2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)
October 25-29, 2020, Las Vegas, NV, USA (Virtual)

Mastering the Skeleton and its Muscles

Neville Hogan

Department of Mechanical Engineering, Massachusetts Institute of Technology (MIT)

Department of Brain and Cognitive Sciences , Massachusetts Institute of Technology (MIT)

Bio

Neville Hogan is Sun Jae Professor of Mechanical Engineering and Professor of Brain and Cognitive Sciences at the Massachusetts Institute of Technology. He earned a Diploma in Engineering (with distinction) from Dublin Institute of Technology and M.S., Mechanical Engineer and Ph.D. degrees from MIT. He joined MIT's faculty in 1979 and presently Directs the Newman Laboratory for Biomechanics and Human Rehabilitation. He co-founded Interactive Motion Technologies, now part of Bionik Laboratories. His research includes robotics, motor neuroscience, and rehabilitation engineering, emphasizing the control of physical contact and dynamic interaction. Awards include: Honorary Doctorates from Delft University of Technology and Dublin Institute of Technology; the Silver Medal of the Royal Academy of Medicine in Ireland; the Henry M. Paynter Outstanding Investigator Award and the Rufus T. Oldenburger Medal from the American Society of Mechanical Engineers, Dynamic Systems and Control Division; the Academic Career Achievement Award from the Institute of Electrical and Electronics Engineers, Engineering in Medicine and Biology Society; and the Saint Patrick's Day Medal for Academia from Science Foundation Ireland.

Abstract

Human muscles are tension actuators that lie outside the bones. Stabilizing that endo-skeletal anatomy requires muscle stiffness to increase at least in proportion to muscle tension. That, in turn, enables mechanical impedance modulation by antagonist muscle co-activation, especially important for the most rapid events, before feedback control has time to respond. But some tasks may require low impedance—e.g. complying with a constraint. If force production is also needed, low impedance appears to be unavailable. A 'work-around' may be found in the kinematic complexity of the skeleton. Pose modulates all aspects of mechanical impedance—stiffness, damping, inertia, and more. Measurements of the stiffness of the wrist and ankle—which support our major points of interaction with the world—show that both are highly anisotropic. Wrist stiffness is extremely low in the direction of the 'dart-throwers' motion, and it appears that muscle action does little to increase it. Thus a key part of motor skill acquisition may be learning the most favorable pose. But controlling pose is complicated by the skeleton's very many degrees-of-freedom. Fortunately, redundant degrees of freedom may be managed without inverting kinematic equations by exploiting the compositionality of mechanical impedance.