System design of an intelligent sweeper robot

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Abstract. With the advancement of technology and science, various intelligence household appliances are becoming increasingly popular. This paper proposes a household sweeping robot with the ability to climb stairs. The robot adopts ATmega328p as controller, two gear motors and a DC motor to drive the robot to walk and vacuum. Using rational algorithms in WEBOTS, the robot is deemed able to effectively avoid obstacles and perform path planning, demonstrating its ability to follow a path to bypass obstacles and climb stairs. Such design proposes a new intelligent path panning solution for floor sweeping robots which enables high coverage and low repetition of cleaning tasks by creating workflow systems and algorithms. As opposed to traditional sweeping robots, the robot can climb stairs and perform cleaning tasks more efficiently and is less expensive. Additionally, the design enables the robot to work in more complex environment such as multi-floor situations, as well as to perform self-cleaning tasks.

Keywords: System design, intelligent sweeper robot.

1. Introduction

With the advancement of modern technology, robots are increasingly involved in various aspects of human life. The first industrial robots appeared in 1960, heralded the era of robotics [1]. The first prototype of a robotic vacuum cleaner appeared in 1991, and in 1997, Sweden's Electrolux went into mass production [2]. In 2002, sweeping robots ushered in the era of random cleaning, the cleaning robot uses a random collision algorithm [3]. Although the cleaning efficiency and floor coverage was low, it was still a cross-era product. To address such limitation of robot cleaning, iRobot had released a beacon locator [4]. Sweeping robots have high requirements for the location of lighthouses, as the cleaning performance of robots is highly dependent on the position of the lighthouse. In 2014, planned cleaning emerged, which utilized cameras for orientation [2]. The method of adding a camera on a sweeping robot has also been used by many sweeping robots until now, as from a technical point of view, the fourth-generation sweeping robot effectively solves the cleaning problem through camera positioning, improving the coverage. However, it is limited to work in dim environments due to the effects of light on the cleaning performance of the robots. Later on, laser scanning and positioning mode was introduced to sweeping robots [2], which provide high coverage and strong cleaning efficiency.

This paper aims to design a small and handy domestic sweeping robot for ordinary household, with the ability to climb stairs using a mechanical arm. The robot used an ATMega328p single-chip microcomputer as the controller, two DC motors and the L293D driver chip to drive the robot to walk, and the ULN2003D driver chip to the drive robot up the stairs and perform cleaning tasks. This paper proposes a new intelligent path panning solution for floor sweeping robots which enables high coverage and low repetition of cleaning tasks by creating workflow systems and algorithms. Besides, as opposed to traditional household sweeping robot, this paper also proposed algorisms that enable the robot to climb stairs autonomously. The proposed technique enables the robot to work in more complex environment such as multi-floor situations, as well as to perform self-cleaning tasks.

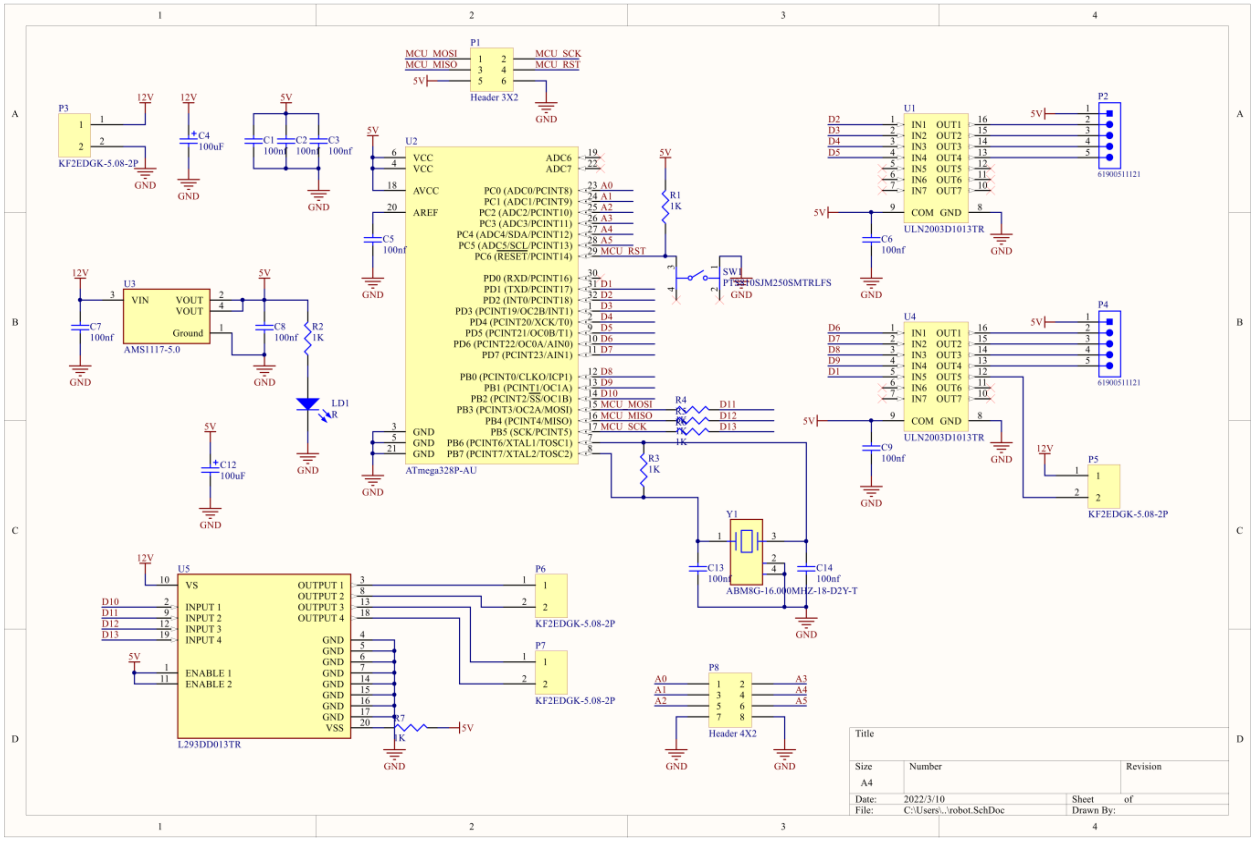


Figure 1. Schematic diagram of sweeping robot.

2. PCB components

2.1. Introduction to ATmega328p

Microchip femto Power 8-bit AVR RISC-based microcontrollers feature 32 KB ISP Flash with read-while-write capabilities, 2 KB SRAM, 1024B EEPROM, 32 general-purpose working registers, 23 general-purpose I/O lines, internal and external interrupts, three flexible counters with compare modes, a byte-oriented Two-Wire serial interface, SPI serial port, serial programmable USART, and a 6-channel (use tables). The device operated over a voltage range of 1.8 to 5.5 volts, and achieves throughputs close to 1 MIPS per MHz by executing strong instructions in one clock cycle, balancing power consumption and processing capabilities.

2.2. PCB schematic diagram of sweeping robot

Using the ATmega328p single-chip microcomputer as the controller, the circuit diagram of the sweeping robot is shown in Figure 1 and the PCB diagram is shown in Figure 2.

2.3. Core control module

The ATmega328p single-chip microcomputer is the core part of the system. The internal crystal oscillator of the single chip is only 8Mhz. For faster changes, an external oscillation circuit with a crystal oscillator and two capacitors is used to vary the frequency to 16 Mhz. It is responsible for robot walking, going up and down stairs with the assistance of mechanical arms, and perform cleaning tasks.

2.4. Drive module

Gear motor with encoder is used for the left wheel and right wheel of the robot, which can measure the speed and control the accuracy of the robot walking. L293D is used to drive. Besides, speed adjustment mode is named PWM. Considering that the dust collection function requires a fast speed of the motor, another motor is replaced as the dust collection motor. A DC Motor is selected for the dust collection motor, and the ULN2003 is used to drive the DC Motor. For track arm, the Stepper Motor is used for track arms to provide power, and the ULN2003 again is selected to drive the Stepper Motor.

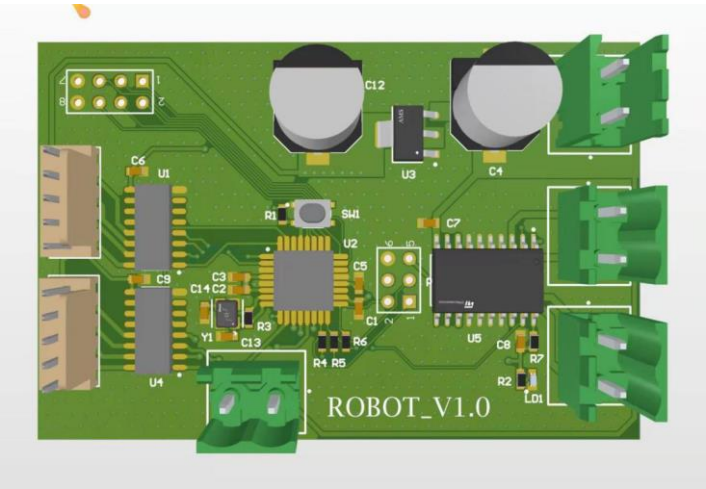


Figure 2. PCB diagram.

2.5. Power module

Considering that some components of the circuit board can only accept 5V power supply, a stabilized power supply is added to provide 5V. Dust collection motor is powered by a 12V power supply.

2.6. Stimulation Results

Figure 3 is a screenshot from a simulation video about the robot going up the stairs. The two DC motors and the dust collection motor worked for 20 seconds, then the two DC motors stop turning. This process simulates the stopping of the robot when it needs to climb the stairs. Next the stepper motors will work to rotate the track arm 45 degrees, then all motors will start working which enables the robot to climb the stairs.

3. ROBOT MODEL PART

The model of the cleaning robot presented in this paper was built in SolidWorks. The cleaning robot is designed with a crawler wheel as the drive unit (see Fig.4) and is equipped with two extendable crawler wheel arms on the left and right sides.

The small tracked wheel arms remain closed on both sides when the robot is performing regional cleaning tasks (see Fig. 5 (a)). When the cleaning robot needs to climb upstairs from the current cleaning area to another cleaning area, the small tracked wheel arms on both sides will extend forward to help the robot complete the steps (see Fig. 5 (b)).

As shown in Figure 6, the sweeping robot designed in this paper has body height of 150mm and overall height of 180mm. Figure 6 (c) depicts the top view of the robot, which shows that the body of the robot is rectangular in the middle and rounded at the front and back. The size of the square is 400mm*400mm, and the distance from the centre of the square to the arc on both front and back is the same, which is 150mm. Figure 6 (d) depicts the side view of the robot, which shows the robot has a length of 495.81mm.

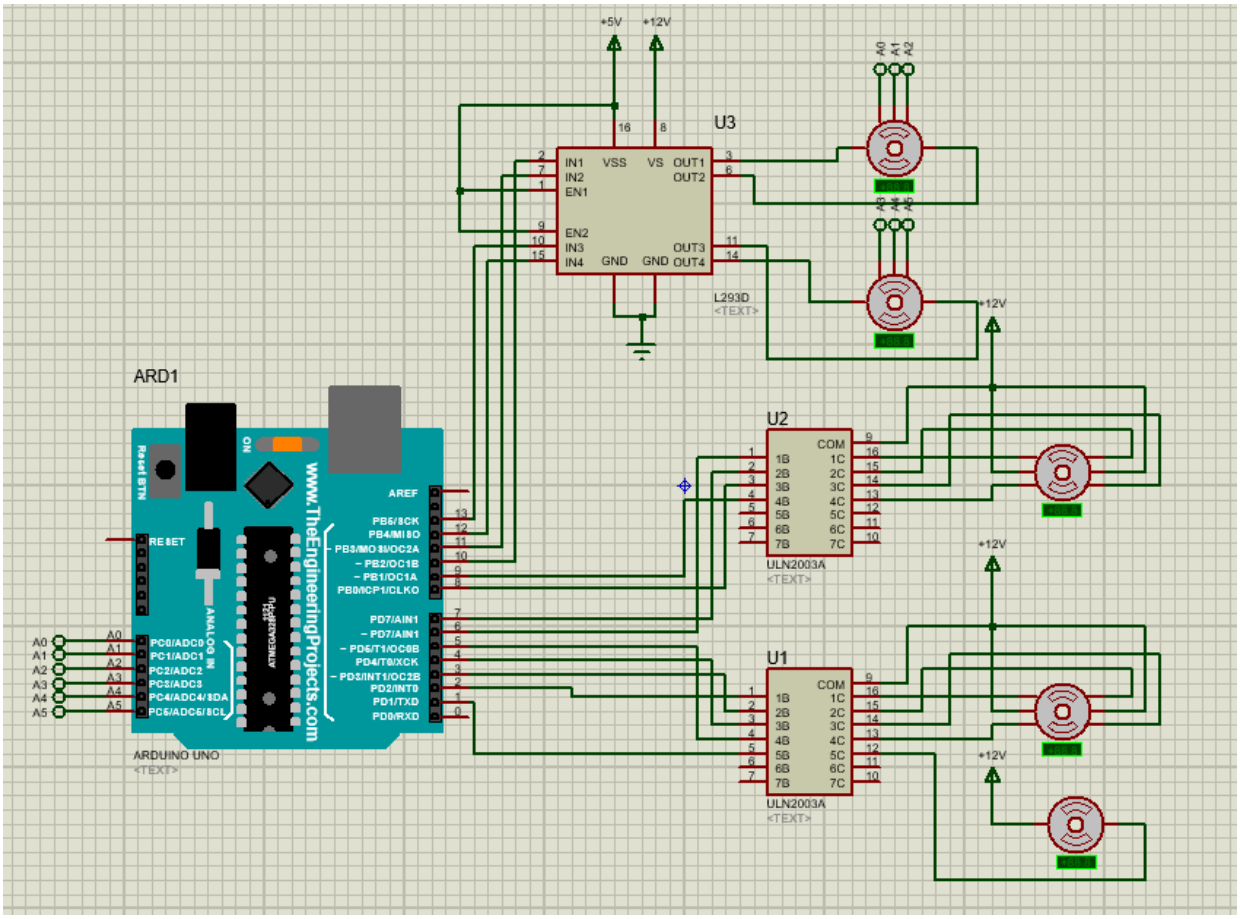


Figure 3. Stimulation Results.



Figure 4. Design of the cleaning robot.

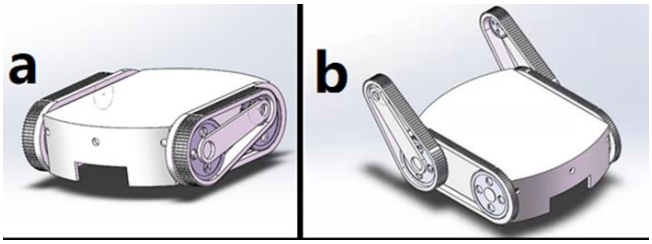


Figure 5. Small track wheel arms.

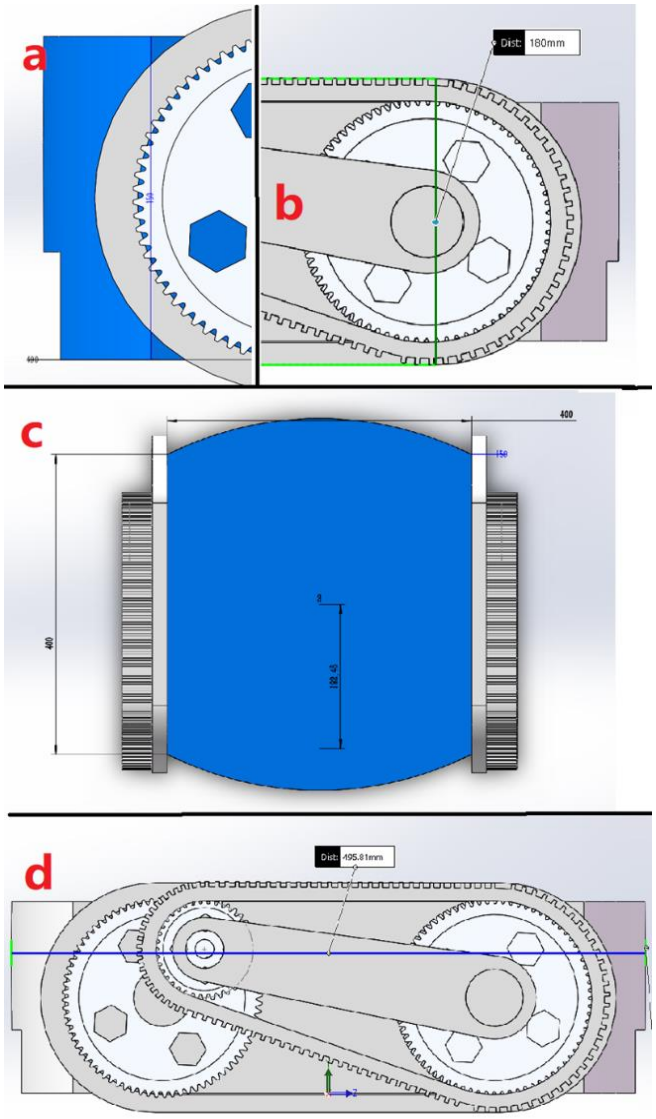


Figure 6. Design of cleaning robot (specification).

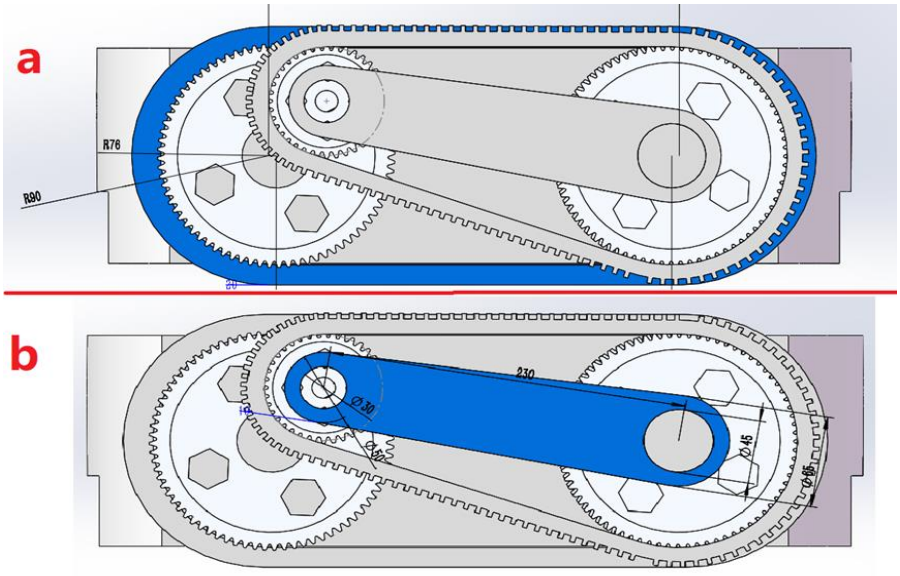


Figure 7. Robot gear data diagram

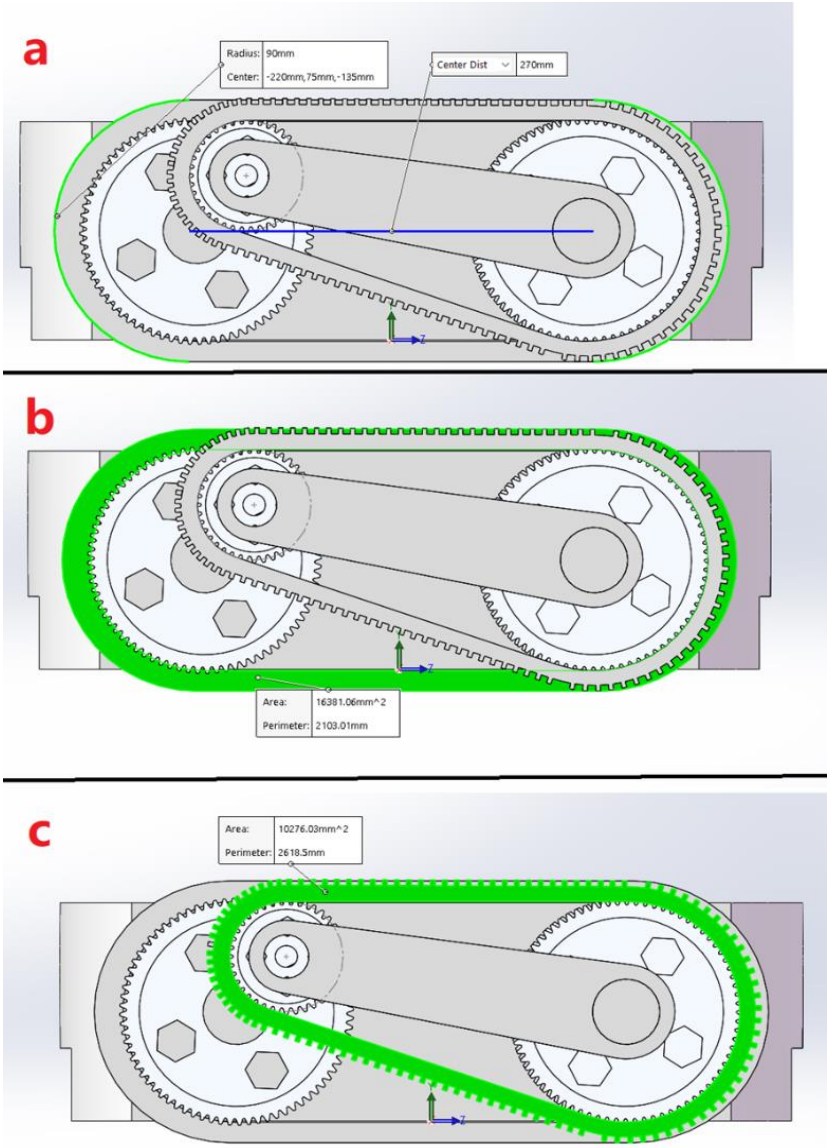


Figure 8. Robot track data diagram.

Figure 7 (a) depicts the side view of the gears controlling the movement of the robot, which have a radius of 76mm, and a distance of 90mm between the centre point to the two circular tracks. Figure 7 (b) depicts the size of the gears which control the track arm of the robot. The gear on the left is 30mm and the gear on the right 45mm. The distance between the centre point of two gears is 230mm [5].

Figure 8 also depicts the side view of the robots, which shows the size of the track. Figure 8 depicts the dimension of the track. The distance between the centres of the two gears is 270mm, and the radius of the circles on both side of the track is 90mm. The track wheel has a circumference of 2103.01mm (one side), and the track wheel arm has a circumference of 2618.5mm (one side).

4. PATH PLANNING PAER

Path planning is primarily concerned with three issues: determining the starting and ending points; avoiding barriers; and optimizing the path as much as feasible [5].

Robot path planning can be categorised into global and local route planning depending on the amount of information known about the environment.

When the environment is known, the path planning is known as global path planning. Path planning accuracy depends on the precision of environment acquisition [6]. Global path planning can

locate the best solution, but it requires correct environmental knowledge ahead of time. This strategy becomes less useful as the environment changes, for example when unknown obstacles appear. As it is a type of forethought, global path planning does not require much real-time processing capabilities of the robot system. Although global and better planning outcomes are obtained, it is less robust to errors and noise in the environment [7].

On the other hand, when the environment is completely unknown or partially known, the path planning is known as local path planning [8]. It focuses on taking into consideration of the robot's current local environmental information, allowing the robot to avoid obstacles effectively, and using sensors to detecting the robot's working environment to gather information about the location and geometric aspects of obstacles. Such planning requires the acquisition of information on the environment and the capability to make corrections for dynamic changes in the environmental at any point in time [9]. The local planning approach integrates environmental modelling with search, and requires robotic systems to have fast and efficient information processing and computational capabilities, a high degree of

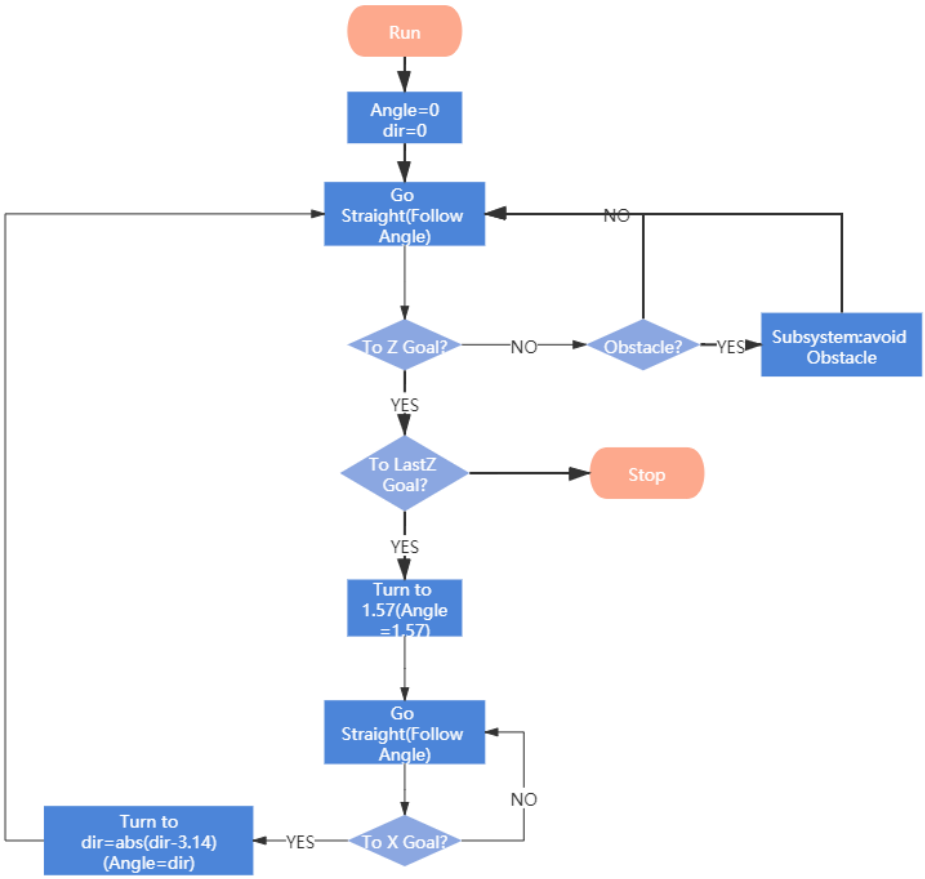


Figure 9. Algorithm

The starting position of the robot is set, and the robot is then allowed to travel straight ahead in the Z-axis direction in the simulated environment. During this time, the robot detects if it encounters any obstacles. When there is no obstacle, the robot continues its original path. If an obstacle is encountered, the robot will avoid it and return to its original path and continue straight ahead. When it reaches the opposite wall, the robot rotates to an arc of 1.57, which is 90 degrees in the direction of the X-axis. It then checks to see if it has reached the target position on the X-axis, and if not, it follows the angle straight ahead to the target position on the X-axis. When the target position in the X-axis is reached, the robot will rotate another 90 degrees to the Z-axis. When this round is completed, the robot repeats the above steps to clean the room in a bow traverse. The robot stops when it reaches the end position (Fig. 9).

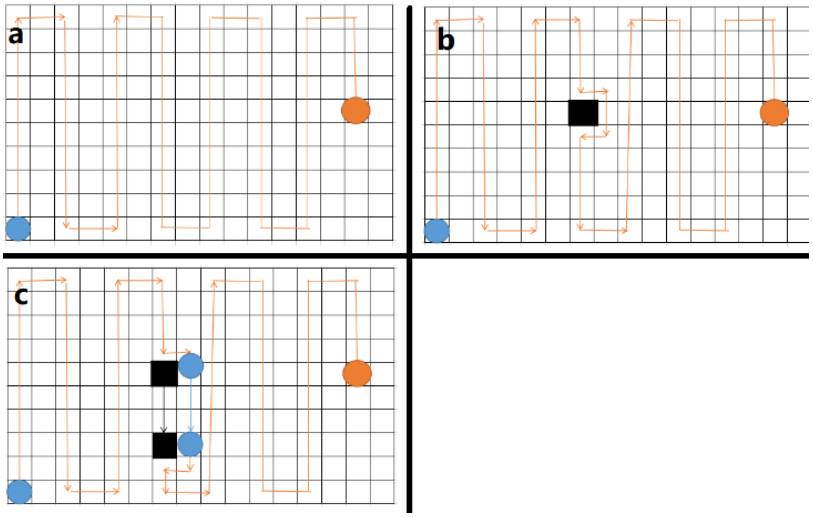


Figure 10. Path Planning

Robustness to noise and errors in the environment model, and the ability to provide feedback and corrections to planning outcomes in a timely manner. However, due to the lack of information on the global environment, planning outcomes could be sub optimal, as it may fail to find the correct path or achieve complete coverage [10].

The path planning method proposed by this paper incorporates both global and local path planning. The grid method is used to create a two-dimensional grid map. Using grid method, the full coverage area is divided into rectangular sub areas, so that full coverage cleaning is carried out one by one in each sub area. By this way, the cleaning robot is able to achieve the cleaning task site with large coverage. Figure 9 depicts the path planning of the robot under various settings. The starting position of the robot is on the bottom left corner on the grid map, where the blue circle represents the position of the robot, the black squares are the obstacle. The ending position of the robot is represented by the orange circle. Figure 10.a depicts the path planning of the robot where there's no obstacles. The robot will clean the surroundings along the bow route. Figure 9.b depicts the setting when the robot comes across an obstacle. The robot will go around it and proceed to its original cleaning path. Figure 10.c depicts the situation when there's a moving obstacle in the cleaning path. The robot is able to recognise it in real time, go around it, and turn back to the original cleaning route.

5. Conclusion

In this paper, a sweeping robot with ATmega328p as the control core is designed. Batteries provide power for the robot, and a gear motor with an encoder effectively controls the robot's walking speed and accuracy. According to the 3D model diagram made by Solid Work, the overall design concept of the robot can be seen more intuitively. In the WEBOTS simulation environment, the robot can realize the bow sweeping path. The robot can climb stairs easily with assistance of mechanical arms with tracks on both sides. In the experiment, the robot can successfully avoid obstacles to complete the cleaning work. As opposed to traditional sweeping robots, the robot can climb stairs and perform cleaning tasks more efficiently and is less expensive.

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