DEVELOPMENT OF HEXAQUAD ROBOT: MODELING AND FRAMEWORK

Addie Irawan[1], Akhtar Razul Razali[2], Wan Faizal Wan Ishak[3], Mohd Rizal Arshad[4] and Tan Yee Yin[5]
[1,5]Robotics and Unmanned Systems (RUS) research group, Faculty of Electrical & Electronics Engineering, Universiti Malaysia Pahang, Malaysia. E-mail: addieirawan@ump.edu.my[1], yeeyin1228@gmail.com[5]
[2]Manufacturing Focus Group (MFG), Faculty of Mechanical Engineering, Universiti Malaysia Pahang, Malaysia.
E-mail: akhtar@ump.edu.my
[3]Centre for Earth Resources Research & Management (CERRM), Universiti Malaysia Pahang, Malaysia. E-mail: faizal@ump.edu.my
[4]Underwater Control and Robotics Research Group (UCRG), School of Electrical and Electronic Engineering, Engineering Campus, Universiti Sains Malaysia, 14300 Nibong Tebal, Penang. E-mail: dr.rizal@gmail.com

ABSTRACT

This paper presents a proposed reconfigurable multi-legged robot named Hexapod-to-Quadruped (Hexaquad) robot. Reconfigurable legged robot is one of the robotics research area that is generally focused on optimizing the usage of leg during locomotion. Until recent years, most of the researches emphasized on leg reconfigurable design in order to solve the fault tolerant, stability, multi-tasking and energy efficiency. However, the emphasis of the Hexaquad robot is on providing optimum leg usage, actuation configuration as well as satisfying the legged robot stability criterion in reconfiguration mechanism. Inspired from several living creatures, such as insects, crustacean and peristaltic creatures, Hexaquad is designed and modeled to perform flexible spine for leg adjustment and foot-to-gripper transformation. The design also implements the indirect and parallel actuation configuration on leg-joint motion for optimum torque on the joint of each leg without motor/actuator mass affect that commonly happens in multi-limbed system with direct drive configuration. The minimum torque on each joint of the leg is calculated using the static torque calculation on multi-link structure before the actuator/motor is selected, and verification is done by performing fundamental testing on the leg's movement and standing using direct switching and supply voltage. Further testing and analysis were conducted on the gripper by performing gripping tests using materials of different weight and shape versus total load current on the leg's actuators. Stress and displacement testing and analysis were also done on the foot-to-gripper (FTG) structure of Hexaquad robot. The results show that the FTG is able to hold 50N forces without any breaking point being detected as well as able to maintain its shape, strength and position upon receiving the forces (surpassing the main objective to lift a 5kg load).

Keywords: Hybrid bio-inspired robot, Reconfigurable mechanism, Foot-to-gripper transformation

INTRODUCTION

A bio-inspired or biomimetic system design and control engineering has become a favorite area in recent robotic research and development. Legged robot, or so called active suspension vehicle (ASV), is one of the bio-inspired system that mimicked horse biological structures was started in 1960s [1]. With significant advantages compared to the wheel type robot/vehicle, a legged robot is capable of navigating irregular and mountainous terrain. In actual situation, earth's landmass is accessible to existing wheeled and tracked vehicles, but a much larger portion can only be reached by animals on foot [2]. Moreover, animal on foot is able to climb and walk on the bottom surface of water. Consequently, several studies and development have been done in the area of legged robot by previous researchers to achieve good adaptability, function, high flexibility and extensibility with extreme and unknown terrain. Until recently, most of the progresses are in system mechanism, structure design/configuration, and workspace on giving efficient design and reducing control complexity in a legged and multi-legged robot. However, some studies have been carried out in designing a reconfigurable legged robot, in which the effectiveness and optimization of the leg usage were considered. Energy efficiency was one of the reasons for the studies, other than fault tolerant [3], multi-tasking [4] and stability [5] in designing a configurable multi-legged robot. Meanwhile, optimization of the actuators used on the robot's leg with the emphasis on designing better under-actuated or parallel actuation leg configuration, such as reported and implemented in [6, 7], has also become another focus area. However, this is in contrast with the effort of reducing the complexity in robot control architectures such as reported in [8], in which additional converter module is needed.

However, some researchers took up the challenge and contributed ideas using intelligent system and robust control approaches. For example, the closed-form solution was introduced by Agheli *et al.* to derive the closed-form equations of the boundary of the constant-orientation workspace used by axially symmetric hexapod robots. The proposed approach can be applied in a robot system with non-symmetric and non-identical kinematic chains [9]. Moreover hormone-based distributed control has been proposed and implemented on CONRO robot gait reconfiguration between caterpillar and spider gait mode [10]. In addition, the organic self-configurable was proposed in hexapod robot named OSCAR from University Lübeck, with the emphasis on overcoming the malfunction leg(s) and optimizing the overall energy during locomotion by performing self-amputation [11].

This study has taken the initiative and the challenge by proposing a reconfigurable multi-legged robot with bio-inspired configuration, named Hexapod-to-Quadruped (Hexaquad) robot (Patent Applied) [12]. Hexapod is a