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 $x[0]=1$

```plaintext
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

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

```javascript
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
end

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

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

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
  ```javascript
  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 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
   motor.left.target = 0
   motor.right.target = SPEED
   call leds.circle(32,32,0,0,0,0,0,0)
end

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 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)

Stage 1
Stage 2
Stage 3
Stage 4
Stage 5

Stage 2a
Stage 2b
Stage 2c

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

```plaintext
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
```
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