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Design and Research of Restaurant Intelligent Cleaning Robot

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Abstract. The restaurant intelligent cleaning robot, belongs to the field of robot technology, including driving the base, control the body and vision system. Mechanical arms are installed on both sides of the top of the machine body. One of the bottom end of the robot arm is installed with clamping claws, and the other mechanical arm bottom is installed with Clean hands for desktop cleaning. Driving wheels are symmetrically arranged on both sides of the bottom surface of the base, the body internal top installed vacuuming assembly, vacuuming components of the vacuum port through the pipe to connect the vacuum cover. Combined with lidar and other sensors, it can achieve automatic identification, automatic cleaning, multi-use, flexible movement. It also can reduce the probability of collision tables and chairs, the use of higher reliability, more convenient.

Keywords. Robot, Cleaning, Automatic recognition

1. Introduction

With the rapid development of science and technology, people pay more and more attention to the working environment and work efficiency. We note that some places such as canteens and restaurants often need to hire cleaning aunts to do repetitive and mechanical work such as sweeping the floor and cleaning the table to maintain hygiene. This not only wastes time and energy, but also needs to pay a lot of money. For the catering industry, what attracts people's attention most is the service robot. The appearance of robots is very attractive. They can not only replace waiters, but also win the smiles of customers and bring laughter. More importantly, nowadays, the labor cost is higher and higher, and the use of robots can save costs.

However, the robot function used in the existing restaurant is too single, which can only complete the simple meal delivery work, can not well meet the needs of the restaurant, and has poor mobility between the narrow dining tables, which is easy to bump into tables and chairs..

The purpose of restaurant intelligent cleaning robot is to provide a convenient restaurant intelligent cleaning robot. It can combine the functions of dust collection, floor mopping and table cleaning, realize automatic identification, automatic cleaning,

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multi-purpose one machine, flexible action at the same time, reduce the probability of collision with tables and chairs, and have higher reliability and convenience.

By studying the mechanical model of restaurant intelligent cleaning robot, this paper establishes the mechanical model, and realizes the automation of restaurant cleaning through the combination of a variety of sensors to meet the needs of robot cleaning in complex environment.

2. Overall structure design of robot

2.1. Overall design parameters

The main body is the basic part of the restaurant intelligent cleaning robot, the installation basis of other assembly components, and one of the main components in motion. The main conditions considered in the design are: (1) the strength and stiffness design of the main body must meet the requirements of the robot itself; (2) Reduce the weight of the main body as much as possible to improve the effective bearing weight; Under the condition of ensuring sufficient rigidity of the main body; (3) Reduce the center of gravity of the main body as much as possible, so as to improve the anti overturning ability of the intelligent cleaning robot of the whole restaurant and ensure the better and stable operation of the intelligent cleaning robot of the restaurant.

In terms of shape, we use a taller and thinner body, combined with the omni-directional movement of mcnamu wheel, so that the robot can shuttle between the dining tables more flexibly.

The fuselage is made of ABS material, which has high strength, good toughness, insulation and corrosion resistance. It is the best choice for the fuselage shell.

The robot design parameters is shown in Table 1.

Table 1. Robot design parameters

Projects	Parameter	Remarks
Overall dimensions (mm)	480×480×1350	
Steering mode	Omnidirectional steering	Can realize in situ steering
Number of steering wheels	2	Horizontal steering wheel
Steering wheel power (Kw)	4	
Number of angle wheels	2	
Load mass (kg)	3000	
Readiness quality (kg)	1500	Including battery
Full load maximum speed (m/s)	0.5	
Control mode	Manual remote control, automatic	
Protection grades	IP54	
Suspension mode	Drum damper	
Battery	Lithium iron phosphate	
Voltage (v)	48	

2.2. Robot work planning

When the robot recognizes that there is food residue and other garbage on a table, it will automatically carry out path planning. Go to the table and clean it with the manipulator with a rag on the right. At the same time, open the cover plate of the robot's dustbin and collect the garbage into the dustbin brought by the robot. If there are cups and other tableware on the table, it can also be clamped by the manipulator on the left manipulator.

When the robot needs to clean the ground, it will start the vacuum cleaner to suck in the dust and garbage. At the same time, the circular mop starts to rotate. A drip device is installed in front of the mop. When dragging the ground, water droplets and detergent will drop to assist in cleaning. After cleaning, the robot puts down the rear tail scraper, which is composed of two layers. The first layer in the front row is similar to sponge material, which can suck residual detergent, etc., and the second layer is rubber material, which can wipe water stains dry.

2.3. Overall structure design

Among them, four groups of driving wheels are evenly arranged on the bottom surface of the driving base, and the driving wheel is mcnamu wheel, which can realize flexible omni-directional movement in a narrow area, make the device move more flexibly, reduce the probability of collision with tables and chairs, and have higher use reliability.

Figure 1. Restaurant intelligent cleaning robot

According to the cleaning requirements of modern restaurants, the overall structure layout is analyzed to meet the cleaning requirements of various restaurants. At the same time, the mechanical model of automatic restaurant intelligent cleaning robot is established. On this basis, the motion control model and software motion simulation are constructed.

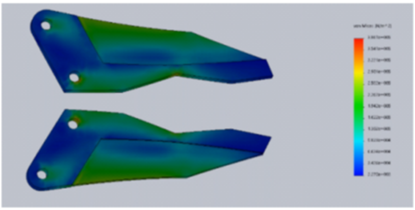

Figure 2. Finite element analysis of gripper

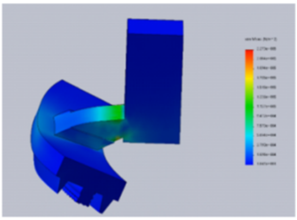

Figure 3. Finite element analysis of scraper hand

The overall structure of the restaurant intelligent cleaning robot is shown in Figure 4:

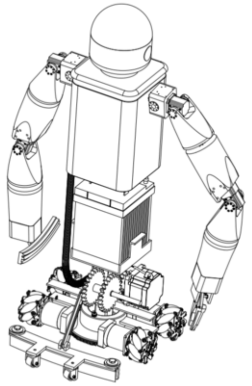

Figure 4. The main frame of restaurant intelligent cleaning robot

The restaurant intelligent cleaning robot comprises a driving base, a control body and a recognition head body arranged on the top of the control body. A mechanical arm is arranged on both sides of the top of the control body, in which the bottom end of one mechanical arm is movably installed with a clamping claw, and the bottom end of the other mechanical arm is movably installed with a cleaning hand for desktop cleaning. Drive wheels are symmetrically arranged on both sides of the bottom surface of the drive base, the top inside the control body is fixedly installed on the dust suction assembly, the dust suction port of the dust suction assembly is connected with a dust suction cover through a pipe, and the dust suction cover is fixedly embedded on one side of the bottom surface of the drive base. A battery assembly is arranged in the inner center of the control body, a cleaning motor is installed in the inner center of the driving base, a cleaning disc is fixedly installed at the power output end of the cleaning motor, the cleaning disc is movably embedded in the center of the bottom surface of the driving base, and a mop mechanism for ground mopping is arranged in the driving base. The manipulator is a five axis manipulator.

Four groups of driving wheels are evenly arranged on the bottom surface of the driving base, and the driving wheels are mcnamu wheels.

The cleaning hand includes a connecting bracket at the bottom end of one of the mechanical arms. A rag cotton body is installed in the center of the bottom surface of the connecting support, a wiper plate is installed on the inner side of the bottom surface of the connecting support, and a cleaning plate is installed on the outer side of the bottom surface of the connecting support.

The mop mechanism includes a mop motor driving the interior of the base. The power output end of the drag washing motor is provided with a driving gear, and one side inside the driving base is provided with a driven wheel group meshing with the driving gear. The driven wheel set is rotationally connected with a movable connecting rod on the side away from the drive gear, which extends to the outside of the drive base and is slidably connected with the drive base. The bottom end of the movable connecting rod is rotatably connected with a mop support, and a mop cotton body is installed in the center of the bottom surface of the mop support. The center of the bottom surface of the mop support is equipped with a scraper plate on the side away from the drive base.

Both sides of the top surface of the towing support are symmetrically connected with side guide wheels, and the towing support is symmetrically connected with the limited position support wheel through the support on the side away from the drive base. The driving base is provided with a liquid spraying device on the side close to the movable connecting rod, which is used to spray detergent.

3. Design of traveling mechanism

As shown in Figure 5, the robot uses mcnamu wheel to replace the traditional universal wheel. The four mcnamu wheels are independently controlled by four motors. It is an omnidirectional wheel with special structure. The shape of mcnamu wheel is similar to a helical gear, and the teeth are drum shaped rollers that can rotate. The roller axis is formed with the wheel axis α Degrees. The roller has three degrees of freedom. When the roller rotates around itself, it can also rotate around the axle and around the point where the roller contacts the ground. In this way, the whole wheel body has three degrees of freedom: 1. Rotation around the axle. 2. Translation along the vertical direction of the roller axis 3. Rotation of the contact point between the roller and the ground. In this way, the driving wheel has active driving ability in one direction and can move freely in the other direction. Many small rollers are distributed around the circumference of the wheel, and the contour of the roller coincides with the theoretical circumference of the wheel, and the roller can rotate freely. When the motor drives the wheel to rotate, the whole wheel moves in the direction perpendicular to the drive shaft in a normal way. At this time, the rollers around the wheel will rotate freely along their respective axes. The wheat wheel can be divided into left rotation and right rotation according to the deflection of the roller. Compared with universal wheel, wheat wheel has the advantages of flexibility, accuracy and high efficiency. It is a controllable universal wheel. The tire arrangement of this structure adopts Abba form, and the tail scraper driven wheel is a universal wheel.

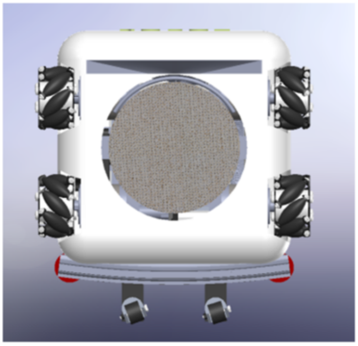

Figure 5. Robot chassis

4. The kinematic analysis

4.1. Calculation of axial velocity of wheat wheel

As shown in figure 7 and figure 8, the movement speed of wheel axis is:

$$\vec{v} = \vec{v}_t + \vec{w} \times \vec{r} \tag{1}$$

Calculate the components of X and Y axes respectively:

$$\begin{cases} v_x = v_{t_x} - w \cdot r_y \\ v_y = v_{t_y} - w \cdot r_x \end{cases} \tag{2}$$

Similarly, the axial speeds of the other three wheels can be calculated.

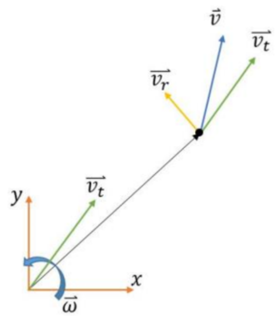

Figure 6. Diagonal analysis of wheat wheel

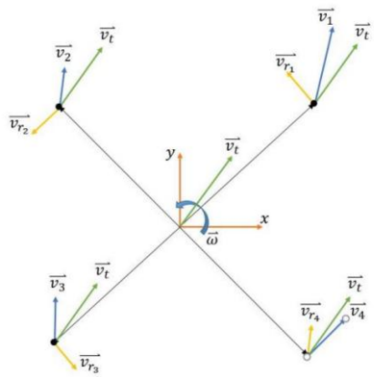

Figure 7. Overall analysis of wheat wheel

4.2. Calculation of axial velocity of wheat wheel

Through the wheel axis speed, the speed perpendicular to the roller and the speed along the roller direction can be decomposed.

Since the speed perpendicular to the roller direction will be converted into the rotation of the roller itself, it can be ignored, as is shown in figure 9.

Thus:

$$\vec{v}_{\Pi} = \vec{v} \cdot \hat{u} = \left(v_x \hat{l} + v_y \hat{j}\right) \cdot \left(-\frac{1}{\sqrt{2}} \hat{l} + \frac{1}{\sqrt{2}} \hat{j}\right) = -\frac{1}{\sqrt{2}} v_x + \frac{1}{\sqrt{2}} v_y \tag{3}$$

Calculation of wheel speed:

$$\vec{v}_w = \frac{v_{\Pi}}{\cos 45^\circ} = \sqrt{2}\left(-\frac{1}{\sqrt{2}} v_x + \frac{1}{\sqrt{2}} v_y\right) = -v_x + v_y \tag{4}$$

Defined by a and B as shown in the figure below, we can get:

$$\begin{cases} v_x = v_{t_x} - w \cdot b \\ v_y = v_{t_y} - w \cdot a \end{cases} \tag{5}$$

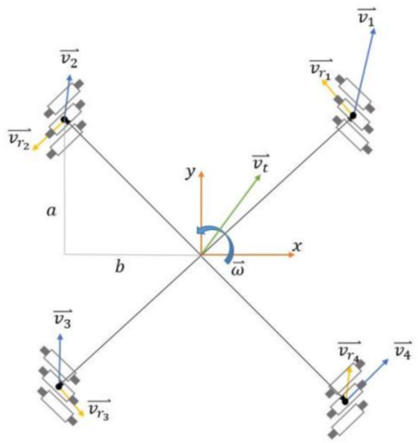

Figure 8. Analysis of moving speed of wheat wheel

To sum up, the rotational speed of the four wheels can be calculated as follows:

$$\begin{cases} v_{w_1} = v_{t_y} - v_{t_x} + w(a+b) \\ v_{w_2} = v_{t_y} + v_{t_x} - w(a+b) \\ v_{w_3} = v_{t_y} - v_{t_x} - w(a+b) \\ v_{w_4} = v_{t_y} + v_{t_x} + w(a+b) \end{cases} \tag{6}$$

Similarly, the equations of the forward kinematics model can be solved by reverse operation:

$$\begin{cases} v_{t_x} = \frac{1}{4}\left(-v_{w_1} + v_{w_2} - v_{w_3} + v_{w_4}\right) \\ v_{t_y} = \frac{1}{4}\left(v_{w_1} + v_{w_2} + v_{w_3} + v_{w_4}\right) \\ w = \frac{1}{4(a+b)}\left(v_{w_1} - v_{w_2} - v_{w_3} + v_{w_4}\right) \end{cases} \tag{7}$$

Write the inverse kinematics model as a matrix:

$$\begin{bmatrix} v_{w_1} \\ v_{w_2} \\ v_{w_3} \\ v_{w_4} \end{bmatrix} = \begin{bmatrix} v_{t_y} \\ v_{t_y} \\ v_{t_y} \\ v_{t_y} \end{bmatrix} + \begin{bmatrix} -v_{t_x} \\ +v_{t_x} \\ -v_{t_x} \\ +v_{t_x} \end{bmatrix} + \begin{bmatrix} +w(a+b) \\ -w(a+b) \\ -w(a+b) \\ +w(a+b) \end{bmatrix} \tag{8}$$

It can be concluded that the rotational speeds of the four wheels required for the current movement can be obtained by simply adding the four wheel speeds of the wheat wheel chassis in X translation, y translation and rotation. The reason is that the omnidirectional moving chassis composed of wheat wheels is a pure linear system.

5. Motion control

For 4-way motor driving wheat wheel, closed-loop control is adopted to ensure consistent rotation speed of wheat wheel, as is shown in figure 10.

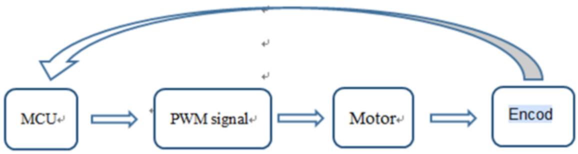

Figure 9. Closed-loop control

When the sensor recognizes the target, the single chip microcomputer carries out image processing and recognition, then outputs pulse signals to the bottom motor to control the robot to approach the target, and then outputs the angle signal to control the steering gear to control the movement of the 5-axis manipulator, as is shown in figure 11.

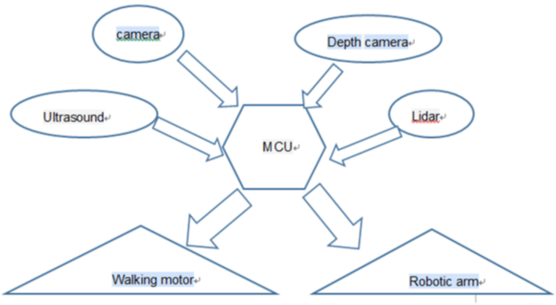

Figure 10. Control flow

6. Cleaning mechanism

In this design, the clamping manipulator, cleaning manipulator, vacuum cleaner, cleaning plate and other cleaning mechanisms are combined to realize various scene cleaning, such as ground cleaning + desktop cleaning. The hand design of the cleaning manipulator adopts a three-layer structure. The first layer is hard to scrape off large pieces of garbage such as bones, the middle layer is a rag to wipe away stains, and the last layer of rubber is used to scrape off residual oil stains. The tail scraper is composed of two layers. The first layer in the front row is similar to sponge material, which can suck residual detergent, etc., and the second layer is rubber material, which can wipe water stains dry. The mechanism controlling the lifting of tail scraper is a group of motor + reduction gear (reduction ratio 1:5) + connecting rod. The motor outputs power to the gear, and the connecting rod is fixed on the inner side of the gear root circle. When the gear rotates, it can drive the connecting rod to make a circular motion around the shaft. At the limit hole at the robot shell, the connecting rod is equivalent to a lever, and the limit hole is the fulcrum. At this time, when the motor rotates, the lifting control of the tail scraper can be realized.

In terms of dust collection, the vacuum cleaner motor is installed above the dustbin, and the robot shell is provided with an air outlet. When the moving impeller rotates at a high speed of 20000-30000 rpm, a negative pressure will be generated at the air inlet to form a vacuum, and then form suction.

Figure 11. Vacuum cleaner motor

7. Machine vision

If the robot wants to have the ability of path planning, lidar is indispensable. Lidar is like the sonar system on bats. It is a sensor that can detect the precise position of objects. It mainly emits laser signals to the target, and then calculates the distance according to the time difference of signals reflected from the object, Then the angle of the laser is emitted to determine the angle of the object and the transmitter, so as to obtain the relative position of the object and the transmitter. The lattice data in two-dimensional space is obtained through continuous scanning, which can help the machine with slam technology

People realize the functions of autonomous positioning, map construction and path planning.

Figure 12. Lidar

Principle of triangular ranging:

The principle of triangulation method is shown in the figure below. The laser first emits the laser, and the laser will be reflected after irradiating the object. The reflected light is received by the linear CCD. Since the laser is separated from the detector for a certain distance, objects with different distances will be imaged at different positions on the CCD according to the optical path. According to the trigonometric formula, the distance of the measured object can be deduced.

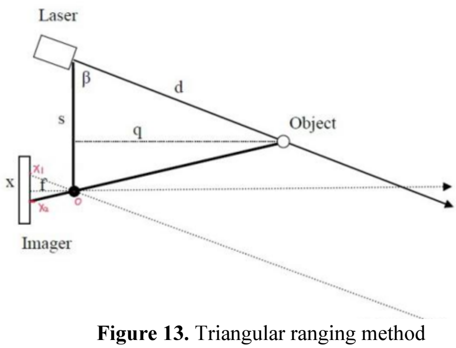

Figure 13. Triangular ranging method

Depth camera, also known as 3D camera, can detect the depth of field distance of shooting space through this camera, which is also the biggest difference from ordinary camera. Through the data obtained by the depth camera, we can accurately know the distance from each point in the image to the camera. In this way, combined with the (x, y) coordinates of the point in the 2D image, we can obtain the three-dimensional spatial coordinates of each point in the image. The real scene can be restored through three-dimensional coordinates to realize applications such as scene modeling.

The ultrasonic module is selected for obstacle avoidance because the ultrasonic module obtains the distance information ($s = 340 * t / 2$) by transmitting ultrasonic and calculating time. S is the distance and t is the time from sending to receiving, so the light will not affect its obstacle avoidance effect.

Combined with OpenCV, the camera first imports the color pictures taken by our camera into the C++ development environment, and converts the original image into gray image (using the cvtcolor function in openCV) to realize garbage recognition.

Slam, combined with sensors such as lidar camera, models the environment, and optimizes filtering in the later stage to realize mapping, positioning and path planning.

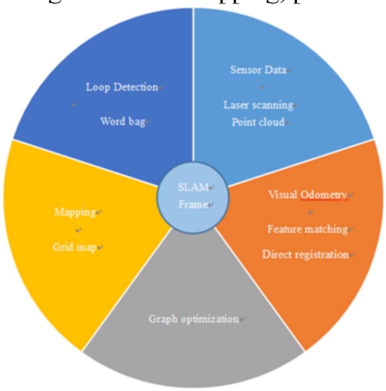

Figure 14. Triangular ranging method

8. Conclusion

The purpose of this paper is to study the robot technology based on restaurant intelligent cleaning, carry out the structure design of the robot body, omni-directional movement analysis and motion simulation system simulation, and through theoretical analysis, the results show that the restaurant intelligent cleaning robot with four servo motors controlling four mcnamu wheels separately has better omni-directional movement performance, It has good vertical and horizontal straight travel and in-situ (zero radius) steering functions, which can meet the flexible omnidirectional movement of the restaurant in a narrow area, make the device move more flexibly, reduce the probability of collision with tables and chairs, have higher reliability, and can better meet the needs of the restaurant. At the same time, information acquisition, image processing, environment modeling, algorithm optimization and fusion are carried out on the premise of the combination of lidar, depth camera, ultrasonic module, camera and other sensors. The results show that the robot with multiple sensors for environment perception has excellent path planning and autonomous obstacle avoidance ability!

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