Design and experiment research of a hydraulic-actuated humanoid biped robot prototype for dynamic walking

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1 Introduction

From the aspect of power density and response, hydraulic -actuated robot may response much faster compared with electric motor. There are three representatives of hydraulic-actuated legged robots. One good template is PetMan[1] and BigDog[2] from Boston Dynamics. The other is HyQ[3][4]. This paper introduces design of mechanical structure, control system and hydraulic servo system of a hydraulic-actuated biped robot prototype and experiment on it. The robot is human-like size, whose 12 degrees of freedom are all actuated by hydraulic. Computer is embedded, on which QNX RTOS is installed. Real-time multi-threaded application program runs on QNX, which executes low-level hydraulic servo control and high-level control strategy computation. Inverted-pendulum-based gait planning is introduced and simulated. Through experiment, compliance legs are found essential for heavy dynamic walking robot. This paper shows some experiments to test load capacity, multi-joint coordinated motion, stable walking and compliance control.

2 System Design

A. Mechanical Structure

The robot has 12 DOFs, two on each ankle, one on knee and three on hip. It weighs 87.2kg and is 1.35m high from hip to foot bottom. To make the robot as light as possible, most parts are ultralumin. Hydraulic actuator is aligned along legs of robot via triangle connection so as to transform linear motion into rotation of joints.

B. Control System

Control system consists of one embedded pc104 computer and two data acquisition cards, which provides in total 12 DA and 24 AD channels. DA channel outputs control voltage signal for servo valves and AD channel collects position and force sensor data. All 12 DA and 24 AD data could be processed within 1ms, which is fast enough for dynamic walking.

C. Hydraulic servo system

Hydraulic system consists of 12 hydraulic actuation units, pump and auxiliary equipment. This paper presents the design of compact hydraulic actuation unit which could output maximum 13,000N force. Each hydraulic actuator is equipped with one LVDT and one force sensor.

3 Stable Walking Plan

In this paper, the robot is modeled as one inverted pendulum. Motion trajectory of linearized inverted pendulum is calculated and decomposed into joint motion trajectory. Foot is always kept horizontal. Velocity and acceleration of foot is set to zero when foot contact ground so as to avoid impact.

4 Simulation & Experiment

Based on stable walking plan given in section 2, simulation and experiment are presented in this section. 3D model of robot is imported into ADAMS and simulation shows the feasibility of stable walking plan. Stable walking test results on designed biped robot platform are presented. Besides, load capacity, multi-joint coordinated motion test and compliance control test are also given in this paper.

5 Figures

Below is the figure of hydraulic- actuated biped robot platform.

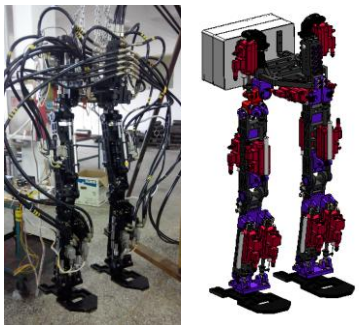

Figure 1: Hydraulic-actuated biped robot platform. Real robot(left) and 3D model(right)

References

[1]Edwards, Lin. "PETMAN robot to closely simulate soldiers." April 27 (2010).
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[3] Semini, Claudio, et al. "Design and experimental evaluation of the hydraulically actuated prototype leg of the HyQ robot." Intelligent Robots and Systems (IROS), 2010 IEEE/RSJ International Conference on. IEEE, 2010.
[4]Semini, Claudio, et al. "HyQ-Hydraulically actuated quadruped robot: Hopping leg prototype." Biomedical Robotics and Biomechatronics, 2008. BioRob 2008. 2nd IEEE RAS & EMBS International Conference on. IEEE, 2008.