PingPongBot

An Autonomous Robot

Set Your Hands Free

Advisor: C. Andras Moritz

Team

Mingrun Zhang

CE

Xumeng Pan

EE

Huiyu Tao

CE

Project Idea

- Build an integrated system that automatically locate and collect ping-pong balls, brings them back to a initialized spot for people to obtain.

Problem Statement Revisited

- For table tennis lovers or athletes, they always practice their skills with hundreds of balls on daily bases. It’s always a heavy task to pick up the balls all over the place manually after practiced hundreds of balls. Many coaches and athletes developed their own little tools like, but the pick-up process still requires lots of time and involves running around handling tools with long poles.
- To free their extra work and time, we decided to design a little robot with the ability to perform this process without human monitoring.

Goals

- Make practice session easier, remotely start our PingPongBot to collect balls.
- Set your hands free, no need of picking up balls by hand.
- Autonomously collect ping-pong balls for people to retrieve.

System Specifications

- System shall be triggered remotely, for example using bluetooth to connect and turn on the system by clicking buttons on a phone app (Arduino Bluetooth controller).
- System shall have a removable bucket which can hold up to dozens of balls.
- System shall be able to run the whole place(6m*6m) and pick up 40 balls within 20 minutes.
- Ideally the vacuum battery should last for around 1 hour.

Calculation for Timing of Collecting Ball(s)

Picking up one ball:

$$vehicle\ speed = \frac{actual\ test\ distance}{average\ actual\ test\ time} = \frac{50[inch]}{\frac{(8.11+8.31+8.90)[s]}{3}} * \frac{0.0254[m]}{1[inch]} = \frac{1.27[m]}{8.44[s]} = 0.15\left[\frac{m}{s}\right]$$

a. $time\ to\ locate\ a\ ball = time\ for\ pixy\ to\ recognize\ objects \approx 0\ [s]$

$\text{average time } measured \text{ to turn 360 degrees } = (21.13 + 20.47 + 18.78)/3 = 20.126s \approx 20s$

b. $time\ it\ takes\ to\ turn = time\ to\ turn\ a\ complete\ round * \frac{rough\ angle\ turned}{degree\ of\ a\ complete\ round} = 20 * \frac{a}{360}[s]$

c. $time\ to\ travel\ to\ a\ ball = \frac{distance\ between\ the\ ball\ and\ vehicle}{vehicle\ speed} = \frac{D}{0.15[m/s]}$

d. $time\ needed\ to\ pick\ up\ a\ ball \approx 0.01[s]$

$average\ vehicle\ delay\ time\ (vehicle\ moving\ response\ lags\ after\ pressing\ a\ button\ on\ the\ phone\ )$
$= (1.03 + 1.21 + 1.91 + 1.89 + 1.93 + 2.61 + 1.4 + 2.29)/8 - 0.03 = 1.75s$

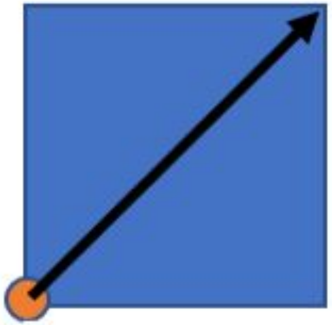
e. $time\ of\ delay = delay\ of\ turning + delay\ of\ moving\ forward = 1.75 + 1.75 = 3.5s$

☺ $time\ to\ collect\ one\ ball = 0 + 20 * \frac{a}{360} + \frac{D}{0.15} + 0.01[s] + 3.5[s]$

Calculation for Timing of Collecting ball(s)

Set a goal for picking up 10 balls with the path routing algorithm with the first design version:

1. The Worst Case:



6m*6m field

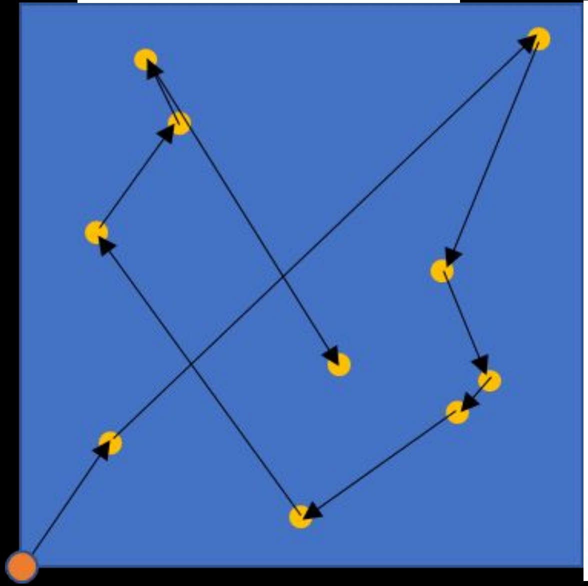
Diagonal: $6\sqrt{2}\,m$

Upper bound: $6\sqrt{2}\,m * 10 = 60\sqrt{2}\,m = 84.85m$

Theoretical maximum time: $\frac{60\sqrt{2}m}{0.15m/s} * \frac{1min}{60s} = 9.42min$ (time in real case will be less than this value)

Calculation for Timing of Collecting ball(s)

2. A Random Case:
   Scale: 1:100



Total distance on map = 1.6+6.3+2.7+1.3+0.5+2+3.8+1.5+0.9+3.9 = 24.5cm

Total theoretical distance = 24.5*100 = 2450cm = 24.5m

a. Approximate turning time = $\text{time takes to turn around} * \sum \frac{\text{Approximate angle turned}}{\text{degree of a complete round}}$

$$= 20 * \left(\frac{30}{360} + \frac{15}{360} + \frac{150}{360} + \frac{135}{360} + \frac{60}{360} + \frac{15}{360} + \frac{90}{360} + \frac{75}{360} + \frac{75}{360}\right) = 35.83s$$

b. Total theoretical traveling time= 24.5m/(0.15m/s) = 163.33s = 2.72min

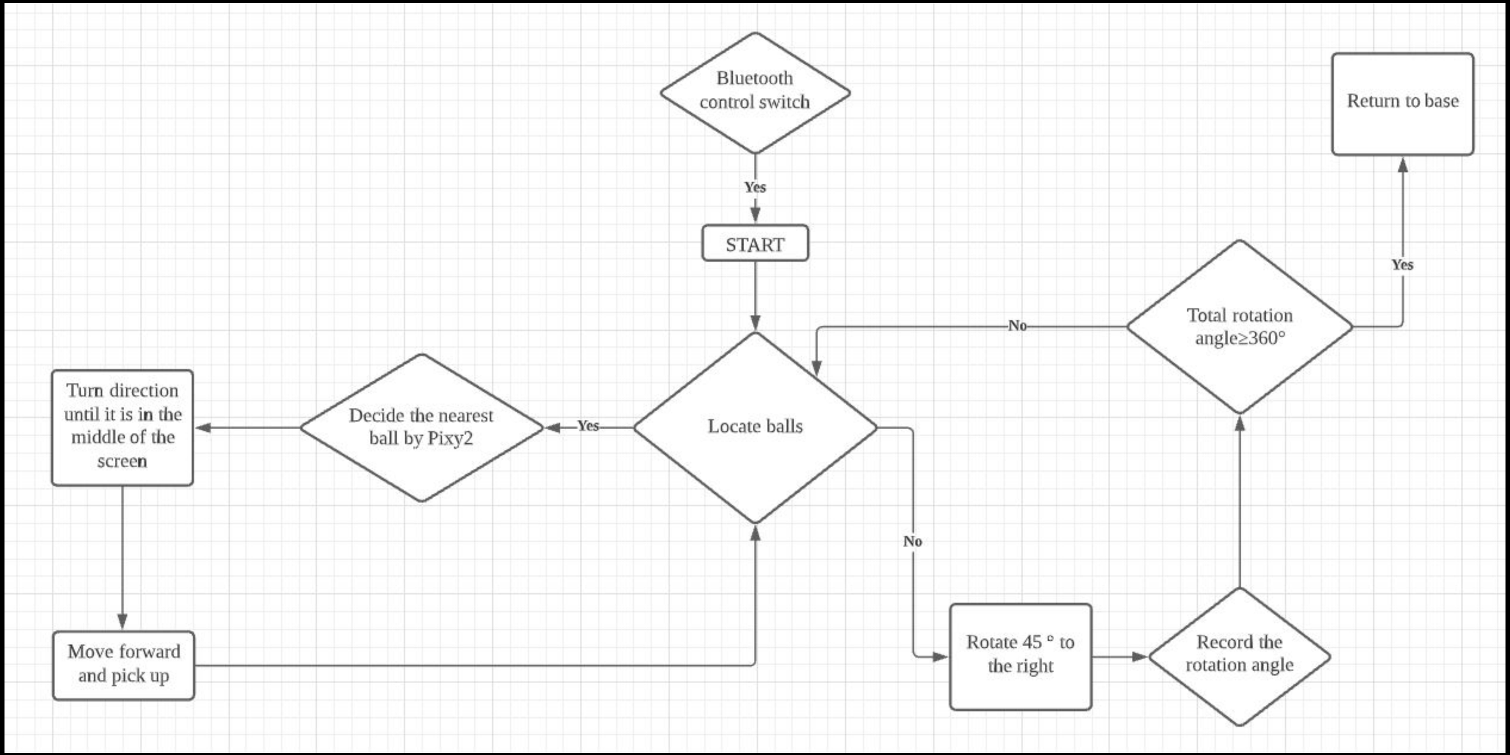
c. Total time needed to suck 10 balls = 0.1*10 = 1s

d. Total delay time = 10*2*1.75s = 35s

☺ Total time for collect 10 balls = 35.83+163.33+1+35 = 235.16s = 3.92min

Plan to use software to generate a probability distribution of total consumed time

Block Diagram of Path Routing Algorithm



Current Battery Supply

Vacuum Battery: 7.4V, 2200mAH, 4.4A, rechargeable

Runtime: 0.5H

Charging time: 1H

Wheels Battery: 6V, 6000mAH, 600mA (AA batteries, non rechargeable)

Runtime: 10H

Battery Plan

Replace original vacuum battery with larger battery:

7.2V, 4200mAH, 4.2A

Runtime: 1H

Replace wheels battery with larger rechargeable 6V battery.

6V, 2200mAH, 600mA, rechargeable

Runtime: 3.6H

Plan B: use 12V rechargeable battery with a voltage regulator (need HW exemption for buck inverters)

Testing Plan (For Final Product)

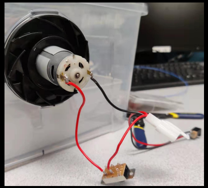
- Demonstrate that the robot will be placed at its base at the beginning, and test if it can autonomously run back to its base at the end.
- Demonstrate that the system can be turned on remotely.
- Perform at least 10 trials to test if the system can perform its picking progress without human inspection once turned on.
- Test if the robot will turn to its base aftering finishing the pick-up process.
- Demonstrate the use of the removable bucket filled with balls.
- Perform at least 10 trials with 40 ping-pong balls placed randomly within the 6*6m field to test if the system can run the whole place and pick up all the balls within 15-20 minutes.
- Perform at least 10 trials with different movements of the robot, run until the battery died or voltage significantly dropped. Record the data and compare with calculation estimation of how long the battery will last.

Hardware Components

ELegoo Uno R3

Chassis

Vacuum Motor



Vision Sensor Pixy2

Straight and Tilted Plastic Tubes

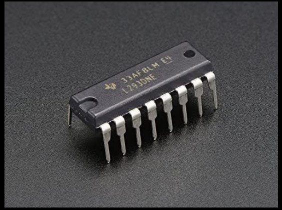
HC-SR04 Distance Sensor

Wheel Motors

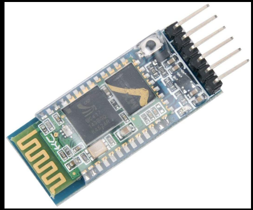
6V & 7.4V DC Batteries

G6E-134PL-US Relay

2 L293D Motor Drivers



HC-05 Wireless Bluetooth



Plastic board

plastic Container

Inside Container

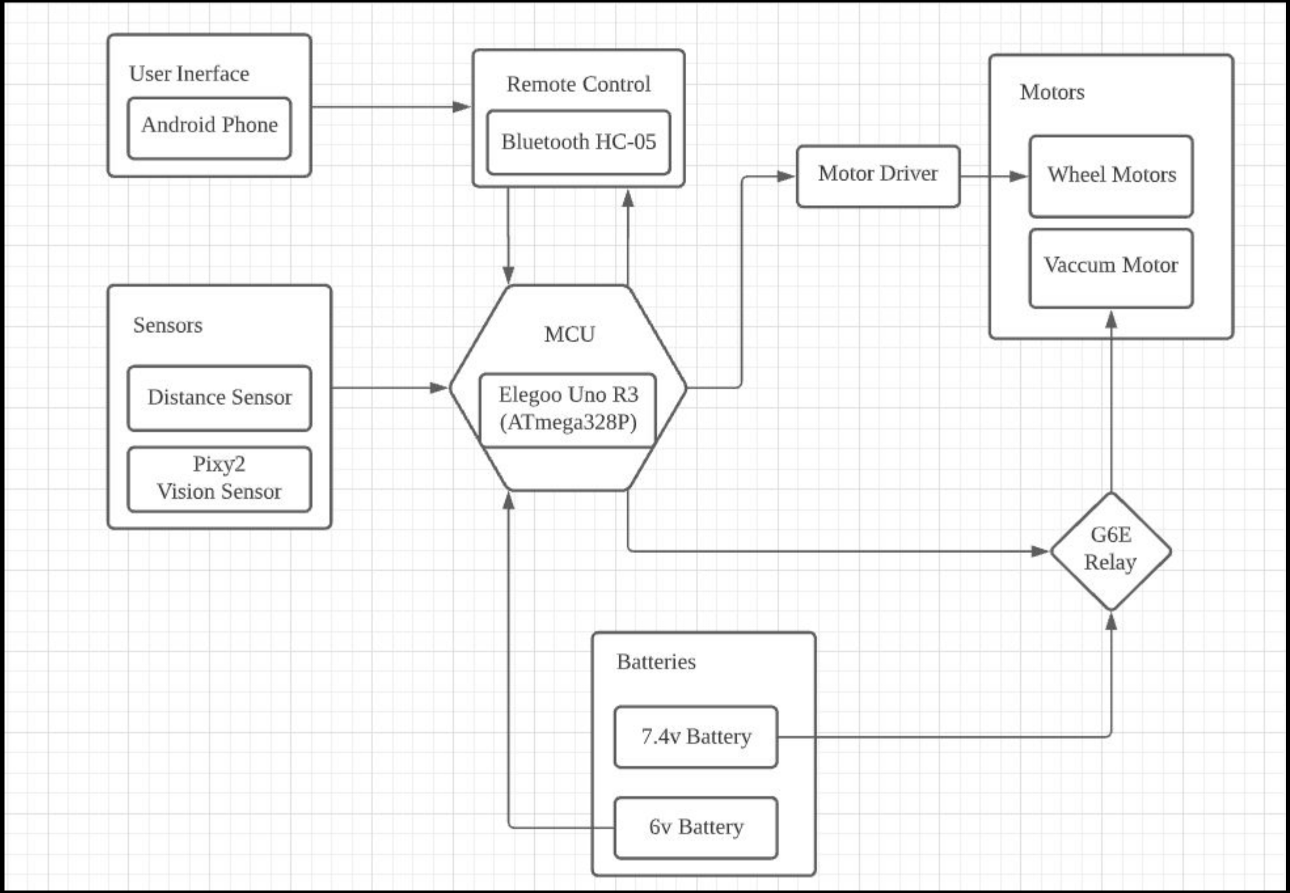
2-stage, six pin toggle switch

Software Components

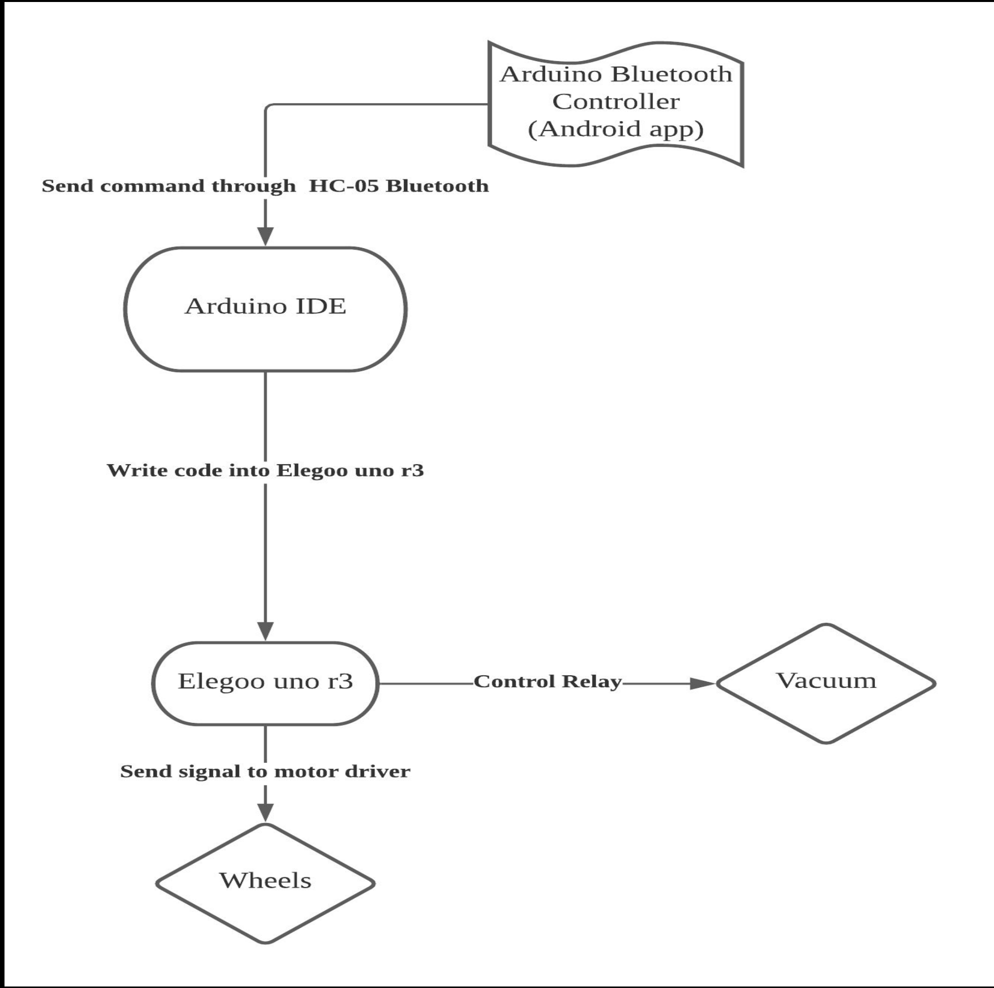
Arduino IDE

Arduino Bluetooth controller

Hardware Diagram



Software Diagram



Justification of Key Hardware Components Choices

Elegoo Uno R3: It uses COM4 port and compatible with Arduino IDE. It's an alternative solution to Arduino Uno.

HC-05 Bluetooth: It has Tx and Rx pins which allows us to transmit and receive data through cell phones remotely.

Pixy2 Vision Sensor: It is capable of detecting the Ping-pong balls by its color, and send the location to MCU.

HC-SR04 Distance Sensor : It is an Ultrasonic distance sensor with range 2-500cm.

L293D Motor Driver: It's capable of driving DC motors. It can change the speed and spinning direction of motors and used with Arduino. So, it works with the wheels motors.

Wheel Motors: They are originally matched with the robot car chassis.

Vacuum Motor: It has suitable power to use to suck ping pong balls after tried several vacuum motors.

G6E-134pl-us Relay: It's 2A 250V for general purpose, and it's recommended for us by a M5 staff.

6V and 7.4V Batteries: 6V voltage can provide more stable power for the wheel motors by comparing with 5V voltage and it's the maximum voltage allowed for HC-05 Bluetooth. 7.4 V battery is the original battery for the vacuum motor.

Justification of Key Software Components Choices

Arduino IDE: It has a good connection to Elegoo Uno R3, and we have some experiences of using it.

Arduino Bluetooth Controller App: It works with both of HC-05 Bluetooth and Arduino, and it’s a popular used App for controlling Bluetooths.

Commitment to The Custom PCB Plan

Parts:

- Atmega328p chip
- Relay
- Motor drivers
- HC-05 bluetooth

Plan:

- Planning to make sure everything we need on PCB and ask if it is able to produce.
- First design of PCB
- Send the request to manufacture company for PCB assembly.
- If doesn’t work, need second design

Demonstration of The Integrated System

- Vision and Distance Sensor will be shown in Demo video.
- Live Demo for the main chassis and vacuum system.

System Noise

Vacuum working volume: 65 dB

Ping-pong court volume: 90-100 dB (dozens of ping-pong balls hit the floor)

Add soundproof materials packing (acoustic foam panels) in CDR prototype.

MDR Deliverables

Subunit 1 Main body prototype

- Show the assembled prototype of the robot's main body, cluding vacuum system (vacuum cleaner, container, and pipes), wheels, and battery assembled together.
- Demonstrate the process of collecting balls into the container through a connected pipe.
- Show capability to control the vehicle e.g., drive the robot to the next ball and collect it.
- Show calculation of power budget – estimation of how long it lasts after fully charged.

Subunit 2 Sensors

- Demonstrate the distance sensor. Place the sensor on a board – not yet integrated with the robot. Move it closer to the wall. It should detect the wall and get the distance results visualized on a laptop.
- Demonstrate the Vision sensor. Place the sensor on a board – not yet integrated with the robot. Dump or put the ping-pong ball in front of it; the vision sensor should recognize the ball and show that it is successfully detected.

Subunit 3 Wireless and routing algorithms

- Set up the wireless Bluetooth control module for starting the robot; show its function by controlling the vehicle to move forward and backward for about 2-3fts far, and for starting the vacuum by pressing a button.
- Design and explore the path routing approach. Show its block diagram and write initial codes for the routing algorithm. Although it may not be fully functional it would be part of initial design exploration and testing that can be built on.
- Show the calculation of the timing needed to locate a ball, travel to it and pick it up - estimation of how long it needs to collect one ball and collect dozens of balls.

Project Expenditures

Item	Projected Cost	Current Cost
Ping-pong Balls	$15	$14.99
Vacuum Pump	$50	$38.99
Pixy2 Vision Sensor	$60	$59.90
Early PCB Revisions	$110	$83.6
Final PCB Revisions	$100	N/A
6V & 7.4V Battery	$30	$27.24
HC-SR04 Distance Sensor	$20	$12.59
Motor	$25	$86.51
Robot Chassis(Wheels, Removable Basket, Plastic Tube)	$60	
Total	$500	$323.82

Gantt Chart

	Task Name	Start Date	End Date	Team Member(s)
Hardware				
	First design of PCB	1/27	2/5	Tao & Pan
	Second design of PCB	2/14	2/21	Tao & Pan
	Implement another bluetooth module	2/22	3/1	Tao & Zhang
	Finalize the design of PCB	2/28	3/6	Tao & Pan
Software				
	Initial Route Algorithms	1/27	2/3	Tao & Pan
	Apply Machine learning	2/3	2/14	Tao & Zhang
	Second Route Algorithms	2/14	2/21	Tao & Pan
	Finalize the Route Algorithms	2/21	2/28	Pan & Zhang
	Edit the coding for microcontroller	1/28	3/7	Pan & Zhang

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7(CDR)
M T W TH F	M T W TH F	M T W TH F	M T W TH F	M T W TH F	M T W TH F	M T W TH F
1/26/2022-1/28/2022	1/31/2022-2/4/2022	2/7/2022-2/11/2022	2/14/2022-2/18/2022	2/21/2022-2/25/2022	2/28/2022-3/4/2022	3/7/2022-3/11/2022

Team Responsibilities

Xumeng

Design the Circuit of Vacuum System

Design and Test Bluetooth Control of Vehicle and Vacuum System

Design Path Routing Algorithm and Draw the Diagram

Calculating the timing for collecting ping pong balls

Test the Integrated System

PCB Lead

Huiyu

Design the Circuit of Vehicle Motor System

Set and Test the Vehicle Motor System

Set and Test Distance sensor

Set and Test Vision Sensor

Design Path Routing Algorithm

Shopping for Components

Soldering Components

Budget Lead

Mingrun

Design and Assemble the Main Body Configuration

Test Vacuum and Motor System

Test Collecting & Basket Capacity

Test the Integrated System

Calculating Power Budget

Shopping for Components

Soldering Components

Team Coordinator

Q&A

Thank You!