

# Control Design for Achieving Walking and Running on a Compliant Bipedal Robot

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## Abstract:

Animals are able to move with great elegance, agility and efficiency over very rough terrain. An objective of the legged robotics community is to endow machines with similar capabilities. A central challenge in legged locomotion is that of coordinating a multi-joint electromechanical system so as to realize walking and running gaits that are stable, agile, energy efficient and fast. One difficulty in meeting this challenge is the high degree of freedom and overall dynamical complexity of typical legged robots. Another difficulty arises due to the high degree of underactuation. This talk will present a controller design and experimental validation on MABEL, a planar biped, weighing 65 Kg, 1 m tall at the hips, and with a novel transmission with series compliance. The presence of compliance in MABEL's transmission has led to new control challenges: Compliance increases the degree of underactuation, and also raises the question of how to use the compliance effectively.



A controller design based on the Hybrid Zero Dynamics (HZD) will be illustrated that preserves the natural compliant dynamics of the system to achieve provably stable, efficient, fast and robust bipedal walking, resulting in a walking gait with mechanical cost of transport that is just a factor of two away from that of humans, and at fast walking at 1.5 m/s.

Further, biomechanics studies have shown that humans and animals adjust their leg stiffness to accommodate for variations in terrain and ground stiffness during running using a combination of tendons, and muscles. Motivated by this, a novel control design that embeds an active force control in the form of virtual compliance within the compliant HZD framework will be presented to achieve running gaits on MABEL leading to a world running speed record of 3 m/s.

## Biosketch:

Koushil Sreenath is a postdoctoral researcher at the GRASP lab at The University of Pennsylvania. His research interests are in modeling, feedback design, and experiments in legged, as well as aerial robotics. His work on the bipedal robot MABEL was featured on The Discovery channel, CNN, ESPN, FOX, CBS television networks in North America and TV-5 News in India. His work on adaptive sampling with mobile sensor networks resulted in a book. He obtained the M.S. in Mathematics and Ph.D. in Electrical Engineering from Univ. of Michigan at Ann Arbor in 2011, he was a Research Engineer with the Intelligent Controls Group, Saint-Gobain R&D in 2006-2007, he received the M.S. in Electrical Engineering from Univ. of Texas at Arlington in 2005, and the B.E. from PES Inst. of Tech., Bangalore, affiliated to Vishweshwaraiah Technological University, Belgaum in 2002.