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東京大学本郷キャンパス 工学部14号館 1階141号室

身体性システム講演会

Sensorimotor control of limb movements: dynamic knowledge for coordination and prediction

Speaker:

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Time: 15:00-17:00 (90min talk+ 30min discussion)
Place: The University of Tokyo, Hongo Campus
Faculty of Engineering Building 14, 1st floor Room 141

Successful performance of many daily living or sport activities, such as reaching for a static object or intercepting a moving object, requires solving complex coordination and prediction problems. To move the hand to a desired location the central nervous system (CNS) must appropriately activate many muscles to coordinate the motion of several mechanical degrees-of-freedom of the limb. To intercept a moving object, because of sensorimotor delays, the CNS must predict its future location. Storing and re-using knowledge of the dynamic behavior of the musculoskeletal system and of the environment might be a general strategy employed by the CNS to simplify coordination and prediction. Muscle synergies, coordinated activation of groups of muscles, may represent a small set of building blocks whose combinations allow to generate all the muscle activation patterns required to perform a motor task, thus capturing the essential knowledge of the dynamic behavior of the arm and of the task constraints. Internal models of the dynamic behavior of flying objects, such as the effect of gravity acceleration on object motion, may allow to make accurate predictions even in the absence of accurate sensory information. In my laboratory, we have investigated how the CNS organizes and combines muscle synergies by recording EMG signals from many muscles during reaching and isometric force generation in multiple directions. A few muscle synergies identified from the recorded EMG using multidimensional decomposition algorithms explain the variation of the muscle patterns across directions, supporting the hypothesis that muscle synergies are basic building blocks for motor coordination. Further support for muscle synergies has come from testing the prediction that it must be harder to adapt to a perturbation that requires new or modified muscle synergies than to a perturbation that can be compensated by recombining existing synergies. Human subjects used myoelectric control to move a mass in a virtual environment and novel perturbations were generated by altering the mapping between EMG and simulated force applied on the mass, as in a complex surgical rearrangement of the tendons (virtual surgery). As predicted, adaptation after compatible surgeries was faster than after incompatible ones. To investigate the role of an internal model of gravity in predicting the location and time of interception of approaching balls, we have developed an automated launching system to precisely control ball flight parameters. We have recorded eye movements, arm and finger kinematics, and EMG activity and we have investigated their relation to catching performance. When subjects were free to choose where to intercept an approaching ball we observed a large inter-individual variability in movement kinematics. Differences in catching performance across individuals were related to the ability of accurately time the closing of the fingers on the ball rather than on ability to intercept the ball trajectory and on the oculomotor strategy used to gather information on ball motion. EMG patterns could be captured by two time-varying muscle synergies. One synergy was recruited with a short and fixed delay from launch time while a second synergy was recruited at a fixed time before impact, suggesting that it was timed according to an accurate time-to-contact estimation. When approaching balls were simulated in an immersive virtual environment, participants achieved a better performance when intercepting accelerated than non-accelerated balls and they made spatial errors indicating they used a priori knowledge of the dynamic effect of gravity to predict when to intercept a moving object. In sum, the results from these two lines of research indicate that the CNS stores and exploits dynamic knowledge of the body and of the environment when mapping sensory information into motor commands.

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