Typed Scheme

From Scripts to Programs

Sam Tobin-Hochstadt
Northeastern University

The PL Renaissance

The PL Renaissance

python

tcl tk

php

Lua

The PL Renaissance

python

tcl tk

php

Lua

What’s good

These languages are

- interactive
- designed for rapid development
- supported by an active community
- modular
- higher-order

And they’re exciting!

What’s not so good

```
(define (main stx trace-flag super-expr
                 deserialize-id-expr name-id
                 interface-exprs defn-and-exprs)
```

```
(let-values ([(this-id) #'this-id]
             [(the-obj) (datum->syntax (quote-syntax here) (gensym 'self))]
             [(the-finder) (datum->syntax (quote-syntax here) (gensym 'find-self))])
  (let* ([def-ctx (syntax-local-make-definition-context)]
         [localized-map (make-bound-identifier-mapping)]
         [any-localized? #f]
         [localize/set-flag (lambda (id)
                              (let ([id2 (localize id)])
                                (unless (eq? id id2)
                                  (set! any-localized? #t))
                                id2))]
         [bind-local-id (lambda (id)
                          (let ([l (localize/set-flag id)])
                            (syntax-local-bind-syntaxes (list id) #f def-ctx)
                            (bound-identifier-mapping-put!
                             localized-map
                             id
                             l)))]
         [lookup-localize (lambda (id)
                            (bound-identifier-mapping-get
                             localized-map
                             id
                             (lambda ()
                               ; If internal & external names are distinguished,
                               ; we need to fall back to localize:
                               (localize id))))])
    ; ----- Expand definitions -----
    (let ([defn-and-exprs (expand-all-forms stx defn-and-exprs def-ctx bind-local-id)]
          [bad (lambda (msg expr)
                 (raise-syntax-error #f msg stx expr))]
          [class-name (if name-id
                          (syntax-e name-id)
                          (let ([s (syntax-local-infer-name stx)])
                            (if (syntax? s)
                                (syntax-e s)
                                s)))])
      ; ------ Basic syntax checks -----
      (for-each (lambda (stx)
                  (syntax-case stx (-init init-rest -field -init-field inherit-field
                                    private public override augride
                                    public-final override-final augment-final
                                    pubment overment augment
                                    rename-super inherit inherit/super inherit/inner rename-inner
                                    inspect)
                    [(form orig idp ...)
                     (and (identifier? #'form)
                          (or (free-identifier=? #'form (quote-syntax -init))
                              (free-identifier=? #'form (quote-syntax -init-field))))]))))))) )
```

+ 900 lines

What's not so good

```
; Start here:
(define (main stx trace-flag super-expr
              deserialize-id-expr name-id
              interface-exprs defn-and-exprs)
```

```
(let-values ([(this-id) #'this-id]
             [(the-obj) (datum->syntax (quote-syntax here) (gensym 'self))]
             [(the-finder) (datum->syntax (quote-syntax here) (gensym 'find-self))])
  (let* ([def-ctx (syntax-local-make-definition-context)]
         [localized-map (make-bound-identifier-mapping)]
         [any-localized? #f]
         [localize/set-flag (lambda (id)
                              (let ([id2 (localize id)])
                                (unless (eq? id id2)
                                  (set! any-localized? #t))
                                id2))]
         [bind-local-id (lambda (id)
                          (let ([l (localize/set-flag id)])
                            (syntax-local-bind-syntaxes (list id) #f def-ctx)
                            (bound-identifier-mapping-put!
                             localized-map
                             id
                             l)))]
         [lookup-localize (lambda (id)
                            (bound-identifier-mapping-get
                             localized-map
                             id
                             (lambda ()
                               ; If internal & external names are distinguished,
                               ; we need to fall back to localize:
                               (localize id))))])
    ; ----- Expand definitions -----
    (let ([defn-and-exprs (expand-all-forms stx defn-and-exprs def-ctx bind-local-id)]
          [bad (lambda (msg expr)
                 (raise-syntax-error #f msg stx expr))]
          [class-name (if name-id
                          (syntax-e name-id)
                          (let ([s (syntax-local-infer-name stx)])
                            (if (syntax? s)
                                (syntax-e s)
                                s)))])
      ; ------ Basic syntax checks -----
      (for-each (lambda (stx)
                  (syntax-case stx (-init init-rest -field -init-field inherit-field
                                         private public override augride
                                         public-final override-final augment-final
                                         pubment overment augment
                                         rename-super inherit inherit/super inherit/inner rename-inner
                                         inspect)
                    [(form orig idp ...)
                     (and (identifier? #'form)
                          (or (free-identifier=? #'form (quote-syntax -init))
                              (free-identifier=? #'form (quote-syntax -init-field))))]))))))) )
```

+ 900 lines

What’s not so good

```
; main : stx bool stx         id  id stxs stxs -> stx
(define (main stx trace-flag super-expr
              deserialize-id-expr name-id
              interface-exprs defn-and-exprs)
```

```
(let-values ([(this-id) #'this-id]
             [(the-obj) (datum->syntax (quote-syntax here) (gensym 'self))]
             [(the-finder) (datum->syntax (quote-syntax here) (gensym 'find-self))])
  (let* ([def-ctx (syntax-local-make-definition-context)]
         [localized-map (make-bound-identifier-mapping)]
         [any-localized? #f]
         [localize/set-flag (lambda (id)
                              (let ([id2 (localize id)])
                                (unless (eq? id id2)
                                  (set! any-localized? #t))
                                id2))]
         [bind-local-id (lambda (id)
                          (let ([l (localize/set-flag id)])
                            (syntax-local-bind-syntaxes (list id) #f def-ctx)
                            (bound-identifier-mapping-put!
                             localized-map
                             id
                             l)))]
         [lookup-localize (lambda (id)
                            (bound-identifier-mapping-get
                             localized-map
                             id
                             (lambda ()
                               ; If internal & external names are distinguished,
                               ; we need to fall back to localize:
                               (localize id))))])
    ; ----- Expand definitions -----
    (let ([defn-and-exprs (expand-all-forms stx defn-and-exprs def-ctx bind-local-id)]
          [bad (lambda (msg expr)
                 (raise-syntax-error #f msg stx expr))]
          [class-name (if name-id
                          (syntax-e name-id)
                          (let ([s (syntax-local-infer-name stx)])
                            (if (syntax? s)
                                (syntax-e s)
                                s)))])
      ; ------ Basic syntax checks -----
      (for-each (lambda (stx)
                  (syntax-case stx (-init init-rest -field -init-field inherit-field
                                         private public override augride
                                         public-final override-final augment-final
                                         pubment overment augment
                                         rename-super inherit inherit/super inherit/inner rename-inner
                                         inspect)
                    [(form orig idp ...)
                     (and (identifier? #'form)
                          (or (free-identifier=? #'form (quote-syntax -init))
                              (free-identifier=? #'form (quote-syntax -init-field))))]))))))  )
```

+ 900 lines

What’s not so good

```
; main : stx bool stx (or #f id) id stxs stxs -> stx
(define (main stx trace-flag super-expr
              deserialize-id-expr name-id
              interface-exprs defn-and-exprs)
```

```
(let-values ([(this-id) #'this-id]
             [(the-obj) (datum->syntax (quote-syntax here) (gensym 'self))]
             [(the-finder) (datum->syntax (quote-syntax here) (gensym 'find-self))])
  (let* ([def-ctx (syntax-local-make-definition-context)]
         [localized-map (make-bound-identifier-mapping)]
         [any-localized? #f]
         [localize/set-flag (lambda (id)
                              (let ([id2 (localize id)])
                                (unless (eq? id id2)
                                  (set! any-localized? #t))
                                id2))]
         [bind-local-id (lambda (id)
                          (let ([l (localize/set-flag id)])
                            (syntax-local-bind-syntaxes (list id) #f def-ctx)
                            (bound-identifier-mapping-put!
                             localized-map
                             id
                             l)))]
         [lookup-localize (lambda (id)
                            (bound-identifier-mapping-get
                             localized-map
                             id
                             (lambda ()
                               ; If internal & external names are distinguished,
                               ; we need to fall back to localize:
                               (localize id))))])
    ; ----- Expand definitions -----
    (let ([defn-and-exprs (expand-all-forms stx defn-and-exprs def-ctx bind-local-id)]
          [bad (lambda (msg expr)
                 (raise-syntax-error #f msg stx expr))]
          [class-name (if name-id
                          (syntax-e name-id)
                          (let ([s (syntax-local-infer-name stx)])
                            (if (syntax? s)
                                (syntax-e s)
                                s)))])
      ; ------ Basic syntax checks -----
      (for-each (lambda (stx)
                  (syntax-case stx (-init init-rest -field -init-field inherit-field
                                          private public override augride
                                          public-final override-final augment-final
                                          pubment overment augment
                                          rename-super inherit inherit/super inherit/inner rename-inner
                                          inspect)
                    [(form orig idp ...)
                     (and (identifier? #'form)
                          (or (free-identifier=? #'form (quote-syntax -init))
                              (free-identifier=? #'form (quote-syntax -init-field))))]))))))   )
```

+ 900 lines

What’s not so good

```
(: main (Stx Bool Stx (U  #f Id) Id Stxs Stxs -> Stx))
(define (main stx trace-flag super-expr
                deserialize-id-expr name-id
                interface-exprs defn-and-exprs)
```

```
(let-values ([(this-id) #'this-id]
             [(the-obj) (datum->syntax (quote-syntax here) (gensym 'self))]
             [(the-finder) (datum->syntax (quote-syntax here) (gensym 'find-self))])
  (let* ([def-ctx (syntax-local-make-definition-context)]
         [localized-map (make-bound-identifier-mapping)]
         [any-localized? #f]
         [localize/set-flag (lambda (id)
                              (let ([id2 (localize id)])
                                (unless (eq? id id2)
                                  (set! any-localized? #t))
                                id2))]
         [bind-local-id (lambda (id)
                          (let ([l (localize/set-flag id)])
                            (syntax-local-bind-syntaxes (list id) #f def-ctx)
                            (bound-identifier-mapping-put!
                             localized-map
                             id
                             l)))]
         [lookup-localize (lambda (id)
                            (bound-identifier-mapping-get
                             localized-map
                             id
                             (lambda ()
                               ; If internal & external names are distinguished,
                               ; we need to fall back to localize:
                               (localize id))))])
    ; ----- Expand definitions -----
    (let ([defn-and-exprs (expand-all-forms stx defn-and-exprs def-ctx bind-local-id)]
          [bad (lambda (msg expr)
                 (raise-syntax-error #f msg stx expr))]
          [class-name (if name-id
                          (syntax-e name-id)
                          (let ([s (syntax-local-infer-name stx)])
                            (if (syntax? s)
                                (syntax-e s)
                                s)))])
      ; ------ Basic syntax checks -----
      (for-each (lambda (stx)
                  (syntax-case stx (-init init-rest -field -init-field inherit-field
                                          private public override augride
                                          public-final override-final augment-final
                                          pubment overment augment
                                          rename-super inherit inherit/super inherit/inner rename-inner
                                          inspect)
                    [(form orig idp ...)
                     (and (identifier? #'form)
                          (or (free-identifier=? #'form (quote-syntax -init))
                              (free-identifier=? #'form (quote-syntax -init-field))))])))))))
```

```
)
```

+ 900 lines

Thesis

Module-by-module porting of code from an untyped language to a typed sister language allows for an easy transition from untyped scripts to typed programs.

Module-by-module porting of code from an untyped language to a typed sister language allows for an easy transition from untyped scripts to typed programs.

Thesis

Module-by-module porting of code from an untyped language to a typed sister language allows for an easy transition from untyped scripts to typed programs.

Module-by-module porting of code from an untyped language to a typed sister language allows for an easy transition from untyped scripts to typed programs.

Why PLT Scheme?

Modules

Contracts

Abstractions

Typed Scheme in 3 Slides

Hello World

```
#lang        scheme                                hello

(printf "Hello World\n")
```

Hello World

```
#lang typed-scheme                                    hello

(printf "Hello World\n")
```

```
#lang        scheme                                  ack

; ack : Integer Integer -> Integer
(define (ack m n)
  (cond [(<= m 0) (+ n 1)]
        [(<= n 0) (ack (- m 1) 1)]
        [else (ack (- m 1) (ack m (- n 1)))]))

(ack 2 3)
```

ack

```
#lang typed-scheme

(: ack (Integer Integer -> Integer))
(define (ack m n)
  (cond [(<= m 0) (+ n 1)]
        [(<= n 0) (ack (- m 1) 1)]
        [else (ack (- m 1) (ack m (- n 1)))]))

(ack 2 3)
```

ack

```
#lang        scheme

; ack : Integer Integer -> Integer
(define (ack m n)
  (cond [(<= m 0) (+ n 1)]
        [(<= n 0) (ack (- m 1) 1)]
        [else (ack (- m 1) (ack m (- n 1)))]))
```

compute

```
#lang        scheme

(require ack)

(ack 2 3)
```

Modules

ack

```
#lang typed-scheme

(: ack (Integer Integer -> Integer))
(define (ack m n)
  (cond [(<= m 0) (+ n 1)]
        [(<= n 0) (ack (- m 1) 1)]
        [else (ack (- m 1) (ack m (- n 1)))]))
```

compute

```
#lang       scheme

(require ack)

(ack 2 3)
```

ack

```
#lang        scheme

; ack : Integer Integer -> Integer
(define (ack m n)
  (cond [(<= m 0) (+ n 1)]
        [(<= n 0) (ack (- m 1) 1)]
        [else (ack (- m 1) (ack m (- n 1)))]))
```

compute

```
#lang typed-scheme

(require [ack
          (Integer Integer -> Integer)])
(ack 2 3)
```

ack

```
#lang typed-scheme

(: ack (Integer Integer -> Integer))
(define (ack m n)
  (cond [(<= m 0) (+ n 1)]
        [(<= n 0) (ack (- m 1) 1)]
        [else (ack (- m 1) (ack m (- n 1)))]))
```

compute

```
#lang typed-scheme

(require ack)

(ack 2 3)
```

Sound Interoperation

Typed & Untyped

```
#lang typed-scheme                    server

(: add5 (Number -> Number))
(define (add5 x) (+ x 5))
```

```
#lang       scheme                    client

(require server)
(add5 7)
```

Untyped code can make mistakes

```
#lang typed-scheme                                  server

(: add5 (Number -> Number))
(define (add5 x) (+ x 5))
```

```
#lang       scheme                                  client

(require server)
(add5 "seven")
```

Untyped code can make mistakes

```
#lang typed-scheme                                    server

(: add5 (Number -> Number))
(define (add5 x) (+ x 5))
```

```
#lang       scheme                                    client

(require server)
(add5 "seven")
```

+: expects type <number> as 1st argument

Catch errors dynamically at the boundary

```
#lang typed-scheme                              server

(: add5 (Number -> Number))
(define (add5 x) (+ x 5))
```

```
#lang       scheme                              client

(require server)
(add5 "seven")
```

client broke the contract on add5

Catch errors dynamically at the boundary

server

```
#lang       scheme

(define (add5 x) "x plus 5")
```

client

```
#lang typed-scheme

(require server
         [add5 (Number -> Number)])
(add5 7)
```

server interface broke the contract on add5

Catch errors dynamically at the boundary

server

```
#lang typed-scheme

(: addx (Number -> (Number -> Number)))
(define (addx x) (lambda (y) (+ x y)))
```

client

```
#lang         scheme

(require server)
((addx 7) 'bad)
```

client broke the contract on add5

The Blame Theorem

If the program raises a contract error, the blame is not assigned to a typed module.

The Blame Theorem

Well-typed modules can’t get blamed.

The Blame Theorem

Allows local reasoning about typed modules,
without changing untyped modules.

Choose how much static checking you want.

Types for Scheme

Occurrence Typing

Variable-Arity

Refinement Types

Ad-Hoc Data

```
#lang typed-scheme                                        occur

(: f (Any -> Number))
(define (f x)
  (if (number? x)
      (add1 x)
      0))
```

```
#lang typed-scheme                                    refine

(: check (String -> (Refinement sql-safe?)))
(define (check s)
  (if (sql-safe? s)
      s
      (error "unsafe string!")))
```

```
#lang typed-scheme                                    union

(define-type-alias BT
  (U Number (Pair BT BT)))
(: sizeof (BT -> Number))
(define (sizeof b)
  (if (number? b)
      1
      (+ 1 (sizeof (car b)) (sizeof (cdr b)))))
```

```
#lang typed-scheme                                          varar

(: wrap (∀ (B A ...)
          ((A ... -> B) -> (A ... -> B))))
(define (wrap f)
  (lambda args
    (printf "args are: ~a\n" args)
    (apply f args)))
```

```
#lang        scheme                              number?


(define (f x)
  (if (number? x)
      (add1 x)
      0))
```

```
#lang typed-scheme                                    number?

(: f (Any -> Number))
(define (f x)
  (if (number? x)
      (add1 x)
      0))
```

Filters & Objects

```
#lang typed-scheme

(: f (Any -> Number))
(define (f x)
  (if (number? x)
      (add1 x)
      0))
```

number?

type: Any

```
#lang typed-scheme                                  number?

(: f (Any -> Number))
(define (f x)
  (if (number? x)
      (add1 x)
      0))
```

type: Any

number?

```
#lang typed-scheme

(: f (Any -> Number))
(define (f x)
  (if (number? x)
      (add1 x)
      0))
```

type: Number

```
#lang typed-scheme                                    number?

(: f (Any -> Number))
(define (f x)
  (if (number? x)
      (add1 x)
      0))
```

type: (Any -> Boolean : Number)

```
#lang typed-scheme                                   number?

(: f (Any -> Number))
(define (f x)
  (if (number? x)
      (add1 x)
      0))
```

type: Any
object: x

```
#lang typed-scheme

(: f (Any -> Number))
(define (f x)
  (if (number? x)
      (add1 x)
      0))
```

number?

type: Boolean
filter: (apply-filter Number x)

```
#lang typed-scheme                                  number?

(: f (Any -> Number))
(define (f x)
  (if (number? x)
      (add1 x)
      0))
```

type: Boolean
filter: Number_x

```
#lang typed-scheme

(: f (Any -> Number))
(define (f x)
  (if (number? x)
      (add1 x)
      0))
```

number?

env: x:Any + $\mathtt{Number}_{x}$

```
#lang typed-scheme

(: f (Any -> Number))
(define (f x)
  (if (number? x)
      (add1 x)
      0))
```

number?

```
env: x:Number
type: Number
```

else

```
#lang        scheme

; s is a symbol, number or string
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

Then & Else

```
#lang typed-scheme                                          else

(: ->string ((U Symbol Number String) -> String))
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

```
#lang typed-scheme                                    else

(: ->string ((U Symb
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

type: (U Symbol Number String)

Then & Else

else

```
#lang typed-scheme

(: ->string ((U Symbol Number String) -
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

type: Symbol

Then & Else

```
#lang typed-scheme                                          else

(: ->string ((U Symbol Number String) -> String))
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

type: (U Number String)

Then & Else

else

```
#lang typed-scheme

(: ->string ((U Symbol Number String) -> String))
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

type: Number

Then & Else

```
#lang typed-scheme                                          else

(: ->string ((U Symbol Number String) -> String))
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

type: String

else

```
#lang typed-scheme

(: ->string (
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

type: (Any -> Boolean : Symbol | Symbol

Then & Else

```
#lang typed-scheme

(: ->string ((U Symbo                                   )
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

else

type: Boolean

filter: Symbol_s | $\overline{\mathrm{Symbol}_s}$

Then & Else

else

```
#lang typed-scheme

(: ->stri
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

env: s:(U Symbol Number String) + Symbol_s

Then & Else

else

```
#lang typed-scheme

(: ->string ((U Symbol                  -> String))
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

env: s:Symbol

Then & Else

```
#lang typed-scheme                                        else

(: ->string ((U Symbol Number String) -> String))
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

nv: s:(U Symbol Number String) + $\overline{\text{Symbol}}_s$

Then & Else

else

```
#lang typed-scheme

(: ->string ((U Symbol Number String) -> String))
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

env: s:(U Number String)

Then & Else

```
#lang typed-scheme                                              else

(: ->string ((U Symbol Number String) -> String))
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

```
type: (Any -> Boolean : Number | Number
```

Then & Else

```
#lang typed-scheme                                      else

(: ->string ((U Symbol Number String) -> String))
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

```
type: Boolean
filter: Number_s | Number_s
```

else

```
#lang typed-scheme

(: ->string ((U Symbol Number String) -> String))
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

env: s:(U Number String) + Number_s

else

```
#lang typed-scheme

(: ->string ((U Symbol Number String) -> String))
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

env: s:Number

```
#lang typed-scheme                                         else

(: ->string ((U Symbol Number String) -> String))
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

env: s:(U Number String) + $\overline{\text{Number}}_s$

```
#lang typed-scheme                                         else

(: ->string ((U Symbol Number String) -> String))
(define (->string s)
  (cond [(symbol? s) (symbol->string s)]
        [(number? s) (number->string s)]
        [else s]))
```

env: s:String

and

```
#lang        scheme
; g : Any (U String Number) -> Number
(define (g x y)
  (cond [(and (number? x) (string? y))
         (+ x (string-length y))]
        [(number? x) (+ x y)]
        [else y]))
```

and

```
#lang typed-scheme
(: g (Any (U Number String) -> Number))
(define (g x y)
  (cond [(and (number? x) (string? y))
         (+ x (string-length y))]
        [(number? x) (+ x y)]
        [else y]))
```

Logical Reasoning

and

filter: $\mathtt{Number}_x \mid \overline{\mathtt{Number}}_x$

```
#lang typed-scheme
(: g (                                   mber))
(define (g x y))
  (cond [(and (number? x) (string? y))
         (+ x (string-length y))]
        [(number? x) (+ x y)]
        [else y]))
```

Logical Reasoning

and

```
#lang typed-scheme
(: g (Any (U Numbe
(define (g x y)
  (cond [(and (number? x) (string? y))
         (+ x (string-length y))]
        [(number? x) (+ x y)]
        [else y]))
```

filter: $\text{String}_y \mid \overline{\text{String}_y}$

and

```
#lang typed-scheme
(
(define (g x y))
  (cond [(and (number? x) (string? y))
         (+ x (string-length y))]
        [(number? x) (+ x y)]
        [else y]))
```

filter: $\texttt{Number}_{x}$ $\texttt{String}_{y}$ |

and

```
#lang typed-scheme
(
(define (g x y)
  (cond [(and (number? x) (string? y))
         (+ x (string-length y))]
        [(number? x) (+ x y)]
        [else y]))
```

filter: Number_x String_y | $\mathrm{Number}_x \supset \overline{\mathrm{String}_y}$

Logical Reasoning

and

```
#lang typed-scheme
(: g (Any (U Number String) -> Number))
(define (g x y)
  (cond [(and (number? x) (string? y))
          (+ x (string-length y))]
         [(number? x) (+ x y)]
         [else y]))
```

env: $\mathtt{Number}_x \supset \overline{\mathtt{String}_y}$

filter: $\mathtt{Number}_x$

Logical Reasoning

```
#lang typed-scheme
(: g (Any (U Number String) -> Number))
(define (g x y)
  (cond [(and (number? x) (string? y))
         (+ x (string-length y))]
        [(number? x) (+ x y)]
        [else y]))
```

and

env: $\mathtt{Number}_x \supset \overline{\mathtt{String}_y}$

filter: $\mathtt{Number}_x\ \overline{\mathtt{String}_y}$

Logical Reasoning

and

```
#lang typed-scheme
(: g (Any (U Number String) -> Number))
(define (g x y)
  (cond [(and (number? x) (string? y))
         (+ x (string-length y))]
        [(number? x) (+ x y)]
        [else y]))
```

env: x:Any y:(U Number String) + $\mathtt{Number}_x$ $\overline{\mathtt{String}_y}$

Logical Reasoning

and

```
#lang typed-scheme
(: g (Any (U Number String) -> Number))
(define (g x y)
  (cond [(and (number? x) (string? y))
         (+ x (string-length y))]
        [(number? x) (+ x y)]
        [else y]))
```

```
env: x:Number y:Number
```

All Together Now

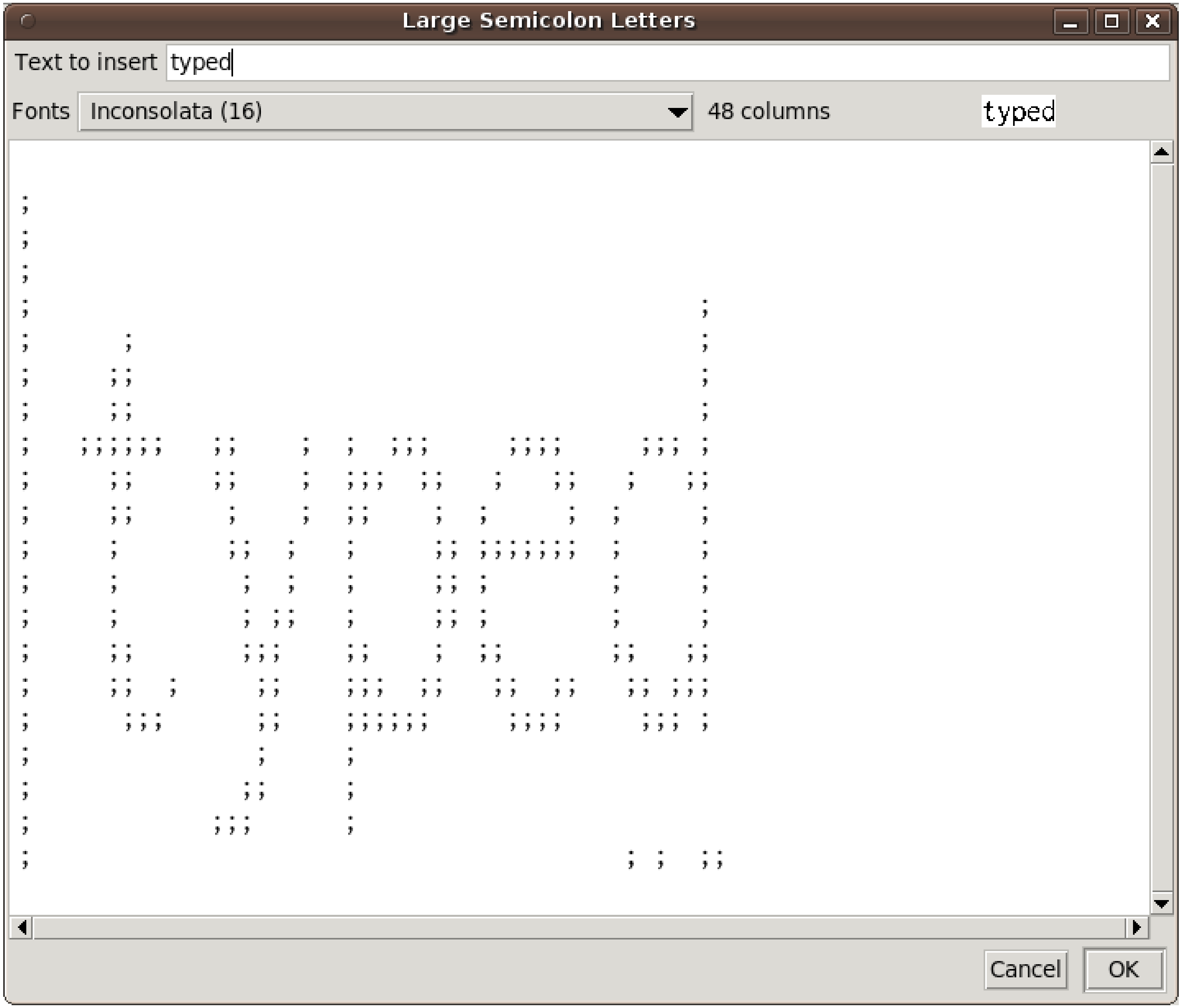
```
#lang typed-scheme

(: f ((U Number String) (Pair Any Any) -> Number))
(define (f input extra)
  (cond
    [(and (number? input) (number? (car extra)))
     (+ input (car extra))]
    [(number? (car extra))
     (+ (string-length input) (car extra))]
    [else 0]))
```

Easy Integration

Implementation Validation

Implementation



```
#lang typed-scheme                                          tslide

(: subtitle-pict : (String -> Pict))
(define (subtitle-pict s)
  (text s (current-title-font) large-text-size))
```

Validation

	Squad	Metrics	Acct	Spam	System	Rand	Total
Lines	**2369**	**511**	**407**	**315**	**1290**	**618**	**5510**
Increase	**7%**	**25%**	**7%**	**6%**	**1%**	**3%**	**7%**
Fixes (Good)	**5**	**3**	**4**	**5**	**8**	**0**	**25**
Problems (Bad)	**7**	**4**	**3**	**1**	**0**	**1**	**16**

Sample Fixes

```
#lang        scheme        assert

(+ 10 (string->number str))
```

```
#lang typed-scheme                          assert

(+ 10 (assert (string->number str)))
```

Sample Fixes

```
#lang        scheme                    div

(define (divs . args)
  (* -1 (apply / args)))
```

Sample Fixes

```
#lang typed-scheme                                  div

(define (divs arg . args)
  (* -1 (apply / arg args)))
```

cond

```
#lang         scheme

(cond [(< x 0) 'negative]
      [(= x 0) 'zero]
      [(> x 0) 'positive])
```

```
#lang typed-scheme                                              cond

(cond [(< x 0) 'negative]
      [(= x 0) 'zero]
      [else    'positive])
```

mutate

```
#lang        scheme

(define pr (make-pair x y))
(when (string? (pair-left pr))
  (set-pair-left! pr (string->symbol (pair-left pr))))
```

Sample Problems

```
#lang typed-scheme                                              mutate

(define pr (make-pair
             (if (string? x) (string->number x) x)
             y))
```

Related Work

Interlanguage Integration

ProfessorJ

- Gray et al. (2005)

Multilanguage Systems

- Matthews and Findler (2007)

Types for Untyped Languages

John Reynolds (1968)

> "Some account should be taken of the premises
>
> in conditional expressions."

Soft Typing

Types for Scheme

Strongtalk

Types for Untyped Languages

John Reynolds (1968)

Soft Typing

- Fagan (1991), Aiken (1994)
- Wright (1997), Flanagan (1999)

Types for Scheme

Strongtalk

Types for Untyped Languages

John Reynolds (1968)

Soft Typing

Types for Scheme

- SPS (Wand 1984), Leavens (2005)
- Infer (Haynes 1995)

Strongtalk

Types for Untyped Languages

John Reynolds (1968)

Soft Typing

Types for Scheme

Strongtalk

- Bracha and Griswold (1993)

Contracts

Findler & Fellesien (2002)

Modules with Macros

Flatt (2002)

Recent Work

Gradual Typing

- Siek et al (2006-2009), Wadler & Findler (2007), Herman et al (2007)

DRuby

- Furr et al (2009)

Conclusion

Thesis

Module-by-module porting of code from an untyped language to a typed sister language allows for an easy transition from untyped scripts to typed programs.

Support

Sound Typed-Untyped Interoperation

Type System for Scheme

Full-scale Implementation

Empirical Validation

Try Typed Scheme

Installer and Documentation

http://www.plt-scheme.org

Thanks to Olin Shivers

Try Typed Scheme

Installer and Documentation
http://www.plt-scheme.org

Thanks to Aaron Turon

Try Typed Scheme

Installer and Documentation
http://www.plt-scheme.org

Thanks to Felix Klock

Try Typed Scheme

Installer and Documentation

http://www.plt-scheme.org

Thanks to James Hamblin

Try Typed Scheme

Installer and Documentation

http://www.plt-scheme.org

Thanks to James Jungbauer

Try Typed Scheme

Installer and Documentation
http://www.plt-scheme.org

Thanks to Dan Brown

Try Typed Scheme

Installer and Documentation

http://www.plt-scheme.org

Thanks to Lazlo Babai

Try Typed Scheme

Installer and Documentation
http://www.plt-scheme.org

Thanks to Matthew Flatt

Try Typed Scheme

Installer and Documentation

http://www.plt-scheme.org

Thanks to Stevie Strickland

Try Typed Scheme

Installer and Documentation
http://www.plt-scheme.org

Thanks to Guy Steele

Try Typed Scheme

Installer and Documentation
http://www.plt-scheme.org

Thanks to Robby Findler

Try Typed Scheme

Installer and Documentation

http://www.plt-scheme.org

Thanks to Sukyoung Ryu

Try Typed Scheme

Installer and Documentation

http://www.plt-scheme.org

Thanks to Carl Eastlund

Try Typed Scheme

Installer and Documentation

http://www.plt-scheme.org

Thanks to Eric Allen

Try Typed Scheme

Installer and Documentation
http://www.plt-scheme.org

Thanks to Ivan Gazeau

Try Typed Scheme

Installer and Documentation

http://www.plt-scheme.org

Thanks to Katie Edmonds

Try Typed Scheme

Installer and Documentation

http://www.plt-scheme.org

Thanks to Mitch Wand

Try Typed Scheme

Installer and Documentation

http://www.plt-scheme.org

Thanks to Dave Herman

Try Typed Scheme

Installer and Documentation

http://www.plt-scheme.org

Thanks to Jan-Willem Maessen

Try Typed Scheme

Installer and Documentation

http://www.plt-scheme.org

Thanks to Matthias Felleisen

Try Typed Scheme

Installer and Documentation
http://www.plt-scheme.org

Thanks to Ryan Culpepper

Try Typed Scheme

Installer and Documentation
http://www.plt-scheme.org

Thanks to Vincent St-Amour

Try Typed Scheme

Installer and Documentation

http://www.plt-scheme.org

Thanks to Jesse Tov

Try Typed Scheme

Installer and Documentation
http://www.plt-scheme.org

Thanks to Christine Flood

Try Typed Scheme

Installer and Documentation
http://www.plt-scheme.org

Thanks to Steve Hochstadt

Try Typed Scheme

Installer and Documentation
http://www.plt-scheme.org

Thanks to David Chase

Try Typed Scheme

Installer and Documentation

http://www.plt-scheme.org

Thanks to Elizabeth Tobin

Try Typed Scheme

Installer and Documentation
http://www.plt-scheme.org

Thanks to Victor Luchangco

Try Typed Scheme

Installer and Documentation

http://www.plt-scheme.org

Thanks to Ryan Culpepper

Proposal

Occurence Typing

- Done, and more

Variable-arity Polymorphism

- Done

Keyword and Optional Arguments

- Done: Use & Import/Export
- Not Done: Definition

Validation

- Some Done