Deriving Actions and Behaviors from Human Motion Data

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We address the problems of modularizing humanoid robot control and representing human activity. We address the problem through the creation of basis behaviors we call *perceptual-motor primitives*. Perceptual-motor primitives serve as a substrate for linking a humanoid's ability to perceive human activities and perform those activities. Thus, by using perceptual-motor primitives, we address both perception and control with the same underlying, synergistic structuring of motion. Furthermore, these primitives provide a mapping between perception and control that allows for imitation, the process of learning new movement patterns and skills by observation.

Our work is concerned with a methodology for automatically deriving such perceptual-motor primitives from human motion-capture data, in an off-line data-driven fashion. Non-linear *dimensionality reduction* (DR) is used to iteratively transform a motion-capture data set into reduced spaces from which actions, and subsequently behaviors, can be extracted, while also accounting for spatio-temporal dependencies in the motion-capture data. Our proposed DR technique is a spatio-temporal extension to Isomap (Tenenbaum et al 2000). A behavior in this context is an ordered set of component actions. After the initial DR iteration, motions generated by the same underlying action are grouped into units of action and generalized into *action primitives*. In further DR iterations, motions generated by the same underlying behavior are grouped into units of behavior and generalized into *behavior primitives*.

We validate and evaluate the above approach to automated derivation of primitives in several ways. First, the methodology is evaluated for multiple sets of human motion-capture data that span a variety of free-space upper-body movement from activities such as dancing and athletics. Second, the approach is evaluated by comparing the results of primitive derivation for manually-segmented and automatically-segmented motion-capture data. Third, the approach is validated based on its ability to: *i)* reconstruct slight variations of original capture motion, *ii)* generate motion for a simulated humanoid robot using the derived actions and behaviors, and *iii)* produce actions and behaviors comparable to a priori knowledge of activities performed in the training motion data.