An overall scheme design and application of a wheeled robot for martial arts challenge competition

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Abstract. With the rapid development of artificial intelligence, driven by the government’s strong support and the transformation and upgrading of traditional industries, the research on robot continues to gain popularity, and robot competitions are attracting more and more attention. In this study, an overall scheme design of a wheeled robot for martial arts challenge competition is introduced. It had been successfully applied in the robot competition of colleges and universities in Jilin province of China in 2018 and the robot fighting competition of the world in 2018. The author achieved good ranks. This shows that the scheme has strong operability.

1. Introduction
In recent years, with the country’s strong support for the robot industry and active encouragement for college students’ innovative practices in China, robot competitions have attracted more and more attention from all sides [1]. Among them, martial arts challenge competition, as an adversarial robot competition, attracts more and more people to participate because of its ornamental and interesting. The main aim of the competition is to promote the spread of intelligent robotics. Teams need to fight each other within the rules with their own self-assembled or homemade robots, and try to win the competition, in the form of adversarial competition to promote the popularity and development of related robotics technology in universities.

2. Competition rules and scoring standards
The robot needs to independently climb onto the 60mm high competition arena, find the opponent in the square arena by using different control methods, and attack each other with the executors allowed by the rules, so as to knock down the opponent (for the humanoid robot) or knock the opponent out of the arena (for the wheeled robot). In this process, if the robot falls down or is pushed out of the arena by the opponent, the robot needs to independently identify, find and board the arena to continue the competition.

The scoring criteria are as follows: (1) When the referee blows the whistle, the participants must start the robot in a non-contact way, such as the photoelectric switch. Otherwise, you need to give your opponent 1 point for every touch of your robot. (2) The robot must start from the starting area below the arena and climb into the arena from any place (no ramp). If one party takes the stage and the other party does not complete the stage within 10 seconds, 1 point will be given to the former [2]. (3) During the competition, if a robot of either party falls out of the arena, it must climb into the arena from any position around the arena within 10 seconds to continue the competition. In addition, the participants are not allowed to touch their robots. If one side fails to take the stage after the 10 seconds verbal countdown, the other side gains 1 point, and then 1 point is awarded every 10 seconds until the robot reenters the arena [2]. (4) In the course of the competition, both parties can choose to restart the
robot. With the approval of the referee, the robot can be taken back to the starting area for restart. However, each restart will give the other party 3 points, and there is no limit on the number of restarts. Both sides fall out of the arena successively and neither score. More than 10 seconds after each party has dropped out of the arena, the referee gives a signal to the two parties to start again from their respective starting areas [2]. (5) The whole game is limited to two minutes.

3. Overall Scheme Design
According to the above competition rules and scoring standards, martial arts competition has a tight schedule and a fast rhythm, which requires a high level of robot self-staging technology, as well as a high level of robot defense and attack strategy. According to the author’s practical experience in robot competition, this paper introduces an overall scheme design with strong operability.

3.1 Overall Design Idea
The author’s martial arts challenge wheeled robot adopts a four-wheel drive structure, similar to the shape of a square box, and is equipped with 12 infrared sensors (8 photoelectric proximity sensors and 4 infrared ranging sensors) and 1 grayscale sensor. Among them, 8 photoelectric proximity sensors are divided into two groups, the first group of four, respectively, placed in the top level of the four vertices, and horizontal angled 45° angle downward sloping shape. A second group of four horizontal plane are placed in the robot chassis midpoint edge. The two groups of sensors work together and detect the edges and the states of being off the arena. Four infrared ranging sensors are placed at the center point of four edges on the horizontal surface of the top floor of the robot. They are used to detect the position of the enemy and the state under the platform. The grayscale sensor is placed in the center of the robot chassis for judging the robot’s own position and detecting the edge of the arena.

For the self-staging part, this scheme is designed to install four mechanical arms similar to the shape of a shovel in the front and rear directions of the robot as the supporting structure. Among them, the two front arms are mainly responsible for realizing the attack of the enemy and the auxiliary coordination, while the two rear arms are mainly responsible for helping the robot to take the stage.

In the actual martial arts competition process, first, the mechanical arm movement control can be realized by programming software. Secondly, the speed of the motor can be adjusted by programming software, and then the speed of the manipulator can be controlled. Finally, combined with the real-time monitoring results of the sensor, the robot can take the stage autonomously by programming software.

The actual robot designed and built according to the above overall scheme is shown in figure1.

![Figure 1. A picture of the robot used in the martial arts competition.](image-url)
wheel. Since most of the martial arts challenge wheeled robot competitions have relevant regulations on wheels, the author adopts the first way of thinking to complete the requirement of self-staging.

The specific method is as follows: firstly, four mechanical arms are installed in the vertical upward direction of the front and rear of the robot relative to the chassis. Each arm is controlled by a steering gear, which controls the rotation angle of the robot around the axis. Secondly, when the sensor detects that the front of the robot is an arena, the corresponding program drives the power supply to accelerate the impact of the robot forward. When the robot rushed to the edge of the arena, two front mechanical arms were put down by the steering gear, and then make its rotate 90°, lift the front wheel, separate the front fuselage. Thirdly, two rear mechanical arms were also put down by the steering gear, and then make its rotate 90°. The robot can successfully climb into the arena with the help of the rear wheel motor drive force and the support force of the two rear mechanical arms. Finally, the front and rear mechanical arms remain unchanged (figure 2).

(a) The robot accelerates to the front of the arena; (b): Put down the two front mechanical arms and lift the front wheel; (c): Put down the two rear mechanical arms and prop up the robot; (d): The robot takes the stage and keep its front and rear mechanical arms unchanged.

Figure 2. The robot takes the stage: (a)→(b)→(c)→(d).

Figure 3. Top view and number of sensors mounted on the robot.
3.2.2 Identification and positioning. For the convenience of understanding, the photoelectric proximity sensors and infrared ranging sensors are numbered 1, 2, 3, ..., 12. The specific situations are shown in figure 3.

(1) Edge detection of arena. The arena of martial arts challenge competition is a cube with the side length of 2400mm and the height of 60 mm (figure 4). The grayscale of the arena surface is from the outside four corners to the center and from pure black to pure white. The starting area is painted blue and yellow, and the robot can be launched from anywhere in the starting area. The ground is white, and there is a 200 mm wide black belt around the arena. There is a black square fence with a height of 500 mm around 700 mm from the site. There is a square red area in the center of the site, and a white “武” in the center of the area.

![Figure 4 A map of the martial arts challenge competition](image)

The robot can detect the gray value of the race platform surface through the grayscale sensor placed under the chassis, and determine its position in the arena by the photoelectric proximity sensor placed at the top angle and the middle point of the chassis edge, and monitor the distance between the robot body and the edge of the arena in real time.

Assuming that X is the threshold value detected by the photoelectric proximity sensor (the value range of X is between 500 and 1500 mm). When the detection result of the sensor is less than the X, it is denoted as a small value; when it is larger than the X, it is denoted as a large value. The edge detection strategy of the arena is shown in table 1.

| Plan | Photoelectric proximity sensor detection | Edge          |
|------|------------------------------------------|---------------|
| 1    | Small                                    | No.10         |
| 2    | Large                                    | No.11         |
| 3    | Small                                    | No.12         |
| 4    | Small                                    | /             |
| 5    | Large                                    | Front left    |
| 6    | Small                                    | Front right   |
| 7    | Large                                    |              |

Table 1. Edge detection strategy.

Table 2. Enemy target detection strategy.

| Plan | Photoelectric proximity sensor detection | Enemy          |
|------|------------------------------------------|----------------|
| 1    | Large                                    | No.2           |
| 2    | Small                                    | No.3           |
| 3    | Large                                    | No.4           |
| 4    | Small                                    | /              |
| 5    | Large                                    | Front          |
| 6    | Small                                    | Right          |
| 7    | Large                                    | Rear           |
| 8    | Small                                    | Left           |

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(1) Enemy target detection. Similar to the arena edge detection method, it is assumed that \( Y \) is the threshold value detected by the photoelectric proximity sensor (the value range of \( Y \) is between 30 and 150 mm). When the detection result of the sensor is less than the \( Y \), it is denoted as a small value; when it is larger than the \( Y \), it is denoted as a large value. The enemy target detection strategy is shown in table 2.

(2) Self-staging detection. According to the rules of the competition, if the robot accidentally falls out of the arena or is pushed out of the arena by the opponent, it needs to come to the stage within 10 seconds. Therefore, it is very important for the robot under the arena to accurately and quickly detect the front position of the arena [1]. Once the robot falls down or is pushed out of the arena by the enemy, the robot may appear in three types of positions. In combination with the competition venue (figure 4), the author proposes the following detection scheme for the robot to take the stage again:

(a) One side of the robot under the platform facing the arena. This situation can be detected by a photoelectric proximity sensor, and the principle is similar to that of arena edge detection method: it is assumed that \( Z_1 \) is the threshold value detected by the photoelectric proximity sensor (the value range of \( Z_1 \) is between 500 and 1500 mm); \( Z_2 \) is the threshold value detected by the infrared ranging sensor (the value range of \( Z_2 \) is between 100 and 250 mm). When the detection result of the sensor is less than the \( Z_1 \) or \( Z_2 \), it is denoted as a small value; when it is larger than the \( Z_1 \) or \( Z_2 \), it is denoted as a large value. The detection scheme is shown in table 3.

| Plan | Photoelectric proximity and infrared ranging sensor detection | Platform |
|------|-------------------------------------------------------------|----------|
| 1    | / Large Small Large Large Small Small Small Rear            |
| 2    | Large / Large Small Small Large Small Small Left             |
| 3    | Small Large / Large Small Small Large Small Large Front      |
| 4    | Large Small Large / Small Small Small Large Right            |

After finding the position of one side of the robot facing the arena in Table 3, the program can be called to adjust the orientation of the robot to face the arena (the robot faces the arena in front), and then the self-stage scheme described above can be adopted to quickly take the stage.

(b) One side of the robot under the platform facing the fence. This situation can be detected by two adjacent photoelectric proximity sensors, and the principle is the same as that of (a). The detection scheme is shown in table 4.

| Plan | Photoelectric proximity and infrared ranging sensor detection | Fence   |
|------|-------------------------------------------------------------|---------|
| 1    | / Large Large / Large Small Small Large Front left          |
| 2    | / / Large Large Large Small Large Small Front right         |
| 3    | Large / / Large Small Large Large Small Right rear           |
| 4    | Large Large / / Small Large Large Large Left rear            |

After finding the position of one side of the robot facing the fence in Table 4, the program can be called to adjust the orientation of the robot to face the arena (the robot faces the arena in front), and then the self-stage scheme described above can be adopted to quickly take the stage.

(c) One side of the robot under the platform is in the corner of the arena. This condition can be detected by three infrared ranging sensors, and the principle is the same as that of (a). The detection scheme is shown in table 5. After finding the orientation of one side of the robot facing the fence in Table 5, the program can be called to adjust the orientation of the robot to face the arena (the robot faces the arena in front), and then the self-stage scheme described above can be adopted to quickly take the stage.
Table 5. Self-staging detection strategy (The robot is in the corner of the arena).

| Plan | Infrared ranging sensor detection | Fence location |
|------|-----------------------------------|----------------|
|      | No.5                              | No.6           | No.7           | No.8           |
| 1    | Large                             | Large          | Small          | Large          | Front, left, right |
| 2    | Large                             | Large          | Large          | Small          | Front, right, rear |
| 3    | Large                             | Small          | Large          | Large          | Front, left, rear |
| 4    | Small                             | Large          | Large          | Large          | Right, left, rear |

3.3 Offensive and Defensive strategy

3.3.1 Offensive strategy. Because the martial arts competition has a certain fighting nature, and only by pushing the enemy target out of the arena can we score points, so it is very important to choose an effective attack plan [1]. Most of the existing martial arts challenge schemes adopt the frontal attack method of accelerating immediately after the discovery of the enemy. However, combined with the mechanical structure of the wheeled robot in martial arts challenge competition, the flank and rear of the robot are two obvious weaknesses [1]. First, once the flank of the robot is attacked by the enemy, part of the fuselage is likely to be suspended, the side wheel loses its grip, and it is difficult to turn, so it is unable to control the fuselage to move forward or backward in time, resulting in being pushed off the stage. Second, once the rear part of the robot is attacked by the enemy in the normal process of moving forward, the fuselage still keeps moving forward due to the influence of inertia, and it is easy to have difficulties in starting the retraction program in time, which is hindered greatly after starting. Therefore, in the actual competition, the author adopts the attack mode of attacking the flank and rear of the enemy robot. The specific operation is as follows: when the sensor detects that the robot is not located at the edge of the arena and finds the enemy target, it will try to circle to the side or rear of the opponent, and then push the enemy robot out of the arena. When the sensor detects that the robot is at the edge of the arena and there is an enemy target, it will fight back immediately.

3.3.2 Defensive strategy. The defensive strategy of robot martial arts challenge competition mainly includes two aspects: one is to avoid falling off the competition stage; the other is to avoid being attacked by the enemy. The former can adopt the arena edge detection scheme mentioned above, and realize it by detecting the arena edge with photoelectric proximity sensor. The latter is a combination of track retrieval and rotation defense, while taking care to avoid being hit by the enemy robot on the flank or rear of our robot. The specific implementation method is as follows: after the robot takes the stage, it moves with the arena edge detection as the highest priority and the tracking retrieval as the second priority. While detecting the edge, it moves along the track in the shape of “X” [4] to track and retrieve the enemy. If the presence of the enemy is detected, it will immediately spin quickly in place to escape the attack and look for the flank and rear of the enemy to attack.

3.4 Handling of Sudden Abnormal Situations

If the robot is accidentally pushed to the edge of the arena by enemy, and the half of the robot body is suspended (the wheels have not yet touched the ground), then the robot can be controlled by the front and rear mechanical arms to perform the push and support action or wheel steering action. If conditions permit, an additional tilt sensor can be placed around the robot chassis to detect the body tilt in real time.

Finally, the control logic diagram for the whole identification, positioning, attack and defense overall scheme design is shown in figure 5.
4. Application of Overall Scheme Design

According to the overall scheme design, the author first finished the martial arts contest with wheeled robot assembly and software programming, and then successively participated in the “Jilin Province Colleges and Universities Robot Competition” and the “World Robot Fighting Competition”, which were held in May 2018 in Changchun and in August 2018 in Beijing, respectively, and successively won the first prize at the provincial level (champion) and the national second prize. This shows that the design of the scheme has strong operability.

5. Conclusions

The author introduces the overall design of the wheeled robot for martial arts challenge competition in detail. This scheme has been applied to provincial and national robot martial arts challenge competitions, and the author finally achieved a good ranking, which proves that the design of this scheme has strong operability. The author hopes it will be helpful to the people who want to participate in such competitions in the future.

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7. References

[1] Chen H 2016 Research on Attack and Defense Control of Martial Arts Competition Robot Based on Kinodynamics (Zhengzhou: Zhengzhou University Press) p10-20
[2] Wang X, Xu X F and Jin C 2016 Electron. Technol. 10 69-70
[3] Zhang Y Q, Wang Y and Sun L 2017 J. Hebei Institute Architecture Civ. Eng. 35 114-117
[4] Li Z L, Zhou C, Dong G G, Guo X L and Deng B Z 2013 Microprocess. 34 63-65