# miniAdapton

## A Minimal Implementation of Incremental Computation in Scheme

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# Memoization

- Remember (i.e. "make a memo of") previous results
- Classic example: fibonacci

$$fib(0) = 1; fib(1) = 1; fib(n) = fib(n-1) + fib(n-2)$$

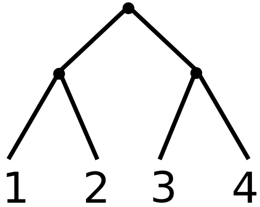
- Naively-implemented fibonacci is exponential
- Using only memoization, fibonacci can be made linear
- Memoization can yield algorithmic speedups
- Memoization forbids mutation

# A Memoized Function

```
(define-memo (max-tree t)
  (cond
    ((pair? t)
     (max (max-tree (car t))
          (max-tree (cdr t))))
    (else t)))
```

# A Memoized Function

```
>(max 1 2 3 4)
4
>(max-tree '((1 . 2) . (3 . 4))
4
```



# User Session with Memoization

```
> (define some-tree '((1 . 2) . (3 . 4)))
> (max 1 2 3 4)
4
> (max-tree some-tree)
4

> (set-cdr! some-tree 5)
> some-tree
((1 . 2) . 5)
> (max 1 2 5)
5
> (max-tree some-tree)
4
```

# What is incremental computation?

- Reuse previous results/computations (like memoization)
- ... specifically for changing inputs

# What is Adapton?

- a general, language-based approach to incremental computation
- “memoization supporting mutation”
- How: remember not just the result of a computation, but also keep track of dependencies between computations
- Specifically, Adapton creates a dependency graph called the DCG (or demanded computation graph).

# What is Adapton?

By analogy to thunks (zero-argument procedures) and promises (memoized thunks)

| Feature | Thunk | Promise | Adapton "Promise" |
|---|---|---|---|
| Stored | closure | + result | + dependencies |
| Avoids Recomputation | no | yes | when correct |
| Supports Mutation | yes | no | yes |

# Aside: Why Mutation?

We live in a temporal world full of mutation, some programs dealing with mutation:

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We live in a temporal world full of mutation, some programs dealing with mutation:

- Make
- Spreadsheets
- Databases
- Interpreters

# What is miniAdapton?

- a minimal version of Adapton
- try to be readable
- try to be portable
- try to be small

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- a minimal version of Adapton
- try to be readable
- try to be portable
- try to be small
- try to be used
- try to be abused

# Visualization of max-tree in Adapton

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(max-tree some-tree)

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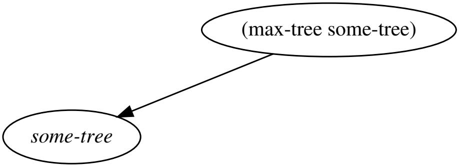

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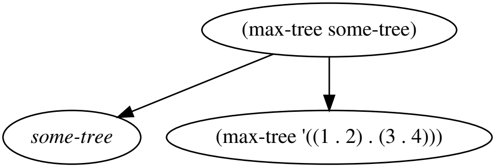

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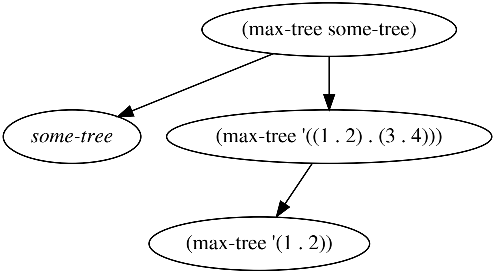

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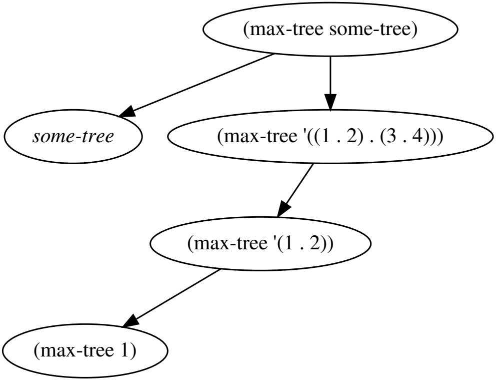

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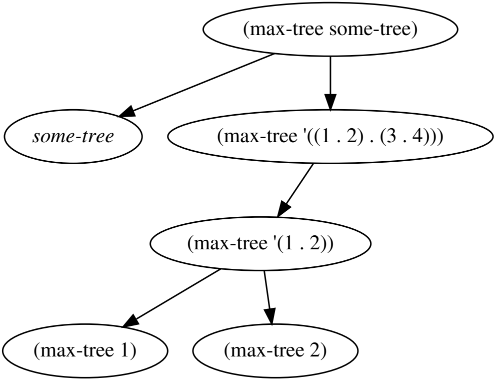

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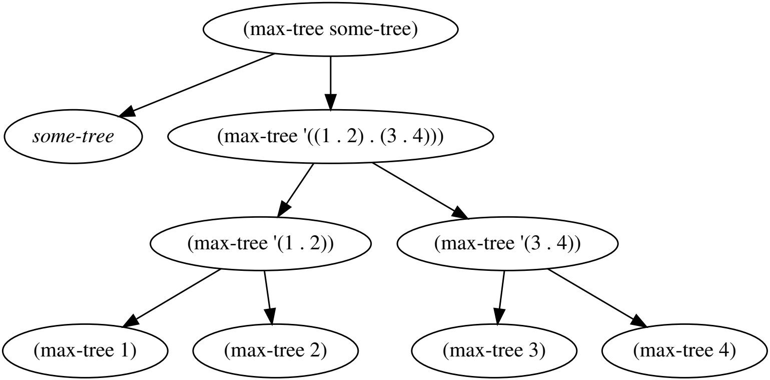

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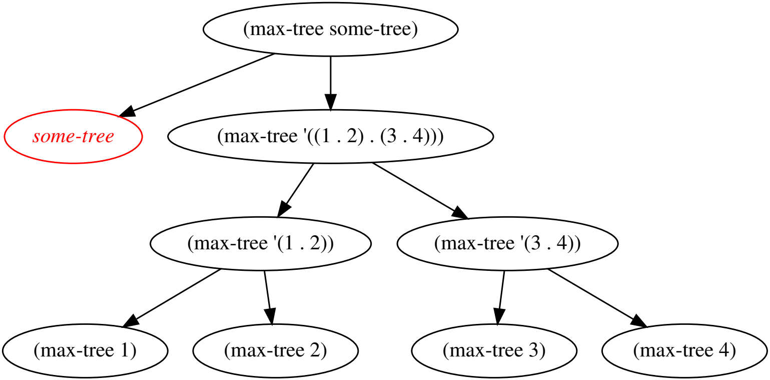

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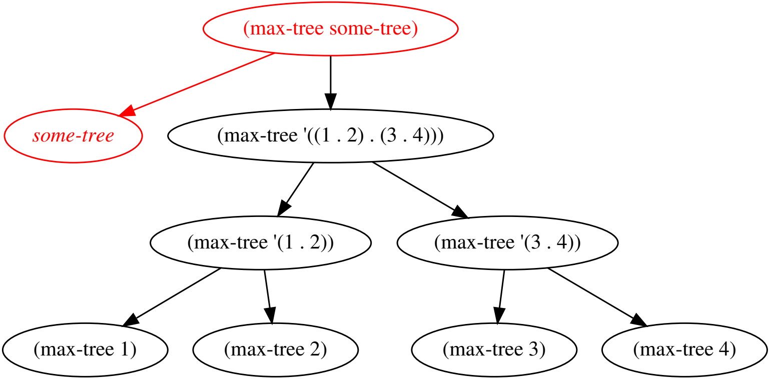

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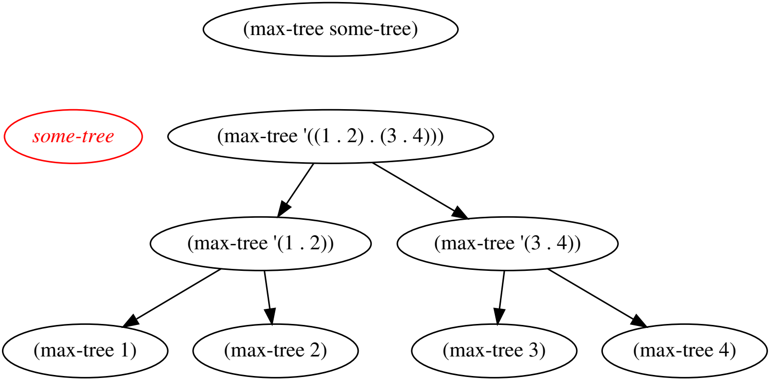
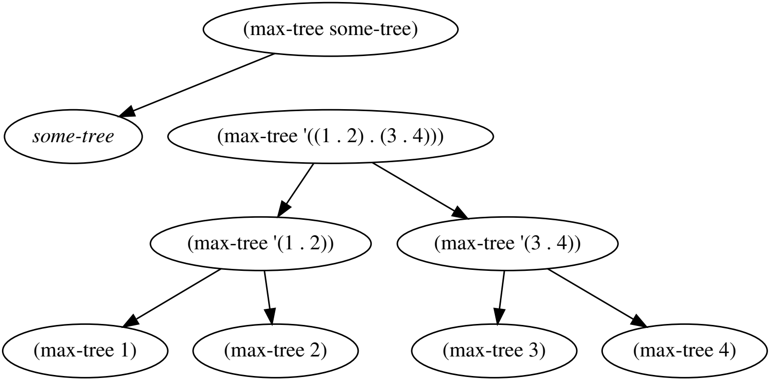


# Visualization of max-tree in Adapton



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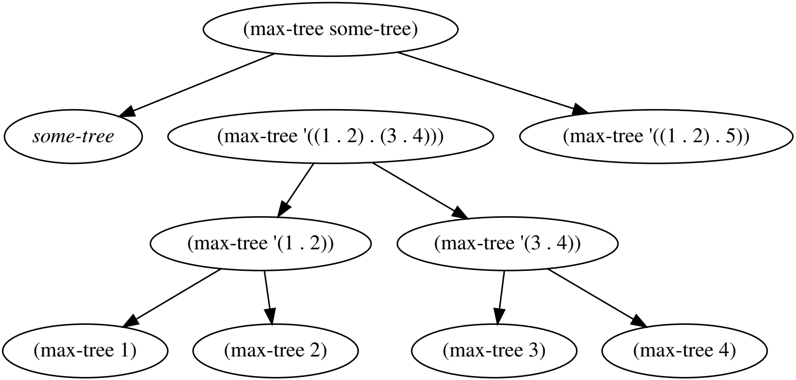

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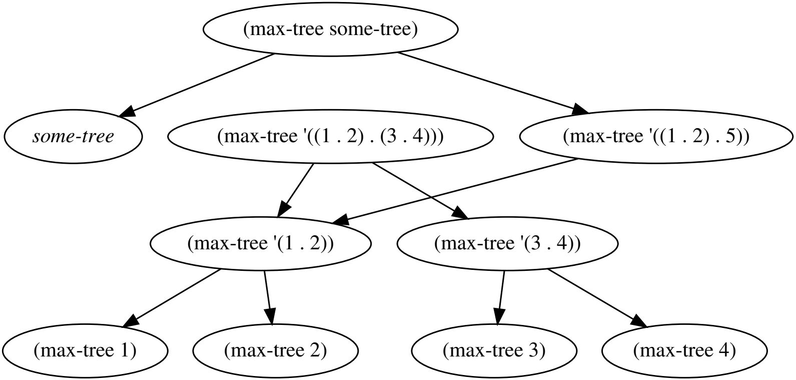

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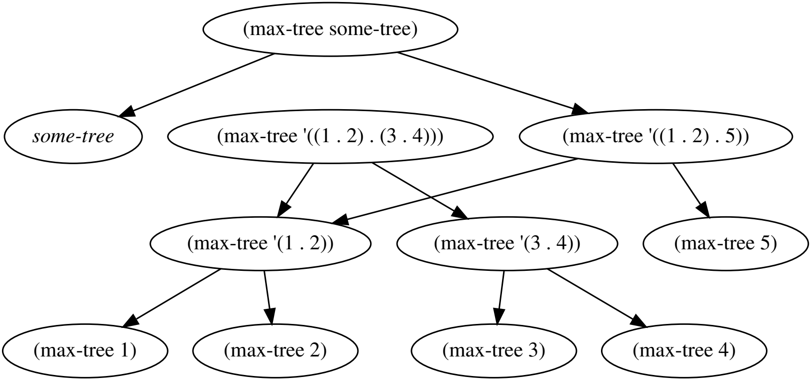


# What's in a node?

```
(define-record-type
  (adapton adapton-cons adapton?)
  (fields
```

# What's in a node?

```
(define-record-type
  (adapton adapton-cons adapton?)
  (fields
   thunk
```

# What's in a node?

```
(define-record-type
  (adapton adapton-cons adapton?)
  (fields
   thunk
   (mutable result)
```

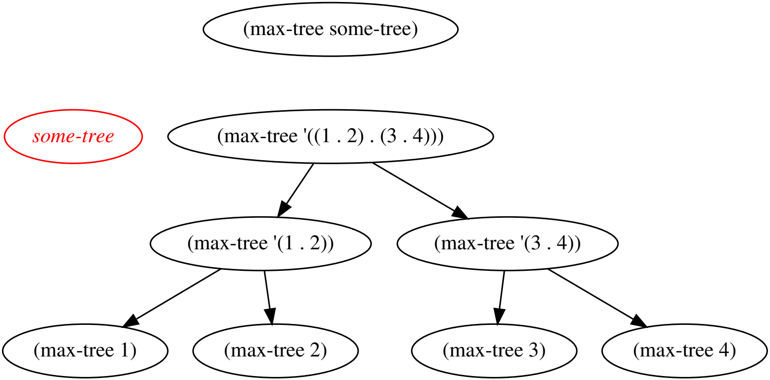
# What's in a node?

```
(define-record-type
  (adapton adapton-cons adapton?)
  (fields
   thunk
   (mutable result)
   (mutable sub)
   (mutable super)
```

# What's in a node?

```
(define-record-type
  (adapton adapton-cons adapton?)
  (fields
   thunk
   (mutable result)
   (mutable sub)
   (mutable super)
   (mutable clean?)))
```

# Nodes



(max-tree some-tree)

*some-tree*

(max-tree '((1 . 2) . (3 . 4)))

(max-tree '(1 . 2))

(max-tree '(3 . 4))

(max-tree 1)

(max-tree 2)

(max-tree 3)

(max-tree 4)

# miniAdapton Interfaces

- Adapton thunks (“athunks”) and Adapton references (“arefs”)
  - adapton-ref
  - adapton-ref-set!
  - adapt
  - adapton-force

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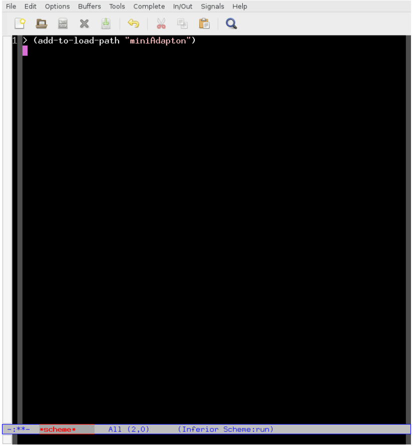
  - adapton-ref
  - adapton-ref-set!
  - adapt
  - adapton-force
- Adapton memoization (“amemo”)
  - adapton-memoize, adapton-memoize-l
  - define-amemo, define-amemo-l

# miniAdapton Interfaces

- Adapton thunks (“athunks”) and Adapton references (“arefs”)
    - adapton-ref
    - adapton-ref-set!
    - adapt
    - adapton-force
- Adapton memoization (“amemo”)
    - adapton-memoize, adapton-memoize-l
    - define-amemo, define-amemo-l
- Adapton variables (“avar”)
    - define-avar
    - avar-get
    - avar-set!

# Interface Demo



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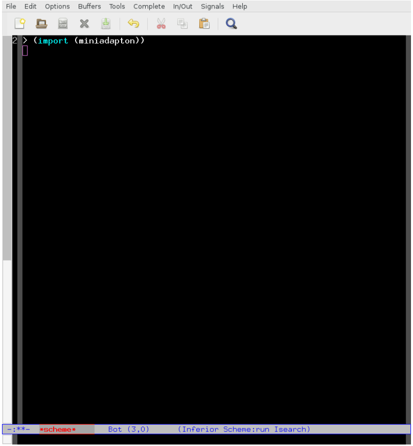
```
1 > (add-to-load-path "miniAdapton")
```

-:**- *scheme* All (2,0) (Inferior Scheme:run)

# Interface Demo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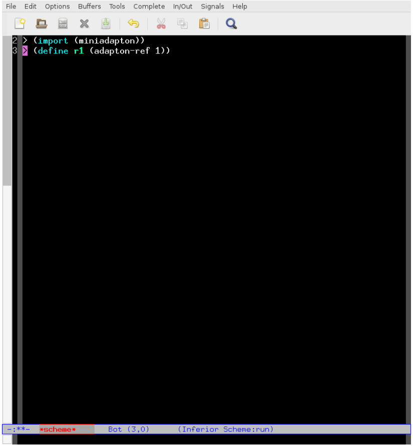
```
2 > (import (miniadapton))
```

```
-:**-  *scheme*     Bot (3,0)      (Inferior Scheme:run Isearch)
```

# Interface Demo



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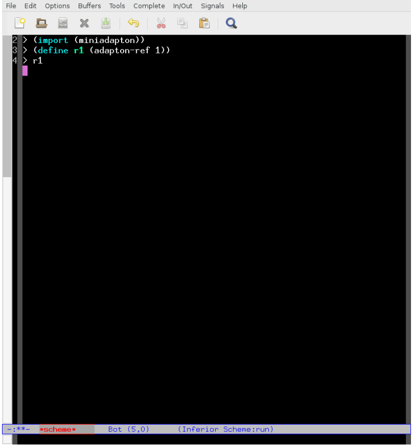
```
> (import (miniadapton))
> (define r1 (adapton-ref 1))
```

-:**- *scheme* Bot (3,0) (Inferior Scheme:run)

# Interface Demo



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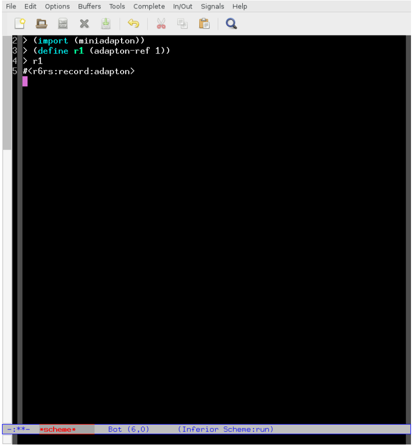
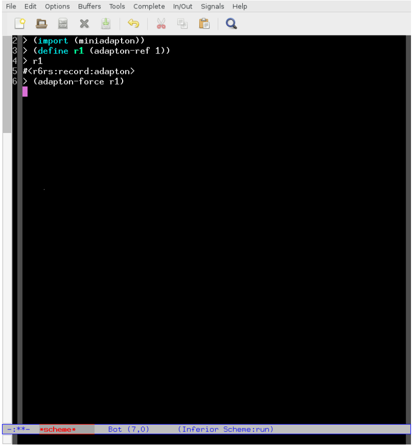
> (define r1 (adapton-ref 1))
> r1
```

# Interface Demo



```
> (import (miniadapton))
> (define r1 (adapton-ref 1))
> r1
#<r6rs:record:adapton>
```

# Interface Demo



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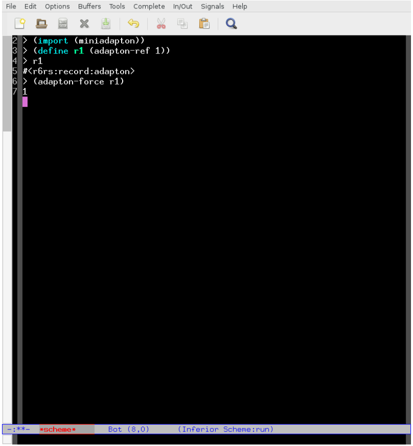
```
> (import (miniadapton))
> (define r1 (adapton-ref 1))
> r1
#<r6rs:record:adapton>
> (adapton-force r1)
```

```
-:**-  *scheme*   Bot (7,0)    (Inferior Scheme:run)
```

# Interface Demo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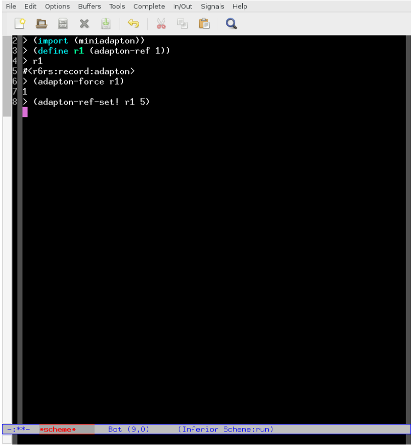
```
> (import (miniadapton))
> (define r1 (adapton-ref 1))
> r1
#<r6rs:record:adapton>
> (adapton-force r1)
1
```

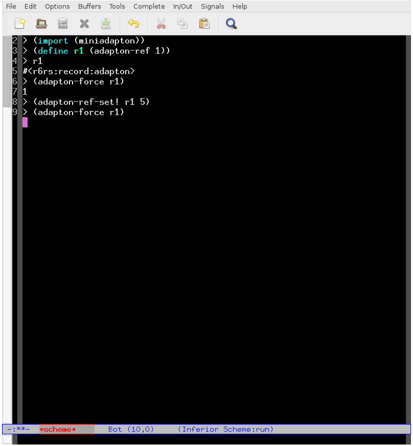
-:**-  *scheme*    Bot (8,0)     (Inferior Scheme:run)

# Interface Demo



```
> (import (miniadapton))
> (define r1 (adapton-ref 1))
> r1
#<r6rs:record:adapton>
> (adapton-force r1)
1
> (adapton-ref-set! r1 5)
```

# Interface Demo



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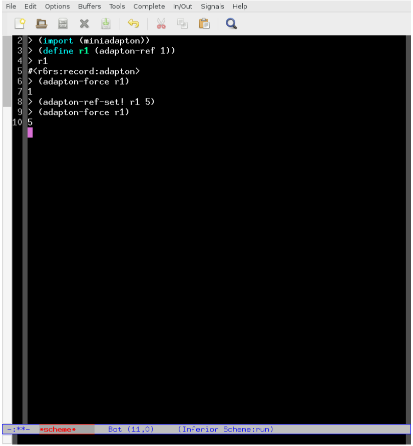
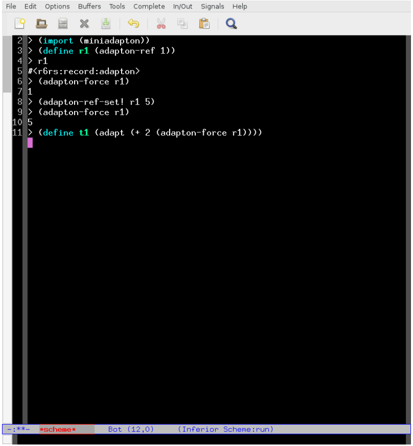
> (import (miniadapton))
> (define r1 (adapton-ref 1))
> r1
#<r6rs:record:adapton>
> (adapton-force r1)
1
> (adapton-ref-set! r1 5)
> (adapton-force r1)
```

# Interface Demo


File Edit Options Buffers Tools Complete In/Out Signals Help
-:**- *scheme* Bot (11,0) (Inferior Scheme:run)

```
> (import (miniadapton))
> (define r1 (adapton-ref 1))
> r1
#<r6rs:record:adapton>
> (adapton-force r1)
1
> (adapton-ref-set! r1 5)
> (adapton-force r1)
5
```

# Interface Demo



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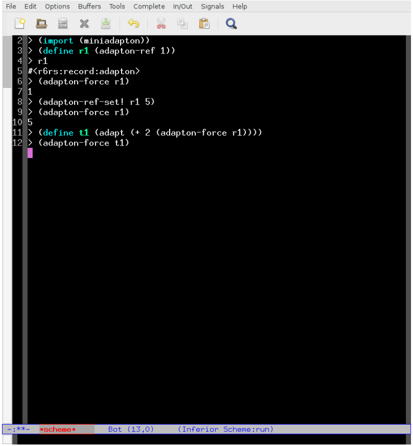
> (define r1 (adapton-ref 1))
> r1
#<r6rs:record:adapton>
> (adapton-force r1)
1
> (adapton-ref-set! r1 5)
> (adapton-force r1)
5
> (define t1 (adapt (+ 2 (adapton-force r1))))
```

# Interface Demo



```
> (import (miniadapton))
> (define r1 (adapton-ref 1))
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#<r6rs:record:adapton>
> (adapton-force r1)
1
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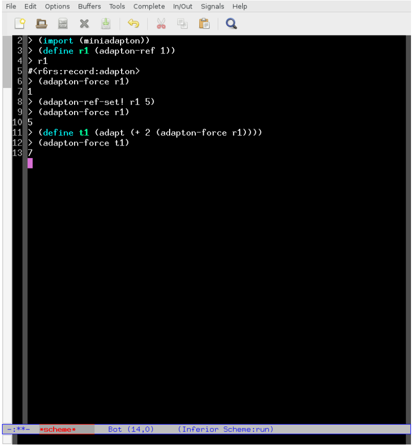
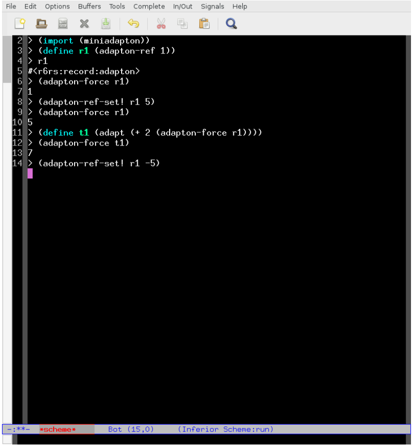
> (adapton-force t1)
```

# Interface Demo


File Edit Options Buffers Tools Complete In/Out Signals Help
-:**- *scheme* Bot (14,0) (Inferior Scheme:run)

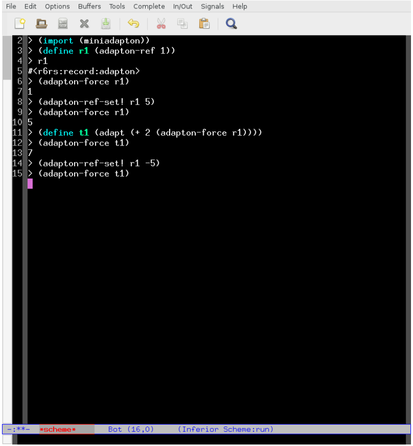
```
> (import (miniadapton))
> (define r1 (adapton-ref 1))
> r1
#<r6rs:record:adapton>
> (adapton-force r1)
1
> (adapton-ref-set! r1 5)
> (adapton-force r1)
5
> (define t1 (adapt (+ 2 (adapton-force r1))))
> (adapton-force t1)
7
```

# Interface Demo


File Edit Options Buffers Tools Complete In/Out Signals Help
-:**- *scheme* Bot (15,0) (Inferior Scheme:run)

```
> (import (miniadapton))
> (define r1 (adapton-ref 1))
> r1
#<r6rs:record:adapton>
> (adapton-force r1)
1
> (adapton-ref-set! r1 5)
> (adapton-force r1)
5
> (define t1 (adapt (+ 2 (adapton-force r1))))
> (adapton-force t1)
7
> (adapton-ref-set! r1 -5)
```

# Interface Demo



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> r1
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1
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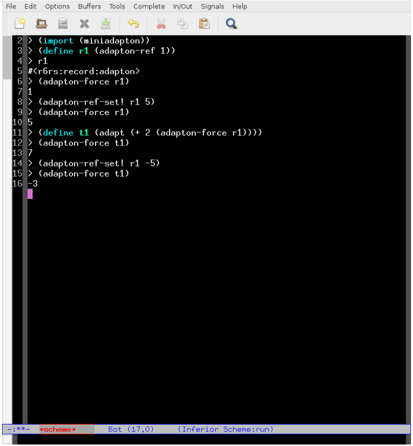
> (adapton-force r1)
5
> (define t1 (adapt (+ 2 (adapton-force r1))))
> (adapton-force t1)
7
> (adapton-ref-set! r1 -5)
> (adapton-force t1)
```

# Interface Demo



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> r1
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> (adapton-force r1)
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> (adapton-force t1)
7
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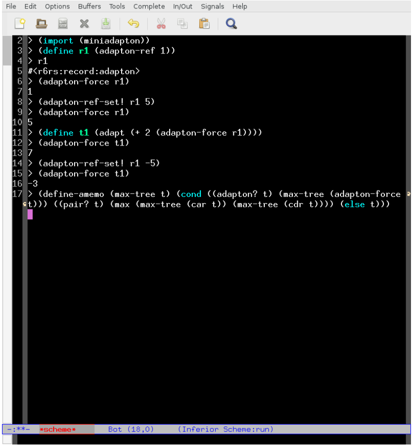
> (adapton-force t1)
-3
```

# Interface Demo



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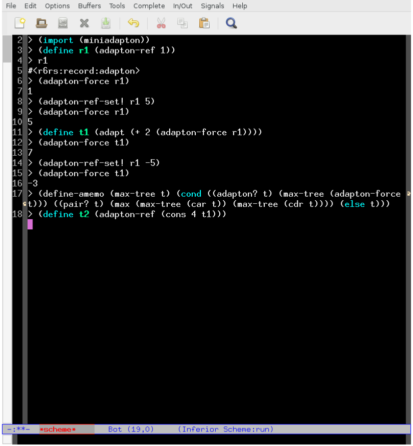
```
> (import (miniadapton))
> (define r1 (adapton-ref 1))
> r1
#<r6rs:record:adapton>
> (adapton-force r1)
1
> (adapton-ref-set! r1 5)
> (adapton-force r1)
5
> (define t1 (adapt (+ 2 (adapton-force r1))))
> (adapton-force t1)
7
> (adapton-ref-set! r1 -5)
> (adapton-force t1)
-3
> (define-amemo (max-tree t) (cond ((adapton? t) (max-tree (adapton-force t))) ((pair? t) (max (max-tree (car t)) (max-tree (cdr t)))) (else t)))
```

-:**-  *scheme*  Bot (18,0)  (Inferior Scheme:run)

# Interface Demo



```
> (import (miniadapton))
> (define r1 (adapton-ref 1))
> r1
#<r6rs:record:adapton>
> (adapton-force r1)
1
> (adapton-ref-set! r1 5)
> (adapton-force r1)
5
> (define t1 (adapt (+ 2 (adapton-force r1))))
> (adapton-force t1)
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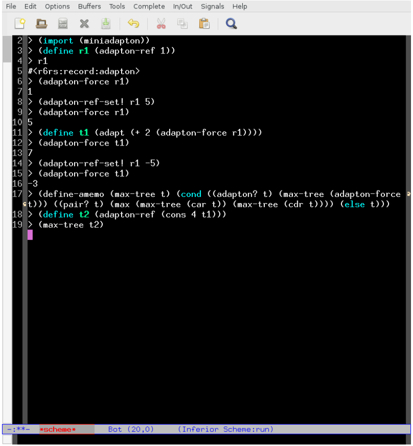
> (define-amemo (max-tree t) (cond ((adapton? t) (max-tree (adapton-force
t))) ((pair? t) (max (max-tree (car t)) (max-tree (cdr t)))) (else t)))
> (define t2 (adapton-ref (cons 4 t1)))
```

# Interface Demo



```
> (import (miniadapton))
> (define r1 (adapton-ref 1))
> r1
#<r6rs:record:adapton>
> (adapton-force r1)
1
> (adapton-ref-set! r1 5)
> (adapton-force r1)
5
> (define t1 (adapt (+ 2 (adapton-force r1))))
> (adapton-force t1)
7
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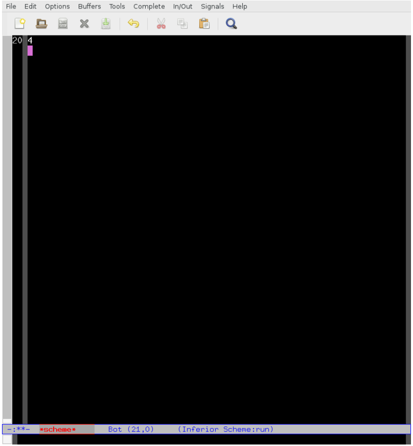
> (adapton-force t1)
-3
> (define-amemo (max-tree t) (cond ((adapton? t) (max-tree (adapton-force
t))) ((pair? t) (max (max-tree (car t)) (max-tree (cdr t)))) (else t)))
> (define t2 (adapton-ref (cons 4 t1)))
> (max-tree t2)
```

```
-:**-  *scheme*    Bot (20,0)    (Inferior Scheme:run)
```

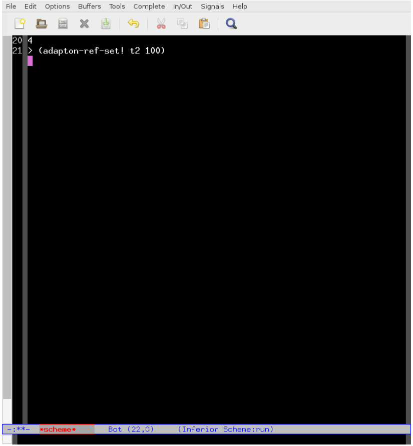
# Interface Demo



```
20 4
```

```
-:**-  *scheme*     Bot (21,0)     (Inferior Scheme:run)
```

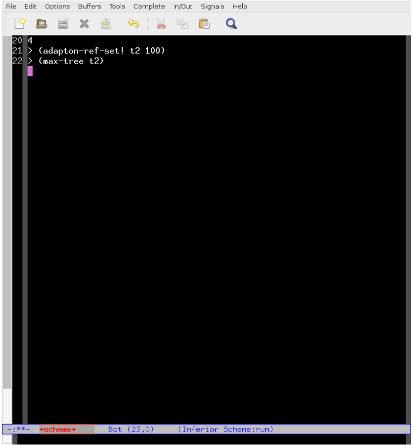
# Interface Demo


File Edit Options Buffers Tools Complete In/Out Signals Help

```
20 4
21 > (adapton-ref-set! t2 100)
```

```
-:**-  *scheme*   Bot (22,0)    (Inferior Scheme:run)
```

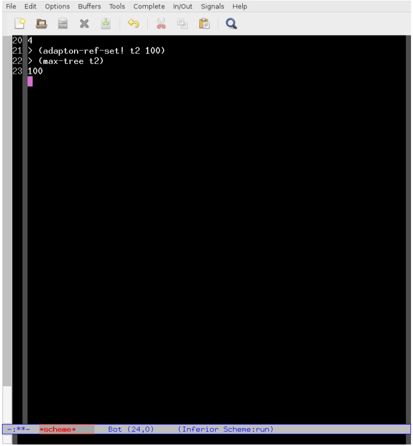
# Interface Demo



```
4
> (adapton-ref-set! t2 100)
> (max-tree t2)
```

```
-:**-  *scheme*    Bot (23,0)     (Inferior Scheme:run)
```

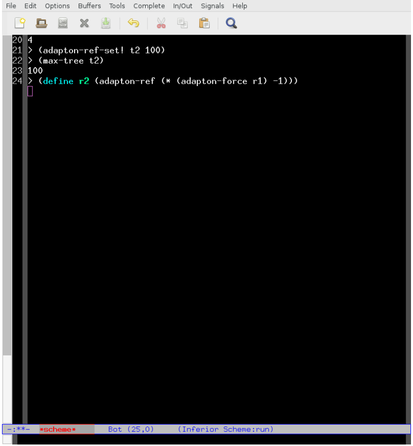
# Interface Demo


File Edit Options Buffers Tools Complete In/Out Signals Help

```
4
> (adapton-ref-set! t2 100)
> (max-tree t2)
100
```

-:**-  *scheme*   Bot (24,0)    (Inferior Scheme:run)

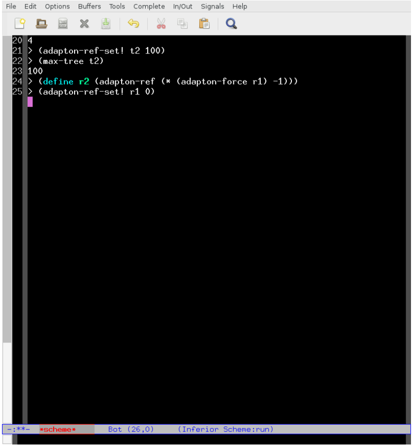
# Interface Demo


File Edit Options Buffers Tools Complete In/Out Signals Help

```
4
> (adapton-ref-set! t2 100)
> (max-tree t2)
100
> (define r2 (adapton-ref (* (adapton-force r1) -1)))
```

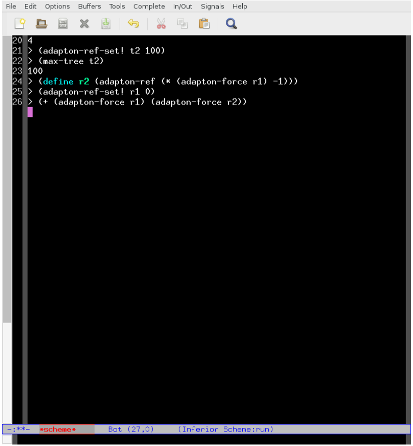
-:**-  *scheme*   Bot (25,0)   (Inferior Scheme:run)

# Interface Demo



```
4
> (adapton-ref-set! t2 100)
> (max-tree t2)
100
> (define r2 (adapton-ref (* (adapton-force r1) -1)))
> (adapton-ref-set! r1 0)
```

# Interface Demo

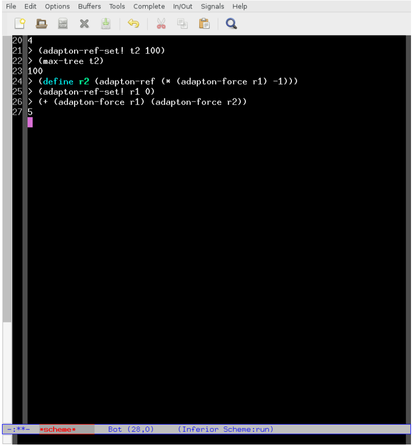


File Edit Options Buffers Tools Complete In/Out Signals Help

```
4
> (adapton-ref-set! t2 100)
> (max-tree t2)
100
> (define r2 (adapton-ref (* (adapton-force r1) -1)))
> (adapton-ref-set! r1 0)
> (+ (adapton-force r1) (adapton-force r2))
```

```
-:**-  *scheme*     Bot (27,0)     (Inferior Scheme:run)
```

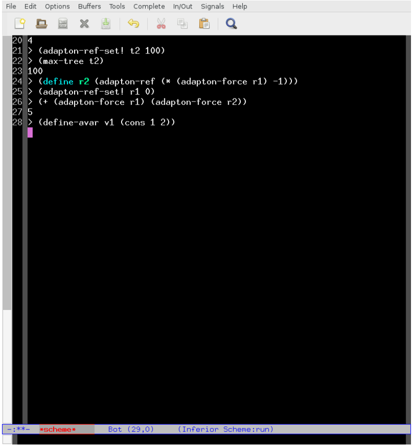
# Interface Demo


File Edit Options Buffers Tools Complete In/Out Signals Help

```
4
> (adapton-ref-set! t2 100)
> (max-tree t2)
100
> (define r2 (adapton-ref (* (adapton-force r1) -1)))
> (adapton-ref-set! r1 0)
> (+ (adapton-force r1) (adapton-force r2))
5
```

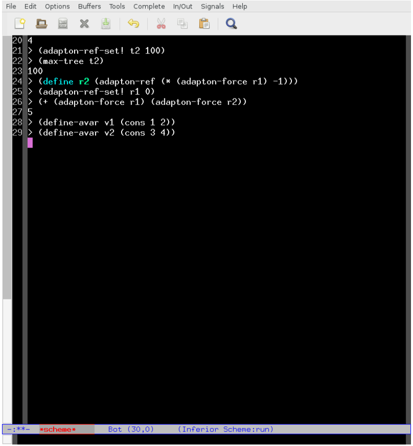
-:**-  *scheme*   Bot (28,0)   (Inferior Scheme:run)

# Interface Demo



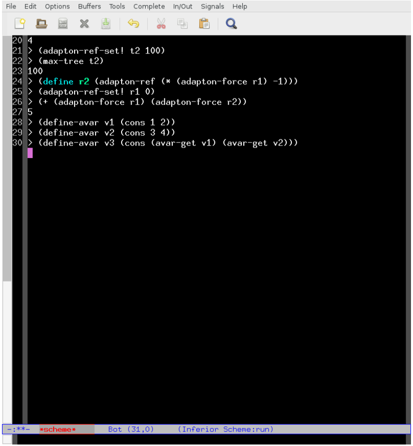
```
4
> (adapton-ref-set! t2 100)
> (max-tree t2)
100
> (define r2 (adapton-ref (* (adapton-force r1) -1)))
> (adapton-ref-set! r1 0)
> (+ (adapton-force r1) (adapton-force r2))
5
> (define-avar v1 (cons 1 2))
```

# Interface Demo


File Edit Options Buffers Tools Complete In/Out Signals Help
-:**- *scheme* Bot (30,0) (Inferior Scheme:run)

```
4
> (adapton-ref-set! t2 100)
> (max-tree t2)
100
> (define r2 (adapton-ref (* (adapton-force r1) -1)))
> (adapton-ref-set! r1 0)
> (+ (adapton-force r1) (adapton-force r2))
5
> (define-avar v1 (cons 1 2))
> (define-avar v2 (cons 3 4))
```

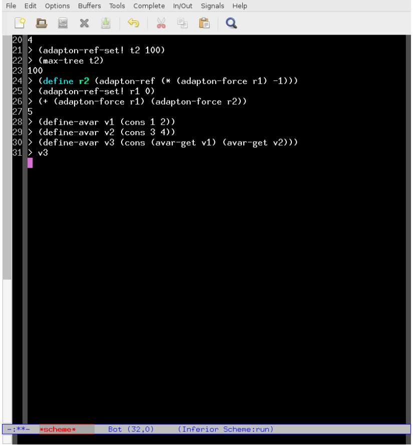
# Interface Demo



```
4
> (adapton-ref-set! t2 100)
> (max-tree t2)
100
> (define r2 (adapton-ref (* (adapton-force r1) -1)))
> (adapton-ref-set! r1 0)
> (+ (adapton-force r1) (adapton-force r2))
5
> (define-avar v1 (cons 1 2))
> (define-avar v2 (cons 3 4))
> (define-avar v3 (cons (avar-get v1) (avar-get v2)))
```

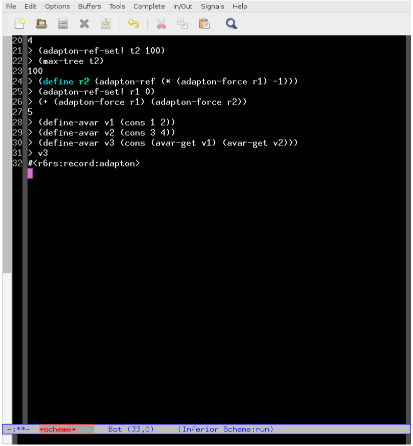
```
-:**-  *scheme*      Bot (31,0)     (Inferior Scheme:run)
```

# Interface Demo


File Edit Options Buffers Tools Complete In/Out Signals Help
-:**- *scheme* Bot (32,0) (Inferior Scheme:run)

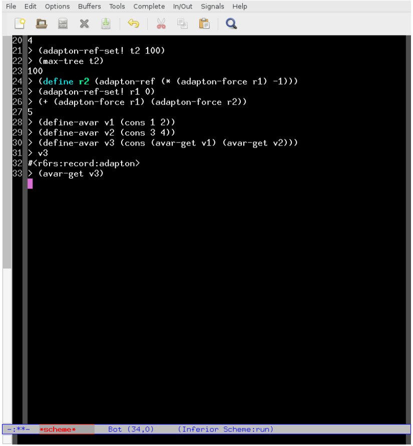
```
4
> (adapton-ref-set! t2 100)
> (max-tree t2)
100
> (define r2 (adapton-ref (* (adapton-force r1) -1)))
> (adapton-ref-set! r1 0)
> (+ (adapton-force r1) (adapton-force r2))
5
> (define-avar v1 (cons 1 2))
> (define-avar v2 (cons 3 4))
> (define-avar v3 (cons (avar-get v1) (avar-get v2)))
> v3
```

# Interface Demo


File Edit Options Buffers Tools Complete In/Out Signals Help
-:**-  *scheme*  Bot (33,0)  (Inferior Scheme:run)

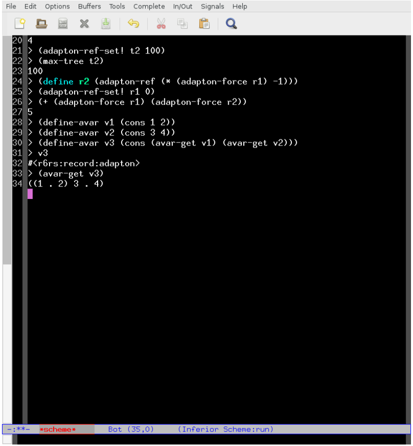
```
4
> (adapton-ref-set! t2 100)
> (max-tree t2)
100
> (define r2 (adapton-ref (* (adapton-force r1) -1)))
> (adapton-ref-set! r1 0)
> (+ (adapton-force r1) (adapton-force r2))
5
> (define-avar v1 (cons 1 2))
> (define-avar v2 (cons 3 4))
> (define-avar v3 (cons (avar-get v1) (avar-get v2)))
> v3
#<r6rs:record:adapton>
```

# Interface Demo



```
4
> (adapton-ref-set! t2 100)
> (max-tree t2)
100
> (define r2 (adapton-ref (* (adapton-force r1) -1)))
> (adapton-ref-set! r1 0)
> (+ (adapton-force r1) (adapton-force r2))
5
> (define-avar v1 (cons 1 2))
> (define-avar v2 (cons 3 4))
> (define-avar v3 (cons (avar-get v1) (avar-get v2)))
> v3
#<r6rs:record:adapton>
> (avar-get v3)
```

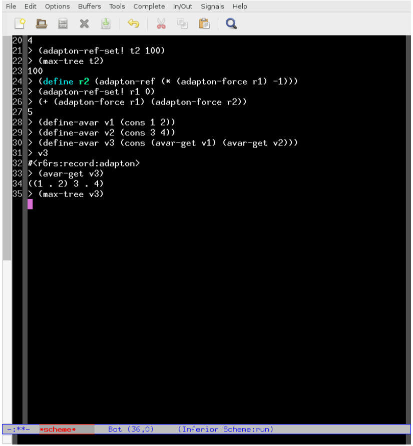
# Interface Demo


File Edit Options Buffers Tools Complete In/Out Signals Help

```
4
> (adapton-ref-set! t2 100)
> (max-tree t2)
100
> (define r2 (adapton-ref (* (adapton-force r1) -1)))
> (adapton-ref-set! r1 0)
> (+ (adapton-force r1) (adapton-force r2))
5
> (define-avar v1 (cons 1 2))
> (define-avar v2 (cons 3 4))
> (define-avar v3 (cons (avar-get v1) (avar-get v2)))
> v3
#<r6rs:record:adapton>
> (avar-get v3)
((1 . 2) 3 . 4)
```

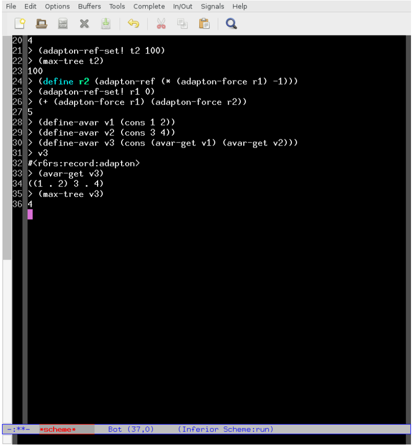
-:**-  *scheme*   Bot (35,0)   (Inferior Scheme:run)

# Interface Demo



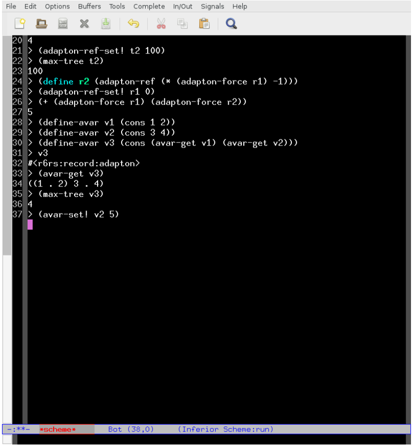
```
4
> (adapton-ref-set! t2 100)
> (max-tree t2)
100
> (define r2 (adapton-ref (* (adapton-force r1) -1)))
> (adapton-ref-set! r1 0)
> (+ (adapton-force r1) (adapton-force r2))
5
> (define-avar v1 (cons 1 2))
> (define-avar v2 (cons 3 4))
> (define-avar v3 (cons (avar-get v1) (avar-get v2)))
> v3
#<r6rs:record:adapton>
> (avar-get v3)
((1 . 2) 3 . 4)
> (max-tree v3)
```

# Interface Demo



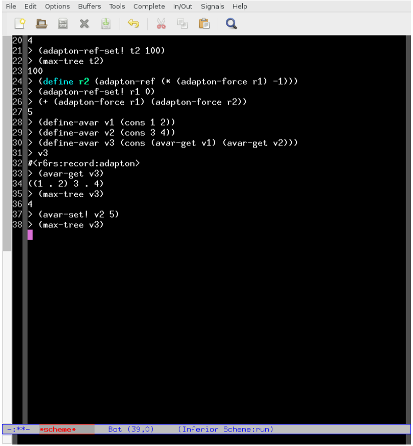
```
4
> (adapton-ref-set! t2 100)
> (max-tree t2)
100
> (define r2 (adapton-ref (* (adapton-force r1) -1)))
> (adapton-ref-set! r1 0)
> (+ (adapton-force r1) (adapton-force r2))
5
> (define-avar v1 (cons 1 2))
> (define-avar v2 (cons 3 4))
> (define-avar v3 (cons (avar-get v1) (avar-get v2)))
> v3
#<r6rs:record:adapton>
> (avar-get v3)
((1 . 2) 3 . 4)
> (max-tree v3)
4
```

# Interface Demo



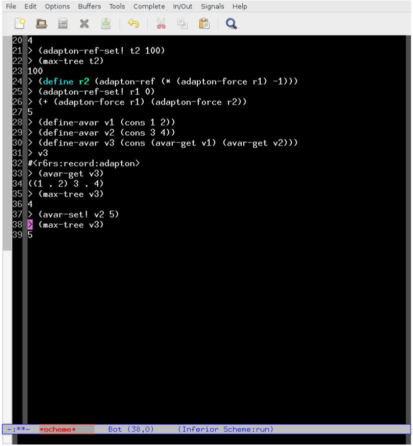
```
4
> (adapton-ref-set! t2 100)
> (max-tree t2)
100
> (define r2 (adapton-ref (* (adapton-force r1) -1)))
> (adapton-ref-set! r1 0)
> (+ (adapton-force r1) (adapton-force r2))
5
> (define-avar v1 (cons 1 2))
> (define-avar v2 (cons 3 4))
> (define-avar v3 (cons (avar-get v1) (avar-get v2)))
> v3
#<r6rs:record:adapton>
> (avar-get v3)
((1 . 2) 3 . 4)
> (max-tree v3)
4
> (avar-set! v2 5)
```

# Interface Demo



```
4
> (adapton-ref-set! t2 100)
> (max-tree t2)
100
> (define r2 (adapton-ref (* (adapton-force r1) -1)))
> (adapton-ref-set! r1 0)
> (+ (adapton-force r1) (adapton-force r2))
5
> (define-avar v1 (cons 1 2))
> (define-avar v2 (cons 3 4))
> (define-avar v3 (cons (avar-get v1) (avar-get v2)))
> v3
#<r6rs:record:adapton>
> (avar-get v3)
((1 . 2) 3 . 4)
> (max-tree v3)
4
> (avar-set! v2 5)
> (max-tree v3)
```

# Interface Demo



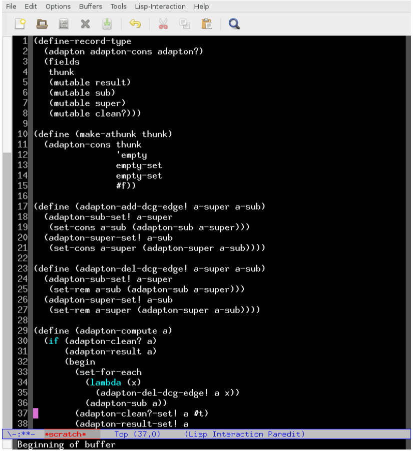
```
4
> (adapton-ref-set! t2 100)
> (max-tree t2)
100
> (define r2 (adapton-ref (* (adapton-force r1) -1)))
> (adapton-ref-set! r1 0)
> (+ (adapton-force r1) (adapton-force r2))
5
> (define-avar v1 (cons 1 2))
> (define-avar v2 (cons 3 4))
> (define-avar v3 (cons (avar-get v1) (avar-get v2)))
> v3
#<r6rs:record:adapton>
> (avar-get v3)
((1 . 2) 3 . 4)
> (max-tree v3)
4
> (avar-set! v2 5)
> (max-tree v3)
5
```

```
-:**-  *scheme*      Bot (38,0)     (Inferior Scheme:run)
```

# microAdapton: the core of miniAdapton

- inspired by microKanren for implementing miniKanren
- implements core operations for miniAdapton
- avoids implicit DCG construction
- miniAdapton builds implicit DCG construction on top of microAdapton

# Implementation - microAdapton



```
(define-record-type
  (adapton adapton-cons adapton?)
  (fields
   thunk
   (mutable result)
   (mutable sub)
   (mutable super)
   (mutable clean?)))

(define (make-athunk thunk)
  (adapton-cons thunk
                'empty
                empty-set
                empty-set
                #f))

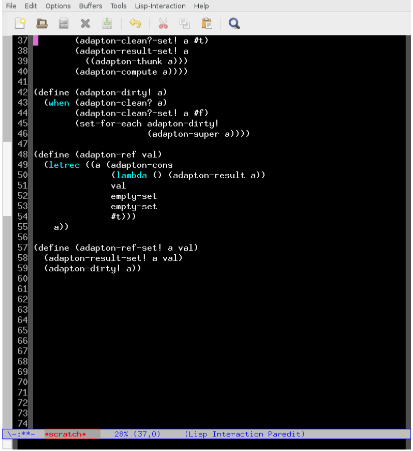
(define (adapton-add-dcg-edge! a-super a-sub)
  (adapton-sub-set! a-super
   (set-cons a-sub (adapton-sub a-super)))
  (adapton-super-set! a-sub
   (set-cons a-super (adapton-super a-sub))))

(define (adapton-del-dcg-edge! a-super a-sub)
  (adapton-sub-set! a-super
   (set-rem a-sub (adapton-sub a-super)))
  (adapton-super-set! a-sub
   (set-rem a-super (adapton-super a-sub))))

(define (adapton-compute a)
  (if (adapton-clean? a)
      (adapton-result a)
      (begin
        (set-for-each
          (lambda (x)
            (adapton-del-dcg-edge! a x))
          (adapton-sub a))
        (adapton-clean?-set! a #t)
        (adapton-result-set! a
```

```
\-:**-  *scratch*    Top (37,0)     (Lisp Interaction Paredit)
Beginning of buffer
```

# Implementation - microAdapton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Options
Buffers
Tools
Lisp-Interaction
Help

```
        (adapton-clean?-set! a #t)
        (adapton-result-set! a
          ((adapton-thunk a)))
        (adapton-compute a))))

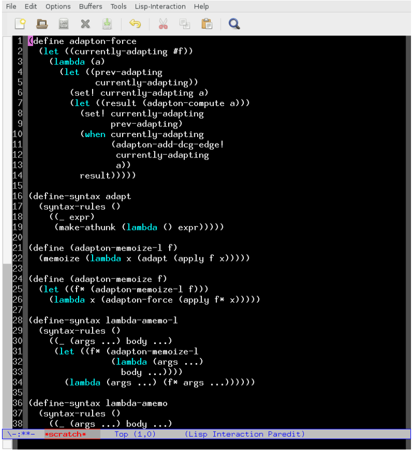
(define (adapton-dirty! a)
  (when (adapton-clean? a)
        (adapton-clean?-set! a #f)
        (set-for-each adapton-dirty!
                      (adapton-super a))))

(define (adapton-ref val)
  (letrec ((a (adapton-cons
               (lambda () (adapton-result a))
               val
               empty-set
               empty-set
               #t)))
    a))

(define (adapton-ref-set! a val)
  (adapton-result-set! a val)
  (adapton-dirty! a))
```

-:**-  *scratch*     28% (37,0)     (Lisp Interaction Paredit)

# Implementation - miniAdapton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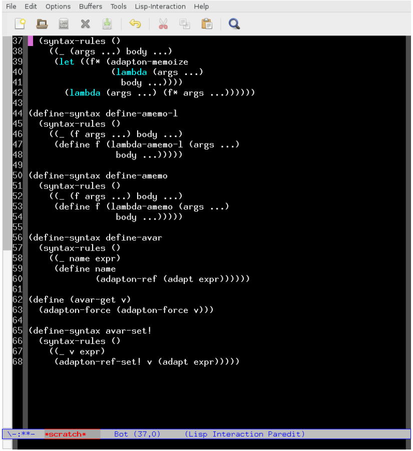
Buffers
Tools
Lisp-Interaction
Help
-:**-  *scratch*    Top (1,0)     (Lisp Interaction Paredit)

```scheme
(define adapton-force
  (let ((currently-adapting #f))
    (lambda (a)
      (let ((prev-adapting
             currently-adapting))
        (set! currently-adapting a)
        (let ((result (adapton-compute a)))
          (set! currently-adapting
                prev-adapting)
          (when currently-adapting
                (adapton-add-dcg-edge!
                 currently-adapting
                 a))
          result)))))

(define-syntax adapt
  (syntax-rules ()
    ((_ expr)
     (make-athunk (lambda () expr)))))

(define (adapton-memoize-l f)
  (memoize (lambda x (adapt (apply f x)))))

(define (adapton-memoize f)
  (let ((f* (adapton-memoize-l f)))
    (lambda x (adapton-force (apply f* x)))))

(define-syntax lambda-amemo-l
  (syntax-rules ()
    ((_ (args ...) body ...)
     (let ((f* (adapton-memoize-l
                (lambda (args ...)
                  body ...))))
       (lambda (args ...) (f* args ...))))))

(define-syntax lambda-amemo
  (syntax-rules ()
    ((_ (args ...) body ...)
```

# Implementation - miniAdapton



```
  (syntax-rules ()
    ((_ (args ...) body ...)
     (let ((f* (adapton-memoize
                (lambda (args ...)
                  body ...))))
       (lambda (args ...) (f* args ...))))))

(define-syntax define-amemo-l
  (syntax-rules ()
    ((_ (f args ...) body ...)
     (define f (lambda-amemo-l (args ...)
                 body ...)))))

(define-syntax define-amemo
  (syntax-rules ()
    ((_ (f args ...) body ...)
     (define f (lambda-amemo (args ...)
                 body ...)))))

(define-syntax define-avar
  (syntax-rules ()
    ((_ name expr)
     (define name
             (adapton-ref (adapt expr))))))

(define (avar-get v)
  (adapton-force (adapton-force v)))

(define-syntax avar-set!
  (syntax-rules ()
    ((_ v expr)
     (adapton-ref-set! v (adapt expr)))))
```

```
\-:**-  *scratch*   Bot (37,0)    (Lisp Interaction Paredit)
```

# Conclusion

- Adapton implemented in a more minimal form
- A minimal implementation encourages hackability

# Conclusion - Play with it

- Incremental computation that you can play with RIGHT NOW

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- We want you to use this as soon as possible

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- `git clone 'https://github.com/fisherdj/miniAdapton'`

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- ...

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- ...
- `git clone 'https://github.com/fisherdj/miniAdapton'`

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- More details about the code are in the paper

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- More details about the code are in the paper

# Challenges

Modifying miniAdapton:

- Avoid recomputation when answers to subcomputations don't change (full Adapton)
- Add debugging information and/or visualization
- miniAdapton in other languages

Using miniAdapton:

- Adapton data structures
- Adapton for interactive applications

# Acknowledgements and Related Work

- Thanks to Jason Hemann and Dan Friedman for microKanren, a huge inspiration and motivation for miniAdapton
- Incremental Computing via Function Caching, Pugh and Teitelbaum POPL 1986 (still a good inspiration for data structures using Adapton)
- The Adapton Project, Hammer et al OOPSLA 2015 and PLDI 2014 (http://adapton.org)
- Self-Adjusting Computation, Acar et al; (http://www.umut-acar.org/self-adjusting-computation)