Modeling and Simulation of a Six-leg-wheel Hybrid Mobile Robot Based on ADAMS

Yanjie Li 1, 2, a, Zhenwei Wu 2,b

1 School of Mechanical Engineering, Shenyang Ligong University, Shenyang, China
2 State Key Laboratory of Robotics, Shenyang Institute of Automation, Chinese Academy of Sciences, Shenyang, China
a lyjsyt@sina.com, b zwwu@sia.cn

Keywords: six-leg-wheel hybrid mobile robot, dynamic modelling, dynamic simulation

Abstract. The dynamic modeling of a six-leg-wheel hybrid mobile robot was built using ADAMS software in this paper. Using the ADAMS model, the kinematic simulation, including the displacement, velocity and acceleration of each part of the robot, can be carried out and the dynamic simulation, including driving torque of joints, contact force and torque between the wheels with ground and the ability of obstacle negotiation, can also be achieved. The simulation examples were presented. The simulation analyses provide the theory basis for the design of the robot control system based on dynamics.

Introduction

Leg-wheel hybrid robot has been a hot topic in the research field of mobile robot recently. Compared with the other kind of mobile robots, such as wheel-based mobile robot, biped robot, the leg-wheel hybrid robot has the reconfiguration ability, effective maneuverability and good application prospect in the hazard environment. The dynamic modeling of the mobile robot is the basement of realizing the complex control algorithm.

The mobile mechanism of the six-leg-wheel hybrid robot has the characteristic of multi-joints, multi-configuration and can adapt to multi-kinds of terrain. The kinematic and dynamic model is relatively complex. The dynamic modeling of the six-leg-wheel hybrid robot was built using the software ADAMS in this paper. The simulation can fulfill the kinematic and dynamic simulation analyses of the robot under several kinds of road condition and simulation of the climbing obstacle capability of the robot.

The ADAMS Modeling of the Six-Leg-Wheel Hybrid Robot

The mechanical structure of the six-leg-wheel hybrid robot consists of a shaft, 6 swing legs and 6 wheels. The mobile structure is lateral symmetry. The three groups of leg-wheel mechanism are installed in lateral. The wheels are connected with the shaft by swing legs. The legs and wheels are driven individually. Adjusting the configuration of the robot using swing legs, the robot can improve its maneuverability and its terrain traversability.

The 3D simulation modeling of the six-leg-wheel hybrid robot was built using ADAMS software. The parameters of the modeling are listed as follows: the net mass of the robot is 60kg; the dimension is 1610 mm×660 mm×700 mm; the radius of the wheel is 230mm; the length of the legs is 260mm; the distance between the joints of the swing legs is 550mm; the width of the wheels is 80mm; the lateral distance between the wheels is 500mm; the height of the shaft is 300mm. The dimension of the model and the mass of the parts are set according to the parameters of the principle prototype. The 3D model of the leg-wheel hybrid robot is shown in Figure 1.
In the proceeding of modeling, the motion function is applied on each rotary joint to replace the real motor and then the model can be simplified under the premise of achieving all the function of the robot.

To simulate and analyze the climbing obstacle capability and motor torques of the robot, the step surface attached to the ground was built and the frictions between the wheels and the terrain were taken in count. The frictions on the rotary axes of the swing legs were relatively small and were neglected.

The setting of the height of the step can be used to analyze the climbing obstacle capability of the robot. The setting of the static and dynamic factors can be used to simulate the different contact condition between the wheel and ground. The setting of the motion velocity of the wheels and swing legs can be used to simulate the motion of the joint motors.

**Dynamic Simulation of the Robot Using ADAMS**

Using the ADAMS simulation model of the six-leg-wheel hybrid robot, the dynamic analyses under different motion condition can be achieved. The motion conditions in the simulation shown in Figure 2 were listed as follows: the height of the step was 30mm, the static friction factor between the wheels and the terrain was 0.3, the dynamic friction factor was 0.1, the wheels rotate counter-clockwise, the angular velocity of all the wheels was $-30^\circ/s$ (The angular velocities are negative while the wheels or the swing legs rotate counter-clockwise). No motion was applied on each swing leg and the simulation time was 25s.

![3D Simulation Model of the six-leg-wheel hybrid robot](image)

**Figure 1 The 3D Simulation Model of the six-leg-wheel hybrid robot**

![Curves of position, velocity, and acceleration](image)

(a) The curves of the position, velocity, and acceleration on the mass center of the robot shaft

![Curves of angular velocity and angular acceleration](image)

(b) The curves of the angular velocity and angular acceleration on the mass center of the robot shaft
The curves of position, velocity and acceleration on the mass center of the front-left wheel.

The curves of position, velocity and acceleration on the mass center of the middle-left wheel.

The curves of position, velocity and acceleration on the mass center of the rear-left wheel.

The contact forces between wheels and ground.

The contact torques between wheels and ground.

Figure 2 The dynamic simulation example of the six-leg-wheel hybrid robot.
30mm-height step under no control algorithm. Figure 2 (c)~(e) show respectively the curves of the position, velocity and acceleration of the mass center of front-left wheel, middle-left wheel and rear-left wheel. Figure 2(f)~(g) shows the forces and torques between each wheel and ground, while contact1~contact6 represent the reaction respectively acting on the front-right wheel, middle-right wheel, rear-right wheel, front-left wheel, middle-left wheel and rear-left wheel.

Conclusions

The dynamic model of the six-leg-wheel hybrid robot was built using ADAMS. Using the dynamic model, the dynamic simulation curves can be achieved. The climbing obstacle capability of the robot can be simulated using the dynamic model. The model will be used to analyze the dynamic characteristic of the robot under complex motion condition such as moving on the uneven terrain in the future works. The analyses can provide the theory basement for the design of the control system of the robot.

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Acknowledgement

This research is supported by the Fundation of State Key Laboratory of Robotics(No.:RLO200807)