Chapter 34
Agile Wheeled Mobile Robots for Service in Natural Environment

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ABSTRACT

Although the wheeled locomotion proved to be very efficient on smooth grounds, it still encounters great difficulties in natural environments, where the ground is subject to wide variations in term of geometry (irregular surface, presence of obstacles...) and material properties (cohesion, grip condition...). This chapter presents recent developments and original systems that improve the capacities of wheeled mobile service robots on natural ground.

First is considered the case of low speed motion. Section 2 presents recent results on reconfigurable suspensions that have two states and can decrease lateral friction and energy consumption during turns for skid-steering vehicles. Section 3 presents an original hybrid kinematics that combines wheels with an articulated frame for creating a mobile-wheeled robot with high obstacle-climbing capacities, using only one supplemental actuator.

Other advances deal with high-speed motion. Section 4 describes a new device dedicated to vehicle dynamic stability, which improves lateral stability on fast mobile robots during turns and contributes to rollover prevention. Finally, Section 5 introduces innovative suspensions with two DOF for fast obstacle crossing. They damp vertical shocks, such as ordinary suspensions, but also horizontal ones, contributing to tip-over prevention on irregular grounds that feature many steep obstacles.

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1. INTRODUCTION

Wheeled locomotion still prevails in the 21st century because of high efficiency on various types of grounds, mechanical simplicity, and ease of control. In natural environment, though, wheels are challenged by other locomotion modes, such as tracks, that provide excellent grip on low cohesion grounds, or legs, that allow moving on irregular environment and cross obstacles.

This chapter presents recent developments that improve the capacities of wheels with additional systems such as innovative suspensions that can have reconfigurable states or additional mobilities. Another interesting solution is to create hybrid systems between wheels and legs, by putting a wheel on a leg or even by transforming the rigid frame of the vehicle into a mechanism.

These new paradigms are particularly interesting in a time where electric actuators can be decentralized close to each wheel, instead of using a central explosion engine, which is still the archetype for most of the cars now. All these solutions appear to be promising and will improve the agility of service robots of the future. Many tasks are becoming possible, such as transport on unstructured grounds and fast inspection by fleets of small agile robots. Civil and military service applications can be imagined for agriculture, forestry, transport, disabled people, industry, defense, and crisis management during natural catastrophes.

This chapter is divided in four sections, which can be classified according to speed (Low speed/High speed) or function (Turning/Obstacle-Crossing) as shown in Table 1. Here is a summary of section contents.

Section 2 analyzes the skid-steering process at low speed of a 6x6 wheeled vehicle (Fauroux, Charlat, & Limenitakis, 2004a, 2004b; Fauroux, Vaslin, & Douarre, 2007; Fauroux & Vaslin, 2010). Skid-steering has similarities with what happens on tracked vehicles, because of transverse friction, a lot of energy is dissipated during steering. This section proposes a model of the vehicle behaviour as well as experimental results, with the general goal to both understand the phenomena and also improve these category of very robust vehicles.

Section 3 deals with another low speed challenge: obstacle crossing. In this part, OpenWheel i3R, an agile modular mobile robot designed by the authors with articulated chassis and four motorized wheels (Fauroux, Chapelle, & Bouzgarrou, 2006; Fauroux, Forlorou, Bouzgarrou, & Chapelle, 2007; Fauroux, Bouzgarrou, & Chapelle, 2008, 2009, 2010; Bouzgarrou, Chapelle, & Fauroux, 2009) is introduced. Chassis mobilities are used to maintain the wheel contacts on ground surface and lift off the wheels during crossover maneuvers in front of obstacles. This maneuver can be seen as a climbing mode, which uses both wheels and inter-axle actuation, thus pertaining to the category of hybrid locomotion. After giving a geometric model and the minimal equations for its control, some experimental results are provided, based on the three prototypes created both at small scale (30cm) and high scale (2m).

Section 4 concerns mainly high-speed applications and fast steering, allowing safe control based on dynamic stability. This section presents the development of new devices dedicated to lateral dynamic stability and rollover prevention based on predictive control law and grip conditions

Table 1. Topic dispatching of the different chapter sections

	Low speed	High speed
Turning	**Section 2:** Skid steering at low speed with a 6x6 architecture	**Section 4:** High speed safe control based on dynamic stability
Obstacle Crossing	**Section 3:** Agile robots for obstacle crossing at low speed	**Section 5:** Innovative suspensions with 2 DOF for high speed obstacle crossing

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