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Brief introduction to the quadruped robot HyQReal

Claudio Semini, Victor Barasuol, Michele Focchi, Chundri Boelens,
Mohamed Emara, Salvatore Casella, Octavio Villarreal, Romeo Orsolino,
Geoff Fink, Shamel Fahmi, Gustavo Medrano-Cerda, and Darwing G. Caldwell

Dynamic Legged Systems (DLS) Lab
Istituto Italiano di Tecnologia (IIT)
Genova, Italy
firstname.lastname@iit.it

Dhinesh Sangiah, Jack Lesniewski, Kyle Fulton, Michel Donadon, and Mike Baker

Moog Controls Ltd.
Tewkesbury, United Kingdom
main contacts: dsangiah@moog.com and mbaker@moog.com

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***Abstract*—This extended abstract provides a short introduction to the latest hydraulic quadruped robot (HyQReal) that has been developed at IIT. Compared to its predecessors HyQ and HyQ2Max, this third generation machine is completely power autonomous and features a smart hydraulic actuation system developed by Moog Inc. The hydraulic actuators and the first outdoor trials with the new robot are briefly introduced.**

***Index Terms*—quadruped robot, hydraulics, power-autonomy**

I. Introduction

HyQReal, the most recent version of IIT's hydraulic quadruped robot series HyQ, is the result of a collaboration between IIT's Dynamic Legged Systems Lab and its industrial partner Moog Inc., a world-leader in reliable, high-performance actuation systems for aerospace and motorsport. Over the last 6-7 years, HyQ [1] has demonstrated a wide repertoire of indoor/outdoor motions ranging from running and jumping to reflexes and careful planned and unplanned walking over rough terrain. Its successor HyQ2Max [2] was more rugged with the added ability to perform self-righting. While these two versions are still used for state-of-the-art research into rough terrain locomotion (e.g. [3]–[6]), they both lack power-autonomy. For the third version of this robot - HyQReal - we addressed this point by integrating within the robot torso a complete hydraulic power system with Lithium-Polymer battery. In this extended abstract, we will provide an overview of HyQReal, focusing on the robot specifications and its hydraulic actuation system.

II. Robot Specifications

The HyQReal robot is based on the designs of the previous robots; HyQ and HyQ2Max. Figure 1 shows a picture of the new robot, while Table I shows the system overview. The abbreviations have the following meaning: Hip Abduction Adduction (HAA), Hip Flexion Extension (HFE), Knee Flexion Extension (KFE). For a more detailed definition refer to [2].

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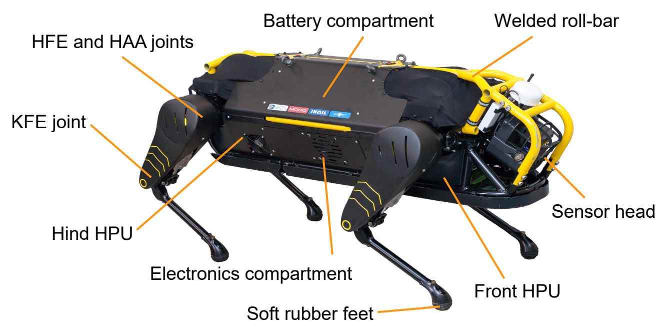


Fig. 1. Picture of HyQReal with labels indicating the key components. HPU stands for Hydraulic Pump Unit.

TABLE I
System Overview and main specifications of HyQReal

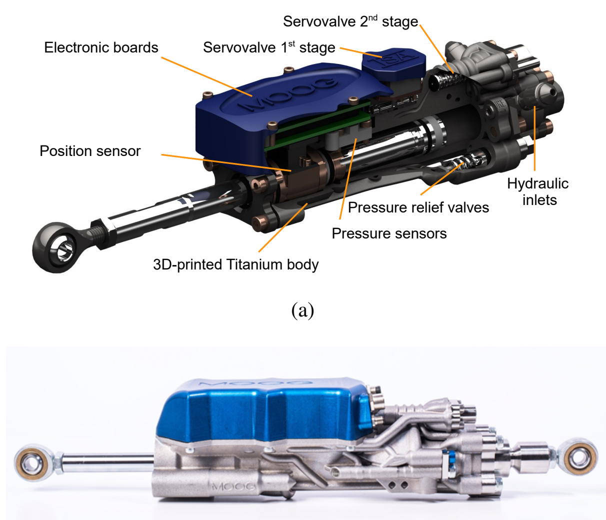
dimensions	1.3 m x 0.67 m x 0.9 m (LxWxH)
distance left/right HAA	0.278 m from axis to axis
distance front/hind HFE	0.887 m from axis to axis
link lengths	hip (HAA-HFE): 0.117 m
	upper leg (HFE-KFE): 0.36 m
	lower leg (KFE-foot): 0.38 m
weight (approximately)	130 kg (onboard hydraulics and battery)
active DOF	12
HAA actuators	double-vane rotary hydraulic actuators
HFE actuators	double-vane rotary hydraulic actuators
KFE actuators	asymm. hyd. cylinders & four-bar linkage
joint motion range	60° (HAA), 110° (HFE), 133° (KFE)
max. torque [HAA]	165 Nm (constant torque at 20 MPa)
max. torque [HFE]	270 Nm (constant torque at 20 MPa)
max. torque [KFE]	240 Nm (peak torque at 20 MPa)
position sensors	absolute position 19 Bit in all joints
torque/load sensors	torque (HAA, HFE), loadcell (KFE)
onboard computer	Intel core i7 with real-time Linux
joint controller rate	torque (5 kHz) & position (1 kHz, EtherCAT)

The custom-designed robot parts are mainly made of a high-strength aluminium alloy and stainless steel. The hollow spine connects the front and hind leg attachment points. A roll bar around the torso acts like a rib-cage protecting the battery, hydraulics and electronics from impacts. A Kevlar and glass fibre skin further protects the robot. Custom-made rubber feet increase the traction between the feet and the ground.

III. Key Components of HyQReal

This section describes some of the key components of the robot, namely the highly integrated smart actuators (ISA) and smart manifolds developed by Moog Inc. Figure 2(a) shows a CAD rendering of the ISA v2 with a cross section to illustrate the main features of the actuator and integrated components. The actuator body is additively manufactured in titanium, creating a compact design with integrated flow paths, wire channels, relief valves, electronics and sensors. The electronics allow joint-level control loops at 1-10kHz frequencies and incorporate communication using CAN or EtherCAT.

To give greater actuator efficiency, that is critical for autonomous robots, several versions of the linear actuator, ISA v2-v5, were developed addressing the conflicting demands of high performance and low energy use (see Fig. 2(b)).



(a)

(b)

Fig. 2. Integrated smart actuators: a) CAD rendering of the ISA v2 with cut-out section to illustrate the main features of the actuator and integrated components (illustration also representative of the ISA v5). b) Picture of the ISA v5.

These ISAs (v5) are mounted in the upper leg of the robot to actuate the knee joints, while the two hip joints are driven by custom hydraulic rotary actuators combined with smart manifolds developed by Moog (see Fig. 3). These manifolds feature the same electronics as the ISAs.

For detailed information about the ISA, the smart manifolds and their control performance, see [7].

IV. First Experiments

The new robot is currently being tested in laboratory, indoor and outdoor trials. In May 2019, the robot demonstrated its strength and performance by pulling a small 3300kg passenger airplane (Piaggio P180 Avanti) at the airport of Genoa, Italy (https://www.youtube.com/watch?v=pLsNs1ZS_TI). The plane is 14.4m long and has a wingspan of 14m.

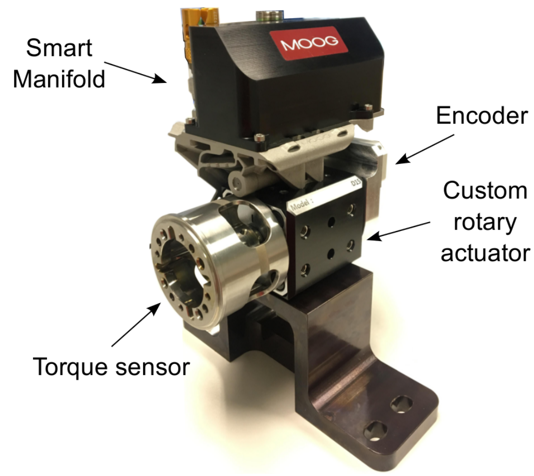


Fig. 3. Smart manifold mounted on a custom made rotary actuator. The torque and position sensors are interfaced with the smart manifold.

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