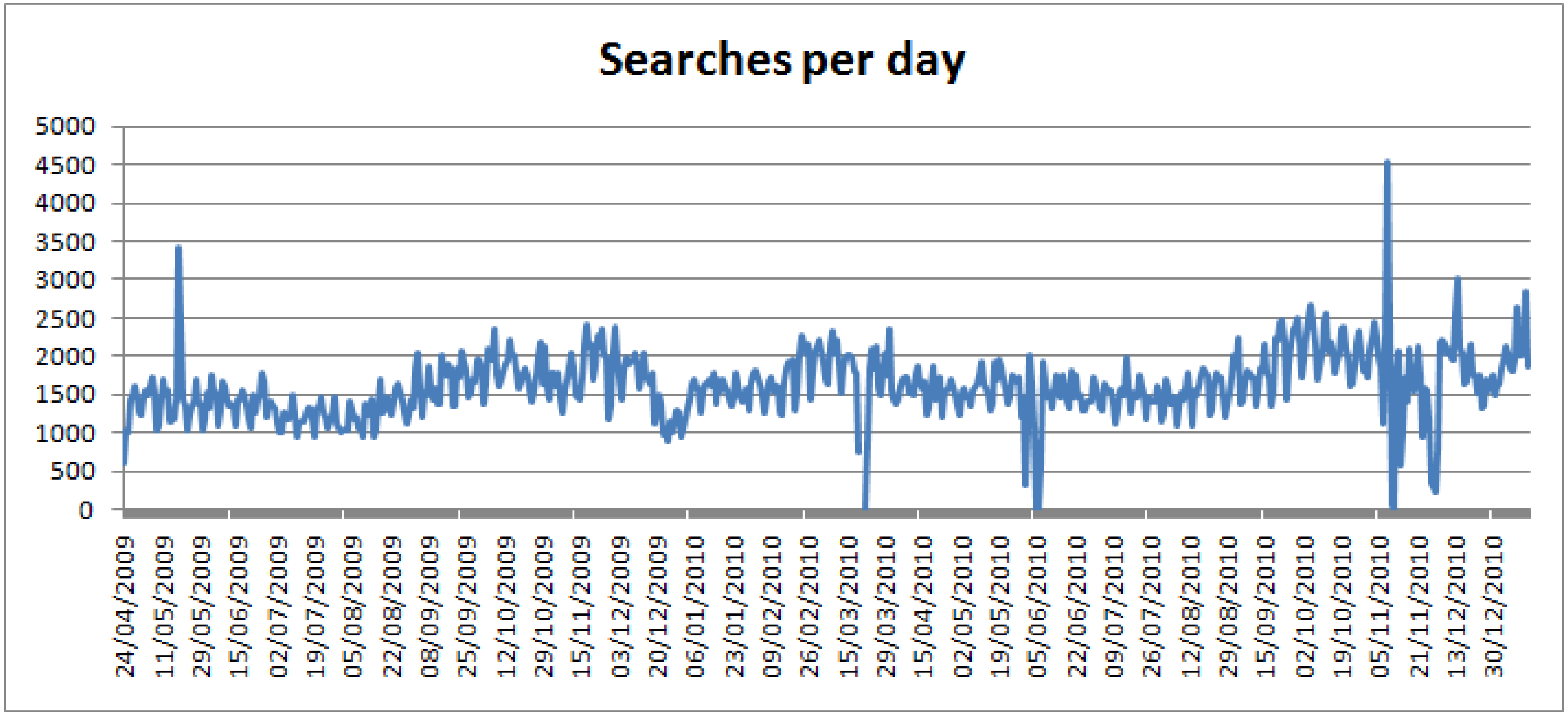
The Hoogle Tool

- Over 6 years old
- 4 major versions (each a complete rewrite)
  - Version 1 in Javascript, 2-4 in Haskell

- Web version
- Firefox plugin, iPhone version, command line tool, custom web server

Hoogle Statistics

- 1.7 million searches up until 1st Jan 2011
- Between 1000 to 2500 a day



Academia + Real World

- Academia
  - Theory of type searching
- Real World
  - Generating databases of type signatures
  - Web server, AJAX interface, interactivity
  - Lots of user feedback, including logs
  - 1/6 of searches are type based

Fixing User Searches

🔍 double to integer

Did you mean: Double → Integer

🔍 where

keyword where

Conclusions

- I now use Hoogle every day
  - Name search lets you look up types/docs
  - Type search lets you look up names
  - Both let you find new functions

- Edit distance works for type search
- Having an online search engine is handy!

haskell.org/hoogle

Funny Searches

- eastenders
- california public schools portable classes
- Bondage
- diem chuan truong dai hoc su pham ha noi 2008
- Messenger freak
- ebay consistency version
- Simon Peyton Jones Genius
- free erotic storeis
- videos pornos gratis
- gia savores de BARILOCHE
- name of Peanuts carton bird
- Colin Runciman