Structural Design and Dynamic Formulation of a Kind of Wheel-Legged Hybrid Robot

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Abstract

A six-legged compound robot is proposed for the movement requirements of mobile robots in complex environments. First, a robot structure with front and rear wheel leg telescopic functions was designed. Secondly, step obstacles are selected as the research object, and the whole process of obstacle crossing is analyzed. . Then the dynamic model of the robot is discussed, including the dynamics of the front body and the contact dynamics between the wheel and the ground.

Keywords

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

1. Introduction

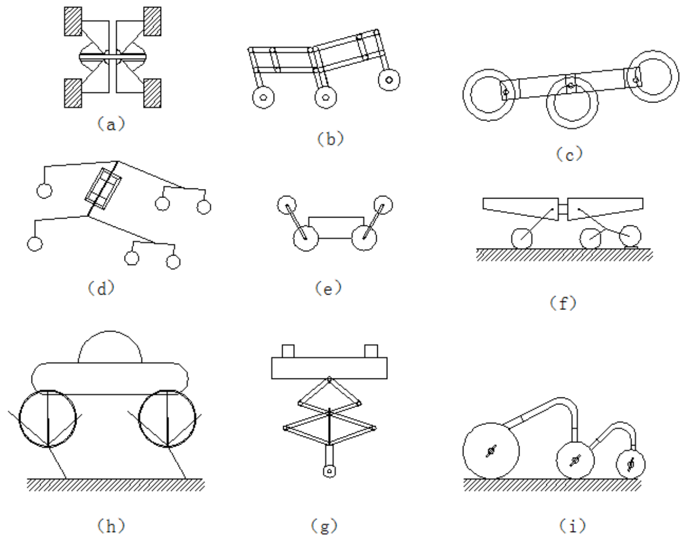
Mobile robots have the advantages of small size, light weight, low cost, good maneuverability and strong survivability. Most of them work in complex and varied field environments, and have very good application prospects in reconnaissance, patrol, search and rescue and detection. . With the development of society and the advancement of science and technology, the emergence and application of robots have brought tremendous changes to the world. With the increasing application of robots, robots are required to have high flexibility and adaptability to non-structural environments. Ability to complete specified tasks successfully and quickly. Mobile obstacle-obstacle robot is a comprehensive system integrating environment perception, dynamic decision-making and planning, behavior control and execution.

Based on the selection of the number of wheel legs, the stability of the two wheels is poor, the three-wheel type is easy to tip over, the four-wheel type off-road capability is limited and the wheel payload is poorly loaded. The six wheels can be adjusted according to the terrain up and down, suitable for walking in complex environments. The eight-wheeled control system is relatively complex . Considering the six-legged model as the number of legs in this design.

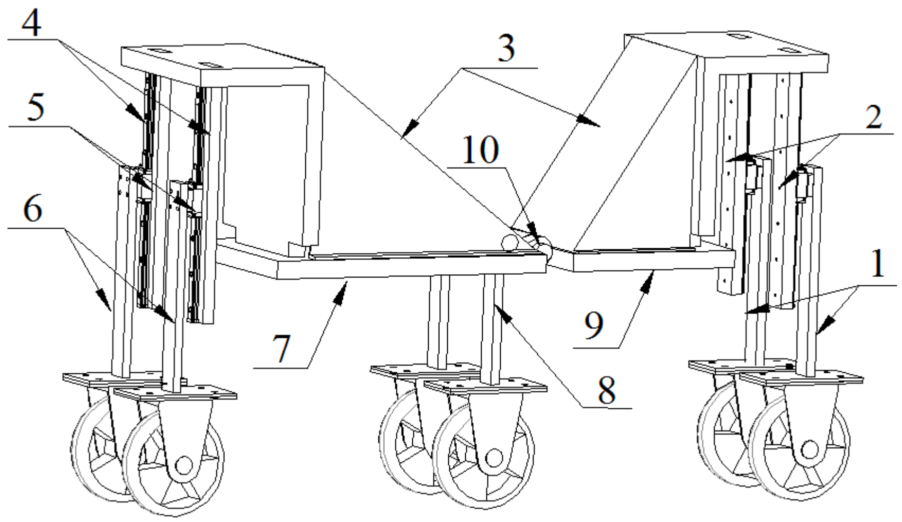
2. Robot Structure Design and Obstacle Crossing Process

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 guide 6. 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

3. Obstacle Process Description

The robot obstacle crossing process analysis is the basis of robot motion control and the basis of robot mechanism design.

The process analysis of this paper selects three typical obstacles: stepped obstacles, grooved obstacles, and sloped obstacles. The obstacle crossing process of the robot mainly relies on the coordination of the front and rear six wheel legs. Generally, it can be divided into three steps, namely, the front wheel obstacle obstacle, the middle wheel obstacle obstacle and the rear wheel obstacle obstacle. The following typical obstacles will be mentioned above. The process of obstacle crossing is detailed.

As the most representative obstacle, the height is often an important parameter to measure the obstacle-obstacle ability of the robot. It will be expressed in the next section, with the step as the object of the obstacle-obscuring process. The specific front wheel is the obstacle and the middle wheel. The obstacle crossing and the rear wheel obstacle crossing process are shown in Figure 3. When the current wheel approaches the obstacle, the front wheel slider drives the movable leg to contract and the rotation of the front body lifts the front wheel to the upper part of the obstacle, and the rear wheel and the intermediate wheel drive the robot to advance, as shown in Fig. 3(b); the middle wheel approaches the obstacle The rear wheel and the front wheel are extended, and the front body rotates back until the middle wheel passes over the obstacle, as shown in Figure 3(c); the front and rear wheels drive the robot forward, when the rear wheel approaches the obstacle, the rear wheel The legs are gradually contracted, the front and middle wheels are driven until the entire robot completely crosses the obstacle, as shown in Figure 3(d).

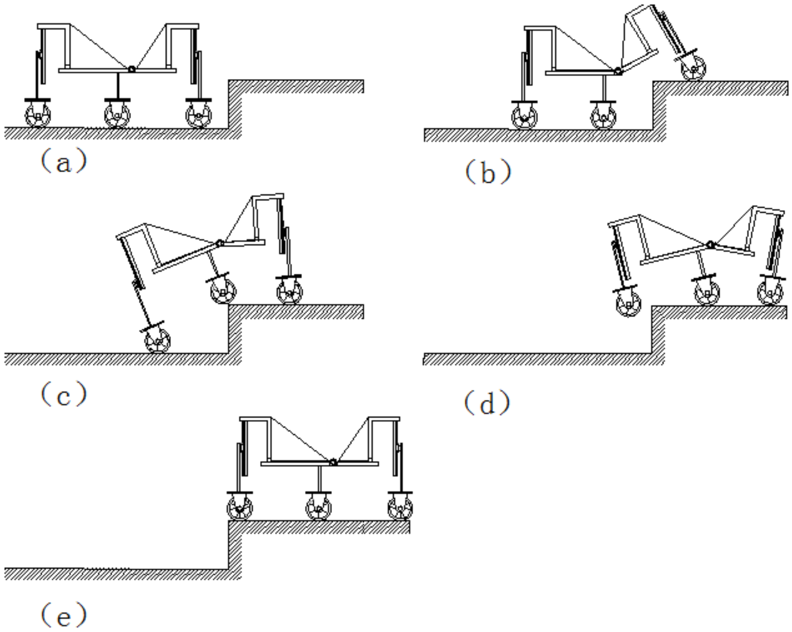


Figure 3. Stepped obstacle process diagram

4. Front Body Dynamics Modeling

The static analysis of the robot is only suitable for the analysis under steady state conditions, and is not suitable for the analysis of dynamic processes. Only the analysis of the dynamic process can determine the structural requirements of the robot and the motor power. In order to establish a more accurate control model and simulation of the robot, the dynamic model of the robot is needed, and only through the dynamic model can the simulation of the working condition of the robot be more realistic. In view of the complexity of the obstacle-obstacle process of the stepped obstacle, it is used as a research object to carry out specific obstacle analysis.

4.1 Front Car Body Obstacle Obstacle Dynamics Model

When the robot begins to overcome obstacles, the front body movement of the robot is mainly the rotation and the telescopic movement of the front wheel legs. After the car body is the base point, the dynamic model of the front body is obtained according to the Lagrangian dynamics, such as Figure 4 shows.

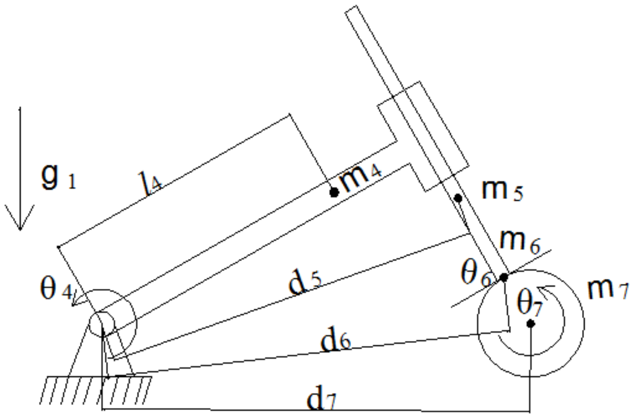


Figure 4. Front car body obstacle obstacle dynamics model

According to system kinetic energy:

$$T_i = \frac{1}{2}m_i(\dot{x_i}^2 + \dot{y_i}^2) + \frac{1}{2}I_4\dot{\theta}_4^2 \tag{1}$$

The kinetic energy of each component of the front body is as follows:

$$\begin{cases} T_4 = \frac{1}{2}m_4 l_4^2\dot{\theta}_4^2 + \frac{1}{2}I_4\dot{\theta}_4^2 \\ T_5 = \frac{1}{2}m_5\left(d_5^2\dot{\theta}_4^2 + \dot{d}_5^2\right) + \frac{1}{2}I_5\dot{\theta}_4^2 \\ T_6 = \frac{1}{2}\ m_6\left(d_6^2\dot{\theta}_4^2 + \dot{d}_6^2\right) +\ \frac{1}{2}I_6\dot{\theta}_4^2 \\ T_7 = \frac{1}{2}\ m_7\left(d_7^2\dot{\theta}_4^2 + \dot{d}_7^2\right) +\ \frac{1}{2}I_7\dot{\theta}_4^2 \end{cases} \tag{2}$$

Therefore, the total kinetic energy is:

$$T = \frac{1}{2}(m_4 l_4^2 + I_4 + m_5 d_5^2 + I_5 + m_6 d_6^2 + I_6 + I_7 + m_7 d_7^2)\dot{\theta}_4^2 \quad + \frac{1}{2}\left(m_5\dot{d}_5^2 + m_6\dot{d}_6^2 + m_7\dot{d}_7^2\right) \tag{3}$$

The potential energy of each component of the front body is as follows:

$$\begin{cases} \mu_4 = m_4 l_4 g_1 sin\theta_4 + m_4 l_4 g_1 \\ \mu_5 = m_5 d_5 g_1 sin\theta_4 + m_5 d_{5max} g_1 \\ \mu_6 = m_6 d_6 g_1 sin\theta_4 + m_6 d_{6max} g_1 \\ \mu_7 = m_7 d_7 g_1 sin\theta_4 + m_7 d_{7max} g_1 \end{cases} \tag{4}$$

Therefore, the total potential energy is:

$$\mu = g_1 sin\theta_4(m_4 l_4 + m_5 d_5 + m_6 d_6 + m_7 d_7) + g_1\ (m_4 l_4 + m_5 d_{5max} + m_6 d_{6max} + m_7 d_{7max}) \tag{5}$$

According to the equation:

$$\tau = \frac{d}{dt}\frac{\partial T}{\partial \dot{q}} - \frac{\partial T}{\partial q} + \frac{\partial \mu}{\partial q} \tag{6}$$

$$\frac{\partial T}{\partial \dot{q}} = \begin{bmatrix} (m_4 l_4^2 + I_4 + m_5 d_5^2 + I_5 + m_6 d_6^2 + I_6 + I_7 + m_7 d_7^2)\dot{\theta}_4 \\ m_5\dot{d}_5 \\ m_6\dot{d}_6 \\ m_7\dot{d}_7 \end{bmatrix} \tag{7}$$

$$\frac{\partial T}{\partial q} = \begin{bmatrix} 0 \\ m_5 d_5\dot{\theta}_4^2 \\ m_6 d_6\dot{\theta}_4^2 \\ m_7 d_7\dot{\theta}_4^2 \end{bmatrix} \tag{8}$$

$$\frac{\partial \mu}{\partial q}=\begin{bmatrix}(m_4l_4+m_5d_5+m_6d_6+m_7d_7)g_1cos\theta_4\\ m_5g_1sin\theta_4\\ m_6g_1sin\theta_4\\ m_7g_1sin\theta_4\end{bmatrix} \tag{9}$$

$$\tau=\begin{bmatrix}\tau_1\\ \tau_2\\ \tau_3\\ \tau_4\end{bmatrix}=\begin{bmatrix}(m_4l_4^2+I_4+m_5d_5^2+I_5+m_6d_6^2+I_6+I_7+m_7d_7^2)\ddot{\theta}_4\\ +(m_4l_4+m_5d_5+m_6d_6+m_7d_7)+(m_5d_5+m_6d_6+m_7d_7)g_1cos\theta_4\\ m_5\ddot{d}_5-m_5d_5\dot{\theta}_4^2+m_5g_1sin\theta_4\\ m_6\ddot{d}_6-m_6d_6\dot{\theta}_4^2+m_6g_1sin\theta_4\\ m_7\ddot{d}_7-m_7d_7\dot{\theta}_4^2+m_7g_1sin\theta_4\end{bmatrix} \tag{10}$$

In the above formula, τ is the moment, and I_4, I_5, I_6, I_7 are the inertia tensors of the members, respectively.

4.2 Contact Dynamics Between the Wheel and the Ground

When the wheel can not be in good contact with the ground, it will not only cause the instability of the entire vehicle body, but also cause energy loss. Therefore, the good contact between the wheel and the ground is the need of wheel-leg coordination in the configuration control process, and it is also a necessary condition for accurately estimating the terrain and ensuring real-time control of the wheel and the ground. The wheel drive motor is detected by the feedback of the wheel drive torque, and the wheel drive motor is set to the torque control mode. After a certain torque is applied, the contact force between the wheel and the ground is measured to determine the contact situation of the wheel.

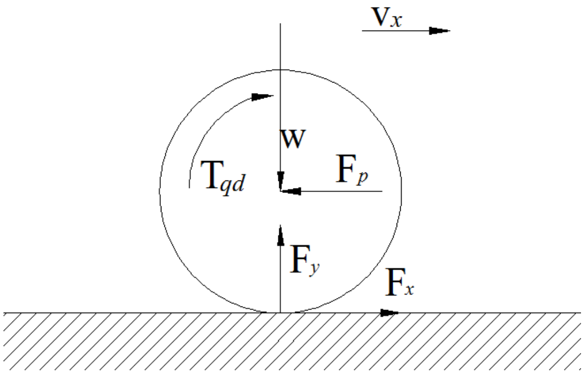


Figure 5. Force diagram of contact between the wheel and the ground

According to Figure 5, the dynamics of the wheel in contact with the ground can be obtained:

$$\begin{cases}F_x+F_p=ma_x\\ F_y+w+mg=ma_y\\ T_{qd}+M_R=j\alpha\end{cases} \tag{11}$$

Where F_y, F_x, M_R are the vertical force, horizontal force and moment of the ground-to-wheel, respectively, , w, F_p, T_{qd}d are the vertical load, horizontal load and driving torque of the drive shaft acting on the wheel, respectively, m is the drive The mass of the wheel, the moment of inertia of the j -drive wheel, a_x is the horizontal translational acceleration of the drive wheel, the vertical translational acceleration of thea_y drive wheel, and α is the angular acceleration of the drive wheel.

5. Conclusion

A six-legged composite mobile robot that can adapt to complex environments is studied. Through the structural design and process control flow of the obstacle-obstacle robot, and then the wheel-leg composite obstacle is established. The process dynamics model can be used to obtain the data of the driving torque and center of gravity required by the robot in the process of obstacle crossing. It provides a theoretical basis for determining the control of the robotic obstacle crossing process, and also finds some shortcomings for subsequent research. Provide ideas.

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