Why does a computer... perform operations concurrently?

Variable Check-Up

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...

One Sequential Script

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?

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

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

when up arrow key pressed
repeat: 10
change y by 10
wait 0.25 sec
repeat: 10
change y by -10

when l/r arrow key pressed
forever
point to direction
move 1 step
wait 0.25 sec
forever
next instruction
Avoiding Race Conditions

Banana Scripts

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

New Situation: Two Sprites need answer

Thief Script
- 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!)

Avoiding Race Conditions

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

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
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?

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

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

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<thead>
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<th>Day</th>
<th>Time</th>
<th>Instructor or TA</th>
<th>Room</th>
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<tbody>
<tr>
<td>Mon</td>
<td>11:00 - 12:00</td>
<td>Prof. A Arpaci-Dusseau</td>
<td>CS 7375 (office)</td>
</tr>
<tr>
<td>Tue</td>
<td>12:30 - 2:25</td>
<td>Thea Hinkle</td>
<td>CS 1370 (lab)</td>
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<tr>
<td>Wed</td>
<td>11:00 - 12:00</td>
<td>Prof. A Arpaci-Dusseau</td>
<td>CS 7375 (office)</td>
</tr>
<tr>
<td>Wed</td>
<td>12:00 - 2:00</td>
<td>Victor Bittorf</td>
<td>CS 1370 (lab)</td>
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<td>4:15 - 6:15</td>
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<td>11:00 - 1:00</td>
<td>Victor Bittorf</td>
<td>CS 1370 (lab)</td>
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Homework 3 due Monday

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