MCE 433 – Mechatronics Final Project:

Manually Controlled Object Avoiding Robot

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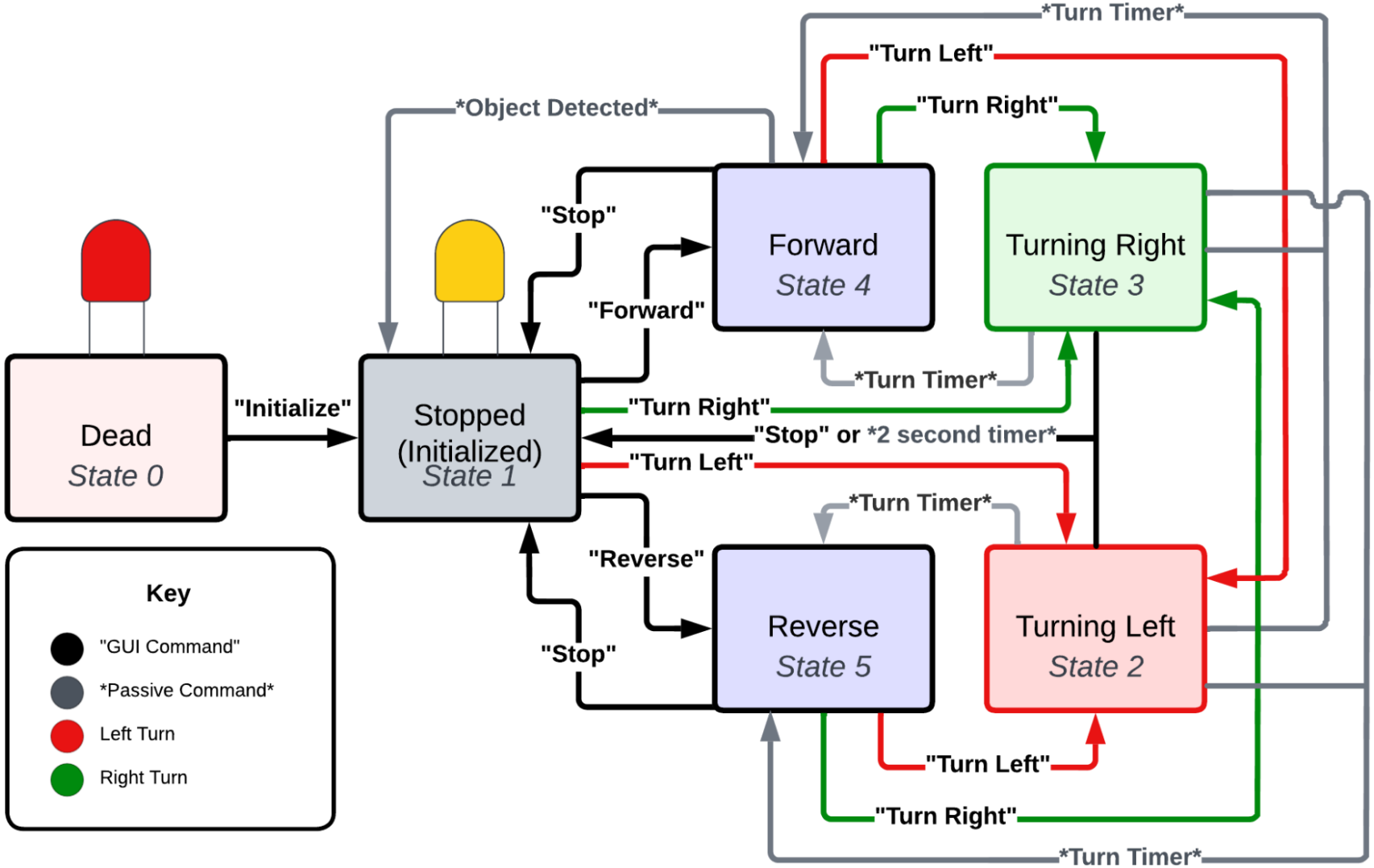
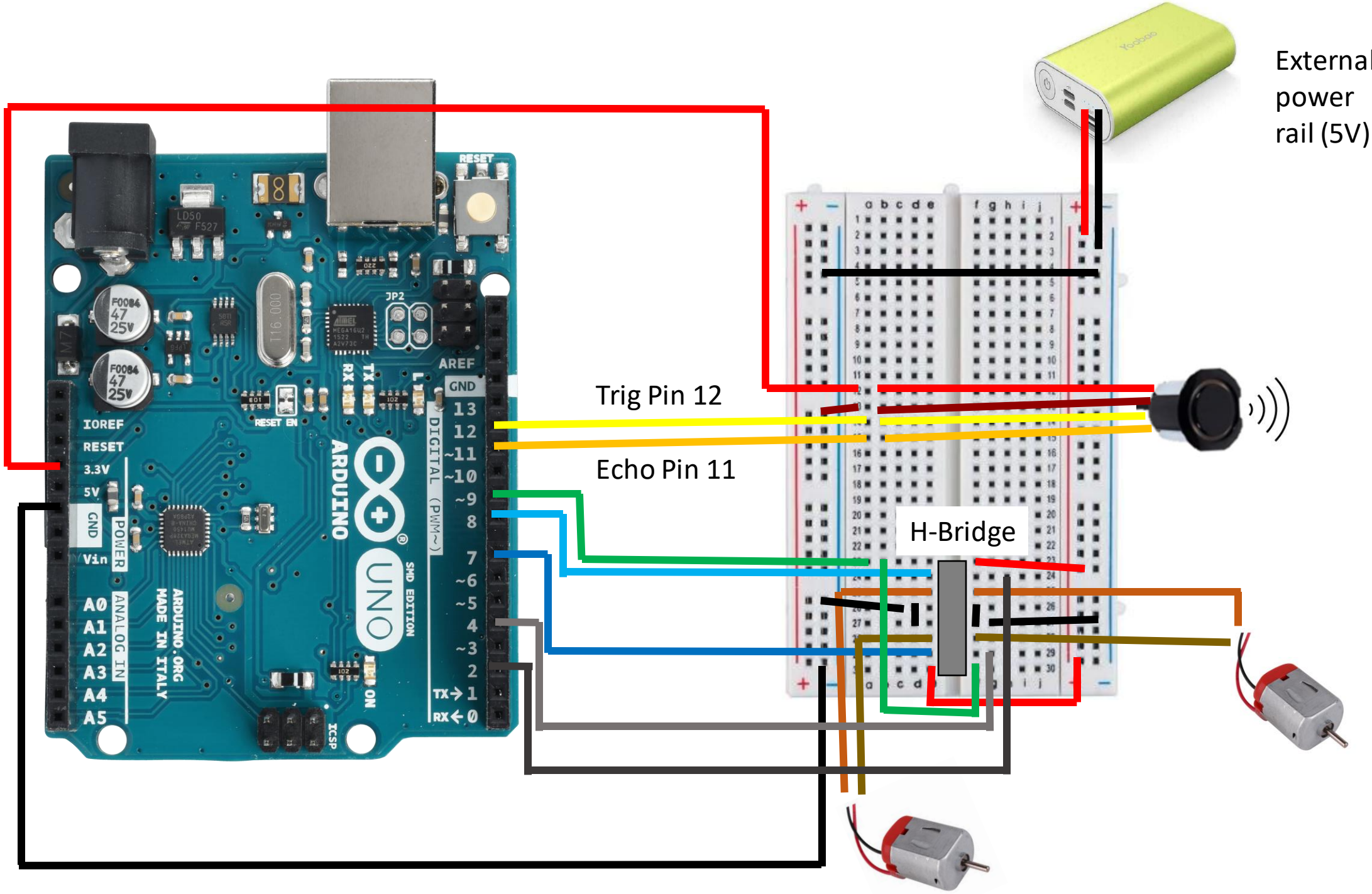
Project Description:

The students developed a wheeled robot based around the Arduino microcontroller. The robot is small, designed with a laser cut wooden frame. Actuation will be from rear-wheel-drive tank tread wheelbase for steering and general motion. PWM commands are sent from the Arduino to control variable speeds of the driving motors. A forward-looking ultrasonic distance sensor is mounted on the front of the vehicle for automated object avoidance (the robot stops when too close to the object). The sensor needed a timer to properly estimate distances of objects by sending the digital input to the Arduino of when the first ping was sent and timing how long the echo took to return to the sensor. The system is powered by an external battery, connected to a variable voltage converter, stepping the 3.6v battery up to 5v. Control commands are sent to the Arduino via a Python GUI connected with a USB cable. The GUI, pictured later, features buttons such as ‘forward’, ‘reverse’, ‘turn left’, and ‘turn right’, in addition to setting the speed of the vehicle (slow, medium, fast). On-board LEDs will be used to indicate whether the vehicle is in the ‘dead’ state (red), or the ‘stopped’ state (yellow).

Components:

- Arduino
- Arduino hat
- USB Cable
- LEDs (Red and yellow)
- 2x 330 Ohm resistor
- H-Bridge
- PCB standoffs
- 2x DC motors
- Voltage converter
- 3.6v battery
- Wheelbase (wheels, treads, and frame)
- Plywood frame
- Miscellaneous wires


Dead
State 0
"Initialize"
Stopped
(Initialized)
State 1
Forward
State 4
Turning Right
State 3
Reverse
State 5
Turning Left
State 2
"Stop"
"Forward"
Object Detected
"Turn Left"
"Turn Right"
Turn Timer
"Turn Right"
"Stop" or *2 second timer*
"Turn Left"
"Reverse"
"Stop"
Turn Timer
Turn Timer
"Turn Left"
"Turn Right"
Turn Timer
Key
"GUI Command"
Passive Command
Left Turn
Right Turn


External
power
rail (5V)
Trig Pin 12
Echo Pin 11
H-Bridge

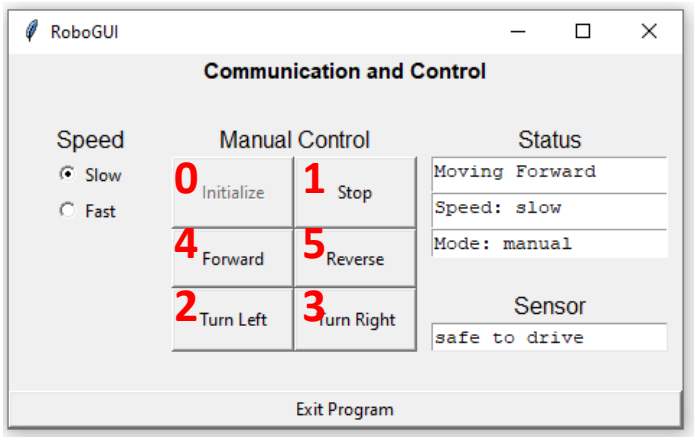
Explanation of States

0. **State 0.** "Dead"
    - **a.** This is the state that the system is initialized into.
    - **b.** A read LED shines.
    - **c.** Motors are off.
    - **d.** When the GUI is started, everything is greyed out, and the only option is to 'initialize' to begin.
1. State 1. "Primed/Armed/Stopped"
    - **a.** This state is the 'home base' for the system.
    - **b.** After 'initialization,' this state is entered.
    - **c.** The motors are off.
    - **d.** A yellow light shines.
    - **e.** You can enter this state from all other states by clicking the 'Stop' button.
    - **f.** When an object is detected, the system automatically enters this state.
    - **g.** The system stays in this state until a button is clicked.
2. State 2. "Turn Left"
    - **a.** To enter this state, click the 'Turn Left' button in the GUI.
    - **b.** This state is *timed* and operates the motors.
    - **c.** The pins connected to the h-bridge are set to cause 'left' angular rotation of the robot.
    - **d.** After a period of time, the state is exited and returns to the previous state.
3. State 3. "Turn Right"
    - **a.** To enter this state, click the 'Turn Right' button in the GUI.
    - **b.** This state is *timed* and operates the motors.
    - **c.** The pins connected to the h-bridge are set to cause 'right' angular rotation of the robot.
    - **d.** After a period of time, the state is exited and returns to the previous state.
4. State 4. "Move Forward"
    - **a.** To enter this state, click the 'Forward' button in the GUI.
    - **b.** The h-bridge pins are set to rotate both motors in the same direction to move the robot forward.
    - **c.** The ultrasonic sensor frequently records measurements; if measurements are less than a threshold, the system moves to the 'Stop' state to shut off the motors. Object avoidance is implemented in this state only.
    - **d.** To manually exit this state, click any other button in the GUI.
5. State 5. "Move Backward" / "Reverse"
    - **a.** To enter this state, click the 'Reverse' button in the GUI.
    - **b.** The h-bridge pins are set to rotate both motors in the same direction to move the robot backward.
    - **c.** To exit this state, click any other button in the GUI.

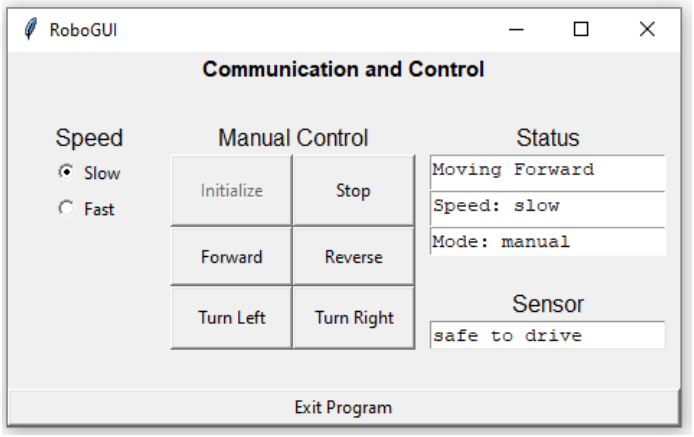
Commands

The 'Manual Control' section of the GUI is responsible for sending commands that move between states in the Arduino. Clicking a button switches to the state number shown on each button.

The radio buttons for speed only update a PWM pin value and do not cause a change of state.



Code In Action



The GUI contains three main sections:

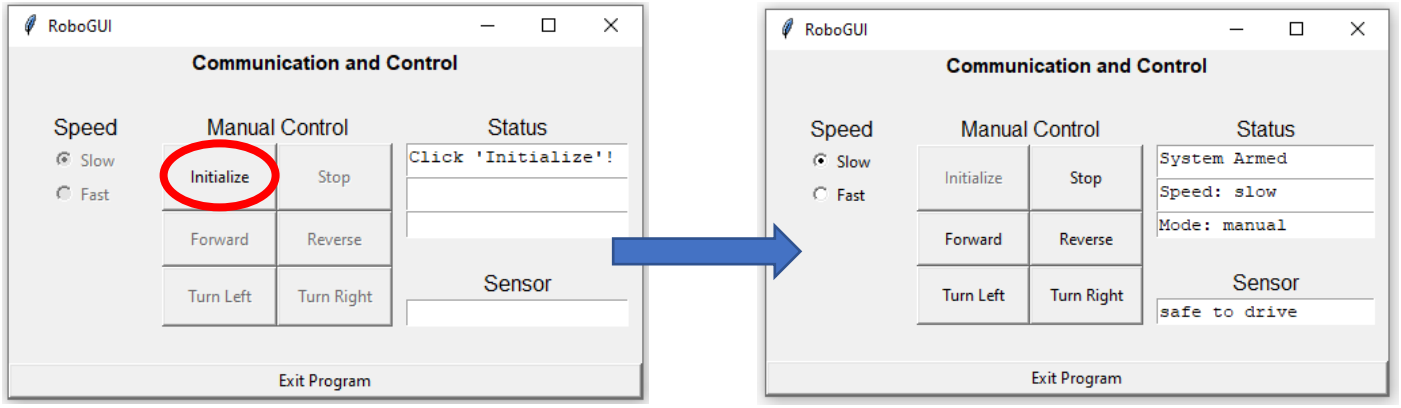
- Speed setting (left)
- Manual Control (center)
- Statuses (right)

The speed setting can be switched between ‘slow’ and ‘fast,’ which alters the PWM value sent to the motors.

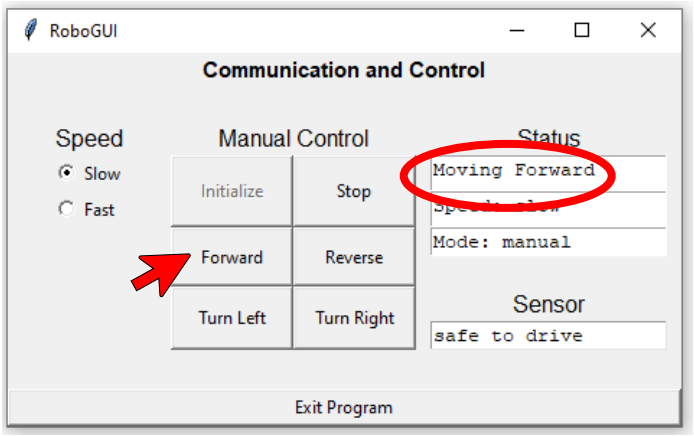
The manual control buttons send commands via serial connection to the Arduino to switch between states.

The ‘Status’ and ‘Sensor’ section are used purely as means to display information to the user and are automatically updated based on system configurations and events that occur.

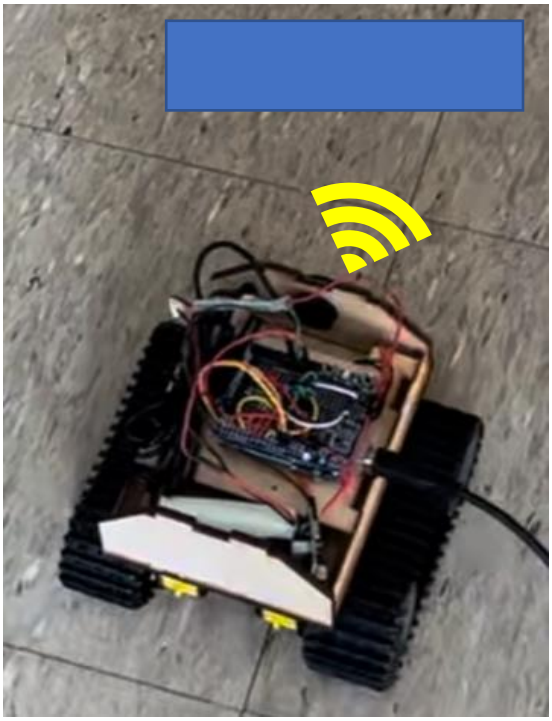
When the GUI is opened, all functionality is blocked until ‘Initialize’ is clicked. Then, regular operation begins.

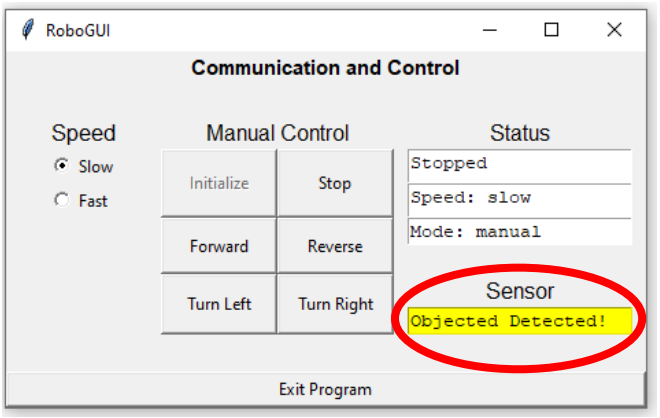


Clicking different buttons in the ‘Manual Control’ section sends commands via serial connection to the Arduino, which switches the system case and updates the digital output pins that connect to the h-bridge for motor control. The GUI updates accordingly.

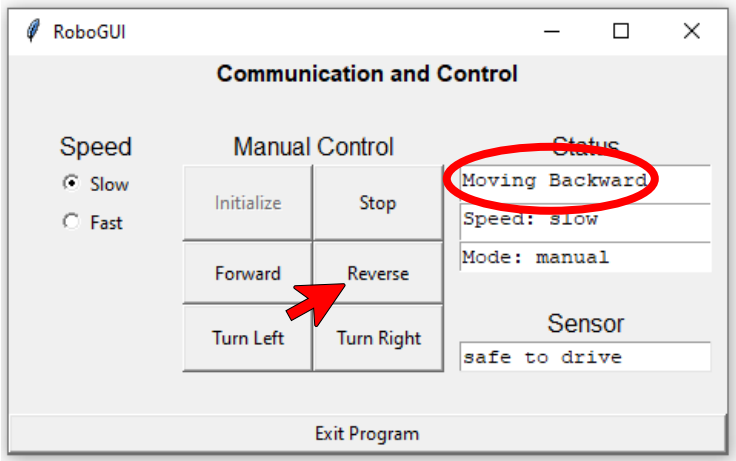


When the robot encroaches upon an object, the ultrasonic sensor detects it and stops the robot. The GUI updates.

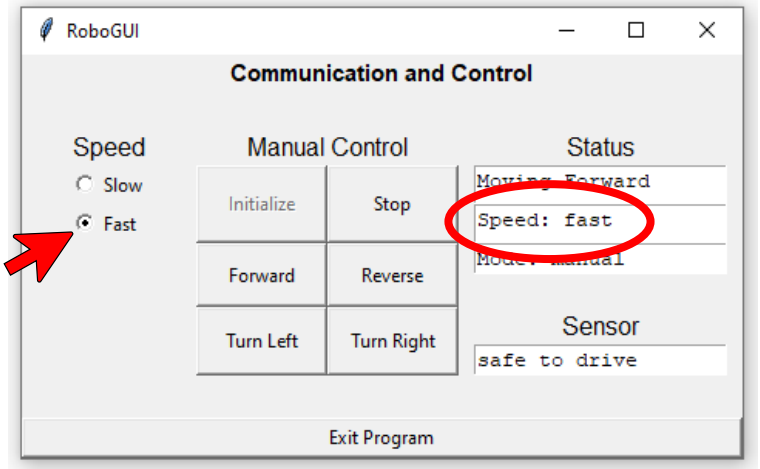




The user is in control and can click any button in the GUI to free the robot from its 'stopped' state. Note that if the user tries to go forward, the robot will again see the object and quickly stop. Hence, backing up (reverse) is advised.



The speed of the robot can be adjusted. Clicking 'slow' or 'fast' sends a command to the Arduino via serial comms and sets the PWM value for the motor (the Pin that goes to the PWM input on the h-bridge).



Appendix A: Python GUI Code

```
# Mechatronics - Jason Noel & Phil Parisi - 6Dec2022
# Final Project - Wheeled Robot


############### NOTES
# Commands for Task 1
      # i --> initialize
    # l --> left
    # r --> right
    # f --> forward
      # b --> back/reverse
    # s --> stop
      # a --> autonomous
    # z --> null

# Other Parameters to Pass to Arudino
      # 1 --> 'slow' speed mode (send as CHAR not int)
      # 2 --> 'fast' speed mode (send as CHAR not int)

############### PACKAGES

import tkinter as tk
import serial
import time


############### SETUP

# Arduino Setup
arduino = serial.Serial(port='COM3', baudrate=9600, timeout=0.05)
valBytes = bytes('d','utf-8')       #Convert to bytes
arduino.write(valBytes)

# Default Values
commandChar = 'z' #Command to switch states DEFAULT "OFF" = 'a'
progMode = 'manual' # 2 modes: 'manual' and 'auto'
currentSpeed = '1' # 2 levels: 'slow' = '1' and 'fast' = '2'
objectDetected = 0 # use to indicate when objects are detected

############### FUNCTIONS
# must define functions before we call them

def initialize():
      global commandChar

      #Clear and Post Status Message in GUI
      outMsg = "System Armed"
      writeTextReadOnly(outMsg, motionBox)
      writeTextReadOnly("Speed: slow", speedBox)
      writeTextReadOnly("Mode: manual", progModeBox)
      writeTextReadOnly("safe to drive", sensorBox)

      # Disable Start Button
      initializeTaskButton.configure(state = 'disable')

      # Enable Other Buttons
      stopTaskButton.configure(state = 'normal')
      forwardButton.configure(state = 'normal')
      backwardButton.configure(state = 'normal')
      turnRightButton.configure(state = 'normal')
      turnLeftButton.configure(state = 'normal')
```

```
	slowSpeedRadio.configure(state = 'normal')
	fastSpeedRadio.configure(state = 'normal')
	manualModeRadio.configure(state = 'normal')
	autoModeRadio.configure(state = 'normal')

	# Update Command
	commandChar = 'i'
	pyToSerial(commandChar)

	# Infinite While Loop
	runMainLoop()


def stop():
	global commandChar
	global objectDetected

	# Clear and Post Status Message in GUI
	outMsg = "Stopped"
	writeTextReadOnly(outMsg, motionBox)

	# Update Command
	commandChar = 's'
	pyToSerial(commandChar)

	if progMode == "auto":
		manualModeRadio.select()
		updateProgMode()

	# Clear Sensor if necessary
	if objectDetected == 1:
		objectDetection()

def moveForward():
	global commandChar
	global objectDetected

	# Clear and Post Status Message in GUI
	outMsg = "Moving Forward"
	writeTextReadOnly(outMsg, motionBox)

	# Update Command
	commandChar = 'f'
	pyToSerial(commandChar)

	# Clear Sensor if necessary
	if objectDetected == 1:
		objectDetection()


def moveBackward():
	global commandChar
	global objectDetected

	# Clear and Post Status Message in GUI
	outMsg = "Moving Backward"
	writeTextReadOnly(outMsg, motionBox)

	# Update Command
	commandChar = 'b'
	pyToSerial(commandChar)

	# Clear Sensor if necessary
```

```
      if objectDetected == 1:
            objectDetection()


def turnRight():
      global commandChar
      global objectDetected

      # Clear and Post Status Message in GUI
      outMsg = "Turning Right"
      writeTextReadOnly(outMsg, motionBox)

      # Update Command
      commandChar = 'r'
      pyToSerial(commandChar)

      # Clear Sensor if necessary
      if objectDetected == 1:
            objectDetection()


def turnLeft():
      global commandChar
      global objectDetected

      # Clear and Post Status Message in GUI
      outMsg = "Turning Left"
      writeTextReadOnly(outMsg, motionBox)

      # Update Command
      commandChar = 'l'
      pyToSerial(commandChar)

      # Clear Sensor if necessary
      if objectDetected == 1:
            objectDetection()


def exitApp():
      # Stop the Motor
      commandChar = 's'
      pyToSerial(commandChar)

      # Quit Application
      #main.quit(),#main.after(1000,lambda:main.destroy())
      main.destroy()
      quit()


def writeTextReadOnly(outMsg, widget):

      # keep the text boxes read only, no user writing
      widget.configure(state = 'normal')
      widget.delete('1.0', "end")
      widget.insert("end", outMsg)
      widget.configure(state = 'disabled')


def updateSpeed():
      # when the radio button for speed is changed, this command is run
      # the radioSpeed variable is automatically changed when the radio buttons hit
      # slow, radioSpeed = "slow"
      # fast, radioSpeed = "fast"
```

```
	global currentSpeed

	radioVal = radioSpeed.get() # "slow" or "fast"

	if radioVal == "slow":
		currentSpeed = '1'
	elif radioVal == "fast":
		currentSpeed = '2'
	else:
		currentSpeed = '1' # default to slowest speed


	outMsg = "Speed: " + str(radioVal)
	writeTextReadOnly(outMsg, speedBox)
	pyToSerial(currentSpeed) # send '1' or '2' to arduino


def setDefaultsGUI():

	# Set Radio Buttons
	fastSpeedRadio.deselect()
	slowSpeedRadio.select()
	manualModeRadio.select()
	autoModeRadio.deselect()

	# Set Statuses
	writeTextReadOnly(" ", speedBox)
	writeTextReadOnly("Click 'Initialize'!", motionBox)
	writeTextReadOnly(" ", progModeBox)
	writeTextReadOnly(" ", sensorBox)

	# Gray Out Buttons except Start
	stopTaskButton.configure(state = 'disable')
	forwardButton.configure(state = 'disable')
	backwardButton.configure(state = 'disable')
	turnRightButton.configure(state = 'disable')
	turnLeftButton.configure(state = 'disable')

	# Gray out all Radio Buttons
	slowSpeedRadio.configure(state = 'disable')
	fastSpeedRadio.configure(state = 'disable')
	manualModeRadio.configure(state = 'disable')
	autoModeRadio.configure(state = 'disable')


def updateProgMode():
	global progMode
	global commandChar
	motionMsg = " "

	if radioProgMode.get() == "manual":

		if progMode == "auto":
			writeTextReadOnly("Stopped", motionBox)
			commandChar = 's' # is this right?

		progMode = 'manual'
		commandToGUI = 1

	elif radioProgMode.get() == "auto":
		if progMode == "manual":
			writeTextReadOnly("Autonomous", motionBox)
```

```
            progMode = 'auto'
            commandToGUI = 0
            commandChar = 'a'

      else:
            progMode = 'manual'
            commandToGUI = 1
            commandChar = 's'
            writeTextReadOnly("Stopped")

      # Update GUI
      setAllGUIFeatures(commandToGUI)
      modeMsg = "Mode: " + str(progMode)
      writeTextReadOnly(modeMsg, progModeBox)


def setAllGUIFeatures(commandToGUI):
      if commandToGUI:
            val = 'normal'
      else:
            val = 'disable'

      # Set GUI Features to 'normal' or 'disable'
      forwardButton.configure(state = val)
      backwardButton.configure(state = val)
      turnRightButton.configure(state = val)
      turnLeftButton.configure(state = val)
      slowSpeedRadio.configure(state = val)
      fastSpeedRadio.configure(state = val)


def pyToSerial(val):
    val_bytes = bytes(val,'utf-8')       #Convert to bytes
    arduino.write(val_bytes)                  #Send to arduino
    print('The encoded value sent to Arduino is: ' + str(val_bytes))
    time.sleep(0.05)               #Delay to allow for transmission


def objectDetection():
      global objectDetected

      if objectDetected == 0:
            sensorBox.config(bg='yellow')
            writeTextReadOnly("Objected Detected!", sensorBox)
            writeTextReadOnly("Stopped", motionBox)
            objectDetected = 1
      elif objectDetected == 1:
            sensorBox.config(bg='white')
            writeTextReadOnly("safe to drive", sensorBox)
            #writeTextReadOnly("Stopped", motionBox)
            objectDetected = 0


def runMainLoop():
      counter = 0

      while True:

            # Update GUI Elements (replacement for main.mainloop() which blocks)
            main.update_idletasks()
            main.update()

            if (arduino.inWaiting()):
```

```
                read_value = arduino.readline()#Read received value from Arduino
                print(read_value)
                objectDetection()

############### GUI SETUP


# Create Window
main = tk.Tk()
main.title('RoboGUI')

# Add Title
mainTitle = tk.Label(main, text = "Communication and Control", font =
("Arial",11,"bold"))
blank1Label = tk.Label(main)

# Labels
selectSpeedLabel = tk.Label(main, text = "Speed", font = ("Arial", 12))
manualControlLabel = tk.Label(main, text = "Manual Control", font = ("Arial", 12))
statusLabel = tk.Label(main, text = "Status", font = ("Arial", 12))
selectModeLabel = tk.Label(main, text = "Mode", font = ("Arial", 12))
sensorLabel = tk.Label(main, text = "Sensor", font = ("Arial", 12))
blank2Label = tk.Label(main)

# Text Boxes
motionBox = tk.Text(main, width = 20, height = 1)
speedBox = tk.Text(main, width = 20, height = 1)
progModeBox = tk.Text(main, width = 20, height = 1)
sensorBox = tk.Text(main, width = 20, height = 1)

# Buttons
initializeTaskButton = tk.Button(main, text = "Initialize", width = 8, command =
initialize)
forwardButton = tk.Button(main, text = 'Forward', width = 8, height = 2, command =
moveForward)
backwardButton = tk.Button(main, text = 'Reverse', width = 8, height = 2, command =
moveBackward)
turnRightButton = tk.Button(main, text = "Turn Right", width = 8, height = 2, command =
turnRight)
turnLeftButton = tk.Button(main, text = "Turn Left", width = 8, height = 2, command =
turnLeft)
stopTaskButton = tk.Button(main, text = "Stop", width = 8,command = stop)
exitAppButton = tk.Button(main, text = "Exit Program", command = exitApp)

# RadioButtons
radioSpeed = tk.StringVar()
slowSpeedRadio = tk.Radiobutton(main, text="Slow", variable = radioSpeed, value = "slow",
command = updateSpeed)
fastSpeedRadio = tk.Radiobutton(main, text="Fast", variable = radioSpeed, value = "fast",
command = updateSpeed)
radioProgMode = tk.StringVar()
manualModeRadio = tk.Radiobutton(main, text="Manual", variable = radioProgMode, value =
"manual", command = updateProgMode)
autoModeRadio = tk.Radiobutton(main, text="Auto", variable = radioProgMode, value =
"auto", command = updateProgMode)

#################### Layout
mainTitle.grid(row = 0, column = 0, columnspan = 5)
blank1Label.grid(row = 1, column = 0, columnspan = 5, pady = 1)

# Speed
selectSpeedLabel.grid(row = 2, column = 0, columnspan = 2, padx = 30)
slowSpeedRadio.grid(row = 3, column = 1, sticky = 'w')
```

```
fastSpeedRadio.grid(row = 4, column = 1, sticky = 'w')

# Mode
#selectModeLabel.grid(row = 6, column = 0, columnspan = 2, padx = 30)
#manualModeRadio.grid(row = 7, column = 1, sticky = 'w')
#autoModeRadio.grid(row = 8, column = 1, sticky = 'w')

# Manual Control
manualControlLabel.grid(row = 2, column = 2, columnspan = 2, padx = 30)
initializeTaskButton.grid(row = 3, column = 2, rowspan = 2, sticky = 'nesw')
stopTaskButton.grid(row = 3, column = 3, rowspan = 2, sticky = 'nesw')
forwardButton.grid(row = 5, column = 2, rowspan = 2, sticky = 'nesw')
backwardButton.grid(row = 5, column = 3, rowspan = 2, sticky = 'nesw')
turnLeftButton.grid(row = 7, column = 2, rowspan = 2, sticky = 'nesw')
turnRightButton.grid(row = 7, column = 3, rowspan = 2, sticky = 'nesw')

# Status
statusLabel.grid(row = 2, column = 4, padx = 30)
motionBox.grid(row = 3, column = 4, sticky = 'ns', padx = 10)
speedBox.grid(row = 4, column = 4, sticky = 'ns')
progModeBox.grid(row = 5, column = 4, sticky = 'n', padx = 10)

# Sensor Reading
sensorLabel.grid(row = 7, column = 4)
sensorBox.grid(row = 8, column = 4, sticky = 'ns', padx = 10)

# Exit Button
blank2Label.grid(row = 10, column = 0, columnspan = 5, pady = 3)
exitAppButton.grid(row = 11, column = 0, columnspan = 5, sticky = 'ew')



######################### BEGIN ACTUAL PROGRAM

setDefaultsGUI() # run GUI defaults
main.mainloop() #start/open GUI
```

Appendix B: Arduino Code

```
// Jason Noel & Phil Parisi - Mechatronics Final Project


// 'z' --> null state (does nothing, holds current state)

// Manual States
byte state0Entry = false;  // 0 --> 'dead' (system off)
byte state1Entry = false;  // 1 --> primed
byte state2Entry = false;  // 2 --> turning left
byte state3Entry = false;  // 3 --> turning right
byte state4Entry = false;  // 4 --> drive forward
byte state5Entry = false;  // 5 --> drive backward

// Immutable 'Variables'
#define bridgeForwardRight 4  // (Hbridge connection 4A)
#define bridgeBackwardRight 2  // (Hbridge connection 3A)
#define bridgeForwardLeft 7  // (Hbridge connection 1A)
#define bridgeBackwardLeft 8  // (Hbridge connection 2A)
#define bridgePWM 9 //PWM pin (Hbridge connection 1,2EN and 3,4EN)
#define redLED 6
#define yellowLED 5

#define slowMotorPWM 170  // these probably need adjustment based on what it takes to
move the motors
#define fastMotorPWM 255

#define serialCheckTimeInterval 50  // time in ms
#define turnTimeInterval 1500 // time in ms NEEDS TO BE TUNED

#define echoPin 11 // attach pin to Echo pin of JSN-SR04T sensor (this is the PWM)
#define trigPin 12 // attach to to Trig pin of JSN-SR04T
#define minimumSensorDistance 25 // centimeters
//#define maxSensorHits 15 // hits below minimumSensorDistance to trigger robot stop
#define sensorPingTime 10 // microseconds
#define maxSensorHitCounts 2

// Mutable 'Global Variables'
byte state;  // State and NextState of 1st task transition diagram
byte nextState;
byte returnToState;
byte sensorTimerOn;

char command;       // User command

unsigned long serialTime;
unsigned long turnTime;
unsigned long sensorTimer;

long objectDistance;
long duration;
long distance;
int sensorHitCounts;

// Function Declarations  (Prototypes)
void controlTask(void);         // Task state transition diagram function
void controlHbridgePWM();
unsigned long getMilliTimeNow(void);  // Returns time in ms units
unsigned long getMicroTimeNow(void);  // Returns time in us units
void motorSetSpeed(int val);
void turnLeft();
void turnRight();
```

```
void moveForward();
void moveBackward();
void objectAvoidance(long distance);
void sensorPing();


// Setup Function
void setup() {

  // Build In LED
  pinMode(LED_BUILTIN, OUTPUT);
  pinMode(redLED, OUTPUT);
  digitalWrite(redLED, LOW);
  pinMode(yellowLED, OUTPUT);
  digitalWrite(yellowLED, LOW);

  // H-Bridge Pin Setup
  pinMode(bridgeForwardRight, OUTPUT);
  pinMode(bridgeBackwardRight, OUTPUT);     // HIGH and LOW values
  pinMode(bridgeForwardLeft, OUTPUT);
  pinMode(bridgeBackwardRight, OUTPUT);
  pinMode(bridgePWM, OUTPUT);               // PWM for speed control

  // H-Bridge Pin Initial Values [all low]
  digitalWrite(bridgeForwardRight, LOW);
  digitalWrite(bridgeBackwardRight, LOW);
  digitalWrite(bridgeForwardLeft, LOW);
  digitalWrite(bridgeBackwardLeft, LOW);
  motorSetSpeed(slowMotorPWM); // sets bridgePWM pin to slowMotorPWM speed as default

  // Sensor Setup
  digitalWrite(trigPin, LOW);
  digitalWrite(echoPin, LOW);
  sensorTimerOn = false;
  sensorHitCounts = 0;

  // Control Flow Setup
  char command = 'z';       // User command
  nextState = 0;            // start in null 'dead' state

  Serial.begin(9600);
}


// Main Loop
void loop() {

  // Starting Timer for Serial Connection
  serialTime = getMilliTimeNow();  // for serial check time interval

  // Infinite While Loop
  while (2 > 1)  // Start infinite loop
  {

    if ((getMilliTimeNow() - serialTime) >= serialCheckTimeInterval)  // This if
statement is used to not check the serial port all the time
    {
      serialTime = getMilliTimeNow();
      // Code to read command (a single char) from serial port here
      if (Serial.available() > 0)  //Wait for a char to show up
      {
        command = Serial.read();  // Read one byte from serial buffer
      }
```

```
    }


  // Tasks for Every Loop
  controlTask(); //  Call ControlTask 1 (looks for commands of the letter format like 's'
'f' 'b')
  controlHbridgePWM(); // allow commands sent from GUI to update the PWM signal for
hbridge (commands of the form '1' for slow and '2' for fast)

  // Reset command
  command = 'z';   // reset this so commands are executed only once
  }
}

// Definition of ControlTask Function
void controlTask(void) {

  state = nextState;

  // Jump between STATES
  switch (state)  // Go to current state
  {

    case 0: // System Off 'Dead'

      if (state0Entry == false)  // if not in the state, get in it!
      {
        state0Entry = true;
        stopMotors();
        digitalWrite(redLED, HIGH);
      }

      if (command == 'i')  // 'initialize', move to State 1!
      {
        nextState = 1;        // change current state
        state0Entry = false;  // we're leaving the state, set it to false
        digitalWrite(redLED, LOW);
      }


      break;


    case 1: // Primed & Stopped

      if (state1Entry == false)  // if not in the state, get in it!
      {
        state1Entry = true;  // we are in state 1
        stopMotors();
        digitalWrite(yellowLED, HIGH);
      }

      if (command == 'f')  // 'forward', move to state 4 (move forward)
      {
        nextState = 4;
        state1Entry = false;
        digitalWrite(yellowLED, LOW);
      }

      if (command == 'b')  // 'reverse', move to state 5 (move backward)
      {
        nextState = 5;
        state1Entry = false;
```

```
      digitalWrite(yellowLED, LOW);
    }

    if (command == 'd') // 'die', go back to initialize
    {
      nextState = 0;
      state1Entry = false;
      digitalWrite(yellowLED, LOW);
    }

    if (command == 'l') // 'left', move to state 2 (turn left)
    {
      returnToState = 1;
      nextState = 2;
      state1Entry = false;
      digitalWrite(yellowLED, LOW);
    }

    if (command == 'r') // 'right', move to state 3 (turn right)
    {
      returnToState = 1;
      nextState = 3;
      state1Entry = false;
      digitalWrite(yellowLED, LOW);
    }

    break;


  case 2: // turn left 90deg

    if (state2Entry == false)  // if not in the state, get into it
    {
      turnTime = getMilliTimeNow();
      state2Entry = true;
      turnLeft();
    }

    if (command == 's')  // Stop Task!
    {
      nextState = 1;        // get into state 1
      state2Entry = false;  // get out of state 2
      turnTime = 0;
    }

    if ((getMilliTimeNow() - turnTime) >= turnTimeInterval)  // we've been learning for
long enough!
    {
      nextState = returnToState;      // go back to previous state
      state2Entry = false;            // get out of current state
      turnTime = 0;
    }

    break;


  case 3: // turn right 90deg
    if (state3Entry == false)  // if not in the state, get into it
    {
      turnTime = getMilliTimeNow();
      state3Entry = true;
      turnRight();
    }
```

```
      if (command == 's')  // stop
      {
        nextState = 1;        //
        state3Entry = false;  // get out of state 2
        turnTime = 0;
      }

      if ((getMilliTimeNow() - turnTime) >= turnTimeInterval)  // we've been turning for
long enough!
      {
        nextState = returnToState;      // go back to previous state
        state3Entry = false;            // get out of current state
        turnTime = 0;
      }

      break;



    case 4: // drive forward
      if (state4Entry == false)  // if not in the state, get into it
      {
        state4Entry = true;
        driveForward();
        digitalWrite(LED_BUILTIN, HIGH);
      }

      if (state4Entry == true) // do this every loop when we're in the state
      {
        sensorPing(); // ping with ultrasonic sensor

        /*
        if ( (getMilliTimeNow() >= 10000) && (getMilliTimeNow() <= 10100) )
        {
          Serial.print('p');
        }
        */

      }

      if (command == 's')   // stop
      {
        nextState = 1;
        state4Entry = false;  // get out of state 4
        digitalWrite(LED_BUILTIN, LOW);
      }

      if (command == 'b')   // go backwards
      {
        nextState = 5;
        state4Entry = false;
        digitalWrite(LED_BUILTIN, LOW);
      }

      if (command == 'd') // 'die'
      {
        nextState = 0;
        state4Entry = false;
        digitalWrite(LED_BUILTIN, LOW);
      }

      if (command == 'l') // 'left', move to state 2 (turn left)
```

```
  {
    returnToState = 4;
    nextState = 2;
    state4Entry = false;
    digitalWrite(LED_BUILTIN, LOW);
  }

  if (command == 'r') // 'right', move to state 3 (turn right)
  {
    returnToState = 4;
    nextState = 3;
    state4Entry = false;
    digitalWrite(LED_BUILTIN, LOW);
  }

  if (nextState != 4)
  {
    state4Entry = false;
    digitalWrite(LED_BUILTIN, LOW);
  }

  break;


case 5: // drive backward
  if (state5Entry == false)  // if not in the state, get into it
  {
    state5Entry = true;
    driveBackward();
  }

  if (command == 's')   // stop
  {
    nextState = 1;
    state5Entry = false;  // get out of state 5
  }

  if (command == 'f')   // go forwards
  {
    nextState = 4;
    state5Entry = false;
  }

  if (command == 'd') // 'die'
  {
    nextState = 0;
    state5Entry = false;
  }

  if (command == 'l') // 'left', move to state 2 (turn left)
  {
    returnToState = 5;
    nextState = 2;
    state5Entry = false;
  }

  if (command == 'r') // 'right', move to state 3 (turn right)
  {
    returnToState = 5;
    nextState = 3;
    state5Entry = false;
  }
```

```
      break;

  }
}


unsigned long getMilliTimeNow(void)  // Returns time in ms units
{
  return (millis());
}

unsigned long getMicroTimeNow(void) // Returns time in us units
{
  return (micros());
}

void driveForward()
{
  // to move forward...
  digitalWrite(bridgeForwardRight, HIGH); // right side foward
  digitalWrite(bridgeBackwardRight, LOW);

  digitalWrite(bridgeForwardLeft, HIGH); // left side foward
  digitalWrite(bridgeBackwardLeft, LOW);
}

void driveBackward()
{
  // to move backward...
  digitalWrite(bridgeForwardRight, LOW); // right side backward
  digitalWrite(bridgeBackwardRight, HIGH);

  digitalWrite(bridgeForwardLeft, LOW); // left side backward
  digitalWrite(bridgeBackwardLeft, HIGH);
}

void turnLeft()
{
  // to turn left...
  digitalWrite(bridgeForwardRight, LOW); // right side backward
  digitalWrite(bridgeBackwardRight, HIGH);

  digitalWrite(bridgeForwardLeft, HIGH); // left side forward
  digitalWrite(bridgeBackwardLeft, LOW);
}

void turnRight()
{
  // to turn right...
  digitalWrite(bridgeForwardRight, HIGH); // right side foward
  digitalWrite(bridgeBackwardRight, LOW);

  digitalWrite(bridgeForwardLeft, LOW); // left side backward
  digitalWrite(bridgeBackwardLeft, HIGH);
}

void stopMotors()
{
  // to stop motors...
  digitalWrite(bridgeForwardRight, LOW); // right side backward
  digitalWrite(bridgeBackwardRight, LOW);

  digitalWrite(bridgeForwardLeft, LOW); // left side backward
```

```
  digitalWrite(bridgeBackwardLeft, LOW);
}

void controlHbridgePWM()
{
  if (command == '1') // slow
  {
    motorSetSpeed(slowMotorPWM);
  }
  if (command == '2') // fast
  {
    motorSetSpeed(fastMotorPWM);
  }
}

void motorSetSpeed(int val)
{
  analogWrite(bridgePWM, val);
}

void sensorPing() // function from Sensor Machine
{
  if (sensorTimerOn == false) // timer is off, start next cycle
  {
    //distance = 1000; // generically high value to not trigger stopping
    sensorTimerOn = true;
    sensorTimer = getMicroTimeNow();
    digitalWrite(trigPin, HIGH);
  }

  if (sensorTimerOn == true) // timer is on, check if enough time has elapsed
  {
    if ((getMicroTimeNow() - sensorTimer) >= sensorPingTime) // if enough time elapsed,
get dist
    {
      digitalWrite(trigPin, LOW);
      duration = pulseIn(echoPin, HIGH);
      distance = duration * 0.0343 / 2;
      sensorTimerOn = false;
      objectAvoidance(distance);
      distance = 1000; // reset distance
    }
  }

}

void objectAvoidance(long distance)
{
  if (distance <= minimumSensorDistance)
  {
    sensorHitCounts = sensorHitCounts + 1;
  }

  if (sensorHitCounts >= maxSensorHitCounts) // allows us to deal with noisy/random hits
that aren't true
  {
    Serial.print('p'); // tell the GUI that we are too close to something!
    nextState = 1;
    sensorHitCounts = 0;
  }
}
```