Study on the Obstacle Crossing Dynamics of a Leg-wheeled Mine Rescue Robot

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Abstract

Aiming at the movement requirements of mobile robots in complex environments, a six-legged robot is proposed. First, a robot structure with front and rear leg expansion and contraction functions is designed and the characteristics of the structure are described. Secondly, stepped obstacles are selected as the research objects, and the whole obstacle movement process is analyzed. The control flow chart is drawn according to the movement process, and the obstacle height formula of the robot is given. Then establish the dynamics model of the robot, including the dynamics of the front body, the dynamics of the entire obstacle-absorption process and the contact dynamics between the wheel and the ground. Finally, the feasibility of obstacle avoidance was verified by simulation, and the curve of wheel position and contact force was obtained.

Keywords

Six-wheel-leg hybrid mobile robot; obstacle negotiation; structural design; dynamic.

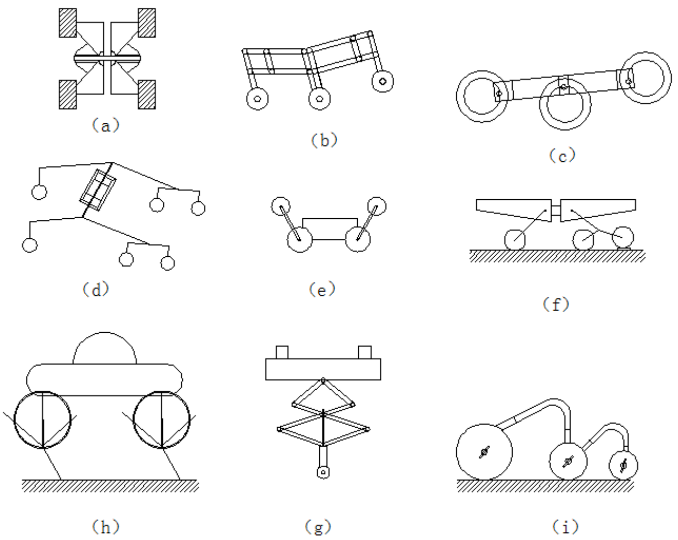
1. Introduction

Common mobile robot motion mechanisms can be divided into three types: wheel, leg and track . Wheeled, legged, and crawler styles all have their own unique advantages, and there are obvious deficiencies. The composite moving mechanism not only retains the advantages of a single structure, but also eliminates the deficiency of a single structure to the greatest extent. The leg wheel combined mobile robot combines the advantages of the leg and wheeled robots. It has the advantages of strong terrain adaptability and flexible movement of the leg mechanism, and has the advantages of high speed, high efficiency and good mobility of the wheel mechanism, so the legs The wheeled composite robot has received great attention and has produced numerous research results. In this paper, a new type of leg-wheel compound mine rescue robot is designed and named as Mine-Titan for the movement requirements of rescue robots in complex mine environments. The Mine-Titan robot has retractable front and rear legs that can span most of the Common obstacles in mine roadways have good adaptability to mine topography.

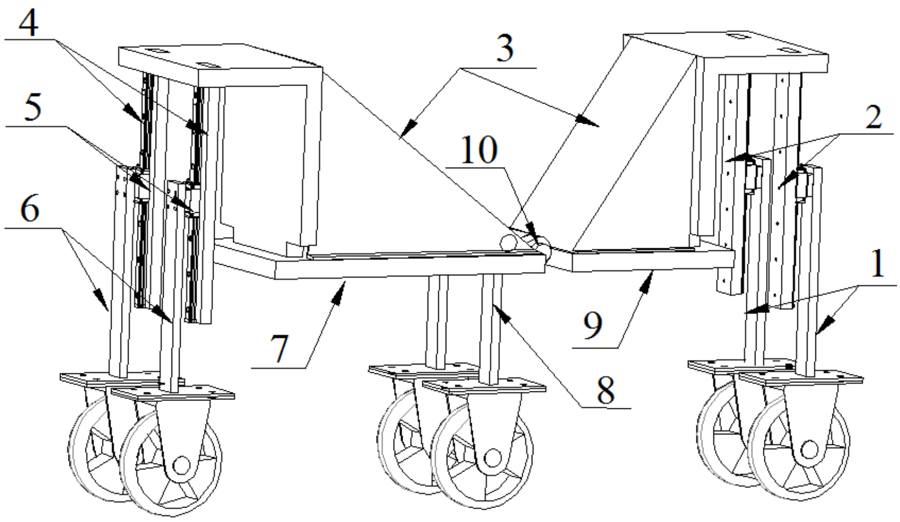
2. Robot structure design

The design of the mechanism is one of the key technologies of the obstacle-obstacle robot. At present, the typical mechanism of the wheel-legged obstacle-obstacle robot is shown in Figure 1.

The structural design is a fusion of the quadrilateral mechanism and the telescopic leg structure, so that the wheel-leg composite robot has a waist rotation and a leg telescopic function, mainly by the front wheel leg, the front car body, the rear car body, and the rear wheel. The legs, the middle wheel legs, etc., as shown in Figure 2.



(a) Telescopic leg chassis mechanism (b) Parallelogram mechanism
(c) Eccentric wheel mechanism(d) Forearm rocker mechanism
(f) Leg separation mechanism (g) Variable width wheel mechanism
(h) Based on the obstacle-bar type (g) telescopic leg mechanism (i) rocker bogie mechanism
Figure 1 Typical mechanism of a wheel-legged obstacle-obstacle robot



1. Front wheel movable leg 2. Front wheel fixed leg 3. Protective cover
4. Rear wheel fixed leg 5. Slider guide6. Rear wheel movable leg 7. Rear body
8. Intermediate wheel leg 9. Front body 10. Car body rotating drive shaft
Figure 2 Wheel-leg composite robot structure

According to the structure and movement characteristics of the wheel-leg composite robot, the control flow chart of the whole obstacle crossing process of the robot can be drawn, as shown in Fig. 3.

Description:

The wheel-ground contact control is the need for coordinated adjustment between the wheel legs, and is also a prerequisite for accurate robot control in complex environments. The contact state of the wheel and the ground is used to detect the contact state, and the feedback of the contact force is a necessary condition for ensuring real-time control of the wheel and the ground.

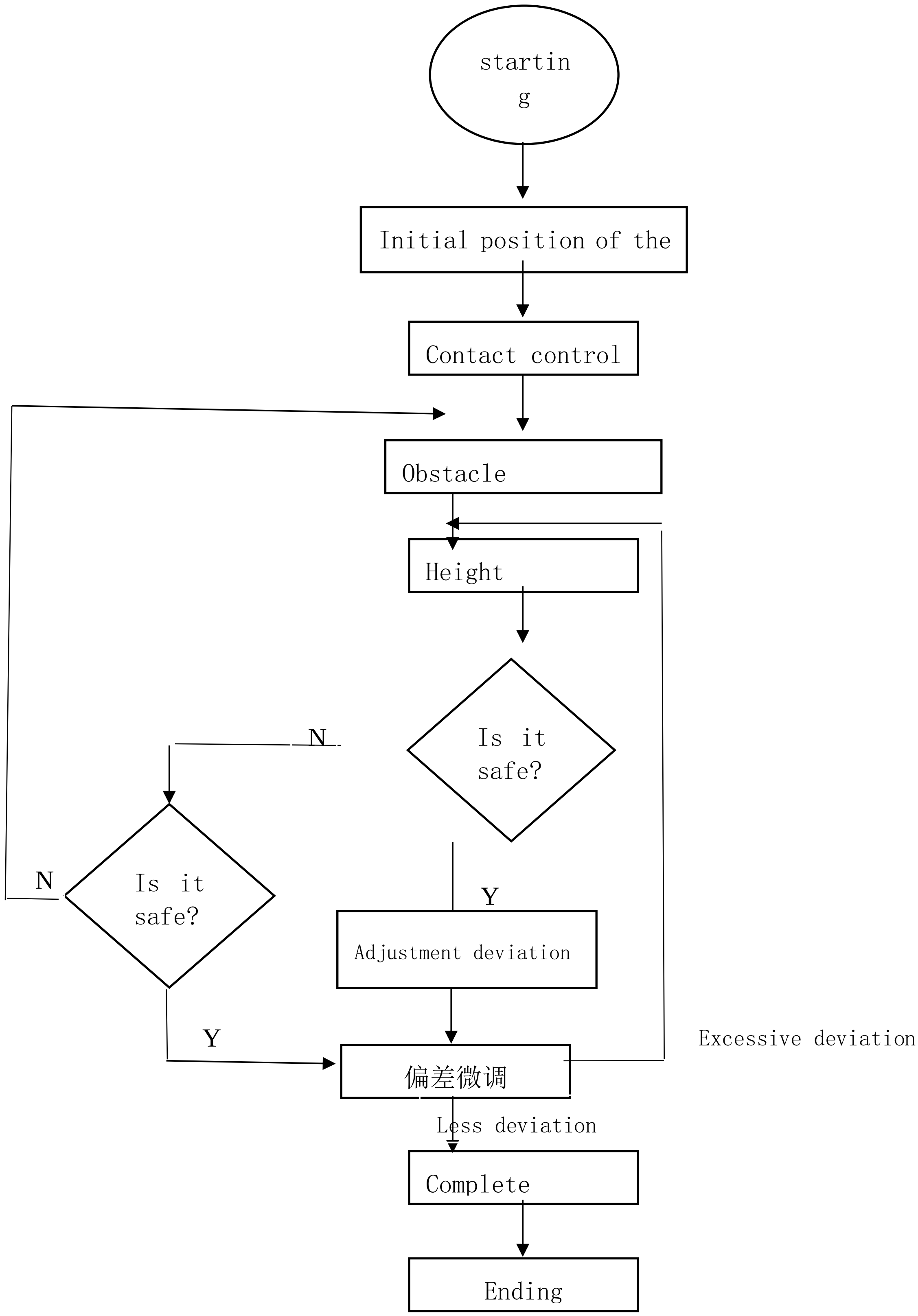


Figure 3 Cross-barrier process control flow chart

3. Simulation

The 3D model of the robot is built by Solidworks. The file is saved in parasolid (*x_t) format, and then imported into the ADAMS virtual prototype to establish the corresponding constraints and then simulate. The robot's entire obstacle-obscuring process time is set to 12s. Through the simulation and post-processing, the simulation animation and curve of the corresponding step obstacle are obtained. The obstacle process simulation is shown in Figure 4. In order to simplify the observation of the simulation model and the simulation process, the front and rear protective covers are removed during the simulation, and the steering problem of the vehicle body is not considered, and only the linear motion is analyzed, so parallel constraints are added to the vehicle body and the ground simulation.

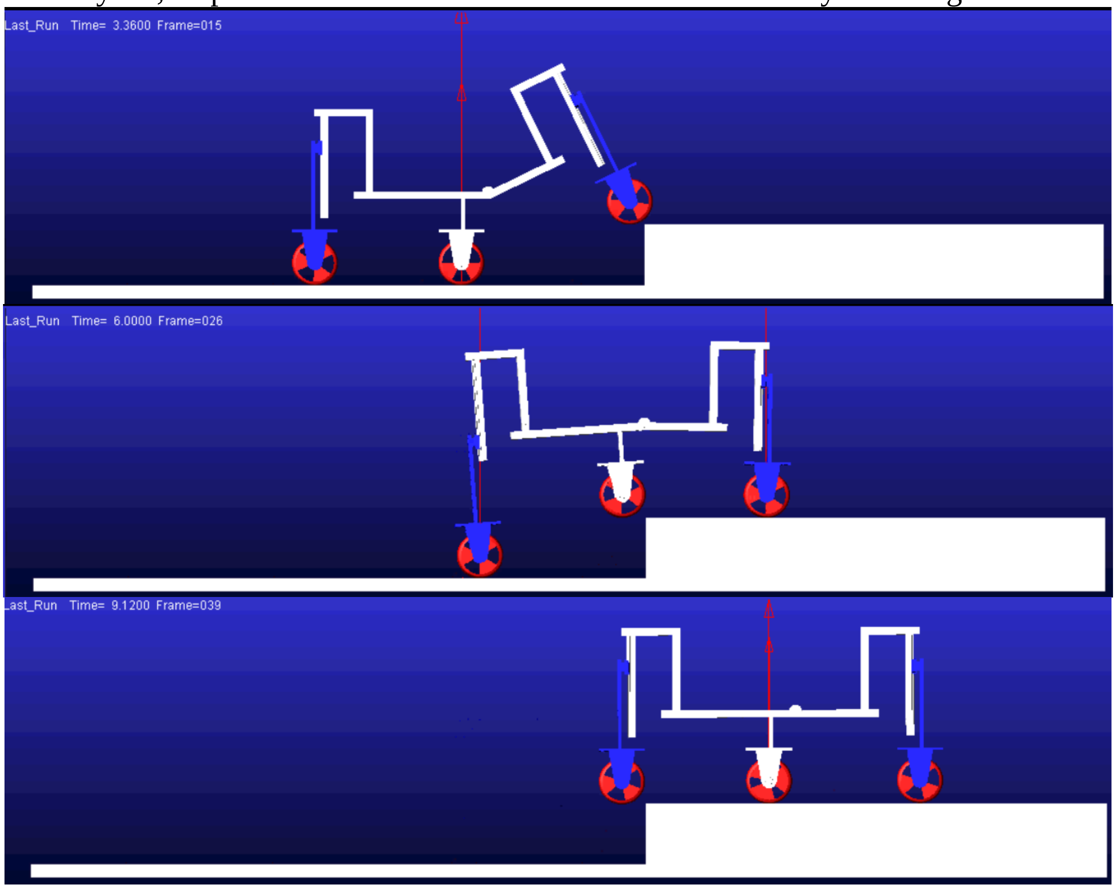


Figure 4 Stepped obstacle process simulation

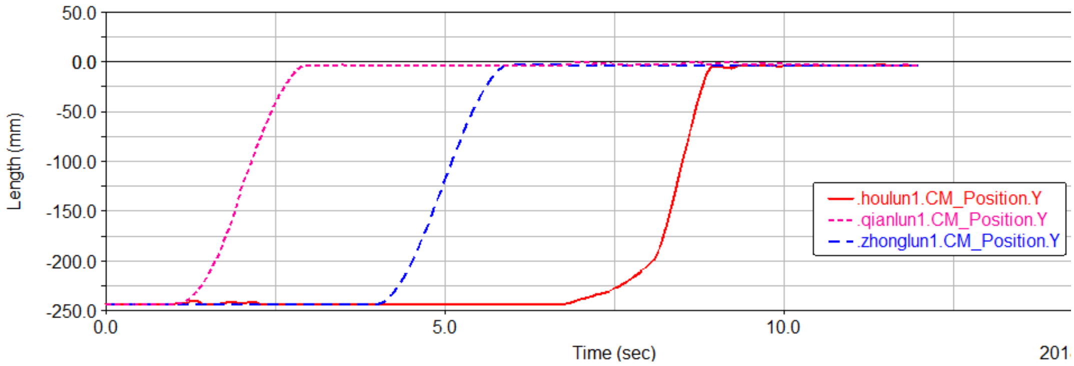


Fig.5 Curve of centroid position during the process of obstacles in the front, middle and rear of the three groups

According to Fig.5, the centroid position change curve during the wheel obstacle crossing process can be obtained. The whole simulation process time is set to 12s. When the robot travels to 1s, the front wheel starts to overcome obstacles. After the current wheel rises smoothly beyond the step height after 2s, it gradually contacts the upper end surface of the step, which means that the front wheel is over obstacle. With the approach of the middle wheel, the middle wheel began to overcome obstacles at 4s. After a steady rise of 2s, the middle wheel completed the obstacle. The robot continues to move forward. When the 7s is reached, the rear wheel begins to overcome obstacles. After 2 seconds, all the centroids of the whole robot are on the upper part of the step. As the robot advances, the entire obstacle process is successfully completed.

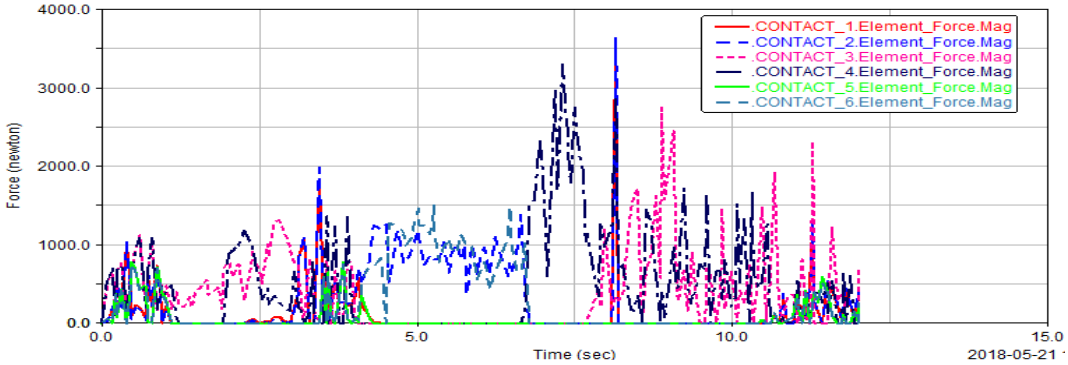


Figure 6 Contact force curve of six wheels and the ground

The ideal contact force curve of the six wheels and the ground, as shown in Figure 6. At the beginning of the robot, the contact forces of the six wheels with the ground are present, so keep in contact. Although the individual wheels are instantaneously free of ground forces due to vibration and shock, etc., the overall contact is in accordance with the contact force requirements during the movement. Specifically, it can be seen that when the first wheel reaches the obstacle, the front wheel starts to overcome the obstacle, and the contact force between the front wheel and the ground can be seen as zero in the figure, that is, no contact, and the duration is 2 s. Until the front wheel crosses the obstacle and re-contacts the ground here, the other wheels remain in good contact with the ground during this process. The situation of the middle and rear wheels is similar to that of the front wheels and will not be repeated.

4. Conclusion

In this paper, according to the obstacle-obstacle requirements of robots in unstructured complex environment, a cross-barrier robot with waist rotation and front and rear wheel leg extension functions is designed. The robot structure has the characteristics of increasing the barrier performance, reducing the impact of obstacles on the wheel, and increasing the stability of the obstacle. For further control research, the control flow chart in the process of obstacle crossing is drawn, and the real-time contact between the wheel and the ground is explained.

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