Automatic Luggage Assistant (ALA) Demonstration

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Agenda

- Introduction
  - What the ALA unit is
- Subsystems
  - Model, Design, and Stress Analysis
  - Material Choice, Manufacturing, and Assembly
  - Main Driver Circuit
  - Sensors
  - Driver Code
  - Simulation
- Q and A

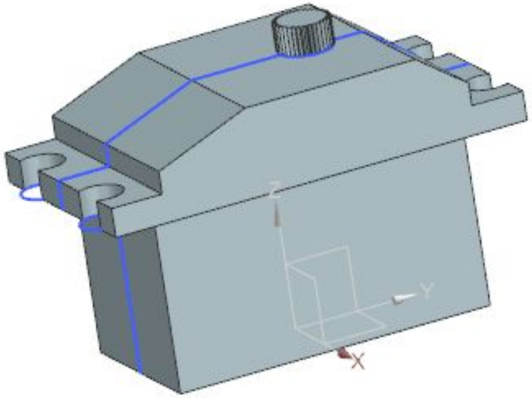
ALA at a glance

A device that carries luggage and will automatically follow the user around the airport to restaurants, lounges and shops.

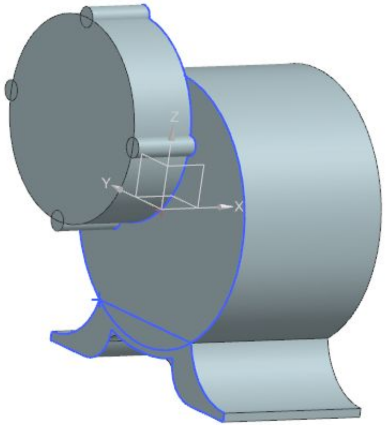
Two main categories to the subsystems

- Design, Frame, and Stress Tolerances
- Circuit and Drive

Speed Motor and Servo Motor



Servo Motor

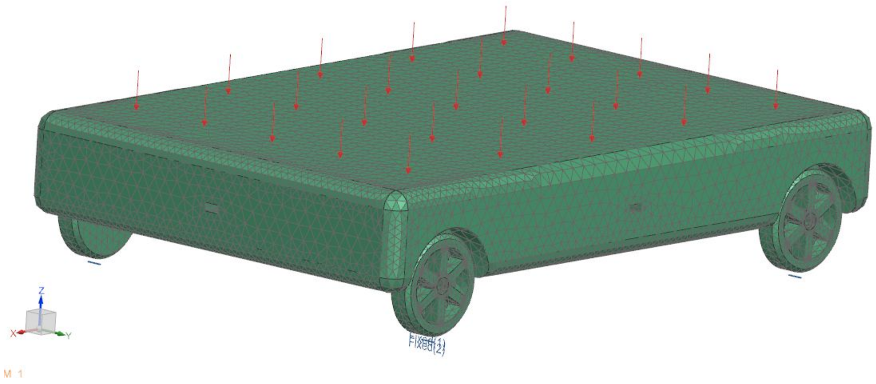


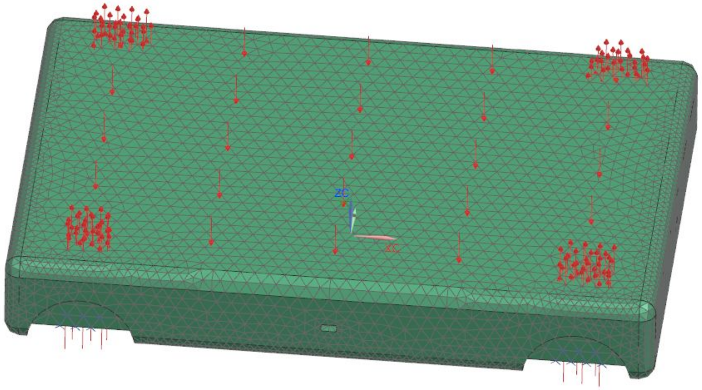
Speed Motor

Weight

- Panel: 34.5043 lbf * 2 = 69.0086 lbs
- Base: 279.4111 lbs
- Wheel: 1.419 lbf *4 = 5.676 lbs
- Total: 354.0957 lbs

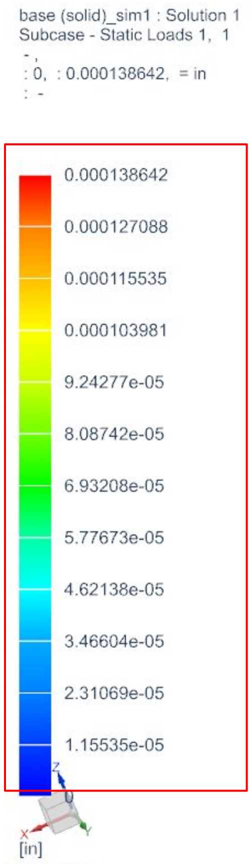
Deformation



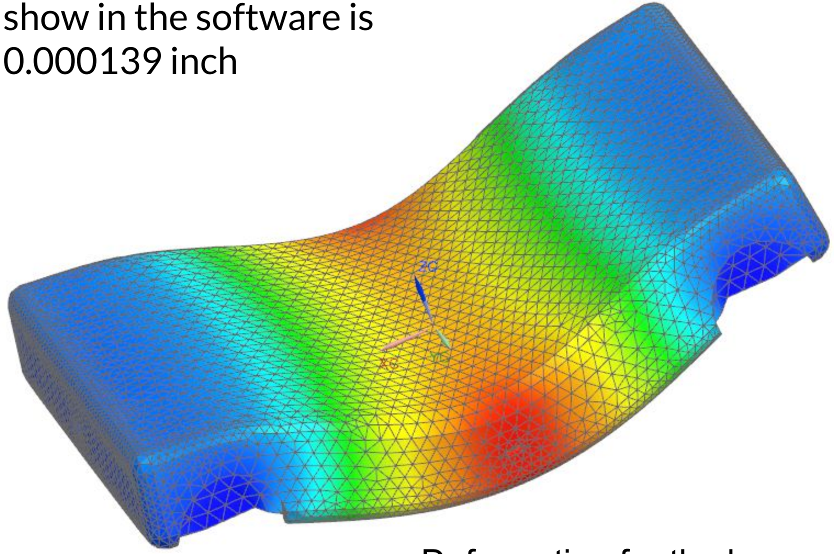


220 lb reaction force on the surface and 50 lb in opposite reaction at each corner.

Polypropylene:



The maximum deformation show in the software is 0.000139 inch



Deformation for the base and wheel

The range of deformation is 0 to 0.0005 inch.

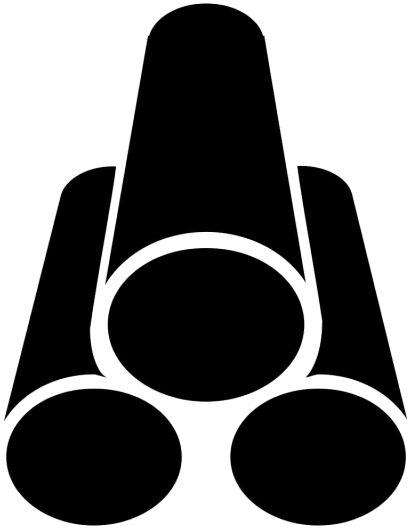
Material Choice

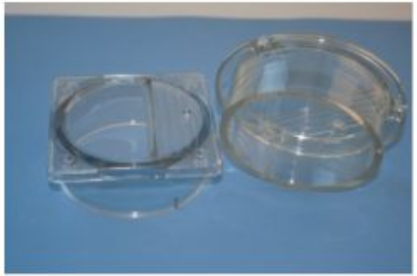
Requirements:

- Strong enough to carry heavy loads
- Light enough to be carried by wheels and motors

Metals such as steel are a versatile and strong option however their weight would make it difficult to be carried by our wheels and motors. While Aluminum is a lighter option it's a much more expensive choice.

Because of this our team decided to look into durable and strong plastics.



Material	Polycarbonate	Polypropylene
		
Cost	\$1.70 /lb	\$0.12 /lb
Weight	75 lb/ft^3	60 lb/ft^3
Tensile Strength	9500 psi	4700 psi

After analyzing both options, our team decided on polypropylene because of its cheaper cost, weight, and look.

Our panels will be composed of aluminum because of its light weight, durability, and aesthetic look.

Manufacturing

Base: Our polypropylene base will be manufactured using injection molding.

Advantages of using injection molding include:

- Detail
- Cheaper manufacturing cost
- Higher strength.

Our material choice, polypropylene, is easy to mold and its low mold viscosity allows it to fill molds quickly which speeds up the manufacturing process.

Panels: To create the outer part of the panel our manufacturers will bend pre-prepared aluminum tubing into the desired shape.

Our panel will then be completed by welding an aluminum sheet to the aluminum tube.

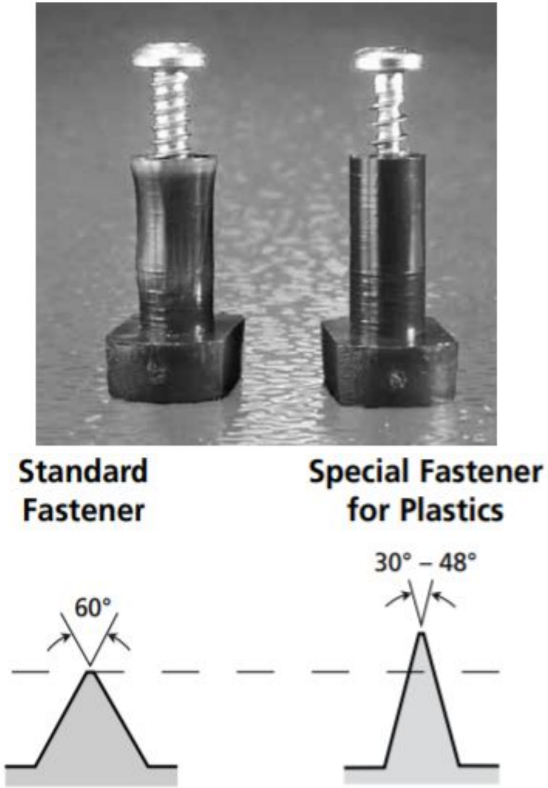
Assembly

Choosing the proper fastener will:

- Increase resistance to loosening
- Reduce material usage
- Reduce cycling time
- Eliminate need for inserts or adhesives
- Limit damage to material

Factors that impact fastener performance:

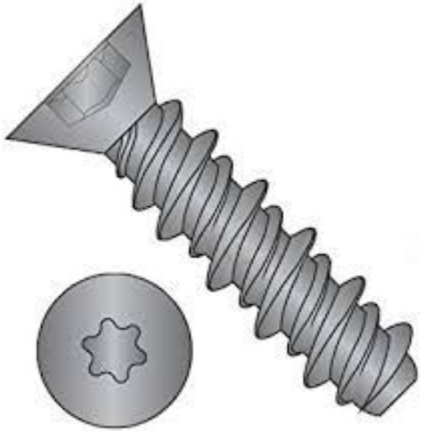
- Stiffness of material
- Thermal Expansion Rate
- Creep Rate



("Threaded Fasteners for Plastics", 2020)

Assembly

Based on all of these considerations as well as price. Our team has decided to go with a flat head thread forming screw with a torx drive.



Price: $0.30/screw
Material: Stainless Steel
Drive Style: Torx Six Lobe
Head Style: Flat Head
Tensile Strength: 73,200 psi

Hole Design Requirements for Polypropylene:

Hole Diameter	Boss Diameter	Length of Engagement
0.70 x d	2.00 x d	2.00 x d

("Threaded Fasteners for Plastics", 2020)

Screw Stress Analysis

Calculating tensile stress area (A_t)

Stainless Steel Ultimate Tensile Strength: 73,200 psi < 100,000 psi

Materials with an ultimate tensile strength less than 100,000 psi yields the following formula for tensile stress area:

$$A_t = 0.7854(D - 0.9743/n)^2$$

For our screw type and screw size

Basic Major Diameter (D)= 0.4375

Thread per Inch (n) = 5

$$= 0.7854(0.4375 - 0.9743/5)^2 = \mathbf{0.0463\ in^2}$$

Screw Stress Analysis

Applying 8.5 factor of safety

Ultimate Force = (FS) * (Actual Force) = 8.5 * 250 lb

Tensile Stress = *F/A* = 2,125 lb

Tensile Stress= *2,125 lb / 0.0465 in*^{2} = ***45,698.92 psi***

45,698.92 psi < 73,200 psi

Meaning the screws are more than capable of withstanding the expected load of 250 lb with plenty of tolerance.

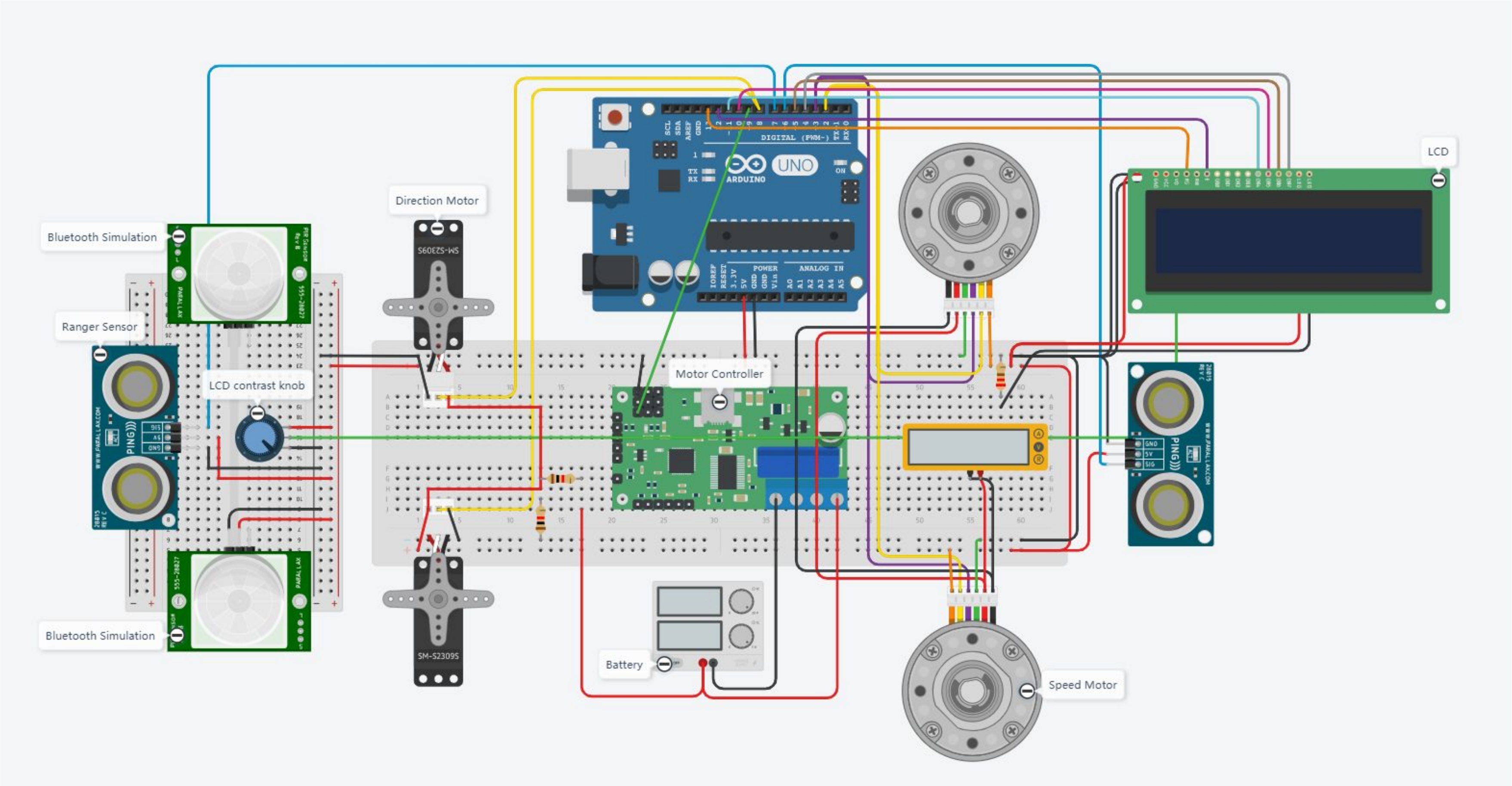
Equipment	Factor of Safety (FoS)
Aircraft components	1.5 - 2.5
Bolts	8.5
Cast-iron wheels	20
Engine components	6 - 8
Heavy duty shafting	10 - 12
Lifting equipment - hooks ..	8 - 9
Turbine components - static	6 - 8
Turbine components - rotating	2 - 3
Spring, large heavy-duty	4.5
Structural steelwork in buildings	4 - 6
Structural steelwork in bridges	5 - 7

Source: EngineeringToolBox.com

Unit Price

Cost of Plastic	$34.84
Cost of Aluminum	$15.18
Servo Motors (2)	$71.36
Speed Motors (2)	$181.76
Battery	$110.00
Bluetooth Sensors (2)	$10.00
Micro controller	$6.00
Ultrasonic sensors (2)	$14.00
PCB	$3.00
Wheels (4)	$72.00
Production and Assembly	$60.00
Total Cost Per Unit	**$578.14**

Overall Circuit



Powering System

Motors

- Two 36V DC motors for main power and speed control.

  Basic data: 350W, 300RPM, Rated Current: 12.5A; No-Load Current: 2.2A

- Two Servo motors working range from 4.8V ~ 8.4V for determining heading direction,

  Basic data: Stall Torque(7.4V): 70 kg.cm, Operating Speed(7.4V): 0.16''/60°, Angle:320°

Power supply:

- One 36V 20Ah DC Li-ion Battery

Powering System-working analysis

For speed motors, the driving force required to overcome the rolling friction .

The Formula: $F = f \times W/R$

F = the force required to overcome the rolling friction
f = the coefficient of rolling friction (units must match same units as R (radius))
W = Load on the Wheel
R = Radius of the Wheel

the rolling friction coefficient for Polyurethane wheel on hard material floor(test using steel).
f = 0.057 inches
Max overall weight = 350 lbs(devic) + 150 lbs (max cargo) = 500lbs

The driving force needed equals 52.80 Newton
For the 3 inch radius wheel, the torque for motors should be 4.02Nm

Powering System-analysis proving

Two 36V DC Motors:

BEMONOC Electric Tricycle Motor MY1016Z3 36V 350W 300RPM DC Electric Bicycle Motor 9 Tooth Sprocket DIY

by DC GEAR MOTOR

9 ratings

Price: $89.99 & **FREE Shipping**

Your cost could be $82.49. Eligible customers get a $10 bonus when reloading $100.

Size: **36 Volt**

24 Volt | **36 Volt**

Color: **300RPM**

- Rated voltage: DC36V; DC Motor No-Load Speed: 3850rpm; DC Motor Rated speed: 3000rpm; Gear Ratio: 9.78:1;

According to the electrical motor torque equation:

Torque=9550*Power(kW) / speed(RPM)

The max torque the motor can reach: 11.14Nm

11.14Nm > 4.02Nm

Powering System-analysis proving

Two servo motors:

Home › Toys Hobbies and Robot › RC Parts › RC Servos

SPT Servo SPT70HV-320 70KG Large Torque Metal Gear Digital Servo For RC Robot RC Car

0 Reviews | 4 answered questions ID: 1577512

Price: US$35.68 ~~US$40.01~~ 11% Off

Promo: SALE Order 2, get 10% off Go to see ›

Coupon: $20 for New User

Ship From: CN

Dispatch: In stock. Ships in 24 hours

Shipping: US$2.82
to New York via Banggood Express
Shipping time:10-15 business days

Stall Torque(7.4V): 70 kg.cm

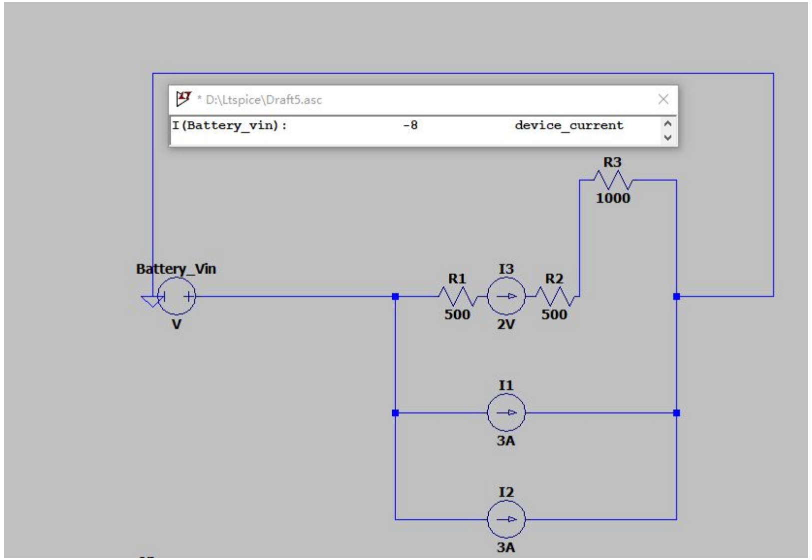
Working Angle:320°/PWM

Voltage Range: 4.8V-8.4V

Operating Speed(7.4V): 0.16''/60°

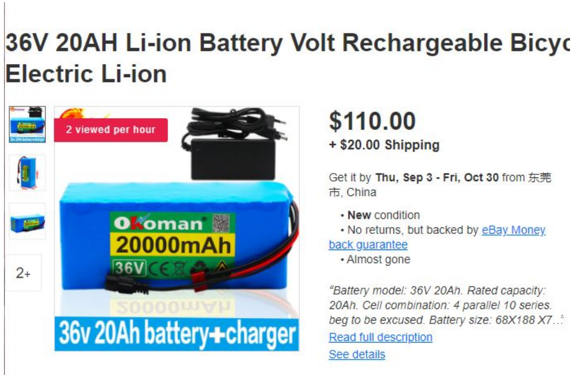
Powering System-analysis proving

Battery selection:



Overall battery maximum current

8A



When powering by this 20Ah battery,
The device is able to work for 2.5hours when fully charged

Sensors and Position Tracking

The ALA unit uses 2 forms of position tracking.

- Bluetooth Received Signal Strength Indicator (RSSI)
- Ultrasonic Sensing

Bluetooth RSSI:

- Indication of distance between devices derived from strength of signal
- Is accurate up to 1 meter between devices

Ultrasonic Sensing:

- Determines distance via SONAR
- Highly accurate between 1 to 3 feet.

Getting Data From Sensors

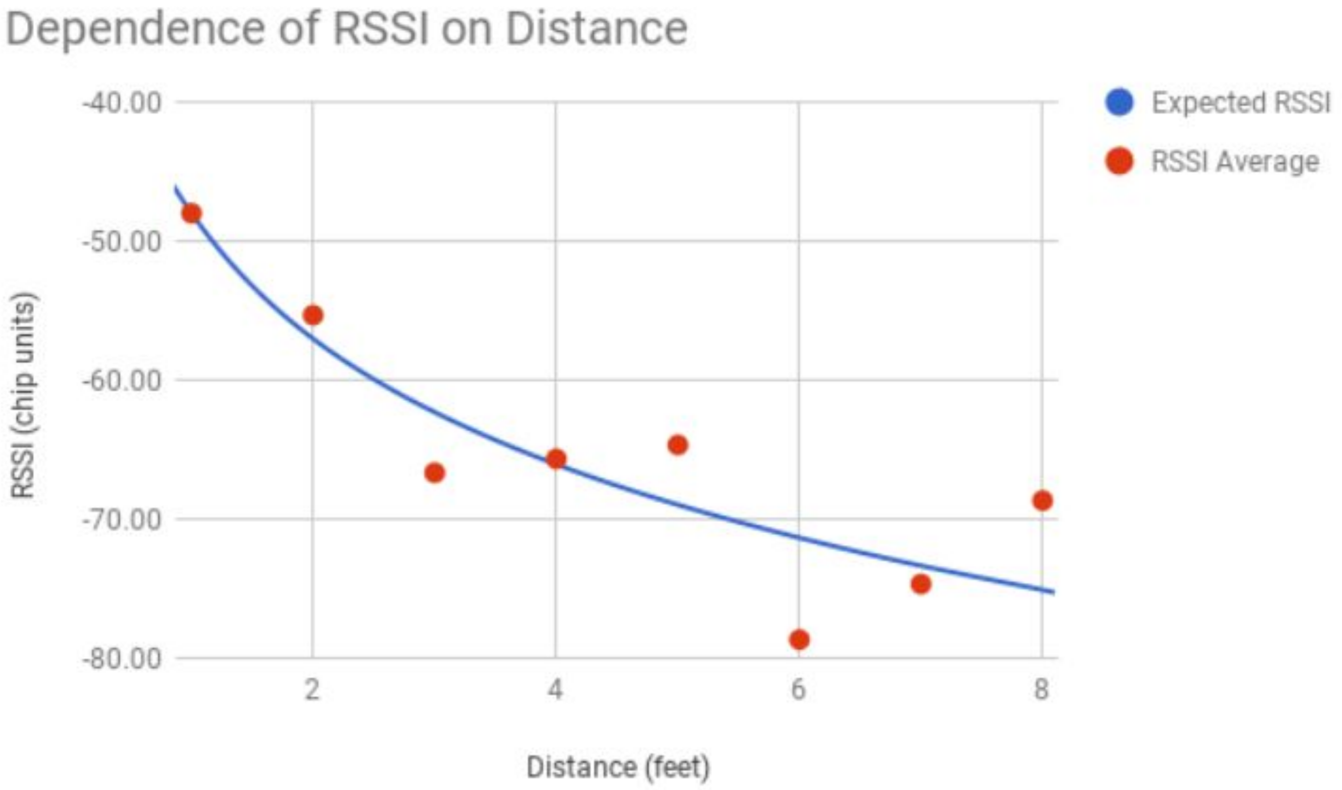
Bluetooth (HC-05):

- Pair Devices
- Put into search mode
- Verify the device to follow
- Receive RSSI data
  - Perform noise removal operations (mode, average, etc.)
- Inputs go to driver code.

```
AT+INQM=1,9,48\r\n
At+INQ\r\n
+INQ:2:72:D2224,3E0104,FFBC
+INQ:1234:56:0,1F1F,FFC1
+INQ:1234:56:0,1F1F,FFC0
+INQ:1234:56:0,1F1F,FFC1
+INQ:2:72:D2224,3F0104,FFAD
+INQ:1234:56:0,1F1F,FFBE
+INQ:1234:56:0,1F1F,FFC2
+INQ:1234:56:0,1F1F,FFBE
+INQ:2:72:D2224,3F0104,FFBC
OK
```

(*HC-05 -Bluetooth to Serial Port Module*, 2010)

A Relation of RSSI to Distance



(Glueck et al., 2017)

Getting Data From Sensors

Converting the RSSI to Distance:

Distance (m) = 10 ^ ((Measured Power - RSSI) / 10 *N)

- Measure Power : 1 meter RSSI threshold
- N : Environmental Factor (Range 2-4)

At the 1 meter RSSI:

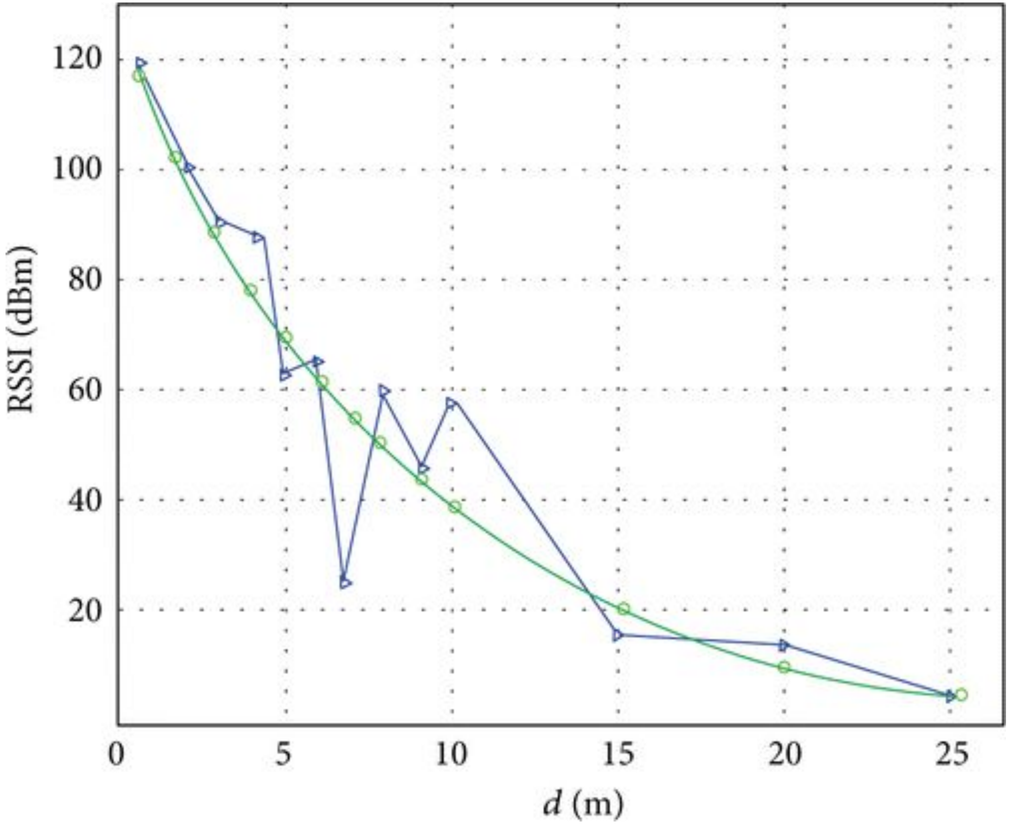
- 10 ^ ((-68 - (-68)) / 10*2) = 1 m

Further than 1 meter:

- 10 ^ ((-68 - (-75)) / 10*2) = 2.2 m

("How to Calculate Distance from the RSSI value of the BLE Beacon", 2016)

RSSI (dBm) and Range Relation



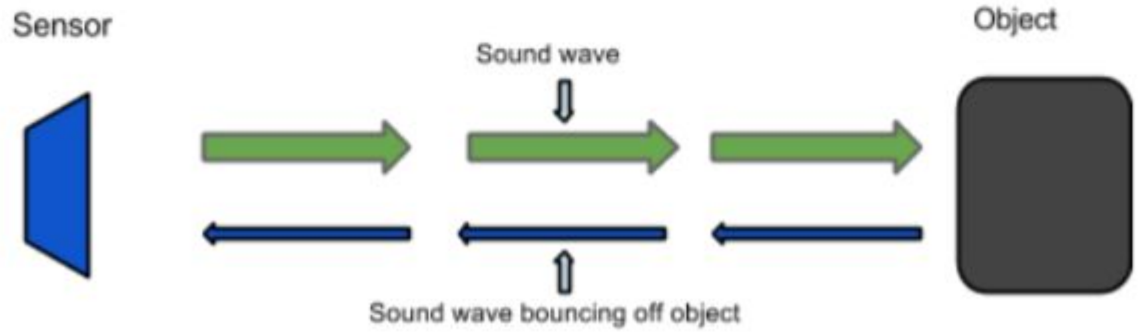
(Shang et al., 2014)

Getting Data From Sensors

Ultrasonic Sensing (HC-SR04):

Using SONAR to calculate distance.

- Pulse Time (µs) / 74 / 2 = Distance in inch
- Pulse Time (µs) / 29 / 2 = Distance in cm



(Morgan, 2014)

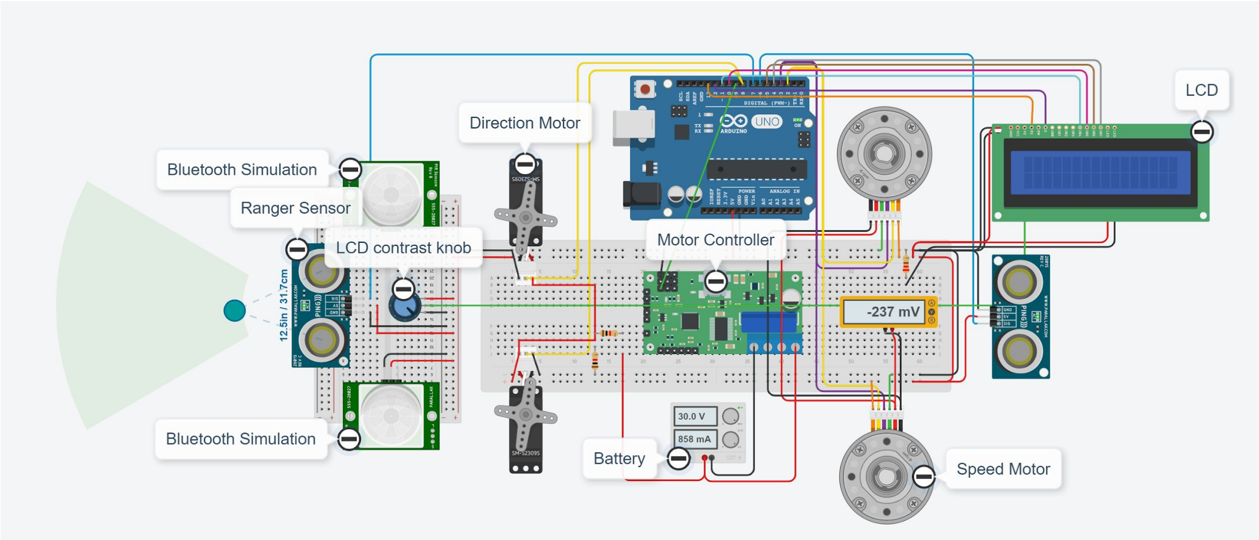
Website For Connection

https://ganqixu.wixsite.com/mysite

Determining speed and turning angle

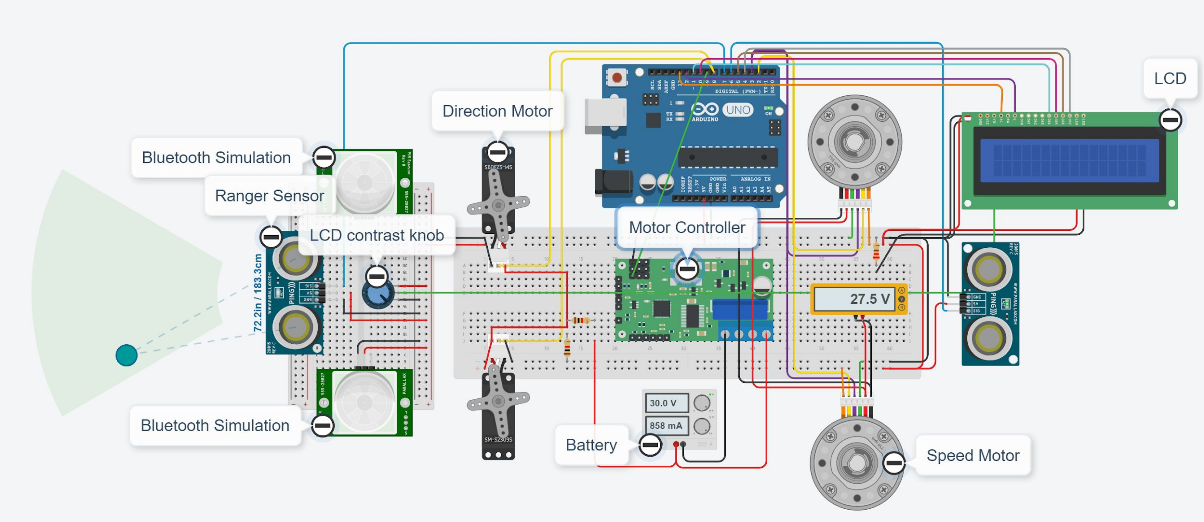
- Get inputs from ultrasonic sensor (real inputs)
- Get inputs from bluetooth (simulated inputs)
- Calculate Pulse width for servo and motor using proportional control
- Assign Pulse width to servo and motor
- Respond to emergency conditions
- Determine maximum speed and range of turning angle
- Calculate angle and speed with proportional relationships to the Pulse width
- Output speed / Angle of the servo

Motor Control



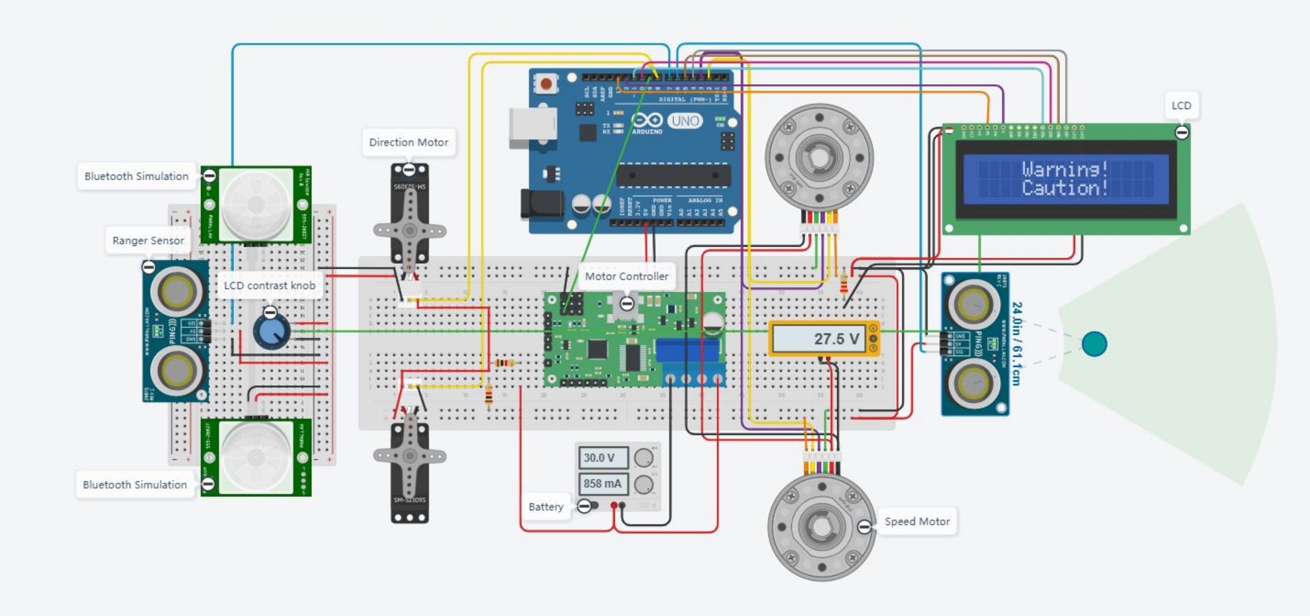
- MOTOR_PW = MOTOR_NEUT + kdrive * (range_front - 12)
- Always maintain 12 inches from the user
- If smaller than 12 inches, speed = 0 mph
- If larger than 12 inches, speed > 0 mph
- speed = 0.00725373 * MOTOR_PW - 20.05657

Servo Control



- SERVO_PW = SERVO_CENTER + ksteer * (RSSI0 - RSSI1);
- User right in front, servo angle = 90 degrees
- User moving to the left, servo angle < 90 degrees
- User moving to the right, servo angle > 90 degrees
- angle = 0.081374 * SERVO_PW - 135

Emergency condition



If people in the back are less than 30 inches from the device, print a warning message

Thank You

Q&A

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