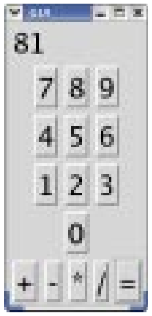
Calculator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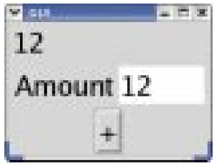
Run

Adding Machine


12

Amount 12

Run

Simple Adder

```
(define TOTAL 0)

(define total-message
  (make-message (number->string TOTAL)))
(define amount-text
  (make-text "Amount"))

(define add-button
  (make-button "+"
               (lambda (evt)
                 (add-to-total
                  (string->number (text-contents amount-text))))))

; add-to-total : num -> true
(define (add-to-total amt)
  (local [(define new-total (+ TOTAL amt))]
    (draw-message total-message (number->string new-total))))

(create-window (list (list total-message)
                     (list amount-text)
                     (list add-button)))
```

Why the Adder is Unlike A Calculator

```
(define (add-to-total amt)
  (local [(define new-total (+ TOTAL amt))]
    (draw-message total-message (number->string new-total))))
```

- Every time we have a new **`amt`**, it’s added to the same original **`TOTAL`**
- The new total is drawn on the screen, then forgotten

We need to remember **`new-total`** for next time

set!

In **Advanced**:

```
(set! TOTAL 17)
```

changes the value of `TOTAL` to 17

- "Constant" definitions are no longer constant — the are ***variable definitions***
- A `set!` expression is called an ***assignment***
- The value of `TOTAL` is the ***state*** of the program

Evaluating set!

```
(define TOTAL 0)
(define (add-amt amt)
  (set! TOTAL (+ TOTAL amt)))
(add-amt 1)
(add-amt 2)
```

→

```
(define TOTAL 0)
(define (add-amt amt)
  (set! TOTAL (+ TOTAL amt)))
(set! TOTAL (+ TOTAL 1))
(add-amt 2)
```

Evaluating set!

```
(define TOTAL 0)
(define (add-amt amt)
  (set! TOTAL (+ TOTAL amt)))
(set! TOTAL (+ TOTAL 1))
(add-amt 2)
```

→

```
(define TOTAL 0)
(define (add-amt amt)
  (set! TOTAL (+ TOTAL amt)))
(set! TOTAL (+ 0 1))
(add-amt 2)
```

Evaluating set!

```
(define TOTAL 0)
(define (add-amt amt)
  (set! TOTAL (+ TOTAL amt)))
(set! TOTAL (+ 0 1))
(add-amt 2)
```

→

```
(define TOTAL 0)
(define (add-amt amt)
  (set! TOTAL (+ TOTAL amt)))
(set! TOTAL 1)
(add-amt 2)
```

Evaluating set!

```
(define TOTAL 0)
(define (add-amt amt)
  (set! TOTAL (+ TOTAL amt)))
(set! TOTAL 1)
(add-amt 2)
```

→

```
(define TOTAL 1)
(define (add-amt amt)
  (set! TOTAL (+ TOTAL amt)))
(void)
(add-amt 2)
```

To evaluate **set!**, change a definition and produce **(void)**

Evaluating set!

```
(define TOTAL 1)
(define (add-amt amt)
  (set! TOTAL (+ TOTAL amt)))
(void)
(add-amt 2)
```

→

```
(define TOTAL 1)
(define (add-amt amt)
  (set! TOTAL (+ TOTAL amt)))
(void)
(set! TOTAL (+ TOTAL 2))
```

Evaluating set!

```
(define TOTAL 1)
(define (add-amt amt)
  (set! TOTAL (+ TOTAL amt)))
(void)
(set! TOTAL (+ TOTAL 2))
```

→

```
(define TOTAL 1)
(define (add-amt amt)
  (set! TOTAL (+ TOTAL amt)))
(void)
(set! TOTAL (+ 1 2))
```

Evaluating set!

```
(define TOTAL 1)
(define (add-amt amt)
  (set! TOTAL (+ TOTAL amt)))
(void)
(set! TOTAL (+ 1 2))
```

→

```
(define TOTAL 1)
(define (add-amt amt)
  (set! TOTAL (+ TOTAL amt)))
(void)
(set! TOTAL 3)
```

It’s important that a variable name is not replaced by its value until the value is needed

Evaluating set!

```
(define TOTAL 1)
(define (add-amt amt)
  (set! TOTAL (+ TOTAL amt)))
(void)
(set! TOTAL 3)
```

→

```
(define TOTAL 3)
(define (add-amt amt)
  (set! TOTAL (+ TOTAL amt)))
(void)
(void)
```

Repairing the Calculator

```
(define (add-to-total amt)
  (local [(define new-total (+ TOTAL amt))]
    ; How do we combine two actions?
    ...
    (set! TOTAL new-total)
    (draw-message total-message (number->string new-total))
    ...))
```

- For drawing, we used **and** to combine actions
- But **`set!`** doesn't return a boolean

Making the Adder Remember Totals

Also new in **Advanced**: the **`begin`** form

```
(define (add-to-total amt)
  (local [(define new-total (+ TOTAL amt))]
    (begin
      (set! TOTAL new-total)
      (draw-message total-message (number->string new-total)))))
```

The **`begin`** form

- Evaluates its first expression
- Throws away the result
- Goes away when only one expression is left

`begin` works with any number of expressions

Run

Evaluating begin

```
(define TOTAL 3)
(define (running-total amt)
  (begin
    (set! TOTAL (+ TOTAL amt))
    TOTAL))
(running-total 10)
```

→

```
(define TOTAL 3)
...
(begin
  (set! TOTAL (+ TOTAL 10))
  TOTAL)
```

Evaluating begin

```
(define TOTAL 3)
...
(begin
  (set! TOTAL (+ TOTAL 10))
  TOTAL)
```

→

```
(define TOTAL 3)
...
(begin
  (set! TOTAL (+ 3 10))
  TOTAL)
```

Evaluating begin

```
(define TOTAL 3)
...
(begin
  (set! TOTAL (+ 3 10))
  TOTAL)
```

→

```
(define TOTAL 3)
...
(begin
  (set! TOTAL 13)
  TOTAL)
```

Evaluating begin

```
(define TOTAL 3)
...
(begin
  (set! TOTAL 13)
  TOTAL)
```

→

```
(define TOTAL 13)
...
(begin
  (void)
  TOTAL)
```

Evaluating begin

```
(define TOTAL 13)
...
(begin
  (void)
  TOTAL)
```

→

```
(define TOTAL 13)
...
(begin
  TOTAL)
```

Evaluating begin

```
(define TOTAL 13)
...
(begin
  TOTAL)
```

→

```
(define TOTAL 13)
...
TOTAL
```

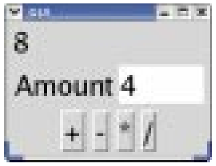
Evaluating begin

```
(define TOTAL 13)
...
TOTAL
```

→

```
(define TOTAL 13)
...
13
```

More Calculator Buttons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Amount 4

Run

Implementing More Calculator Buttons

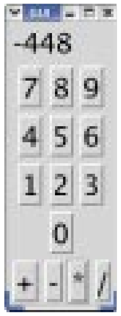
```
...

; op-button : string (num num -> num) -> button
(define (op-button label OP)
  (make-button label
               (lambda (evt)
                 (change-total
                  OP
                  (string->number (text-contents amount-text))))))

; change-total : (num num -> num) num -> true
(define (change-total OP amt)
  (local [(define new-total (OP TOTAL amt))]
    (begin
      (set! TOTAL new-total)
      (draw-message total-message (number->string new-total)))))

(create-window (list (list total-message)
                     (list amount-text)
                     (list (op-button "+" +)
                           (op-button "-" -)
                           (op-button "*" *)
                           (op-button "/" /))))
```

The Digit Buttons



Run

Now two pieces of state:

- The running total
- The number we’re typing, so far

Implementing Digit Buttons

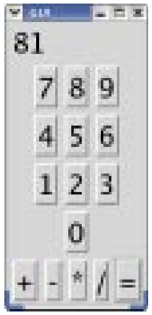
```
...
(define WORKING 0)

; digit-button : num -> button
(define (digit-button n)
  (make-button (number->string n)
               (lambda (evt)
                 (add-digit n))))

; add-digit : num -> true
(define (add-digit n)
  (begin
    (set! WORKING (+ n (* WORKING 10)))
    (draw-message total-message (number->string WORKING))))

; change-total : (num num -> num) num -> true
(define (change-total OP amt)
  (local [(define new-total (OP TOTAL amt))]
    (begin
      (set! TOTAL new-total)
      (set! WORKING 0)
      (draw-message total-message (number->string new-total)))))
...
```

Infix Operations



Run

A normal calculator uses infix (algebra-like) order

New piece of state:

- The operation to perform when the number is ready

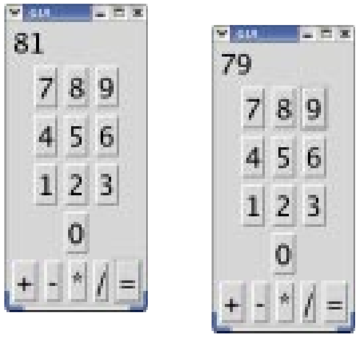
Implementing Infix Operations

```
...
(define PREV-OP +)

; op-button : string (num num -> num) -> button
(define (op-button label OP)
  (make-button label
               (lambda (evt)
                 (begin
                   (change-total PREV-OP WORKING)
                   (set! PREV-OP OP)
                   true))))
...

(create-window (list (list total-message)
                     (map digit-button ’(7 8 9))
                     (map digit-button ’(4 5 6))
                     (map digit-button ’(1 2 3))
                     (map digit-button   ’(0))
                     (list (op-button "+" +)
                           (op-button "-" -)
                           (op-button "*" *)
                           (op-button "/" /)
                           (op-button "=" (lambda (tot new) new)))))
```

Multiple Calculators



Run

How can we keep the calculators from using the same **TOTAL**?

Easy — use **local**

Implementing Multiple Calculators

```
(define (make-calculator)
  (local [(define TOTAL 0)
          (define WORKING 0)
          ...]
    (create-window
     (list (list total-message)
           (map digit-button '(7 8 9))
           (map digit-button '(4 5 6))
           (map digit-button '(1 2 3))
           (map digit-button   '(0))
           (list (op-button "+" +)
                 (op-button "-" -)
                 (op-button "*" *)
                 (op-button "/" /)
                 (op-button "=" (lambda (tot new) new)))))))
(make-calculator)
(make-calculator)
```

When to use State

Use state and **set!** when

- a function needs to remember something about previous calls, and
- you have no control over the callers

When NOT to use State

The following is a unacceptable use of **set!**

```
(define REV empty)
(define (reverse-list l)
  (cond
    [(empty? l) REV]
    [(cons? l)
     (begin
       (set! REV (cons (first l) REV))
       (reverse-list (rest l)))]))
(reverse-list '(1 2 3 4 5))
```

- Recursive calls build on earlier results, but we control all of the recursive calls
- It produces the wrong result when you call it a second time