Computational Contracts

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Contracts

Agreement

Exchanged Values

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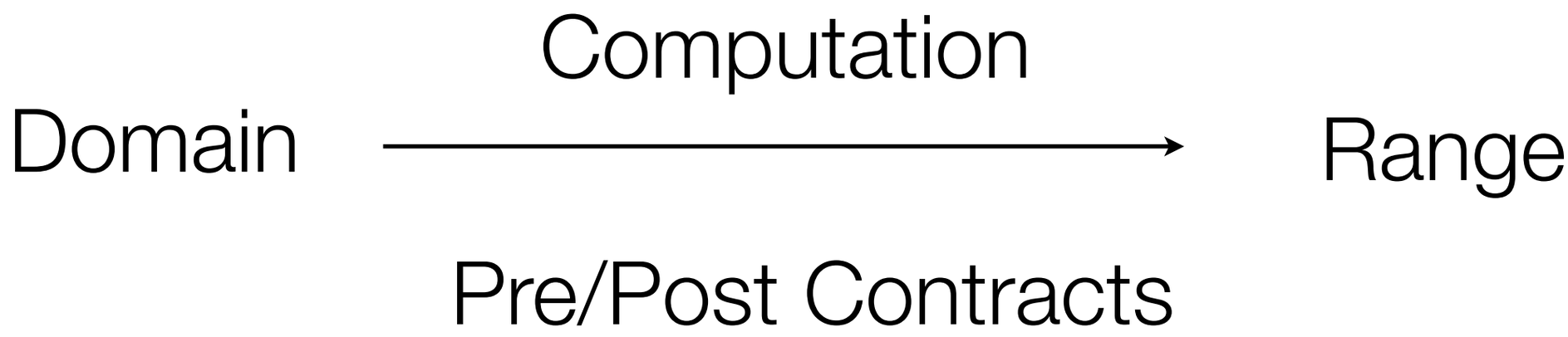
Overview



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Overview

Domain → Range

Computation

Pre/Post Contracts

3

Overview

Domain → Computation → Range

Computational Contracts

A computational contracts ***verifies a (sequence of) events*** during the execution of a contracted entity.

3

Contracts in Racket

4

Pre/Post Contracts

provider.rkt

```
(define (sqrt x)
  ...)
(provide/contract
  [sqrt (-> positive? positive?)])
```

```
Welcome to DrRacket, version 5.1.3 [3m].
Language: scheme [custom]; memory limit: 128 MB.
> (sqrt -2)
lascheme-api.rkt:219:34: Sqrt: contract violation, expected <positive?>, given: -2
  contract from
    /Users/cfscholl/Desktop/Research/DCC-SVN/LAScheme/provider.rkt
  blaming
    /Users/cfscholl/Desktop/Research/DCC-SVN/LAScheme/user.rkt
  contract: (-> positive? positive?)
       at: /Users/cfscholl/Desktop/Research/DCC-SVN/LAScheme/provider.rkt:174.2
```

5

Pre/Post Contracts

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contract: (-> positive? positive?)
      at: /Users/cfscholl/Desktop/Research/DCC-SVN/LAScheme/provider.rkt:174.2
```


5

Higher-Order Contracts

provider.rkt

```
(define (map-pos f l)
  (map f l))

(provide/contract
 [map-pos (->
           (-> positive? positive?)
           (listof positive?)
           (listof positive?))])
```


6

Higher-Order Contracts

provider.rkt

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(define (map-pos f l)
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6

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provider.rkt

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 [map-pos (->
           (-> positive? positive?)
           (listof positive?)
           (listof positive?))])
```


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Higher-Order Contracts

provider.rkt

```
(define (map-pos f l)
  (map f l))

(provide/contract
 [map-pos (->
           (-> positive? positive?)
           (listof positive?)
           (listof positive?))])
```

user.rkt

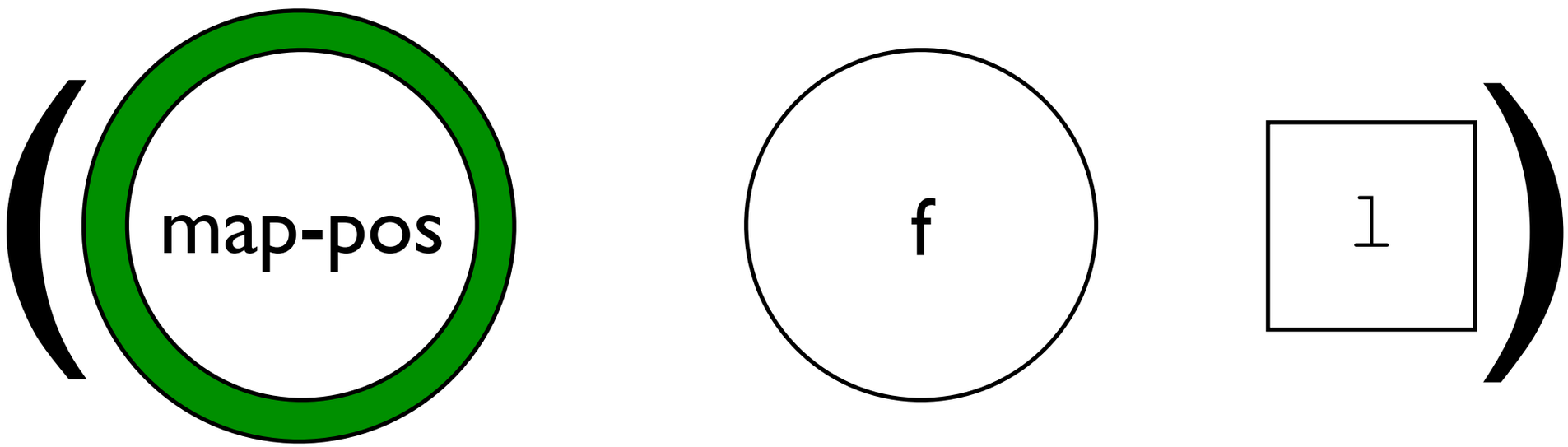
```
(map-pos integer? '(1 2 3))
```

Higher-Order Contracts

provider.rkt

```
contract violation: expected <integer?>, given: #t
  contract on map-pos from
    (file .../provider.rkt)
  blaming
    (file .../user.rkt)
  contract:
    (->
     (-> positive? positive?)
     (listof positive?)
     (listof positive?))
```

Principle of HOCs



There is no simple predicate that can verify the contract defined over f.

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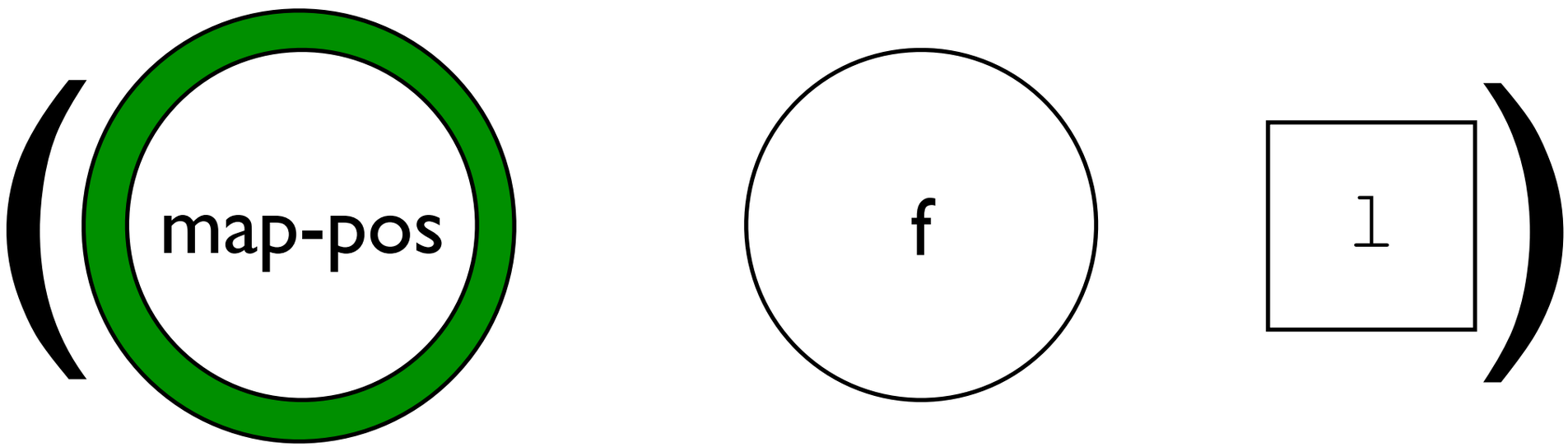
Principle of HOCs



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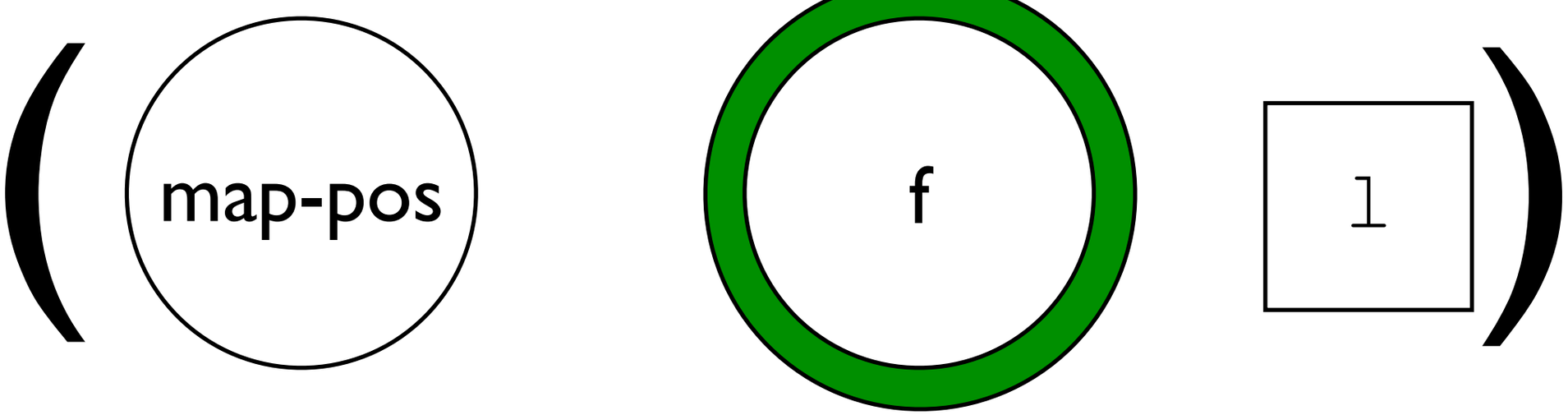

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Computational Contracts

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Computational Contracts

Safety

Prohibit contract

Liveness

Promise contract

9

Computational Contracts

Safety

Prohibit contract

Liveness

Promise contract

9

Prohibit Contract

Computational Contracts over a single event

provider.rkt

```
 (define (map-silent f l)
   (map f l))

(provide/contract
 [map-silent (->
              (prohibit/c  (call display))
              (listof any?)
              (listof any?))])
```

10

Prohibit Contract

Computational Contracts over a single event

provider.rkt

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(provide/contract
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Computational Contracts over a single event

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Prohibit Contract

Computational Contracts over a single event

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   (map f l))

(provide/contract
 [map-silent (->
              (prohibit/c  (call display))
              (listof any?)
              (listof any?))])
```

user.rkt

```
(define (inc x) (display x) (+ x 1))
(map-silent inc  '(1 2 3 4))
```

Prohibit Contract

Computational Contracts over a single event

provider.rkt

```
(define (map-silent f l)
  (map f l))
```

(file user.rkt)
broke the contract
(->
prohibit-call-display
(listof any?)
(listof any?))
on map-silent; computational contract violation ...

```
(map-silent inc '(1 2 3 4))
```

Promise Contract

Computational Contracts over a single event

provider.rkt

```
(define (set-x! x) ...)
(provide/contract
 [set-x!
  (and/c (promise/c (call notify))
         (-> integer? any?))])
```

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Promise Contract

Computational Contracts over a single event

provider.rkt

```
(define (set-x! x) ...)
(provide/contract
 [set-x!
  (and/c (promise/c (call notify))
         (-> integer? any?))])
```

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Promise Contract

Computational Contracts over a single event

(file .../provider.rkt)
broke the contract
 (and/c
  promise-call-notify
  (-> integer? any?))
on set-x!;
computational contract violation ....

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Computational Contracts

Sequence of Events

Prohibit Contract

Promise Contract

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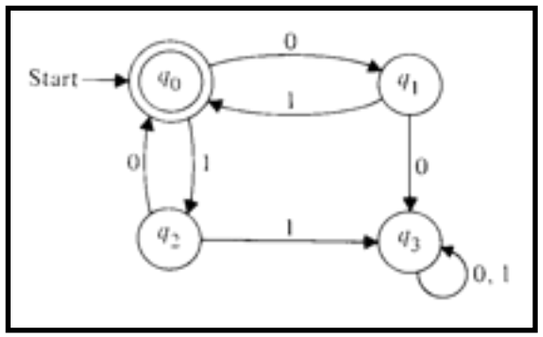
Computational Contracts

Sequence of Events



Prohibit Contract

Promise Contract

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Sequence of Events

Computational Contracts

Promise:

A file that is opened will eventually be closed

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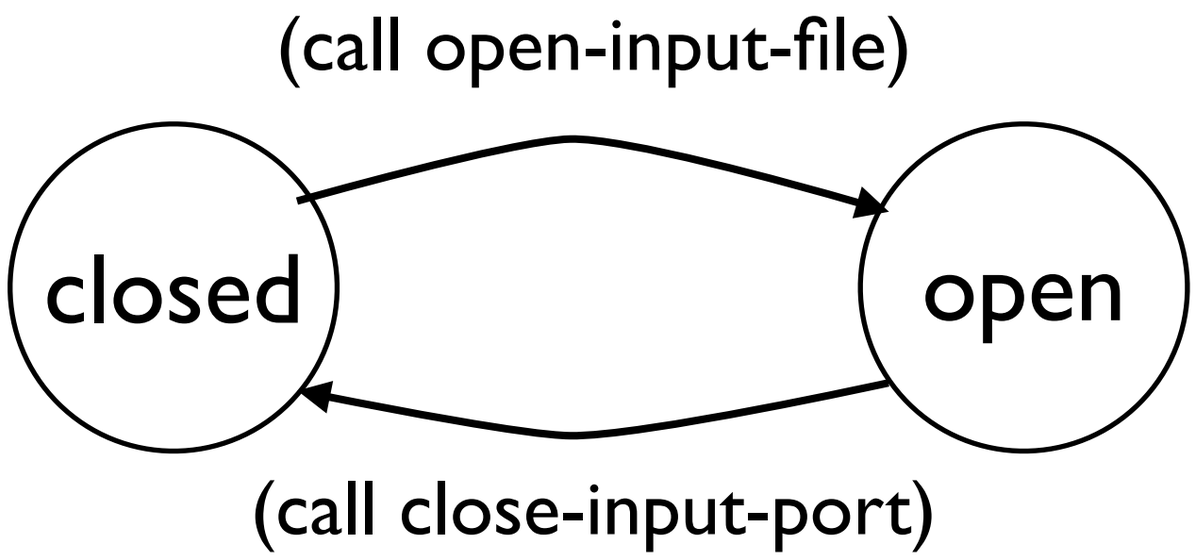
Sequence of Events

Computational Contracts

Promise:

A file that is opened will eventually be closed

file-protocol



13

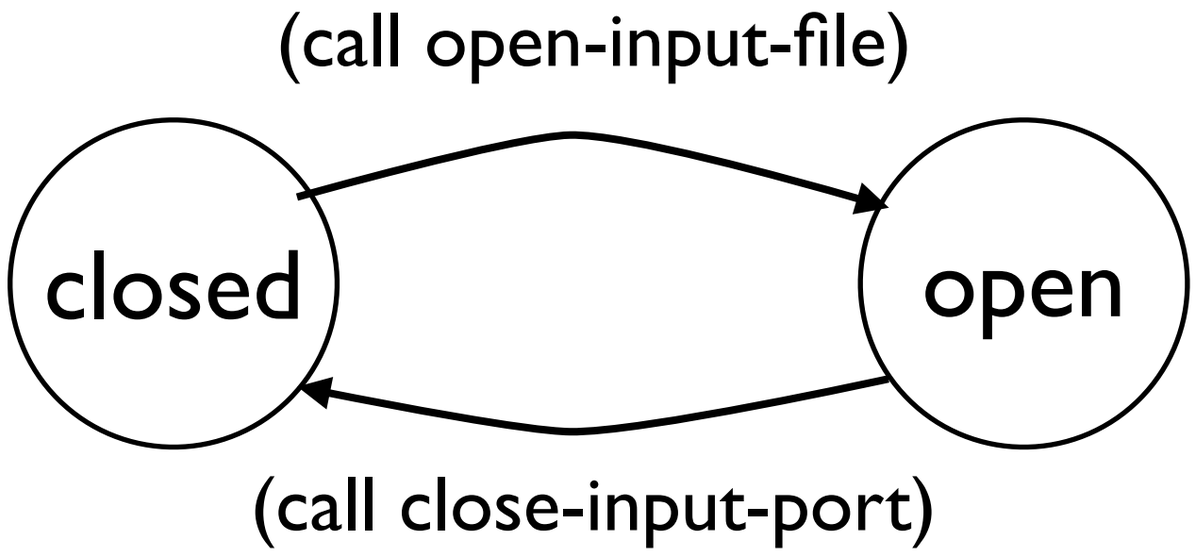
Sequence of Events

Computational Contracts

Promise:

A file that is opened will eventually be closed

file-protocol



end state SHOULD be reached

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Sequence of Events

Computational Contracts

provider.rkt

```
(define (get-content reader)
  (reader "myfile.rkt"))
(provide/contract
 [get-content
  (promise/c file-protocol) -> string?])
```


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Sequence of Events

Computational Contracts

provider.rkt

```
(define (get-content reader)
  (reader "myfile.rkt"))
(provide/contract
 [get-content
  (promise/c file-protocol) -> string?])
```

user.rkt

```
(get-content bad-reader)
```


14

Sequence of Events

Computational Contracts

provider.rkt

```
(define (get-content reader)
```

(file .../user.rkt)
broke the contract
 (-> promise-protocol/c string?)
on get-content; promise-protocol/c
violated, not in end state, last transition
after 'open-input-file

14

Sequence of Events

Computational Contracts

provider.rkt

```
(define file-protocol
  (protocol end
            [end : ((call open-input-file)
                                  -> open)]
            [open : ((call close-input-port)
                                  -> end)]))
```

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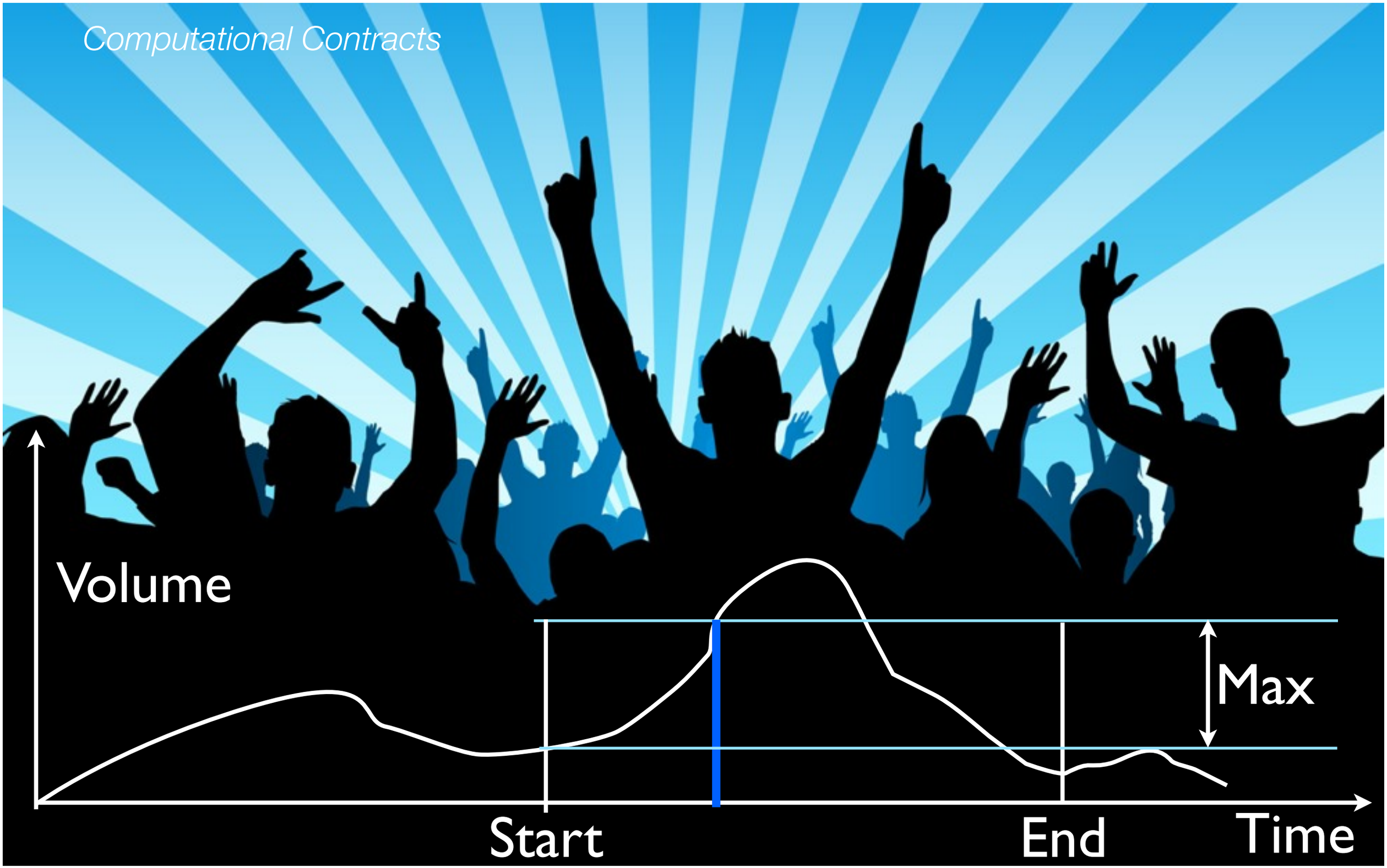
Stateful Monitors

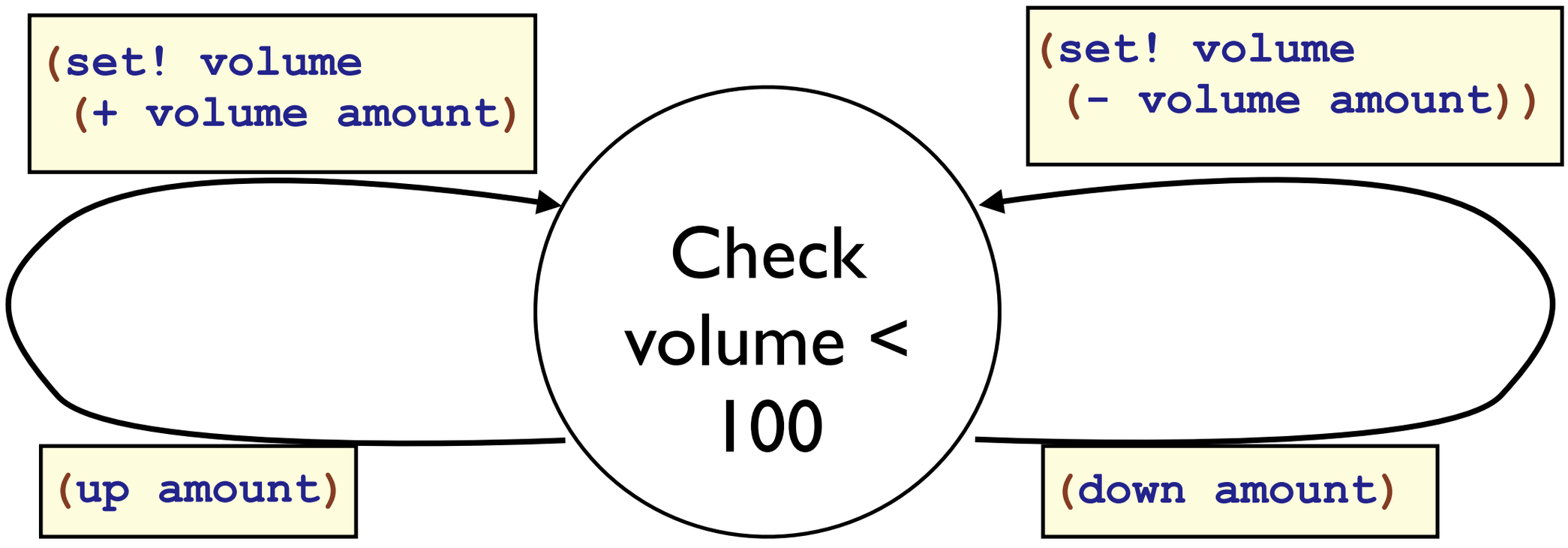
Computational Contracts



Stateful Monitors

Computational Contracts

sound-monitor



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Stateful Monitors

Computational Contracts

provider.rkt

```
(define (sound-monitor max-volume)
  (monitor
   [(volume 0)]
   [(< volume max-volume)]
   [((up amount)   ->  (set! volume (+ volume amount)))
    ((down amount) ->  (set! volume (- volume amount)))]))
(provide/contract
 [speak
  (and/c (promise/c (sound-monitor 100))
         (-> string? any?))])
```

Stateful Monitors

Computational Contracts

provider.rkt

(file .../provider.rkt)
broke the contract
promise-monitor/c
on speak;
monitor computational contract violation
#<procedure:...user.rkt:138:53>

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Implementation

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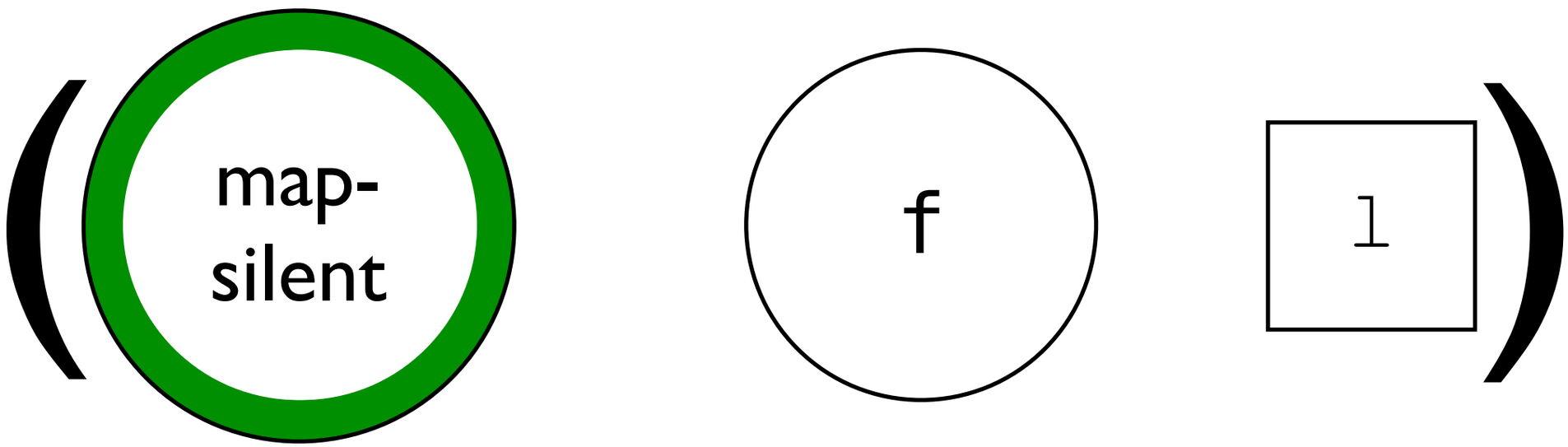
Computational Contracts



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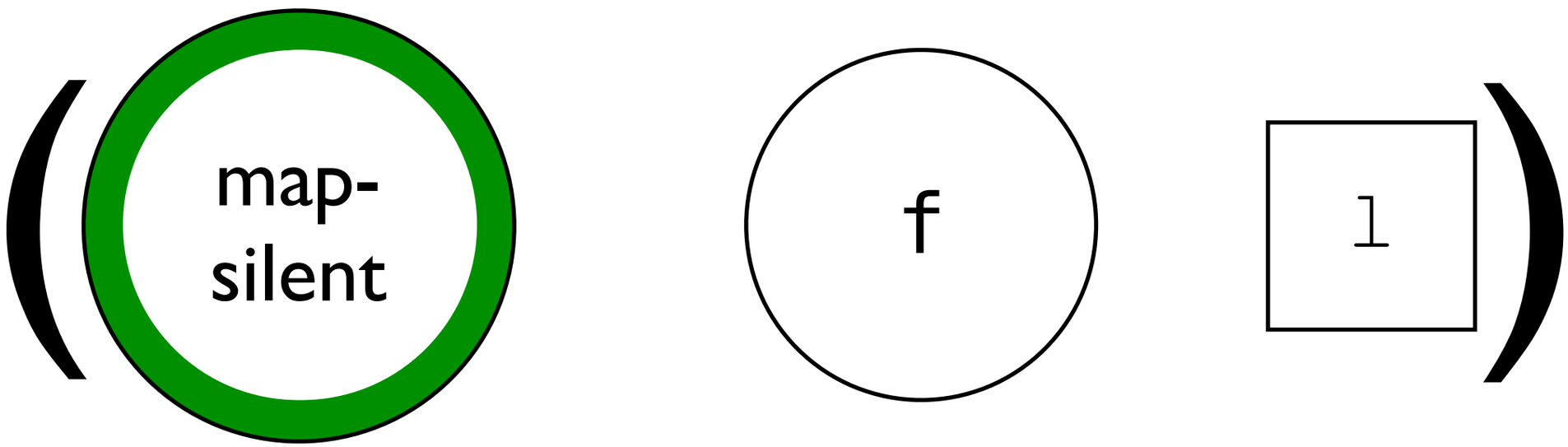
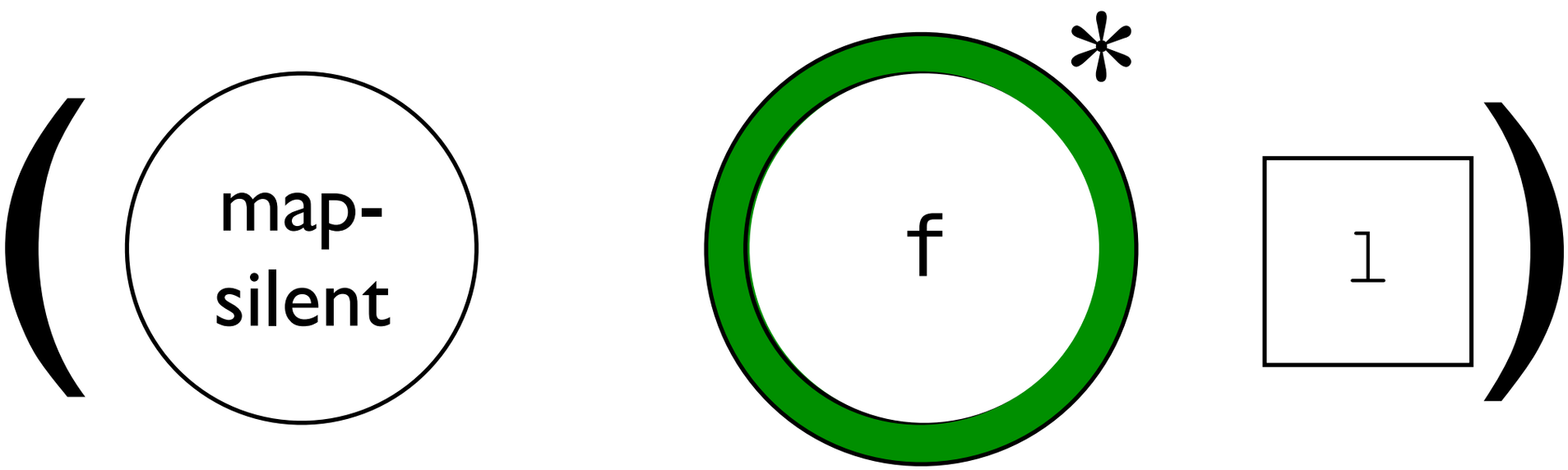
Computational Contracts





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Contract Representation

```
(provide/contract
 [map-silent (->
              (prohibit/c  (call display))
              (listof any?)
              (listof any?))])
```


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Contract Representation

```
(provide/contract
 [map-silent (->
              (prohibit/c  (call display))
              (listof any?)
              (listof any?))])
```

pos? —*!display*→ pos? x list-int? → list-int?

map-silent

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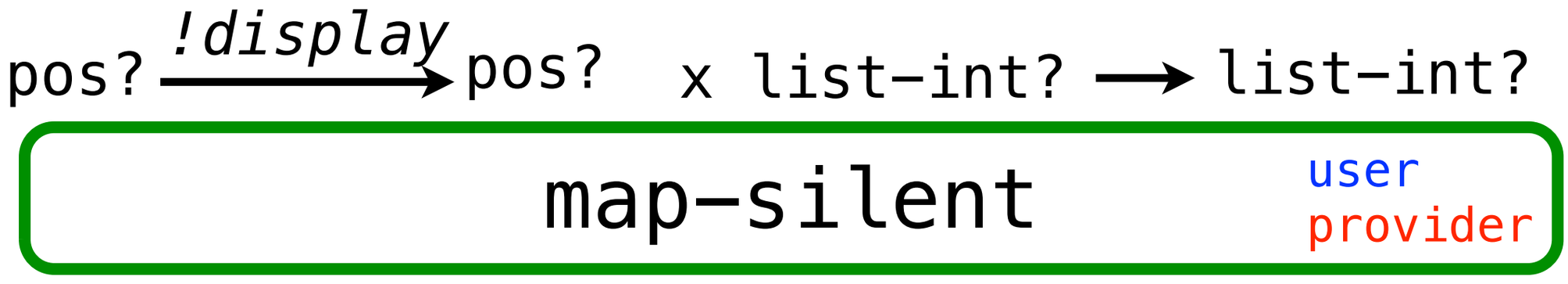
Contract Representation

```
(provide/contract
 [map-silent (->
              (prohibit/c  (call display))
              (listof any?)
              (listof any?))])
```



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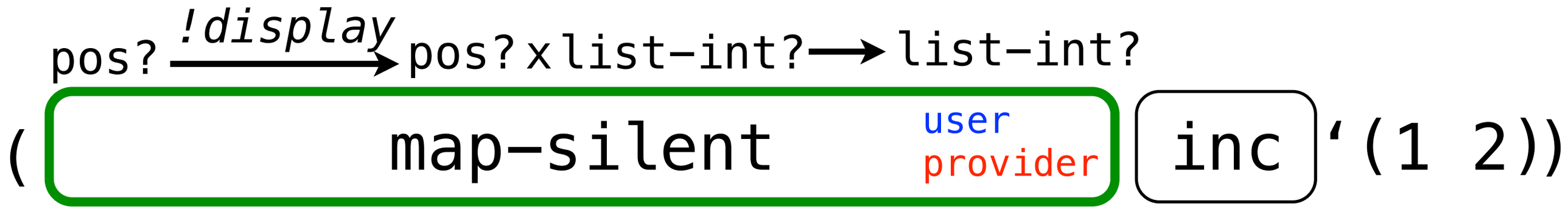
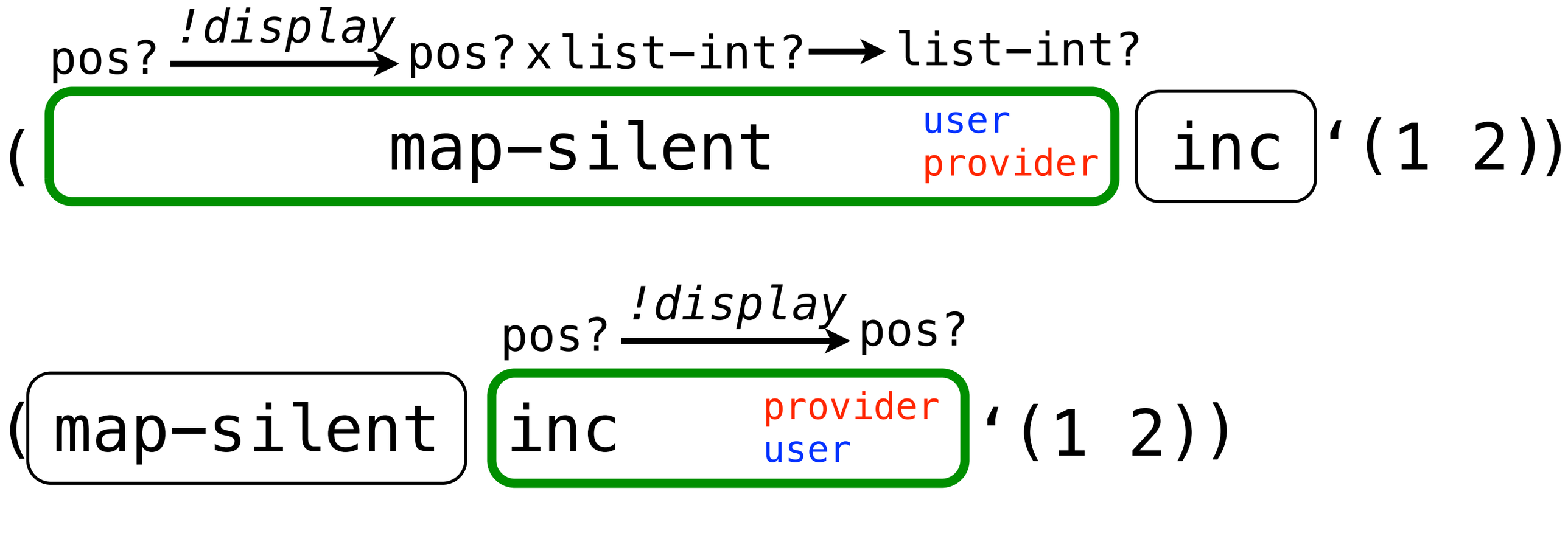

pos?
!display
pos? x list-int?
list-int?
(
map-silent
user
provider
inc
'(1 2))


pos?
!display
pos? x list-int?
list-int?
(
map-silent
user
provider
inc
'(1 2))
pos?
!display
pos?
(
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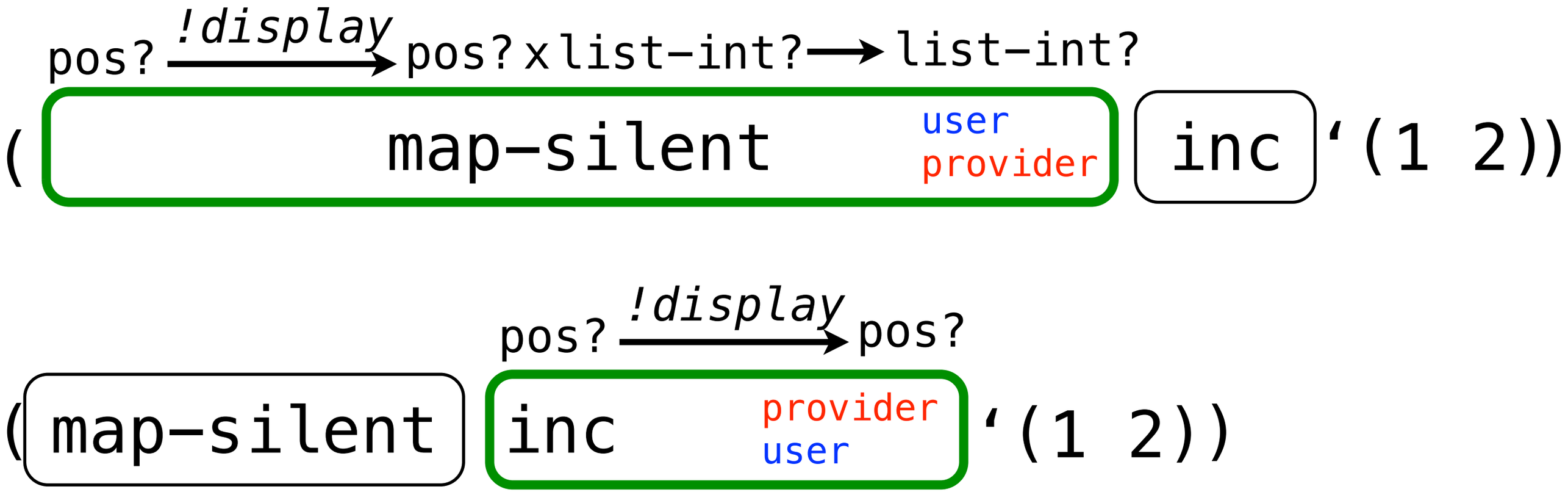
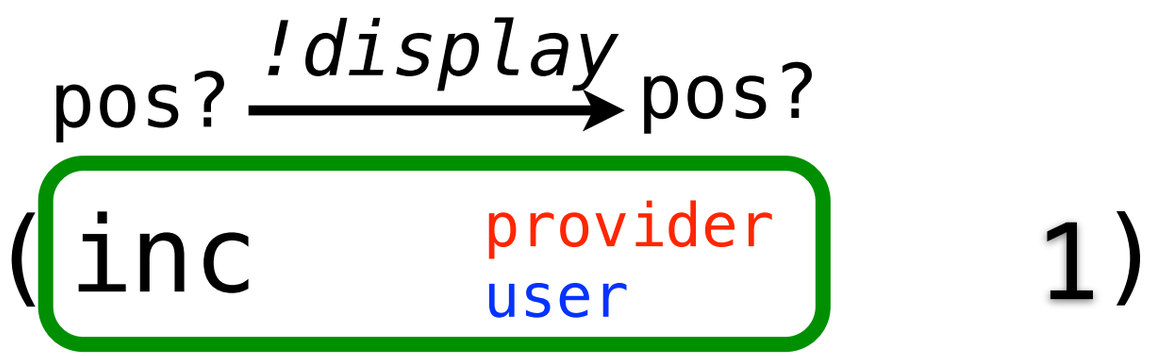

pos?
!display
pos? x list-int? → list-int?
(
map-silent
user
provider
inc
'(1 2))
pos?
!display
pos?
(
map-silent
inc
provider
user
'(1 2))


pos?
!display
pos?
(
inc
provider
user
1)

pos? —!display→ pos? x list-int? → list-int?

(map-silent user provider inc '(1 2))

pos? —!display→ pos?

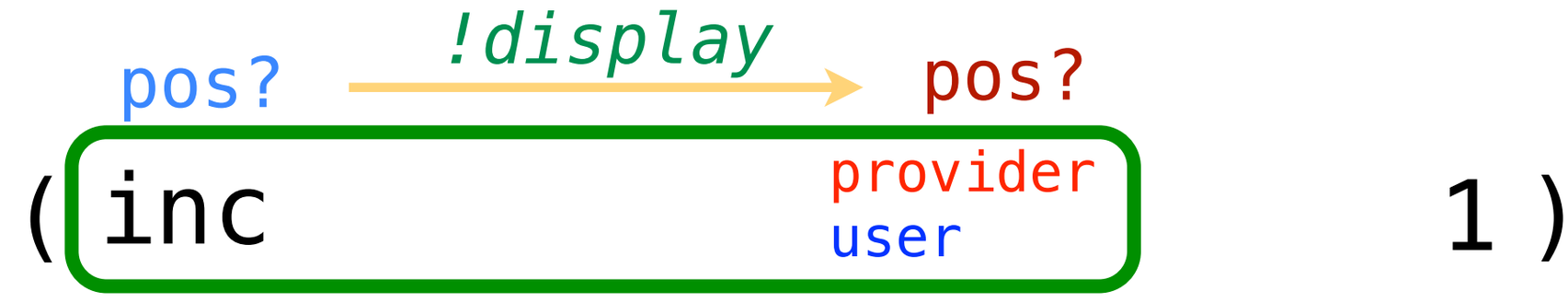
(map-silent inc provider user '(1 2))

pos? —!display→ pos?

(inc provider user 1)

(inc 1)!display user

Implementation Overview



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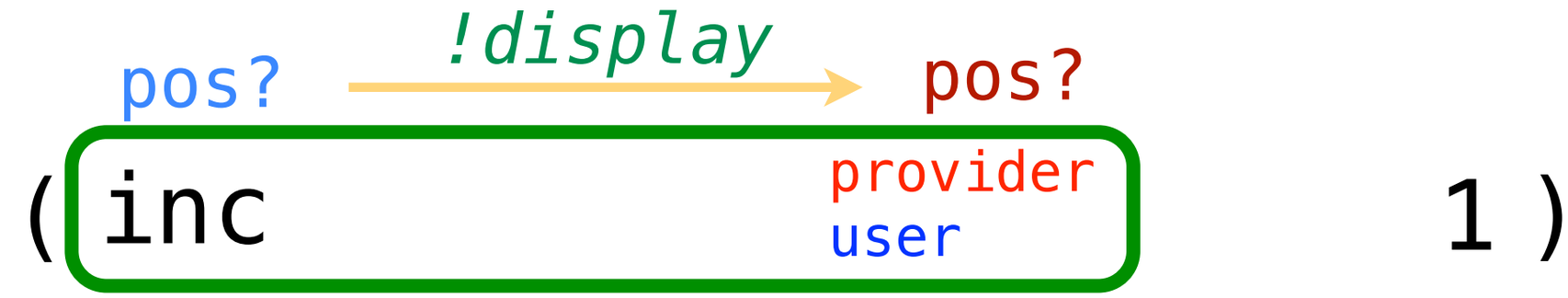
Implementation Overview



Domain

```
(if(pre? arg)
  (computation)
  (blame `provider)))
```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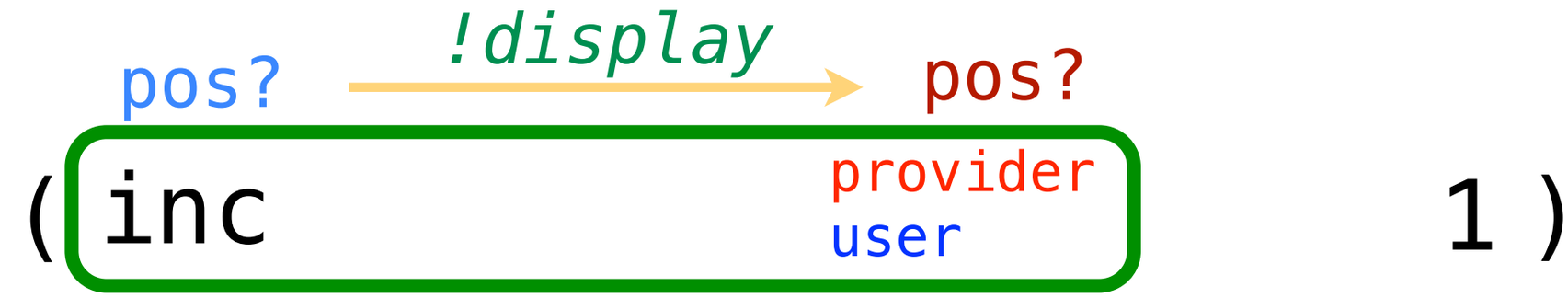
Implementation Overview



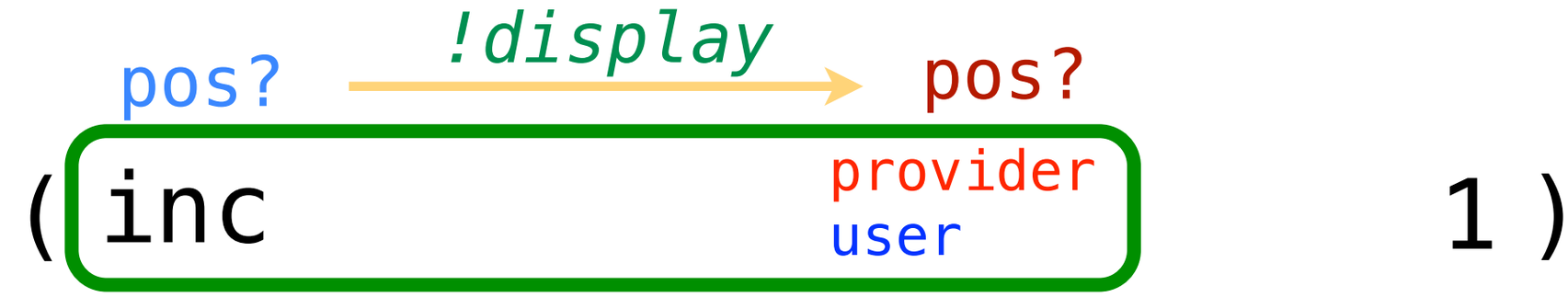
Domain

```
(if(pre? arg)
  (computation)
  (blame `provider)))
```

Range

```
  (if(post? result))
     result
    (blame `user))
```

Implementation Overview



Domain Predicate

```
(if(pre? arg)
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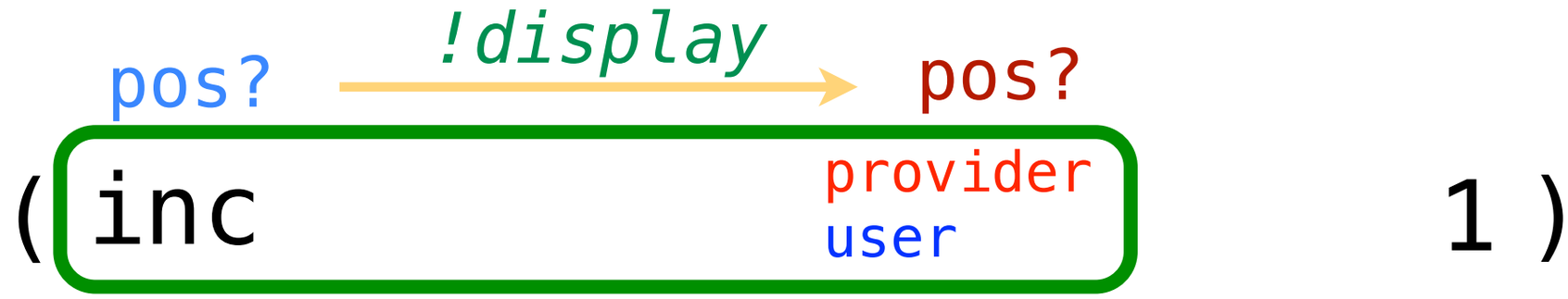
```

Range Predicate

```
  (if(post? result))
     result
    (blame `user))
```

Implementation Overview



Domain Predicate

```
(if(pre? arg)
  (computation)
  (blame `provider)))
```

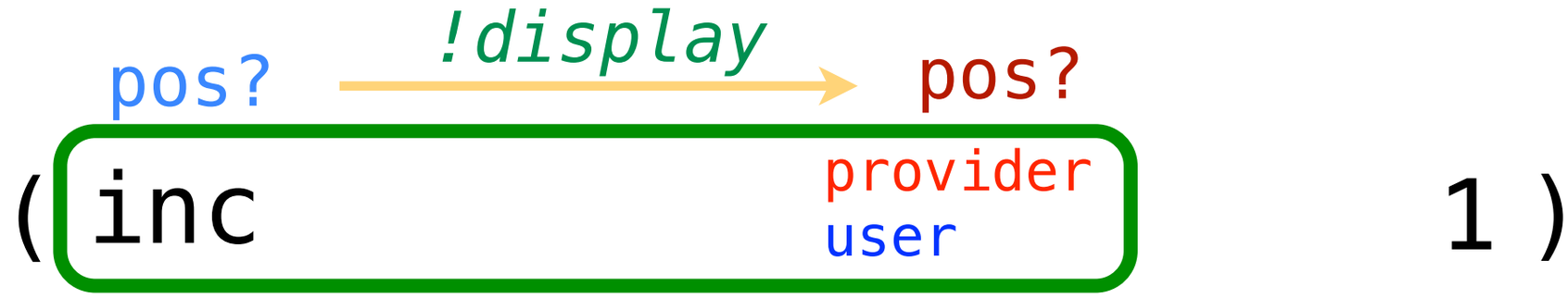
Computation

```
(deploy-fluid
  (call display)
  (blame-adv `user)
 (inc arg))
```

Range Predicate

```
  (if(post? result))
     result
    (blame `user))
```

Implementation Overview



Domain Predicate

```
(if(pre? arg)
  (computation)
  (blame `provider)))
```

Computation Dynamic aspect

```
(deploy-fluid
  (call display)
  (blame-adv `user)
 (inc arg))
```

Range Predicate

```
(if(post? result))
    result
  (blame `user))
```

Status

- Implemented in Racket
- using LAScheme
- integrated with Racket's contract system

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Status

- Implemented in Racket
- using LAScheme
- integrated with Racket's contract system

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Applications

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Applications

- Existing computational contracts in disguise
  - QoS contracts, access permission contracts, ...

25

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- Existing computational contracts in disguise
  - QoS contracts, access permission contracts, ...
- Side-effect free contract for futures (Racket)

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Applications

- Existing computational contracts in disguise
  - QoS contracts, access permission contracts, ...
- Side-effect free contract for futures (Racket)
- Protocols
  - different kinds of protocols [Beckman+11]: initialization, deactivation, redundant operation, ...
  - looking into Racket's libraries

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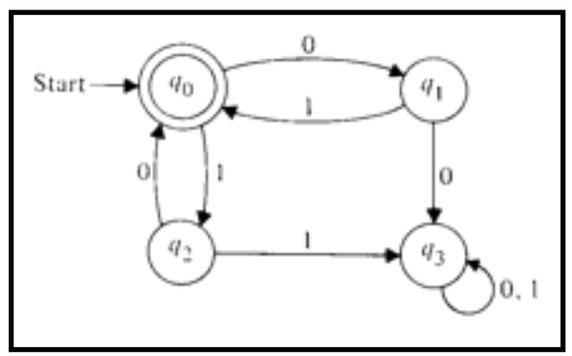
Computational Contracts

Domain ⟶ Range

Computational Contracts



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Temporal Higher-Order Contracts

```
(define (free x) 2)
(define (malloc) (free 2) 2)
(provide/contract
 [malloc (monitor/c memmon 'malloc (-> number?))]
 [free   (monitor/c memmon 'free (-> number? void))])
```

```
(define allocated (make-weak-hasheq))
(define memmon
  (match-lambda
    [(monitor:return 'malloc _ _ _ _ _ _ (list addr))
     (begin
       (display "Malloc called \n")
       (hash-set! allocated addr #t))
     #t]
    [(monitor:call 'free _ _ _ _ _ (list addr))
     (begin (display "calling free")
            (hash-has-key? allocated addr))]
    [(monitor:return 'free _ _ _ _ _ (list addr) _)
     (hash-remove! allocated addr)
     #t]
    [_
     #t]))
```

Tim Disney, Cormac Flanagan, and Jay McCarthy.

“Temporal Higher-Order Contracts".

International Conference on Functional Programming, 2011.

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Temporal Higher-Order Contracts

```
(define (free x) 2)
(define (malloc) (free 2) 2)
(provide/contract
 [malloc (monitor/c memmon 'malloc (-> number?))]
 [free   (monitor/c memmon 'free (-> number? void))])
```

```
(define allocated (make-weak-hasheq))
(define memmon
  (match-lambda
    [(monitor:return 'malloc _ _ _ _ _ _ (list addr))
     (begin
       (display "Malloc called \n")
       (hash-set! allocated addr #t))
     #t]
    [(monitor:call 'free _ _ _ _ _ (list addr))
     (begin (display "calling free")
            (hash-has-key? allocated addr))]
    [(monitor:return 'free _ _ _ _ _ (list addr) _)
     (hash-remove! allocated addr)
     #t]
    [_
     #t]))
```

Tim Disney, Cormac Flanagan, and Jay McCarthy.

“Temporal Higher-Order Contracts".

International Conference on Functional Programming, 2011.

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Temporal Higher-Order Contracts

```
(define (free x) 2)
(define (malloc) (free 2) 2)
(provide/contract
 [malloc (monitor/c memmon 'malloc (-> number?))]
 [free   (monitor/c memmon 'free (-> number? void))])
```

```
(define allocated (make-weak-hasheq))
(define memmon
  (match-lambda
    [(monitor:return 'malloc _ _ _ _ _ _ (list addr))
     (begin
       (display "Malloc called \n")
       (hash-set! allocated addr #t))
     #t]
    [(monitor:call 'free _ _ _ _ _ (list addr))
     (begin (display "calling free")
            (hash-has-key? allocated addr))]
    [(monitor:return 'free _ _ _ _ _ (list addr) _)
     (hash-remove! allocated addr)
     #t]
    [_
     #t]))
```

```
Welcome to DrRacket, version 5.1.3 [3m].
Language: racket [custom]; memory limit: 128 MB.
> (malloc)
Malloc called
2
>
```

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