Chapter 19

Mechatronic Design of Mobile Robots for Stable Obstacle Crossing at Low and High Speeds

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ABSTRACT

This chapter presents recent mechatronics developments to create original terrestrial mobile robots capable of crossing obstacles and maintaining their stability on irregular grounds. Obstacle crossing is both considered at low and high speeds. The developed robots use wheeled propulsion, efficient on smooth grounds, and improve performance on irregular grounds with additional mobilities, bringing them closer to legged locomotion (hybrid locomotion). Two sections are dedicated to low speed obstacle crossing. Section two presents an original mobile robot combining four actuated wheels with an articulated frame to improve obstacle climbing. Section three extends this work to a new concept of modular poly-robot for agile transport of long payloads. The last two sections deal with high-speed motion. Section four describes new suspensions with four mobilities that maintain pitch stability of vehicles crossing obstacles at high speed. After the shock, section five demonstrates stable pitch control during ballistic phase by accelerating-braking the wheels in flight.

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1. MECHATRONIC DESIGN OF MOBILE ROBOTS FOR OBSTACLE CROSSING

We are currently seeing a strong expansion of flying drones (UAVs, Unmanned Aerial Vehicles) of every sizes for professional activities and leisure. Although some of them are strong enough to carry a small payload, most of them are inexpensive light robots only equipped with vision sensors for tasks related to aerial inspection.

However, the majority of human activities are located on the ground and terrestrial mobile robots have a higher potential for helping humans in a convincing way, with a longer autonomy. Many tasks are becoming possible, such as transport on unstructured grounds or fast inspection by fleets of small agile robots. Civil and military service applications can be imagined for agriculture, forestry, transport, disabled people, industry, defence and crisis management during natural catastrophes.

One difficulty that prevents the extension of terrestrial mobile robots, compared to flying robots, is the varied nature of ground environments. For example, they can be structured or non-structured, flat or irregular, with cohesive or granular materials. Mobile robots are already well known in industry, where they move easily on structured flat cohesive grounds, guided by referenced landmarks. For example, Automatic Guided Vehicles (AGVs) are commonly used for transporting large parts for aeronautics and performing logistics tasks. However, as soon as the environment is natural, with irregular surfaces and granular grounds, without regular roadways and reference points, terrestrial mobile robots have difficulties to move and to perform their task.

1.1 Mechatronics for Mobile Robotics

Mechatronics can be seen as a unifying transversal discipline touching many sectors, from automotive to robotics (Habib, 2007). The particular domain of mobile robotics requires suitable mechatronic architectures for robots that evolve in varied environments (Siegwart, Nourbakhsh, & Scaramuzza, 2011). A semantic map of some useful concepts connected with mechatronics for mobile robotics can be seen in Figure 1. Moreover, many general terms useful for this paper are regrouped in a glossary at the end of this work in the section 'Key Terms and Definitions.'

Defining a mobile robot architecture generally starts by choosing its kinematics, propulsion devices and locomotion modes. Although the majority of vehicles use one of the three main types of propulsion devices that are wheel / track / leg, reviews show that many new kinematics and ways to combine propulsion devices appear each year, so this research sector can be considered very active (Bruzzone & Quaglia, 2012). Some architectures claim to be efficient on several types of terrains such as rocky and sandy areas, inclined planes or stairs (A. K. Gupta & V. K. Gupta, 2013). Kinematic redundancy and modularity can be another way to enhance mobility on rough terrain (Labenda, Sadek, & Heckes, 2010).

Mobile robots use varied types of sensors to provide information about the environment. Distance sensors such as odometers and ultrasound sensors allow localizing the robot with respect to obstacles (Izumi, Habib, Watanabe, & Sato, 2008). Attitude sensors such as accelerometers, gyrometers, gyroscopes and IMUs (Inertial Measurement Units) can evaluate angles, angular speeds and accelerations. Global sensors such as cameras (De Croon, De Weerdt, De Wagter, & Remes, 2010) or LIDARs (Light Detection and Ranging) help to construct maps of the environment, either during locomotion or by using preliminary observation (Ohki, Nagatani, & Yoshida, 2013). Force sensors can be used to detect contacts and even be included into the wheels for ground characterization (Park, Kim, & Lee, 2012). Whatever the precision of the sensors, fusion is often required between data coming from varied sensors in order to improve reliability of the information about the environment (Shih, Chen, & Chou, 2012).