Proceedings of the 4th International Conference on Computing and Data Science (CONF-CDS 2022)
DOI: 10.54254/2755-2721/2/20220574

Design Scheme of Intelligent Robot Based on Crawler Sports Chassis

Yifei Lyu

Xi'an Mingde Institute of Technology

1154151858@qq.com

Abstract. The chassis structure design of mobile robots is currently separated into four categories: wheel type, mechanical leg type, McNair wheel type, compound type, and crawler type, with wheel leg type, common crawler type, and wheel crawler type being under compound type. A formula Complex application scenarios frequently limit the robot's passibility throughout the actual application process. A new robot design plan is offered to overcome this problem: an intelligent robot built on a crawler-type moving chassis. To achieve the robot's astute observation of the surrounding environment, the advantages of wheeled and legged robots will be organically merged, and intelligent control terminals will be included in the hardware design. The mechanical framework will be built on a traditional crawler chassis, with leg guiding added. The crawler actuator of the structure will drive the crawler actuator of the leg-guided design to enable the robot to get out of problems in the face of challenging terrain conditions such as stairs, steps, and steep slopes. This work proposes an intelligent robot design strategy based on crawler motion chassis with high practicability, novelty, and broad applicability.

Keywords: crawler sports chassis, intelligent robot, wheeled, legged, robot chassis

1. Introduction

The adaptability of robots to the environment is constantly improving as the robot industry expands and develops, principally reflected in the structural design of the robot motion chassis. The first robot motion chassis was mainly fixed and could only rotate 360 degrees. The robot's mobility in the horizontal direction is zero for the rotation function. Still, it is reliable and primarily employed in positions with high reliability and fixed requirements, such as automobile manufacturing plants, assembly-line plants, and steel plants. Robots with revised chassis can no longer match current needs due to the advancement of industrial intelligence and the rapid development of the logistics industry. This paper proposes a new robot design scheme based on a crawler-type moving chassis after a comprehensive analysis and investigation with the above robots with moving chassis. Besides adding an infrared camera to perceive the surrounding environment, the robot can process the recognized image and then realize the function of intelligent obstacle avoidance; simultaneously, in the face of complex terrain, the robot can drive the crawler-type moving chassis.

2. Literature review

The robot with a wheeled chassis structure has the advantages of a simple design, high efficiency, and ease of maintenance. Still, its poor adaptability to different working environments limits its scope of

© 2025 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

DOI: 10.54254/2755-2721/2/20220574

application. In contrast, the robot with a mechanical leg chassis structure can adapt to different working environments, such as the Big Dog quadruped intelligent transport robot developed by Boston Dynamics for the US military, the robot's mechanical legs imitate the human legs [1]. The basic framework of the robot can be maintained constant throughout mobility, allowing it to assist US forces in having weapons and equipment, transporting supplies, and carrying injured people during combat [2]. Robots with mechanical leg chassis structures, unlike traditional wheeled robots, can adjust to diverse terrain conditions and have superior passability and flexibility. On its head is a pair of robotic arms that the operator may control remotely to achieve flexible manipulation of the target object. The existing mechanical leg-type chassis design, on the other hand, has the disadvantages of a complex procedure, a high failure rate, and poor stability, all of which are difficult to achieve in a short amount of time—promotion from within[3].



Figure 1. Intelligent robot designed by Boston company [(1) Mechanical structure diagram of Big Dog; (2) SpotMini quadruped robot].

Figure 1 shows that the number of robots created using the Mecanum wheel chassis structure has gradually increased in recent years, owing to the omnidirectional dynamic benefits of the Mecanum wheel, such as omnidirectional mobile platform robots. The Mecanum wheel, conceived in 1973 by Swedish engineer Bengt Ilon, comprises a set of congruent rollers results of a systematic around the wheel body. The rotation of the generatrix forms the surface of each roller, and there is a specific angle between its axis b and the wheel axis a, which is often +45° or -45°. A separate motor drives each Mecanum wheel, and the torque provided by the engine can be communicated to the ground through the Mecanum wheel to give the vehicle. It gives the three degrees of freedom required for omnidirectional motion on the surface [3].

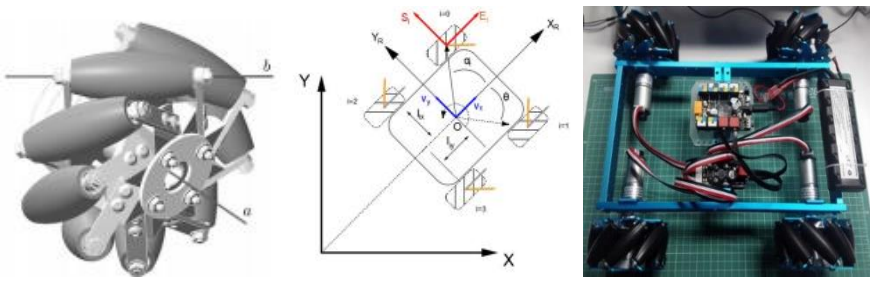


Figure 2. Omnidirectional mobile platform robot designed with Mecanum wheel chassis structure.

Figure 2 shows that the omnidirectional mobile platform robot uses a four-wheel independent Mecanum chassis configuration, as shown in Figure 2. This arrangement means that each wheel has its driving power, allowing the movable platform to alter its position in response to the present surroundings. Each wheel's landing spot can create a rectangle. The constraint equation of the platform motion state can be determined by studying the motion state of each side of the rectangle. To determine the driving force supplied to each wheel, plug the goal point into the constraint equation. This will allow the mobile platform to travel all around and quickly. Because the Mecanum wheel comprises numerous separate rollers, its load capacity is restricted, and it cannot meet the demands of high-load applications [4].

The advantages of wheeled and legged robots can be spontaneously combined when a robot is constructed with a crawler chassis configuration. Heavy vehicles, such as tanks, excavators, and unique robots, typically use the crawler chassis framework. It has a straightforward structure that is simple to maintain. And it has the characteristics of a variety of applications. Still, in the face of complex terrain

DOI: 10.54254/2755-2721/2/20220574

conditions, such as stairs, steps, and steep slopes, it cannot be changed due to its fixed crawler design, and there is a situation of underpinning and slipping, so the crawler type must be adjusted. The motion chassis must be rebuilt, and the robot must be equipped with an intelligent controller. The robot can make adjustments independently in different types of geographical conditions. The structural design is shown in Figure 3.

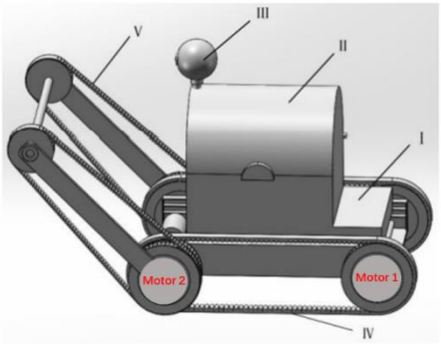


Figure 3. Design scheme of intelligent robot based on crawler sports chassis.

ZDI is the main structure of the crawler robot, which mainly includes the motor for driving the crawler, the motor controller, the main control chip, the GPRS wireless communication part, and the power supply part; II is the load module of the crawler robot, which can be used to load objects or machinery Arm; III is the visual perception and ultrasonic module of the crawler robot, which can perceive the environment around the robot, detect obstacles in time and determine its position coordinates; IV and V are crawler-type mobile mechanisms, which are driven by two independent motors [5,6]. When the same pulse drive is applied, the robot can move forward or backward in a straight line, and when different pulse drives are used, the robot can move in a curve. When the drive motor is driven with opposite pulses, the robot will rotate around a fixed axis. The above three motion forms can meet the motion requirements of the robot in any situation. V is a crawler actuator with a leg-guided structure driven by the motor 2. It can rotate 360 degrees in the face of special terrain conditions, providing sufficient power for the robot to get out of trouble and overcome obstacles.

3. Methodology

The research method used in this paper is a hybrid of literature research and case study research. Based on a review of the literature on mobile robot chassis structure design, it is concluded that the current robot chassis structure design has flaws such as complex construction, low efficiency, and limited application scope. Defects, re-design the crawler-type sports chassis structure, offer an intelligent robot design scheme based on the crawler-type sports chassis, assess the first-order and second-order obstacles that the robot must overcome, and suggest a crawler actuator with a leg-guided structure. The proposed robot design method, as demonstrated by the example analysis, allows the created robot to overcome both the first-order and second-order obstacles.

4. Discussion

The total capacity of the robot to get out of problems and overcome obstacles is tied to the design of the crawler actuator of the leg-guided structure. Therefore, it is necessary to model and analyze the crawler actuator with leg guide structure,When the robot faces first-order obstacles,the height of obstacle is h, unit is mm, which is the Angle formed by the crawler actuator of the leg guide structure and the contact ground. The driving wheel O_2 of the crawler actuator of the leg-guided structure, the radius is r_1, unit is mm, Its structural analysis diagram is shown in Figure4.

DOI: 10.54254/2755-2721/2/20220574

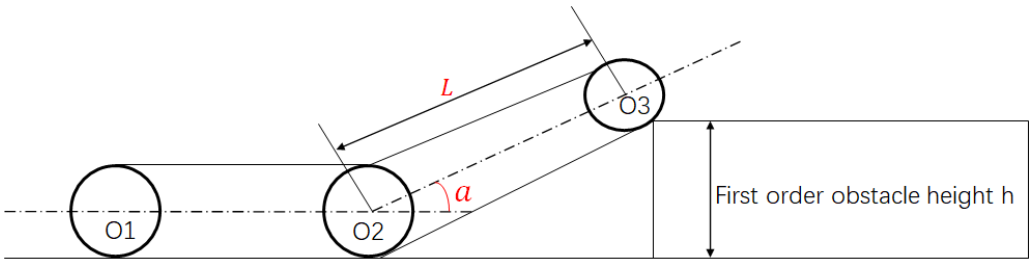


Figure 4. Analysis of the structure of the robot to overcome obstacles: when the first-order obstacle.

When the robot escapes from a first-order obstacle, the crawler actuator and obstacle height of the leg-guided structure need to meet:

$$LO_2O_3 * sina \geq h - r_1$$

The hurdles that robots will meet in their practical use will have multi-order characteristics [7]. As a result, multi-order modeling analysis is necessary to establish the passage parameters of intelligent robots based on crawler-type moving chassis when faced with multi-order obstacles.

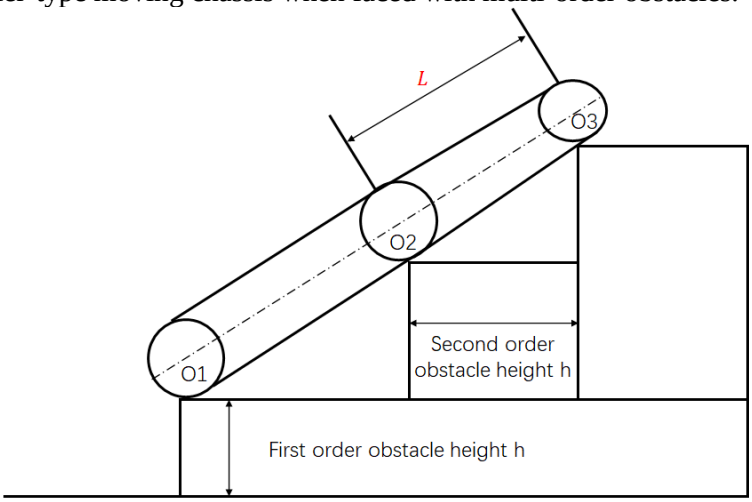


Figure 5. Structural analysis of robot obstacle crossing: when multi-order obstacles.

When confronted with multi-order obstacles, the robot must ensure that its center of gravity may traverse the junction of the second-order obstacle and the first-order obstacle, with the key condition of the robot's center of gravity being exactly on the angle of the second-order obstacle. The robot's center of gravity objects corresponds to and is the width of the second-order obstacle in G. In the Figure 5 , O_2 and G conincided, w is the width of the second-order obstacle O_2 . Crossing the critical condition of second order obstacle, the crawler actuator of the robot's leg-guided structure must be in touch with the edge of the second-order obstacle at least once during the essential condition of passing the second-order obstacle. so the robot The overall length and the length of the crawler actuator of the leg guide structure need to satisfy the following relationship:

$$L_{O_1O_2} + L_{O2G} \geq \sqrt{h^2 + w^2}$$

$$L_{GO_3} \geq \sqrt{h^2 + w^2}$$

By merging the image returned by the camera and the information produced by the ultrasonic sensor, the intelligent robot built in this study can identify and analyze impediments. The main procedure is to apply grayscale transformation and binarization to the data provided by the camera, then extract the picture information gained, and then use the region expanding algorithm to remove the obstacle

DOI: 10.54254/2755-2721/2/20220574

information detected by the ultrasonic sensor, and finally obtain the robot: the height, width, and distance between the robot and the surrounding obstacles.



Figure 6. Original image and region growing image.

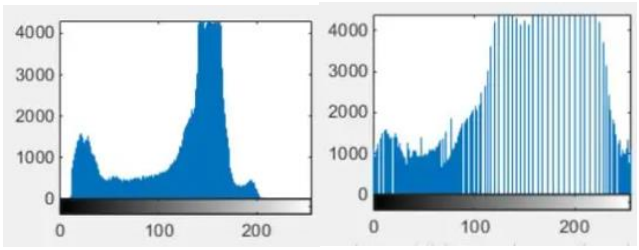


Figure 7. The image after binarization.

The ultrasonic sensor's only job as an auxiliary sensor is to measure the distance between the robot and the obstacle and then communicate that information back [8]. To determine the distance between the robot and the obstacle, the robot will compare the measured distance information with the focal length of the camera. The true height and width of the obstacle can be retrieved by bringing the size of the obstacle into the feature function of the region expanding image. The actual application scene is shown in Figure 8.

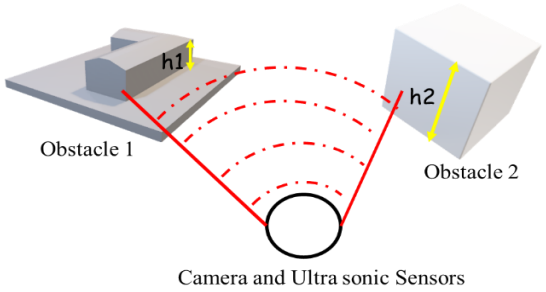


Figure 8. Robot intelligent perception application scenarios.

The ultrasonic sensor data , as shown in the application scenario of perception in Figure 8, the camera and the ultrasonic sensor will sample and measure the surrounding obstacles respectively, $h_1, h_2, h_3 \cdots \cdot\cdot h_n$and extract ma sample point in the height direction of each obstacle, and each sample obtained The horizontal distance between the point and the camera $L(n,m)$, and then calculate the measured height value and the corresponding average horizontal distance $L_{\text{average}}(n)$. When the robot obtains the average horizontal distance and the height value of the nearest horizontal distance direction, it will judge whether the obstacle's height in the most immediate direction meets the Obstacle crossing conditions. If it is completed, the robot will adjust the crawler actuator of the leg-guided structure according to the obstacle's height and then overcome the obstacle. The obstacle crossing condition of the first-order obstacle conforms to the following constraint equations, where $\delta$is the measurement error in the height direction :

DOI: 10.54254/2755-2721/2/20220574

$$\begin{cases} \left||L(i,1)-L(i,2)|\right| \le \delta; \\ ||L(i,2)-L(i,3)|| \le \delta \\ \vdots \\ ||L(i,j)-L(i,j+1)|| \le \delta \\ \vdots \\ ||L(i,m-1)-L(i,m)|| \le \delta \\ i = 1,2,\cdots,n \end{cases}$$

When facing a multi-step obstacle, the difference between the horizontal distances is used to determine whether the obstacle has multiple steps. If the difference between the horizontal distances of the two measurement surfaces is numgreater than the threshold f, there is a multi-step obstacle. The height difference of the object is used to adjust the crawler actuator of the leg-guided structure to achieve obstacle crossing. The obstacle crossing conditions of multi-order obstacles conform to the following constraint equations, where $\varepsilon$is the measurement error in the height direction, and the $f$threshold is set for the system:

$$\begin{cases} if \left||L_{average}(i)-L_{average}(j)\right| \ge \varepsilon,\ num = num+1 \\ i = 1,2,\cdots,n; j = i+1; \\ if\ num \ge f \end{cases}$$

5. Conclusion

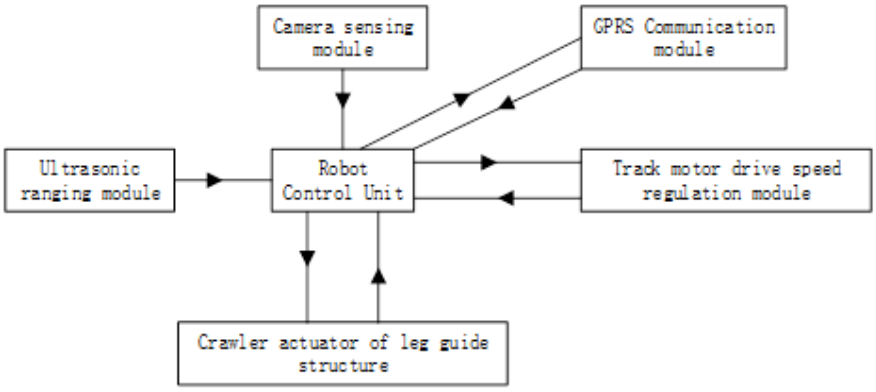


Figure 9. Design of the overall frame of the intelligent robot based on the crawler sports chassi.

The camera perception module, G PRS wireless communication module, robot main control board, crawler motor drive speed regulation module, ultrasonic ranging module, and crawler actuator with leg guiding structure make up the intelligent robot based on crawler motion chassis. Through the G PRS communication module, the robot may upload numerous measurement parameters to the remote control console. At the same time, the staff can use the remote control terminal to send various commands to the robot and then control each of the robot's motors to drive the speed regulation module. When the robot cannot leave, the staff can alter the angle of the leg-guided structure's crawler actuator and the motor's driving current to aid the robot's escape.

References

[1] T. Masuda, H. Kimura and K. Takase. Emergence of a quadru- ped bound gait as interactiona-mong the brain, body and envi- ronment, SICE Annual Conference, Tokyo, 20-22 August 2008:2501-2506.

[2] Wan Tao. Boston Dynamics officially launched the wheel-legged robot Handle[J]. Big Data Era, 2017(2):72.

DOI: 10.54254/2755-2721/2/20220574

[3] Liu Jingyun . From Big Dog to Spot Mini: Evolutionary History of Boston Dynamics Quadruped Robot [J]. Robot Industry, 2018(2):109-116.
[4] Fang Dianjun , Lu Yanting, Shen Jianing. Research on the control method of omnidirectional AGV mobile platform based on Mecanum wheel [J]. Logistics Technology, 2019,38(5):62-65,116.
[5] Li Sheng & Wu Yifei.(2007). The Application of GPRS in Robot Remote Control. Microcomputer Information (08), 239-240.
[6] Wu Changzhong,Ge Fan,Shang Guangchao,Guo Hengshuai,Wu Liang,Zhao Mingpeng & Wang Guitao.(2021).Research on Visual Perception of Intelligent Robots Based on ADMS. Journal of Physics: Conference Series(2). doi:10.1088/1742-6596/1748/2/022005.
[7] (2020).Robotics; Findings from Cornell University Update Understanding of eRobotics (Plath Planning Under Malicious Injections and Removals of PerceivedObstacles: a Probabilistic Programming Approach). Computer Technology Journal.
[8] Azeta Joseph,Bolu Christian,Hinvi Daniel & Abioye Abiodun A.(2019).Obstacle detection using ultrasonic sensor for a mobile robot. IOP Conference Series: Materials Science and Engineering. doi:10.1088/1757-899x/707/1/012012.