Guide to Programming with Turtle Art

Turtle Blocks expands upon what children can do with Logo and how it can be used as the underlying motivator for “improving” programming languages and programmable devices.

In this guide, we illustrate this point by both walking the reader through numerous examples, but also by discussing some of our favorite explorations of Turtle Blocks, including multi-media, the Internet (both as a forum for collaboration and data collection), and a broad collection of sensors.

Getting Started

Turtle Blocks Javascript is designed to run in a browser. Most of the development has been done in Chrome, but it should also work in Firefox. You can run it from a server maintained by Sugar Labs, from the github repo, or by setting up a local server.

You can also open it directly from `file://` with some browsers, e.g., FireFox.

Once you've launched it in your browser, start by clicking on (or dragging) blocks from the *Turtle* palette. Use multiple blocks to create drawings; as the turtle moves under your control, colorful lines are drawn.

You add blocks to your program by clicking on or dragging them from the palette to the main area. You can delete a block by dragging it back onto the palette. Click anywhere on a "stack" of blocks to start executing that stack or by clicking in the *Rabbit* (fast) or *Turtle* (slow) on the Main Toolbar. The *Snail* will step through your program, one block per click.

For more details on how to use Turtle Blocks JS, see Using Turtle Blocks JS for more details.

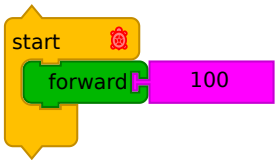
ABOUT THIS GUIDE

Many of the examples given in the guide have links to code you can run. Look for RUN LIVE links that will take you to http://turtle.sugarlabs.org.

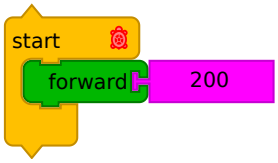
TO SQUARE

The traditional introduction to Logo has been to draw a square. Often times when running a workshop, I have the learners form a circle around one volunteer, the "turtle", and invite them to instruct the turtle to draw a square. (I coach the volunteer beforehand to take every command literally, as does our graphical turtle.) Eventually the group converges on "go forward some number of steps", "turn right (or left) 90 degrees", "go forward some number of steps", "turn right (or left) 90 degrees", "go forward some number of steps", "turn right (or left) 90 degrees", "go forward some number of steps". It is only on rare occasions that the group includes a final "turn right (or left) 90 degrees" in order to return the turtle to its original orientation. At this point I introduce the concept of "repeat" and then we start in with programming with Turtle Blocks.

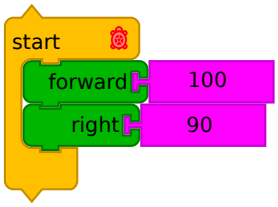
1. Turtle Basics



A single line of length 100 RUN LIVE

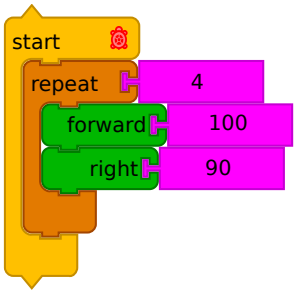


Changing the line length to 200 RUN LIVE

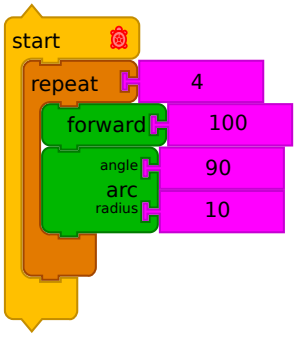


Adding a right turn of 90 degrees. Running this stack four times produces a square. RUN LIVE

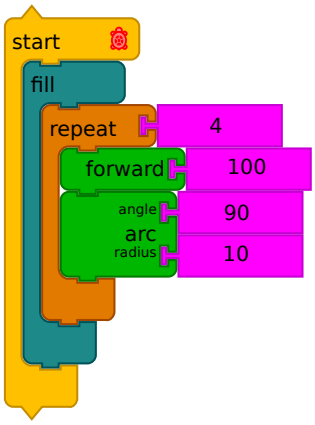
Forward, right, forward, right, ... RUN LIVE



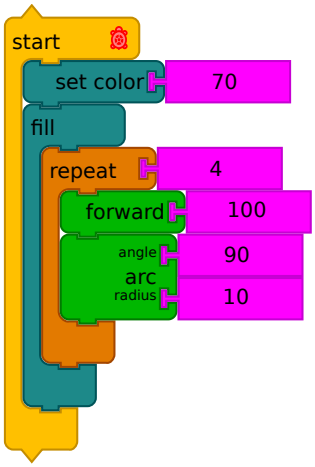
Using the *Repeat* block from the *Flow* palette RUN LIVE



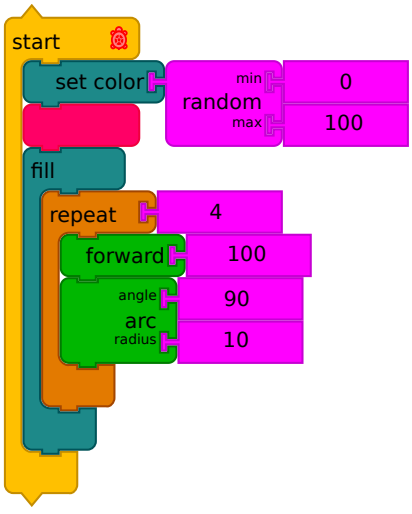
Using the *Arc* block to make rounded corners RUN LIVE



Using the *Fill* blocks from the Pen palette to make a solid square (what ever is drawn inside the *Fill* clamp will be filled upon exiting the clamp.) RUN LIVE



Changing the color to 70 (blue) using the *Set Color* block from the *Pen* palette RUN LIVE



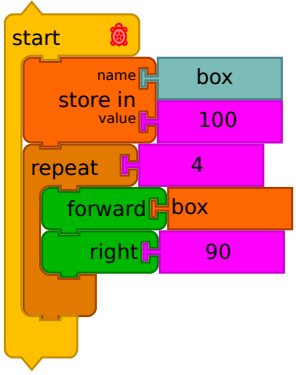
Using the *Random* block from the *Numbers* palette to select a random color (0 to 100) RUN LIVE

A SHOEBOX

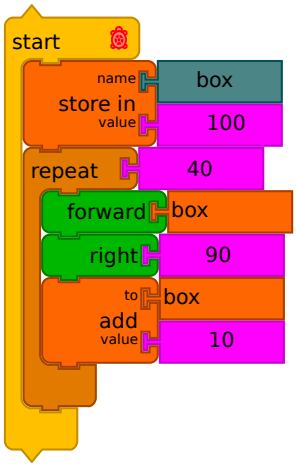
When explaining boxes in workshops, I often use a shoebox. I have someone write a number on a piece of paper and put it in the shoebox. I then ask repeatedly, "What is the number in the box?" Once it is clear that we can reference the number in the shoebox, I have someone put a different number in the shoebox. Again I ask, "What is the number in the box?" The power of the box is that you can refer to it multiple times from multiple places in your program.

2. Boxes

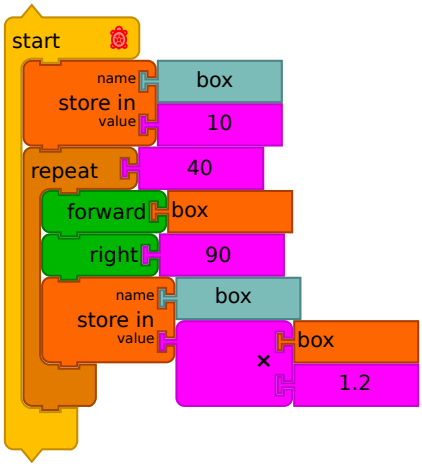
Boxes let you store an object, e.g., a number, and then refer to the object by using the name of the box. (Whenever you name a box, a new block is created on the Boxes palette that lets you access the content of the box.) This is used in a trivial way in the first example below: putting 100 in the box and then referencing the box from the Forward block. In the second example, we increase the value of the number stored in the box so each time the box is referenced by the Forward block, the value is larger.



Putting a value in a *Box* and then referring to the value in *Box* RUN LIVE



We can change the value in a *Box* as the program runs. Here we add 10 to the value in the *Box* with each iteration. The result in this case is a spiral, since the turtle goes forward further with each step. RUN LIVE



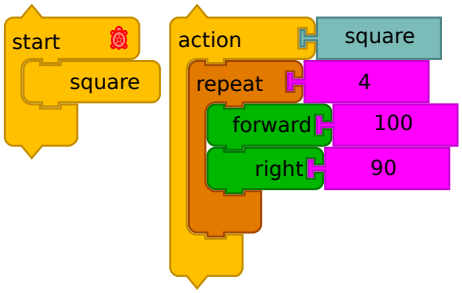
If we want to make a more complex change, we can store in the *Box* some computed value based on the current content of the *Box*. Here we multiply the content of the box by 1.2 and store the result in the *Box*. The result in this case is also a spiral, but one that grows geometrically instead of arithmetically.

In practice, the use of boxes is not unlike the use of keyword-value pairs in text-based programming languages. The keyword is the name of the *Box* and the value associated with the keyword is the value stored in the *Box*. You can have as many boxes as you'd like (until you run out of memory) and treat the boxes as if they were a dictionary. Note that the boxes are global, meaning all turtles and all action stacks share the same collection of boxes. RUN LIVE

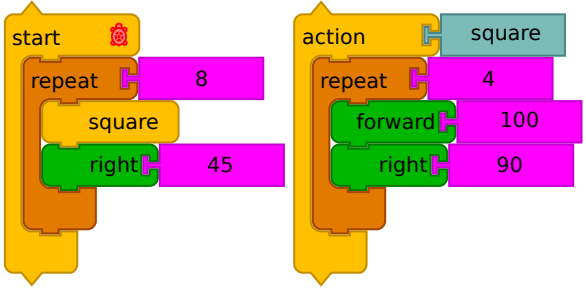
3. Action Stacks

With Turtle Blocks there is an opportunity for the learner to expand upon the language, taking the conversation in directions unanticipated by the Turtle Block developers.

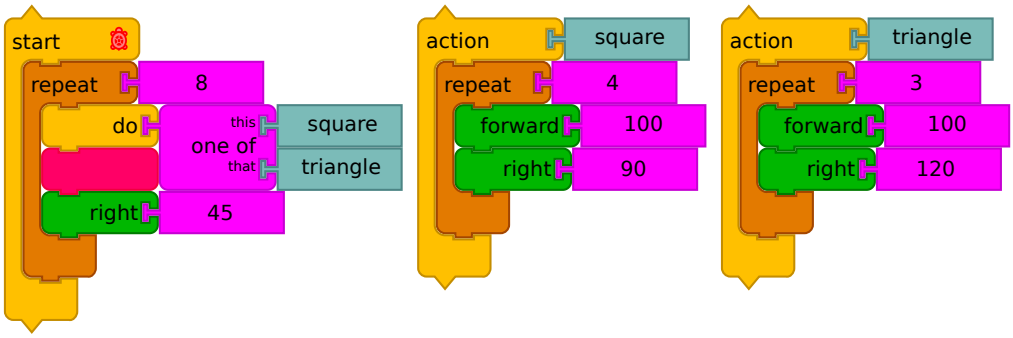
Action stacks let you extend the Turtle Blocks language by defining new blocks. For example, if you draw lots of squares, you may want a block to draw squares. In the examples below, we define an action that draws a square (repeat 4 forward 100 right 90), which in turn results in a new block on the *Actions* palette that we can use whenever we want to draw a square. Every new *Action* stack results in a new block.



Defining an action to create a new block, "*Square*" RUN LIVE



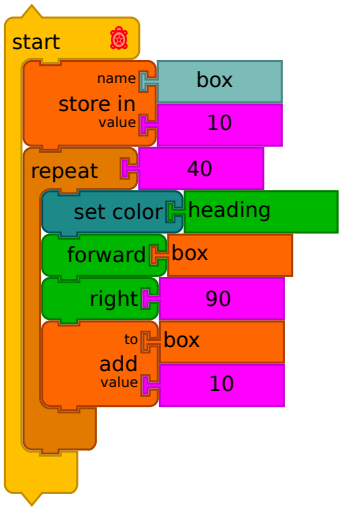
Using the "*Square*" block RUN LIVE



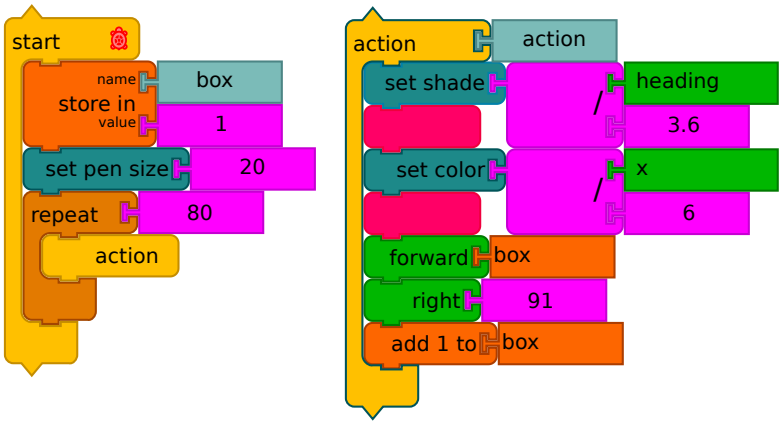
The *Do* block lets you specify an action by name. In this example, we choose "one of" two names, "*Square*" and "*Triangle*" to determine which action to take. RUN LIVE

4. Parameters

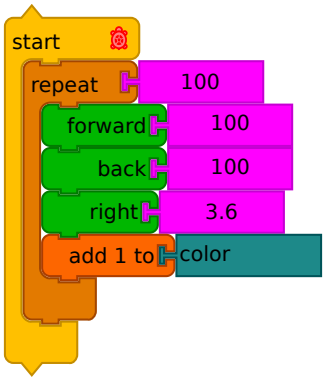
Parameter blocks hold a value that represents the state of some turtle attribute, e.g., the x or y position of the turtle, the heading of the turtle, the color of the pen, the size of the pen, etc. You can use parameter blocks interchangeably with number blocks. You can change their values with the *Add* block or with the corresponding set blocks.



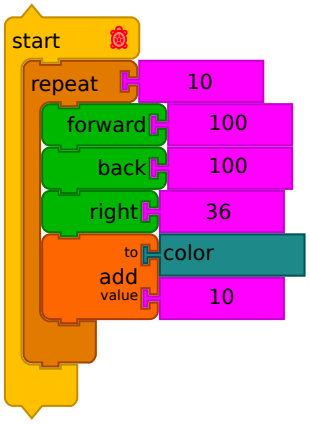
Using the *Heading* parameter, which changes each time the turtle changes direction, to change the color of a spiral RUN LIVE



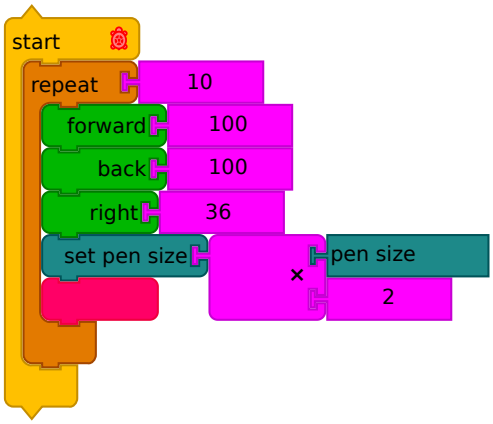
"Squiral" by Brian Silverman uses the *Heading* and *X* parameter blocks. RUN LIVE



Often you want to just increment a parameter by 1. For this, use the *Add-1-to* block. RUN LIVE



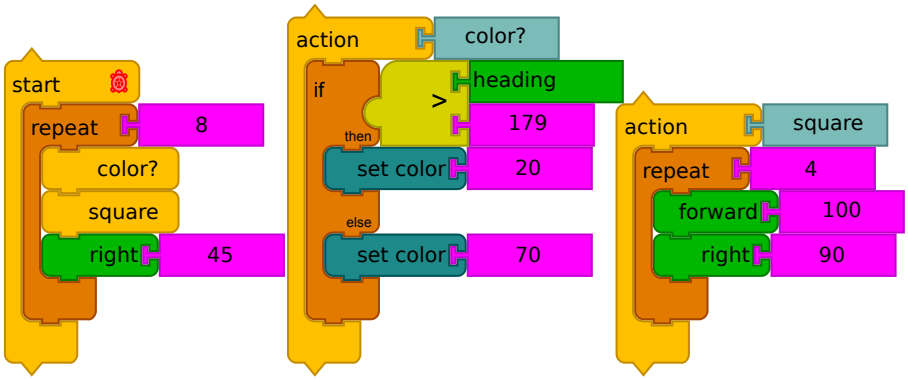
To increment (or decrement) a parameter by an arbitrary value, use the *Add-to* block. RUN LIVE



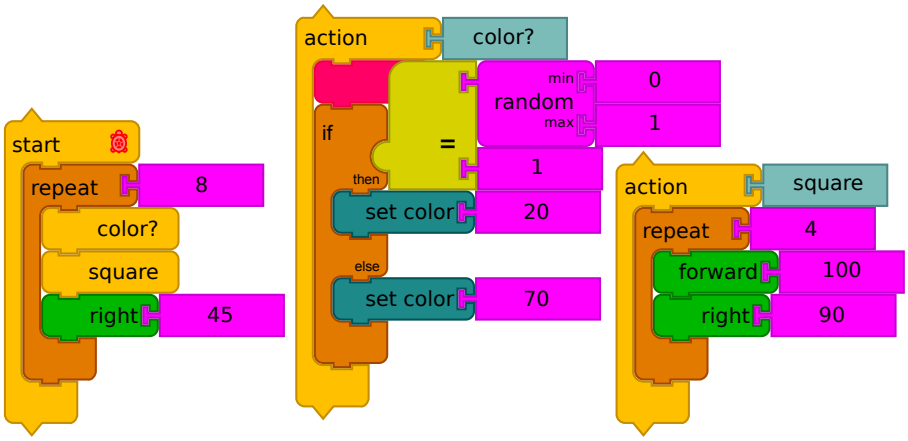
To make other changes to a parameter based on the current value, use the parameter's *Set* block. In this example, the pen size is doubled with each step in the iteration. RUN LIVE

5. Conditionals

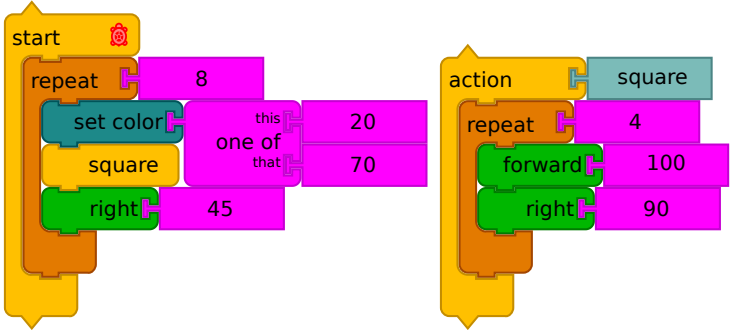
Conditionals are a powerful tool in computing. They let your program behave differently under differing circumstances. The basic idea is that if a condition is true, then take some action. Variants include if-then-else, while, until, and forever. Turtle Blocks provides logical constructs such as equal, greater than, less than, and, or, and not.



Using a conditional to select a color: Once the heading > 179, the color changes. RUN LIVE



Conditionals along with the *Random* block can be used to simulate a coin toss. RUN LIVE

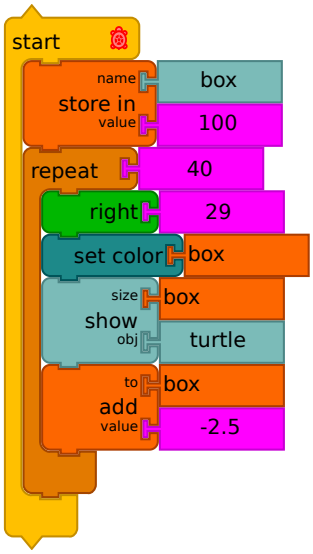


A coin toss is such a common operation that we added the *One-of* block as a convenience. RUN LIVE

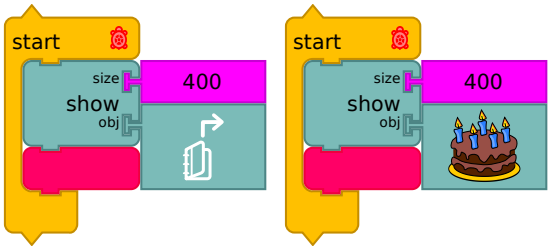
6. Multimedia

Turtle Blocks provides rich-media tools that enable the incorporation of sound, typography, images, and video.

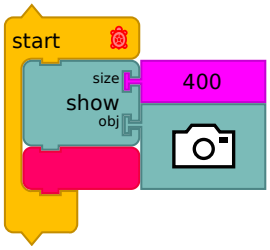
At the heart of the multimedia extensions is the *Show* block. It can be used to show text, image data from the web or the local file system, or a web camera. Other extensions include blocks for synthetic speech, tone generation, and video playback.



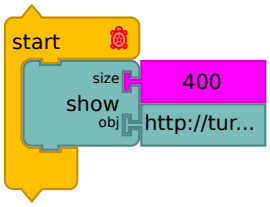
Using the *Show* block to display text; the orientation of the text matches the orientation of the turtle. RUN LIVE



You can also use the *Show* block to show images. Clicking on the Image block (left) will open a file browser. After selecting an image file (PNG, JPG, SVG, etc.) a thumbnail will appear on the *Image* block (right).



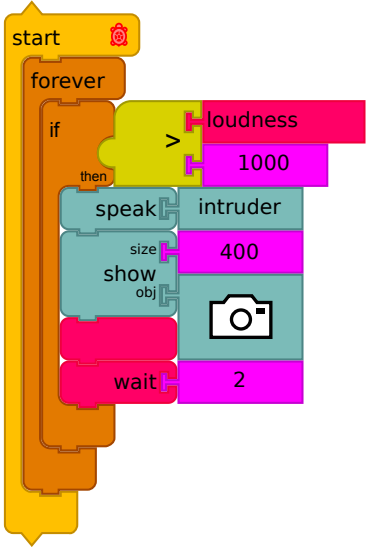
The *Show* block in combination with the *Camera* block will capture and display an image from a webcam. RUN LIVE



The *Show* block can also be used in conjunction with a URL that points to media. RUN LIVE

7. Sensors

Seymour Papert's idea of learning through making is well supported in Turtle Blocks. According to Papert, "learning happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe". Research and development that supports and demonstrates the children's learning benefits as they interact with the physical world continues to grow. In similar ways, children can communicate with the physical world using a variety of sensors in Turtle Blocks. Sensor blocks include keyboard input, sound, time, camera, mouse location, color that the turtle sees. For example, children may want to build a burglar alarm and save photos of the thief to a file. Turtle Blocks also makes it possible to save and restore sensor data from a file. Children may use a "URL" block to import data from a web page.



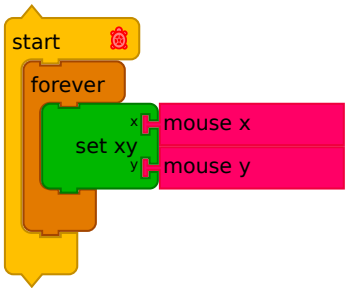
Using sensors. The *Loudness* block is used to determine if there is an intruder. A loud sound triggers the alarm action: the turtle shouts “intruder” and takes a picture of the intruder.

Teachers from the Sugar community have developed extensive collection of examples using Turtle Block sensors. Guzmán Trinidad, a physics teacher from Uruguay, wrote a book, *Physics of the XO*, which includes a wide variety of sensors and experiments. Tony Forster, an engineer from Australia, has also made remarkable contributions to the community by documenting examples using Turtle Blocks. In one example, Tony uses the series of switches to measure gravitational acceleration; a ball rolling down a ramp trips the switches in sequence. Examining the time between switch events can be used to determine the gravitational constant.

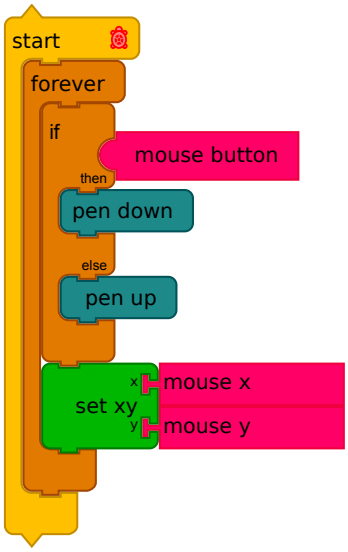
One of the typical challenges of using sensors is calibration. This is true as well in Turtle Blocks. The typical project life-cycle includes: (1) reading values; (2) plotting values as they change over time; (3) finding minimum and maximum values; and finally (4) incorporating the sensor block in a Turtle program.

Example: Paint

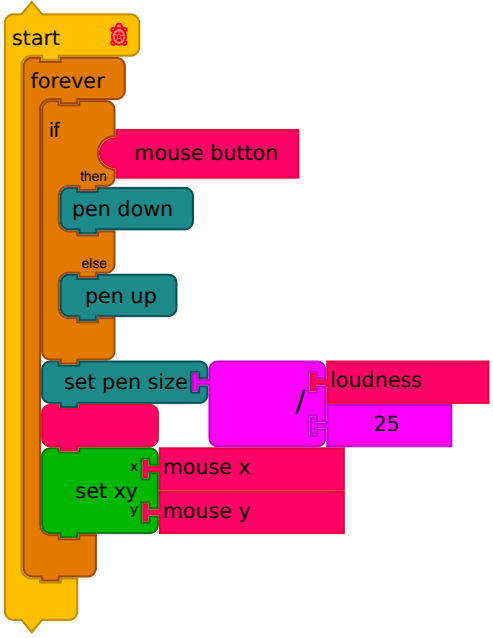
As described in the Sensors section, Turtle Blocks enables the programmer/artist to incorporate sensors into their work. Among the sensors available are the mouse button and mouse x and y position. These can be used to create a simple paint program, as illustrated below. Writing your own paint program is empowering: it demystifies a commonly used tool. At the same time, it places the burden of responsibility on the programmer: once we write it, it belongs to us, and we are responsible for making it cool. Some variations of paint are also shown below, including using microphone levels to vary the pen size as ambient sound-levels change. Once learners realize that they can make changes to the behavior of their paint program, they become deeply engaged. How will you modify paint?



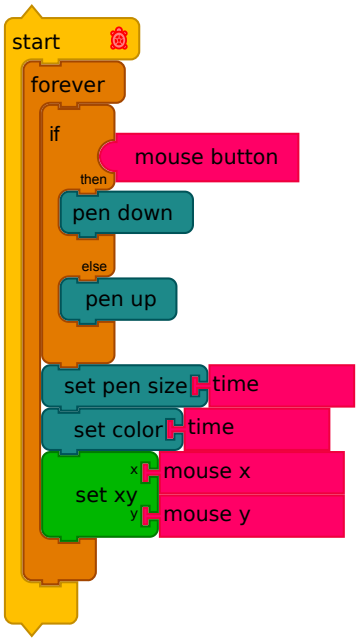
In its simplest form, paint is just a matter of moving the turtle to wherever the mouse is positioned. RUN LIVE



Adding a test for the mouse button lets us move the turtle without leaving a trail of ink. RUN LIVE

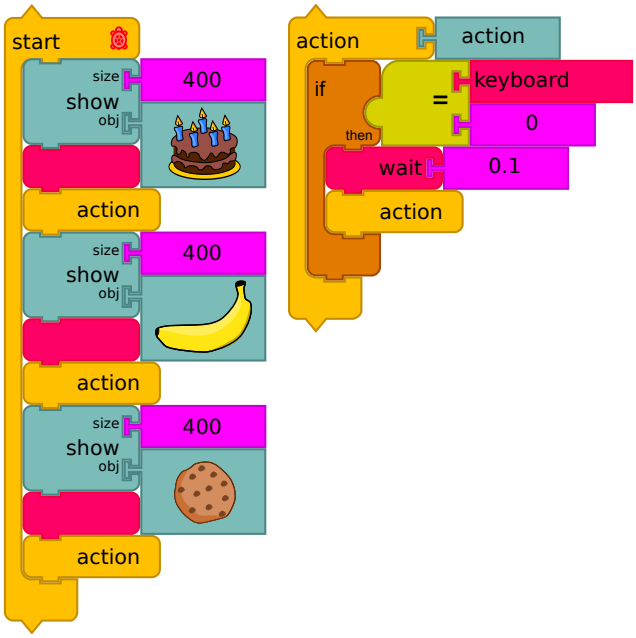


In this example, we change the pen size based on the volume of microphone input. RUN LIVE



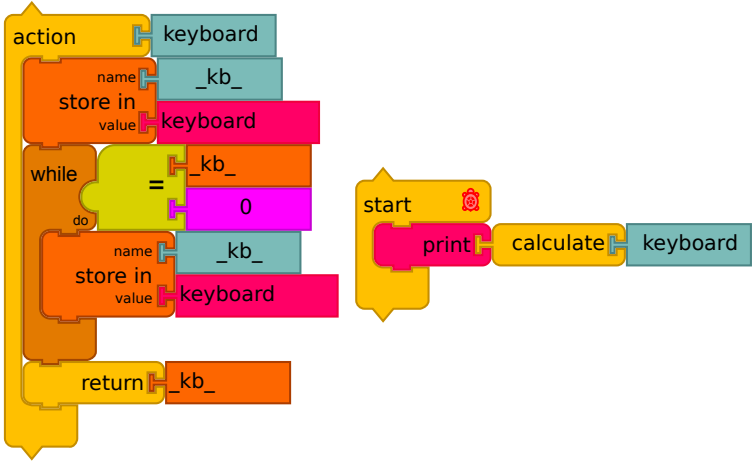
In another example, inspired by a student in a workshop in Colombia, we use time to change both the pen color and the pen size. RUN LIVE

Example: Slide Show

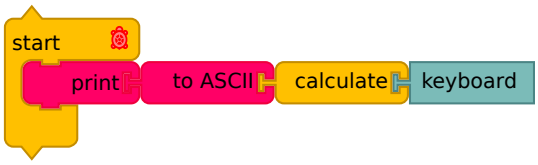


Why use Powerpoint when you can write Powerpoint? In this example, an Action stack is used to detect keyboard input: if the keyboard value is zero, then no key has been pressed, so we call the action again. If a key is pressed, the keyboard value is greater than zero, so we return from the action and show the next image.

Example: Keyboard

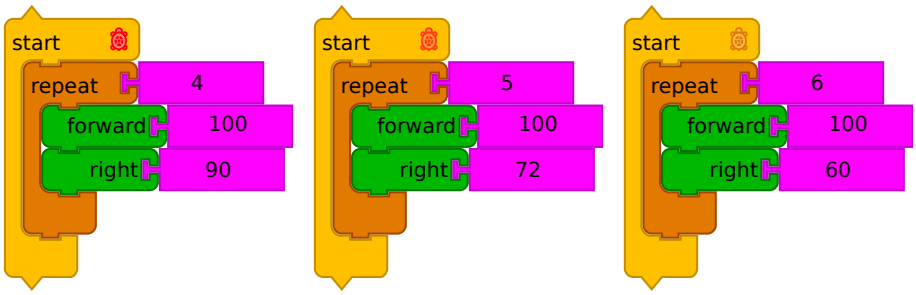


In order to grab keycodes from the keyboard, you need to use a *While* block. In the above example, we store the keyboard value in a box, test it, and if it is > 0, return the value. RUN LIVE

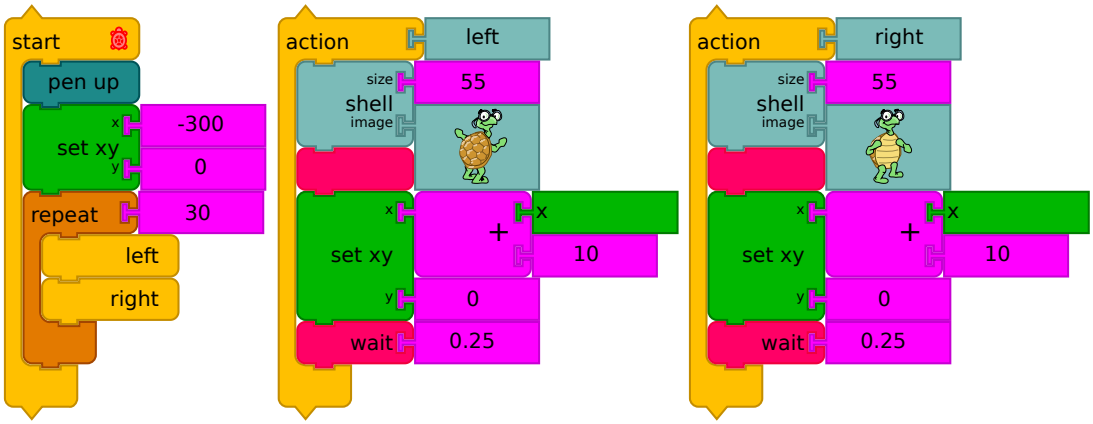


If you want to convert the keycode to a alphanumeric character, you need to use the *To ASCII* block. E.g., *toASCII(65) = A* RUN LIVE

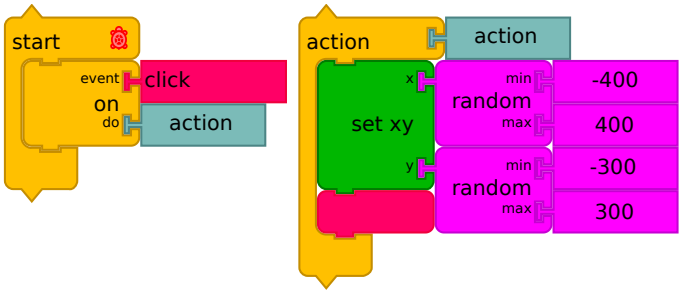
8. Turtles, Sprites, Buttons, and Events



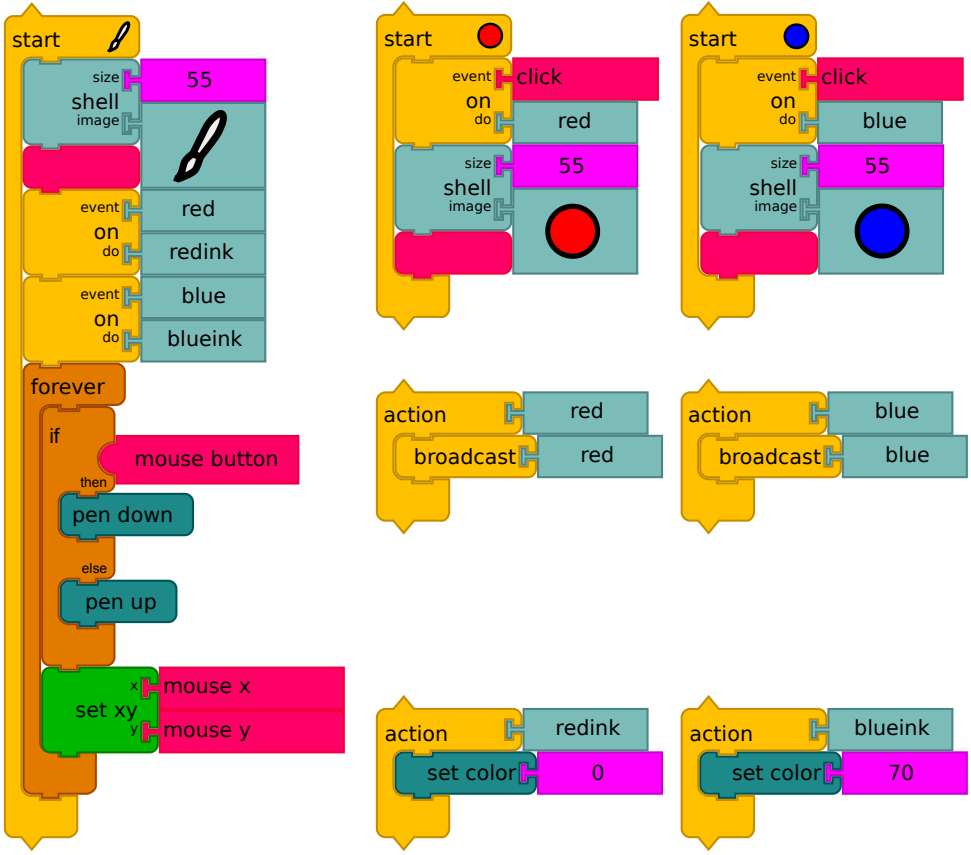
A separate turtle is created for each *Start* block. The turtles run their code in parallel with each other whenever the *Run* button is clicked. Each turtle maintains its own set of parameters for position, color, pen size, pen state, etc. In this example, three different turtles draw three different shapes. RUN LIVE



Custom graphics can be applied to the turtles, using the *Shell* block on the *Media* palette. Thus you can treat turtles as sprites that can be moved around the screen. In this example, the sprite changes back and forth between two states as it moves across the screen. RUN LIVE



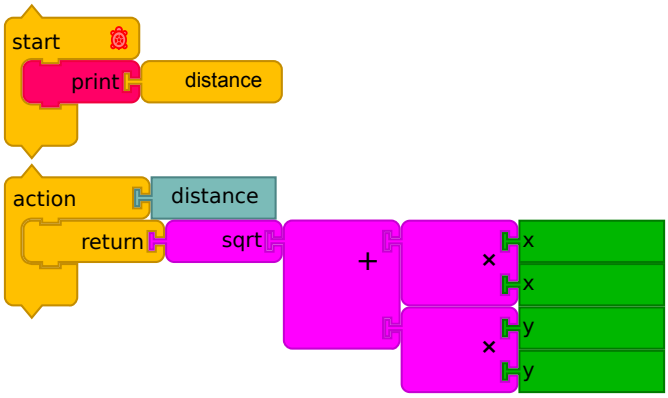
Turtles can be programmed to respond to a "click" event, so they can be used as buttons. In this example, each time the turtle is clicked, the action is run, which move the turtle to a random location on the screen. RUN LIVE



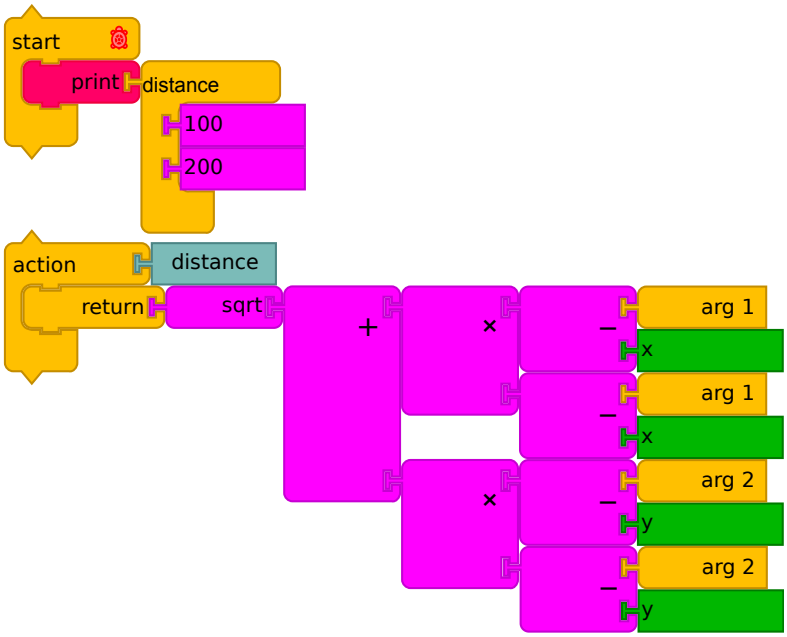
Events can be broadcast as well. In this example, another variant on Paint, turtle "buttons", which listen for "click" events, are used to broadcast change-color events. The turtle used as the paintbrush is listening for these events. RUN LIVE

9. Advanced Actions

Sometime you might want an action to not just run a stack of blocks but also to return a value. This is the role of the return block. If you put a return block into a stack, then the action stack becomes a calculate stack.



In this example, a *Calculate* stack is used to return the current distance of the turtle from the center of the screen. Renaming an action stack that has a *Return* block will cause the creation of a new block in the *Actions* palette that can be used to reference the return value: in this case, a *Distance* block is created. RUN LIVE

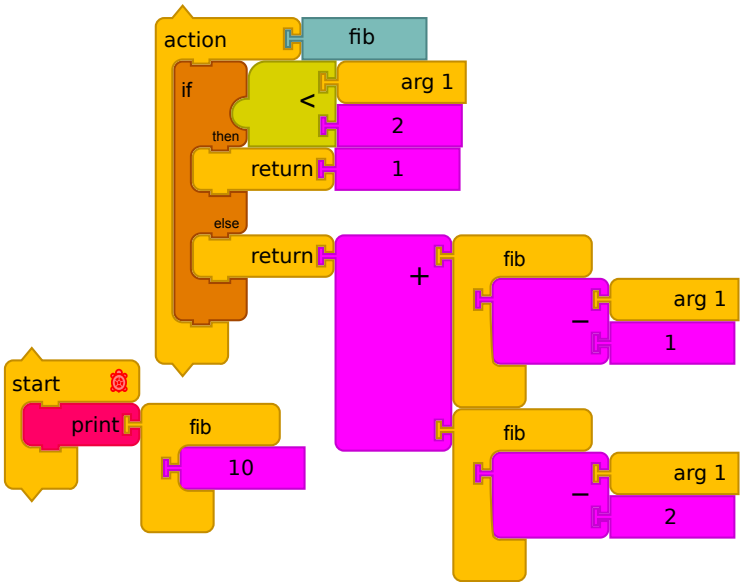


You can also pass arguments to an *Action* stack. In this example, we calculate the distance between the turtle and an arbitrary point on the screen by passing x and y coordinates in the *Calculate* block. You add additional arguments by dragging them into the "clamp".

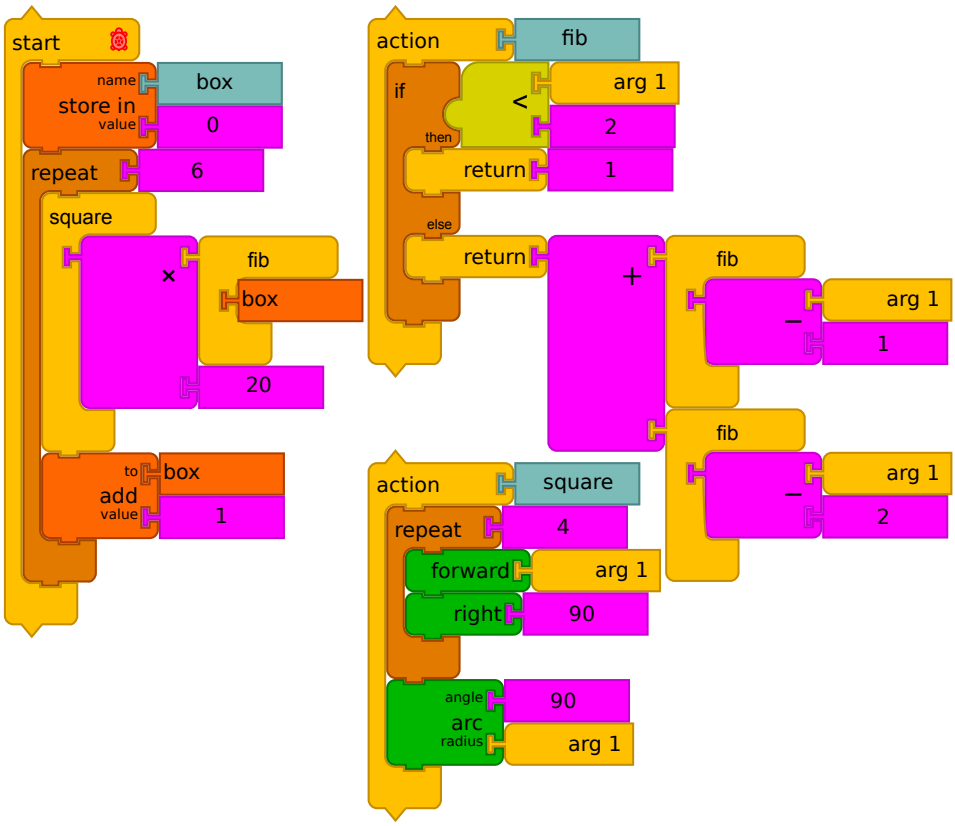
Note that args are local to *Action* stacks, but boxes are not. If you planned to use an action in a recursive function, you had best avoid boxes. RUN LIVE

Example: Fibonacci

Calculating the Fibonacci sequence is often done using a recursive method. In the example below, we pass an argument to the *Fib* action, which returns a value if the argument is < 2; otherwise it returns the sum of the result of calling the *Fib* action with argument - 1 and argument - 2.



Calculating Fibonacci RUN LIVE

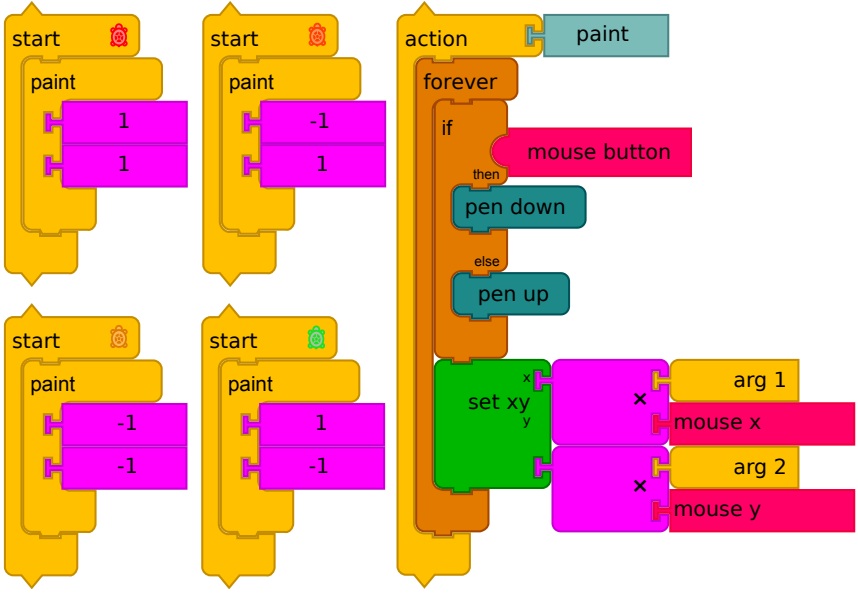


In the second example, we use a *Repeat* loop to generate the first six Fibonacci numbers and use them to draw a nautilus.

Draw a nautilus RUN LIVE

Example: Reflection Paint

By combining multiple turtles and passing arguments to actions, we can have some more fun with paint. In the example below, the *Paint Action* uses *Arg 1* and *Arg 2* to reflect the mouse coordinates about the y and x axes. The result is that the painting is reflected into all four quadrants.

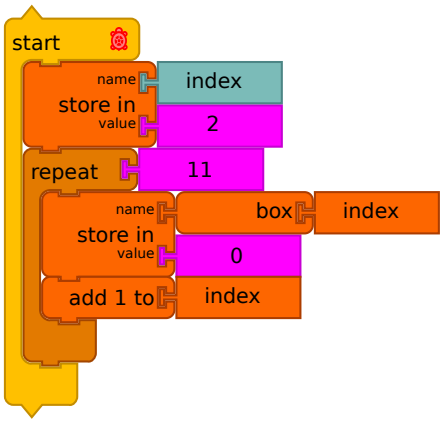


Reflection Paint RUN LIVE

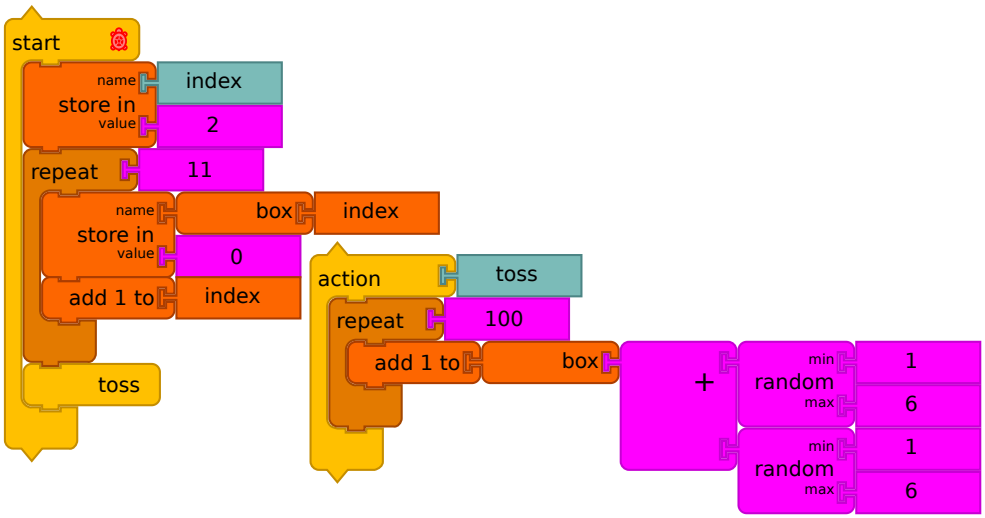
10. Advanced Boxes

Sometimes it is more convenient to compute the name of a *Box* than to specify it explicitly. (Note that the *Do* block affords a similar mechanism for computing the names of actions.)

In the following examples, we use this to accumulate the results of toss a pair of dice 1600 times (example inspired by Tony Forster).



Rather than specifying a box to hold each possible result (2 through 12), we use a *Box* as a counter (index) and create a box with the name of the current value in the counter and store in that box a value of 0.



Next we add an *Action* to toss the dice 1600 times. To simulate tossing a pair of dice, we sum two random numbers between 1 and 6. We use the result as the name of the box we want to increment. So for example, if we throw a 7, we add one to the *Box* named 7. In this way we increment the value in the appropriate *Box*.

Finally, we plot the results. Again, we use a *Box* as a counter ("index") and call the *Plot Action* in a loop. In the *Bar Action*, we draw a rectangle of length value stored in the *Box* with the name of the current value of the index. E.g., when the value in the index *Box* equals 2, the turtle goes forward by the value in *Box 2*, which is the accumulated number of times that the dice toss resulted in a 2; when the value in the *Index Box* is 3, the turtle goes forward by the value in *Box 3*, which is the accumulated number of times that the dice toss resulted in a 3; etc. RUN LIVE

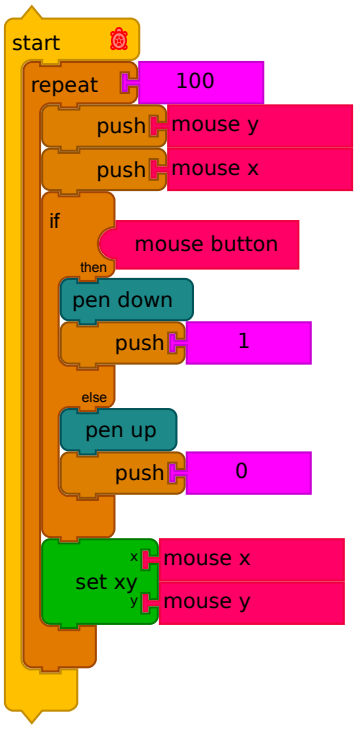
11. The Heap

Sometimes you need a place to temporarily store data. One way to do it is with boxes (as mentioned at the end of the Boxes section of this guide, they can be used as a dictionary or individual keyword-value pairs). However, sometimes it is nice to simply use a heap.

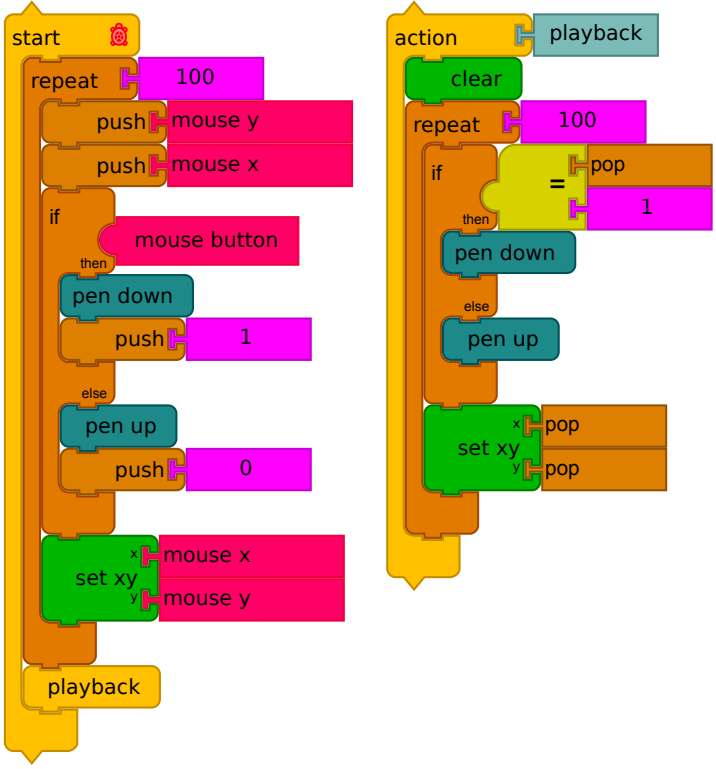
A heap is a essential a pile. The first thing you put on the heap is on the bottom. The last thing you put on the heap is on the top. You put things onto the heap using the *Push* block. You take things off of the heap using the *Pop* block. In Turtle Blocks, the heap is first-in last-out (FILO), so you pop things off of the heap in the reverse order in which you put them onto the heap.

There is also an *Index* block that lets you refer to an item in the heap by an index. This essentially lets you treat the heap as an array. Some other useful blocks include a block to empty the heap, a block that returns the length of the heap, a block that saves the heap to a file, and a block that loads the heap from a file.

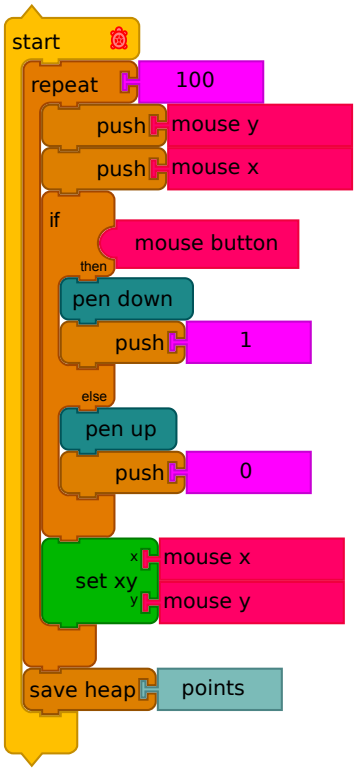
In the examples below we use the heap to store a drawing made with a paint program similar to the previous examples and then to playback the drawing by popping points off of the heap.



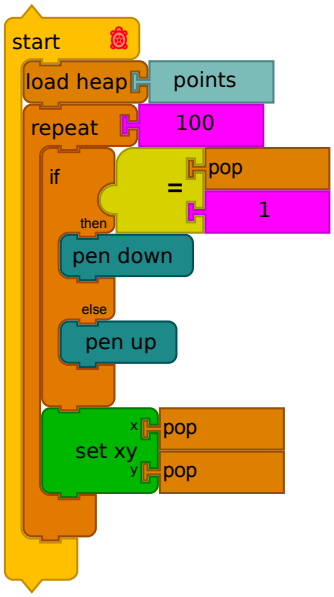
In the first example, we simply push the turtle position whenever we draw, along with the pen state. Note since we pop in the reverse order that we push, we push y, then x, then the mouse state.



In the second example, we pop pen state, x, and y off of the heap and playback our drawing. RUN LIVE



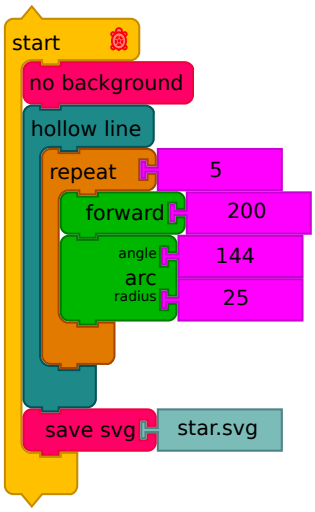
Use the *Save Heap* block to save the state of the heap to a file. In this example, we save our drawing to a file for playback later. RUN LIVE



Use the *Load Heap* block to load the heap from data saved in a file. In this example, we playback the drawing from data stored in a file. RUN LIVE

12. Extras

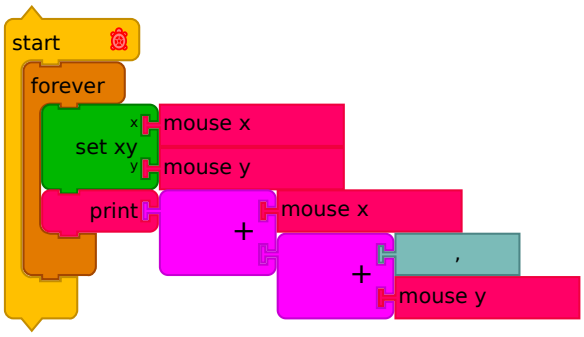
The *Extras* palette is full of utilities that help you use your project's output in different ways.



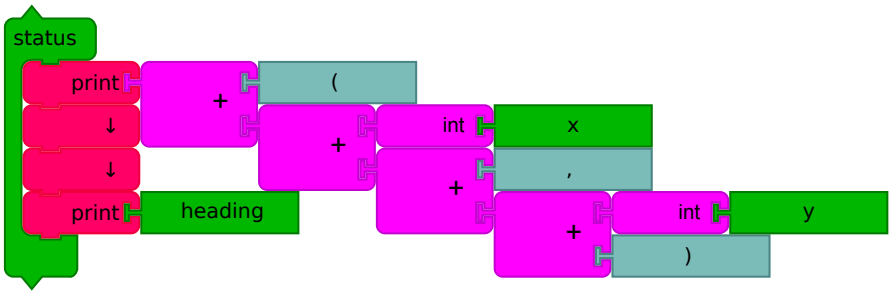
The *Save as SVG* block will save your drawing as simple vector graphics (SVG), a format compatible with HTML5 and many image manipulation programs, e.g., Inkscape. In the example above, we use it to save a design in a from that can be converted to STL, a common file format used by 3D printers. A few things to take note of: (1) the *No Background* block is used to suppress the inclusion of the background fill in the SVG output; (2) *Hollow lines* are used to make graphic have dimension; and (3) the *Save as SVG* block writes to the Downloads directory on your computer. (Josh Burker introduced me to Tinkercad, a website that can be used to convert SVG to STL.) RUN LIVE

13. Debugging Aids

Probably the most oft-used debugging aid in any language is the print statement. In Turtle Blocks, it is also quite useful. You can use it to examine the value of parameters and variables (boxes) and to monitor progress through a program.



In this example, we use the addition operator to concatinate strings in a print statement. The mouse x + ", " + mouse y are printed in the inner loop. RUN LIVE



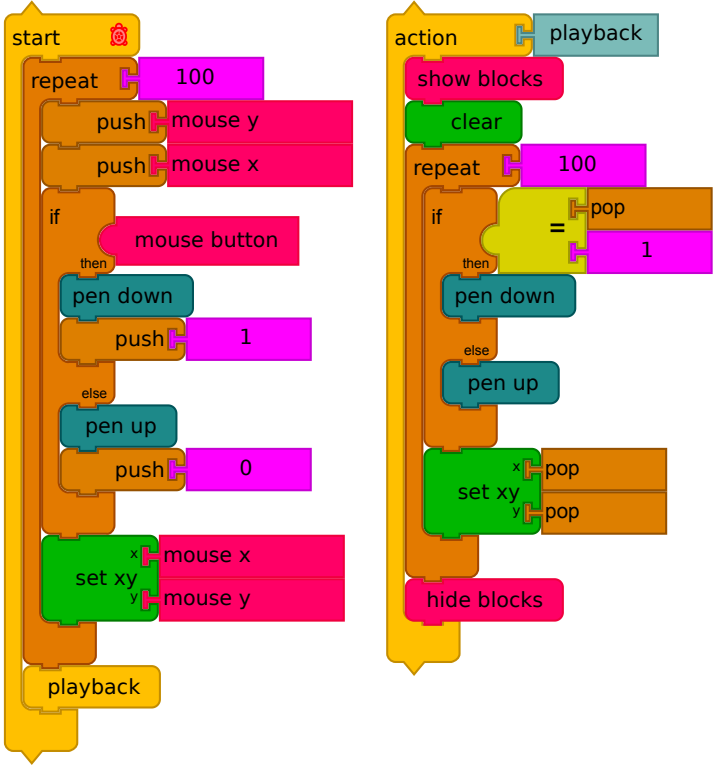
☒		heading
	(100, 50)	45
	(0, 0)	90

There is also a *Status* widget that can be programmed to show various paramters as per the figures above. RUN LIVE

Parameter blocks, boxes, arithmetic and boolean operators, and many sensor blocks will print their current value as the program runs when running in "slow" or "step-by-step" mode, obviating the need to use the Print block in many situations.

The *Wait* block will pause program execution for some number (or fractions) of seconds.

The *Hide* and *Show* blocks can be used to set "break points". When a *Hide* block is encountered, the blocks are hidden and the program proceeds at full speed. When a *Show* block is encountered, the program proceeds at a slower pace an the block values are shown.



A *Show* block is used to slow down execution of the code in an *Action* stack in order to facilitate debugging. In this case, we slow down during playback in order to watch the values popped off the heap. RUN LIVE

14. Advanced Color

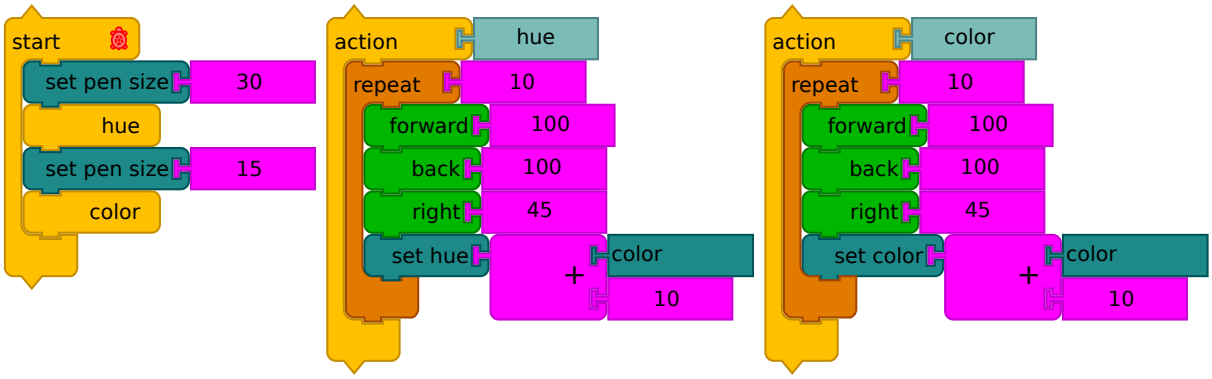
The internal representation of color in Turtle Blocks is based on the Munsell color system. It is a three-dimensional system: (1) hue (red, yellow, green, blue, and purple), (2) value (black to white), and (3) chroma (gray to vivid).

There are parameters for each color dimension and corresponding "setters". All three dimensions have been normalized to run from 0 to

1. For Hue, 0 maps to Munsell 0R. For Value, 0 maps to Munsell value 0 (black) and 100 maps to Munsell value 10 (white). For chroma, 0 maps to Munsell chroma 0 (gray) and 100 maps to Munsell chroma 26 (spectral color).

A note about Chroma: In the Munsell system, the maximum chroma of each hue varies with value. To simplify the model, if the chroma specified is greater than the maximum chroma available for a hue/value pair, the maximum chroma available is used.

The *Set Color* block maps the three dimensions of the Munsell color space into one dimension. It always returns the maximum value/chroma pair for a given hue, ensuring vivid colors. If you want to more subtle colors, be sure to use the *Set Hue* block rather than the *Set Color* block.



Color vs. hue example RUN LIVE

To set the background color, use the *Background* block. It will set the background to the current hue/value/chroma triplet.

15. Plugins

There are a growing number of extensions to Turtle Blocks in the from of plugins. See Plugins for more details.