

A finite and receding horizon neural controller in humanoid robotics

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Optimal trajectory planning of a humanoid arm is addressed. The goal is to make the end effector, located in the wrist, reach a desired target or track it when it moves in the arm's workspace in an unpredictable way. As a reference setup, we considered the 7 degrees of freedom left arm of the humanoid robot James, which is being developed at the Italian Institute of Technology. Physical constraints require the on-line computations to be very quick: this is a strict requirement in our framework, as the integration with a visual feedback will be addressed in the future. A Receding-Horizon (RH) method is proposed that consists in assigning the control function a fixed structure (e.g., a feedforward neural network) where a fixed number of parameters have to be tuned. The classical RH technique assumes the control vectors to be generated after the solution of a Finite Horizon (FH) optimal control problem, at each time instant of control: this assumption is unrealistic in the case of humanoid robotics, as the robot and the target dynamics are very fast. We will design a feedback controller that concentrates the computational burden in an off-line phase, while in runtime it generates the control actions almost instantly. More specifically, in the off-line phase, a set of neural networks (corresponding to the control functions over a Finite Horizon) is optimized using the Extended Ritz Method (ERIM). The training set corresponds to a sampling of the arm and target position and velocity configuration space. The expected value of a suitable cost is minimized with respect to the free parameters in the neural networks. Thus, a nonlinear programming problem is addressed that can be solved by means of a stochastic gradient technique. The resulting approximate control functions are sub-optimal solutions, but thanks to the well-established approximation properties of the neural networks (ERIM with sigmoidal neural networks relates to Barron's theorem) one can achieve any desired degree of accuracy. Once solved the off-line FH problem, only the first control function is retained in the on-line phase: at any sample time t , given the system's state and the target's position and velocity, the control action is generated with a very small computational effort, amounting only to a neural network forward.