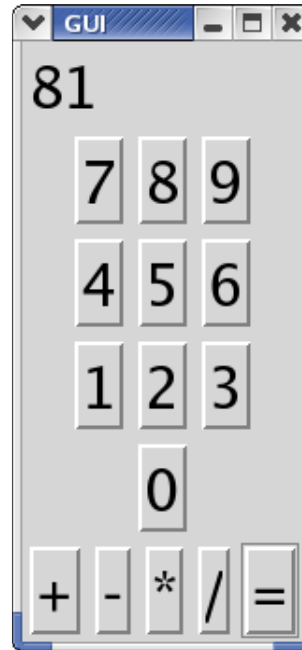
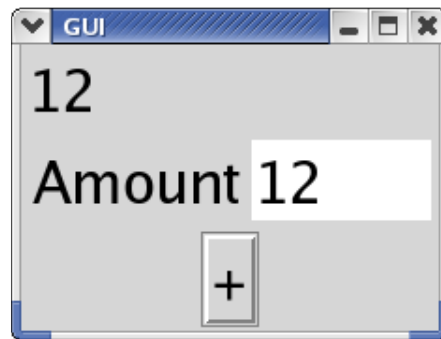


# Calculator



Run

# Adding Machine



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

# 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

# set!

In **Advanced**:

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

changes the value of **TOTAL** to 17

- "Constant" definitions are no longer constant — they 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)
```



## 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)
```

## 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)
```

## 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)
```

## 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)
```



## 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))
```

## 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))
```

## 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)
```

## 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))
    ...))
```



# 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))))))
```

# 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)
```

## 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)
```

## 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)
```



# 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)
```

# Evaluating begin

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

→

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

# Evaluating begin

```
(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)
```

# Evaluating begin

```
(define TOTAL 13)
```

```
...
```

```
(begin  
  TOTAL)
```

→

```
(define TOTAL 13)
```

```
...
```

```
TOTAL
```

# Evaluating begin

```
(define TOTAL 13)
```

```
...
```

```
TOTAL
```



# Evaluating begin

```
(define TOTAL 13)
```

```
...
```

```
TOTAL
```

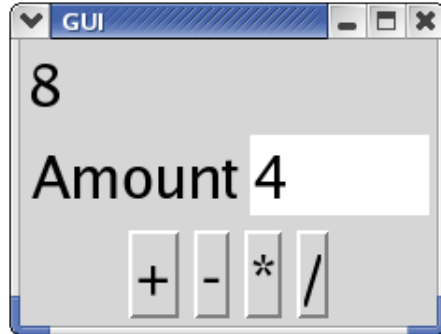
→

```
(define TOTAL 13)
```

```
...
```

```
13
```

# More Calculator Buttons



Run

# Implementing More Calculator Buttons

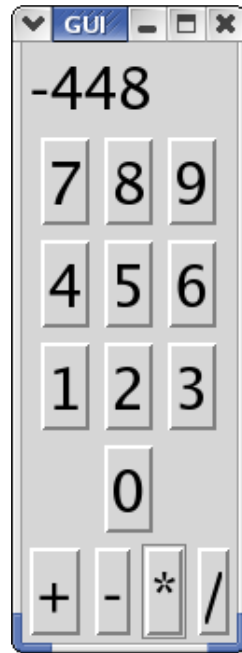
...

```
; 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
```

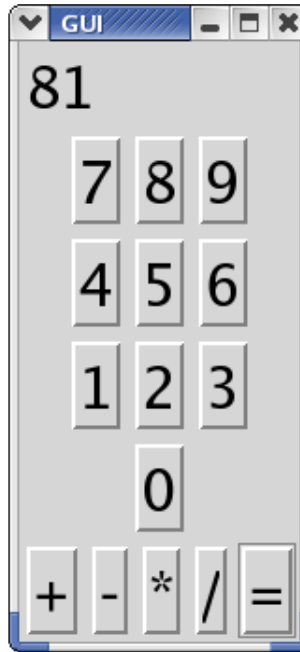
```
(define (add-digit n)
  (begin
    (set! WORKING (+ n (* WORKING 10)))
    (draw-message total-message (number->string WORKING))))
```

```
; 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

...

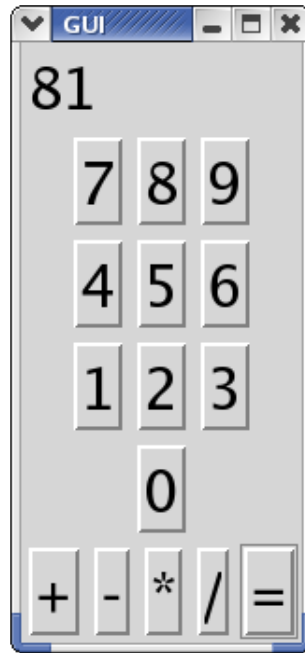
```
(define PREV-OP +)

; 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

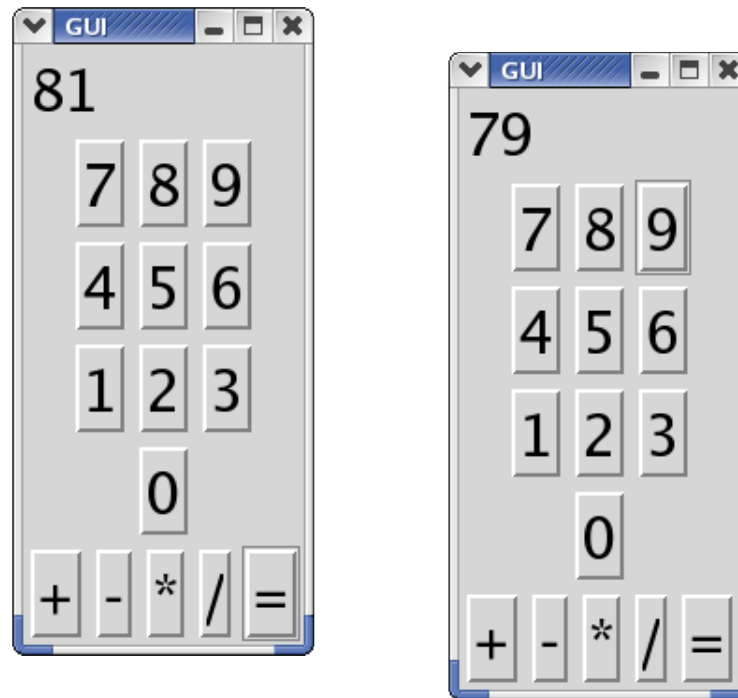


[Run](#)

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



# 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