Preface

Robotics technology covers very wide area. Fully autonomous robots in particular are associated with three functions, namely, manipulation, locomotion, and communication. Locomotion robots may be classified by the environment in which they travel: (1) Land or home robots are most commonly wheeled, unmanned ground vehicles (UGVs) but also include legged robots with two or more legs, like humanoids or resembling animals or insects. (2) Aerial robots are usually referred to as unmanned aerial vehicles (UAVs). (3) Underwater robots are usually called autonomous underwater vehicles (AUVs). Wheeled and tracked UGVs, UAVs, and AUVs are already in use for real applications. The exceptions are legged robots. Unfortunately, legged robots based on the use of animal-like and human-like legs are still in the research phase even though many research outcomes have been achieved. The main reason for their remaining in the research stage may be that the locomotion speed and the energy efficiency of legged robots are still very low compared with those of wheeled robots. However, wheeled vehicles are unable to move on rough, off-road or unmodified natural terrain and need paved surfaces in order to operate smoothly.

According to the United States Army, approximately half of the Earth's land surface is inaccessible to either wheeled or tracked vehicles. Legged animals and humans are capable of legged locomotion and as a result they can access any part of the Earth's land surface without great difficulty. These legged creatures can walk on rough or irregular terrain by establishing foot contact with the ground at selected points according to the terrain conditions and by varying their leg configurations in order to adapt themselves to irregularities in terrain. Thus, legs are inherently adequate systems for locomotion on rough and irregular terrain. This fact was a motivation for the development of artificial legged locomotion systems.

Among the various types of legged robots, hexapod walking robots offer a good static stability margin and locomotion speed, and at the same time they are fault-tolerant. Therefore, hexapod walking robots have emerged as a popular robotic system for various critical and hazardous field applications. The origin of our research motivation was to build a human-like de-mining robot using hexapod robots. We need a fast, safe, and robust technique for de-mining operations, and walking robots can be considered an effective and efficient means for that purpose. Hydraulically actuated hexapod walking robots can be used for the detection and removal of landmines while providing safety and security for the operating personnel. Hydraulically actuated hexapod robots are mechanically robust, have a high level of static stability margin, and are suitable for operation in rough terrain. Therefore, their deployment for de-mining tasks is advantageous from the point of view of their safe locomotion capability in a mine field and their capability to carry large payloads of the tools required for de-mining missions. Nonami group at the Robotics and Control System Laboratory (Nonami Laboratory), Chiba University, Japan, has developed and successfully tested the hydraulically actuated hexapod robots COMET-III and COMET-IV for achieving robot-assisted de-mining. This book describes the essential design, implementation, and control of hydraulically actuated hexapod robots.

Chapter 1 covers various theoretical and practical aspects of legged locomotion and also introduces many popular and successfully implemented legged robots around the world. Chapter 2 presents a condensed perspective of the historical evolution of walking robots. Chapter 3 describes the group's attempt to fundamentally review the basic specifications of a robot, such as the mechanism, gait, drive system, and control system, and to approach the optimization-based design of COMET-IV—the hexapod dangerous-operations robot. Chapter 4 deals with kinematics and path planning of COMET-IV. In particular, the developed kinematics and dynamics are exploited to be used for end-effecter force on foot detection and overall COMET-IV stability for force-attitude control purposes. In COMET-IV research, the total force on the foot is calculated for center-of-mass (CoM) identification as an input for robot attitude during walking sessions. Chapter 5 starts with a general description of position-control-based locomotion control of walking robots. Then the various nonlinearities of the hydraulic actuation system are briefly described. Finally, two sliding-mode-based locomotion control techniques and the robust adaptive fuzzy-control-based locomotion control technique of COMET-III in the position-control-based framework are presented with real-time experimental results. In Chap. 6, it is shown that, with the capability of active suspension (legs), the strong role of legged/walking robot design makes it possible to pass through any uneven terrain as long as the obstacles are lower than the robot's maximum or minimum overall body height, if compare to the wheel type robot. Therefore, force or impedance control is needed to make a dynamic response on each leg in order to identify the different level of the terrain or any sudden changes in the terrain. Moreover, this control is crucial in hidden areas that could not be identified by a vision system via pre-scanning and localization. Chapter 7 proposes several algorithms such as impedance control implementation for the hexapod robot COMET-IV. Also, in the case of heavy-weight and large-scale-structured robots, inclinometers from attitude angles must be designed to control the long-term attitudes of the body without any vibration caused by changes in support of the legs. This shaking is considered a natural scenario since the robot is using a hydraulic system and an automotive engine. Chapter 8 deals with cases of extreme environments, where it is difficult to achieve full autonomy. Therefore, a teleoperation-based system has been designed on the COMET-IV for extreme environments. The teleoperation assistant system is designed to understand the ambient environment and the movement conditions of the robot. These include legged robot changes that affect the height of the body and the robot's attitude. In this chapter, we applied an omni-directional vision sensor and 3D robot animation. The online 3D virtual reality technique is proposed for achieving synchronous control between virtual 3D animation and the physical COMET-IV in a real environment. Chapter 9 proposes several methods for crossing an obstacle and descending and ascending a cliff based on LRF 3D point cloud data. Experimental results show that the proposed methods are useful for performing assigned tasks. Chapter 10 describes challenges and new frontiers.

Hydraulically actuated hexapod robots form a very useful class of walking robots in the context of service robotics, field robotics, search and rescue, and high-risk operations. They can also be utilized as a test bed for designing and validating various gaits and walking behaviors. Many potential applications may be possible with the advent of various technologies associated with the design and manufacturing of such robots.

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Chiba, Japan — Kenzo Nonami
Kolkata, India — Ranjit Kumar Barai
Pahang, Malaysia — Addie Irawan
Pahang, Malaysia — Mohd Razali Daud

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