Benchmarking bipedal walking: Towards international consensus

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1 Introduction

In the R&D community there is a growing awareness of the importance of benchmarking. Benchmarks not only allow comparing performance of different technologies, devices, and algorithms, but also define and thereby boost R&D targets and directions, and are an important support to standardization and regulation procedures towards market introduction. Benchmarking has been recently considered by the Horizon 2020 Programme the primary instrument to evaluate the Technology Readiness Levels (TRL) of the technology. The Multi-Annual Roadmap for Robotics in Europe [1] highlights the need for new benchmarks to reliably measure the performance and safety of robots. Benchmarking is gaining relevance also in the field of humanoids, as demonstrated by the success of recent competition-based initiatives (e.g Darpa Robotic Challenge, Robocup). In all these scenarios, the issue of a truly comparison with the human performance is taking a central role, since humans still represents the golden standard for interaction ability, efficiency and stability.

2 The proposed benchmarking scheme

Driven by these motivations, we have recently started an international joint effort for the definition of a benchmarking framework for bipedal walking. So far, two steps in this direction have been taken. First, we involved the international community by means of a web-based survey [2], and the organization of a number of workshops, aimed at identifying needs and critical issues [3,4] within the relevant communities. Second, we conceived and developed a unified framework for benchmarking [5, 6], with the goal of providing practical guidelines for experimental procedures to be shared across a wide range of scenarios and laboratory settings. Several European projects¹ actively collaborated in this initiative. Similarly, more than 100 independent researchers in the field of wearable robotics, humanoids and biomechanics showed their interests in participating in the discussion, through their subscription to the recently created mailing list "benchmarking bipedal locomotion" [7]. Our aim is to draw the attention of different robotics communities on the importance of having a common view on the benchmarking of bipedal functions. We believe that reaching an international consensus will be extremely beneficial for finding reliable methods to test and compare different bipedal systems, and to measure the TRL of new technologies. In addition, benchmarks may also support the understanding of the biological principles by means of quantitative comparison with human counterparts. Developing a comprehensive and practical scheme that takes into account the several aspects of bipedal locomotion is not an easy task. Aspects as stability, efficiency, robustness, versatility, dynamicity, compliance, safety, may assume different levels of importance, and even different meanings, depending on the research field considered. To organize these different aspects, the benchmarking scheme has been structured in three sections, interlaced to each other (see Figure 1):

- 1) A *taxonomic* system to intelligently classify motor skills into sub-functions and perturbed conditions.
- 2) A set of benchmarks to evaluate motor skills, under the *performance* and *human likeness* perspectives.
- 3) A guideline to define standardized batteries of tests, which can be shared across different laboratories.



Figure 1: Structure of the benchmarking scheme

We would like to share this scheme with the DW community to gather new views on the crucial features of dynamic walking, and human likeness in general. Our final goal is to enlarge this newborn benchmarking community and find the most effective ways of bringing benchmarks into the daily life of legged locomotion research.

References

[1] http://www.eu-robotics.net/cms/upload//Multi-

Annual Roadmap2020 ICT-24 Rev B full.pdf

¹ H2R (www.h2rproject.eu), BALANCE (www.balancefp7.eu), Koroibot (www.koroibot.eu), Walkman (www.walkman.eu) and Biomot (www.biomotproject.eu)

^[2] Benchmarking bipedal locomotion - A survey. Still accessible at: <u>http://goo.gl/forms/FL9Pd1xXgb</u>

^[3] http://www.h2rproject.eu/humanoids2013

^[4] http://orb.iwr.uni-heidelberg.de/koroibot/?page_id=492

^[5] Torricelli et al., Benchmarking Human-Like Posture and Locomotion of Humanoid Robots: A Preliminary Scheme, LNCS Vol 8608, 2014, pp 320-331

^[6] Torricelli et al., Benchmarking bipedal locomotion in humanoids, wearable robots and humans: a unified scheme, IEEE Robot. Autom. Mag. (submitted)

^[7] https://listas.csic.es/wws/info/benchmarking_list