Autonomous cleaner robot applied with random and zigzag movement algorithm

Xe tự hành ứng dụng thuật toán dẫn đường ngẫu nhiên và zigzag

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Abstract

In recent decades, researchers have been interested in and developed the control problem for autonomous vehicles. The obtained results are used in autonomous vehicles for service, industry and transportation… However, with the different requirements of control algorithms, the driving structure and the navigation problem so that accuracy and efficiency always change. In the paper, the author presents design, and control algorithms, random routing and zigzag applications for self-propelled cleaner models. The experiment results proved the correctness of the control algorithm and the performance of robot design.

Keywords:

Sensor: Navigation; Controller; Autonomous Vehicle

Tóm tắt

Trong các thập niên gần đây, các nhà nghiên cứu đã có sự quan tâm và phát triển các bài toán điều khiển cho xe tự hành. Một trong các kết quả thu được áp dụng cho xe tự hành trong các ngành dịch vụ, công nghiệp và vận chuyển,… Tuy nhiên, các yêu cầu khác nhau về thuật toán điều khiển, cấu trúc lái và vấn đề dẫn đường dẫn tới độ chính xác và hiệu quả thường xuyên thay đổi. Trong bài báo, tác giả đã biểu diễn thiết kế hệ thống, thuật toán điều khiển, dẫn đường ngẫu nhiên và zig zag áp dụng cho mẫu xe tự hành lau dọn. Các kết quả thực nghiệm đã minh chứng cho sự đúng đắn của thuật toán điều khiển và chất lượng của hệ thống thiết kế robot.

Từ khóa:

Cảm biến; Dẫn đường; Điều khiển; Xe tự hành;

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1. INTRODUCTION

Technology plays an important role in the fast develop of our social and life. Nowadays, the industrial revolution 4.0 is growing and spreading very strongly in almost fields of life. Mobile robotics and particularly the area dedicated to autonomous robot, remains as one of the robotics sectors with more activity, promoted essentially by the robust development of controller systems improving their safety and comfort [1÷8].

Visual sensors (cameras) are one of the existing technologies that have been currently being used in industrial and non-industrial applications including robotic placement via high technology camera [1,2,4]. Even though cameras provide significant advantages over other types of non-contact proximity sensors, the images taken tend to be influenced by numerous external parameters, such as background lighting, and are limited in their accuracies due to technological problems. In addition, image acquisition and processing rates can be very slow. Furthermore, the cost will be increased by data processing system, high quality camera, lens and light system. In response to these limitations, several types of proximity sensors have been developed and used for the direct measurement of robotic end-effector positions [4, 6].

Proximity sensors include magnetic sensors that can either use inductive or capacitive principles, acoustic sensors and electrooptical sensors [5]. The sensing systems have employed popularly in robotic applications has been dedicated to the measurement of the pose of the object to he handled, rather than the end-effector [6].

Cleaner autonomous robots work in home environment. This environment is complex with multiple obstacle like desks, chairs, walls or stairs, and these obstacles can be changed by the users daily. There are also many types of floor like wood, ceramic tile, rug. This requires the robots to adapt to many situations [7, 8]. The line follower mechanism is obviously not suitable in the home environment. Visions guided is effective but costly and hard to implement. Moreover, the autonomous robot will move the largest available area to clean. Finally, the solution is to use sensors guided as our robot guiding mechanism because of the easy implementation, the suitability for environments and the expense. In the paper, the author presents design, and control algorithms, random routing and zigzag applications for self-propelled vehicle models. The experiment results obtained demonstrate the correctness of the construction theory and the required quality control.

2. MECHANICAL DESIGN

Technical parameters:
- Shape: Circular.
- Weight: 5kg.
- Maximum velocity: 0.25m/s.
- Diameter: 280 - 350mm.
- Height: 70 - 120mm.

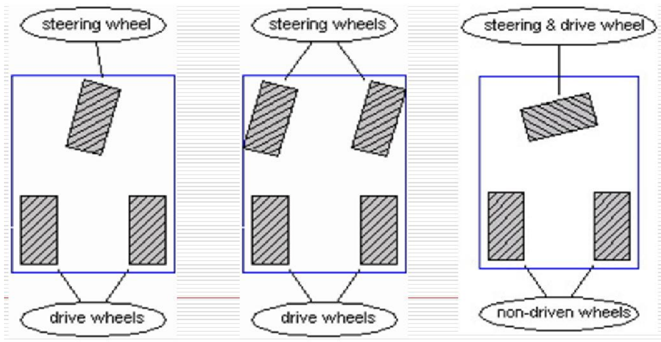


Fig 1. Several common driving mechanism

The mechanism of 2 drive wheel and 1 or 2 steering wheels is used for robots carrying high load and high speed. The disadvantage is to require the large space needed for the robot to turns. Proposed drive mechanism uses 2 wheels with variable speed. Free wheels which can turn freely are used for balance. This mechanism allows the robots to turn in tight space.

The simple diagram for the robot is shown in Fig. 3. Denote a(m)=0.13m is the width of the robot cleaning path (the area cleaned behind the robot when it moves along a trajectory) and ν(m/s) is the speed of the robot. The cleaning speed of the robot in square meters per seconds, denoted as S, can be calculated as: $S = a\nu$ in Fig. 3.

The speed of the robot should be slow to enable enough time for cleaning action. The author chooses $\nu = 0.25$ m/s. The robot can cover 20m^2 floor area in 20 minutes (1800 seconds), so we have $S = 0.01$ m^2/s.

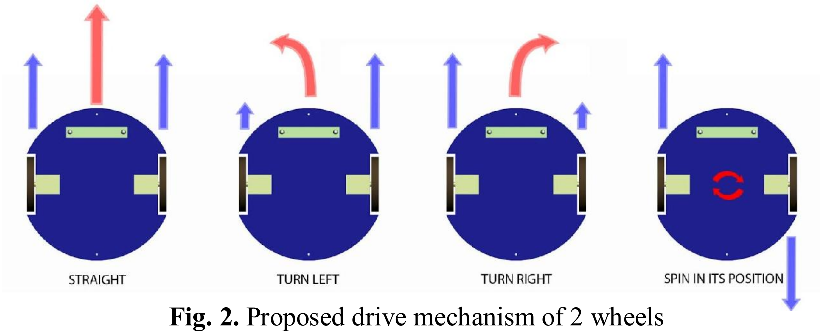


Fig. 2. Proposed drive mechanism of 2 wheels

As for the function of avoiding the obstructs, the autonomous robot uses the bumper mechanism to detect obstacles and transmit signal to analysis the data of navigation. While the robot is cleaning, it avoids steps (or any other kind of drop-off) using four infrared sensors on the front underside of the unit. When it knocks into something, its bumper retracts, activating mechanical object sensors that tell the robot it has encountered an obstacle. Then, it performs and repeats the sequential actions of backing up, rotating and moving forward until it finds a clear path.

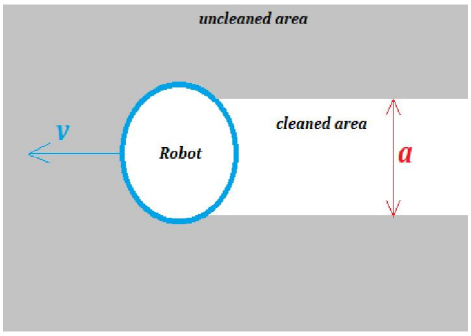


Fig. 3. Diameter diagram

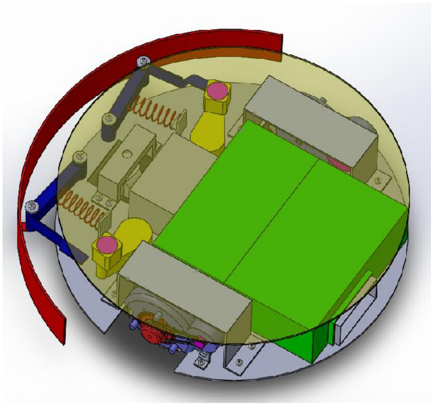


Fig. 4. Technical drawing of 3D assembly of robot

3. CONTROL SYSTEM DESIGN

The main function of the control system is to receive data from input sources (sensor and command from user) and control the actuator to execute the command in the most effective way possible.

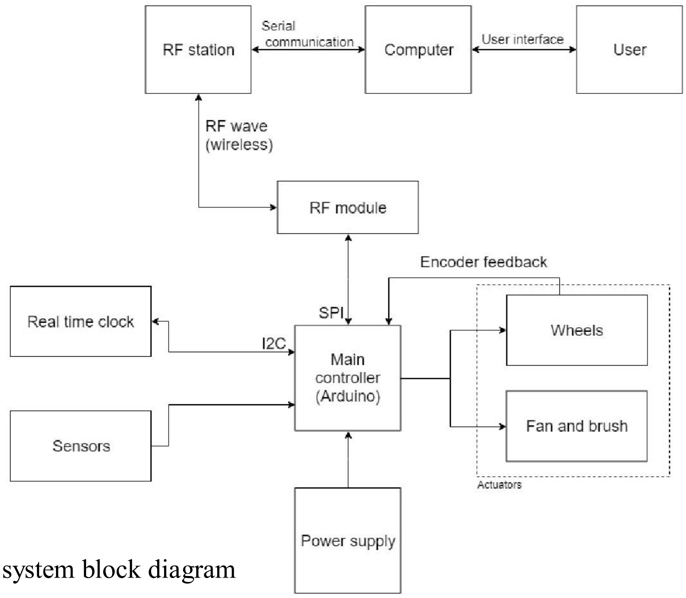
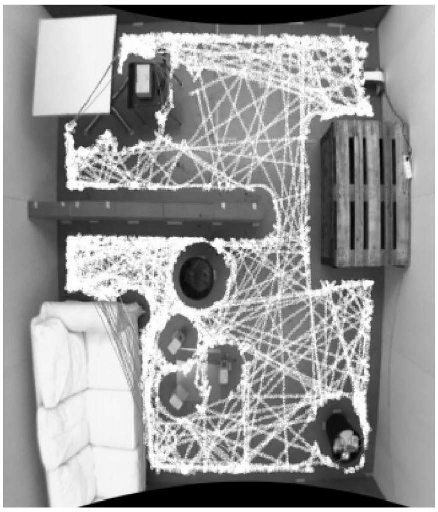


Fig. 5. Control system block diagram

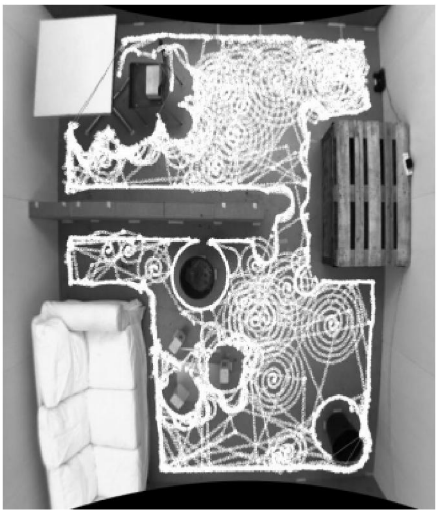
3.1. Control algorithm

3.1.1. Random movement

The simplest strategy is random navigation. The robot simply moves forward until it meet an obstacle, then the robot will react by turn around. Another variation of this random movement process is spiral movement. The robot moves in spiral pattern until sensors detect obstacle then the robot will move to a new location and start the spiral movement again.



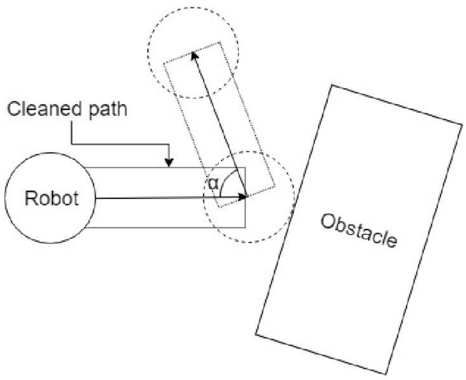
a). Linear movement



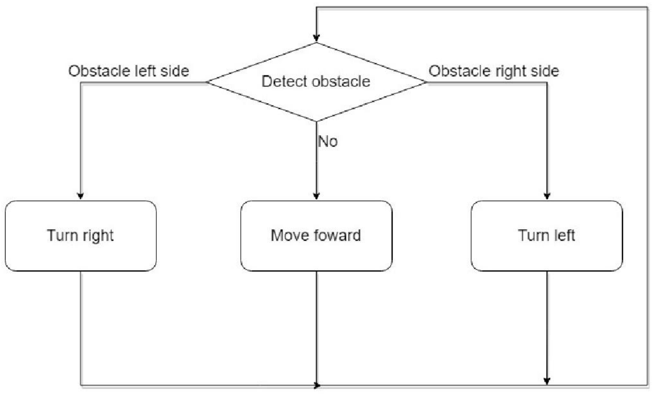
b). Spiral movement

Fig. 6. Random movement

The random movement strategy is proposed as follow:



a). The principle of proposed random movement

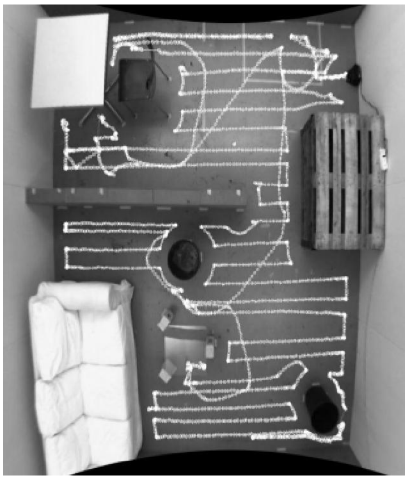


b). The diagram of random movement control algorithm

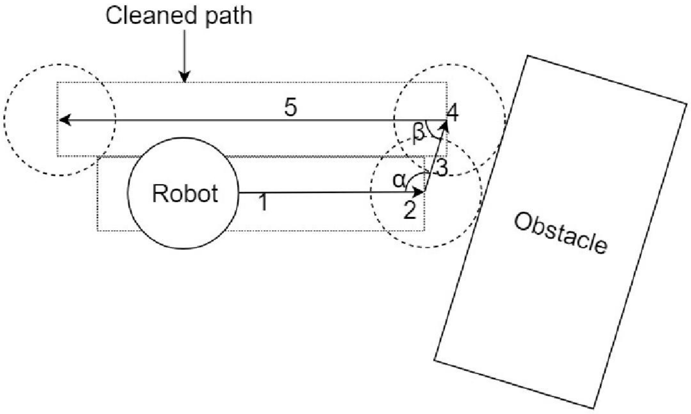
Fig. 7. Proposed random movement control

The angle α is the fixed turn angle. Each time the robot detects an obstacle, it will turn around itself and continue moving. The process then repeats. The diagram in Fig. 7 shows the random movement strategy.

3.1.2. Zigzag movement



a). Zigzag movement



b). The principle of proposed zigzag movement

Fig. 8. Proposed zigzag movement control

The zigzag strategy is proposed as follows:

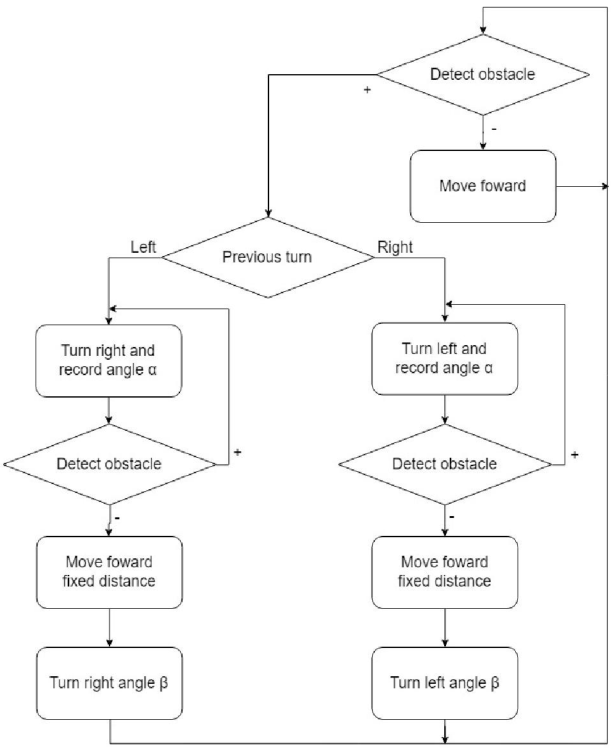


Fig. 9. The diagram of proposed zigzag movement control algorithm

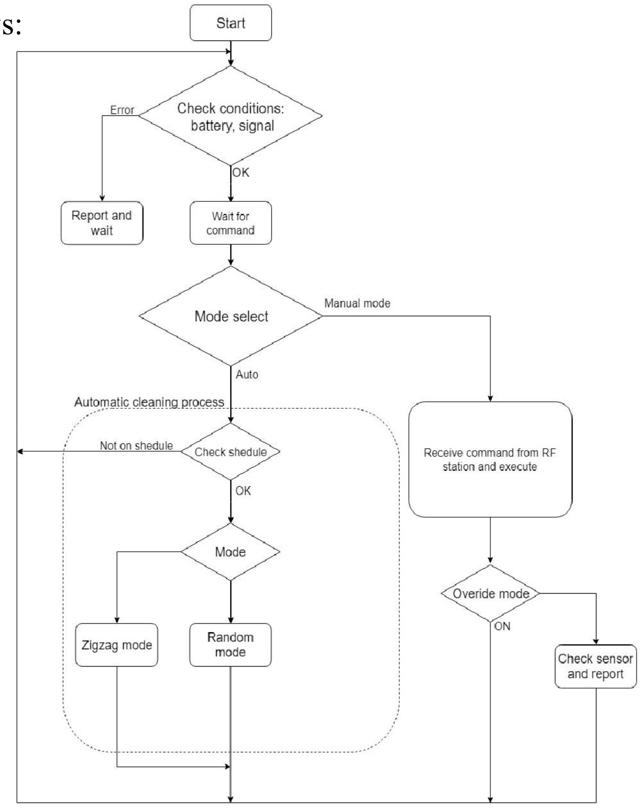


Fig. 10. Robot firmware flowchart

3.2. Control system software

Robot firmware is the code programed into the Arduino which control the robot. The block diagram of the robot firmware is shown in Fig. 10.

The computer control software is the program running on Windows computer to control the robot via an easy to use interface as below:

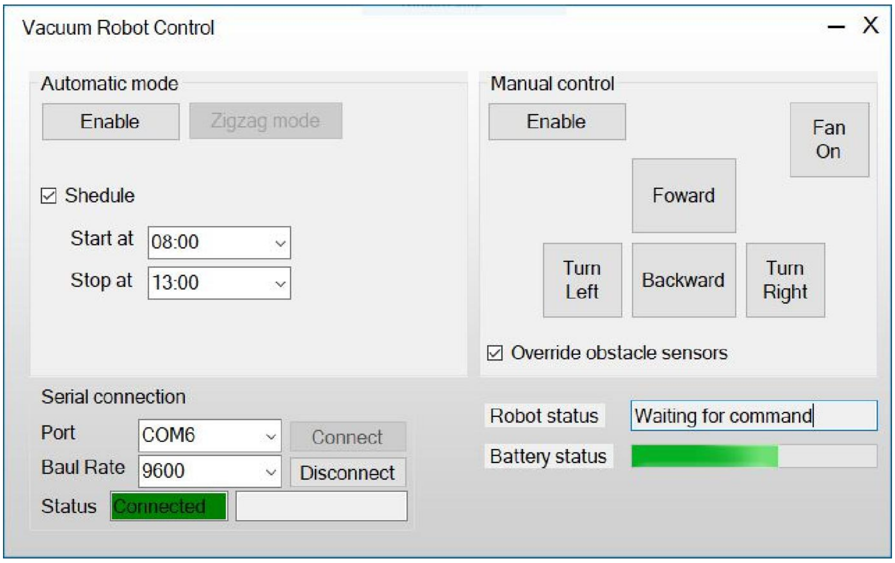
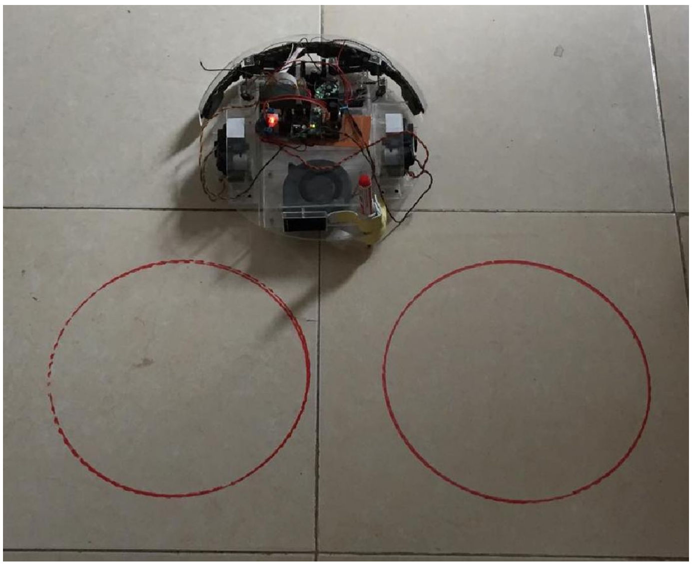


Fig. 11. Robot firmware flowchart

4. EXPERIMENT RESULTS

First, we test basic movement command of the robot. The figures below show the trajectory of the robot in simple case like moving on straight line and turn around.

a). Straight line



b). Turning trajectory

Fig. 12. Robot moving test

To test the random strategy and zigzag strategy, we set up a simple experiment as shown below. The testing environment is constrained rectangular cage with length of 2 meters and height of 1 meter. We film the movement of the robot with both strategy and use video editing software to generate the movement of the robot. A cross mark is placed in the center of the robot to easily record the trajectory. The trajectory is indicated by the red lines of dot. The trajectories shown is the movement of the center of the robot, hence they always are at a distance from any obstacle. The cleaned zone is on both side of the trajectories. The figure below is the trajectory of the robot in 5 minutes moving in 2 environments: no obstacle (2 minutes run time) and with obstacle (5 minutes runtime).

a). Movement without obstacle

b). Movement avoiding obstacle

Fig. 13. Random movement

From the observed result, we can conclude that the random strategy is working as intended. Continuously, in the mode of zigzag movement the robot performs obstacle avoidance sequence properly. The robot alternating between turning left twice and turning right twice to gradually covers the test area. The overall time it takes for the robot to clean the whole environment is a lot smaller than random strategy.

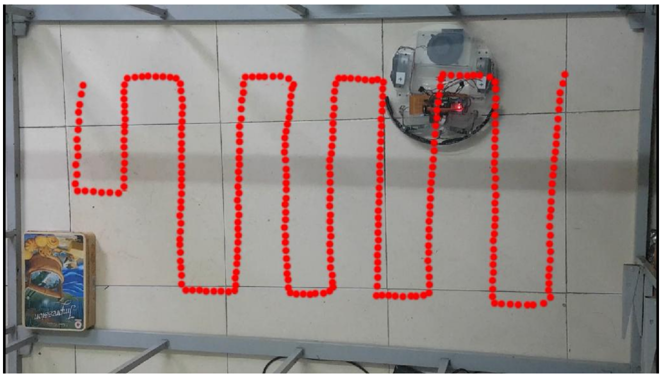


Fig. 14. Zigzag movement

5. CONCLUSIONS

The author presents design, and control algorithms, random routing and zigzag applications for self-propelled vehicle models. The experiment results obtained demonstrate the correctness of the construction theory and the required quality control. However, in complex environment, the zigzag strategy does not perform as good. The robot can get into tight space and start to show strange and chaotic behavior. In conclusion, the zigzag strategy works best in simple environment with few obstacles. To further increase the performance of this strategy and prevent error, we need a better sensor system which can accurately determine the robot position.

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