



CSCI 1108

Debugging



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[i]=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

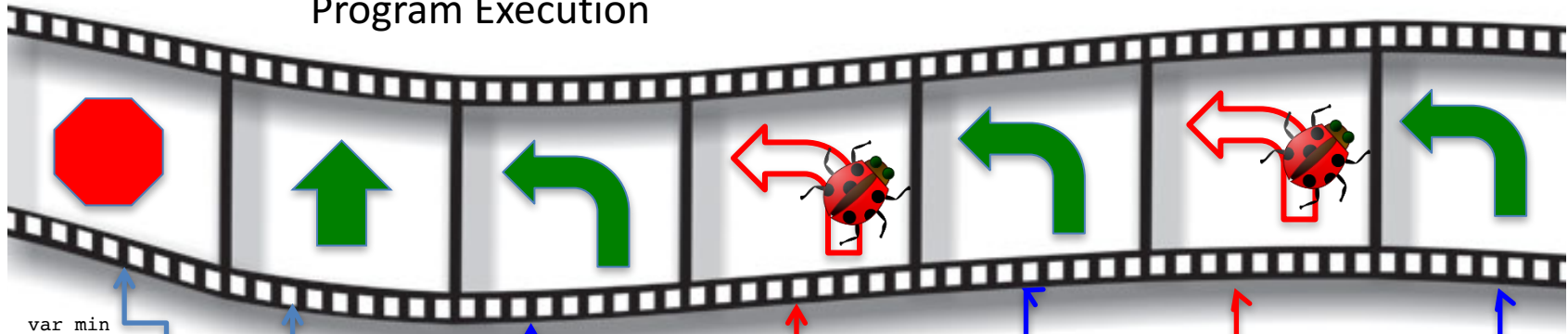
onevent prox
  call math.stat( prox.horizontal[0:4],
                 min, max, mean )

  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

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

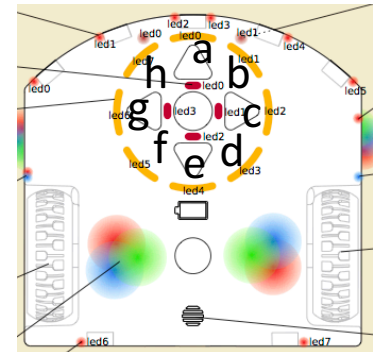
  when state == TURN and max <= THRESHOLD do
    call leds.circle(32,0,0,0,0,0,0,0)
    state = FORWARD
    call leds.circle(32,32,0,0,0,0,0,0)
    motor.right.target = SPEED
    call leds.circle(32,32,32,0,0,0,0,0)
  end
end

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
```

- 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

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

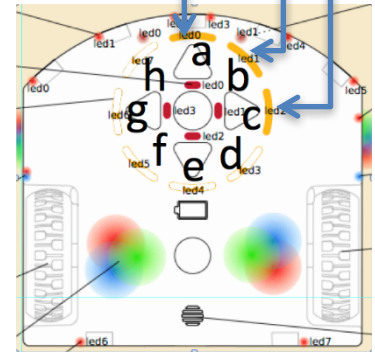
  when state == TURN and max <= THRESHOLD do
    call leds.circle(32,0,0,0,0,0,0,0)
    state = FORWARD
    call leds.circle(32,32,0,0,0,0,0,0)
    motor.right.target = SPEED
    call leds.circle(32,32,32,0,0,0,0,0)
  end
end

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
```

- 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

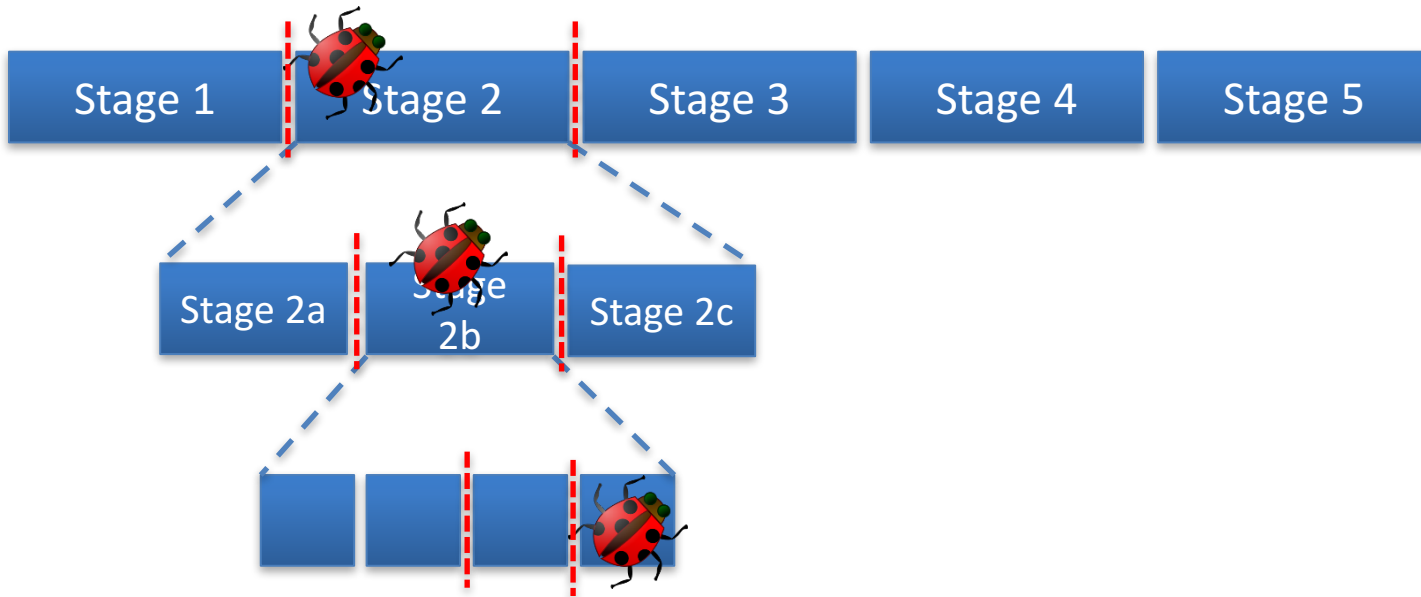
- **Question:** How do you search a phonebook?
- **Idea:** We can search a program for bugs in the same manner
- **Observation:**
 - Programs are linear entities
 - Programs comprise phases or stages



- **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  
var mean  
var state = STOPPED
```

0

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

1

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

2

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

3

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

3a

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

3b

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

- 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
- Compare closely your expectation with program output
- Have good luck