

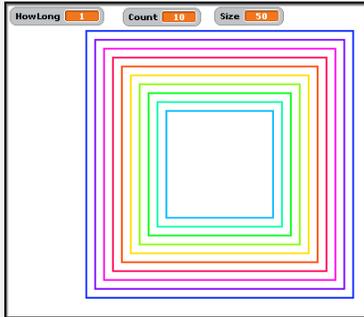
# Scratch Programming

<http://cs.oregonstate.edu/~mjb/scratch>



Oregon State University  
Mike Bailey

mjb@cs.oregonstate.edu



scratch.pptx

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## Here's What These Notes Are Going to Cover ☺



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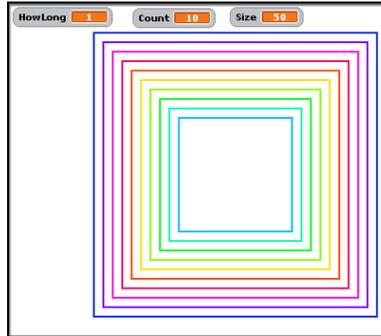
### What is "Scratch"?

3

Scratch is a programming environment that lets you create your own artwork and animations. It's easy and it's fun! It also teaches you the fundamentals of programming, possibly without you realizing that's what you are doing.

Scratch was developed at MIT. It is free, and runs on Windows, Mac, and Linux machines. There is now also a web browser-only version.

In these notes, we will write a program that makes spiraling squares that change color. This is just a start -- you can do lots more than this!



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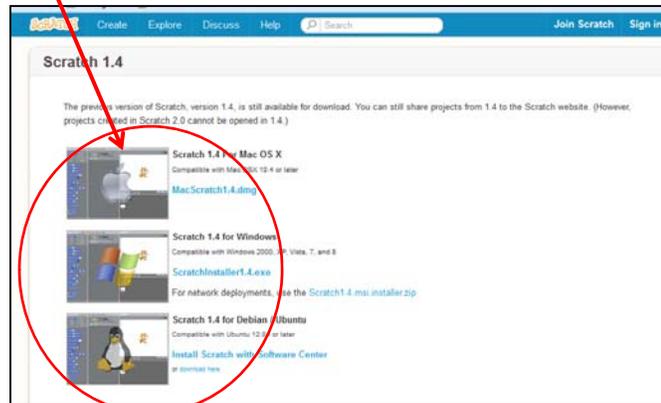
### How Can You Get Scratch 1.4 for Free?

4

Scratch is free. To download it, go to the Scratch web site:

[http://scratch.mit.edu/scratch\\_1.4/](http://scratch.mit.edu/scratch_1.4/)

and click here on one of these:



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### How Can You Get Scratch 2.0 for Free?

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Scratch 1.4 is very stable and has the features you most want to use. However, there is a new Scratch 2.0 that has some new features you might have fun with (e.g., cloning, code blocks). Download it at:

<http://scratch.mit.edu/scratch2download/>

You can also get a web browser-based version of Scratch 2.0 at:

<http://scratch.mit.edu/projects/editor/>

Explanations of some of the new Scratch 2.0 features are found later in these notes.

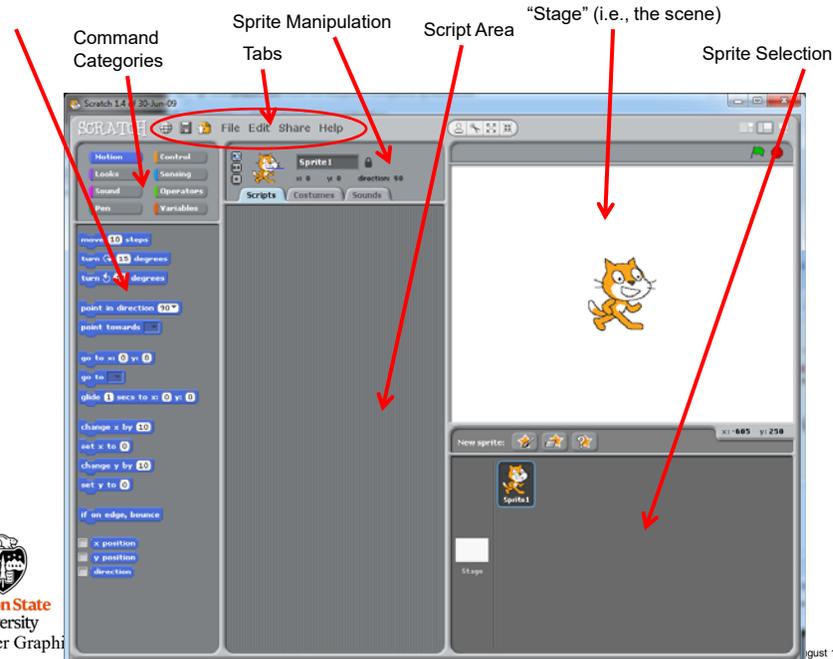


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### Scratch Screen Layout

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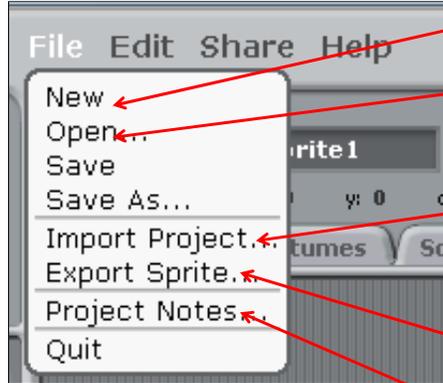
Commands in a Selected Menu



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### Menu Tabs -- File

7



Abandon the current project and start a new one

Abandon the current project and open an existing one

Without abandoning the current project, bring an existing one in and assign all its properties (including its scripts) to a new sprite

Write out all of the information about the current sprite

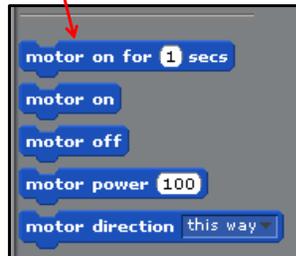
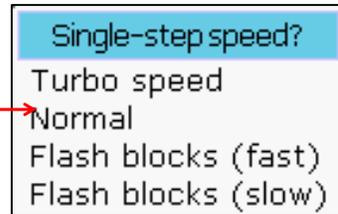
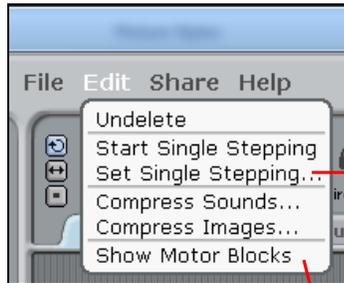
Brings up a notepad for you to record information about this project



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### Menu Tabs -- Edit

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### Menu Tabs -- Share

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The screenshot shows the 'Share' menu with options: 'Share This Project Online...', 'Go To Scratch Website...', and 'Share Project on Twitter...'. A red arrow points from the 'Share This Project Online...' option to the 'Upload to Scratch Server (scratch.mit.edu)' dialog box. The dialog box contains fields for 'Your Scratch website login name:', 'Password:', and 'Project name:'. It also has checkboxes for 'Animation', 'Art', 'Game', 'Music', 'Simulation', and 'Story', a 'Project notes' text area, and a 'Compress sounds and images' checkbox. 'OK' and 'Cancel' buttons are at the bottom right.

  
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### Menu Tabs -- Help

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The screenshot shows the 'Help' menu with options: 'Help Page...', 'Help Screens...', and 'About Scratch...'. The 'Help' menu is highlighted, and the 'Help Page...' option is selected.

  
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### Icons 11

  
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### A Good Way to Start Any Program – A Collection of Comments Describing What You Are Trying To Do 12

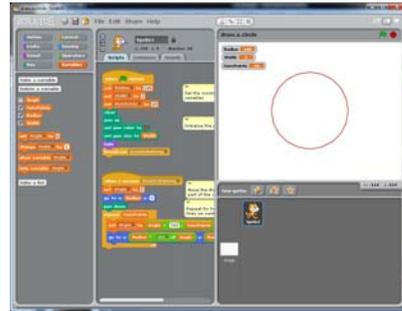
  
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```

Set the constant variables
Initialize the pen
Move the the +x part of the circle
Repeat for however many lines we want to use
Increment the angle
Draw to Rcos,Rsin

```

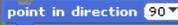
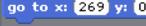
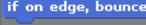


A set of English-readable statements are a better way to start than just entering code.

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The next step is to know what Scratch code statements you have to work with ...

### Motion Menu

- 
Move the sprite a certain number of steps (pixels) in the direction it is pointing
- 
Change the pointing direction clockwise or counterclockwise
- 
Set the pointing compass direction
- 
Point towards something in particular (e.g., mouse-pointer)
- 
Move the sprite to a particular location
- 
Move the sprite somewhere in particular (e.g., mouse-pointer)
- 
Animate the sprite somewhere in particular
- 
Change the sprite's x location by a certain amount (+ or -)
- 
Set the sprite's x location to a certain amount
- 
Change the sprite's y location by a certain amount (+ or -)
- 
Set the sprite's y location to a certain amount
- 
If this sprite is on a scene edge, turn it around so it can move in the other direction
- 
Display the x and y locations in the scene
- 
Display the direction angle in the scene
- 
Display the direction angle in the scene

point in direction 90°

- (90) right
- (-90) left
- (0) up
- (180) down

### Costumes

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Each sprite can have multiple ways it can look. Each of these is called a **costume**.



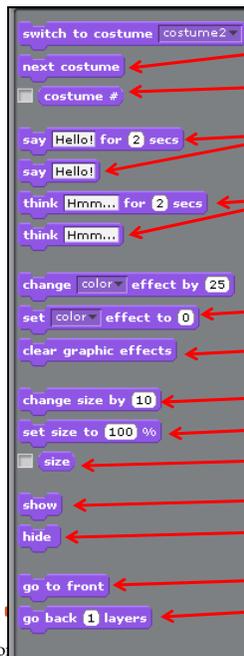
These can be changed during the course of an animation to give the appearance that the subject is moving or has simply changed its "look".



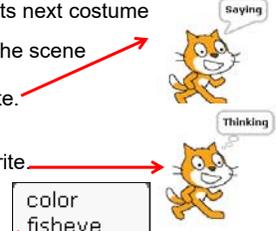
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### Looks Menu

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- Change this sprite to look like its designated "costume"
- Change this sprite to look like its next costume
- Display the costume number in the scene
- Put a talking balloon on this sprite.
- Put a thinking balloon on this sprite
- Change one of these effects
- Set one of these effects
- Clear all of these effects
- Change the sprite size (%)
- Set the sprite size (units are percent of original size)
- Display the sprite size in the scene
- Display this sprite
- Don't display this sprite
- Move this sprite in front of all the others
- Move this sprite behind one layer of sprites



- color
- fisheye
- whirl
- pixelate
- mosaic
- brightness
- ghost

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### Effects in the Looks Menu 17

color  
fisheye  
whirl  
pixelate  
mosaic  
brightness  
ghost



color



fisheye



whirl



pixelate



mosaic



brightness



ghost



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### If You Have Selected a Background, the Looks Menu Appears Like This 18

switch to background worldw

next background

background #

change color effect by 25

set color effect to 0

clear graphic effects



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### Sound Menu

Play a particular sound. Keep executing commands while the sound plays.

Play a particular sound. Pause until the sound is done playing.

Stop playing all sounds

Play a particular drum sound (35-81)

Stop playing the drum for a moment

Play a particular note

Set the instrument number 1-128

Change the volume (percent)

Set the volume (units are percent)

Display the volume in the scene

Change the tempo (+ or -, units are beats per minute)

Set the tempo (units are beats per minute)

Display the tempo in the scene

(35) Acoustic Bass Drum  
 (36) Bass Drum 1  
 (37) Side Stick  
 (38) Acoustic Snare  
 (39) Hand Clap  
 (40) Electric Snare  
 (41) Low Floor Tom  
 (42) Closed Hi-Hat  
 (43) High Floor Tom  
 (44) Pedal Hi-Hat  
 (45) Low Tom  
 (46) Open Hi-Hat  
 (47) Low-Mid Tom  
 (48) Hi-Mid Tom  
 (49) Crash Cymbal 1  
 (50) High Tom  
 (51) Ride Cymbal 1  
 (52) Chinese Cymbal  
 (53) Ride Bell  
 (54) Tambourine  
 (55) Splash Cymbal  
 (56) Cowbell  
 (57) Crash Cymbal 2  
 (58) Vibration  
 (59) Ride Cymbal 2  
 (60) Hi Bongo  
 (61) Low Bongo  
 (62) Mute Hi Conga  
 (63) Open Hi Conga  
 (64) Low Conga  
 (65) High Timbale  
 (66) Low Timbale  
 (67) High Agogo  
 more...

(1) Acoustic Grand  
 (2) Bright Acoustic  
 (3) Electric Grand  
 (4) Honky-Tonk  
 (5) Electric Piano 1  
 (6) Electric Piano 2  
 (7) Harpsichord  
 (8) Clavinet  
 (9) Celesta  
 (10) Glockenspiel  
 (11) Music Box  
 (12) Vibraphone  
 (13) Marimba  
 (14) Xylophone  
 (15) Tubular Bells  
 (16) Dulcimer  
 (17) Drawbar Organ  
 (18) Percussive Organ  
 (19) Rock Organ  
 (20) Church Organ  
 (21) Reed Organ  
 (22) Accordion  
 (23) Harmonica  
 (24) Tange Accordion  
 (25) Nylon String Guitar  
 (26) Steel String Guitar  
 (27) Electric Jazz Guitar  
 (28) Electric Clean Guitar  
 (29) Electric Muted Guitar  
 (30) Overdriven Guitar  
 (31) Distortion Guitar  
 (32) Guitar Harmonics  
 (33) Acoustic Bass  
 more...

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### A Real Pen Plotter

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### Pen Menu

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Annotations:

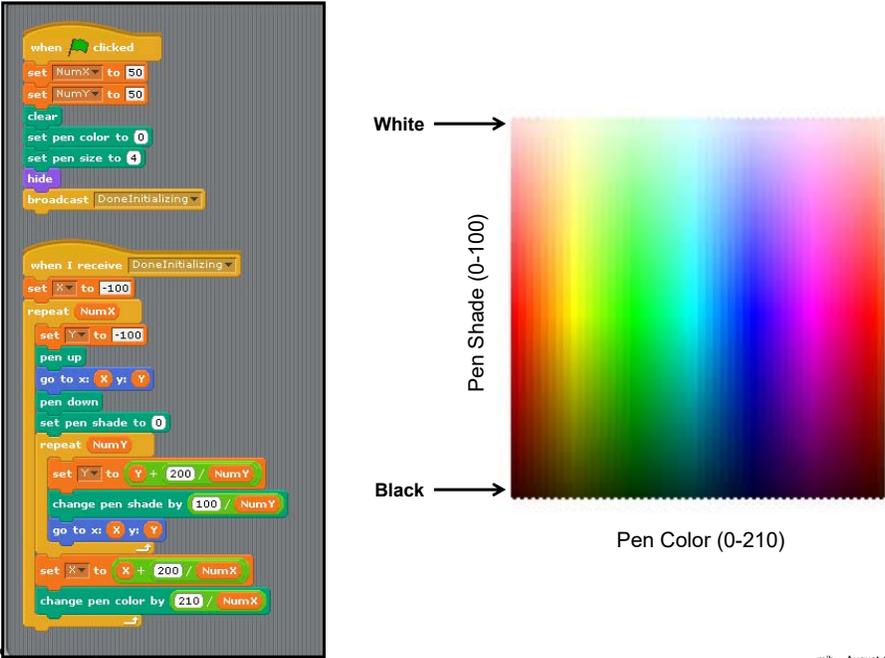
- clear → Erase all previous plotter linework
- pen down → Will the next pen movement leave a trace or not?
- pen up → Will the next pen movement leave a trace or not?
- set pen color to → Click here to bring up a color palette to choose from
- change pen color by 10 → (See the next slide)
- set pen color to 0 → (See the next slide)
- change pen shade by 10 → (See the next slide)
- set pen shade to 50 → (See the next slide)
- change pen size by 1 → Control the width of the trace
- set pen size to 1 → Control the width of the trace
- stamp → Stamp a permanent copy of the sprite

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### The Meanings of "Pen Color" and "Pen Shade"

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Code:

```
when clicked
  set NumX to 50
  set NumY to 50
  clear
  set pen color to 0
  set pen size to 4
  hide
  broadcast DoneInitializing

when I receive DoneInitializing
  set X to -100
  repeat NumX
    set Y to -100
    pen up
    go to x: X y: Y
    pen down
    set pen shade to 0
    repeat NumY
      set Y to Y + 200 / NumY
      change pen shade by 100 / NumY
      go to x: X y: Y
    set X to X + 200 / NumX
    change pen color by 210 / NumX
```

White →

Pen Shade (0-100)

Black →

Pen Color (0-210)

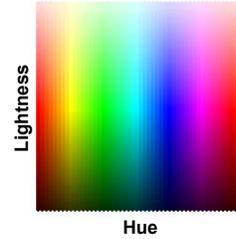
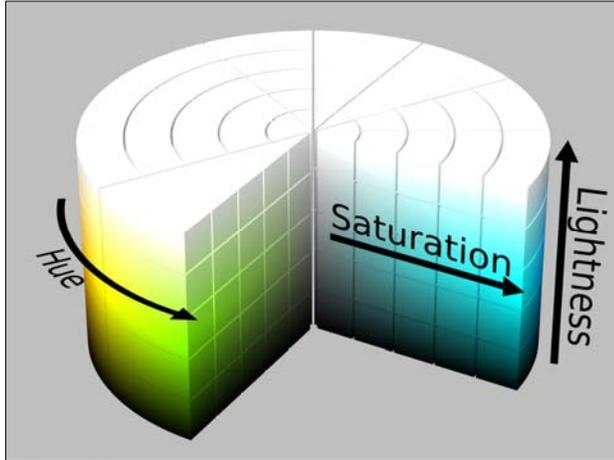
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### The Meanings of “Pen Color” and “Pen Shade”

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In computer graphics, this sort of color representation is referred to as Hue-Lightness. In the diagram below, the Scratch pen colors occupy the outer skin of the cylinder. Full color representation has a third component, Saturation, which Scratch doesn't give you access to.



“Pen Color” = Hue.  
“Pen Shade” = Lightness

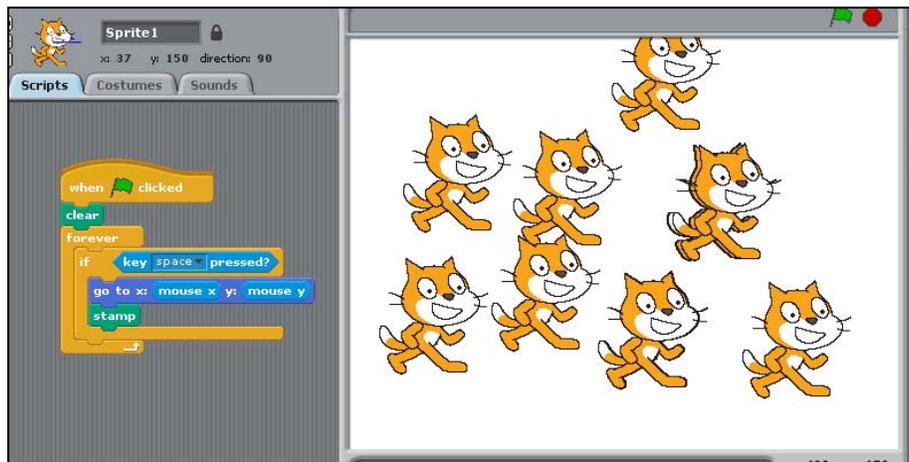
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[http://en.wikipedia.org/wiki/HSL\\_and\\_HSV](http://en.wikipedia.org/wiki/HSL_and_HSV)

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### The Meaning of “Stamp”

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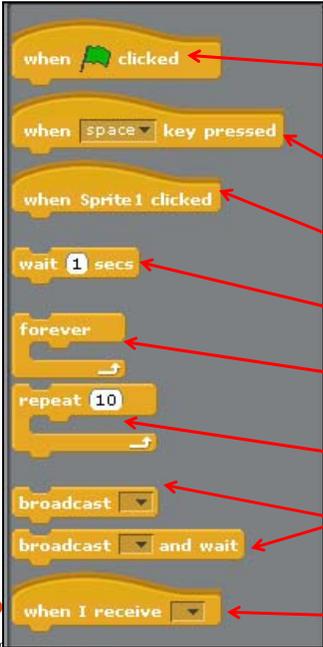


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### Controls Menu, I

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Annotations for Controls Menu I:

- when green flag clicked**: When the green flag at the top of the screen is clicked, this part of the program will start executing. You can have as many of these as you want.
- when space key pressed**: When a particular key is pressed, this part of the program will start executing. You can have as many of these as you want.
- when Sprite 1 clicked**: When this sprite is clicked, this part of the program will start executing.
- wait 1 secs**: Pause
- forever**: Loop forever
- repeat 10**: Loop a particular number of times
- broadcast**: Send a signal out to everyone. You get to pick the name. The "wait" option will wait until everyone has actually received the signal.
- broadcast and wait**: Send a signal out to everyone. You get to pick the name. The "wait" option will wait until everyone has actually received the signal.
- when I receive**: When this signal is broadcast, this part of the program will start executing. You can have as many of these as you want.

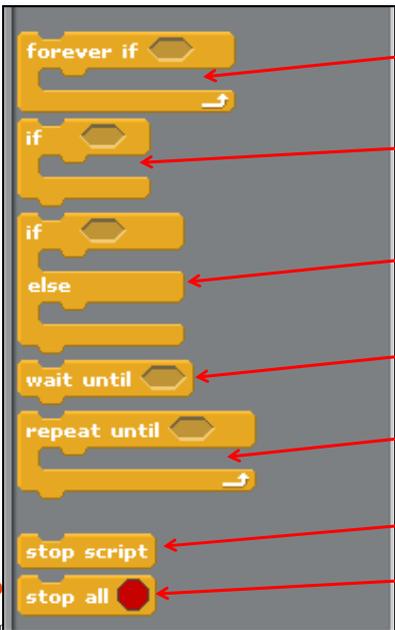


When this signal is broadcast, this part of the program will start executing. You can have as many of these as you want.

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### Controls Menu, II

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Annotations for Controls Menu II:

- forever if**: Loop forever if the given condition is **true**
- if**: Execute this block of statements if the given condition is **true**
- if else**: Execute the first block of statements if the given condition is **true**, otherwise execute the second
- wait until**: Pause until the given condition is **true**
- repeat until**: Loop until the given condition is **true**
- stop script**: Stop this script
- stop all**: Stop all scripts

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### Sensing Menu 27

The Sensing Menu contains the following blocks and their functions:

- touching [ ] ?**: true if this actor is touching the given other actor
- touching color [ ] ?**: true if this actor is touching the given color
- color [ ] is touching [ ] ?**: true if this color is touching the given color
- ask [ ] and wait**: Ask a question and wait for an answer
- answer**: The **ask** command automatically fills the variable "answer"
- mouse x**: The x and y coordinates of the mouse
- mouse y**: The x and y coordinates of the mouse
- mouse down?**: true if the left mouse button is down
- key [ ] pressed?**: true if a particular keyboard key is pressed
- distance to [ ]**: Computes the distance to something (e.g., the mouse-pointer)
- reset timer**: Set the internal timer to 0. This counts up by seconds.
- timer**: The **timer** command automatically fills the variable "timer"
- x position of [ ]**: Gives you some property of a sprite
- loudness**: Gives you the volume detected by the microphone (0-100)
- loud?**: Gives true if a "loud sound" is detected on the microphone
- [ ] slider sensor value**: Works with one of the external boards
- sensor [ ] button pressed ?**: Works with one of the external boards

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### If the Motor Controls are Turned On, You Also get... 28

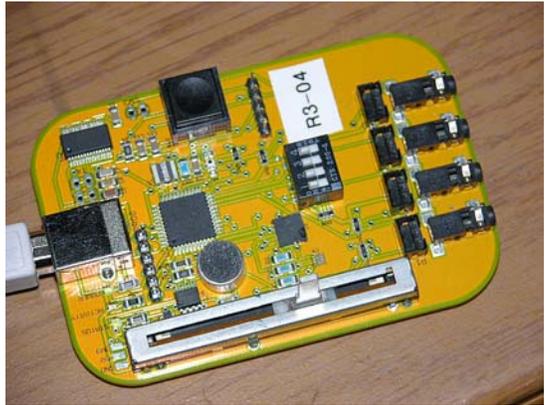
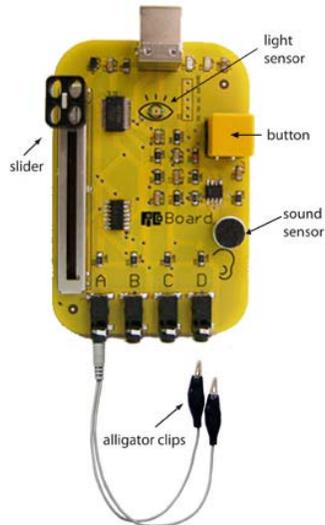
The Motor Controls menu includes the following blocks:

- motor on for [ ] secs**
- motor on**
- motor off**
- motor power [ ]**
- motor direction [ ]**

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### The Scratch Board

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### The Lego WeDo Construction Set

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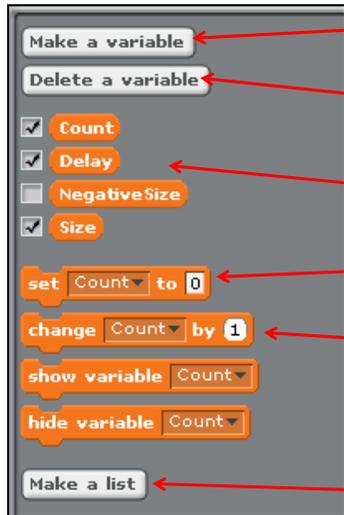
<http://education.lego.com/en-gb/lego-education-product-database/wedo/9580-lego-education-wedo-construction-set>

  
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### Variables Menu

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- ← Create a new variable – you will be asked to give it a name
- ← Choose which variable to delete from a list of variables
- ← These are variables I had created at the time. The checkboxes say whether or not you want them to be displayed in the scene.
- ← Used to set the variable to an initial value
- ← Change the variable's value by a certain amount (plus or minus)
- ← Start a list. A list is a multi-value variable (like an array in C and Java).

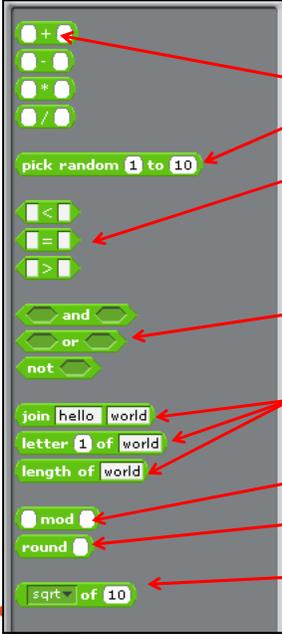
### Variables Menu: New Commands Get Added if You Make a List

32



- ← Display the contents of your list in the scene
- ← Append something to the end of the list
- ← Delete something from within the list
- ← Insert something within the list
- ← Change something in the list
- ← Lookup an item in the list
- ← Get the length of the list
- ← Returns **true** if "thing" is in the list

### Operators Menu 33



Placeholders like these can be numbers or variable names

Random number generator. You select the range.

These return **true** or **false**, and are typically used in **if**, **forever-if**, and **repeat-until** statements

These are used to link multiple **true/false**-producing statements together

String manipulation (good for creating strings for the sprite to say or think)

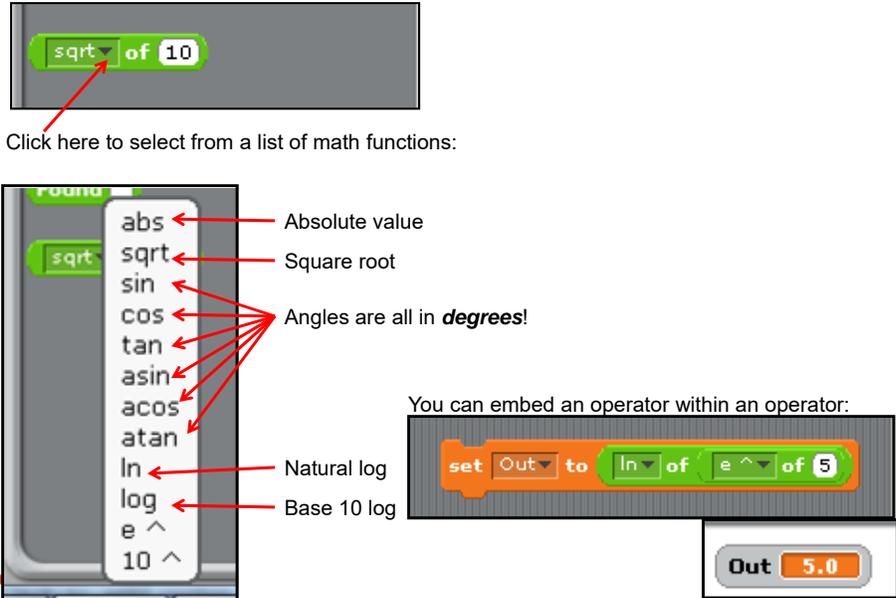
Modulo function (i.e., the remainder after a division is done)

Round to the nearest integer

(See the next slide)

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### Operators Menu: Math Functions 34



Click here to select from a list of math functions:

- abs - Absolute value
- sqrt - Square root
- sin, cos, tan, asin, acos, atan - Angles are all in **degrees!**
- ln - Natural log
- log - Base 10 log
- e ^ - e to the power of
- 10 ^ - 10 to the power of

You can embed an operator within an operator:

set Out to ln of e ^ of 5

Out 5.0

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### Shape Encoding within Scratch

35

Ovals are a place to put numeric constants and variables

Hexagons are a place to put Boolean values (i.e., values that can be either **true** or **false**)

Puzzle piece interlocks on the top and bottom show where connections can be made. A command without an interlock on the top is an **Event**.

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### The Paint Editor

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Enlarge/Shrink   Rotate   Flip

Paint Editor

Import   Clear

Undo   Redo

Brush size: ▾ •

Set costume center

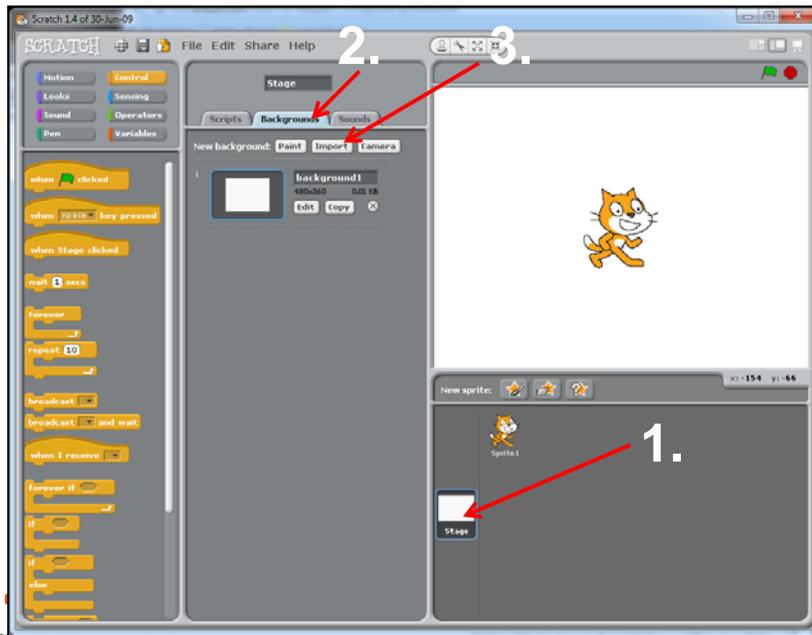
OK   Cancel

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### Setting the Background to a Handy X-Y Grid

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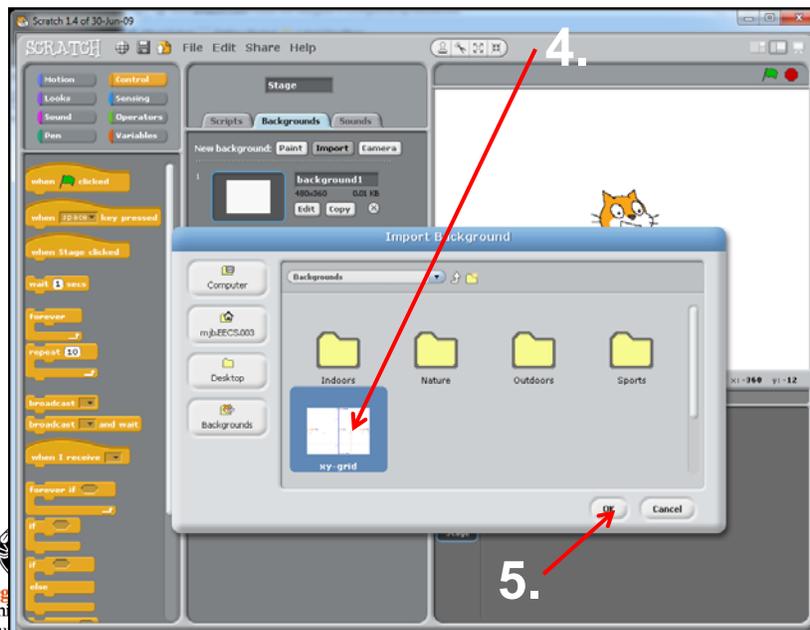


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### Setting the Background to a Handy X-Y Grid

38



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### This is What the X-Y Grid Looks Like – It is Useful When you are Creating your Animation

39

The screenshot shows the Scratch 1.4 interface. The main stage area features a white grid with a blue cat sprite positioned at the origin (0,0). Several coordinate labels are placed on the grid:  $x = -240, y = 180$  at the top-left,  $x = 240, y = 180$  at the top-right,  $x = 0, y = 180$  on the top edge,  $x = -240, y = -180$  at the bottom-left, and  $x = 240, y = -180$  at the bottom-right. The origin is labeled  $x = 0, y = 0$ . The grid lines are labeled with values like 100, 200, and 300. The left sidebar shows the 'Scripts' and 'Backgrounds' tabs, and the 'Backgrounds' panel displays 'xy-grid' as the selected background. The bottom-left corner features the Oregon State University Computer Graphics logo, and the bottom-right corner has the text 'mjb - August 1, 2018'.

### Work with the Cat Sprite Again

40

Click on the Cat sprite to get  
back to working with it

The screenshot shows the 'New Sprite' dialog box in Scratch. A red arrow points from the text 'Click on the Cat sprite to get back to working with it' to the Cat sprite icon, which is labeled 'Sprite 1'. Below the sprite icon is a 'Stage' button. The bottom-left corner features the Oregon State University Computer Graphics logo, and the bottom-right corner has the text 'mjb - August 1, 2018'.

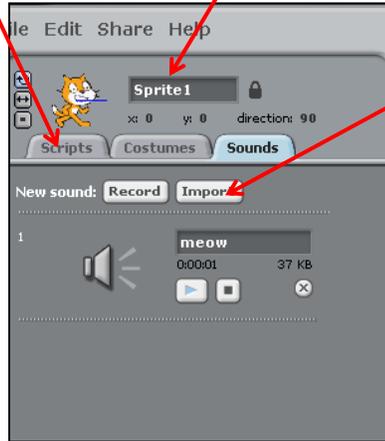
### We Want a Sound to Confirm When Our Program is Done

41

3. Click on the Scripts tab to go back to creating your program.

1. Click on the Sounds tab and verify that there is already a sound named "meow".

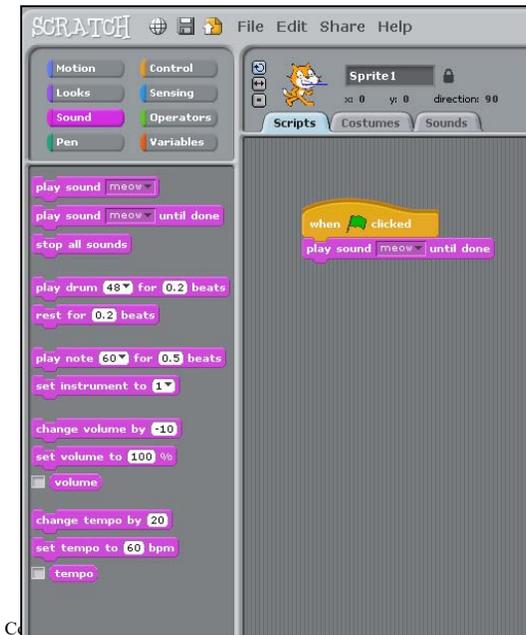
2. If there isn't, click on the Import button and load the sound.



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### Drag Each of These Commands From Its Menu and Hook Them Together

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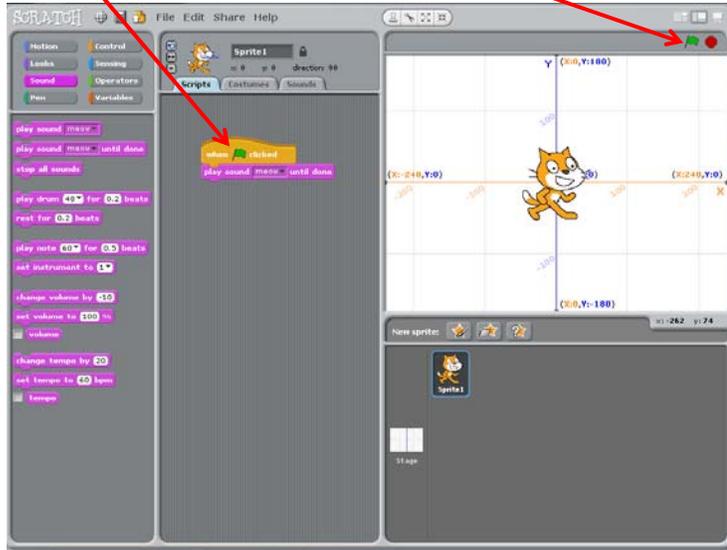


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### Running Your Program

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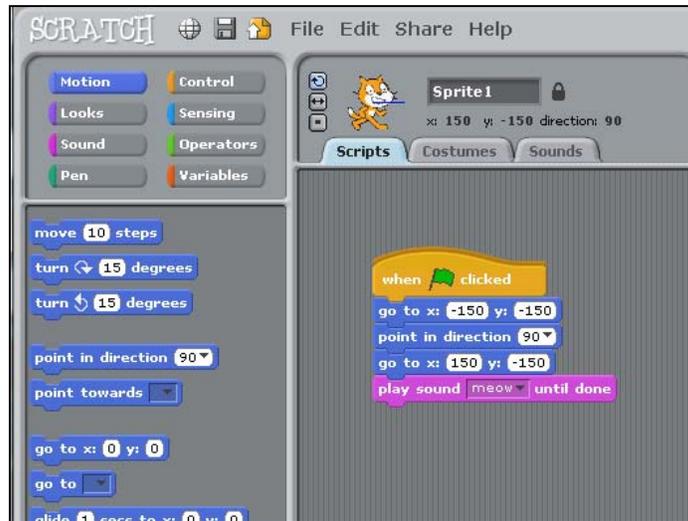
- 1. Clicking here . . .
- 2. . . . triggers this, and everything below it



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### Bring in the Sound-playing Command, and then Drag Each of These Commands From Its Menu and Hook Them Together

44

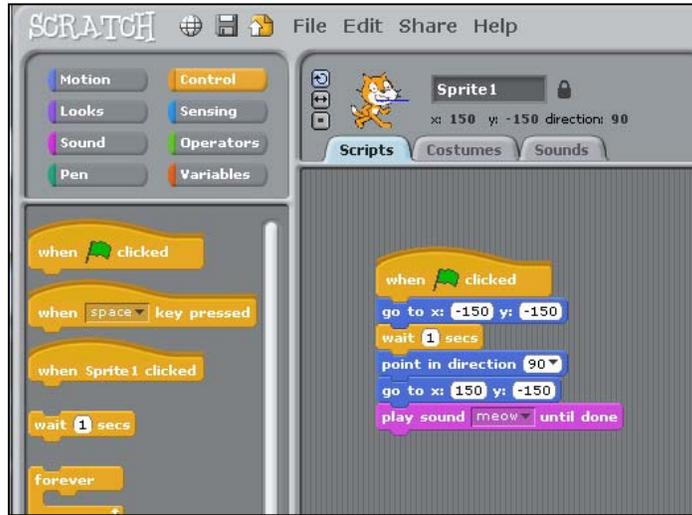


Run this program! What happens? It's probably not what you were hoping for. Why? (Hint: because you told it to.)

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### Add a "wait" after the first "go to"

45



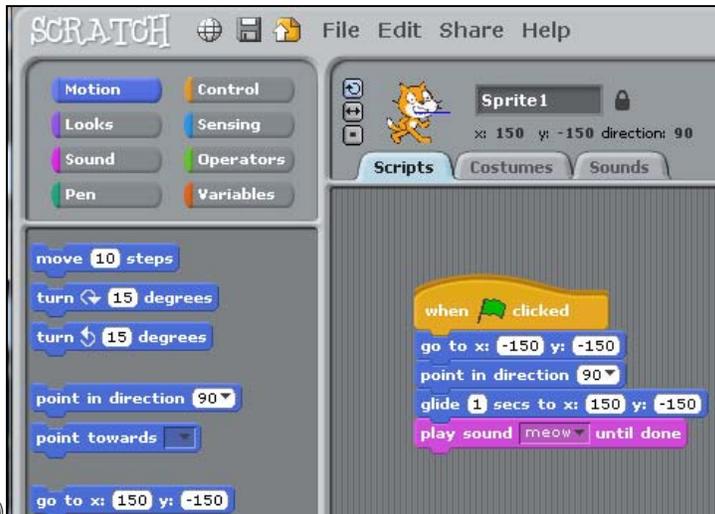
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Now what happens? It's still probably not what you were hoping for. Why?

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### Get rid of the "wait" and change the second "go to" to a "glide"

46



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Now what happens? This is probably the effect you were hoping for.

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### Have the Cat Run a Lap

47

```

when clicked
  go to x: -150 y: -150
  point in direction 90
  glide 1 secs to x: 150 y: -150
  point in direction 0
  glide 1 secs to x: 150 y: 150
  point in direction -90
  glide 1 secs to x: -150 y: 150
  point in direction 180
  glide 1 secs to x: -150 y: -150
  play sound meow until done

```



What if we want to change how long it takes the cat to get from one place to another?

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### Changing the Glide Time in Four Places is a Pain, So Do This

48

1. Make a variable
2. Call it **HowLong**
3. Put this command in here
4. Set **HowLong** to some value – you can always try other values

5. Drag from here to use the variable Delay instead of a numeric value

The image shows the Scratch interface with a variable named 'HowLong' created. In the 'Scripts' area, a 'when clicked' event triggers a 'set HowLong to 1' block. This variable is then used in four glide blocks: 'glide HowLong secs to x: 150 y: -150', 'glide HowLong secs to x: 150 y: 150', 'glide HowLong secs to x: -150 y: 150', and 'glide HowLong secs to x: -150 y: -150'. A 'play sound meow until done' block follows. Red arrows indicate the flow from the instructions to the variable creation and its application in the script.



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### And Let's Repeat It Multiple Times

49

```
when clicked
  set HowLong to 1
  repeat 5
    go to x: -150 y: -150
    point in direction 90
    glide HowLong secs to x: 150 y: -150
    point in direction 0
    glide HowLong secs to x: 150 y: 150
    point in direction -90
    glide HowLong secs to x: -150 y: 150
    point in direction 180
    glide HowLong secs to x: -150 y: -150
  play sound meow until done
```

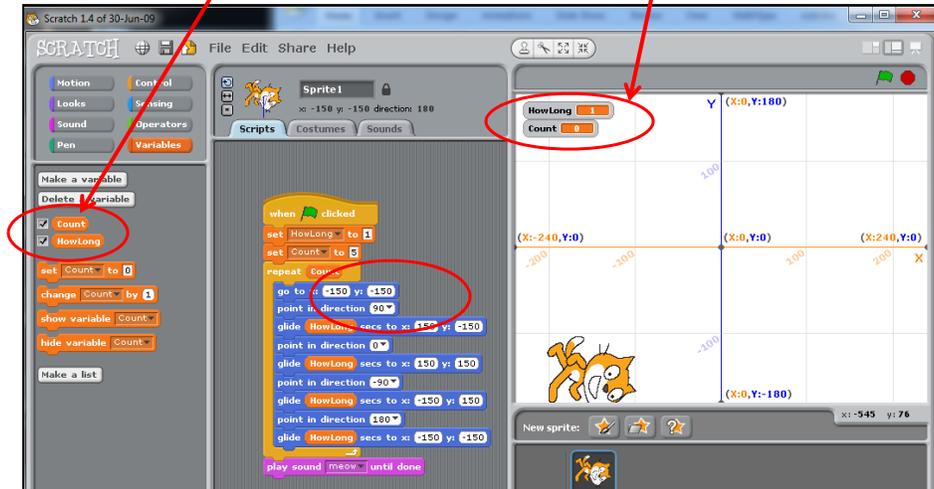


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### Putting the Repeat Count into a Variable

50

Clicking these checkboxes causes your variables to display on the Stage



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### Let's Tie a Colored Pen to the Moving Cat

51

Clear the screen, Set the pen color, Set the pen width, Put the pen down (touching the page)  
This draws this square

The screenshot shows the Scratch code editor with a script for drawing a square. The script starts with an 'when clicked' event, followed by 'set 'Count' to 1', 'clear', 'set pen color to blue', 'change pen color by 10', 'set pen color to 0', 'change pen shade by 10', 'set pen shade to 50', 'change pen size by 1', 'set pen size to 2', and 'pen down'. A red circle highlights the 'set pen color to blue' block. The script then enters a 'repeat loop' of 5 times, containing 'go to x: 150 y: 150', 'point in direction 90', 'glide 1 sec to x: 150 y: 150', 'point in direction 180', 'glide 1 sec to x: 150 y: 150', 'point in direction 270', 'glide 1 sec to x: 150 y: 150', 'point in direction 0', 'glide 1 sec to x: 150 y: 150', 'pen up', and 'play sound [meow - until done]'. The right side of the editor shows a stage with a cat sprite and a square drawn in blue. The 'cat\_running\_laps' variable is set to 1, and the 'Count' variable is set to 5. The 'New sprite' panel shows the cat sprite selected.

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### Time to Change the Background to Something Else

52

The screenshot shows the Scratch code editor with the 'Backgrounds' panel open. The panel has tabs for 'Paint', 'Import', and 'Camera'. Under 'Paint', there are two options: 'background d1' and 'ay\_grid'. Under 'Import', there is a 'Stage' option. Red arrows point to these options: arrow 1 points to 'Stage', arrow 2 points to 'background d1', and arrow 3 points to 'ay\_grid'. A yellow box at the bottom right contains the text: 'You can also Import lots of built-in backgrounds, or even your own GIF and JPEG files'. The 'cat\_runni' variable is set to 1, and the 'Count' variable is set to 10.

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### Even trickier – Change the Size and Color of Each Square

53

The screenshot shows the Scratch interface. On the left, the Scripts area contains the following code:

```

when clicked
  set HowLong to 1
  set Count to 10
  set Size to 150
  show
  clear
  set pen color to blue
  set pen size to 2
  repeat Count
    set NegativeSize to 0 - Size
    pen up
    go to x: NegativeSize y: NegativeSize
    pen down
    point in direction 90
    glide HowLong secs to x: Size y: NegativeSize
    point in direction 0
    glide HowLong secs to x: Size y: Size
    point in direction -90
    glide HowLong secs to x: NegativeSize y: Size
    point in direction 180
    glide HowLong secs to x: NegativeSize y: NegativeSize
    change Size by -10
    change pen color by 20
  pen up
  think Pretty Cool! for 2 secs
  play sound meow until done
  hide
  
```

On the right, the Stage area shows a cat sprite and a stage with 10 concentric squares. The top of the stage has three monitors: 'HowLong' with value 1, 'Count' with value 10, and 'Size' with value 50. The squares are drawn in a sequence of colors: blue, green, yellow, orange, red, purple, pink, light blue, light green, and light yellow.

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### Even trickier – Change the Size and Color of Each Square !

54

1. Define a variable called Size
2. Define another one called NegativeSize
3. Set Size to 150
4. Set NegativeSize to "0-Size" (i.e., -Size)
5. Lift the pen up, move to the start location, then put the pen down
6. Use Size and NegativeSize to give the coordinates to glide to
7. Change the size after each Repeat. Change the pen color too
8. After the Repeat is over, make the cat think something, meow, and then disappear

The screenshot shows the same Scratch code as slide 53, but with red circles and arrows highlighting specific parts of the code corresponding to the numbered list items:

- Item 1 points to the 'set Size to 150' block.
- Item 2 points to the 'set NegativeSize to 0 - Size' block.
- Item 3 points to the 'set Size to 150' block.
- Item 4 points to the 'set NegativeSize to 0 - Size' block.
- Item 5 points to the 'pen up' block.
- Item 6 points to the 'go to x: NegativeSize y: NegativeSize' block.
- Item 7 points to the 'change Size by -10' and 'change pen color by 20' blocks.
- Item 8 points to the 'think Pretty Cool! for 2 secs', 'play sound meow until done', and 'hide' blocks.

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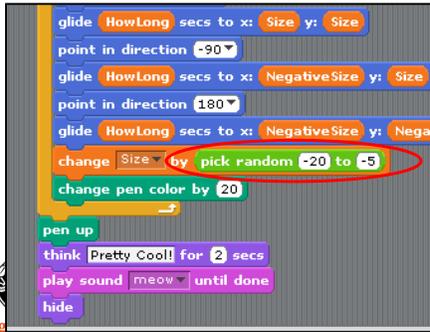
### Adding Randomness to Your Animation

55

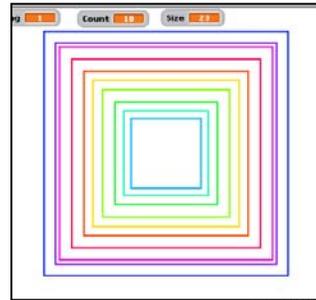
Sometimes these animations are more exciting when you can't predict exactly what will happen. This command will pick a random number between the two numbers that you give it:



You can drag it into place anywhere you would have otherwise used an actual number. For example, doing this ...



... could produce something like this:



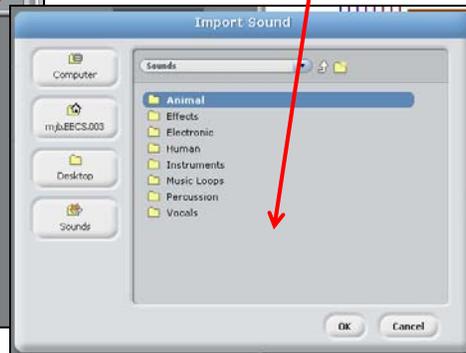
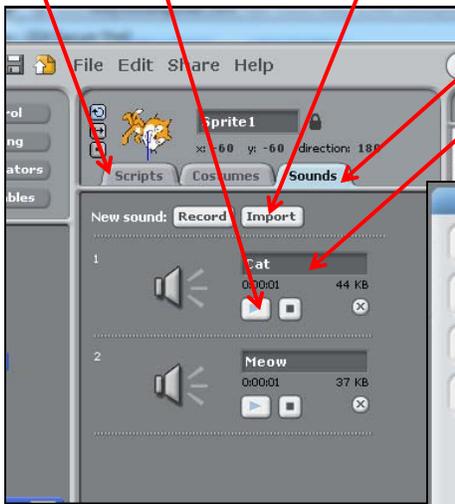
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### Making More Sounds Available for Your Animation!

56

1. Click on the **Sounds** tab
2. Click on the **Import** button
3. Select a sound
4. See what it sounds like
5. Give it a name you like
6. Click on the **Scripts** tab to use the new sound



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## Other Things To Try

57

1. Have other sprites moving at the same time (hint: each sprite should have its own script)
2. Do something differently depending on the user pressing specific keyboard keys

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## Changing the Animation When a Key is Pressed

58

The screenshot shows the Scratch code editor with the following script:

```

when green flag clicked
  set HowLong to 1
  set Count to 10
  set Size to 150
  show
  clear
  set pen color to blue
  set pen size to 2
  repeat (Count)
    set NegativeSize to 0 - Size
    pen up
    go to x: NegativeSize y: NegativeSize
    pen down
    point in direction 90
    glide HowLong secs to x: Size y: NegativeSize
    point in direction 0
    glide HowLong secs to x: Size y: Size
    point in direction -90
    glide HowLong secs to x: NegativeSize y: Size
    point in direction 180
    glide HowLong secs to x: NegativeSize y: NegativeSize
    change Size by pick random (20) to (-5)
    change pen color by 20
  pen up
  think Pretty Cool! for 2 secs
  play sound meow until done
  hide
  
```

When the space key is pressed, the script branches to:

```

when space key pressed
  change Size by pick random (-20) to 20
  set NegativeSize to 0 - Size
  think Hmmm! for 2 secs
  
```

The right side of the screenshot shows a stage with a square drawn in blue, and a 'New sprite' panel with a cat sprite selected.

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### Changing the Animation When a Key is Pressed 59

Both of these sequences are "running" at the same time



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### Using Your Own Files 60

**Backgrounds:** bmp, gif, jpg, png  
 Aspect ratio needs to be 4:3  
 480 x 360?  
 640 x 480?

**Costumes:** bmp, gif, jpg, png  
 The cat is 95 x 111  
 Looks like most any resolution will work

**Sounds:** wav

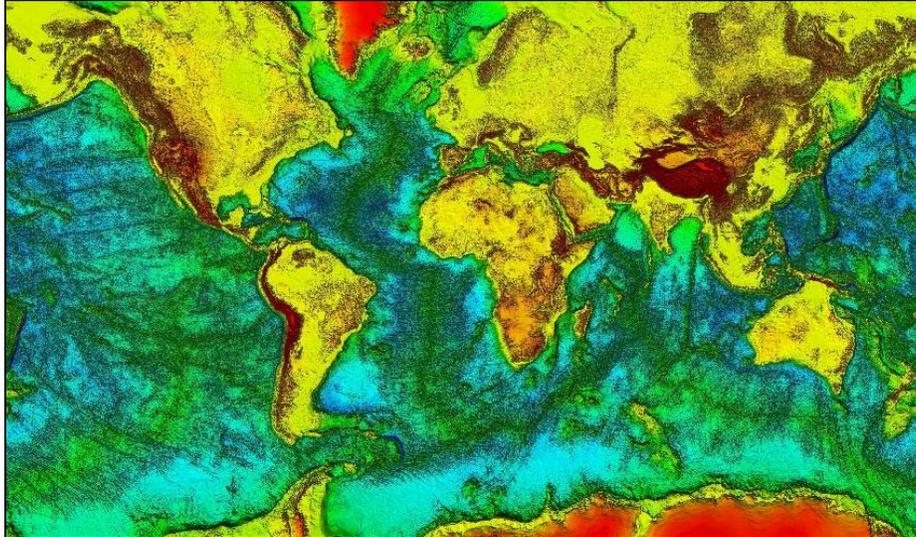


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### ChromaDepth: Encoding Depth into Image Colors

61

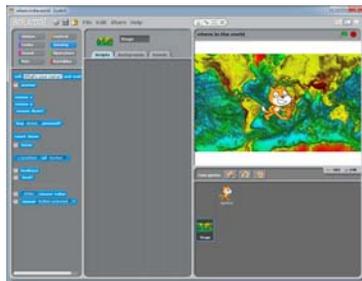


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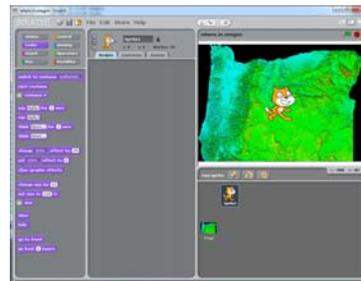
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### Custom ChromaDepth Map Backgrounds for Scratch

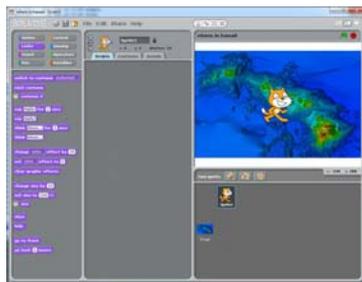
62



Background file = worldmap.jpg



Background file = oregonmap.jpg



Background file = hawaiimap.jpg  
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You can find these background map files at:  
<http://cs.oregonstate.edu/~mjb/scratch>

You can find more ChromaDepth stuff at:  
<http://cs.oregonstate.edu/~mjb/chromadepth>

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### Other Custom Map Backgrounds for Scratch

63



Background file = earthe.jpg



Background file = earthw.jpg



Background file = mars.jpg

You can find these background map files at:  
<http://cs.oregonstate.edu/~mjb/scratch>

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64

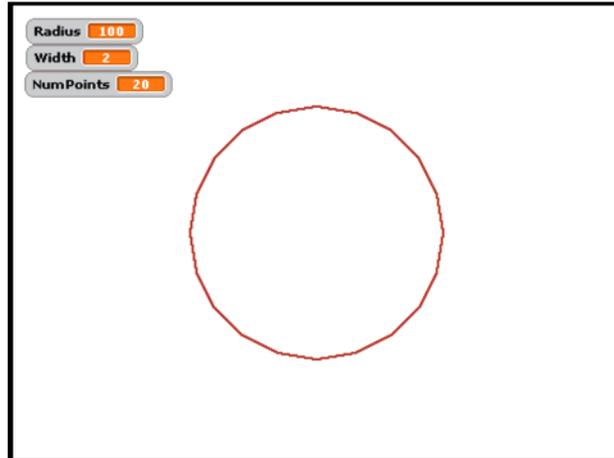
# Exercises

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### Drawing a Circle

65

There are a lot of fun things you can do with Scratch that are of the form “increment-some-quantity-to-create-a-cool-drawing”. In this case, the “some-quantity” is the angle.



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### Drawing a Circle

66

```

when clicked
  set Radius to 100
  set Width to 2
  set NumPoints to 20
  clear
  pen up
  set pen color to red
  set pen size to Width
  hide
  broadcast DoneInitializing
  
```

```

when I receive DoneInitializing
  set Angle to 0
  go to x: Radius y: 0
  pen down
  repeat NumPoints
    set Angle to Angle + 360 / NumPoints
    go to x: Radius * cos of Angle y: Radius * sin of Angle
  
```



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## Can We Imitate a SpiroGraph®? Sure!

67

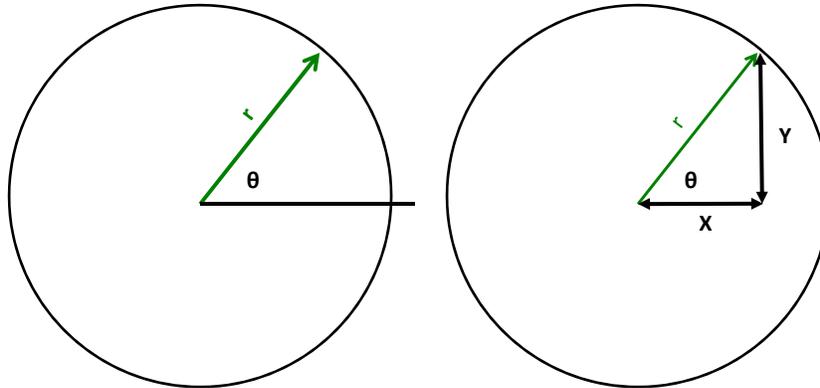


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## First, We Need to Know About Polar Coordinates

68



$$r = \sqrt{x^2 + y^2}$$

$$\theta = \tan^{-1}\left(\frac{y}{x}\right)$$

$$x = r \cos \theta$$

$$y = r \sin \theta$$



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## "Polar Rose"

69

$$r = \sin(N\theta)$$

$$x = r \cos \theta$$

$$y = r \sin \theta$$

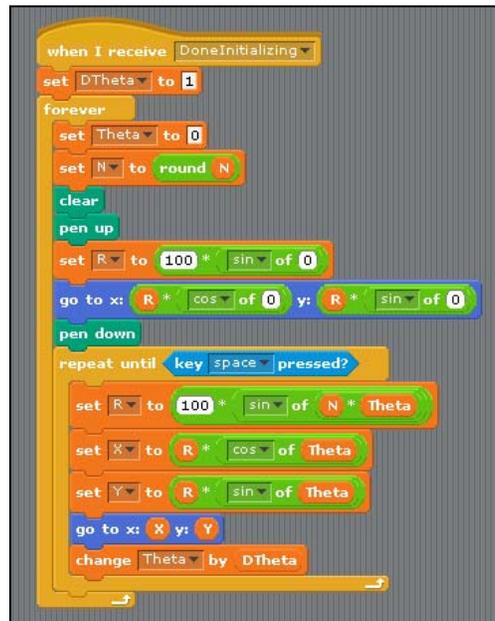
Start with  $\theta=0$ . and keep incrementing it by a small amount



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## "Polar Rose"

70

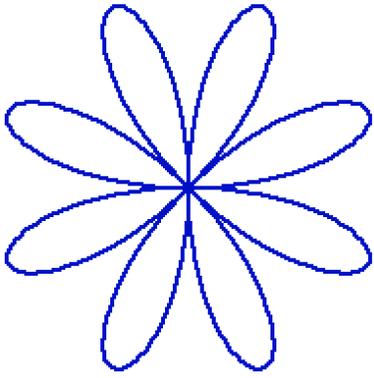


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**“Polar Rose”** 71

N 4

DTheta 1



What happens when N is odd?  
 What happens when N is even?  
 What happens if N doesn't have to be a whole number?

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**“Polar Tulip”** 72

$$r = \sin \theta + \sin^3 \left( \frac{5\theta}{2} \right)$$

$$x = r \cos \theta$$

$$y = r \sin \theta$$

Start with  $\theta=0$ . and keep incrementing it by a small amount

From James Stewart, *Single Variable Calculus*, Brooks/Cole, 2001.



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### "Polar Tulip"

73

```

when clicked
hide
set N to 2.50
clear
set pen color to blue
set pen size to 2
broadcast DoneInitializing
            
```

```

when I receive DoneInitializing
forever
set DTheta to 1
clear
pen up
set Theta to 0
set SinNTheta to sin of N * Theta
set R to 100 * sin of Theta + SinNTheta * SinNTheta * SinNTheta
go to x: R * cos of Theta y: R * sin of Theta - 75
pen down
repeat until key space pressed?
set SinNTheta to sin of N * Theta
set R to 100 * sin of Theta + SinNTheta * SinNTheta * SinNTheta
set X to R * cos of Theta
set Y to R * sin of Theta - 75
go to x: X y: Y
change Theta by DTheta
            
```



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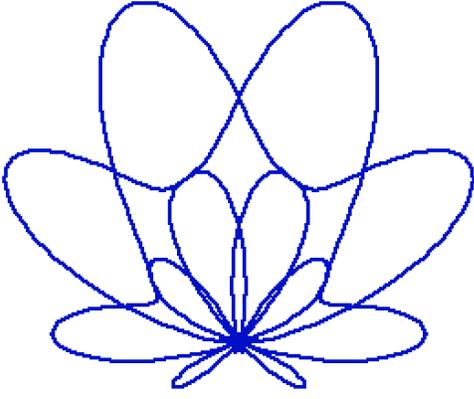
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### "Polar Tulip"

74

N 2.50

DTheta 1





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## Limaçons (French for “snail”)

75

$$r = 1 + c \cdot \sin \theta$$

$$x = r \cos \theta$$

$$y = r \sin \theta$$

Start with  $\theta=0$ . and keep incrementing it by a small amount

From James Stewart, *Single Variable Calculus*, Brooks/Cole, 2001.



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## Limaçons

76

```

when I clicked
  hide
  set C to 1
  clear
  set pen color to blue
  set pen size to 2
  broadcast DoneInitializing

```

```

when I receive DoneInitializing
  set DTheta to 1
  forever
    clear
    pen up
    set Theta to 0
    set R to 50 * 1 + C * sin of Theta
    go to x: R * cos of Theta y: R * sin of Theta + 0
    pen down
    repeat until key space pressed?
      set SinNTheta to sin of N * Theta
      set R to 50 * 1 + C * sin of Theta
      set X to R * cos of Theta
      set Y to R * sin of Theta + 0
      go to x: X y: Y
      change Theta by DTheta

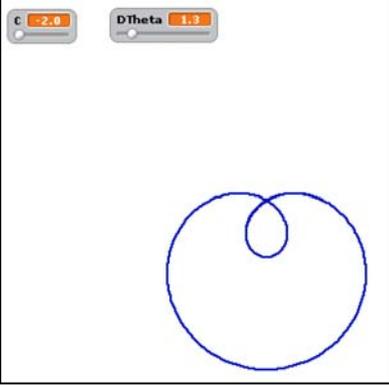
```



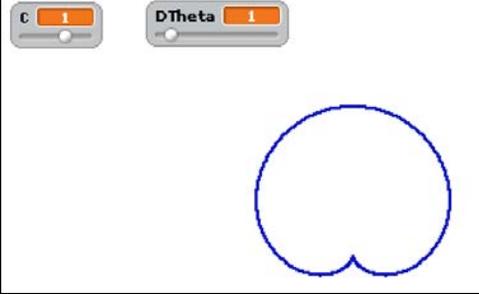
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### Limaçons 77

**c** -2.0      **DTheta** 1.3



**c** 1      **DTheta** 1



c = 1 is a "cardiod"



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### Lissajous Pattern 78

$$x = A \cos(ct + d)$$

$$y = B \sin(et + f)$$

Start with t=0. and keep incrementing it by a small amount



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### Lissajous Pattern

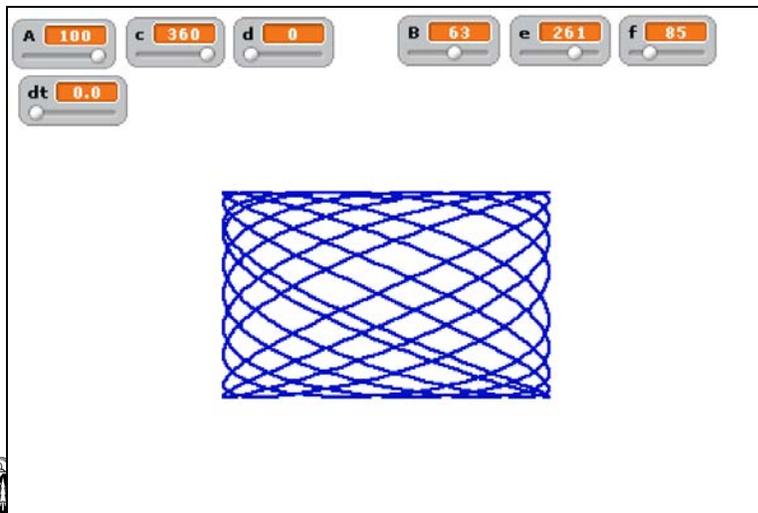
79

```
when clicked
  hide
  set A to 100
  set B to 100
  set c to 360
  set d to 0
  set e to 360
  set f to 0
  set MaxT to 10
  clear
  set pen color to blue
  set pen size to 2
  broadcast DoneInitializing

when I receive DoneInitializing
  set dt to .0100
  forever
    set t to 0.0000
    clear
    pen up
    go to x: A * cos of d y: B * sin of f
    pen down
    repeat until key space pressed?
      set X to A * cos of c * t + d
      set Y to B * sin of e * t + f
      go to x: X y: Y
      change t by dt
```

### Lissajous Pattern

80



Here are some others that should work too,  
but I haven't had the chance to try them yet

81

**Epicycloid:**  $x = (R + r) \cos \theta - r \cos \left( \frac{R + r}{r} \theta \right)$

$$y = (R + r) \sin \theta - r \sin \left( \frac{R + r}{r} \theta \right)$$

<http://en.wikipedia.org/wiki/Epicycloid>

**Epitrochoid:**  $x = (R + r) \cos \theta - d \cos \left( \frac{R + r}{r} \theta \right)$

$$y = (R + r) \sin \theta - d \sin \left( \frac{R + r}{r} \theta \right)$$

<http://en.wikipedia.org/wiki/Epitrochoid>



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Here are some others that should work too,  
but I haven't had the chance to try them yet

82

**Hypotrochoid:**  $x = (R - r) \cos \theta + d \cos \left( \frac{R - r}{r} \theta \right)$

$$y = (R - r) \sin \theta - d \sin \left( \frac{R - r}{r} \theta \right)$$

<http://en.wikipedia.org/wiki/Hypotrochoid>

**Hypocycloid:**  $x = (R - r) \cos \theta + r \cos \left( \frac{R - r}{r} \theta \right)$

$$y = (R - r) \sin \theta - r \sin \left( \frac{R - r}{r} \theta \right)$$

<http://en.wikipedia.org/wiki/Hypocycloid>

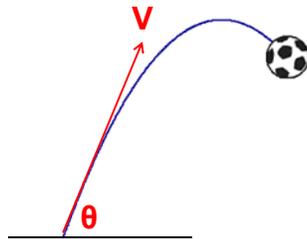


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### Projectile Motion

83



**Use:**  
 m for length units  
 seconds for time units

$$g = 9.8 \text{ m/sec}^2$$

$$v_{x0} = V \cos \theta$$

$$v_{y0} = V \sin \theta$$

$$x = x_0 + v_{x0}t$$

$$y = y_0 + v_{y0}t + \frac{1}{2}gt^2$$



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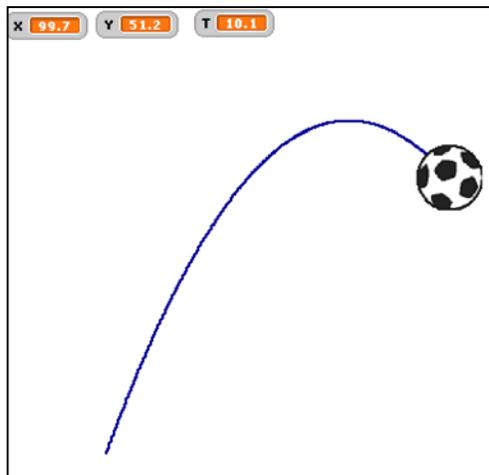
### Projectile Motion

84

```

when clicked
  set G to 1 * -9.8
  set X0 to -160
  set Y0 to -160
  set Vel0 to 73
  set Angle0 to 70
  set Vx0 to Vel0 * cos of Angle0
  set Vy0 to Vel0 * sin of Angle0
  clear
  set pen color to blue
  set pen size to 2
  pen up
  go to x: X0 y: Y0
  broadcast DoneInitializing

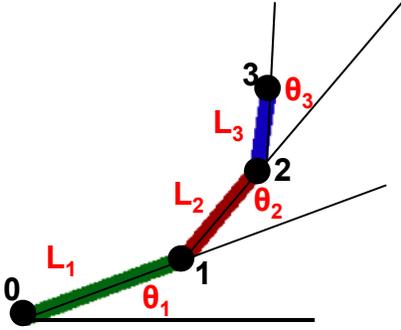
when I receive DoneInitializing
  pen down
  reset timer
  repeat 600
    set T to 1 + timer
    set X to X0 + Vx0 * T
    set Y to Y0 + Vy0 * T + 0.5 * G * T * T
    go to x: X y: Y
  
```



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### Forward Kinematics 85



$$x_1 = x_0 + L_1 \cos \theta_1$$

$$y_1 = y_0 + L_1 \sin \theta_1$$
  

$$x_2 = x_1 + L_2 \cos(\theta_1 + \theta_2)$$

$$y_2 = y_1 + L_2 \sin(\theta_1 + \theta_2)$$
  

$$x_3 = x_2 + L_3 \cos(\theta_1 + \theta_2 + \theta_3)$$

$$y_3 = y_2 + L_3 \sin(\theta_1 + \theta_2 + \theta_3)$$

```

x1 = x0 + L1 cos theta1
y1 = y0 + L1 sin theta1

x2 = x1 + L2 cos(theta1 + theta2)
y2 = y1 + L2 sin(theta1 + theta2)

x3 = x2 + L3 cos(theta1 + theta2 + theta3)
y3 = y2 + L3 sin(theta1 + theta2 + theta3)
                    
```



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### Forward Kinematics 86

**when clicked**

hide

set L1 to 110

set L2 to 75

set L3 to 50

set Ang1 to 20

set Ang1 to 20

set Ang1 to 20

set X0 to -140

set Y0 to -140

set pen size to 10

broadcast DoneInitializing

**when I receive DoneInitializing**

forever

clear

pen up

go to x: X0 y: Y0

pen down

set X to X0 + L1 \* cos of Ang1

set Y to Y0 + L1 \* sin of Ang1

set pen color to green

go to x: X y: Y

change X by L2 \* cos of Ang1 + Ang2

change Y by L2 \* sin of Ang1 + Ang2

set pen color to red

go to x: X y: Y

change X by L3 \* cos of Ang1 + Ang2 + Ang3

change Y by L3 \* sin of Ang1 + Ang2 + Ang3

set pen color to blue

go to x: X y: Y



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### Forward Kinematics 87

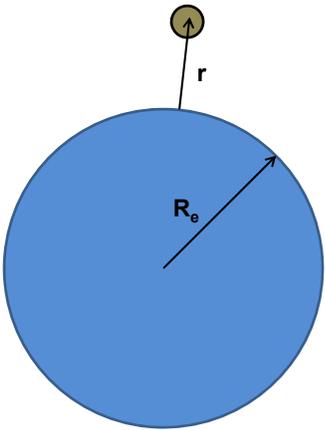
L1 <b>110</b>	L2 <b>75</b>	L3 <b>50</b>
Ang 1 <b>20</b>	Ang 2 <b>31</b>	Ang 3 <b>31</b>



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### Orbital Mechanics 88



$$P = \sqrt{\frac{4\pi^2 (R_e + r)^3}{gR_e^2}}$$

$$\theta = \frac{360}{P} t$$

**Use:**  
 km for length units  
 minutes for time units

g = 35.28 km/min<sup>2</sup>  
 R<sub>e</sub> = 6400 km

**Scale animation time:**  
 The Scratch **timer** returns time in seconds,  
 but we will treat it as minutes.  
 We will also use a **TimeScale** factor.



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### Orbital Mechanics

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```
when clicked
  set G to 35.28
  set Re to 6400
  set Pi to 3.14159
  set R to 160
  set TimeScale to 1
  set Scale to .001
  reset timer
  broadcast DoneInitiatizing

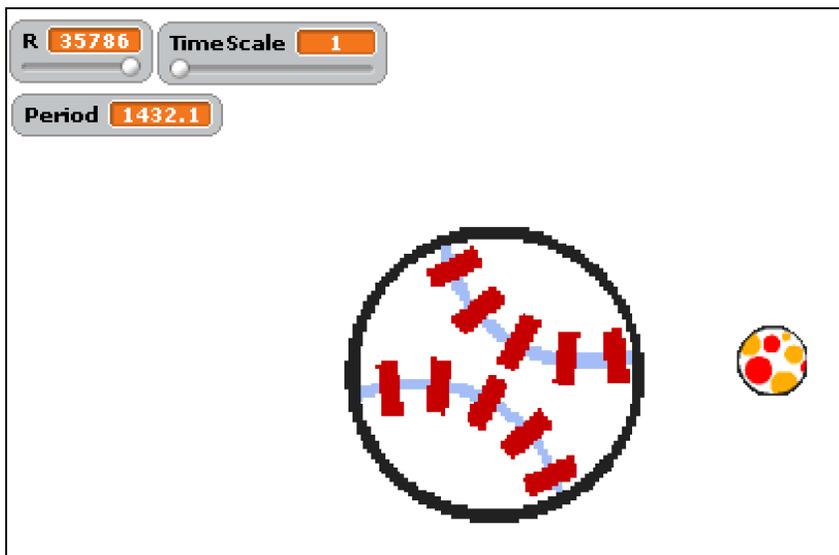
when I receive DoneInitiatizing
  forever
    set TotalR to Re + R
    set Num to 4 * Pi * Pi * TotalR * TotalR * TotalR
    set Den to G * Re * Re
    set Period to sqrt of Num / Den
    set T to TimeScale * timer
    set Theta to T * 360 / Period
    set ScaledR to 100 + Scale * R
    set X to ScaledR * cos of Theta
    set Y to ScaledR * sin of Theta
    go to x: X y: Y
```



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### Orbital Mechanics

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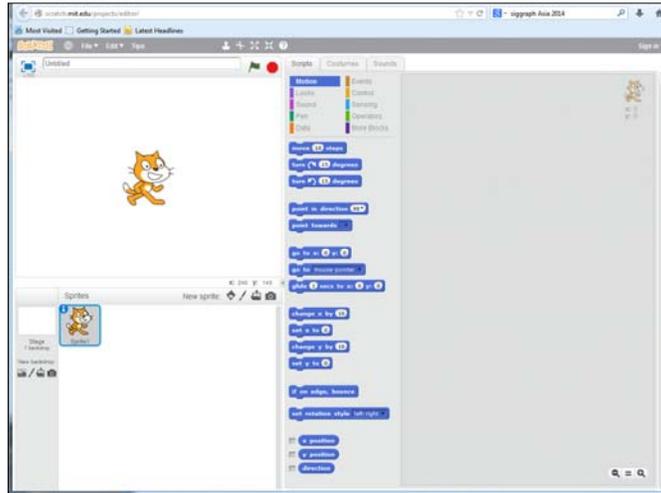


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Scratch 2.0

91

<http://scratch.mit.edu/projects/editor/>  
<http://scratch.mit.edu/scratch2download/>



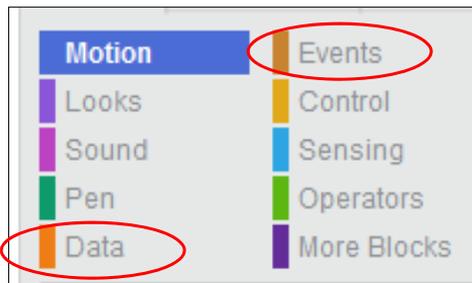
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Differences in Scratch 2.0

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<http://scratch.mit.edu/projects/editor/>  
<http://scratch.mit.edu/scratch2download/>

- The online version can run from a web browser
- Clones
- Code Blocks
- Some of the categories have been renamed  
 Control → Events + Control  
 Variables → Data
- Motion detection



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### Scratch 2.0 Events Menu

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The Events Menu in Scratch 2.0 contains the following blocks:

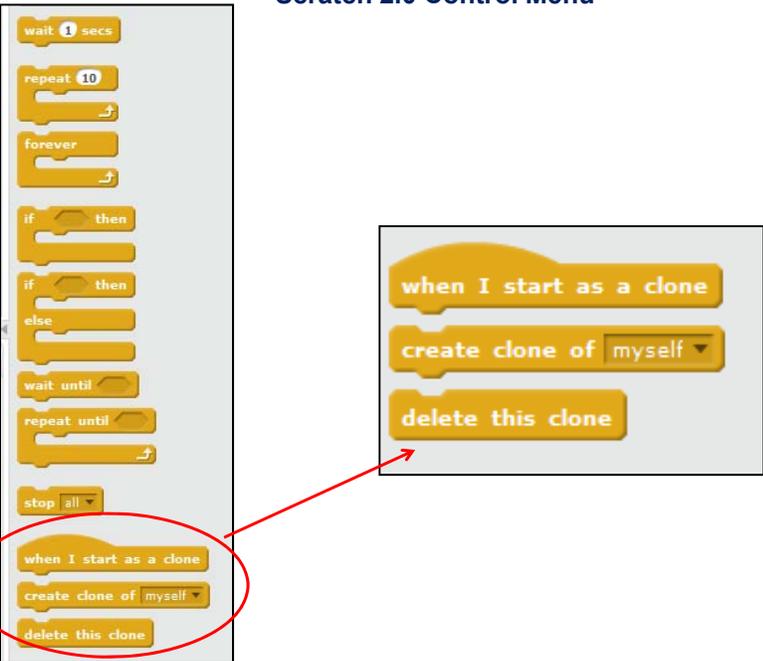
- when green flag clicked
- when space key pressed
- when this sprite clicked
- when backdrop switches to backdrop
- when loudness > 10
- when I receive message1
- broadcast message1
- broadcast message1 and wait

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### Scratch 2.0 Control Menu

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The Control Menu in Scratch 2.0 contains the following blocks:

- wait 1 secs
- repeat 10
- forever
- if then
- if then else
- wait until
- repeat until
- stop all
- when I start as a clone
- create clone of myself
- delete this clone

The 'when I start as a clone', 'create clone of myself', and 'delete this clone' blocks are circled in red. A red arrow points from this circle to a separate box on the right containing these three blocks:

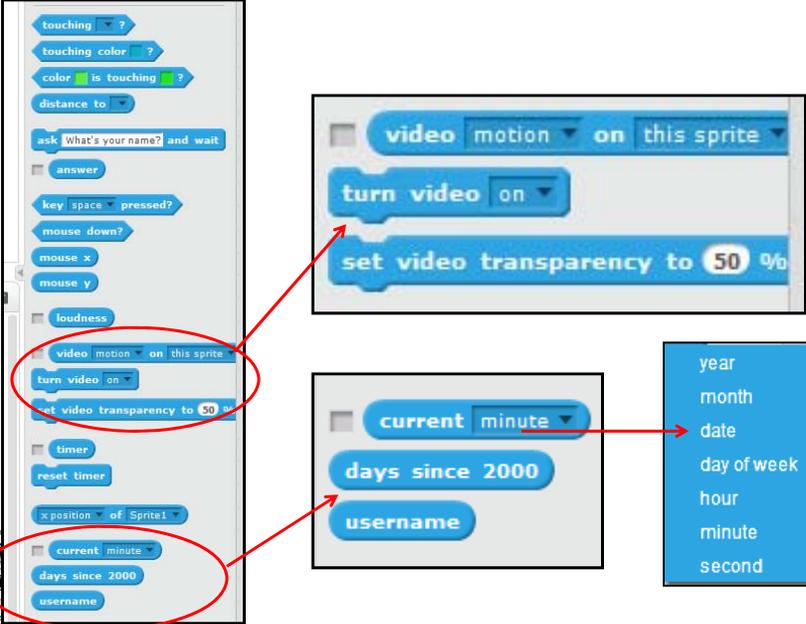
- when I start as a clone
- create clone of myself
- delete this clone

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### Scratch 2.0 Sensing Menu

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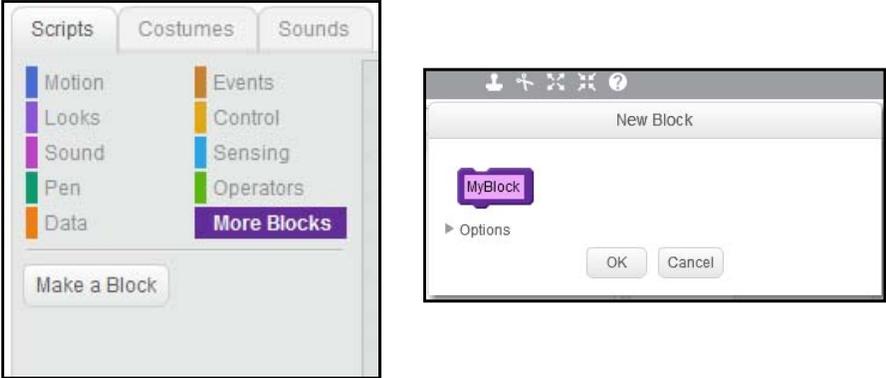
The screenshot shows the Scratch 2.0 Sensing menu on the left, with three red circles highlighting specific blocks: 'video motion on this sprite', 'current minute', and 'username'. To the right, three callout boxes show expanded views of these blocks. The top callout shows 'video motion on this sprite' with sub-blocks 'turn video on' and 'set video transparency to 50 %'. The middle callout shows 'current minute' with sub-blocks 'days since 2000' and 'username'. The bottom callout shows a list of time-related options: 'year', 'month', 'date', 'day of week', 'hour', 'minute', and 'second'. A red arrow points from the 'current minute' block in the middle callout to the 'date' option in the bottom callout.

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### Blocks (aka Procedures, Functions, Subroutines)

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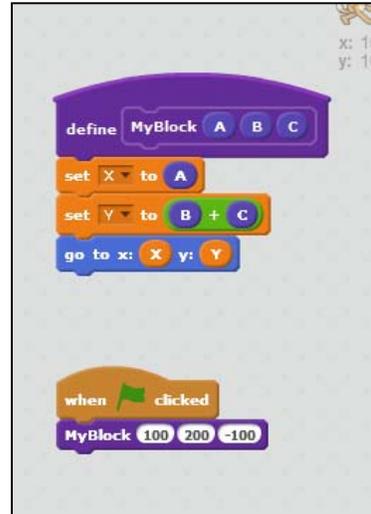
The screenshot shows the Scratch Blocks menu on the left, with tabs for 'Scripts', 'Costumes', and 'Sounds'. Under 'Scripts', there are categories: Motion, Looks, Sound, Pen, and Data. Under 'Events', there are categories: Events, Control, Sensing, and Operators. A 'More Blocks' button is highlighted in purple. A 'Make a Block' button is at the bottom. To the right, a 'New Block' dialog box is shown, featuring a 'MyBlock' button, an 'Options' label, and 'OK' and 'Cancel' buttons.

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### Blocks (aka Procedures, Functions, Subroutines)

97



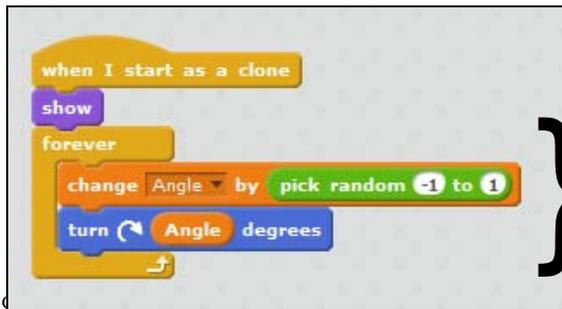
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### Send in the Clones

98



Creates a clone of the cat sprite and a separate copy of all its variables, properties, and scripts.

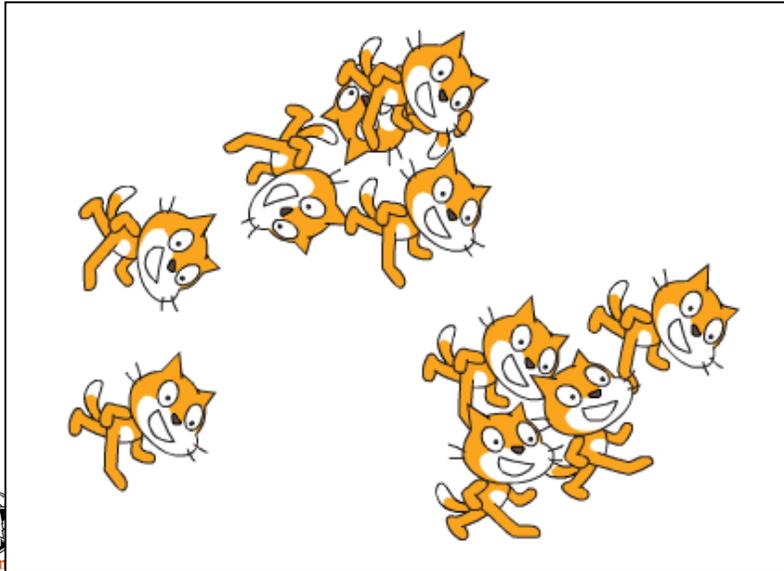


This script gets run for each of the clones. Sure beats writing this 10 times!

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### Send in the Clones

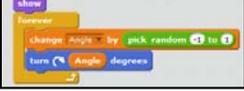
99



### Send in the Clones

100

Think of it as 10 simultaneous scripts are running, each controlling its own sprite:

### Using Clones to Create a Particle System

101

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### Particle System

102

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### Particle System – Doesn't Have to Be Actual "Particles"

103

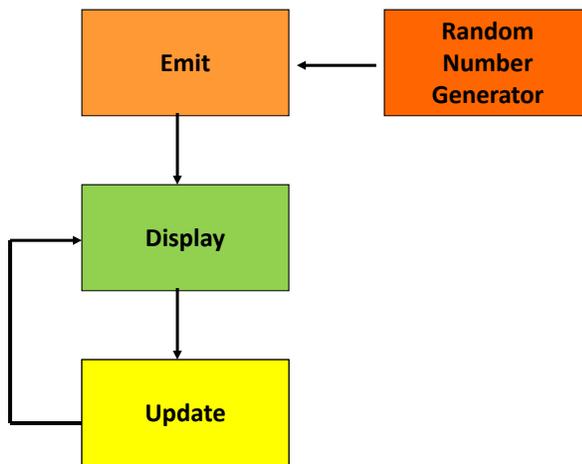


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### Particle System

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The basic process is this:



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### Particle System

105

```
when green flag clicked
  clear
  hide
  repeat 50
    create clone of myself
    set Dt to 0.5
    set X to pick random -150 to 150
    set Y to pick random -150 to 150
    set Angle to pick random -180 to 180
    set Velocity to pick random 1 to 10
    go to x: X y: Y
```

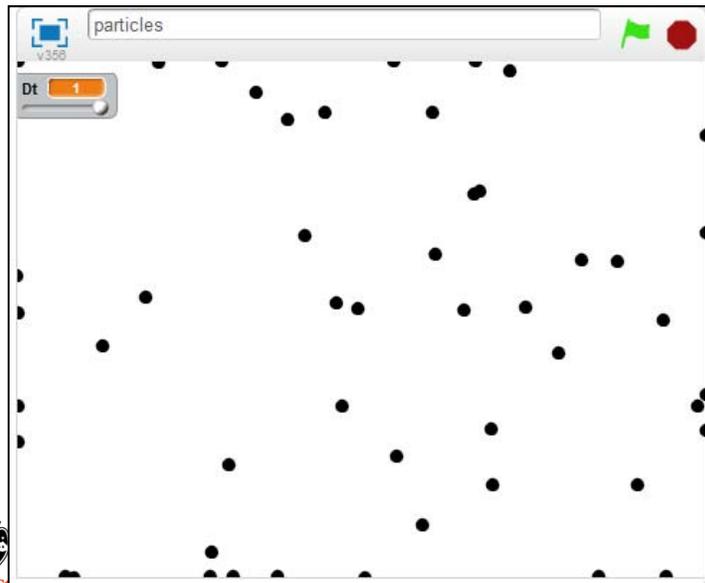
```
when I start as a clone
  show
  forever
    change X by Dt * Velocity * cos of Angle
    change Y by Dt * Velocity * sin of Angle
    go to x: X y: Y
    if key space pressed? then
      set X to pick random -150 to 150
      set Y to pick random -150 to 150
      set Angle to pick random -180 to 180
      set Velocity to pick random 1 to 10
      go to x: X y: Y
```



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### Particle System

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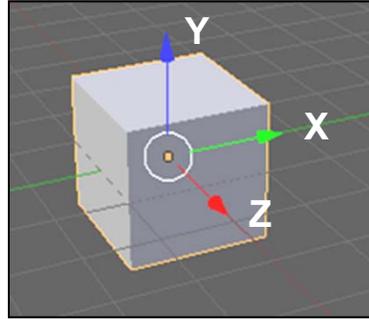


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### Using Blocks to Work in Three Dimensions

107

A 3D Right-handed Coordinate System:



**First rotating about the Y axis**

$$x' = x \cos \theta_y + z \sin \theta_y$$

$$y' = y$$

$$z' = -x \sin \theta_y + z \cos \theta_y$$

**Then rotating about the X axis**

$$x'' = x'$$

$$y'' = y' \cos \theta_x - z' \sin \theta_x$$

$$z'' = y' \sin \theta_x + z' \cos \theta_x$$



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### Three Dimensions

108

Note: a great use for Blocks (aka Procedures, Functions, Subroutines))

```

define ThreeD X Y Z
  set C to cos of Angle
  set S to sin of Angle
  set cx to cos of AngleX
  set sx to sin of AngleX
  set xp to X * C + Z * S
  set yp to Y
  set zp to Z * C - X * S
  set xpp to xp
  set ypp to yp * cx - zp * sx
  set zpp to zp * cx + yp * sx
  set zpp to 150 - zpp
  go to x: xpp y: ypp
  
```

```

define Square Z
  pen up
  ThreeD MinusSize MinusSize Z
  pen down
  ThreeD Size MinusSize Z
  ThreeD Size Size Z
  ThreeD MinusSize Size Z
  ThreeD MinusSize MinusSize Z
  
```

```

define LineZ X Y
  pen up
  ThreeD X Y MinusSize
  pen down
  ThreeD X Y Size
  
```

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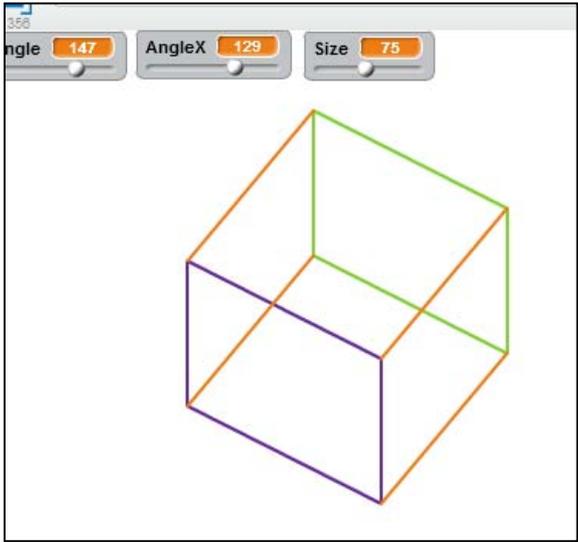
### Three Dimensions 109



```

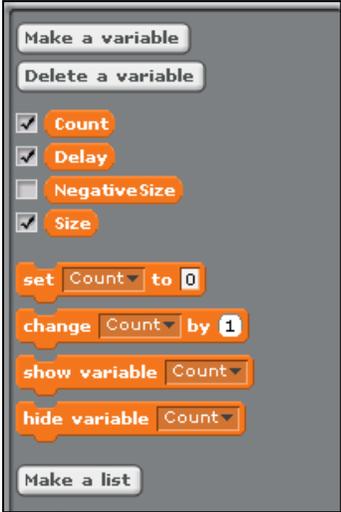
when clicked
  hide
  set Size to 100
  set Angle to 0
  set AngleX to 0
  broadcast DoneInitializing

when I receive DoneInitializing
  forever
    set MinusSize to 0 - Size
    clear
    set pen color to purple
    set pen size to 2
    Square MinusSize
    set pen color to green
    Square Size
    set pen color to orange
    LineZ MinusSize MinusSize
    LineZ Size MinusSize
    LineZ Size Size
    LineZ MinusSize Size
            
```



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### How Scratch Relates to C/Java Programming 110



```

Make a variable
Delete a variable
[Count]
[Delay]
[Negative Size]
[Size]
set Count to 0
change Count by 1
show variable Count
hide variable Count
Make a list
            
```

```

int Count ;

Count = 0 ;

Count = Count + 1 ;
            
```

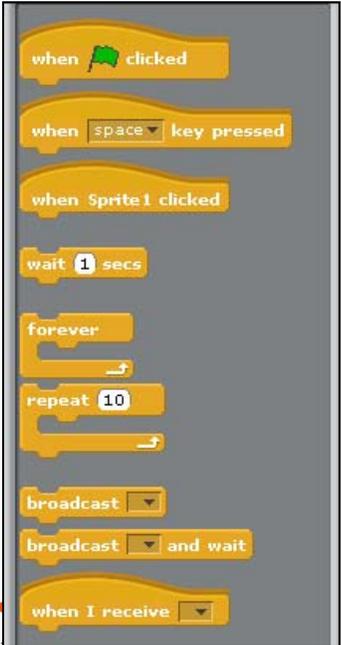


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### How Scratch Relates to C/Java Programming

111



```
sleep( 1 );
```

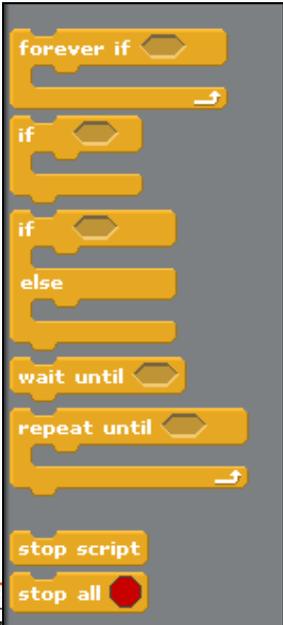
```
for( ; ; )  
{  
    statements ...  
}
```

```
for( i = 1 ; i <= 10; i = i + 1 )  
{  
    statements...  
}
```

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### How Scratch Relates to C/Java Programming

112



```
while( i < j )  
{  
    statements...  
}
```

```
if( i < j )  
{  
    statements ...  
}
```

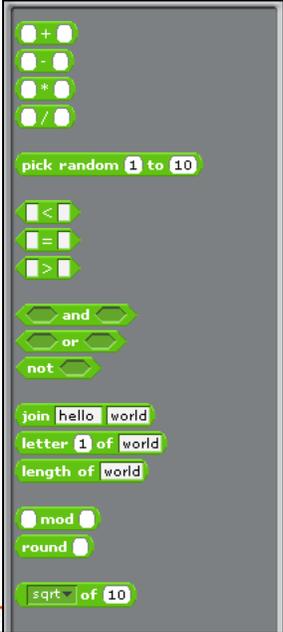
```
if( i < j )  
{  
    statements ...  
}  
else  
{  
    other statements ...  
}
```

```
do  
{  
    ;  
}  
while!( i < j );
```

```
do  
{  
    statements ...  
}  
} while!( i < j );
```

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### How Scratch Relates to C/Java Programming 113



Scratch blocks shown include: +, -, \*, /, pick random 1 to 10, <, =, >, and, or, not, join hello world, letter 1 of world, length of world, mod, round, and sqrt of 10.

```

i + j
i - j
i * j
i / j

if( i < j )
if( i == j )
if( i > j )

if( i < j && j < k )
if( i < j || j < k )
if( ! ( i < j ) )

i % j;
```

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### How Scratch Relates to C/Java Programming 114



Scratch event blocks shown: when clicked, when Sprite 1 clicked, and when I receive.

```

public class Flashing implements ActionListener
{
    //declare what event will be listening:
    button.addActionListener(this);
    ...

    // declare what to do when the event happens:
    public void actionPerformed(ActionEvent e)
    {
        // do something to make the display flash:
        ...
    }
}
```

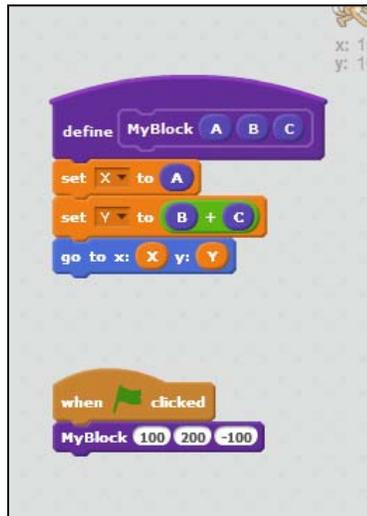


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## How Scratch Relates to C/Java Programming

115



```
void
MyBlock( int A, int B, int C )
{
    int X = A;
    int Y = B + C;
    glVertex2i( X, Y );
}
```

```
MyBlock( 100, 200 -100 );
```



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## Best Practices, I

116

Start with the goals in mind  
List of comments  
State Diagrams  
Data Flow Diagrams

Don't hard-code constants into the code – use variables so it is clear what you are doing  
Use variables to simplify expressions  
Pick good variable names  
Initialize all variables, even to zero

Modularize  
Separate sections with Broadcasts  
Separate initializing from executing  
Use Function Blocks

Generalize  
For example, don't use **timer**, use **t = scale\*timer**



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### Best Practices, II

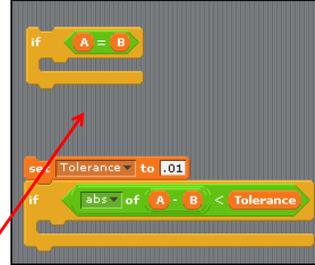
117

Remember that, unless specified, Scratch commands happen "instantaneously" and then the script moves on to the next instruction

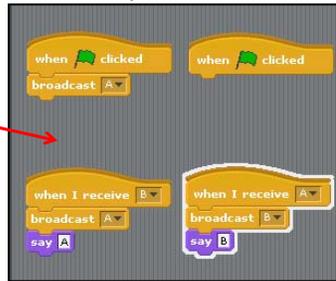


Be careful you get loop conditions correct

Floating point numbers rarely exactly equal each other  
Use < or > to compare them  
Use Absolute Value function to compare them



Watch out for Race Conditions, Deadlock, Livelock



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### Debugging

118

"Print" variables into the scene

Enlarge your view of the script

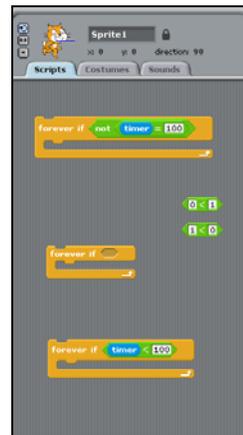
Single-stepping

If-statements that make something visible happen

Sound

Say or Think

Color change



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