# Typed Clojure: Wishful Thinking

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# This talk

- Quick intro to Typed Clojure
- List of challenges/solutions to improve Typed Clojure
  - Barriers to Entry
  - Annotation Burden
  - Strictness
  - ClojureScript
- Hopefully some discussion

# What is Typed Clojure?

- Optional type system for Clojure
  - Write expected types for your program, checker will validate
- Static analysis
  - Checks your program without running it

# Example

```
(defalias Point
  ‘‘A point with x-y coordinates’’
  ‘{:x Int :y Int})

(ann point [Int Int -> Point])
(defn point [x y]
  ‘{:x x :y y})

(ann add-xy [Point -> Int])
(defn add-xy [{:keys [x y] :as p}]
  (+ x y))
```

# True unions + Flow typing

```
(ann maybe-add-xy [(U nil Point) -> (U nil Int)])
(defn maybe-add-xy [{:keys [x y] :as p}]
  (when p
    (+ x y))) ; x : Int, y : Int
```

# Expands before checking

```
(defmacro my-when [& body] `(when ~@body))

(ann maybe-add-xy [(U nil Point) -> (U nil Int)])
(defn maybe-add-xy [{:keys [x y] :as p}]
  (my-when p
    (+ x y)))
```

# Challenges

# Part 1: Barriers to entry

- initialization time in production
- bad error messages
- lack of library annotations

# Challenge

Don’t want to increase initialization time for type checked libraries

- collecting annotations
- expanding/defining wrapper macros

# Solution

Delay loading annotations

```
(ns foo …)
; lazily load ann
(t/register-ns!
  'foo.annotations)

(def f 1)
```

```
(ns foo.annotations
  (:require […]))

(t/ann f Int)
(t/ann g Int)
…
```

# Challenge

No source of type annotations for libraries

- libraries don’t provide their own types
- no central place for annotations like DefinitelyTyped for TypeScript

# Solutions

- Start a suite of annotations under typedclojure GitHub org
- reuse specs as a type annotations
  - unfortunately, specs don’t often make good types
    - no polymorphism
    - how to translate semantics to types? (eg. fspec, every)
    - s/keys’s implicit optional entries
  - can we retrofit these specs to be more useful as types?
- Guidelines for how to add type annotations to your own libraries

# Challenge

Error messages from macro expansions point to code the user didn't write

```
(inc (when foo 1))
```

```
Type error: Expected Number, found nil
in: nil
in: (if foo 1 nil)
```

# Solution

Custom typing rules

```
(when foo 1)
```

```
Type error: Expected Number, found nil
Message: Else branch of `when` expected nil
in: (when foo 1)
```

The custom rule:

```
(if foo
  1
  (with-blame {:form ‘(when foo 1)
               :msg ‘‘Else branch of `when` expected nil’’}
    nil))
```

# Part 2: Annotation burden

- too many `fn` annotations
- brittle polymorphic inference
- need “wrapper” macros to help check complex expansions
- these macros need their own annotations

# Challenge

Need to annotate “obvious” function arguments

```
(let [f (fn [x :- Int] (inc x))]
  (f 1))
```

# Solution

Delay type checking `fn` body until called

```
(let [f #(inc %)]
  ; f : (Lambda #(inc %))
  (f 1)) ; checking happens here
```

Caveats:

- Need to handle infinite recursion (eg. checking y-combinator)
- Can we avoid redundantly re-checking body of `fn`?

# Challenge

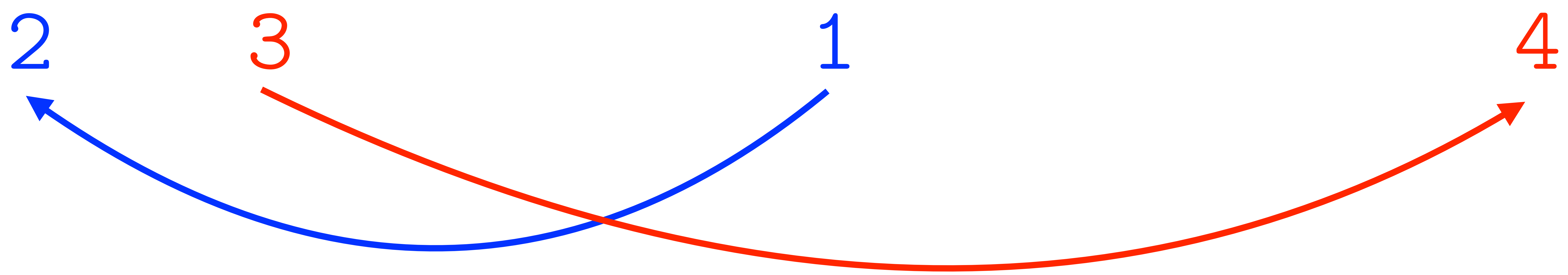
Need to annotate polymorphic higher-order function arguments

```
(map (fn [a :- Int] …) [1 2 3])
```

# Solution: Smarter inference

Deduce an optimal “ordering” for checking arguments

```
(All [a b]
  [[a -> b] (Seqable a) -> (Seqable b)])
```




1. Check collection first
2. Use collection type to seed function argument
3. Now we have the return argument type
4. Which travels to the return of the entire function

# Type checking comp

```
(ann f [Number -> Number])
(def f (comp #(inc %) #(dec %)))
```

# Type checking comp

```
                1               6
(ann f [Number -> Number])
(def f (comp #(inc %) #(dec %)))
                 5      4  3      2
```

```
; Type of `comp`

(All [a b c]
            5                          6
  [[b -> c] [a -> b] -> [a -> c]])
    4         2    3      1
```

# Type checking map transducer

```
                             1        4
(ann f (Transducer [Num -> Num]))
(def f (map #(inc %)))
               3     2
```

```
; Type of the `map` transducer

(All [a b]
  [[a -> b] -> (All [r] [[r b -> r] -> [r a -> r]])])
```

# Scale to comp+transducers

```
; Call (sequence (comp (map #(inc %)) (map #(dec %))) [1 2 3])

                    #(inc %)              #(dec %)

;(map #(inc %))                           ;(map #(dec %))
(All [a b]                                (All [a b]
  [[a -> b] ->                              [[a -> b] ->
   (All [r] [[r b -> r] -> [r a -> r]])])    (All [r] [[r b -> r] -> [r a -> r]])])

;(comp ..)
(All [a b c]
  [[b -> c] [a -> b] -> [a -> c]])

;(sequence ..)
(All [a b]
  [(All [r] [[r b -> r] -> [r a -> r]]) (Seqable a) -> (Seqable b)])
```

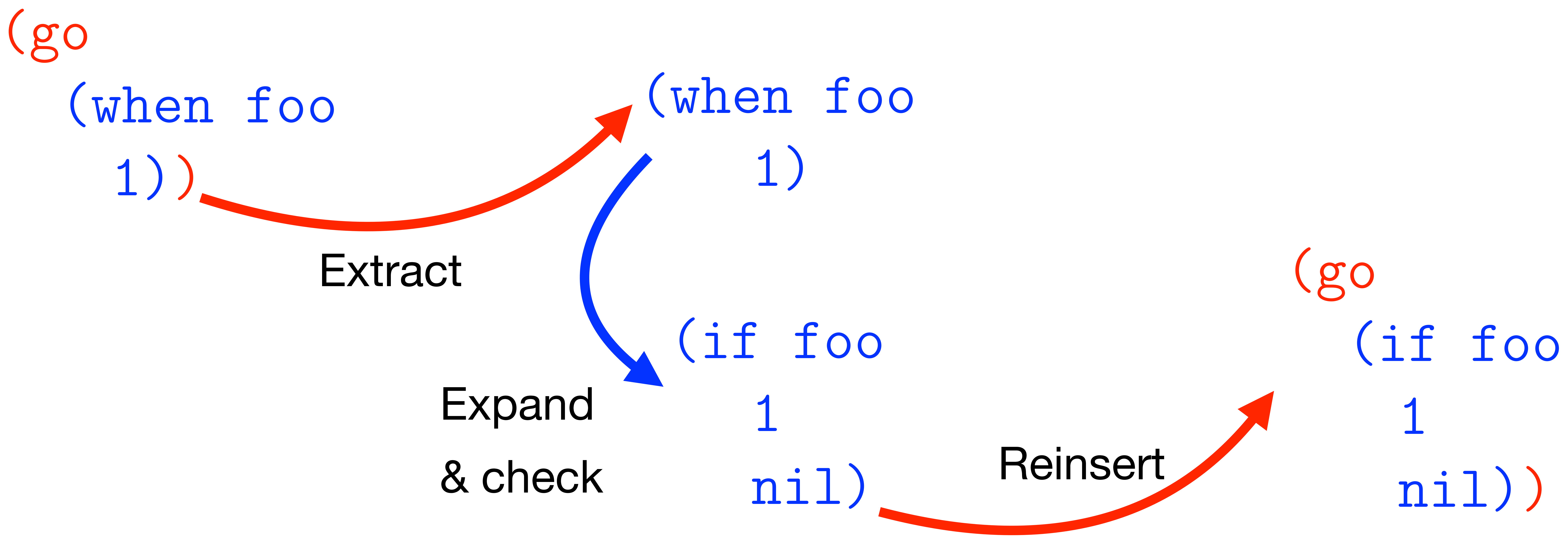
# Challenge

Need to write typed wrappers for macros with complex expansions

```
(require '[clojure.core.typed.async :as ta])
(ta/go
  (when foo
    1))
```

# Solution

Support custom rules for macros that don't require expansion, then expand them *after* type checking



# Challenge

Need to write local annotations for wrapper macros

```
(t/doseq [a :- Int, [1 2 3]] :- Int
  …)
```

# Solution

Write custom typing rules to direct inference.

```
(t/doseq [a :- Int, [1 2 3]] :- Int
  ...)
```

# Part 3: Strictness

- stricter map operations
- opt-in unsoundness

# Challenge

Map ops don't catch enough type errors

***Assoc wrong key***

```
(ann m1 (HMap :optional {:foo Int}))
(def m1 (assoc {} :foob 1))
```

***Get wrong key***

```
(ann v (U nil Int)
(def v (get {:exists 1} :non-existent-key))
```

# Solutions(?)

More restrictive subtyping for HMap's

***Assoc wrong key***

```
(ann m1 (HMap :optional {:foo Int}))
(def m1 (assoc {} :foob 1))
```

Error: unknown key :foob

***Get wrong key***

```
(ann v (U nil Int))
(def v (get {:exists 1} :non-existent-key))
```

# Challenge

Typed Clojure is too strict with unannotated code

```
(defn my-fn […]
  (let [a (lib1 …)
        b (lib2 …)
        c (lib3 …)]
    (lib4 …)))
```

# Solution

Opt-out of soundness—closer to TypeScript when needed

```
(check-ns ‘my-ns
   :check-config {:check-ns-dep :never
                  :unannotated-def  :unchecked
                  :unannotated-var  :unchecked
                  :unannotated-arg  :unchecked})
```

# Part 4: ClojureScript

- analyzer that supports partial analysis
- undefined/nil
- Closure/TypeScript annotations

# Challenge

Analyzer that can partially expand code (does not exist yet)

```
(go (when foo 1))
```

```
(go (if foo 1 nil))
```

# Challenge

ClojureScript mostly treats nil/undefined as equivalent

```
(defalias Nilable
  (TFn [x] (U nil x)))

(defalias Nilable
  (TFn [x] (U undefined nil x)))
```

# More problems…

Solution: Introduce new base types js/Null and js/Undefined

But now…:

- Is nil == js/Null?
- Is js/Undefined <: nil? since `(nil? js/undefined) => true`
  - Either choice has interesting consequences

# Challenge

How to use Closure/TypeScript annotations to our advantage?

# What is Typed Clojure good at?

- Flow typing
- Checking higher-order idioms (channels, functions, atoms)
- Specifying polymorphic functions

# Problems with Typed Clojure

- Insufficient local type inference
- Large annotation burden
- Slow (checking speed & dev iterations)
- Macro usages hard to check
- Sometimes too strict, sometimes too loose

# Possible Solutions

- custom typing rules
  - better inference, error messages
- “directed” local type inference
- more flexible checking

# Thanks