Human Movement Understanding

By Emel Demircan, Dana Kulic, Denny Oetomo, and Mitsuhiro Hayashibe

Robotics research has been deeply inspired by humans as a system—from the design of the anthropomorphic aspects of manipulators, sensors, and actuators to the way a robot coordinates the motion of its body and the higher-level strategies for realizing complex tasks and interacting with the external environment. In recent years, robotics computational strategies have contributed significantly to the analysis of human motion and manipulation skills. These analyses have led to advancements in the field of robotics by enabling human-inspired capabilities in robots and simulated systems as well as biologically inspired techniques for robot learning from observation. Furthermore, these analyses have provided a deeper understanding of the human body and its motion-generation strategies. Natural human motion is central to many of the technologies we develop in the field of robotics. This trend is quite visible from the growing number of papers related to the topic of human movement understanding, as shown in Figure 1.

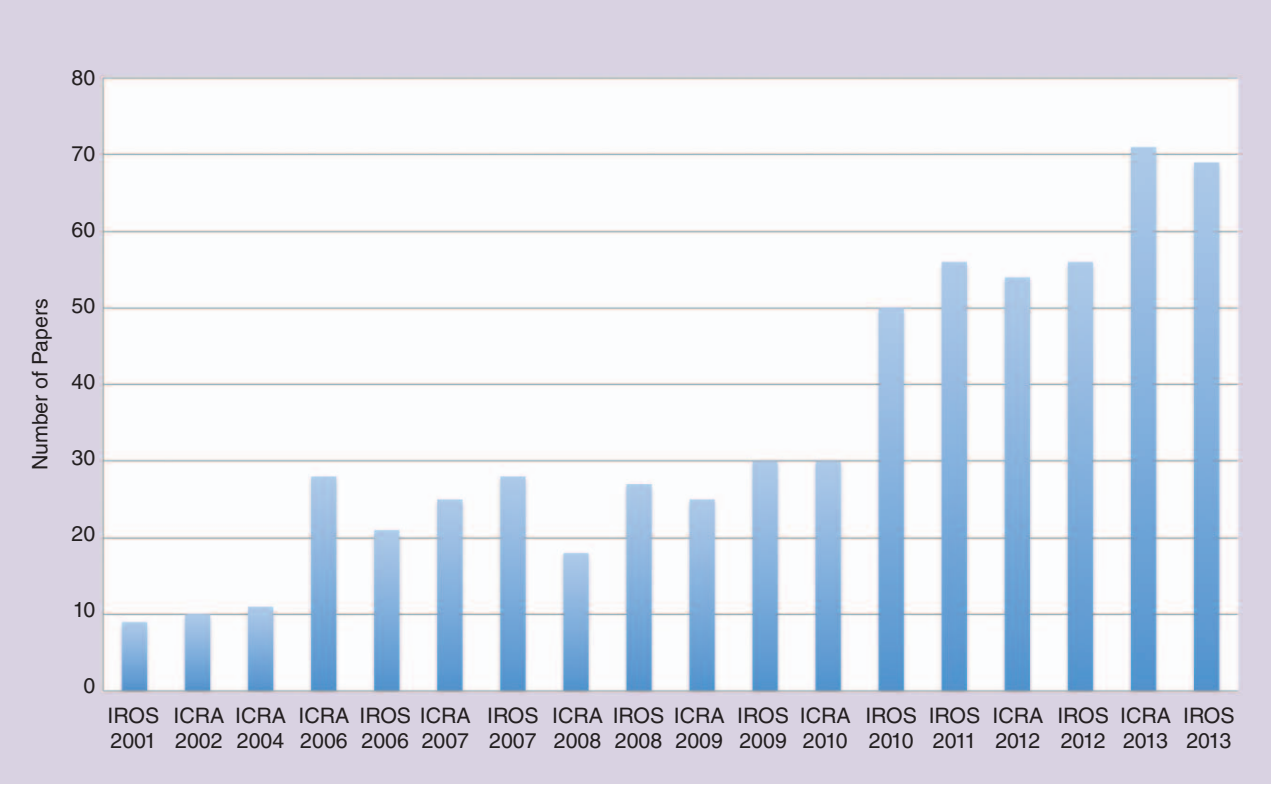

Figure 1. The number of papers related to human motion understanding presented in the last ten years at the technical sessions of the IEEE/Robotics Society of Japan International Conference on Intelligent Robots and Systems (IROS) and the IEEE International Conference on Robotics and Automation (ICRA).

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This human-inspired vision has led to an intersection of robotics and many traditional fields concentrating on the study of human body neuromechanics, such as clinical rehabilitative studies, biomechanics, and neuroscience. Fundamental robotics techniques now find a new frontier of challenges in engaging directly with the human body: in characterizing human motion in terms of physiological aspects, modeling the acquisition of skills, recovery from the traumainduced impairment, generation of natural motion that optimizes the mechanical advantage of the human body, and many others.

Through a robotics view, we aim at gaining fundamental insight into natural human movement and understanding the mechanisms that lead to improved quality of human motion analysis, rehabilitation, and neuroscience (Figure 2). The new IEEE Robotics and Automation Society (RAS) Technical Committee (TC) on Human Movement Understanding was established in May 2014 to create a focal point for this emerging interdisciplinary research field and to facilitate the dissemination within both the robotics and neurophysiology research fields as well as sharing the contributions and the emerging applications with the broader scientific community.

Organizational Structure and Priority Areas

The main organizational structure of this TC consists of four cochairs, with 84 members from universities, clinical institutions, and industry. The current cochairs of the TC are Emel Demircan (United States and Japan), Dana Kulic (North America), Denny Oetomo

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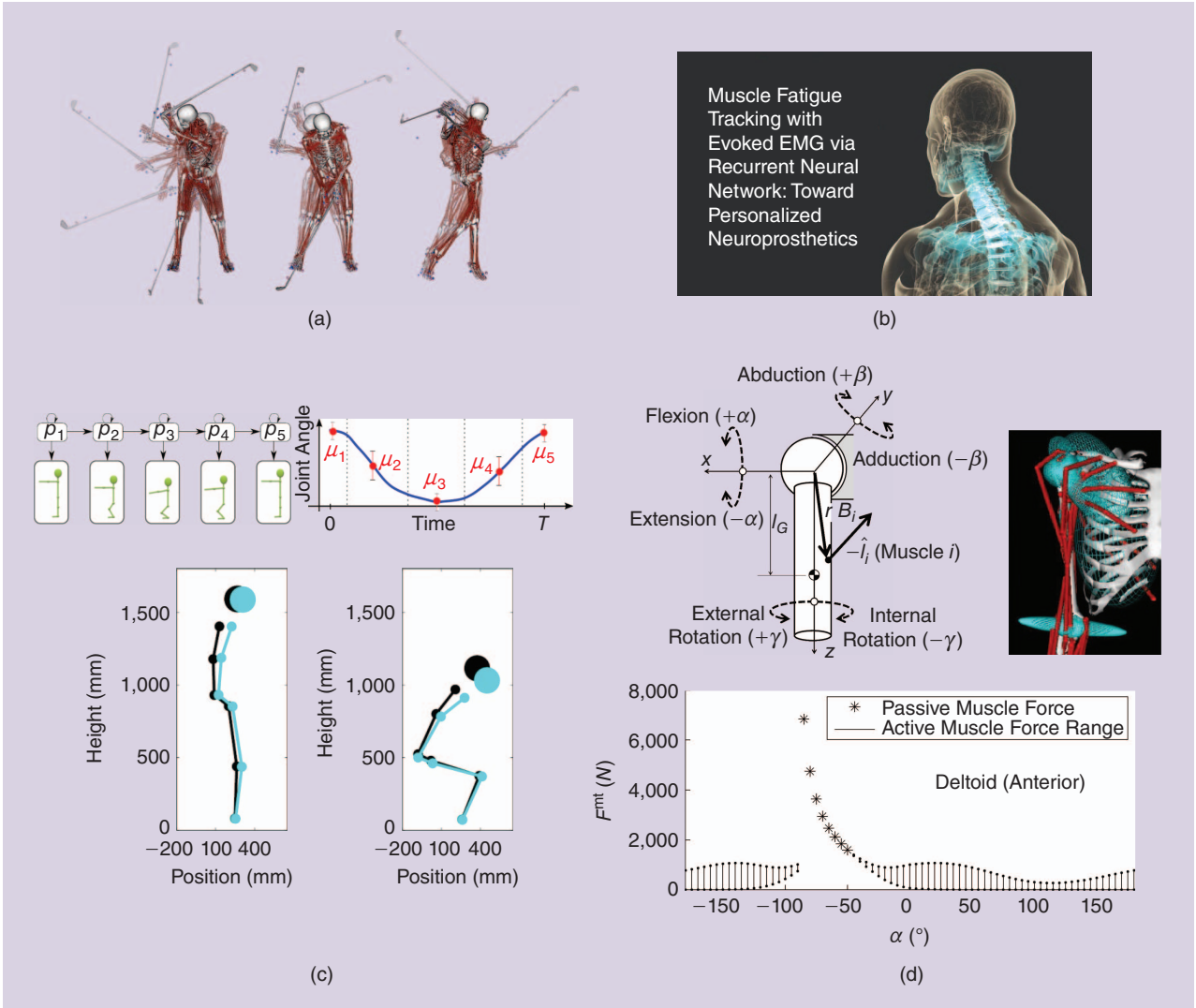

Figure 2. The relevant application fields of the TC on Human Motion Understanding: (a) human motion analysis and biomechanics [1], [2], (b) neuroprosthetics and neurorehabilitation [3], (c) human motion recognition and evaluation [4], and (d) human motion characterization and workspace analysis [5].

(Asia and Oceania), and Mitsuhiro Hayashibe (Europe and Japan).

The priority areas for the TC include the following:

- The application of advanced computational tools to
  - characterize natural human motion and the higher-level strategies used to realize complex tasks and interact with the external environment
  - develop tools for characterizing changes in human motion due to disease, aging, or injury to facilitate applications in rehabilitation and neuroprosthetics and exoskeleton design
  - predict behavior and synthesize humanlike motions.
- The development of strategies for human motion reconstruction on engineered anthropomorphic systems, such as humanoid, modular manipulators, and simulated systems.
- Human motion generation and task learning, including but not limited to the strategies for generalization of learned tasks to the learning of new tasks, resolution of human motor redundancy, and human strategies in handling constraints.

In the next ten years, many scientific challenges will be addressed by the TC on Human Movement Understanding.

Related Activities Organized by the TC

Since the establishment of the TC, a broad range of activities has been initiated in the last few years:

- ICRA 2013—full-day workshop on Computational Techniques in Natural Motion Analysis and Reconstruction, 6 May 2013, Karlsruhe, Germany
- IROS 2013—full-day tutorial on Robotics-Based Methods for the Identification, Recognition, and Synthesis of Human Motions, 3 November 2013, Tokyo, Japan
- ICRA 2014—full-day workshop on Latest Advances on Natural Motion Understanding and Human Motion Synthesis, 31 May 2014, Hong Kong, China
- Humanoids 2014—half-day workshop on Human Motion Modeling and Human-Inspired Motor Control, 18 November 2014, Madrid, Spain
- ICRA 2015—half-day workshop on Human Movement Understanding and Neuromechanics, 26 May 2015, Seattle, Washington.

These upcoming activities are scheduled for this year and 2016:

- a special issue on movement science for humans and humanoids: methods and applications in *IEEE Transactions on Robotics* (target publication date: February or April 2016)
- a summer school on human movement understanding, supported by RAS at Stanford University in 2016 and held jointly with SimTK Opensim group.

Future Directions

In the next ten years, many scientific challenges will be addressed by the TC on Human Movement Understanding. We aim at posing questions to advance the research for understanding natural human movement using robotics research—providing a computational basis for the analysis of movement disorders and performance improvement, the development of novel tracking and identification methods on physiological signals, kinematic, and dynamic modeling of human musculoskeletal systems, the development of strategies for human motion reconstruction on engineered anthropomorphic systems, and synthesizing and predicting human natural motions—having benefits in motor control and learning, ergonomics, biomechanics, physical therapy, neuroscience, sports medicine, and rehabilitation.

To promote the development and application of robotics methodologies and tools for the modeling, simulation, and synthesis of human motion, establish a network of expert researchers in robotics and neurophysiology, and encourage junior researchers in the area, the TC has formed several communication channels. The main one is a public website and its associated mailing list. We welcome new members to join us. Anyone can subscribe to the mailing list by visiting https://sites.google.com/site/ieeehmu/.

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