CSCI 1106
Lecture 18

Debugging

Announcements

- Today's Topics
  - Motivation
  - Where to start
  - The "printf" method
  - Divide and conquer strategy

Bugs Suck (Mosquitoes too)

- Most programs have bugs
  - Design flaws
  - Typos
  - Bad assumptions
  - Logic and calculation errors
- Bugs cause programs to misbehave
  - Crash
  - Have incorrect behaviour
  - Corrupt data
  - Can cause loss of life, limb, and property
- Buggy programs must be debugged (fixed)

This Program Does Not Work… Why?

The robot is moving the distance *d=2* in a given time interval. We want to calculate the position *x* of the robot at each of the 10 intervals when the position at the first time interval is x[0]=1

```
var i
var x[10]=[0,0,0,0,0,0,0,0,0,0]
var distance=2
x[0]=1

for  i in 1:9 do
          x[1]=x[i-1]+distance
end
```

[1,3,5,7,9,11,13,15,17,19]

[1,2,0,0,0,0,0,0,0,0]

Asking the Right Questions

- Why is the program not working?
  - Because it has a bug…
- **Assumption:** Most of the program is correct
- **Observation:** The bug's location is the point in the program where it starts to misbehave
- **Conclusion:** So, we ask ***where is the bug***?
  - *When* does the bug appear?
  - *How* does the bug manifest?

The When and the How

- Question: Why do we care about
  - *When* the bug appears?
  - *How* the bug manifests?
- Answer:
  - Programs are large and complicated
  - Want to restrict our bug search to part of the program
  - This makes debugging easier, but …
- Still need to find the bug

Where to Start …

- **Recall**: We assume that program misbehaviour begins shortly after bug is encountered
- **Goal**: Narrow our search for the bug
- **Idea:** Determine the first instance of program misbehaviour

- So… **where in the program do things go wrong?**

Manifestation, Location, Match

- Idea:
  - Bugs manifest in program misbehaviour
  - Misbehaviour corresponds to a program location
  - Need to match the manifestation to the location
- To do:
  - Identify the bug manifestation
    - How do we know that something is wrong?
  - Identify the manifestation location
    - Where in the code does this something occur?

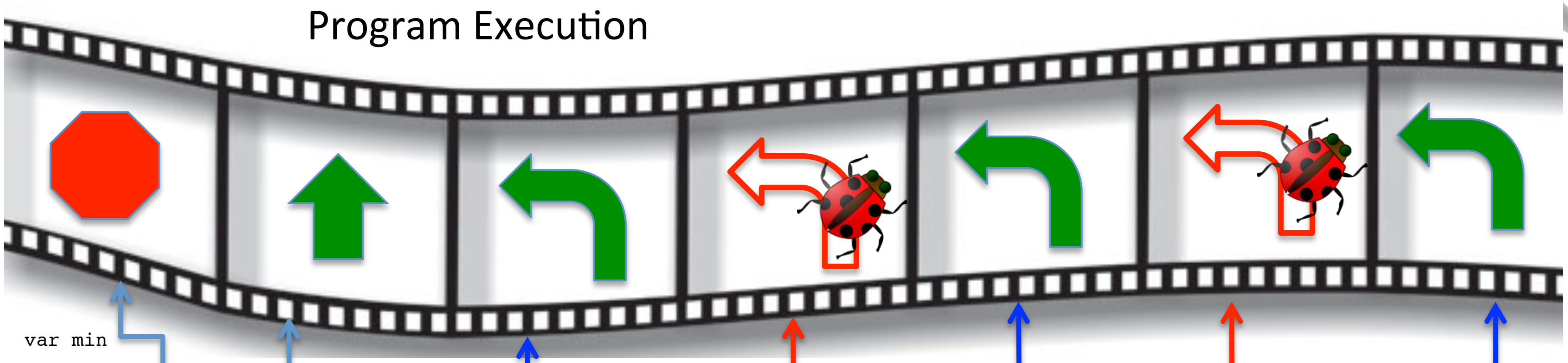
Bug Manifestation

```
var min
var max
var mean
var state = STOPPED

onevent button.forward
  state = FORWARD
  motor.left.target = SPEED
  motor.right.target = SPEED

onevent button.backward
  state = STOPPED
  motor.left.target = 0
  motor.right.target = 0
```

```
onevent prox
  call math.stat( prox.horizontal[0:4],
                  min, max, mean )

  when state== FORWARD and max > THRESHOLD do
     state = TURN
     motor.left.target = -SPEED
  end

  when state == TURN and max <= THRESHOLD do
    state = FORWARD
    motor.right.target = SPEED
  end
```

- This program fails to make the robot move forward after the robot starts to turn
- Where in the code does it fail?

Program Execution



Program Code

```
var min
var max
var mean
var state = STOPPED

onevent button.forward
  state = FORWARD
  motor.left.target = SPEED
  motor.right.target = SPEED

onevent button.backward
  state = STOPPED
  motor.left.target = 0
  motor.right.target = 0

onevent prox
  call math.stat( prox.horizontal[0:4],
                  min, max, mean )

  when STATE == FORWARD and max > 0 do
     state = TURN
     motor.left.target = -SPEED
  end

  when state == TURN and max <= 0 do
    state = FORWARD
    motor.right.target = SPEED
  end
```

How do we know what part of execution corresponds to what part of the program?

The “printf” Method

- We have two options:
  - Visually match code to execution (ok for small programs)
  - Use a mechanical procedure to narrow our search
- Goal:
  - Need to determine when we have reached specific locations in our program
  - Want the program to let us know when it has reached a specific location
- Idea:
  - Perform output when specific locations are reached
  - I.e., Turn on LEDs when our program reaches a set location

Add LED Activations

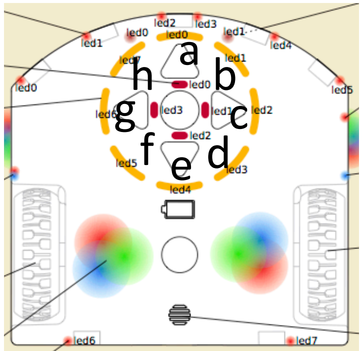
```
var min
var max
var mean
var state = STOPPED

call leds.circle(0,0,0,0,0,0,0,0)

onevent button.forward
  state = FORWARD
  motor.left.target = SPEED
  motor.right.target = SPEED

onevent button.backward
  state = STOPPED
  motor.left.target = 0
  motor.right.target = 0
```

```
onevent prox
  call math.stat( prox.horizontal[0:4],
                  min, max, mean )

  when STATE == FORWARD and max > THRESHOLD do
     state = TURN
     motor.left.target = -SPEED
  end

  when state == TURN and max <= THRESHOLD do
    call leds.circle(32,0,0,0,0,0,0,0)
    state = FORWARD
    call leds.circle(32,32,0,0,0,0,0,0)
    motor.right.target = SPEED
    call leds.circle(32,32,32,0,0,0,0,0)
  end
```

- Use the circle of LEDS on top of the robot

  `call leds.circle(a,b,c,d,e,f,g,h)`

  - Parameters range between 0 (off) and 32 (very bright)
- Run the program

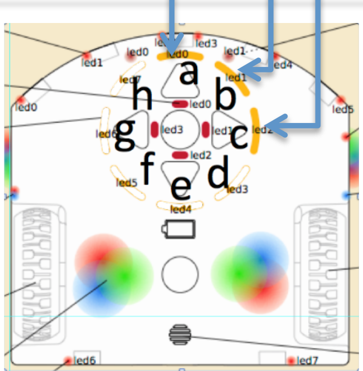


The Result

```
var min
var max
var mean
var state = STOPPED

call leds.circle(0,0,0,0,0,0,0,0)

onevent button.forward
   state = FORWARD
   motor.left.target = SPEED
   motor.right.target = SPEED

onevent button.backward
   state = STOPPED
   motor.left.target = 0
   motor.right.target = 0
```

```
onevent prox
   call math.stat( prox.horizontal[0:4],
                   min, max, mean )

   when STATE == FORWARD and max > THRESHOLD do
       state = TURN
       motor.left.target = -SPEED
   end

   when state == TURN and max <= THRESHOLD do
      call leds.circle(32,0,0,0,0,0,0,0)
      state = FORWARD
      call leds.circle(32,32,0,0,0,0,0,0)
      motor.right.target = SPEED
      call leds.circle(32,32,32,0,0,0,0,0)
   end
```

- Observation: The LEDs light up
- Therefore, the second when statement is being executed
- But the motors are not behaving correctly
- So the bug is likely in this part of the code



Deduction

- All three LEDs came on
  - Where in the program does this occur?
  - What else happens in the same part of the program?
  - Is this correct?
  - Why or why not?
- Assume: Bug is near by (not always the case)

Where is the Bug?

```
var min
var max
var mean
var state = STOPPED

call leds.circle(0,0,0,0,0,0,0,0)

onevent button.forward
  state = FORWARD
  motor.left.target = SPEED
  motor.right.target = SPEED

onevent button.backward
  state = STOPPED
  motor.left.target = 0
  motor.right.target = 0
```

```
onevent prox
  call math.stat( prox.horizontal[0:4],
                  min, max, mean )

  when STATE == FORWARD and max > THRESHOLD do
     state = TURN
     motor.left.target = -SPEED
  end

  when state == TURN and max <= THRESHOLD do
    call leds.circle(32,0,0,0,0,0,0,0)
    state = FORWARD
    call leds.circle(32,32,0,0,0,0,0,0)
    motor.right.target = SPEED
    call leds.circle(32,32,32,0,0,0,0,0)
  end
```

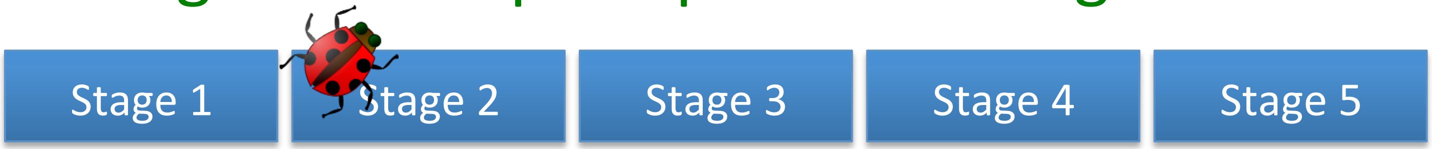
- Should be
  `motor.left.target = SPEED`
- Because the left motor was set to –`SPEED` earlier on

Drowning in Complexity

- Observations:
  - This is a simple program
  - Yet, debugging it was not easy
  - Imagine what happens with more complex programs
- Question: How do we debug large programs?
  - Sometimes bugs are not near their manifestation
  - We cannot use LEDs everywhere
    - Too few LEDs
    - Takes too long to do
  - We need to be selective
- We need a debugging strategy!

Divide and Conquer

- **Question:** How do you search a phonebook?
- **Idea:** We can search a program for bugs in the same manner
- **Observation:**
  - – Programs are linear entities
  - – Programs comprise phases or stages

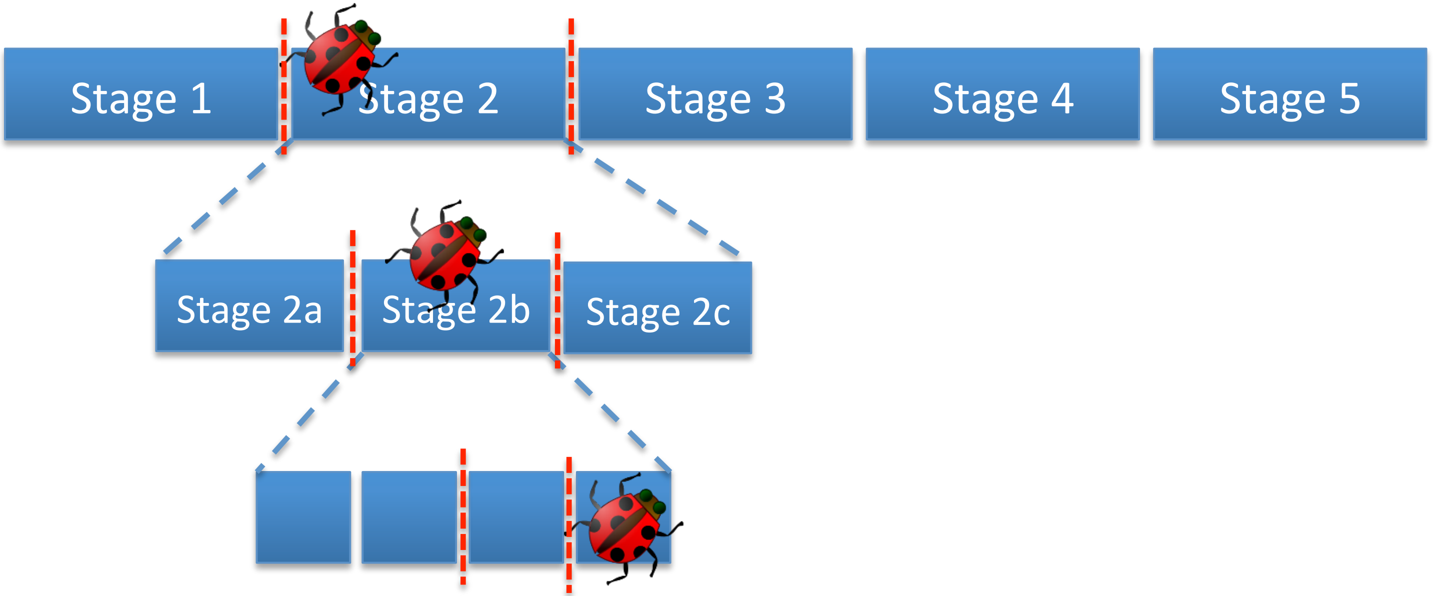


Stage 1 Stage 2 Stage 3 Stage 4 Stage 5

- **Question:** Does the bug occur before Stage 3?

Finding the Bug

Key Idea: The partitions are where you place print blocks (LEDs)



Question: What happens if the program cannot be subdivided further?

Example

```
var min
var max                          0
var mean
var state = STOPPED

onevent button.forward           1
  state = FORWARD
  motor.left.target = SPEED
  motor.right.target = SPEED

onevent button.backward          2
  state = STOPPED
  motor.left.target = 0
  motor.right.target = 0
```

```
                                                        3
onevent prox
  call math.stat( prox.horizontal[0:4],
                  min, max, mean )

  when STATE == FORWARD and max > 0 do
     state = TURN                                       3a
     motor.left.target = -SPEED
  end

  when state == TURN and max <= 0 do
    state = FORWARD                                     3b
    motor.right.target = SPEED
  end
```

Discussion

- Debugging is an art, not a science
  - It’s hard to do
  - A little different each time
  - Requires you to solve many small problems
  - Can take a long time
- There is no silver bullet (no quick fix)
- There systematic approaches to ease debugging
  - Use output to identify location of bug manifestation
  - Use “divide and conquer” to narrow your search
  - Have someone look over your shoulder (really!)

Debugging Rules of Thumb

- Bugs are likely to be found close to where they manifest
- Use an output mechanism (such as LEDs) to locate the point in your program where the bug manifests
- Use divide and conquer to narrow your search in large programs
- Use as few LEDs as possible
- Have good luck