Development of a Control System of an Omni-directional Vehicle with a Step Climbing Ability

Daisuke Chugo[1], Kuniaki Kawabata[2], Hayato Kaetsu[2], Hajime Asama[3] and Taketoshi Mishima[1]

[1] Saitama University
255, Shimo-Ookubo, Saitama-shi, Saitama 338-8570, Japan
chugo@riken.go.jp / mishima@ics.saitama-u.ac.jp

[2] RIKEN (The Institute of Physical and Chemical Research)
2-1, Hirosawa, Wako-shi, Saitama 351-0198, Japan
kuniakik@riken.go.jp / kaetsu@riken.go.jp

[3] The University of Tokyo
4-6-1 Komaba, Meguro-ku, Tokyo 153-8904, Japan
asama@race.u-tokyo.ac.jp

Abstract. We proposed a new holonomic mobile mechanism which is capable of running over the step. This mechanism realizes omni-directional motion on flat floor and passes over non-flat ground in forward or backward direction. The vehicle equips seven omni-directional wheels with cylindrical free rollers and two passive body axis that provide to change the shape of the body on the rough terrain. This paper presents a method to control the wheels for passing over rough terrain with the stable posture. Our vehicle is required to keep synchronization among its wheels for climbing the step without slipping and blocking. Therefore, in this paper, an algorithm of synchronization among all wheels is proposed. The performance of our system is experimented by means of computer simulations and experiments using our prototype vehicle.

1 Introduction

In recent years, mobile robots are expected to perform various task in general environment such as nuclear power plants, large factories, welfare care facilities and hospitals. However, there are a lot of narrow spaces with steps and slopes in such environments, and it is difficult for general car-like vehicles to run around.

Generally for effective task execution, it is required to realize quick and efficient mobile function. The omni-directional mobile capability is useful for the tasks in narrow spaces, because there is no holonomic constraint on its motion [1]. On the other hand, it is required to run over the irregular terrain. Both of these capabilities are required to compose high mobility system for field and service robots.

In related works, various types of omni-directional mobile robots are proposed: legged robots, ball-shaped wheel robots, crawler robots, and so on. The legged robots [2] can move in all directions and pass over rough terrain. However, its mechanism and control system tend to be complicated and energy efficiency is generally not so high. The robot with ball-shaped wheels can run in all directions [3], however, it cannot run on the rough grounds. The special crawler mechanism [**?**] is also proposed

S. Yuta et al. (Eds.): Field and Service Robotics, STAR 24, pp. 245–254, 2006.

for the omni-directional mobile robot. It can move on the rough terrain, but it cannot climb over large steps.

For realization of running in narrow spaces and on irregular terrain, we developed a new holonomic omni-directional vehicle with step-climbing ability. [5] Our prototype utilized the rocker-bogie suspension system and also has the redundant actuators, and it is important to keep synchronization among the wheels. However, during the vehicle is climbing steps, it is difficult to synchronize the wheels without slipping and blocking.

For wheel control, we utilized the traction control. Several traction control methods for mobile robots to pass over the rough terrain were already proposed [6,7]. These methods consider to control only single wheel and do not address the problem related to synchronization among plural wheels.

Our proposed method realizes that the mobile robot passes over the irregular terrain with synchronization among the wheel rotations. The key idea of our method is that not only the single wheel state but also the plural wheel states are utilized as feedback value. We verify the performance of the proposed control method through the computer simulations and experiments.

This paper is organized as follows: we discuss the mechanical design, the kinematic model of the robot in section 2; the new control method is proposed in section 3; we show the implementation and experimental results in section 4; section 5 is conclusion of this paper.

2 System Configuration

2.1 Mechanical Design

We already developed a prototype mobile mechanism [5] and also an advanced prototype vehicle system (Figure 1 and 2). The vehicle has seven wheels with DC motors. The size of the vehicle is 750mm(L) x 540mm(W) x 520mm(H) and the total weight is approximately 22 [kg] with the batteries.

The mobile mechanism consists of seven special wheels with free rollers and a rocker-bogie suspension system. The special wheels consist of twelve cylindrical free rollers (Figure 2) [8] and realize to generate the omni-directional motion. Generally, on the viewpoint of energy efficiency of running on the structured terrain [9], the wheeled mobile system is better than the other type of mobile systems (e.g., legged or crawler type). Thus, our mobile mechanism realizes the omni-directional function and high-energy efficiency, compatibly.

Our mechanism utilizes the rocker-bogie suspension system, which consists of passive links, and it can adapt itself to rough terrain. [6,10]. No sensors and no additional actuators are equipped to pass over irregular terrain. In general environment, it is not easy task to estimate terrain condition precisely. Our system realizes such estimate function only using passive body axis.