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Are Internal Models of the Entire Body Learnable?

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Abstract

Recent research has provided increasingly more evidence for the existence of internal models in biological motor control - either as forward models or inverse models. In the most visionary theories, internal models of the entire body dynamics and kinematics are required to accomplish motor competence. However, from a statistical learning viewpoint, the acquisition of such large internal models is very complex due to the hundreds of (possibly irrelevant/redundant) input dimensions from various afferent and efferent sources - a similar problem as faced by the cerebellum. To assess the learnability of such large-scale internal models, we used a variety of advanced statistical tools, including mixtures of factor analyzers, local singular value decomposition, and local projection regression, to analyze full-body human movement data from several subjects collected using a special full-body exoskeleton that records 35 joint angles of the human body at 100Hz. Our analyses of the local dimensionality of the human data in the context of a full-body inverse dynamics model confirmed that the 105-dimensional input space (35 position, velocity, and acceleration dimensions) could be locally compressed to about 5 to 10 dimensions. Such locally low dimensional distributions can be efficiently exploited by neural network learning, suggesting that full-body internal models are indeed learnable. We discuss reasons for the existence of low dimensional distributions of movement data in the context of known invariances of movement behavior, including the minimum jerk/torque-change hypothesis, the 2/3 power law, smoothness of movement, and rhythmic pattern generation.