

CS50's

Understanding Technology

OpenCourseWare

Donate  (<https://cs50.harvard.edu/donate>)

David J. Malan (<https://cs.harvard.edu/malan/>)

malan@harvard.edu

 (<https://www.clubhouse.com/@davidjmalan>)  (<https://www.facebook.com/dmalan>)

 (<https://github.com/dmalan>)  (<https://www.instagram.com/davidjmalan/>) 

(<https://www.linkedin.com/in/malan/>)  (<https://orcid.org/0000-0001-5338-2522>) 

(<https://www.quora.com/profile/David-J-Malan>) 

(<https://www.reddit.com/user/davidjmalan>)  (<https://www.tiktok.com/@davidjmalan>)

 (<https://davidjmalan.t.me/>)  (<https://twitter.com/davidjmalan>)

Programming

by Spencer Tiberi

Introduction

(<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=0m9s>)

- David plays a game called Oscartime that was the first Scratch program he created
- Scratch is a graphical programming language created by MIT's Lifelong Kindergarten Group
- The language not only helps get kids excited about programming, but it's also very instructive

Software

<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=1m9s>

- Programming is ultimately about making software
 - Software is what runs on our hardware
 - Could run on a desktop, or phone, etc.

Finding Mike Smith

<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=1m44s>

- Code is just a technical implementation of algorithms
 - Algorithms are step by step instructions for solving problems
- Consider a phonebook full of thousands of names and phone numbers
- How do we lookup someone like Mike Smith?
 - We could start at the first page, move to the next, and so on until we find him
 - This is a correct algorithm, as we will find Mike Smith eventually
 - However, it's inefficient
 - We could start at the first page and count by 2s
 - I would find Mike Smith twice as quickly
 - However, this alone is not correct as we could miss Mike Smith if his name is sandwiched between two pages
 - We could fix this by checking the previous page if we go past where Mike Smith should be
- More likely, we'd probably go to the middle of the phonebook and find ourselves in the "M" section
 - As Smith is after M, he must be in the latter (right) half of the book
 - We can ignore the other half
 - After removing the other half, we are left with half of the book, representing the same problem we started with fundamentally
 - We can keep repeating this process until we're down to one page with Mike's number on it
 - This leverages the fact that the book is sorted alphabetically
 - We are deviding and conquering

- 1000 pages → 500 pages → 250 pages → 125 pages...

Phonebook Algorithm

<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=6m1s>

```
1 pick up phone book
2 open to middle of phone book
3 look at names
4 if Smith is among names
5     call Mike
6 else if Smith is earlier in book
7     open to middle of left half of book
8     go back to step 3
9 else if Smith is later in book
10    open to middle of right half of book
11    go back to step 3
12 else
13    quit
```

Pseudocode

<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=7m40s>

- This example algorithm is code, not written in a programming language, but rather English
- This is called Pseudocode
 - Code-like syntax written in English
 - Numbered lines to maintain order and reference lines
 - `pick up`, `open to`, `look at`, `call`, `open`, and `go back` are functions
 - `if`, `if else`, and `else` are conditions
 - `Smith is among names`, `Smith is earlier in book`, and `Smith is later in book` are Boolean expressions
 - Can be either true or false
 - If these are true, the indented code below is executed
 - Both line 8 and 11 say to go back to step 3
 - This creates a loop
 - Doing the same thing again and again

Programming Constructs

<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=10m45s>

- These constructs of loops, Boolean expressions, functions, and conditions as well as others such as variables, threads, events, and more are common across all programming languages

C

<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=11m35s>

- C is one of the oldest programming languages that someone might still write in

```
#include <stdio.h>

int main(void)
{
    printf("hello, world\n");
}
```

- Some of this syntax may look cryptic, but you can likely guess what it does
 - It prints “hello, world” to the screen
 - The other details can be learned
 - Just like with written human languages that are foreign, you just haven’t learned the patterns yet
- Many programming languages have similarities, so it becomes easier to learn new ones with knowledge under your belt
- Ultimately, programming is about writhing software to control hardware to solve a problem
- However, computers only understand binary (0’s and 1’s)
 - Source code what we humans write and it can be converted into machine code (0’s and 1’s)
 - This is achieved by using a program called a compiler
 - This allows a human to write the code and a machine to read and run it

C++

<https://video.cs50.net/cscie1a/2017/fall/lectures/programming>

[ng?t=16m0s\)](#)

```
#include <iostream>

int main()
{
    std::out << "hello, world" << std::endl;
}
```

- This program written in C++ still prints “hello, world”
- Many programming languages do the same things differently
 - We can solve the same problem using any different number of languages
 - It could be easier to use one programming language for a specific problem
 - Different languages were invented to tackle different kinds of problems

Python

[https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=17m26s\)](https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=17m26s)

```
print("hello, world")
```

- Straightforwardly, this prints “hello, world”
- Python is a different type of language as you don’t type source code and manually convert it into machine code
 - A special program called an interpreter converts the source code into an intermediate language called byte code
 - Which is not machine code (0’s and 1’s)

2	0 LOAD_GLOBAL	0 (print)
	3 LOAD_CONST	1 ('hello, world')
	6 CALL_FUNCTION	1 (1 positional, 0 keyword pair)
	9 POP_TOP	
	10 LOAD_CONST	0 (None)
	13 RETURN_VALUE	

- The interpreter reads this one line at a time
- The takeaway from this is that there different ways of doing the same thing in many different languages
 - And languages get used in different ways!
 - Sometimes you need to compile code, sometimes you need to interpret code

- At the end of the day, the consumer interacts with the software in the same way
 - They don't need to know what language it's written in as long as it runs on their computer
 - Programs are often packaged differently for different operating systems

Other Programming Language

<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=20m38s>

■ Java

```
class Hello
{
    public static void main(String [] args)
    {
        System.out.println("hello, world");
    }
}
```

■ Ruby

```
puts "hello, world"
```

■ Lisp

```
(print "hello, world")
```

■ JavaScript

```
console.log("hello, world")
```

Introducing Scratch

<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=21m24s>

- Each of these languages has a lot more features, but they have commonalities
 - Functions, loops, conditions, Boolean expressions, variables, threads, etc.
- To focus on these ideas in a graphical manner, we'll explore Scratch
- In the earlier Oscartime example, trash was moving down the screen
 - A screen is just a grid of pixels
 - To make animation, we move an image on it slightly

- If done quickly, it looks like movement
- To make the trash stop at the bottom of the screen, we use some Boolean expression and condition
 - “If you’re touching the bottom of the screen, stop moving”
 - Or “Only if you’re not touching the bottom of the screen, keep moving”
- When trash is put in the can, the lid lifts and Oscar counts the pieces of trash disposed of
 - The sprite for Oscar is using a variable
 - Initialized (set initially) to 0
 - Increments (adds 1 to the variable) for each piece of trash
 - A condition is also used here
 - “If a piece of trash is added, then increment the variable for trash pieces”
- The music was playing in some kind of loop
- Even though this program is complex enough to take 8 hours to make, it’s ultimately built with the same fundamental building blocks of conditions, loops, etc.

hello, world in Scratch

(<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=26m3s>)



- This is how we say “hello, world” in Scratch
 - By default, a graphical cat will preform this code
 - Can change the cat into other things



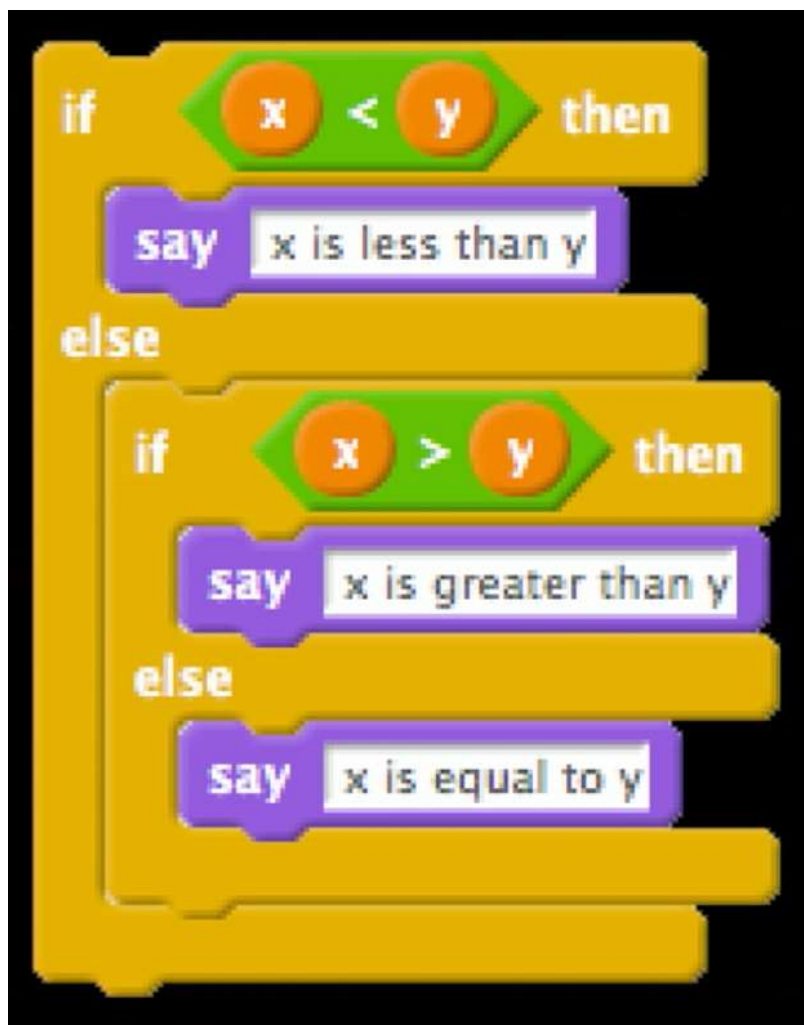
- This is the function for say



- This says "hello, world" forever



- This says "hello, world" 50 times

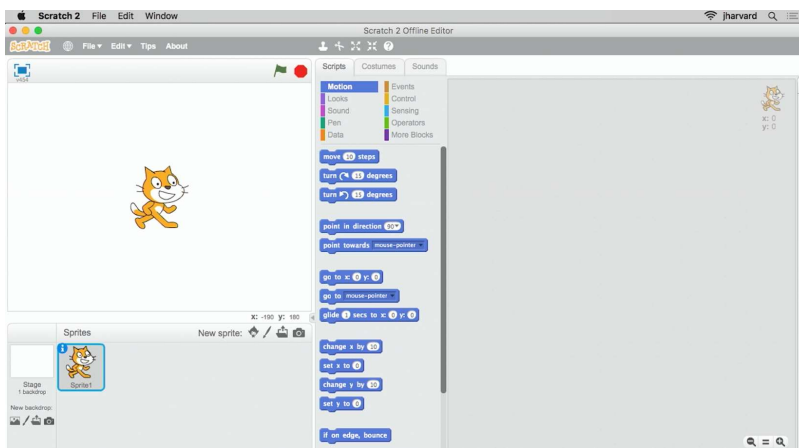


- This is an example of how to specify things conditionally
- Scratch allow you to programing by piecing together puzzle pieces with shapes that imply what to do
- We can put an if else inside another if else
- The green blocks are Boolean Expressions

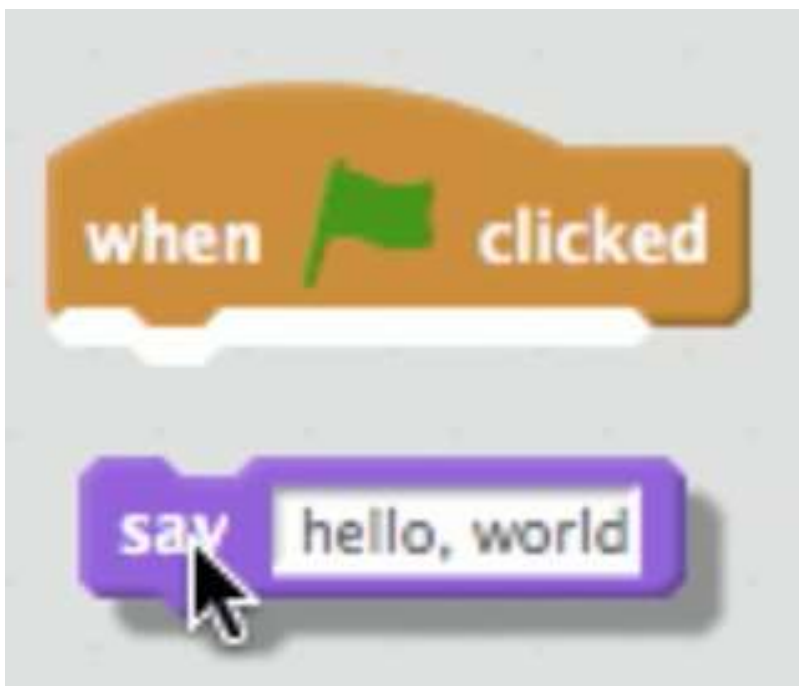
Scratch Interface

(<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=28m51s>)

- Scratch is not only a language but a programming environment as well



- On the left is Scratch the cat in a 2D world with height and width
 - Can change background and more sprites to this world
- In the middle are palettes containing scripts
 - Blue are motion blocks
 - In the costumes tab we can change aesthetics
 - The sounds tab can introduces sounds and multimedia
- The blank slate on the right is where we can drag and drop the puzzle pieces and connect them in order to instruct Scratch to do things
- `when green flag clicked` is equivalent to the start of your program
 - The green flag button starts, the red stop sign button ends
- When we drag blocks together, the edge of the block glows white to signify they connect

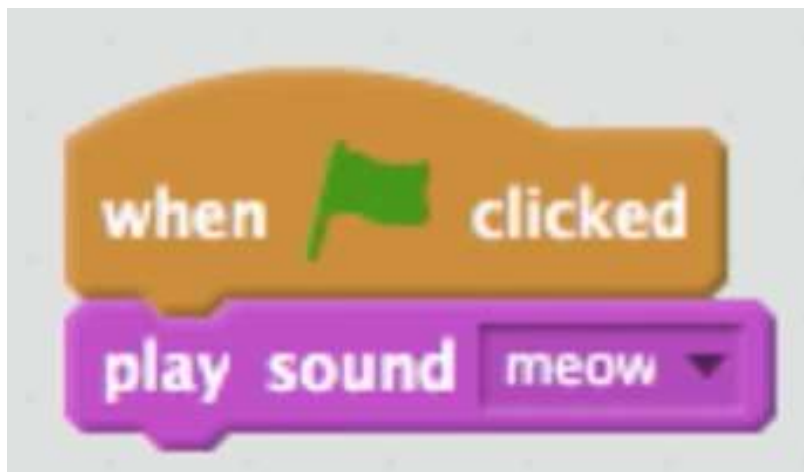


- The hello, world Scratch program won't stop until we click the red stop sign as we never told Scratch to stop in the script

Sounds

(<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=31m32s>)

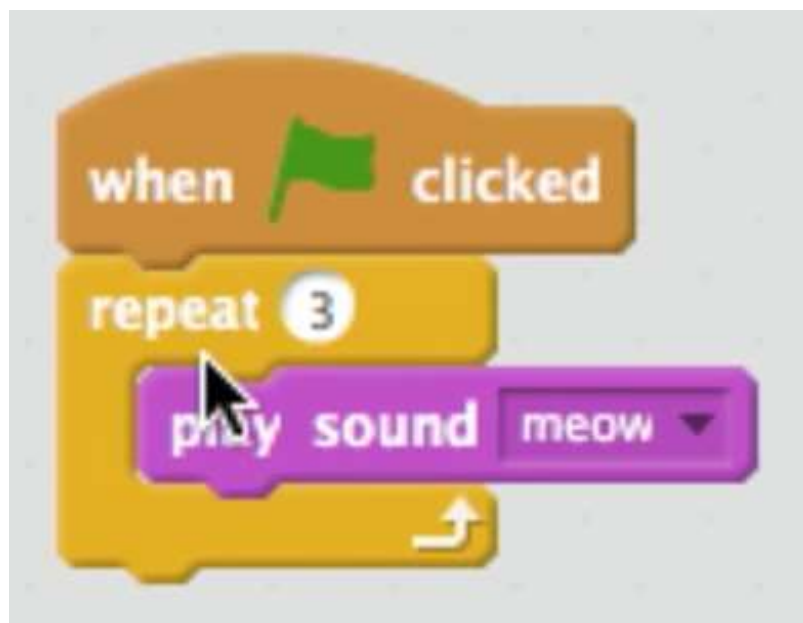
- We can also add sounds



Loops

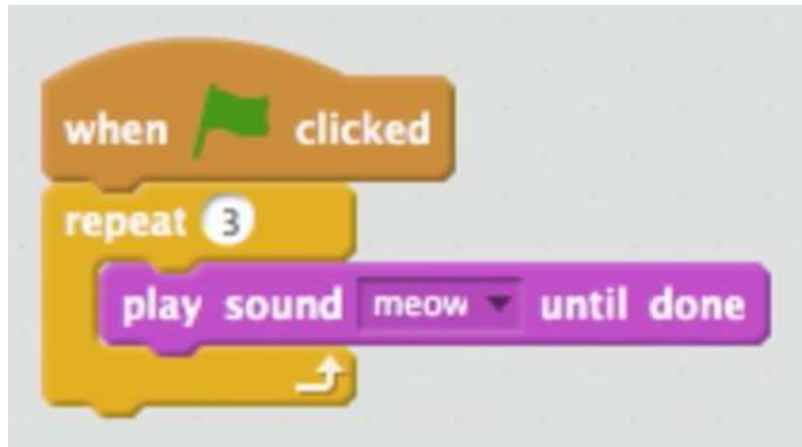
(<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=32m30s>)

- If we want Scratch to do something repeatedly, we can use loops
 - Can move the sound into a repeat block
 - The containing block will grow to fit



- This seems to only ply the meow once

- The sound repeats so quickly they overlap

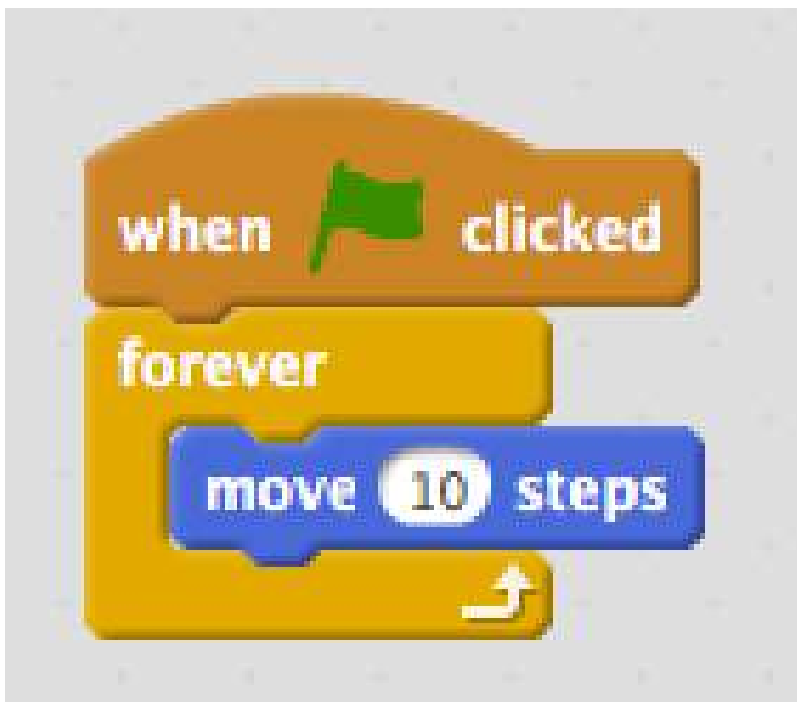


- This one plays the sound until done before the next cycle in the loop
- This process was an example of a common and frustrating experience when programming: bugs

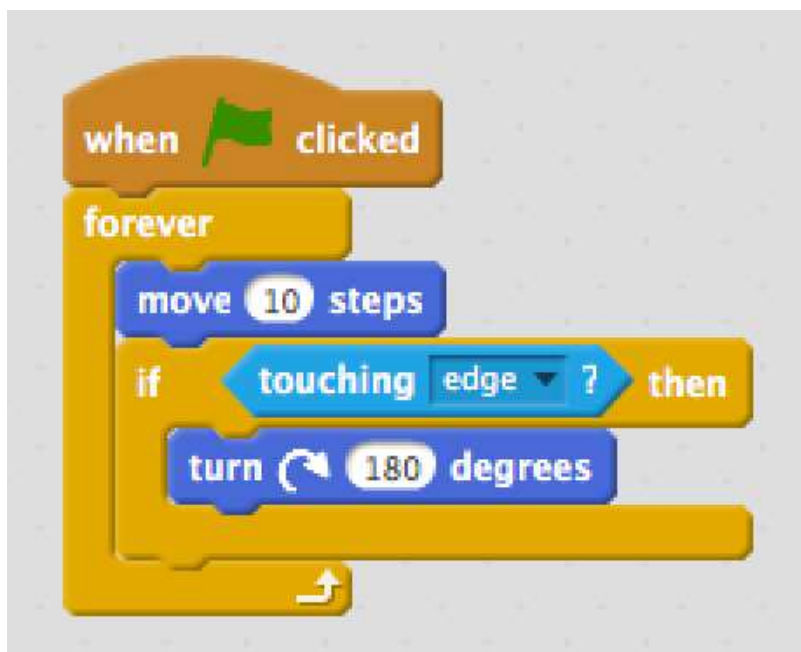
Animation

(<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=37m25s>)

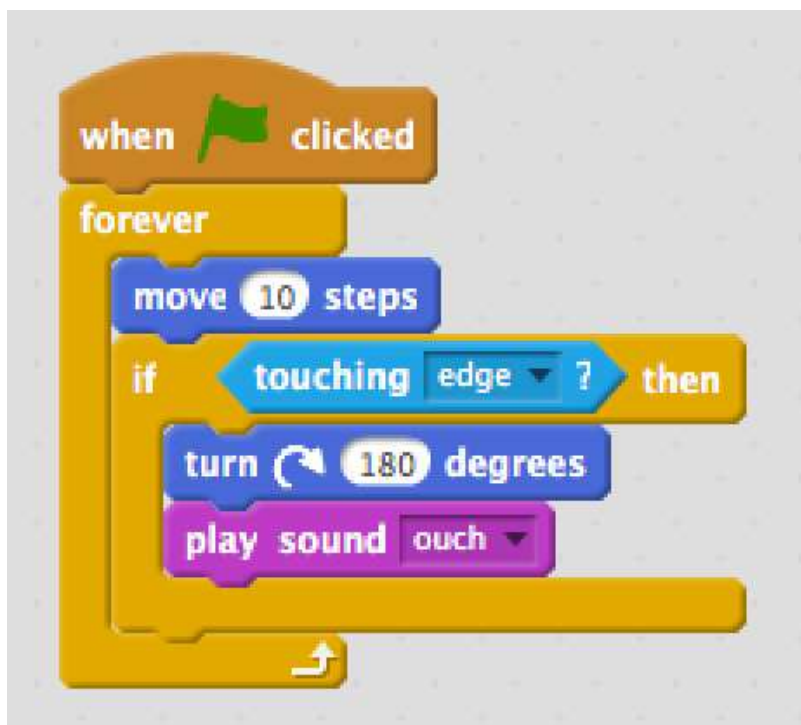
- I want the cat to move back and forth forever



- This moves the Scratch the cat forward (to the right) until he hits the edge
 - If we drag the cat back, he'll keep moving forward



- Scratch will now rotate 180° if touching the edge of the screen
 - But scratch is flipping upside down (literally rotating 180°)
 - Another bug!
- We can record custom sounds under the sounds tab and add it



Breaking Down Problems

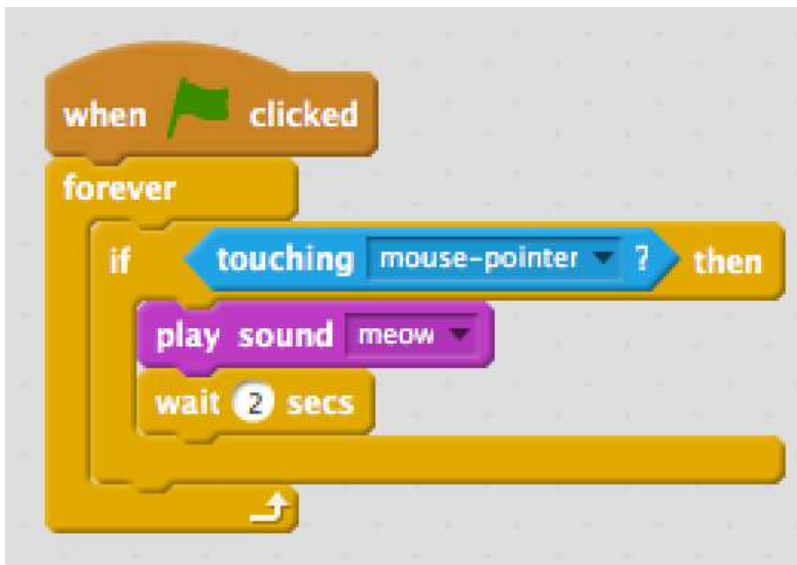
(<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=41m53s>)

- Its much easier to write complex programs if you start out by breaking them down into their component parts
 - Consider individual milestones for yourself
- Even companies like MS didn't create Word in a day
 - Software developers make one small feature at a time
 - Eventually, this becomes millions of lines of code

pet the cat

<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=43m4s>

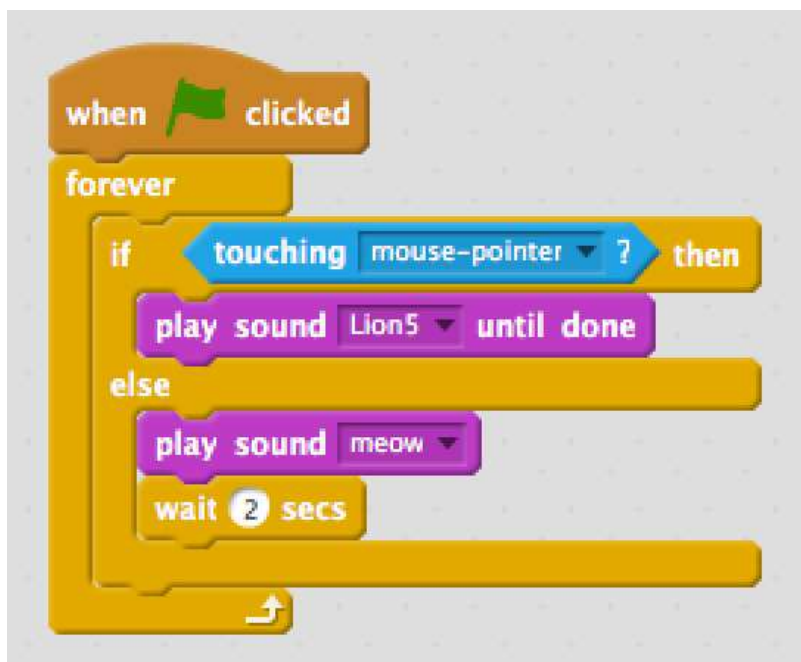
- Reading and understanding code is another side of software development
 - Teams need to do this to collaborate



- When this program starts, nothing happens until the mouse pointer touches the cat, in which the cat meows

don't pet the cat

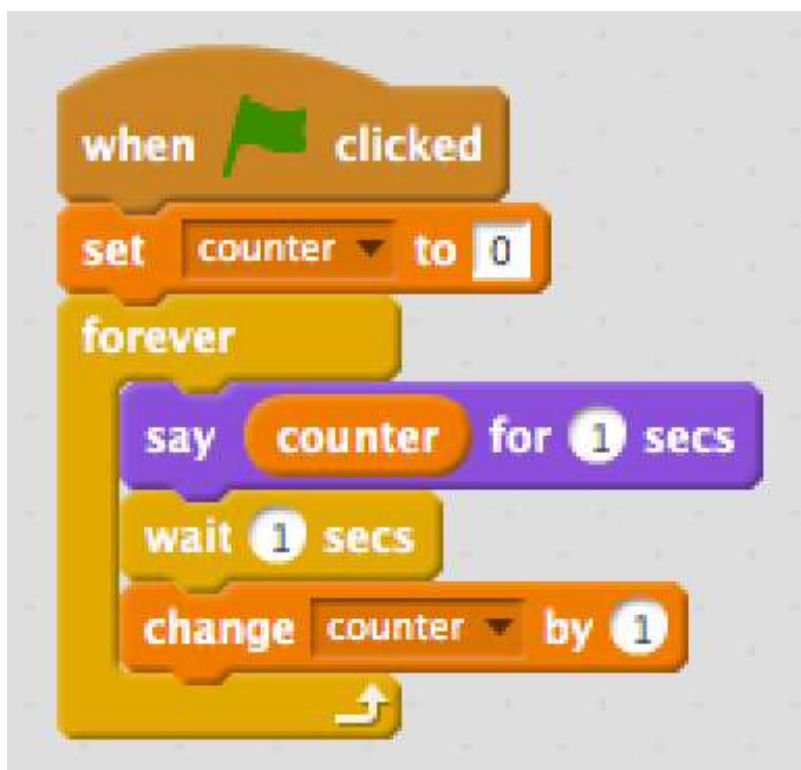
<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=43m4s>



- This script has an `if else`
- Will play a lion's roar if the mouse pointer touches the cat, but will meow and wait 2 seconds if not

counting sheep

(<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=46m27s>)

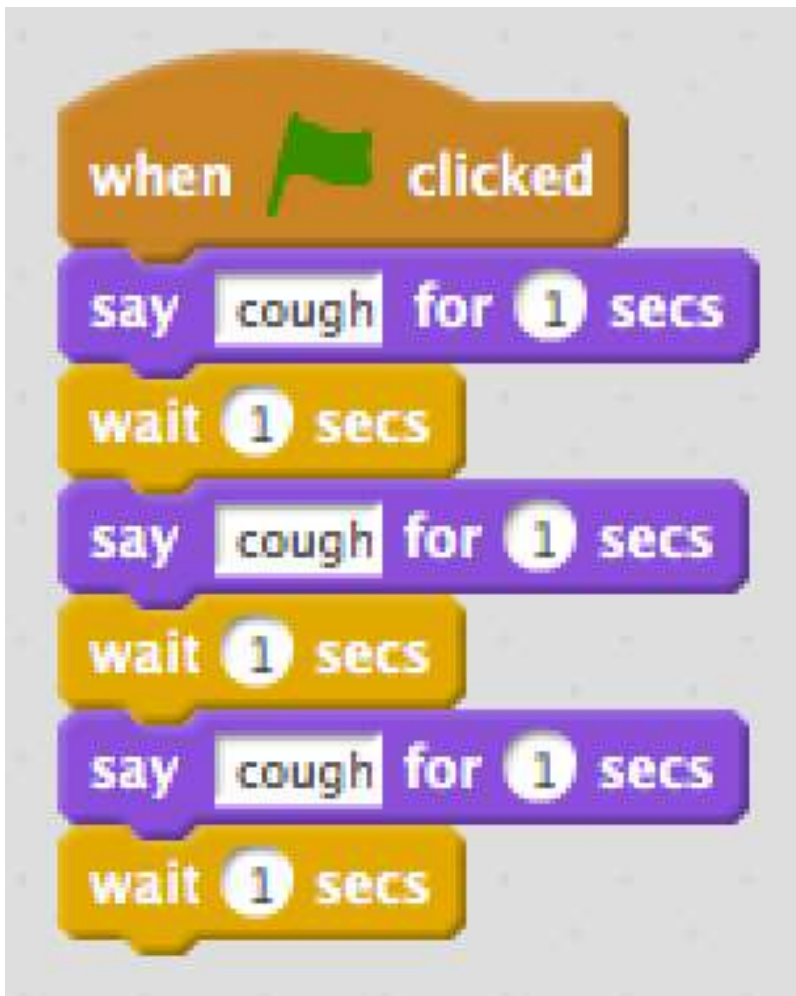


- This first sets a variable called `counter` to 0
- It will forever say counter for 1 second, wait one second, then increment the counter
- Ultimately, this will count forever

cough0

(<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=48m9s>)

- We can create our own puzzle pieces
 - We can do this in most programming languages
 - Where we create functions
 - In scratch we can utilize the functionality of existing puzzle pieces

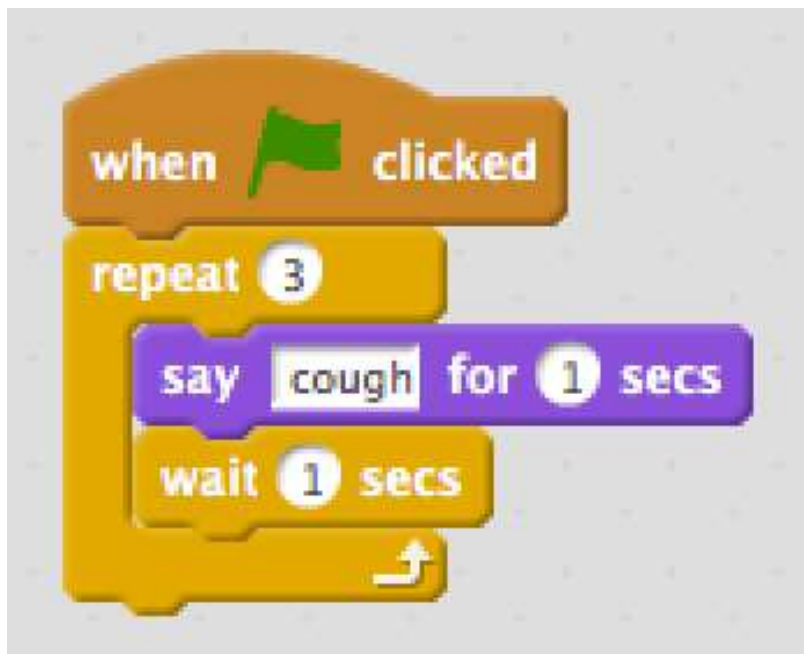


- There is an opportunity for better design here
 - IT looks like we've copied and pasted puzzle pieces

cough1

<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=49m55s>

- We can improve this with loops



- Better design as we can change what the cat is saying or the wait time in one place

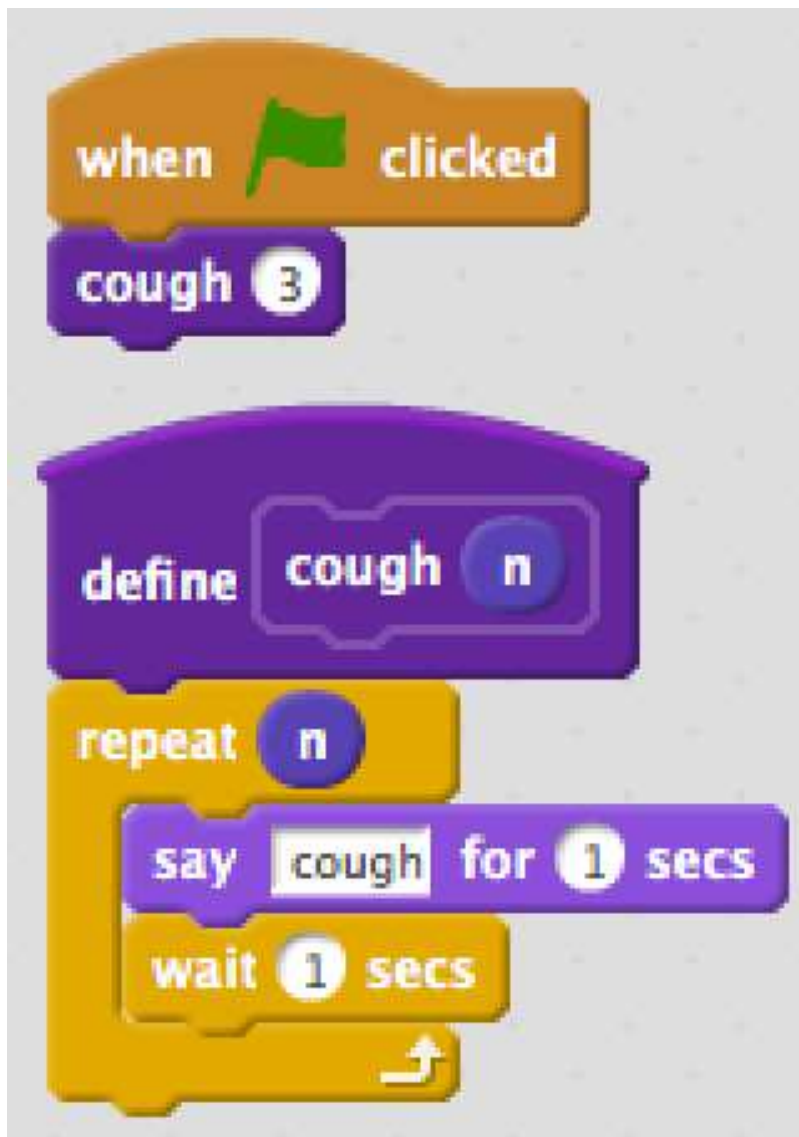
cough2

<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=50m31s>

- What if I just want a puzzle piece to make any sprite cough?
 - Gain the ability to share the functionality to use elsewhere



- We've defined a new block called `cough`
 - We repeat `cough` 3 times, abstracting away the complexity



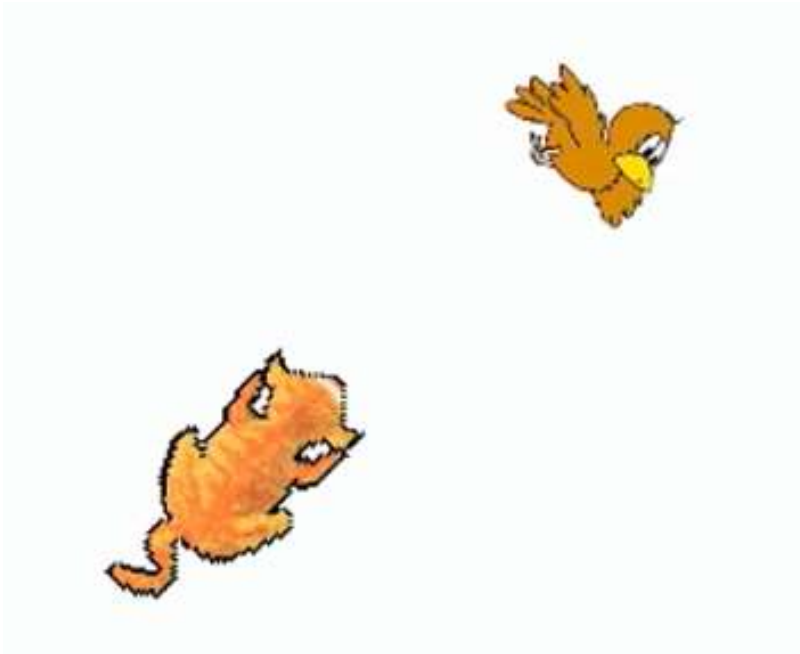
- We can go even further by passing in a value to your custom block
 - This value is called an argument or parameter
 - For example, the say block takes in an argument of “hello, world” or some other phrase
- Whatever the user passed into `cough` will replace `n`!
- The evolution of this program is an example of what it’s like to program and solve problems
 - There were opportunities to improve from a correct yet poor design
 - To be good at programming is to be able to notice opportunities like this

Threads

<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=55m21s>

- In Scratch, we can have multiple sprites, each with their own scripts

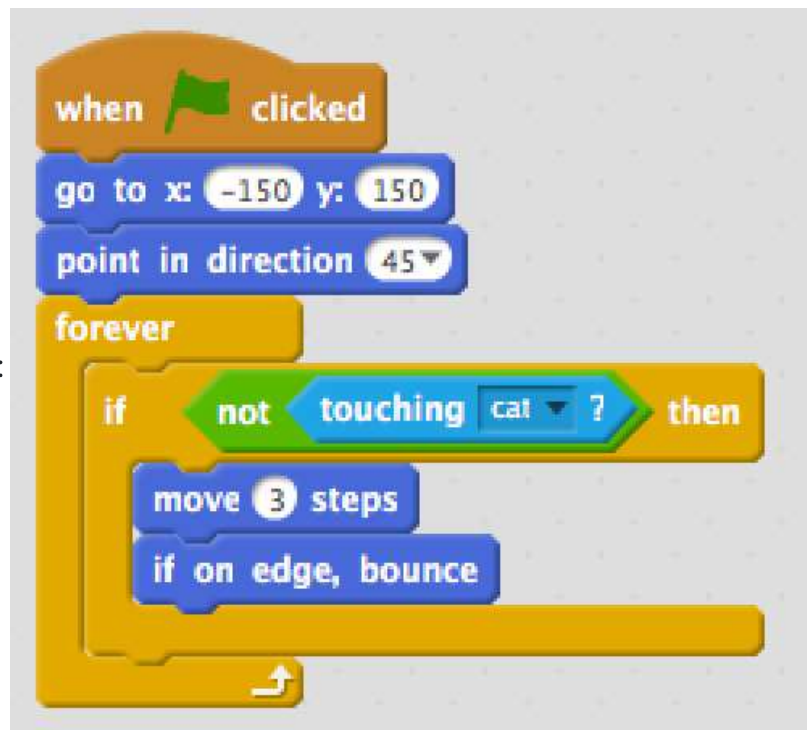
- Two things will happen simultaneously, called threads



- This program has a cat chasing a bird

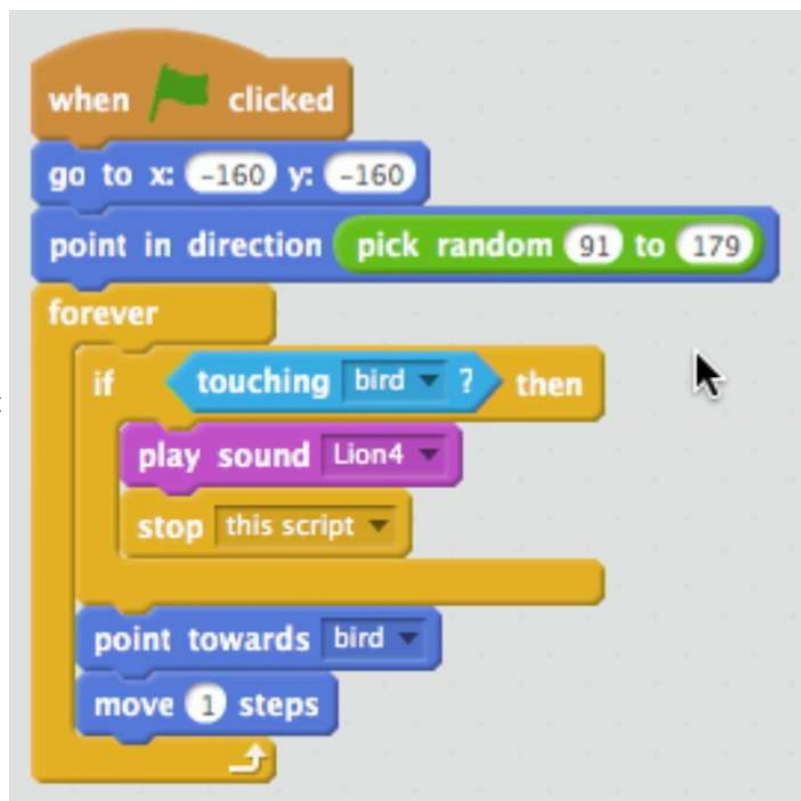
■

Here's what guides the bird:



- Location in the world can be addressed with coordinates
- Will keep moving around if not touching the cat

Here's what guides the cat:

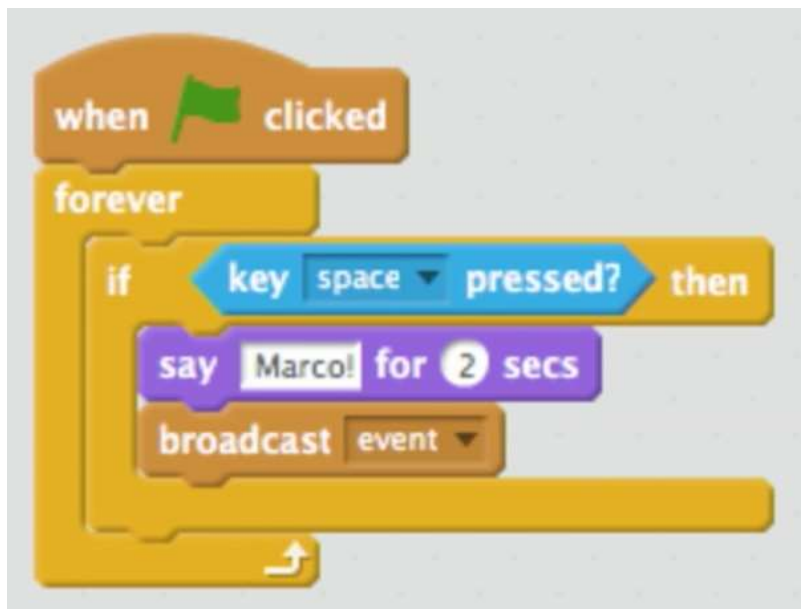


- The cat will point in a random direction
- Forever checks if touching the bird and moves towards the bird
 - If touching the bird, a lion's roar will play and the script will stop
- If we increase the movement speed of the bird to 6 steps, it still gets caught
- If we increase the movement speed of the cat to 10 steps, the bird stands no chance!

Events

(<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=59m52s>)

- A computer can do multiple things at a time due to multithreading
 - Now that computers have multiple cores, they can literally do two things at once
 - However, computers are so fast that even if two things are technically not happening at the same time, we can't notice the difference
 - These threads can also intercommunicate in Scratch with events



- This sprite (an orange puppet) will forever check for the spacebar being pressed
 - If this happens, the sprite will say “Marco!” for 2 seconds and broadcast `event`
 - Events are messages only the computer can hear
 - If another sprite is configured to listen for `event` it can respond



- This sprite will say “Polo!” for 2 seconds if it hears `event`



- When the green flag is clicked, the orange puppet will wait for the spacebar and then tell the other sprite when to say “Polo!”
- This idea allows two sprites to interact in such a way that one sprite does something only if the other does something first

Closing Thoughts

(<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=1h3m19s>)

- Programmers in the real world don't typically program by dragging and dropping code blocks
 - They write textual lines of code (C, Java, Python, etc.)
 - However, the ideas are fundamentally identical
 - Scratch gets rid of the syntactical distractions
- Understanding functions, loops, conditions, variables, etc. provides a fundamental understanding of what it's like to program
- We focused on imperative or procedural programming, but other types of programming exist as well
 - Object oriented programming
 - Functional programming
- Even in all these different ways of programming, we are still utilizing the same basic building blocks we've explored in Scratch
 - We can assemble these building blocks to solve problems
- Oscartime was a complex game
 - Zooming in, we see these basic concepts
 - Forever loops make the trash fall, an if conditions to raise the lid of the trash, etc.
- There are many more languages out there
 - https://en.wikipedia.org/wiki/List_of_programming_languages
(https://en.wikipedia.org/wiki/List_of_programming_languages)
 - There tend to be trends in the industry
 - A programmer typically has one or a few languages that they reach for to tackle a problem
 - Good to introduce yourself to new languages
 - They are easier to learn than spoken or written languages as the ideas persist

It's Raining Men

(<https://video.cs50.net/cscie1a/2017/fall/lectures/programming?t=1h6m53s>)

- David closes it all with another Scratch project