Dynamic Modeling and Motion Control of a One-Wheel Robot

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Recently, new types of one-wheel mobile robots which have internal driving mechanisms contained in closed surfaces have been developed. Two pioneers in this field are Benjamin H. Brown and Yangsheng Xu at Carnegie Mellon University. They proposed a unique wheel-like robot which was actuated by an internal gyroscope mechanism.

The one-wheel robots are composed of two parts – the driving mechanisms and gyroscopes. Both parts are contained in closed surfaces. Gyroscopes are used for dynamically stabilizing and steering robots to track the desired trajectory.

The one-wheel robots have many advantages over the conventional mobile robots. The shells protect themselves from the external environment so that they can be used in the outdoor environment. Because of the smooth external profile, they would not be struck by any obstacles. These robots are able to self-recover after falling in the case when they bump into some objects. They are suitable for exploring tasks in the narrow passages.

However, these robots are subjected to the nonholonomic constraints while rolling without slipping on horizontal plane. Kane's equation is used to formulate the equations of motion under these constraints. The main advantage of this method is that we can obtain the equations of motion in term of independent variables without using Lagrange multipliers. Consequently, the computation burden is also reduced.

In order to realize an autonomous control for the robot we study its dynamic and nonholonomic control systems. The one-wheel robot is also an underactuated system because it has two inputs to control its orientation. We design both linear and nonlinear controller to control its forward velocity and steering rate to follow the desired paths. Kanayama and Fahroo's steering function are adopted in this work. This method can be use with straight line paths, circular paths, and the combination of the two paths. The advantage of this method is that it is independent of the robot structure and controller.

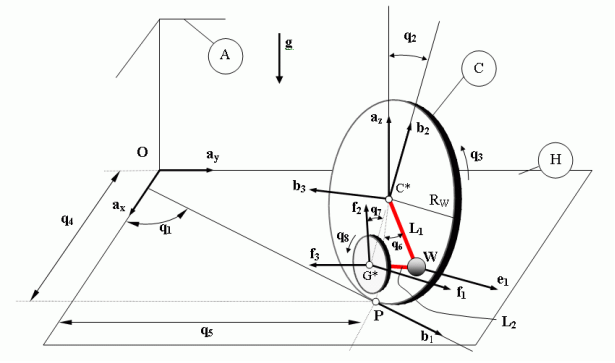

Fig.1 A One-wheel robot rolling without slipping on a horizontal plane along a desired trajectory

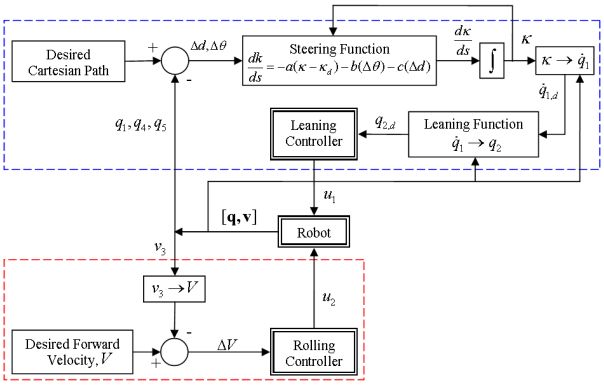

Fig.2 Block diagram of path following control of a one-wheel robot

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