Typed Clojure

An optional type system for Clojure

What if Type Systems were more like Linters?

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Me

- A Practical Optional Type System for Clojure (2012)
- Typed Clojure Indiegogo Campaign
- @ambrosebs

Pluggable, Optional Type Systems

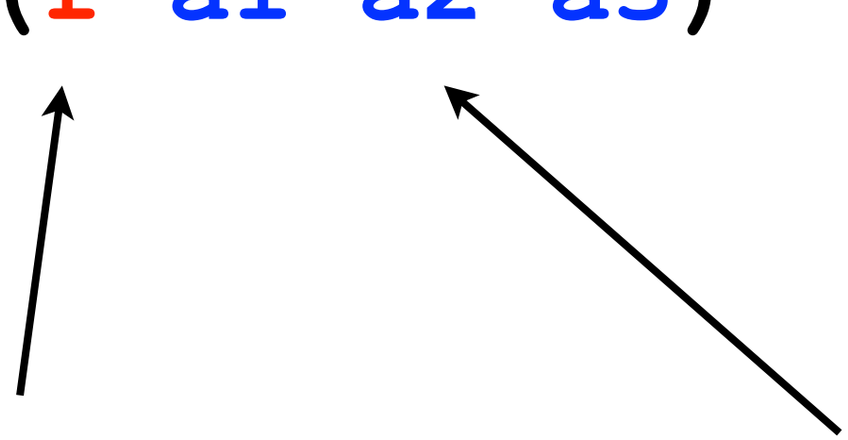
- Do not affect program semantics
- Same tooling
- Opt-in
- Combinations

Clojure

- Lisp dialect
- Dynamically typed
- Hosted (JVM, JavaScript, CLR)
- Immutability

Clojure Syntax

```
(f a1 a2 a3)
```



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Goals

- Type checker as a Library
- Understand common Clojure style
- Sound type checking

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Type System

- Does not affect runtime semantics
- Statically sound
- Explicitly typed with local inference

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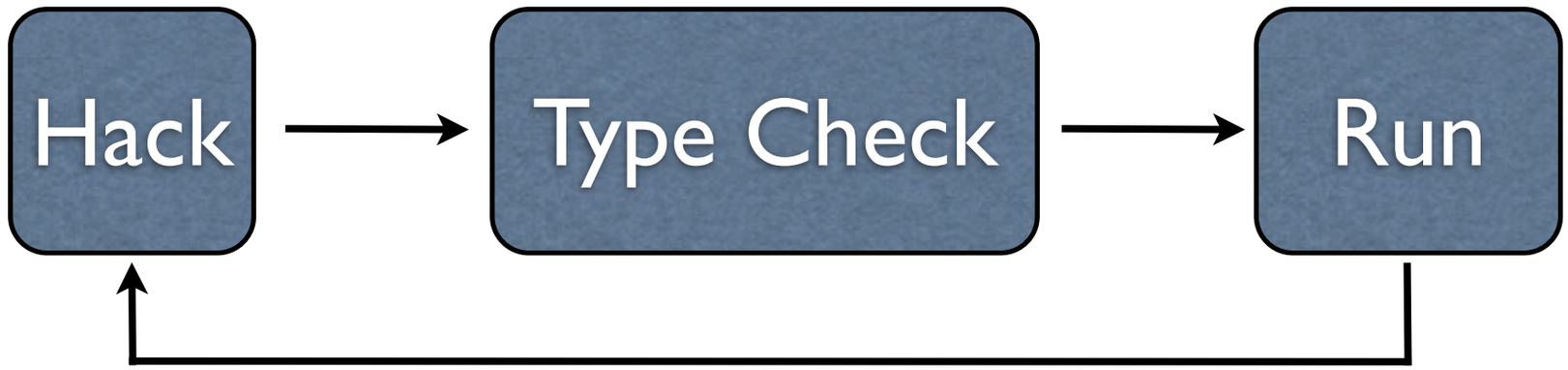
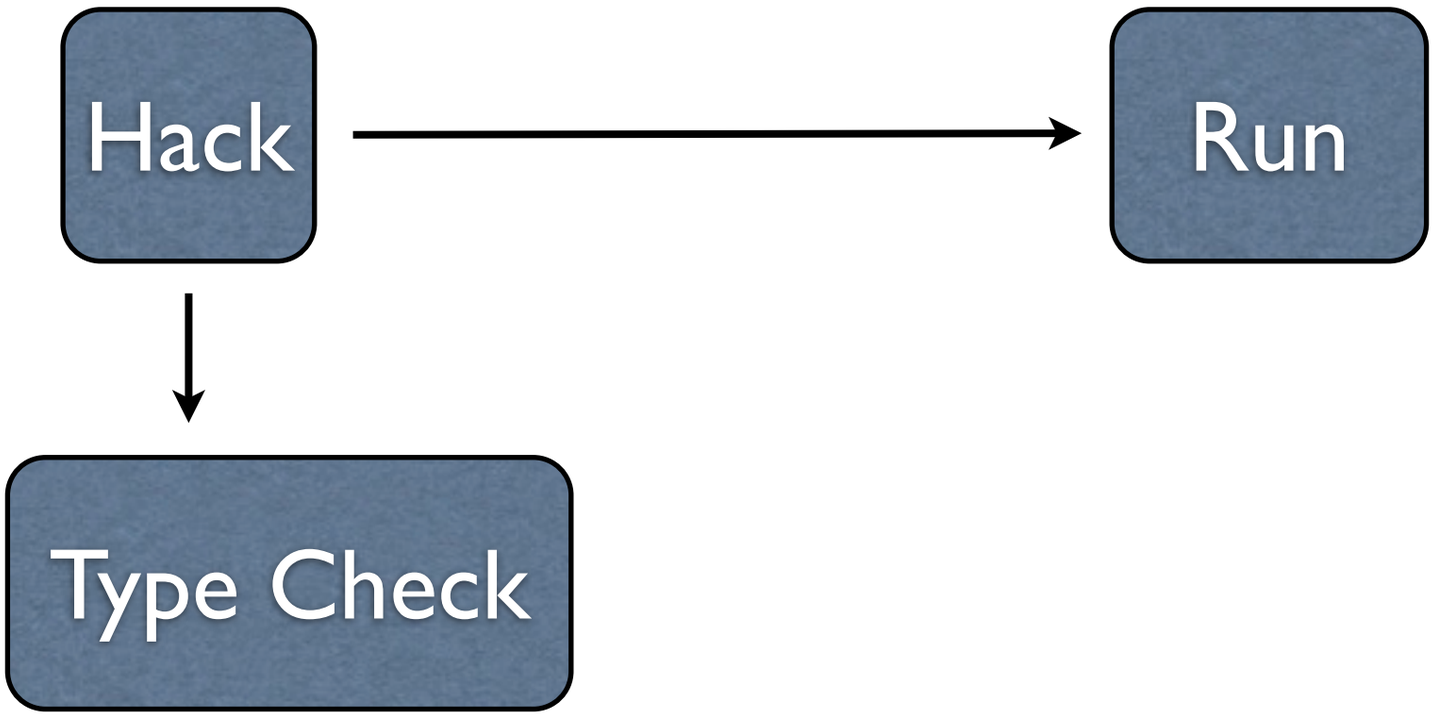
Traditional Type Systems



Pluggable, Optional Type Systems



Simple Types

```
'a
; clojure.lang.Symbol

1
; java.lang.Long

<some-expression>
; Any

(throw e)
; Nothing
```

Simple Types

```
(fn> [a :- Number] (inc a))
; [Number -> Number]
```

Immutable Collections

```
[1 'a :b]
; (Vec (U Number Keyword Symbol))
```

```
{1 2, 3 4}
; (Map Number Number)
```

Type Aliases

```
(def-alias MyName
  "Optional docstring"
  Symbol)
```

Unions

- Ad-hoc/untagged unions
- Model data flow common in dynamic languages

Unions

```
(if c?
    'sym
    1.2)
;  (U Number Symbol)
```

Control Flow

- Need to eliminate union members
- *Occurrence typing* understands common control flow

Eliminating Unions

```
(let [a (if c? `a 1)]
  (if (symbol? a)
    (name a)
    (inc a)))
```

Inline Assertions

```
(let [a (if c? `a 1)]
  (assert (number? a))
  (inc a))
```

Data

- Clojure emphasises *data*
- Maps, vectors, lists
- Often implied structure
  - Typed Clojure understands common patterns

Maps

- Heterogeneous maps
- Optional keys
- Partial maps
- Common operations
  - add/remove keys, merge

Creating Maps

```
{:a 1, :b 1.2, :c 'a}
; (HMap :mandatory {:a Int,
;                   :b Number,
;                   :c Symbol}
;       :complete? true)
```

Modifying Maps

```
(assoc {:a 1} :b 1.2)
; (HMap :mandatory {:a (Value 1),
;                   :b (Value 1.2)}
;      :complete? true})

(dissoc {:a 1} :a)
; (HMap :complete? true)
```

Lookup Maps

```
(:a {:a 1})
; Number
```

```
(:a (if c?
      {:a 1}
      {:b 2}))
; (U nil Number)
```

Merging Maps

```
(merge (if c?
           {:a 1, :c 'a}
           {:b 2})
       {:c 3})
;  (HMap :mandatory {:c Number}
;        :optional {:a Number
;                   :b Number}
;        :complete? true)
```

Occurrence Typing + Maps

```
(let [a {:a
         {:b (if c? 1 'a)}}]
  (if (number? (-> a :a :b))
    (inc (-> a :a :b))
    (name (-> a :a :b))))
```

Maps + Unions

```
(def-alias Expr
  (Rec [Expr]
    (U `{:op (Value :if)
         :test Expr, :then Expr
         :else Expr}
       `{:op (Value :do)
         :exprs (Coll Expr)}
       ...)))

(defmulti parse :op)
(defmethod parse :if
  [{:keys [test then else]}] ...)
(defmethod parse :do
  [{:keys [exprs]}] ...)
```

Java Interop

- Pessimistic by default, overridable by programmer
- Understands Java invariants

Functions

- Ordered intersections (like TypeScript)
- An ordered list of arities that represents a function

Functions

```
(ann foo [Number -> Number])
(defn foo [n] (inc n))
```

Multiple Arities

```
(def-alias NumSym (U Number Symbol))
(def-alias NumStr (U Number String))

(ann foo2 (Fn [Number -> Number]
              [Symbol -> String]
              [NumSym -> NumStr]))
(defn foo2 [n]
  (if (number? n)
    (inc n)
    (name n)))
```

Keyword Arguments

```
(ann kwarg [& :optional {:kw Number} -> Any])
(defn kwarg [& {:keys [kw]}]
  ; kw :- (U nil Number)
  ...)

(foo2 :kw 1)
```

Polymorphism

- Polymorphic Functions
- Bounded polymorphism

Simple Polymorphism

```
(ann id (All [x] [x -> x]))
(defn id [a] a)
```

Bounded Polymorphism

```
(ann add-a (All [[x :< (Map Any Any]]
                [x -> (Assoc x ':a Number)]))
(defn add-a [m]
  (assoc m :a 1))

(inc (:a (add-a {:b 1})))
(inc (:b (add-a {:b 1})))
```

Dotted Polymorphism

```
; Infinite number of arities.
; Dotted polymorphism defines a template
; that covers all valid usages.
(map + [1 2 3])
(map + [1 2 3] [4 5 6])
(map + [1 2 3] [4 5 6] [7 8 9])
(map + [1 2 3] [4 5 6] [7 8 9] [10 11 12])
```

Macros

- macros + types = yum!
- Roll your own syntax

Pretty def

```
(defmacro def [nme _ t init]
  `(do (ann ~nme ~t)
       (core/def ~nme ~init))
```

```
(def v :- Symbol 'a)
; Same as:
; (do (ann v Symbol)
;     (def v 'a))
```

Conclusion

- Pluggable type systems don't change semantics
- They provide layers of verification on top of a language
- Your favourite language?