AuE 835
Automotive Electronics Integration

PROJECT 2: EMBEDDED SYSTEM AND AUTONOMOUS BOATS

Project Schedule

- Oct 18 – Arduino and programming
- Oct 23 – Ultrasonic sensing, vehicle control & Project 1 Announcement
- Oct 25 – Signal processing review and Project 1 hands-on
- Oct 30 – Control review and Project 1 hands-on
- Nov 1 - Project 1 debugging, Q&A, Test details
- Nov 8 - Project 1 Test

- Nov 13 – (2 classes) Lectures on boat building and boat autonomy & Project 2 Announcement
- Nov 15 – No class
- Nov 20 – Project 2 debugging, Q&A, Test details
- Nov 27 – Project 2 Test

- Presentations and report writing

Congratulations on Project 1: Autonomous Vehicle!

What's next?

You can keep the vehicle till the end of the semester.

- Record data and videos from Project 1
- Prepare for the presentation (group)
- Prepare for the final report (individual)
- Have some fun with it?

Project 2: Autonomous Boats

https://www.youtube.com/watch?v=rHverweu1xA

BOSCH
Invented for life
The Drive & Control Company
Rexroth
Bosch Group

Ocean Conservation Project

How to use emerging technologies to address plastic pollution problems in our oceans?

Bosch Rexroth apprentices accepted the challenge and designed an inventive pollution-collecting boat in 2017!

Apprentice Team 10: Branden Williams, Rena Mitchell, Allan McMillan, Jared Thompson, Alonzo Calwite and Kevin Pooley.

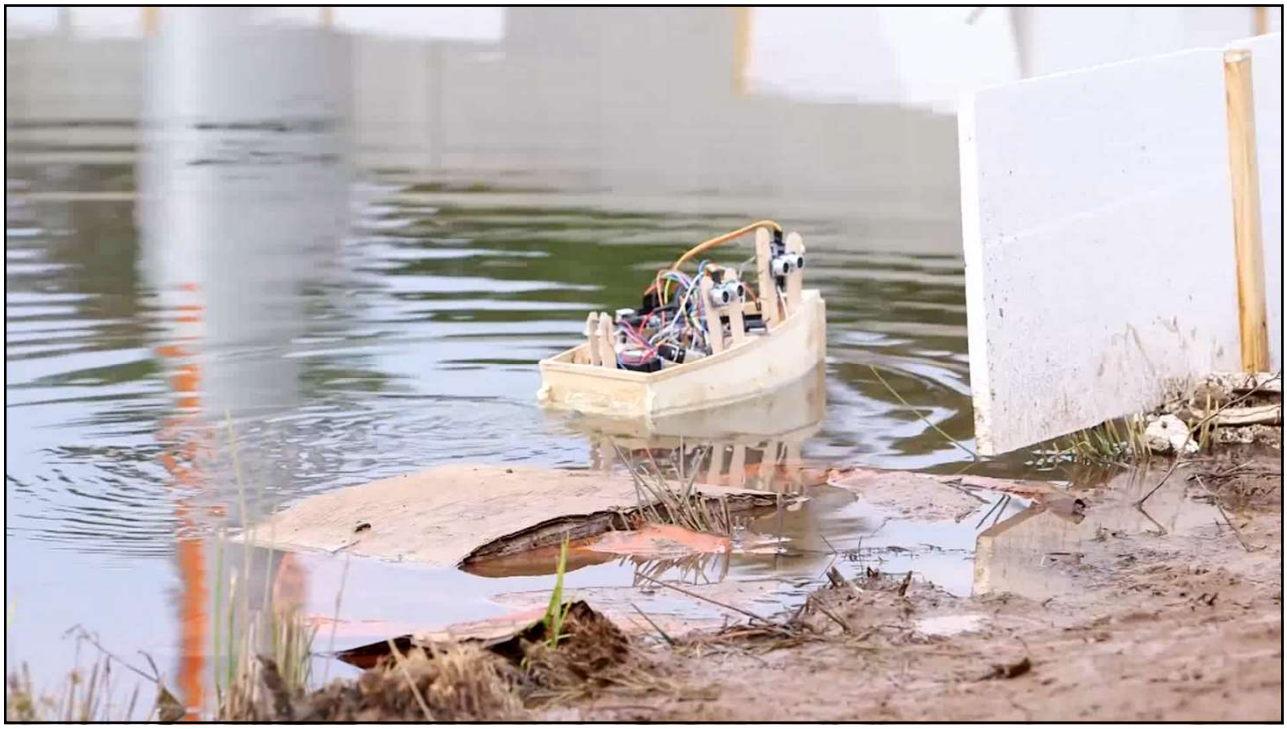
Leader: Mike McCormick, Vice President and Technical Plant Manager at the Bosch Rexroth facility in Fountain Inn, S.C.

The Bosch Rexroth Environmental Robot

The capture system has 2 levels of waste capture. The large baskets on each side and in the middle of the boat will pickup the larger trash items. The filter socks attached to the rear of each basket will pickup the fine plastic pieces.

◂ **Remote controlled boat with pollution capture nets lowered and raised**

How to turn this boat into autonomous?



Multi-Disciplinary Team For Project 2

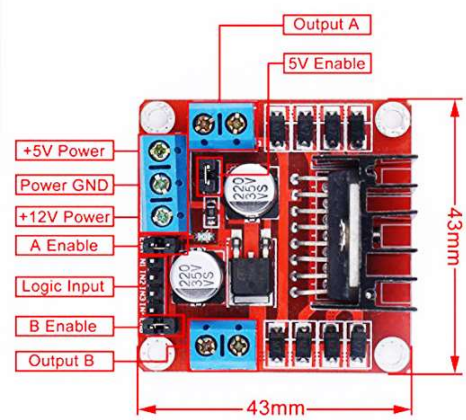
Project 2 will be a collaboration with Dr. Srikanth Pilla

- Each two teams will have a new student member from Dr. Pilla's composite materials course
- The new student member will help select boat materials (e.g., composite) and assist boat building/design process

How to build boats?

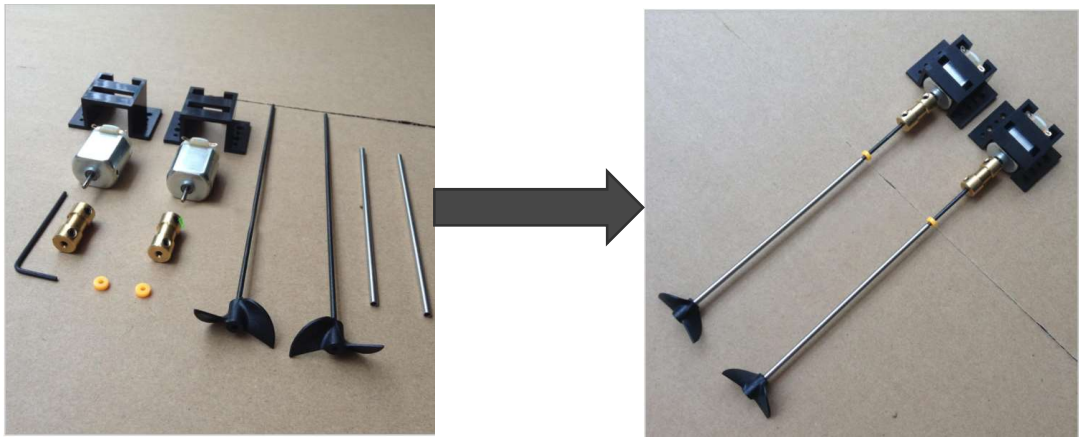
- Additional hardware to each group

Two motor and propeller sets



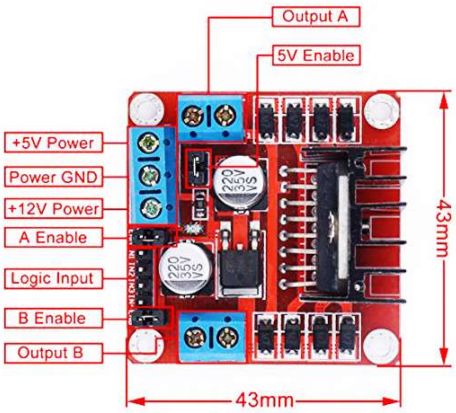
1 motor controller to control two motors

Hardware Setup ---- Motor Assembly



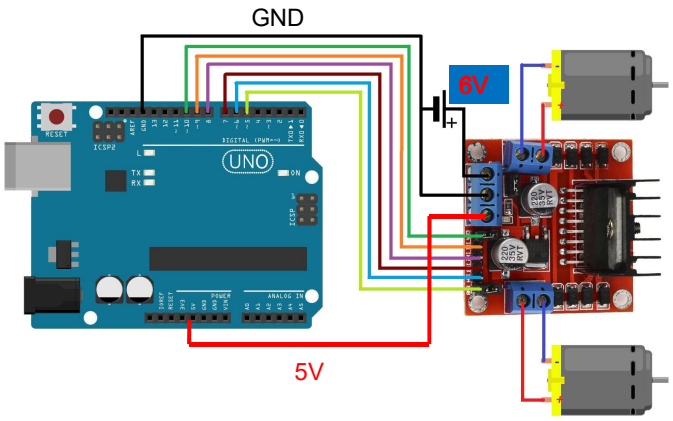
Hardware Setup ---- Motor Drive

Port Name	Connect To
EN_A	PWM pin of Arduino. Speed of Motor A.
IN1	Normal digital I/O of Arduino. Direction of Motor A
IN2	Normal digital I/O of Arduino. Direction of Motor A
IN3	Normal digital I/O of Arduino. Direction of Motor B
IN4	Normal digital I/O of Arduino. Direction of Motor B
EN_B	PWM pin of Arduino. Speed of Motor B.
+12V Power	+ port of battery pack (+6V with 4AA)
GND Power	- port of battery pack, GND of Arduino
+5V Power	+5V of Arduino (power supply of Arduino)
Output A	2 wires to Motor A
Output B	2 wires to Motor B



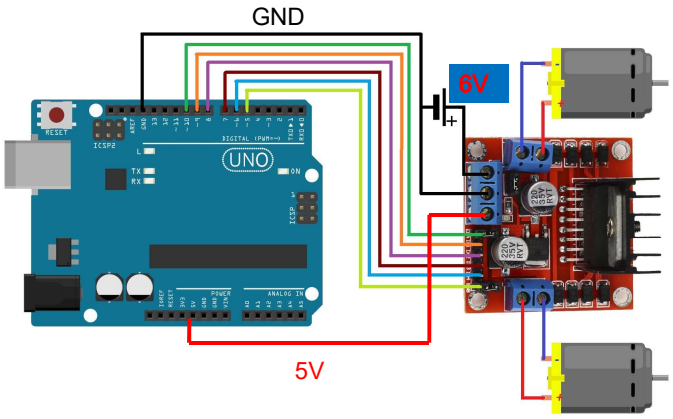
IMPORTANT

Hardware Setup ---- Motor Control

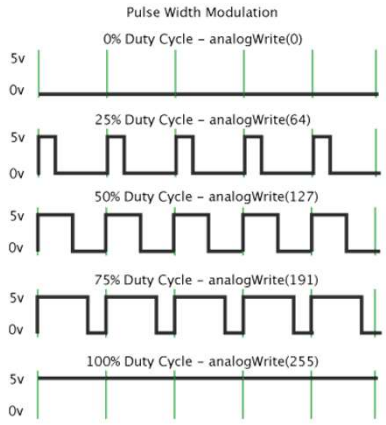


Note:
1. This figure is just an example to connect the motors, motor driver and Arduino.
2. The Table on previous slide gives the rules you should obey with.
3. The motor are controlled by PWM waves

Hardware Setup ---- Motor Control



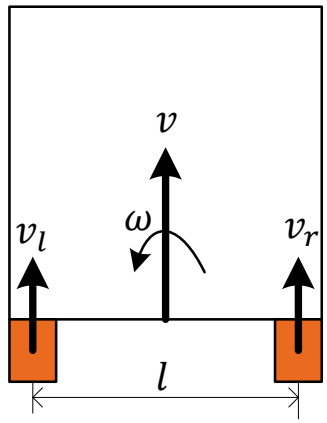
Pulse Width Modulation (PWM) is a technique for getting analog results with digital means. Digital control is used to create a square wave, a signal switched between on and off.



Hardware Specifications

- 1. The current when empty load for each motor is around 0.4 A
- 2. The current when motor is stalled is around 1.43 A
- 3. The rate current of each channel of the motor driver: 2 A
- 4. The motors cannot provide large torque. Never Over Constrain the shaft.
  - You can try to turn the motor with your finger. The torque before assembly and the torque after assembly should be almost the same.
- 5. If you directly connect the 6V battery pack to the motor with empty load, it should be turning at very high rpm (10k).
  - You can do this test after you finish the mechanical assembly and before you connect the motor drive.
- 6 If you motor driver become very hot, let it cool down and check your mechanical assembly.

Modeling and Control of Differential Drive Boat



v_l: left propeller speed
v_r: right propeller speed

→ v: boat moving speed
ω: boat steering speed

$$v = (v_l + v_r)/2$$
$$\omega = (v_r - v_l)/l$$

→

$$v_l = v - \omega l/2$$
$$v_r = v + \omega l/2$$

Write this as a function in Arduino
Input: v and ω
Inside the function: transfer v and ω to v_l and v_r and send them to motor for execution

Base Code Explanation

A base code for boat control has been uploaded to canvas under Project 2 folder.

```
22  //=============================================================
23  // Pin definition
24  // Pins for motor control
25  // The 6 pins of motor control are  defined here, you need
26  // to change the value to meet your hardware configuration
27  // Note: The enable pins of both motors must be a PWM pin
28  // Others can be normal Digital I/O pin.
29  #define ML_IN1 2    // For Motor 1 direction
30  #define ML_IN2 4    // For Motor 1 direction
31  #define ML_EN 3     // For Motor 1 speed
32  #define MR_IN3 7    // For Motor 2 direction
33  #define MR_IN4 8    // For Motor 2 direction
34  #define MR_EN 6     // For Motor 2 speed
```

```
36  //=============================================================
37  // Constant definition
38  // Index of motor
39  #define MOTOR_LEFT 1
40  #define MOTOR_RIGHT 2
41  // Set a limit for velocity and omega
42  #define OMEGA_LIMIT 20
43  #define VEL_LIMIT 235
44
45  // Control frequency
46  #define CONTROL_FREQ 20
```

The numbers are based on PWM waves, but not physical values

Note:
1. The base code is only an example. You may need to change all the parameters in this page to make it work for your boat.
2. It's a start point, but NOT an answer to your project.

Base Code Explanation (Cont.)

```
52  // User define functions
53  void set_motor_speed(int motor, int speed) {
54    // The motor left and motor right are used as variables
55    // here, but you should change either the code or your
56    // hardware configuration to make the code match the
57    // hardware
58
59
60    // Set direction and speed for certain motor.
61    // constrain speed into [0, 255]
62    int vel_cmd = constrain(abs(speed), 0, 255);
63    if (motor == MOTOR_LEFT){
64      if (speed > 0) {
65        // Turn the motor in one direction
66        digitalWrite(ML_IN1, LOW);
67        digitalWrite(ML_IN2, HIGH);
68        analogWrite(ML_EN, vel_cmd);
69        Serial.println("vel_left > 0");
70      }
71      else if (speed < 0) {
72        // Turn the motor in another direction
73        digitalWrite(ML_IN1, HIGH);
74        digitalWrite(ML_IN2, LOW);
75        analogWrite(ML_EN, vel_cmd);
76        Serial.println("vel_left < 0");
77      }
```

```
77      }
78      else
79      {
80        // Stop the motor
81        digitalWrite(ML_IN1, LOW);
82        digitalWrite(ML_IN2, LOW);
83        analogWrite(ML_EN, 0);
84        Serial.println("vel_left = 0");
85
86      }
87    }
88    else if (motor == MOTOR_RIGHT){
89      if (speed > 0) {
90        // Turn the motor in one direction
91        digitalWrite(MR_IN3, HIGH);
92        digitalWrite(MR_IN4, LOW);
93        analogWrite(MR_EN,vel_cmd);
94        Serial.println("vel_right > 0");
95      }
96      else if (speed < 0) {
97        // Turn the motor in another direction
98        digitalWrite(MR_IN3, LOW);
99        digitalWrite(MR_IN4, HIGH);
100       analogWrite(ML_EN,  vel_cmd);
101       Serial.println("vel_right < 0");
102     }
103     else
```

Base Code Explanation (Cont.)

```
103     else
104     {
105       // Stop the motor
106       digitalWrite(MR_IN3, LOW);
107       digitalWrite(MR_IN4, LOW);
108       analogWrite(MR_EN, 0);
109       Serial.println("vel_right = 0");
110
111     }
112   }
113 }
114
115 void set_boat_move(int vel, int omega){
116   // This function is called to set the
117   // linear and angular velocity of the
118   // boat. You cna find the nutural position
119   // of your boat by tuning the v and omega.
120
121   // Linear and anglular velocity
122   int v=constrain(vel, -VEL_LIMIT, VEL_LIMIT);
123   int w=constrain(omega, -OMEGA_LIMIT, OMEGA_LIMIT);
124   // Motor velocity command for both motors
125   int vel_L = constrain(v+w, -255, 255);
126   int vel_R = constrain(v-w, -255, 255);
127   // Set speed for both motors
128   set_motor_speed(MOTOR_LEFT, vel_L);
129   set_motor_speed(MOTOR_RIGHT,vel_R);
130
131 }
```

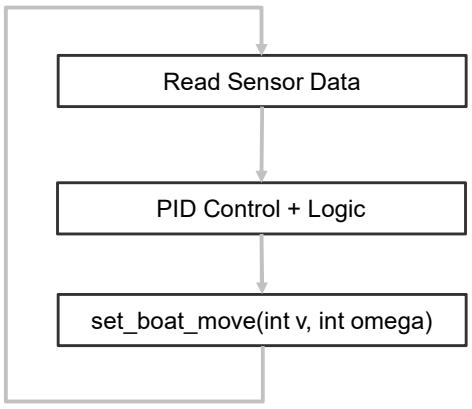
```
131 }
132
133 //=========================================================
134 // Arduino Setup
135 void setup() {
136
137   // Setup serial port
138   Serial.begin(9600);
139
140   // Init Pins
141   // Set pin for motor drive
142   pinMode(ML_IN1, OUTPUT);
143   pinMode(ML_IN2, OUTPUT);
144   pinMode(ML_EN, OUTPUT);
145   pinMode(MR_IN3, OUTPUT);
146   pinMode(MR_IN4, OUTPUT);
147   pinMode(MR_EN, OUTPUT);
148
149   // Set both motor speed as zero
150   set_motor_speed(MOTOR_LEFT, 0);
151   set_motor_speed(MOTOR_RIGHT, 0);
152
153   // Wait for 1 second, let the system become stable
154   delay(1000);
155
156 }
```

Not model based. If you use PID control, you can keep it. If you use model-based control, you need to change it based on your boat parameters

$$v_l = v - \omega l/2$$

$$v_r = v + \omega l/2$$

Base Code Explanation (Cont.)

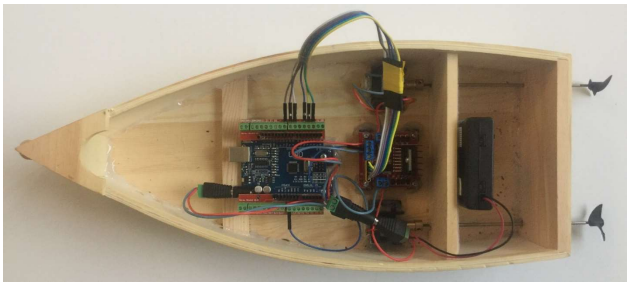



```
158  //============================================================
159  // Arduino Loop
160  void loop() {
161    //--------------------------------------
162    // Test for set_motor_speed()
163    // Set both motor speed
164    set_motor_speed(MOTOR_LEFT, 220);
165    set_motor_speed(MOTOR_RIGHT, 220);
166    Serial.println("+++++");
167    delay(3000);
168
169    // Set both motor speed
170    set_motor_speed(MOTOR_LEFT, -220);
171    set_motor_speed(MOTOR_RIGHT, -220);
172    Serial.println("----");
173    delay(3000);
174    //--------------------------------------
175    //--------------------------------------
176    // Test for set_boat_move()
177    // Set both motor speed
178    set_boat_move(200, 0);
179    delay(3000);
180
181    // Set both motor speed
182    set_boat_move(200, -15);
183    delay(3000);
184
185    // Set both motor speed
186    set_boat_move(200, 10);
187    delay(3000);
188  }
```

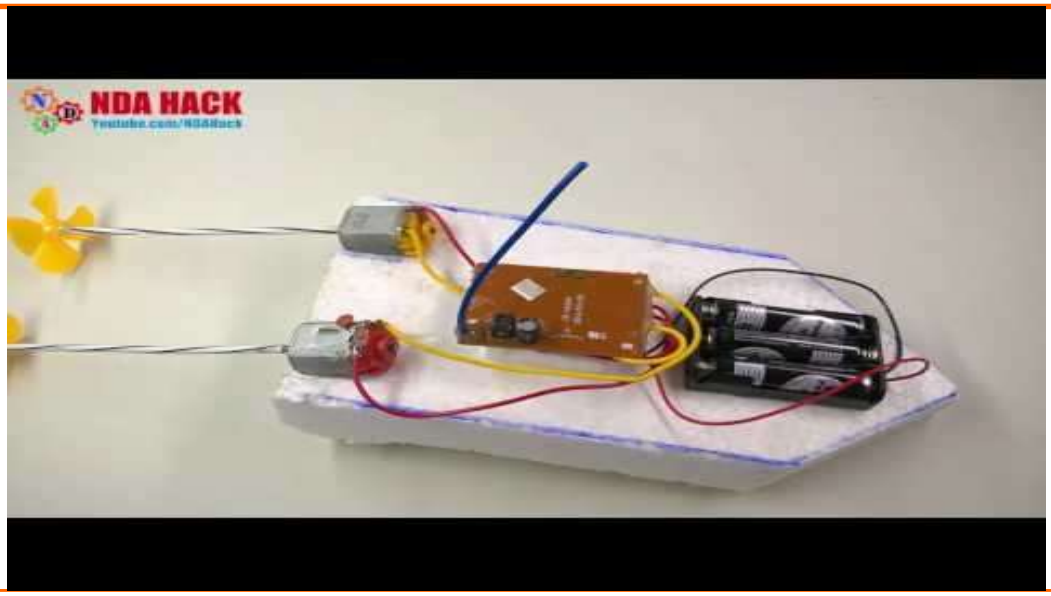
Hardware Setup --- Boat Building

- TAs' Example
  - Make a wood boat
  - Drill 4 holes
  - Attach everything with glue gun
  - Seal all holes with glue gun
  - Connect the wires
  - Run the base code

Tips:
1. Safety: boat waterproof
2. Balance: center of mass
3. Dynamics: shape of boat hull
4. Driving: position of propellers



Examples of Boat Building



https://www.youtube.com/watch?v=Cds-yvbpJds

Examples of Boat Building

https://www.youtube.com/watch?v=0UZsnhFo6ao

Examples of Boat Building

https://www.youtube.com/watch?v=6gT_pSOI8W8

Examples of Boat Building

https://www.youtube.com/watch?v=8DqgNq7m4QM

Hardware Setup --- Boat Building

- Some more examples online
- Go to Youtube
  - https://www.youtube.com/watch?v=0UZsnhFo6ao
  - https://www.youtube.com/watch?v=W_gCXX7izZM&t=333s
  - https://www.youtube.com/watch?v=6e9sRfHchJU&t=517s
  - https://www.youtube.com/watch?v=8DqgNq7m4QM
  - ……
- Source of Tools and Materials
  - Go to the student area on ground floor
    - Screwdrivers
    - Electric Wires
    - Zip Ties and Tape
    - Soldering Station
    - Drills
    - Knifes
    - Glue Gun
  - Foams in Hobby Lobby, Walmart …