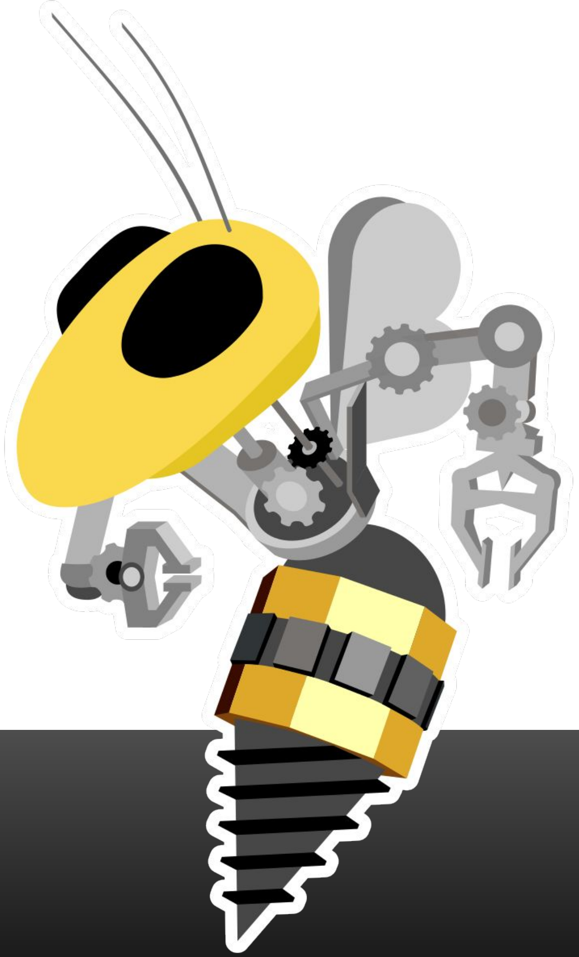
Welcome!

Firmware Training
Week 2



RoboJackets

Competitive Robotics at Georgia Tech

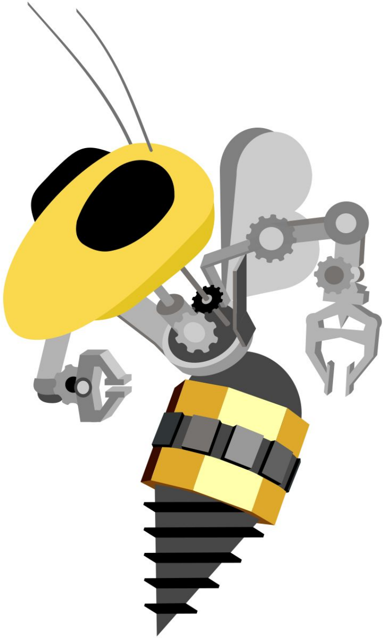
www.robojackets.org

Last Week!

- Microcontrollers
- Intro to C++
- Prototyping

This Week!

- C++ Continued
- Interrupts
- State Machines
- Lab



Firmware Training Board

What is this thing?

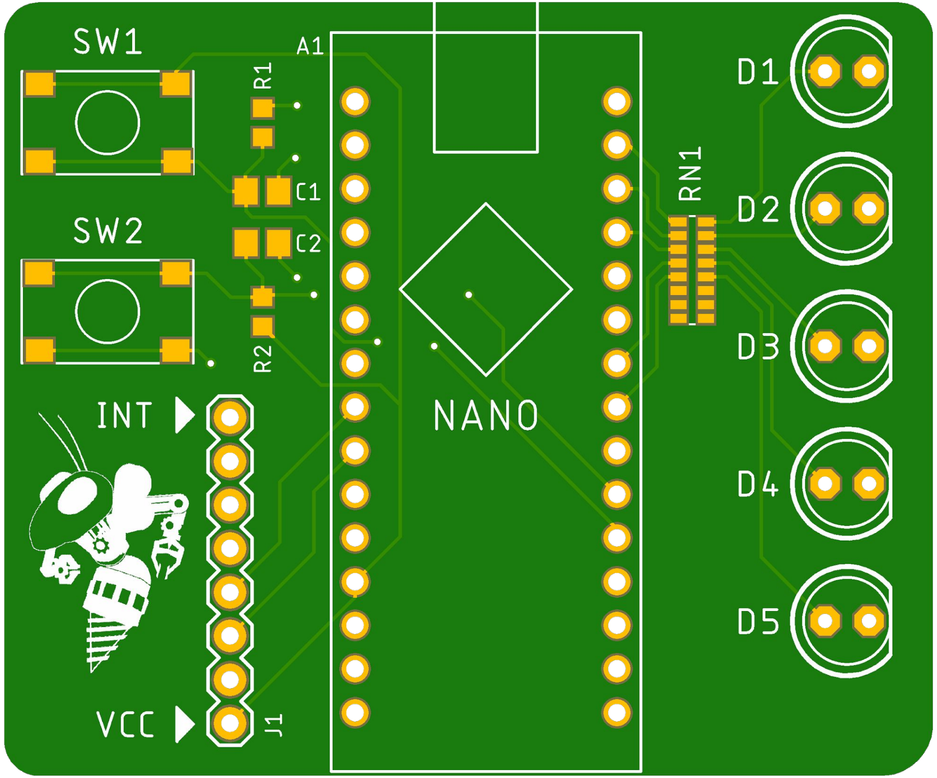
Features

- Arduino Nano
- 5 LEDs controlled by the Arduino
  - PWM capable (use in week 3)
- 2 Buttons
  - Two inputs buttons
- MPU-6050 IMU (use in week 4)

ROBOJACKETS
COMPETITIVE ROBOTICS AT GEORGIA TECH

Firmware Training Board

No more breadboards

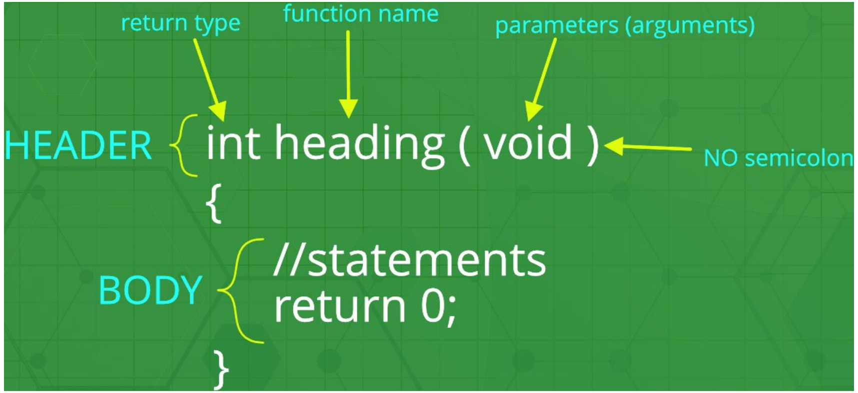


C++ Continued

See Plus Plus

Functions

- Helps to organize code into chunks
- Makes it easier to read and prevents duplicated code
- Define before using it in your code



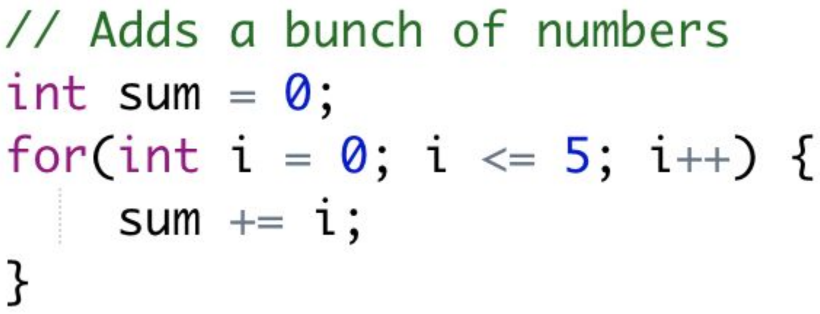
```
int heading ( void )
{
    //statements
    return 0;
}
```

Variable Scope

- Local variables
  - Within functions
  - Can't be accessed elsewhere
- Global variables
  - What you used before (before setup)
  - Accessible everywhere in the file
- Volatile
  - Variables used in interrupts
  - Compilers check for variables that are not either

For Loops

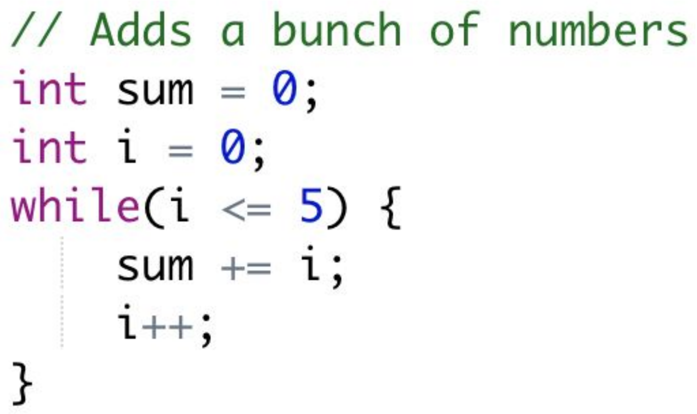
- Designed to repeat code a fixed number of times
- Three part syntax
    - Initialize counter
    - Bounds check
    - Increment counter



```
// Adds a bunch of numbers
int sum = 0;
for(int i = 0; i <= 5; i++) {
    sum += i;
}
```

While Loops

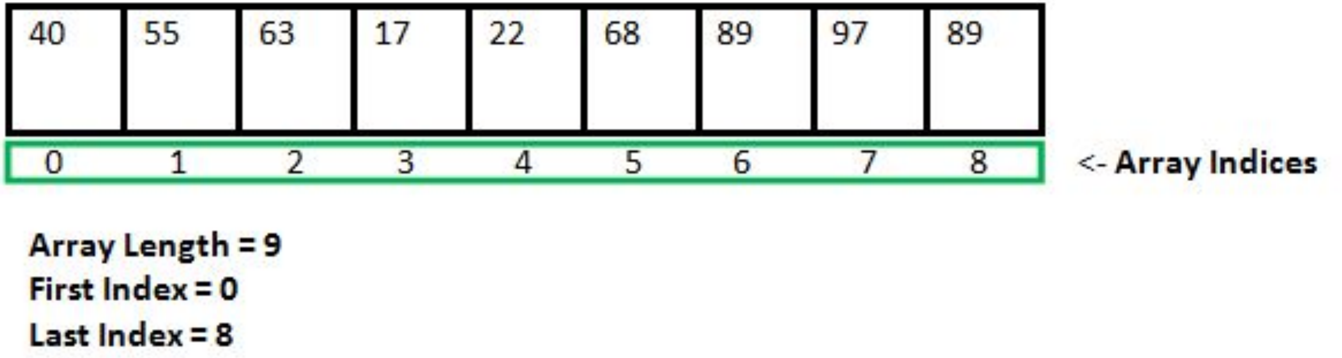
- Designed to repeat code until condition is met
- Three part syntax
  - Initialize counter
  - Condition check
  - Increment counter



```
// Adds a bunch of numbers
int sum = 0;
int i = 0;
while(i <= 5) {
    sum += i;
    i++;
}
```

Arrays

- Way to organize data (collection of same data type)
- Has a fixed size at creation
- Access using an index

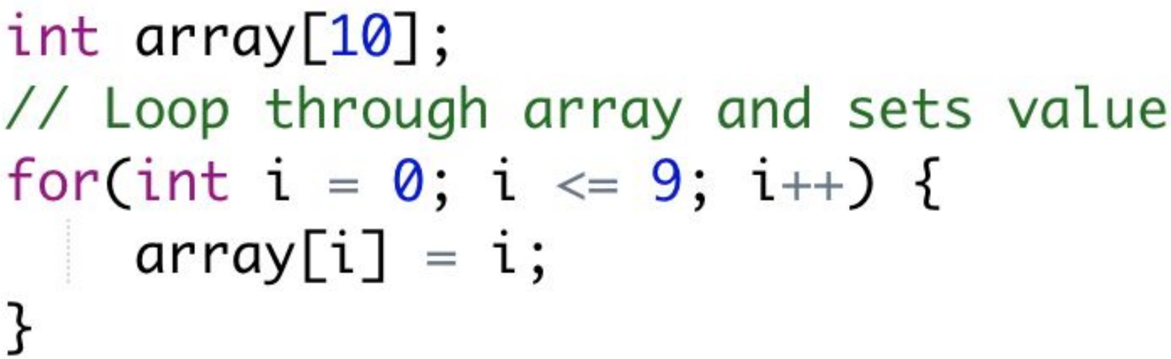


40	55	63	17	22	68	89	97	89	
0	1	2	3	4	5	6	7	8	<- **Array Indices**

Array Length = 9
First Index = 0
Last Index = 8

Using Arrays

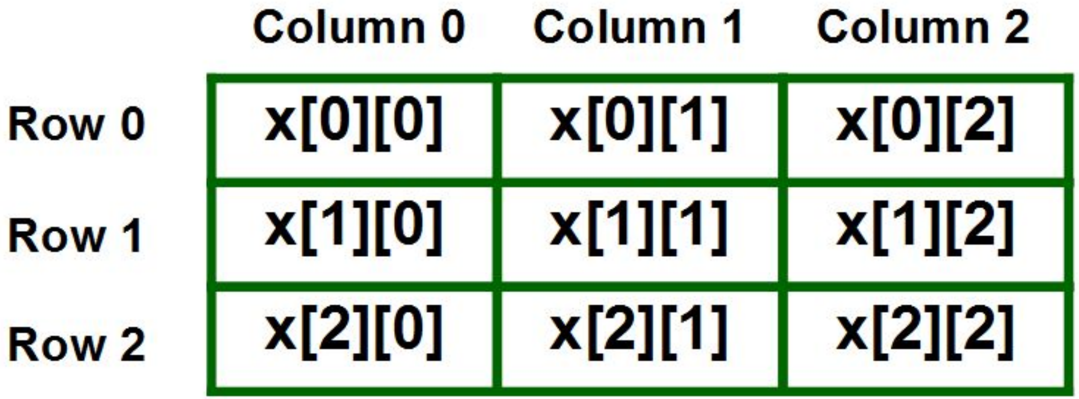
- Create with *type name[size]* syntax
- Read and set data with *name[index]* syntax
    - You should always set before you read



```
int array[10];
// Loop through array and sets value
for(int i = 0; i <= 9; i++) {
    array[i] = i;
}
```

2D Arrays

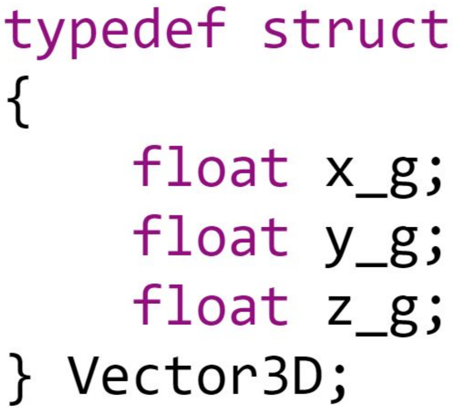
- Make an array of arrays (multiple dimensions)
- Created by adding another dimension *[size1][size2]*



	Column 0	Column 1	Column 2
Row 0	x[0][0]	x[0][1]	x[0][2]
Row 1	x[1][0]	x[1][1]	x[1][2]
Row 2	x[2][0]	x[2][1]	x[2][2]

Structs

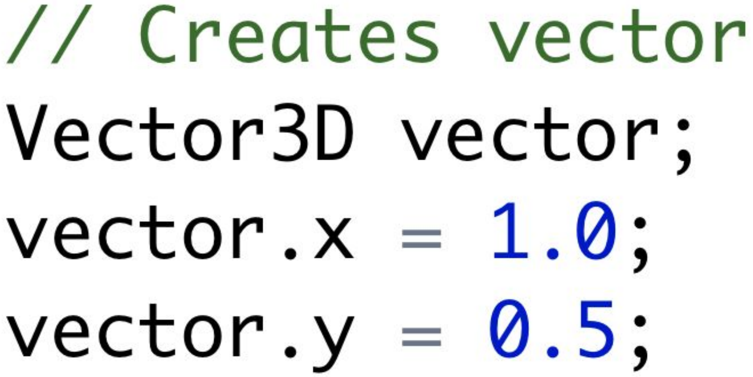
- Ways to organize data of same or different types
  - A vector has multiple different quantities
- Commonly used to package related data



```
typedef struct
{
    float x_g;
    float y_g;
    float z_g;
} Vector3D;
```

Using Structs

- Create as you would a variable, *type name* syntax
- Read and set using *name.field* syntax
    - You should always set before you read



```
// Creates vector
Vector3D vector;
vector.x = 1.0;
vector.y = 0.5;
```

Interrupts

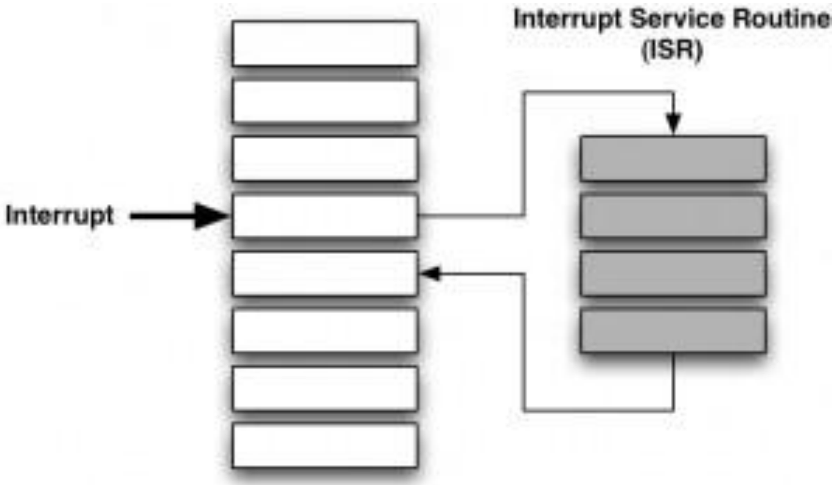
Hey Mom. Mom. Mom. Mom. Mo- WHAT!

What are Interrupts

- Mechanism built into processors to run a function when an event occurs
  - Can be hardware (a pin) or software (a timer)
- The function that gets called is known as an ISR (interrupt service routine)
- It stops (interrupts) the main code before returning back to the main code

Using Interrupts

- Allows us to not waste time checking if a device is ready (polling)
- Instead the device just tells us it is ready (interrupts)
- Returns to our normal code right after



Arduino and Interrupts

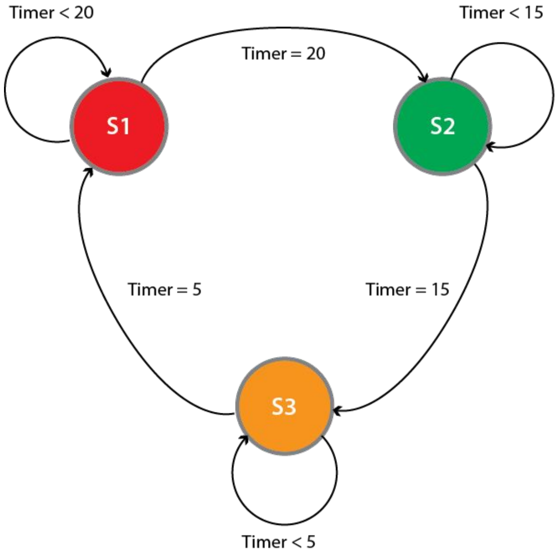
- Arduino provides the attach interrupt method for this
  - Triggers an interrupt when the signal to an input pin changes
  - *attachInterrupt(pin, ISR, trigger mode)*
- Mode:
  - Rising/Falling/Change Edge trigger
  - Calls ISR on 0 to 1 change, 1 to 0 change, or both

State Machines

“Ferst Driiive, walk sign is on to cross, Ferst Driiiive”

What is a State Machine?

- Stores a status, or state, at any given time
- Takes in inputs and gives outputs to interact with other devices
- Switches states based on current states and inputs



Traffic Light State Machine

Purpose of a State Machine

- Provide a way to use a sequence or history of inputs, not just current input values
- Restrict behavior of a system to certain actions based on a variety of inputs
- Provide a sort of memory - tied to history of inputs
  - Combination lock
  - Traffic signals && crosswalks
  - Robots!

Usages of State Machines

- Making sure things happen in the right order (startup)
- Controlling behavior of robots better - output based off of states (stable), not directly by inputs
- A CPU (and a Microcontroller)!

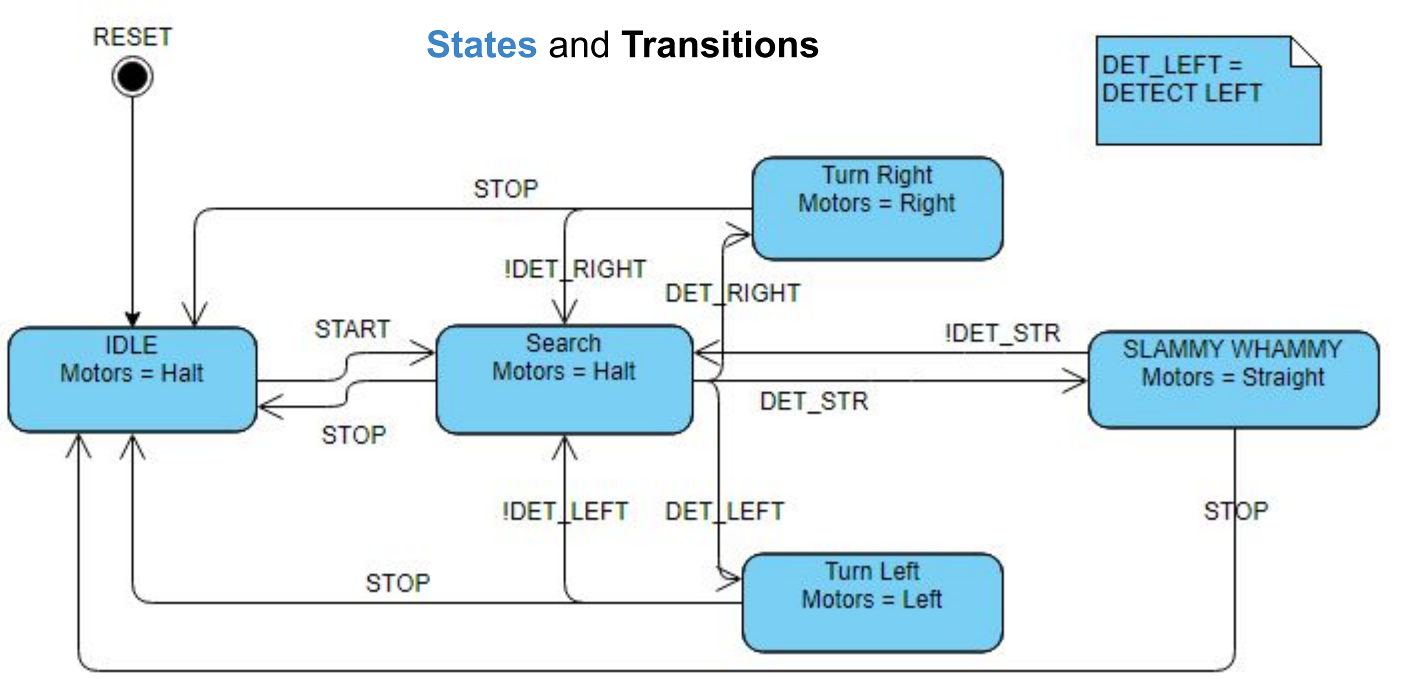
Types of State Machines

- **Moore state machine** - outputs are based only on current state
- Mealy state machine - outputs are based on the current state and the input (transitions)
- We typically use a Moore State Machine

Inputs and Outputs

- Inputs frequently include sensors or buttons
  - Prefer boolean state transition
- Outputs can be motors or LEDs
  - Behaviors (running motors, running code) of the robot

Example Diagram (RoboWrestling)



Lab Time

Lab Info

- Create a counter state machine
- Write interrupts for each button
  - One to count up
  - One to count down
- Implement state machine
- Display state using board LEDs