NEURAL MODEL OF MULTIJOINT MOVEMENT LEARNING AND CONTROL

Alexander A. Frolov, Vadim Y. Roschin, Elena V. Biryukova
Institute of Higher Nervous Activity and Neurophysiology of Russian Academy of Science, Moscow, Russia

The proposed neural network model of multijoint movement learning and control uses the velocity of functionally significant point of the body (working point or WP) in the external space as the main parameter of movement planning. The neural network which learns to perform the transformation of the movement plan to the appropriate muscle forces has two sets of inputs, one representing the desired WP velocities and another representing the current values of joint angles (the feedback from the mechanical system). The special three layers structure of the network is chosen to provide the transformation to be linear in the first set of inputs and nonlinear in the second one. The joint torques are assumed to be proportional to the difference between current and desired angular velocities. The movement induced by these torques is computed with the use of the model of the mechanical system dynamics. The discrepancy between the current and desired WP velocities stimulates neural network training which is performed according to the modified error back-propagation rule.

Velocity control used in the model allows to linearize the transformation and then to increase the learning rate and accuracy; theoretically it permits to obtain any desired control accuracy; lastly, it has good neurophysiological justification.

EFFECT OF ADDITIONAL WEIGHT ON MUSCULAR POWER AND PERFORMANCE IN VERTICAL JUMP MOTION

Norihisa FUJII* and Toshimichi MORIWAKI**
*Graduate School of Science and Technology, **Faculty of Engineering
KOBE University, JAPAN

The relations between the anthropometric characteristics of human body and the vertical jump motion were investigated from the viewpoints of muscular power and performance. The vertical jump motions of four male subjects were analyzed under the four conditions, in which an additional weight was attached to the subject at the shoulder, waist, or ankle in order to vary the anthropometric characteristics of the subjects intentionally. Simulations were also carried out based on the musculoskeletal model, in which the parameters of body segments were selected according to the experimental conditions. It was shown that the power generation of the mono-joint muscle under the condition with the additional weight at the ankle was less than those of other conditions. It was also shown that the jump height with the additional weight at ankle was less than those of other conditions. It was suggested that the cause of the differences of the jump height was that the two-joint muscles could not control the power generation of mono-joint muscles enough for the reason of transferring the large power to shank segment at which the additional weight was attached. It was also suggested that not only the muscular power but also the mass distribution of human body were important to improve the jump height in the vertical jump motion.

AN OPTIMAL CONTROL MODEL FOR RISING FROM A CHAIR

Brian A. Garner, Kristin E. Daigle, Marcus G. Pandy, and Frank C. Anderson
Departments of Mechanical Engineering and Kinesiology, The University of Texas at Austin, Austin, Texas.

To understand how muscles coordinate motion of the body segments as humans stand up from a seated position, we developed a detailed optimal control model for rising from a chair. We modeled the human body as a three-segment, articulated, planar linkage actuated by eight lower-extremity musculotendinous units. Because the performance criterion for rising from a chair is ambiguous, we evaluated several measures of performance. Minimizing a quantity which depends upon muscle force alone (e.g., normalized muscle force squared, STRESS) produces a ballistic movement characterized by a rapid upward acceleration of the model's center of mass near seat lift-off. In contrast, minimizing a quantity which depends upon the time derivative of normalized muscle force (FDOT) produces a more gradual acceleration of the model's center of mass since muscle force changes less rapidly with time. However, minimizing FDOT alone does not produce a response of the model which replicates the way humans stand up from a seated position as muscles are recruited from the very beginning of the movement. Therefore, we formulated a constraint-based performance criterion to simulate rising from a chair (STRESSFDOT) in which STRESS was minimized prior to seat lift-off and FDOT was minimized after seat lift-off. In agreement with experiment, most muscles in the model remained silent until just prior to seat lift-off, after which they were recruited gradually and continuously until the model reached standing. Furthermore, the peak vertical ground force generated by the model was in close agreement with that obtained experimentally. We are planning to use this model to study the effects of muscle strength, seat height, and foot position on performance biomechanics of rising from a chair.

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