Computational Motor Control for Humans and Humanoids

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Over the last decade, two major developments could be observed in research on motor control. First, in the area of robotics, there was the advent of a new kind of complex robotic system, ranging from pet robots up to full-scale humanoid robots. These new robots constitute a major departure from classic industrial robotics in terms of the number of degree-of-freedom to be controlled, their light-weightiness, the nonlinear dynamics of these systems, the need for multisensory perception, and the demand for autonomous control in dynamically changing and uncertain environments, as typical in a human world. The second noteworthy development has been in the area of biological motor control. Advanced methods of experimentation with humans and animals have created a huge amount of data of motor behaviors and their underlying neural activity. For the interpretation of such complex data, researchers have resorted increasingly more to methods from robotics and machine learning, and formal models of robotics have made major progress in the computational understanding of biological information processing.

At the interface of these two developments, research on computational motor control tries to use formal methods from robotics and machine learning to help understanding the mechanisms of the neural control of movement, but simultaneously, also tries to extract new principles and inspiration from biological motor control to create novel control methods for robots. Such an approach is particularly promising for the new kind of “primate-like” robots as described above, as many core principles of physics, control theory, and mathematics are shared between biological and technical systems. This presentation will describe some of the main advances that have been made in computational motor control in the past years. We will review some of the work on motor control will internal models, i.e., the use of learning to automatically model kinematic and kinetic properties of one’s own body in order to improve the quality and dexterity of control. We will also provide an overview on new ideas of motor planning with motor primitives, i.e., a method to create complex movement from simple constituents. This topic has interesting ramifications towards advanced forms of interaction with robots, for instance, by means of teaching the robot, or by mitigation learning. The latter issue will broaden the discussion towards a vision of the future use of robots in the human society. Assistive robotics, i.e., robots that help human in their daily environment, particularly in sectors where there is too little personnel, will be described a worldwide upcoming initiative. Research on computational motor control will be among the key fields to realize such visions.

Keywords:

Computational motor control: A research approach that uses formal models from robotics and machine learning to investigate the algorithms of neural computation in the brain, and that tries to advance the development of new technologies in robotics by means of principles of biological information processing.

Internal model control: Internal models are mechanisms that can mimic the in-put/output characteristics of the motor apparatus (forward models), or their inverse (inverse models).

Internal model control denotes the autonomous learning of such models for advanced nonlinear control.

Motor primitives: Units of action that are employed for the generation of complex movement in movement planning and movement execution. The theory of motor primitives involves how to learn individual motor primitives (including the question of what consititutes a primitive), and how to learn to combine them for complex behavior generation.

Assistive robotics: The use of robotic technology for the larger benefit of the human society. Assistance is defined broadly, including physical assistance, cognitive assistance, social assistance, educational assistance, etc.