Realization of micromouse consecutive turning based on STM32

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Received 01 December 2013, www.cmnt.lv

Abstract

In order to improve the stability and reduce dashing time of micromouse in complex maze, the traditional turning trajectory and speed-time curves were abandoned. "S" turning method is proposed to achieve fast consecutive turning. For the "S" turning in straight way, controller fully considers passing of the last turning and leading of the next turning, with the help of compensation and navigation sensors to realize precise correction of micromouse position; For the "S" turning in arcs, different speeds are used to track different arcs, gyroscope records its rotation angle and does real-time angle compensation. "S" turning method is verified by micromouse based on STM32. Experiments of seven consecutive turnings show that the method can greatly improve the stability and reduce the turning time of micromouse.

Keywords: micromouse, robot, consecutive turning, servo, gyroscope

1 Introduction

Micromouse is a maze robot, its technology covers many areas; Micromouses can automatically memory maze information and select the shortest path, then use artificial intelligent algorithm and quickly dash to the set destination. In foreign countries micromouse competitions have been hold for nearly 30 years, many useful robots are designed according to its principle [1-5].

The basic function of a micromouse is searching from the start to the destination and finds the shortest path, then dashes from the start to destination along the shortest path [6-11]. Technology of domestic developed micromouse is relatively backward. After long time operation in complex maze finds that: low-level algorithm is often used in the micromouse, which leads to the dashing path is not really the shortest, contrary to the actual principle of micromouse; Stepper motors make the temperature of the system increase quickly, which leads to the micromouse can not run in high speed; Due to the surrounding environment is not stable, especially the disturbance of light, micromouse based on MCS-51 often appears abnormal, which causes its dashing out of control.

STM products contains a comprehensive range of microcontrollers, from low-cost 8-bit MCUs up to 32-bit ARM-based Cortex®-M0 and M0+, Cortex®-M3. In order to solve those problems of traditional micromouse, new type micromouse based on STM32F103 is researched and developed. Controller takes STM32F103 as the processing core, which is used to realize real-time control of two DC motors. Principle of designed micromouse is shown as Figure 1. In order to reduce size of controller, L298N is used in the system.

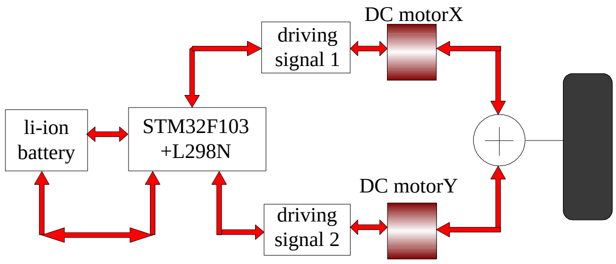


FIGURE 1 Principle of improved micromouse

2 Micromouse dashing topology

Before a dashing, micromouse is often placed on the set point, and usually is called as coordinate (0, 0), as shown in Figure 2.

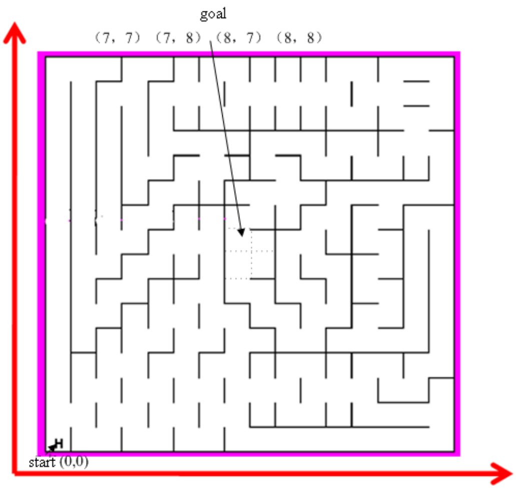


FIGURE 2 Map of micromouse maze

Then the micromouse waits for the controller to send command of dashing. When the power is turned on, system initialization will be completed first, then the optimal maze information will be obtained, once dashing key is pressed, according to the key information, micromouse will dash to destination (7, 7), (7, 8), (8, 7) or (8, 8) with a high speed along the shortest path.

Analysis above maze topology, the dashing of micromouse is divided into the following four.

Straight way dashing: if there are no walls along the dashing path, micromouse need not change its dashing direction in straight way until wall exists.

Turning right dashing: when micromouse runs along the optimal path forward, if there is a wall in the front, and at the same time there is a wall in the left, the micromouse only can turn right, then the micromouse runs along another different straight way, the traditional turning right trajectory is shown in Figure 3.

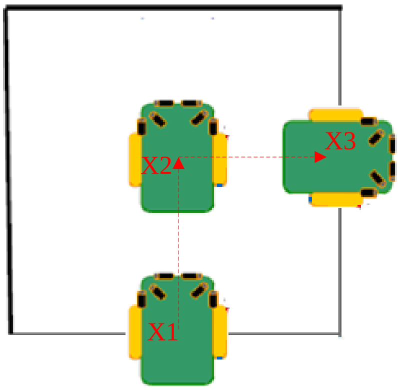


FIGURE 3 Traditional turning right trajectory

Turning left dashing: when micromouse runs along the optimal path forward, if there is a wall in the front, and at the same time there is a wall in the right, the micromouse only can turn left, then the micromouse runs along another different straight way, the traditional turning left trajectory is shown in Figure 4.

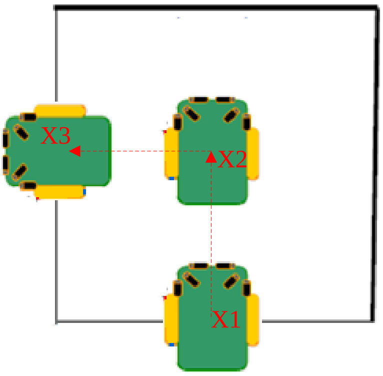


FIGURE 4 Traditional turning left trajectory

Consecutive turning dashing: when micromouse dashes along the optimal path forward, if it's dashing path as Figure 5 shows, it can be seen that the path is a combination of many right and left turnings, known as consecutive turning. In the actual operation of such turnings, if this path is regarded as a simple combination of left and right turnings, and use the trajectory of Figure 3 and Figure 4 to realize this type turnings, a lot of time will be taken, which leads to a longer dashing time.

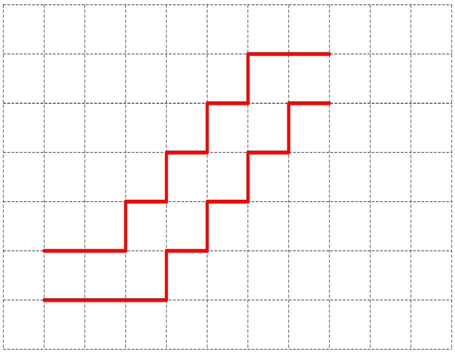


FIGURE 5 Path of consecutive turnings

3 Principle of fast consecutive turning

In order to meet the acceleration continuity of micromouse fast dashing in a complex maze, the traditional acceleration dashing curves were abandoned; According to the speed-time curve(as Figure 6 shows), micromouse control its acceleration and deceleration. Areas contained in the figure are the distances of micromouse need to run.

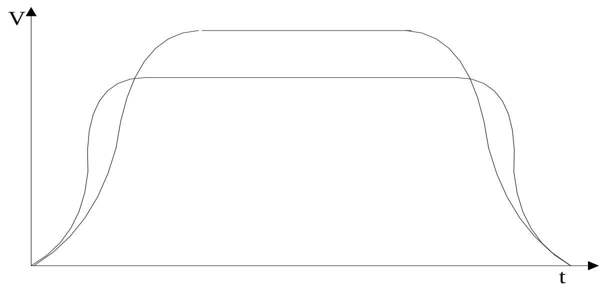
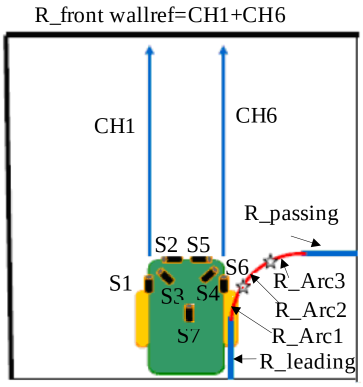


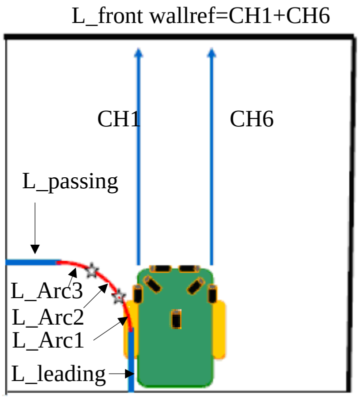
FIGURE 6 Speed- time curve

In order to improve the stability of micromouse and reduce its dashing time, according to its actual turning action, the paper presents a method of single turn as shown in Figure 7: the left or right turning trajectory is divided into five different paths: straight way navigation positioning distance leading, slow turning Arc1, fast turning Arc2, slow adjustment turning Arc3, straight way compensation distance passing. In order to reduce the effect of external light on high-speed dashing, photoelectric compensation S7 is added to the system, which can detect external abnormal light source and inform the controller to do compensation. Also gyroscope ADXRS300 is added to the system, which is used to record the rotation angle of micromouse, when the recording value is smaller or larger than set value, angle compensation will be done to correct micromouse's posture.

In the micromouse dashing command, if the dashing path shows as Figure 5, the micromouse will use the ideal S curve (as Figure 8 shows) to realize its dashing, which can short the dashing distance and reduce its dashing time.



(a) right turning



(b) left turning

FIGURE 7 Principle of five-path trajectory turning

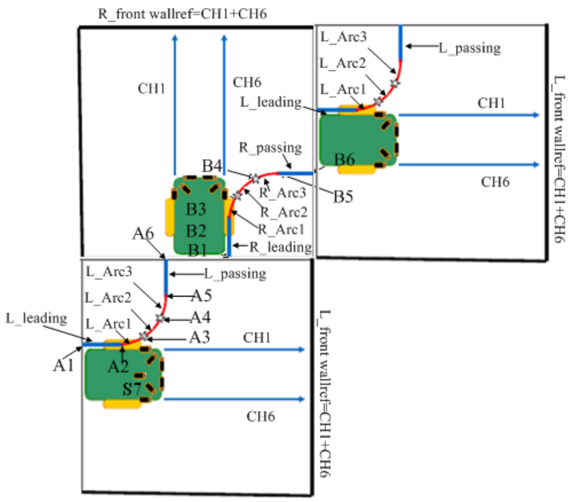


FIGURE 8 Principle of S curve movement

In the actual operation, if the S consecutive curve(as Figure 8 shows) is regarded as a simple combination of left and right turnings, micromouse will can not turn out the maze in high speed, because without sensor calibration and compensation, error of finished turnings will be gradually accumulated, which leads to the failure of final turning. In order to ensure micromouse's accurate and fast turning in complex maze, various navigation and compensation sensors of the micromouse should be considered.

When the next dashing command is a consecutive turning, micromouse depends on sensors S2, S3 and S4, S5 correct its position first, which ensures it can run in the centre of the straight way, then the front navigation sensors S1 and S6 begin to do position compensation. From the method the micromouse can accurately reach A1, and then the micromouse begins its first turning.

According to different requirements of micromouse dashing time and running condition, L_leading is converted into servo control parameters by STM32F103, and then STM32F103 combines with real-time motor feedback of current, speed and position, PWM control signal of motors are generated, which can drive the left and right wheels with the same acceleration and speed straight forward. In the whole process of travelling, sensor S4 and S5 provide a criterion for the straight way navigation. Before the micromouse reaches the goal of A2, in order to reduce the effect of the external light interference, photoelectric sensor S7 begins to work, and under its help, S1and S6 do position error compensation.

Under the help of S1 and S6, once the micromouse reaches the goal A2, according to different requirements of dashing time and micromouse running condition, L_Arc1 is converted into servo control parameters by STM32F103, and then STM32F103 combines with real-time motor feedback of current, speed and position, PWM control signals of motors are generated, then speeds of motor X and motor Y are adjusted to L90_VelX11and L90_VelY11, the left and right wheels run with a constant ratio C11. In the whole process of L_Arc1 turning, gyroscope ADXRS300 will record the rotation angle of micromouse in real time, and then the rotation angle error compensation will be done according the recording of ADXRS300, until the micromouse reaches the set point A3.

Once micromouse reaches the goal A3, according to different requirements of dashing time and micromouse running condition, L_Arc2 is converted into servo control parameters by STM32F103, and then STM32F103 combines with real-time motor feedback of current, speed and position, PWM control signals of motors are generated, then speeds of motor X and motor Y are adjusted to L90_VelX21and L90_VelY21, the left and right wheels run with a constant ratio C21. In the whole process of L_Arc2 turning, gyroscope ADXRS300 will record the rotation angle of micromouse in real time, and then the rotation angle error compensation will be done according the recording of ADXRS300, until the micromouse reaches the set point A4.

Once micromouse reaches the goal A4, according to different requirements of dashing time and micromouse running condition, L_Arc3 is converted into servo control parameters by STM32F103, and then STM32F103 combines with real-time motor feedback of current, speed and position, PWM control signals of motors are generated, then speeds of motor X and motor Y are adjusted to L90_VelX31and L90_VelY31, the left and right wheels run with a constant ratio C31. In the whole process of L_Arc3 turning, gyroscope ADXRS300 will record the rotation angle of micromouse in real time, and then the rotation angle error compensation will be done according the recording of ADXRS300, until the micromouse reaches the set point A5.

Before micromouse reaches the goal of A5, the photoelectric compensation sensor S7 begins to work, sensor S1 and S6 starts to do position error compensation. In order to adjust the micromouse to a better posture, the only way is to increase the distance of the straight way, so

L_Passing and R_Leading are set as one parameter. According to different requirements of micromouse dashing time and running condition, L_Passing+R_Leading is converted into servo control parameters by STM32F103, then STM32F103 combines with real-time motor feedback of current, speed and position, PWM control signals of motors are generated, which can drive the left and right wheels with the same acceleration and speed straight forward. In the whole process of travelling L_Passing and R_Leading, sensor S2 and S3 provide a criterion for the micromouse navigation in straight way. Before the micromouse reaches the goal of B2, in order to reduce effect of external light interference, photoelectric sensor S7 still works, and under its help, S1and S6 begin to do position error compensation.

Under the help of S1, S6 and S7, once the micromouse reaches the goal B2, according to different requirements of dashing time and micromouse running condition, R_Arc1 is converted into servo control parameters by STM32F103, and then STM32F103combines with real-time motor feedback of current, speed and position, PWM control signals of motors are generated, then speeds of motor X and motor Y are adjusted to R90_VelX11 and R90_VelY11, the left and right wheels run with a constant ratio C12. In the whole process of R_Arc1 turning, gyroscope ADXRS300 will record the rotation angle of micromouse in real time, and then the rotation angle error compensation will be done according the recording of ADXRS300, until it reaches the set point B3.

Once micromouse reaches the goal B3, according to different requirements of dashing time and micromouse running condition, R_Arc2 is converted into servo control parameters by STM32F1032, and then STM32F103 combines with real-time motor feedback of current, speed and position, PWM control signals of motors are generated, then speeds of motor X and motor Y are adjusted to R90_VelX21and R90_VelY21, the left and right wheels run in a constant ratio C22. In the whole process of L_Arc2 turning, gyroscope ADXRS300 will record the rotation angle of micromouse in real time, and then the rotation angle error compensation will be done according the recording of ADXRS300, until it reaches the set point A4.

Once micromouse reaches the goal B4, according to different requirements of dashing time and micromouse running condition, R_Arc3 is converted into servo control parameters by STM32F103, and then STM32F103 combines with real-time motor feedback of current, speed and position, PWM control signals of motors are generated, then speeds of motor X and motor Y are adjusted to R90_VelX31and R90_VelY31, the left and right wheels run with a constant ratio C32. In the whole process of R_Arc3 turning, gyroscope ADXRS300 will record the rotation angle of micromouse in real time, and then the rotation angle error compensation will be done according the recording of ADXRS300, until it reaches the set point B5.

Before micromouse reaches the goal B5, the photoelectric compensation sensor S7 begins to work, sensor S1 and S6 starts to do position error compensation. Once the position is corrected, L_leading and R_passing are set as one parameter, according to different requirements of dashing time and micromouse running condition, R_Passing+L_Leading is converted into servo control parameters by STM32F1032, and then STM32F1032 combines with real-time motor feedback of current, speed and position, PWM control signals of motors are generated, which can drive the left and right wheels with the same acceleration and speed straight forward. In the whole process of travelling, sensor S4 and S5 provide a criterion for the micromouse navigation in straight way.

Under the help of S1 and S6, micromouse will run in straight path R_Passing and L_Leading. Once the micromouse reaches the goal B6, the first "S" turning is finished.

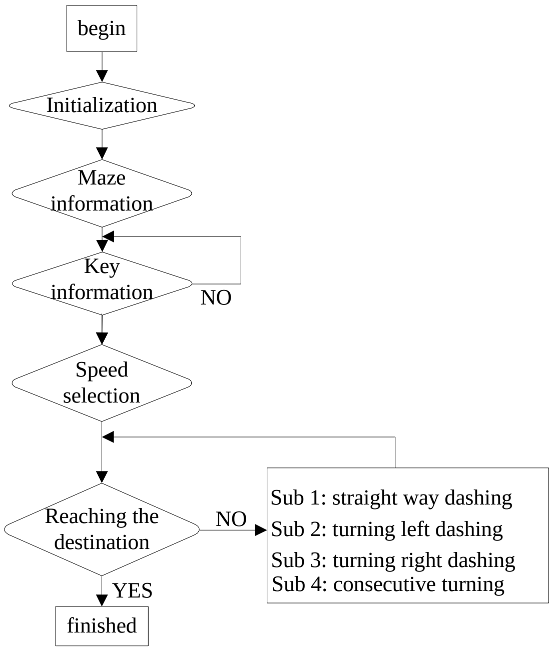


FIGURE 9 Main program of dashing

4 Software design

Micromouse designed in this paper is based on STM32. Before a dashing, the micromouse is placed in the starting point of maze. At the moment of power on, the micromouse first enters the state of self locking and the dashing path is confirmed. Once dashing command is triggered, dashing path of the micromouse is converted into servo control parameters first, and then micromouse depends on sensors in the front, left and right sides to realize autonomous navigation, with a high speed dashes to the end of the path.

The most important task of micromouse is dashing. In its dashing process, micromouse should always judge it's the dashing is in straight way, or turning right, or turning left or consecutive turning. After the finishing the task, controller resets the parameters of dashing and lets micromouse return to the start point and wait for another dashing command. The main program of dashing is shown as Figure 9.

5 Experiment

PWM waveform of micromouse when it enters a maze cell is shown in Figure 10. From the figure can be seen that PWM of two channels have the same duty ratios, because under the help of S2~S5, the micromouse runs in the straight way, speed of motor X equals speed of motor Y, the speed of DC motor is proportional to its input voltage.

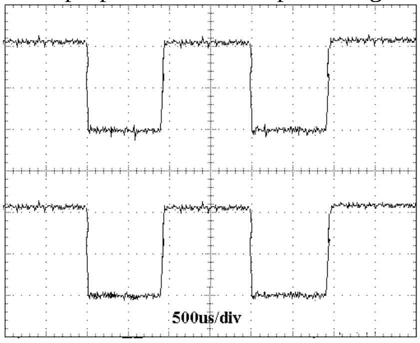


FIGURE 10 PWM waveform of micromouse entering a maze

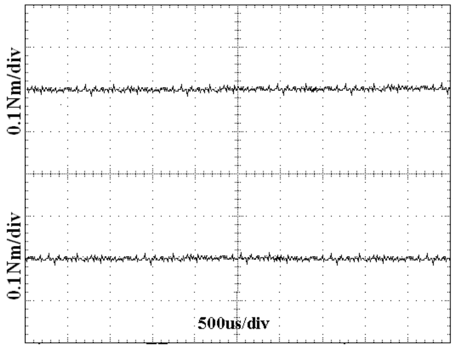


FIGURE 11 Torque waveform of micromouse entering a maze

Torque waveform of micromouse when it enters a maze cell is shown in Figure 11. From the figure can be seen that ripple torques of motors are both small, also torque values are equal, which make the micromouse can run in the straight way with the same acceleration, because the acceleration of motor is proportional to its torque.

In order to verify the micromouse anti-interference ability, a disturbance torque is added to the system in its running process, can be seen that the torque of driving micromouse changes greatly (as Figure 12 shows). Torque on-line identification algorithm begins to work, through about 100ms adjustment, the torque restores to its normal value.

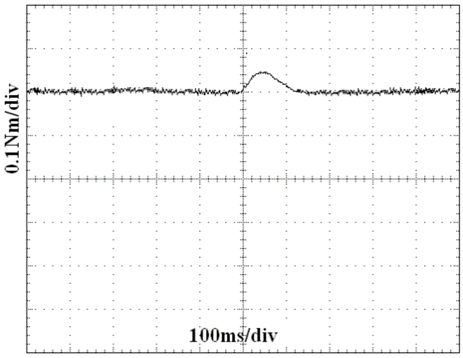


FIGURE 12 Micromouse anti-interference experiment

In order to verify the algorithm designed in this paper, maze designed as shown in Figure 13, which can realize seven consecutive turnings.

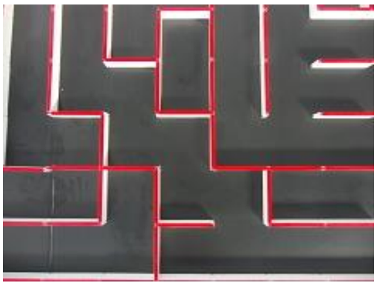


FIGURE 13 Maze of seven consecutive turnings

In seven consecutive turning experiments, pictures of micromouse in the maze are shown in Figure 14. As can be seen that micromouse can achieve very good 90 degree turning in the maze transfer point by “S” turning. From the help of side sensors, the direction of micromouse enters a cell is vertical to the front wall, which provides a good foundation to the micromouse next precise position correction.

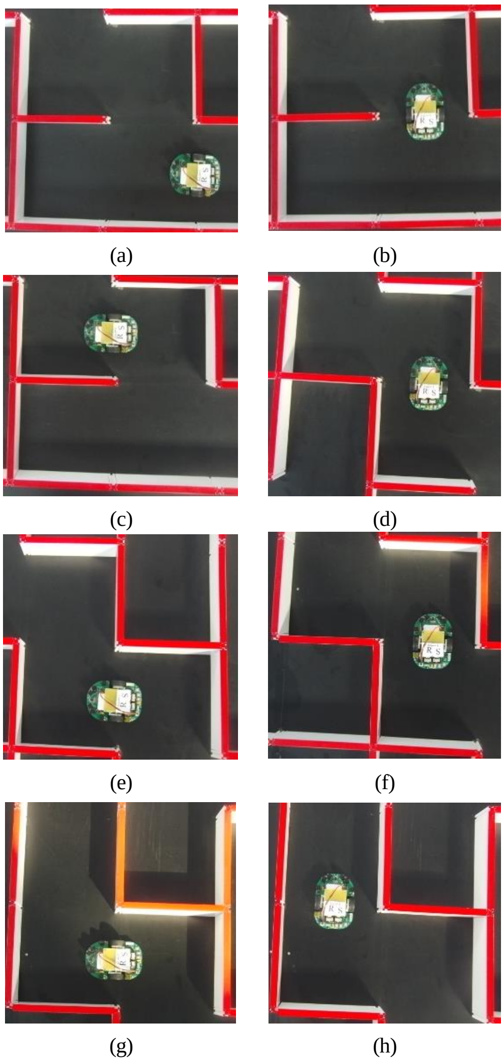


FIGURE 14 Pictures of seven consecutive turning

In order to verify the ability of micromouse anti-light interference, as Figure 14(g) shows, the interference light is added in its turning process, as can be seen from the picture that even if there is external disturbance of light, under the help of photoelectric compensation sensor S7, micromouse depends on S1, S6, S4 and S5, it is also able to accurately reach set position.

6 Conclusion

SMT components are used in the system, not only reduce the size and weight of the micromouse, but also reduce its centre of gravity, which is conducive to high speed dashing.

The controller uses STM32F103 to process maze reading and calculation algorithm of dashing, which greatly improves the efficiency and stability of micromouse dashing.

In order to reduce the time of turning dashing, single turning trajectory of micromouse is divided into five paths differently; Turning errors are compensated by compensation and navigation sensors.

To the consecutive turning, controller fully considers passing of the last turn and leading of the next turn, then the controller combines with sensors' compensation, precise correction of micromouse position is realized.

Acknowledgments

It is a project supported by basic research programs of Suzhou science and Technology Department - industrial application part (SYG201327) and 2012 Innovation Project (QING LAN) of JiangSu Province.

References

[1] Su J-H; Lee C-S; Huang H-H 2011 A micromouse kit for teaching autonomous mobile robots *International Journal of Electrical Engineering Education* **48**(2) 188-201

[2] Mishra S, Bande P 2008 Maze Solving Algorithms for Micro Mouse *Proceedings of the 2008 IEEE International Conference on Signal Image Technology and Internet Based Systems* 11

[3] Jiang X, Ren H-l, Ma Z-l 2011 Research on How ARM-based Micromouse Gets Out of Maze *Modern Electronics Technique* (08) 14-6

[4] Tondr A D, Hall Drew 2004 The inception of chedda: a detailed design and analysis of micromouse *Las Vegas: University of Nevada*

[5] Zhang H, Peh L S, Wang Y 2014 Software design for micromouse special navigation *Applied Mechanics and Materials Vols* 599-601 1700-3

[6] Fu X-w, Zhang H 2012 Design of the MicroMouse hardware based on the ARM-M3 *Journal of Jilin Institute of Chemical Technology* (01) 47-9

[7] Zhang H, Peh L S, Wang Y 2013 Study on Flood-fill Algorithm Used in Micromouse Solving Maze *Applied Mechanics and Materials* 599-601 1981-4

[8] He S-B, Sun K-H 2012 Design and Optimization of Micro-mouse Solving the Maze Algorithm Based on Central Method *Computer Systems & Applications* (09) 79-82

[9] Bo E, Yu Y 2011 Design and Implementation of Micromouse Based on STM32 [J] *Value Engineering* (20) 136-7

[10] Qiu Z, Li A, Zhang W 2013 Design of Micromouse System based on ARM and FPGA *Instrumentation Analysis Monitoring* (02) 88-91

[11] Zhang H, Peh L S, Wang Y 2013 Calibrate the turning of micromouse *Advanced Materials Research* 971-973 1088-91

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