

UNIVERSITY of WISCONSIN-MADISON
Computer Sciences Department

CS 202: Introduction to Computation Professor Andrea Arpaci-Dusseau

Why does a computer... perform operations concurrently?




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"Good luck, everyone! Maybe this will be the year somebody finishes the race!"

Variable Check-Up

```

when clicked
ask Please input x and wait
set x to answer
repeat until x = 1
if x mod 2 = 0
set x to x / 2
else
set x to 3 * x + 1
    
```

The block "x mod 2" divides x by 2 and returns the remainder. For example, "7 mod 2" returns 1 "6 mod 2" returns 0.

Even...
Odd...

What happens to the value of x over time if x is initially 2? Input x = 8? Input x =

One Sequential Script

```

when clicked
point in direction 90
clear graphic effects
switch to costume costume1
go to x: 0 y: 0
set size to 100 %
wait 1 secs
move 10 steps
turn 15 degrees
play sound meow until done
glide 4 secs to x: 150 y: 100
say Hello! for 1 secs
next costume
change color effect by 25
set size to 150 %
    
```

Blocks in one script run sequentially, in order, one after another

Good:

- Behavior is very predictable

Bad:

- No interaction with other sprites
- Not much happening

What happens with multiple scripts?

```

when clicked
point in direction 90
clear graphic effects
switch to costume costume1
go to x: 0 y: 0
set size to 100 %
wait 1 secs
move 10 steps
turn 15 degrees
play sound meow until done
say Hello! for 1 secs
next costume
change color effect by 25
    
```

```

when clicked
wait 1 secs
glide 4 secs to x: 150 y: 100
set size to 150 %
    
```

Both scripts run "concurrently"

- Appear to run simultaneously

Good: Interesting behavior
Bad: Behavior is much harder to predict

Concurrency in Scratch
Every script stack executes concurrently with all others

Why do we want concurrency?

Concurrency usually good thing:

- Can do many things at "same" time!
- Multiple Sprites can be moving at same time
- Play music in background
- Multiple Sprites can be checking different conditions
 - If key pressed
 - If touching another Sprite

Why do we want Concurrency outside of Scratch?

You want to do many things at same time

- Use web browser, itunes, word processor -- all simultaneously

Concurrency on single processor:

- Context switch quickly between active processes: Time sharing

Parallel Systems

- Multicore, multi-processors
- Distributed systems
- Multiple processes running at **same time**
- Can greatly improve performance



Today's Scenario: How to Manage Concurrency??

Imagine: You've written a great Scratch program

- Lots of interacting Sprites, variables
- Most of the time it works like you expect...

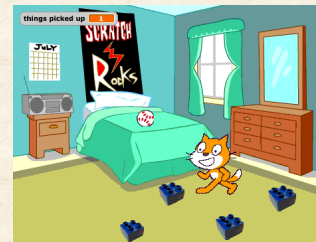
But, sometimes... Funny results

- Sprites disappear/reappear in unexpected ways
- Points don't increment
- Hard to be sure -- is something wrong or not?

Answer Today

- What is going wrong?
- How can we fix this type of problem?

Easy Points Game



User controls cat with arrow keys

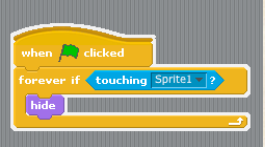
Cat picks up 6 objects for points

Game over when pick up all 6 objects


How might one implement this?

Problem: Asking Same Question Twice

Sprite 11 (baseball)



Sprite 1 (cat)



Why won't this code always work?
If ball sees "touching Sprite1" and hides first, Sprite 1 won't see "touching ball", won't increment!

Problem:
Two Sprites ask same question, and get different answers!

Solution?
Only one Sprite asks question; how?

- Ball should increment variable

Problem of Concurrency: Race Conditions!

Race condition: Ordering of instructions across scripts impacts results

Results: Sometimes get result A, sometimes get result B...

Problematic when multiple scripts access shared state

- Access + modify what appears on stage (touching vs. hiding)
- Access + modify same variables

Second Example: Monkey Game

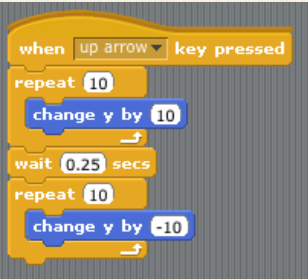
Many things happening concurrently!

- Multiple bananas falling from tree
- Thief monkey moving
- User moves monkey with keys
 - Up and l/r simultaneously
 - More efficient way to move with keys

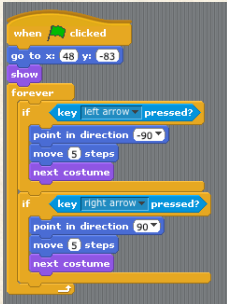


Main Character Movement

Jump: Monkey moves up, waits, moves back down



Left right movement: Lets user hold down keys



Avoiding Race Conditions

Banana Scripts

```

when clicked
show
go to x: pick random 150 to 95 y: pick random 180 to 60
forever
change y by pick random 0 to 4
if touching monkey?
change Bananas! by 1
go to x: pick random 150 to 95 y: pick random 180 to 60
if touching edge?
go to x: pick random 150 to 95 y: pick random 180 to 60
    
```

Only Banana Sprite asks question "touching"

- Increments shared variable
- Goto new position

Monkey does not ask same question

- Monkey doesn't need to know answer

Avoiding Race Conditions

Thief Script

```

when clicked
show
go to x: 163 y: -97
point in direction 90
forever
move 1 steps
if on edge, bounce
if touching monkey?
change Stolen Bananas! by Bananas!
set Bananas! to 0
say Thanks! for 2 secs
broadcast Sad Monkey
    
```

New Situation: Two Sprites need answer

Actions when Thief and Monkey meet

- Change Banana count
- Thief says Thanks
- Monkey says "Oh no!"

How to avoid Race condition?

- Only one sprite asks questions
- Broadcast message to other

Scripts for Simplified Bug on a Plate very similar (check out code!)

Monkey Script

```

when I receive Sad Monkey
say Oh no! for 2 secs
    
```

How is Concurrency Implemented in Scratch?

How does Scratch environment pick block to run next?

Repeat until all blocks completed

- Run "few" commands from each **stack**
- (Remember last position in each stack)
- Update screen

Order of stacks is unknown!

- Don't know which stack will be first or next
- Could pick different stack each time
- Cannot assume any order across stacks!
- May differ from run to run, across versions, machines, web version...

Example: No Concurrency

```

when clicked
set test to 2
set test to 0
set test to 1
set test to 3
say test for 2 secs
    
```

What will Sprite say?

Will say "3"

Blocks WITHIN script run sequentially (in order)

Example: Concurrent Initialization

Multiple stacks initialize same variable (test)

What will Sprite say?
Could say 0, 1, 2, 3 or 4!

Conclusion:
Cannot make any assumption about stack ordering

Example: How many Meows?

Confused Cat Scripts

How many meows?
Could be 0, 1, or 5!

How to ensure initialize correctly? (assume want test = 5 before repeat loop)

Must control order blocks are executed

Easiest Fix: Remove Concurrency

Single script does everything No concurrency within a script

Blocks in single script execute in order

Guaranteed to initialize variables before entering repeat loop

Doesn't work if multiple initial scripts use "test" variable

How to have multiple Sprites access same variable?

Problem Statement
Cat and Duck Sprite can each meow (or quack)
Ask user how many times they should "talk"

Both should "talk" that number of times

Stage

Cat

Duck

How do we reason about Concurrency?

Problem:

Difficult to build programs when no assumptions about switches between stacks

Solution:

Atomic operation: Will not be interrupted in the middle

Scratch: Each command block executes atomically except:

Blocks that wait

- Specified amount of time
 - Examples: "wait," "glide", "say"
- For something to finish
 - Examples: "play sound and wait", "broadcast and wait"



Are Multiple Blocks in Same Script Atomic?

Scratch executes some number of blocks in each stack before moving to next stack

Scratch runs all blocks in one stack until

- Reach end of stack
- Reach waiting or time-based block
- Reach end of innermost loop
 - Might or might not choose to continue running same stack!

Example: move, next costume, turn: Atomic

What happens with multiple scripts?

when clicked

point in direction 90

clear graphic effects

switch to costume costume1

go to x: 0 y: 0

set size to 100 %

wait 1 secs

move 10 steps

turn 15 degrees

play sound meow until done

say Hello! for 1 secs

next costume

change color effect by 25

when clicked

wait 1 secs

glide 4 secs to x: 150 y: 100

set size to 150 %

Cat will go to initial position and wait for 1 second
 While cat is gliding it will:
 turn, meow, say hello, switch costumes, and color
 When done gliding, will increase size

Check-Up

when clicked

forever

turn 15 degrees

move 10 steps

when clicked

forever

change color effect by 25

play sound Cave until done

- Will two scripts run concurrently?
- Will cat turn while Cave music is playing?
- Will cat move while Cave music is playing?
- Will cat change colors while Cave music is playing?

Announcements

Feel free to work in 1370 at any time

Day	Time	Instructor or TA	Room
Mon	11:00 - 12:00	Prof. A Arpaci-Dusseau	CS 7375 (office)
Tue	12:30 - 2:25	Thea Hinkle	CS 1370 (lab)
Wed	11:00 - 12:00	Prof. A Arpaci-Dusseau	CS 7375 (office)
Wed	12:00 - 2:00	Victor Bittorf	CS 1370 (lab)
Thurs	4:15 - 6:15	Thea Hinkle	CS 1370 (lab)
Friday	11:00 - 1:00	Victor Bittorf	CS 1370 (lab)

Homework 3 due Monday

- Should be able to do all 3 parts now
- Ideas for sharing Interactive Stories???