An Autonomous Pool Cleaner

ECE 445 Design Document

#Team 24

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1 Introduction

1.1 Objective

Regular pool maintenance and cleaning is essential for maintaining good pool hygiene, but traditional manual cleaning methods can be time-consuming and labor-intensive. With the increasing demand for pool usage due to improved lifestyles, there is a need for more efficient and effective pool cleaning solutions to keep pools clean with minimal intervention. Moreover, traditional methods of pool cleaning not only require extensive physical labor but also result in the excessive use of water resources, making it an environmental concern.

Our goal is to create an autonomous pool cleaner that can efficiently clean pools with minimal human intervention. The cleaner is a waterproof machine that contains sensors to detect obstacles and avoid collisions, wheels to navigate around the pool, and brushes and filters to collect debris and particles from the pool water. In addition, it is equipped with batteries that provide power and a remote control system that allows the machine to be started and stopped from the ground. This autonomous pool cleaner is a highly efficient and effective underwater cleaning device that can save time, effort, and water resources. It can plan an optimal cleaning path, and navigate around the pool with ease.

1.2 Background

There are many companies providing pool cleaner, including Zodiac, Hayward, Pentair, Dolphin, and Maytronics. And these companies offer different kinds of pool cleaners, including manual cleaner and atonomous pool cleaners with or without wire.

The price range for a manual pool cleaner is around 200 dollars, and the price for autonomous pool cleaner with or without wire for large pool is around 1400 dollars. And our wireless autonomous pool cleaner will have the price of 600 dollars. It is more convenient than manual pool cleaner and also much cheaper than the autonomous pool cleaner in the market, which could make up for the lack of wall-climbing ability. The The cost of our pool cleaner is about 300 dollars, and the payment of our group is about 9000 dollars, which means that after selling 30 cleaners, the cost will be covered, and we are going to make profit. Overall, our pool cleaner has a high possibility to success.

1.3 Visual aid

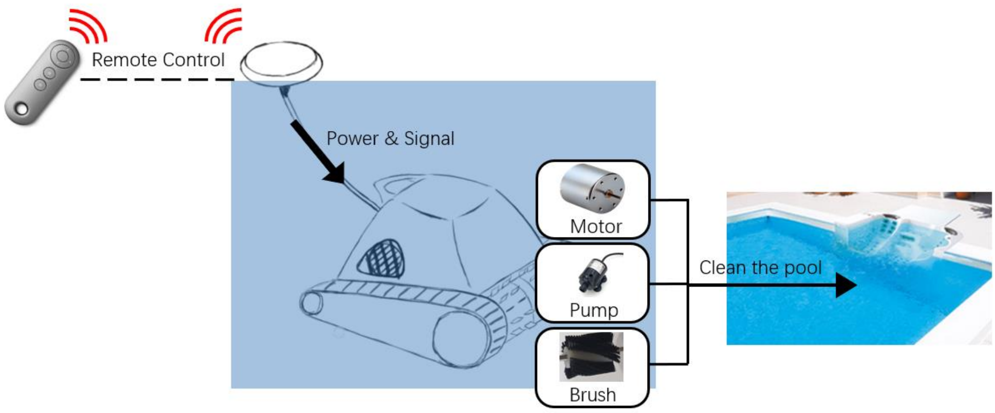

Fig. 1. Visual aid

1.4 High-Level Requirements

- The battery of the device needs to have a large capacity to provide enough power to ensure normal work in a swimming pool of at least 500 square meters.
- The pool cleaner can follow programmed routes and are able to cover the entire pool.
- The pool cleaner runs continuously in one cleaning and is able to hold approximately 500 grams of dirt and litter.

2 Design

The hardware structure of the autonomous pool cleaner consists Power Supply Subsystem, Propulsion Subsystem, Information Collection Subsystem, Control Subsystem, Clean Subsystem, and Remote Control Subsystem. Power Supply Subsystem is used to provide different voltages. Propulsion Subsystem is used to control motors. Information Collection Subsystem is used to collect the location of the cleaner. Control Subsystem is used to control the turning angle of the cleaner. Clean Subsystem is used to control pump and the motors of brushes to work. And the Remote Control Subsystem allows people to control the cleaner remotely by their phones.

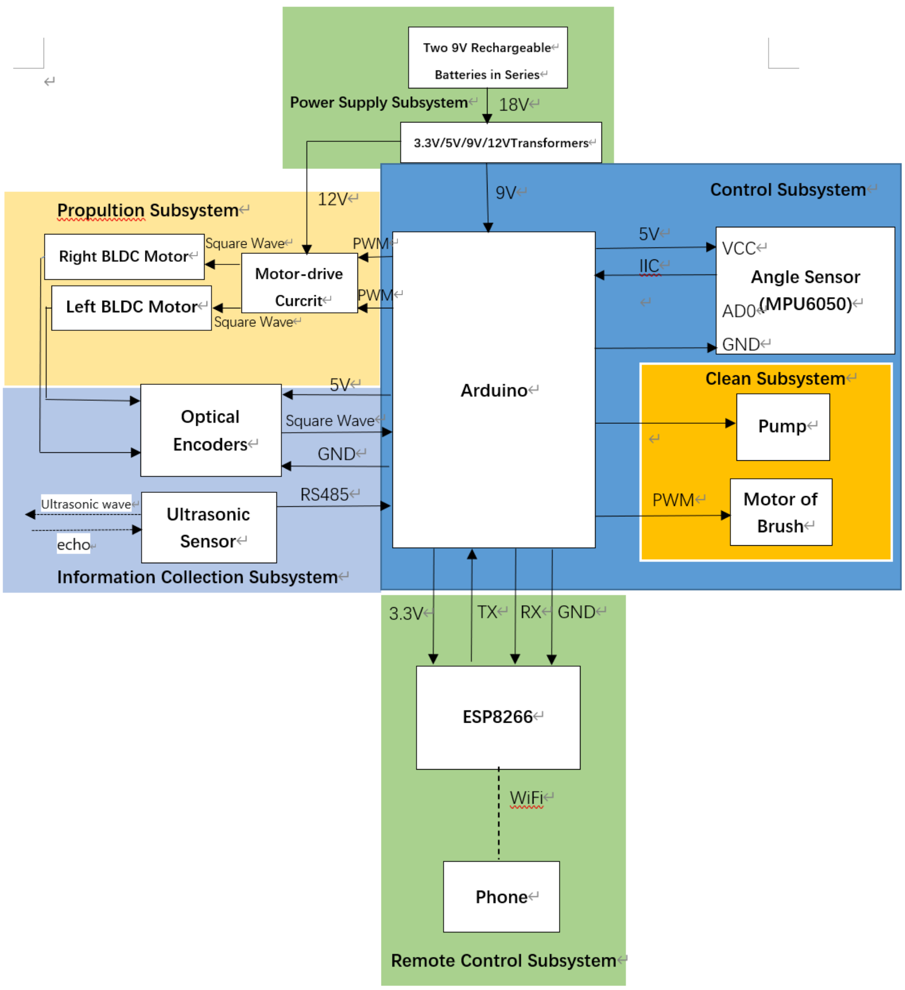

Fig. 2. Block Diagram

The cleaner's body consists of two main parts, one at the bottom of the pool for cleaning and moving; the other floating on the water surface, carrying the power system and the main circuits and chips. The two are connected by wires, and the power supply of the lower circuit and components is realized by the upper part and wires. Meanwhile, the upper part carries a Wi-Fi module for remote control with cell phone connection.

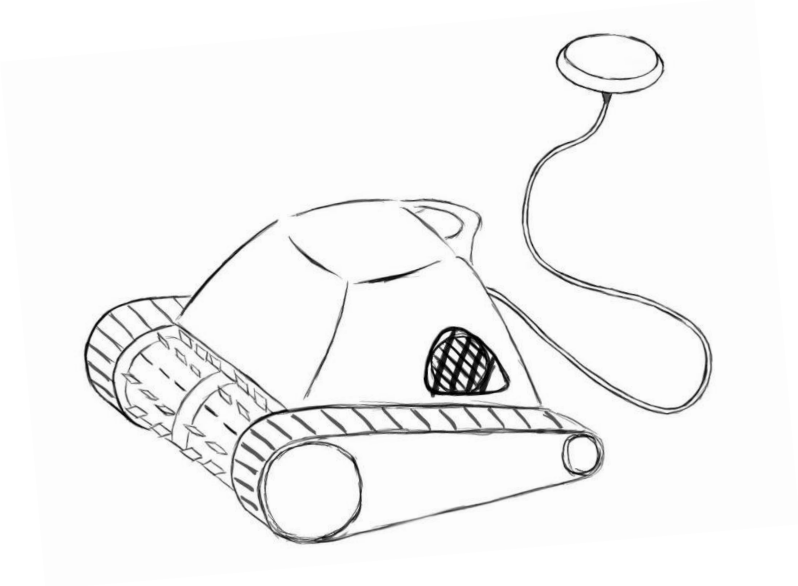

Fig. 3. Physical design sketch

2.1 Information Collection System

In this subsystem, we use ultrasonic underwater sensors to enable the robot to walk underwater along walls, steer etc. The robot moves around the pool's edge starting from a certain position. Use this to create the pool's contour information L,W.

2.1.1 Ultrasonic Sensor

We use two ultrasonic sensors to detect the distance between the wall and the cleaner. The ultrasound probe emits ultrasound, which propagates through the water, encounters the target, and is reflected back to the ultrasound probe. The distance between the probe and the measured target can be calculated by D=C*T/2. The following is the data of the sensor we will first try with (120F35TR).

frequency	Voltage supply	Measuring distance	Blind spot	angle
120KHZ	5-24VDC	20.0 m	0.5-0.6m	30°-40°

The output of the ultrasonic sensor is interfaced with Arduino through RS485 Modbus. It uses the 5V output of the Arduino to power the ultrasonic sensor, after which the RS485 data interface is connected to an RS485 to TTL module (MAX485), which communicates with the Arduino by setting up a soft serial port.

Here is how to keep the cleaner a distance L from the wall. Assume the cleaner goes clockwise. In the beginning, let both wheels of the cleaner walk at the same duty cycle, ensuring that the ultrasonic sensor is perpendicular to the cleaner's direction of travel and that the vertical distance from the wall is slightly greater than L. The angle between the cleaner and the wall is smaller than θ/2 (for 120F35TR, θ=40°) [1]. Allow the cleaner to move at a high speed. At the same time, the ultrasonic sensor starts to operate. The emission angle of the ultrasonic sensor is θ. If the angle between the central axis of the beam and the wall-normal is large, the ultrasound reflected cannot be received, or the error is large, so the angle between the central axis of the beam and the wall-normal should be controlled within θ/2.[1] Since the ultrasonic sensor position is fixed on the cleaner, the ultrasonic sensor's rotation angle equals to the cleaner's rotation angle. In order for the car not to lose control, we require the drift angle of the cleaner α with respect to the wall is also less than θ/2. Then we can get

$$\alpha = (\omega_1 - \omega_2)rt/2\pi l \times 360° < \theta/2$$

Due to the small difference in speed between the two wheels, the drift angle when the cleaner first passes through the plane at a distance L from the wall is less than θ/2, and then the cleaner can walk close to the wall through the proximity wall-following algorithm. If the speed difference between the two wheels is determined, the smaller the drift angle at the first pass of L, the straighter the cleaner will go; conversely, the trajectory will be smoother, but the cleaner may lose control.

We also need to analyze the limit positions to avoid collision. The car's body is considered to be rectangular. In differential steering, the body is moving in a circle around an axis. If the car collides with a wall, the collision site must be the two top corners of the front of the body, as shown in the picture.

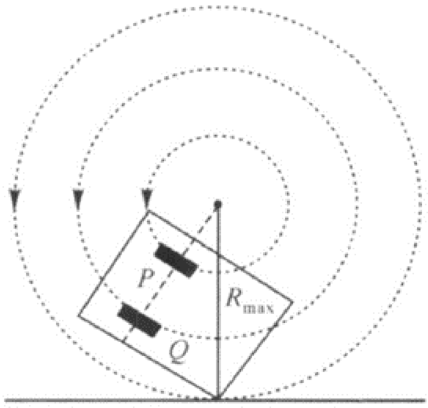

Fig 4. limit positions to avoid collision

The front of the car is also equipped with an ultrasonic sensor, which requires the car to turn 90° to the right when the distance of the car from the wall is less than the set value.

requirement	verification
When the sensor is fixed perpendicular to the car, the car should not lose control.	The emission angle of the ultrasonic sensor is 40°, so a range of + 20° to - 20° between the central axis of the beam and the wall normal can be used as the optimum range for detection. In order for the car not to lose control, the angle between the trolley and the wall must not exceed 20°.
When the sensor is fixed perpendicular to the car, and should not crash into the pool wall.	1. The ultrasonic sensor we have chosen has a strong signal and requires a measurement distance of at least 60cm, so we require that the distance from the ultrasonic sensor to the wall is kept constant at 60cm. The following two requirements need to be met: 1. The angle of the car passing the 60cm line for the first time from the initial position does not exceed 20°. 2. The ratio of the speed of the slower car wheel to the faster wheel is less than 0.89. (In the design we

	make this ratio 0.85, so the car does not touch the wall) 2. The front of the car also has an ultrasonic sensor. In order for the car to turn without colliding with the wall, ensure it turns at least 25cm from the wall.

2.1.2 Step Motor

In order to make the cleaner start parallel to the pool wall, self-adjustment of the cleaner's position and posture can be achieved by the combination of stepper motors and ultrasonic sensors. For the step motor, we will use 42HS34-FS, driven by HPD322. The distance to the wall is measured once per step and the measured value is fed to Arduino, which gives 200 distance values for a 360° rotation of the ultrasonic motor. The distances to the points within 2 mm of each other are measured (n points) and the midpoint of these points is the nearest point on the wall to the ultrasonic sensor. The following is the data of the step motor.

Technical Parameters for 42HS34-FS				
Phase	Step Angle Error	Step Angle	Rated Voltage	Rated Current
2	0.09	1.8°	3.1V	1.3A

requirement	verification
Because the shaft of the stepper motor is exposed to water, the stepper motor should be waterproof.	The 42HS34-FS has a waterproof level of IP68.

2.2 Control Subsystem

Control Subsystem consists of a MPU6050, which is to detect the angle of the cleaner; a Arduino board that is used to receive the signal from MPU6050, ESP8266, Photoelectric sensors, and Ultrasonic sensors. And Arduino will send different PWM waves to control motors.

2.2.1 MPU6050

frequency	Voltage supply	Full Scale Range	LSB Sensitivity
8kHZ	5VDC	+/- 250degrees/s	131 LSB/deg/s

It will output the angle of the cleaner to Arduino. We can use the angle in PID control and make the cleaner turn to certain angles.

Incremental pid control algorithm:

$$u(k) = Kp \cdot \Delta e(k) + Ki \cdot e(k) + Kd \cdot [\Delta e(k) - \Delta e(k-1)]$$

$\Delta e(k)$ will be calculated by the desired angle $\theta 1$ and the current angle $\theta 2$.

$\Delta e(k) = \theta 1 - \theta 2$

u(k) will be added to PWM waves to control the motor and make the cleaner turn to a certain angle.

To control the cleaner go straight, we need to make the right motor and left motor run in same speed. With signals from right and left photoelectric sensor, we can get the speed difference. And by using the speed difference as $\Delta e(k)$, the cleaner can go straight.

requirement	verification
1. Output angles according to angular speed, and the pression should be in 1°. 2. Pid control should control the cleaner to turn to certain angle in 10s, and the pression should be in 1°.	1,2. Draw a straight line on the floor and let the machine parallel to it. And let the cleaner turn 60°. Then measure the actuall angle it turns. If the angle is between 59° and 61°, it success.

3. Pid control should let the cleaner maintain a certain angle after turning.	3. Use a long ruler to see if the cleaner goes straight.

2.2.1 Optical Encoder

Optical encoders are used to accurately measure the displacement of a robot as it travels. The optical encoder is a sensor that converts the angular displacement into an electrical pulse signal by photoelectric conversion. The code disc is engraved with equally spaced radiating light-transmitting slits and rotates coaxially with the motor. The diode emits light, which is absorbed by the light-sensitive detector through the equally-spaced slits and the signal is processed to output three sets of square wave pulses. The incremental optical encoder outputs A and B pulses with a 90° difference so that the direction of rotation can be easily determined. At the same time, it outputs a marker signal Z for each rotation of the code disc. The Incremental optical encoder is easy to implement, with a long average mechanical life of tens of thousands of hours or more. It also has high resolution, high resistance to interference, long distances of signal transmission and high reliability.

If the diameter of the cleaner's active wheel is D, the number of slits is n, and the number of pulses read from the light detector A/B in time Δt is N, then the distance ΔS travelled by the trolley in Δt is

$$\Delta S = \pi DN/n$$

The distances travelled by the left and right active wheels in time Δt are ΔS_l and ΔS_r, respectively, and the distance between the two active wheels is B, then the distance of travel ΔS and the angle of rotation Δθ in Δt are

$$\Delta S = (\Delta S_l + \Delta S_r)/2$$

$$\Delta\theta = (\Delta S_r - \Delta S_l)/B$$

After measuring the cleaner's motion data using sensors, the cleaner's motion model can be described in a two-dimensional coordinate system. Assuming that the robot's location at moment k-1 is (x_{k-1}, y_{k-1}), then the robot's locus at moment k is

$$x_k = x_{(k-1)} + \left(\Delta S_{(k-1)}\right)/\left(\Delta\theta_{(k-1)}\right)\left(\sin\left(\theta_{(k-1)} + \Delta\theta_{(k-1)}\right) - \sin\theta_{(k-1)}\right)$$

$$\theta_k = \theta_{(k-1)} + \Delta\theta_{(k-1)}$$

$$y_k = y_{(k-1)} + \left(\Delta S_{(k-1)}\right)/\left(\Delta\theta_{(k-1)}\right)\left(-\cos\left(\theta_{(k-1)} + \Delta\theta_{(k-1)}\right) + \cos\theta_{(k-1)}\right)$$

The following is the datasheet of the optical encoder (E6B2-CWZ3E).

Working Voltage	Resolution	Output
5VDC-12VDC	2000	Voltage

2.3 Communication Subsystem

In this subsystem, the design of a WiFi module based on the ESP8266-01S chip, which will be used to remotely control a pool cleaner. The aim is to connect the module to a smartphone application and also to an Arduino, which will be responsible for controlling the pool cleaner. The CH340C chip will be used for testing purposes.

Module Features:

- Built-in WiFi chip (ESP8266-01S)
- UART and SPI communication protocols
- Built-in antenna for wireless communication
- Capable of operating in both client and server modes
- Can be programmed using the Arduino IDE or other programming platforms
- Low-cost and easy to integrate with other devices

Design Requirements:

- The WiFi module should be able to connect to a smartphone application
- The module should be able to communicate with an Arduino for pool cleaner control

- The module should be able to handle emergency stop signals from the smartphone application
- The module should be easy to program and integrate with the Arduino
- The module should be reliable and durable for outdoor use

Design Specifications:

To achieve the above requirements, the following design specifications have been identified:

- The module will connect to the smartphone application using the TCP/IP protocol over WiFi
- The module will communicate with the Arduino using the UART protocol
- The module will use a custom protocol to handle emergency stop signals from the smartphone application
- The module will be programmed using the Arduino IDE and will use the ESP8266WiFi library for WiFi communication
- The module will be enclosed in a weather-resistant case to protect it from outdoor elements

2.3.1 ESP8266-01S Chip

The ESP8266-01S module is a low-cost WiFi chip, which is capable of connecting to a variety of networks. The chip is capable of operating in both client and server modes, and can be programmed using the Arduino IDE or other programming platforms. The module comes with a built-in antenna and supports a range of communication protocols, including UART and SPI.

Power Consumption	Effective Range	Connection Speed	Max Throughput
around 70mA in active mode and less than 200uA in sleep mode	up to 50m indoors and up to 100m outdoors, depending on environmental factors	up to 72 Mbps	up to 16 Mbps

The ESP8266-01S WiFi module is a versatile and reliable solution for wireless connectivity in a variety of applications. Its low power consumption, extended range, and high data rates make it ideal for use in the pool cleaner controller project described in this document. By leveraging the ESP8266-01S's UART interface, the module can easily be integrated with the CH340C and other external devices, while the SPI interface provides an alternative for more demanding applications.

requirement	verification
1. ESP8266-01S should be able to connect to a mobile application. 2. ESP8266-01S should consume less than 100mA of current. 3. ESP8266-01S should have a range of at least 30 meters. 4. ESP8266-01S should have a data transfer rate of at least 1 Mbps.	1. connect it to a mobile application and verify that data can be transferred successfully. 2. Measure the current consumption of the module and verify that it is less than 100mA. 3. Test the module at various distances and verify that it can communicate with the mobile application at a range of at least 30 meters. 4. Test the module's data transfer rate using a speed test tool and verify that it can achieve a rate of at least 1 Mbps.

2.3.2 UART and SPI

The ESP8266-01S module comes equipped with both UART and SPI interfaces. UART is the default interface used for communication between the ESP8266-01S and external devices such as the CH340C USB-to-serial converter, while SPI can be used as an alternative interface for certain applications.
When using UART, the ESP8266-01S operates in either transparent or command mode. In transparent mode, the module behaves like a serial port to the external device, with data packets being transparently forwarded to the WiFi network. In command mode, the module accepts AT commands sent over the serial interface to perform various configuration tasks.
SPI is typically used when the ESP8266-01S is interfaced with another microcontroller or digital device. SPI allows for higher data rates than UART and can also support full duplex communication.

requirement	verification
• The ESP8266-01S module shall support communication via UART/ SPI interface with the host device. • The UART communication speed shall be configurable. • The UART/ SPI interface shall be able to receive and transmit data. • The SPI communication speed shall be configurable.	• Verify that the ESP8266-01S module can successfully establish communication with the host device through UART/ SPI interface. • Verify that the UART communication speed can be configured as per the requirements. • Verify that the module can receive and transmit data through the UART/ SPI interface. • Verify that the SPI communication speed can be configured as per the requirements.

2.3.3 CH340C Chip

The CH340C chip is a USB to serial converter chip that is commonly used in microcontroller programming and debugging. It allows for communication between a computer and other electronic devices that use serial communication protocols, such as the ESP8266 WiFi module.

requirement	verification
• The ESP8266-01S module must be properly connected to the CH340C chip and the computer. • The CH340C chip is properly connected to the computer via USB cable.	• Verify that the CH340C chip is correctly installed on the computer and recognized by the operating system. • Verify that the CH340C chip is properly recognized by the computer and that the appropriate drivers are installed.

2.3.4 Software Design

The module will be programmed to connect to a mobile application through the WiFi network. The application can be developed in-house or using existing software.
Some popular choices for developing mobile applications include Java/Kotlin for Android and Swift/Objective-C for iOS. There are also cross-platform frameworks, such as React Native and Flutter, that allow you to write code once and deploy it to both Android and iOS.
Alternatively, we can use existing software to communicate with the ESP8266 module over WiFi. This can be a simpler and faster solution, as there are many pre-built mobile applications and libraries available that provide this functionality.

requirement	verification

• The mobile application must be able to connect to the ESP8266 module over WiFi and send/receive data to/from the module.	• Send data: Verify that the mobile application can send data to the ESP8266 module, and that the module can receive and process the data correctly. • Receive data: Verify that the mobile application can receive data from the ESP8266 module, and that the data is displayed or processed correctly within the application. • Error handling: Verify that the mobile application can handle any errors or exceptions that may occur during communication with the ESP8266 module, and that appropriate error messages are displayed to the user.

2.4 Route Design System

At the beginning of our design, we first assumed the pools to be rectangular without any obstacles for simplicity. Under these circumstances, the main strategy we plan to use is the clockwise inner spiral trajectory. After we implement this foundation, more complicated environments will be introduced, such as irregular pools or encountering obstacles.

2.4.1 Inner helical trajectory

The spiral trajectory can help to reduce the overall cleaning time required, which can help to improve the robot's performance and reduce energy consumption.

Commonly used strategies in traversal path planning include random turn strategy (a), roundabout S-type strategy (b), and inner spiral strategy (c). The first strategy is extremely inefficient. The second S-type strategy is simple to control, the path is regular, and the direction can be corrected multiple times according to the wall.

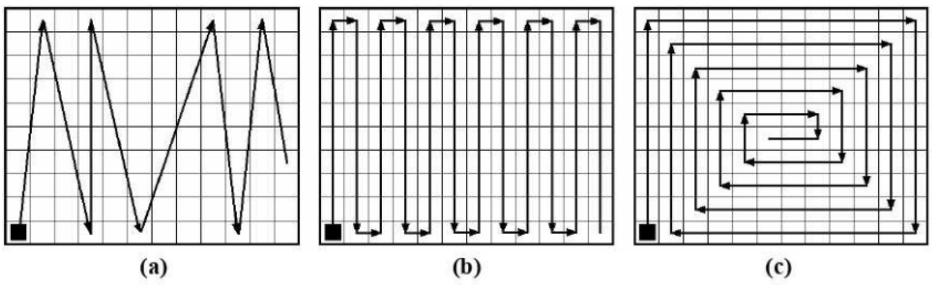

Fig. 5. Three Strategies

The third strategy, Inner helical trajectory refers to the spiral path taken by a pool cleaning robot during its cleaning process. This method of cleaning has several advantages over other methods, such as reducing the overall cleaning time required, which in turn improves the performance of the robot and reduces energy consumption. More importantly, since the cost of turning is relatively high, this strategy can make as few turns as possible. Additionally, this trajectory allows the robot to clean in a way that minimizes unnecessary movement and energy, Resulting in a more cost-effective and environmentally friendly cleaning solution.

requirement	verification

• The cleaner can cover all areas according to the inner spiral trajectory.	• The Wall Following Algorithm (2.8.1) can successfully complete the first circle of the path. • The Optical Encoder (2.2.1) guarantees the cleaner to finish the remaining part of the path.

2.4.2 Drawback Mechanism
Due to the limitation of not being able to turn in place, we will further move back and forth to supplement the positions that have not been swept. By following a spiral path, the robot is able to cover the entire pool area systematically and efficiently, without missing any spots. The back mechanism will be used on the first lap route, with only early turns required later.

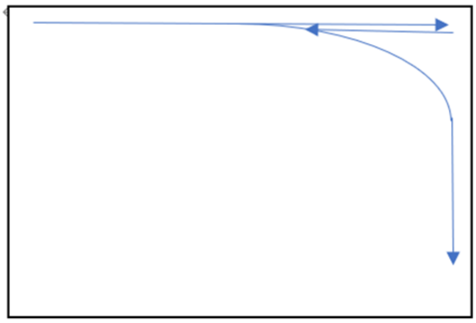

Fig. 6. Drawback

requirement	verification
• After turning 90 degrees, the cleaner can enter the track in exactly the other direction	• Test multiple times for the distance required to turn 90 degrees.

2.4.3 More Complicated Environments
If it is necessary to adapt to more complex environmental conditions in the future, such as irregular swimming pools, obstacles in the swimming pool, etc., we have prepared more solutions.

First, use the Grid Map to estimate the absolute position of the pool cleaner, and approximate the environmental information, with a grid no larger than the cleaning width as the smallest unit of the Grid Map. Second, use the A* algorithm, a heuristic search algorithm, for intelligent path search, avoiding obstacles and adapting to complex environments. Third, we can selectively use the roundabout S-type strategy for the protruding parts of the right-angle shape.

2.5 Cleaning System
The process of cleaning is through the brush to sweep the pool's garbage to the bottom of the cleaner, the pump will pump the water and garbage from the bottom suction port to the inside of the cleaner, the water pumped up through the internal filter and then discharged from the body's outlet, the impurities in the water will be left in the body by the filter, so as to achieve the effect of water purification.

2.5.1 Brush
The role of the roller brush is to assist the pump work, it needs to sweep the small objects under the water to the inlet at the bottom of the cleaner.

Requirement	Verification
1. Have a certain breadth of coverage 2. The bristles need to be hard and dense to concentrate the waste	1. According to the structural design of the cleaner, two roller brushes with a length of 12cm and a diameter of 5cm are required. The length allows ±1cm error and the diameter allows ±0.5cm error. 2. A. Mount the roller brush on the shaft, and then use the motor to drive. B. Arrange a 40cm*40cm area of diffuse leaves and small particles of impurities. C. Move the shaft as fast as the cleaner travels. D. Ensure that after the shaft travels through this area, the garbage will be swept to the edge of this area.

2.5.2 Pump

The water pump needs to pump the water from the pool into the cleaner along with the trash and impurities at the bottom.

Requirement	Verification
1. The flow rate meets the need for the cleaner to be able to pump up the water directly under the body. 2. Have a large power to be able to suck up the impurities in the water.	1. The volume of water directly under the cleaner body is 2.5-3L, and the movement speed of the cleaner is 0.05-0.08m/s. According to the calculation, the flow rate of the pump needs to be more than 800L/H. 2. A. Put some fallen leaves and small particles at the bottom of the pool. B. Place the pump at 1.5cm from the bottom and connect the power supply. C. Ensure that impurities are pumped up by the pump.

2.5.3 Filter

The role of the filter is to filter the impurities in the water.

Requirement	Verification
Able to filter out impurities of 15 microns or more.	Cut 30cm * 15cm filter mesh to pass water containing impurities at a faster flow rate to ensure that the filtered water has no impurities visible to the naked eye.

2.6 Propulsion Subsystem

The propulsion subsystem contains wheels and motors, responsible for achieving the basic walking function of the cleaner.

2.6.1 Wheels

The wheels are driven by motors and are used to achieve the basic action functions of the cleaner.

Requirement	Verification
Provides enough friction to ensure no slippage during walking.	Let the cleaner move at the set speed of 0.05m/s. Ensure that the cleaner keeps

	moving forward without slipping.

2.6.2 Motor

The motor needs to provide enough power to ensure the proper functioning of the wheels.

Requirement	Verification
The set running speed is 0.05-0.08m/s, cleaner weights 4.8-5.2kg and standard pool bottom static friction coefficient is about 0.5. According to these data, the motor needs to provide power should be greater than 25w.	Place the cleaner at the bottom of the pool and start it. Make sure the cleaner can move at 0.05-0.08.

2.7 Body Subsystem

The body system is the overall mechanical design, including the shell and base of the cleaner as well as the internal parts and structural design.

Requirement	Verification
1. The shape and material of the shell need to be able to resist the pressure of the bottom of the deep water of the pool. 2. The design and material of the shell should be completely waterproof to protect the internal circuitry and chips, which pass IP68 environmental codes. 3. The shape of the shell needs to minimize the resistance of the cleaner in underwater movement. 4. The cleaner whose weight should be 4.8-5.2kg to ensure that the cleaner will not float during the work.	1. Place the shell under water at a depth of 2m for two hours. Ensure that the shell does not break. 2. A. In the shell installation of circuitry and components inside the space filled with a few grams of dyed anhydrous powder. B. Completely submerge the enclosure in water for two hours. C. Make sure all the powder remains white and dry (any powder that turns the intended dye color has been hydrated).

2.8 Power Supply Subsystem

The Power Supply Subsystem consists of two 9V batteries, and transformers that transform the voltage to 3.3V, 5V, 9V, and 12V.

Requirement	Verification
1. The transformers should output voltage that is within 1% of the required voltage.	1. Use a voltmeter to measure the output voltage of a transformer, and see if it is accurate enough.

2.9 Software

2.9.1 Wall Following Algorithm

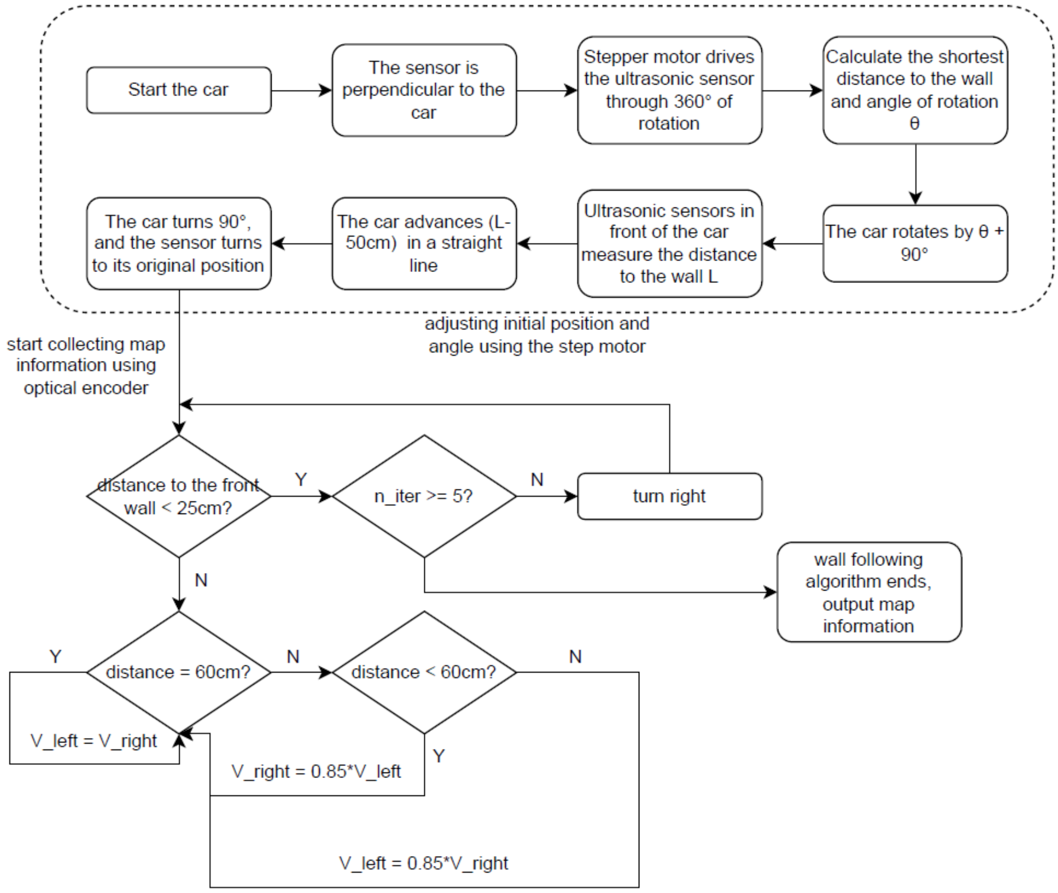

Fig. 7. Wall following algorithm

2.9.2 Angle-turning Algorithm

The angle-turning algorithm uses 0.1s to do zero correction before the cleaner moves. And when it receives angles from Route Design Subsystem or Information Collection Subsystem, it will use pid control to let the cleaner turn to certain angles.

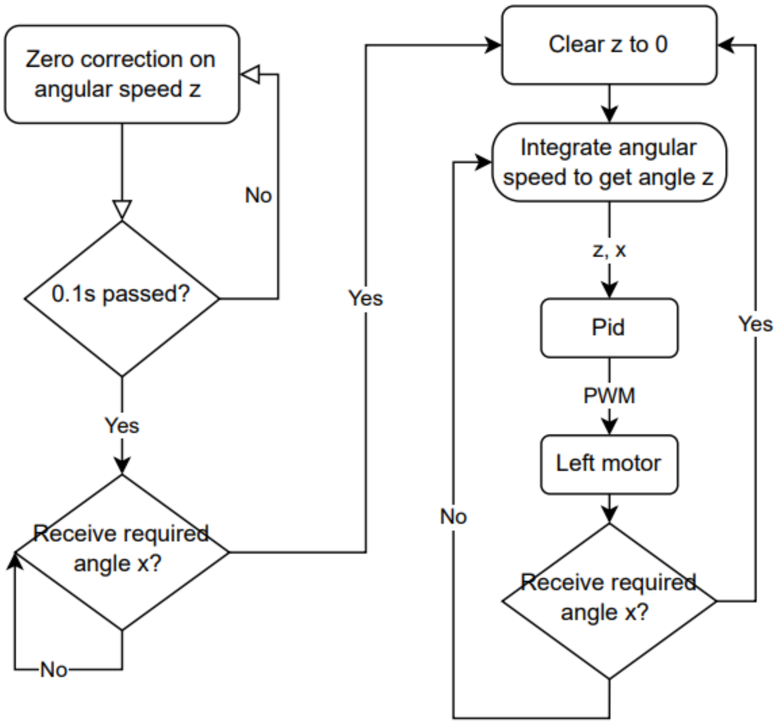

Fig. 8. Angle-turning algorithm

2.9.3 Inner Spiral Algorithm

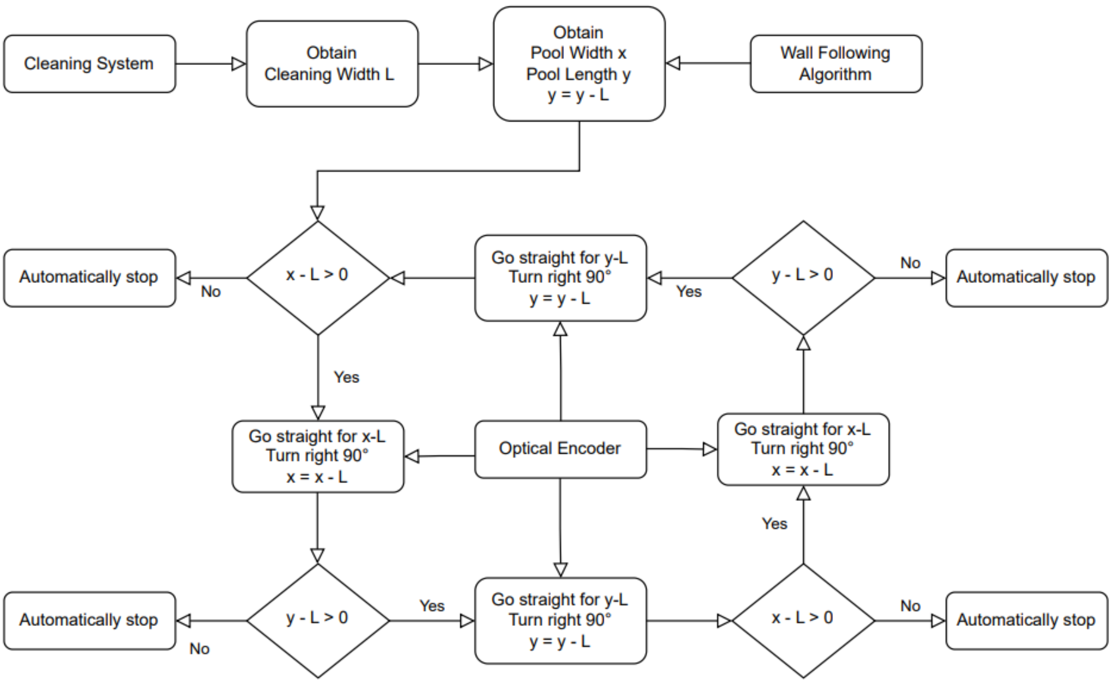

Fig. 9. Inner Spiral Algorithm

2.10 Schematics

Information Collection System

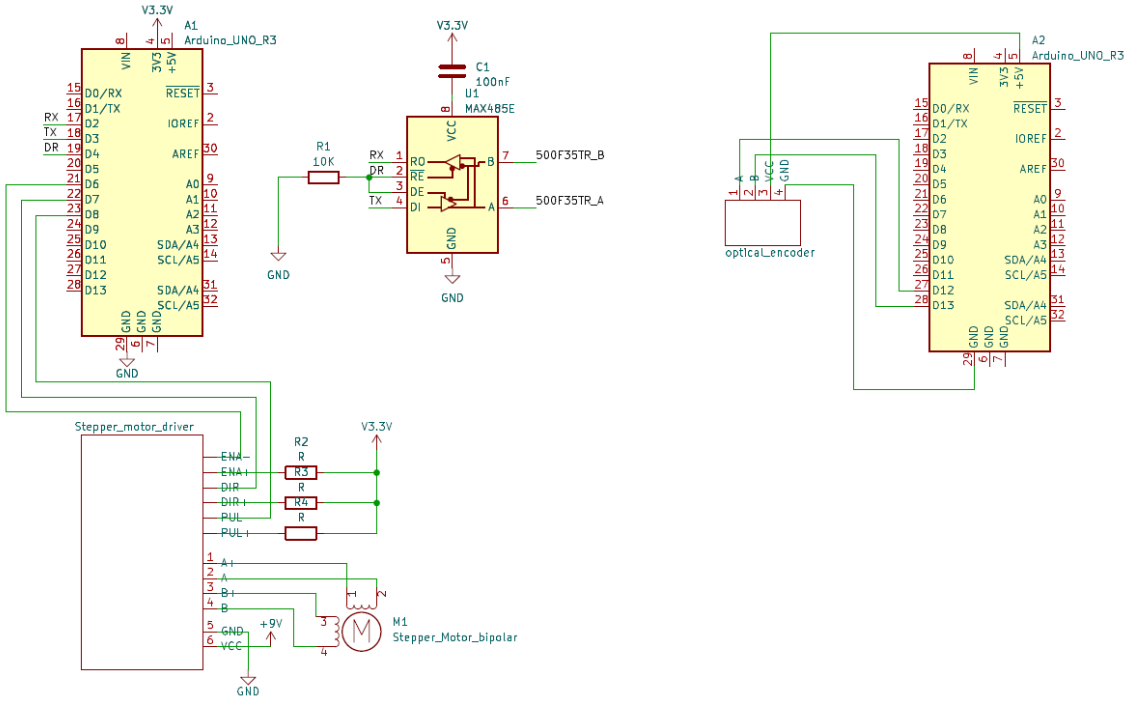

Fig. 10. Information Collection Subsystem schematic

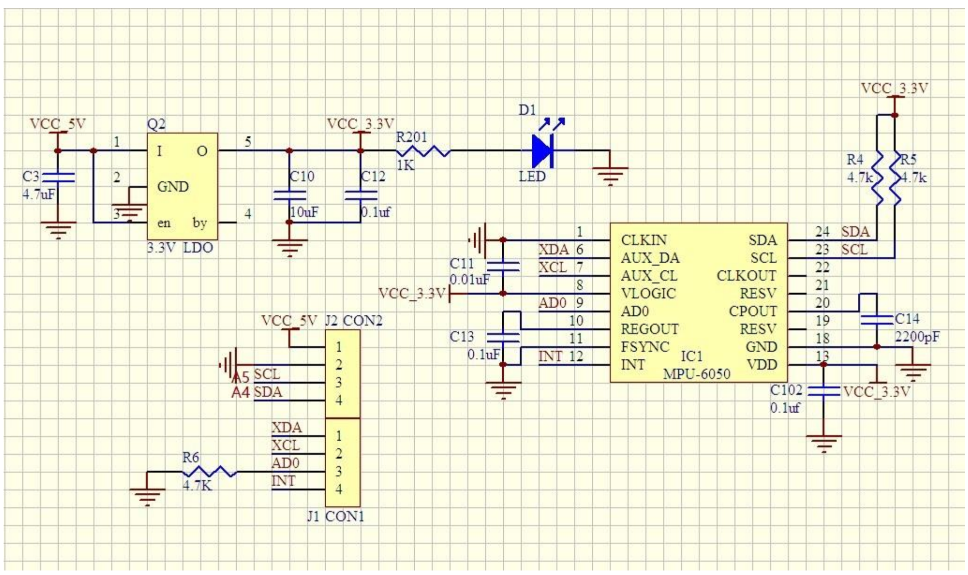

Fig. 11. MPU6050 schematic

2.11 Tolerance Analysis

1. The wall-following algorithm is only possible if the pool is a rectangle, and the walls are flat. If the pool is irregular, a more advanced algorithm is required to implement the traversal.

2. Swimming pool cleaners are generally designed to clean the entire surface of the pool.

However, there is always a risk that the cleaner may miss certain areas or corners due to its design or limitations in its technology. This could result in some debris or dirt being left behind, which could lead to a buildup over time and potential hygiene issues.
To verify the effectiveness of a pool cleaner in reaching all areas, it is recommended to conduct an external camera tracking test while the cleaner is operating in a dry pool environment. By continuously monitoring the cleaner's movements and coverage, it can be determined whether it is successfully cleaning all areas or if there are any blind spots. This type of testing can help to identify any potential issues and ensure that the cleaner is operating at optimal performance to maintain a clean and safe swimming pool.

3. Cost Analysis

3.1 Labor

The salary for every person is $30/hour, and everyone works 10 hours per week. It takes us 8 weeks to finish the design. We have four members in the group, so the total cost for labor is 30*10*8*4=9600$.

3.2 Parts

part	cost
Stepper motor (42HS34-FS)	105 RMB
Driver for stepper motor (HPD322)	51 RMB
Ultrasonic sensor (120F35TR)	600 RMB *2
MAX 485	14 RMB
Optical encoder (E6B2-CWZ3E)	100 MRB *2
9V Battery	2.8 RMB *3
MPU 6050	9.5 RMB
Arduino Uno	28 RMB
Electronic Component Box	4.5 RMB
Wi-Fi Module (ESP8266-01S)	8.5 RMB
USB to Serial Chip (CH340C)	10 RMB
DC Motor (JGA25-2418)	40RMB*2
Rubber wheel set	60RMB
800 mesh filter	40RMB
Total	1813.3RMB ≈ 264$

4 Schedule

Week	Jiayu Zhang	Tianle Li	Wenbo Ye	Hanwei Yu
3/13/2023	Select proper MPU 6050, MPU 6050 implementation on arduino	Confirm the design of information collection system, buy some elements for experiment. Learn arduino.	Became familiar with the Arduino platform and C++, learned how to use the Wi-Fi module to implement remote control	Refer to the existing pool cleaning robots on the market to determine the approximate size and structure of our cleaner.

3/20/ 2023	Finish and order version 2 PCBs MPU 6050 output and control the turning angle of a car with pid control.	Purchase elements such as ultrasonic sensors, stepper motor, and optical encoder. Write basic functions on arduino to enable the motor to spin, measure distance, and avoid obstacles.	Purchase an ESP8266-01S and its connector CH340C. Consider the path planning that may need to be used for more complicated environments such as irregular pools or encountering obstacles.	Complete sketch design. Searched and compared components such as DC motors, pumps, tracks, filter. Start modeling of the cleaner.
3/27/ 2023	Design and test the circuits that output 3.3V/5V/9V/12V. Design motor-drive circuits.	Connect the ultrasonic sensor with the stepper motor. Complete the wall following algorithm.	Learn the AT instruction set and do some basic programming for ESP8266 module; planned to connect a cellphone to the WIFI network of the chip, and then the phone will receive a webpage where the cleaner can be controlled	Update sketch design. Determine the specific type of elements including DC motor, wheels and filter. Solve the waterproof problem of the main circuit. Complete the modeling of some components.
4/3/2 023	Work on information collection subsystem.	Try to record the position and angle of the cleaner through the optical encoder. Refine the information collection system.	Develop a webpage or smart mobile application to connect to ESP8266-01S Wi-Fi modules.	Determined the internal structure. Solve the waterproof problem of the motor underwater. Keep on modeling.
4/10/ 2023	Work on PCB design.	Further improve the cleaner's performance to make it walk more precisely.	Use network protocols to enable communication between mobile phones and Wi-Fi modules	Refine and optimize modeling. Start 3D printing of components.
4/17/ 2023	Test the whole system.	PCB design.	Connect the ESP 8266-01S to the Arduino motherboard and achieve mobile phone control over the start and stop of the cleaner	Complete the modeling and print the shell. Test the waterproof performance and structural strength of the body.
4/24/ 2023	Test the PCB board and assemble the whole cleaner.	Choose a reasonable method for conducting environment testing. Conduct environment testing	Further optimize the cleaner's performance in more complicated environments	Assembling the cleaner. Optimize the waterproof treatment.
5/1/2 0	Test the whole cleaner.	Test the whole cleaner. Prepare for final demo.	Test the whole cleaner. Prepare for final.	Test the cleaner. Prepare for demo and fianl report.

5. Ethics and Safety

IEEE Code of Ethics require us to put the safety, health and welfare of the public first [2], and we will ensure that cleaner is designed with safety and environmental sustainability in mind. We need to ensure that the components of the cleaner can operate for long periods of time under a certain water pressure and must completely prevent dust or water vapor from entering the control module and circuitry to prevent operational failures and safety issues from leakage and rechargeable battery leaks. Therefore, strict enforcement of IP68 guidelines through the use of waterproof coatings and the design of a tight waterproof structure is necessary for the safe operation of the cleaner.

ACM Code of Ethics 1.6 mentioned privacy [3], we will ensure that the pool data and location information collected by cleaner will not be leaked and will not violate the rights of users.

Reference

[1]Y. Ando, T. Tsubouchi, and S. Yuta, "A Reactive Wall Following Algorithm and Its Behavior of an Autonomous Mobile Robot with Sonar Ring," Journal of Robotics and Mechatronics, vol. 8, no. 1, pp. 33–39, Feb. 1996, doi: https://doi.org/10.20965/jrm.1996.p0033.

[2] Ieee.org, "IEEE code of Ethics," IEEE. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 08-Mar 2023].

[3] "ACM Code of Ethics and Professional Conduct
," [Online]. Available: https://www.acm.org/code-of-ethics[Accessed: 08-Mar 2023].