Unscented Kalman Filtering for Identification of Haptic Robotic Systems

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Abstract

Successful implementation of model-based control strategies heavily relies on accurate knowledge of the system and its parameters. For haptic systems, this can be crucial to stability, performance, and transparency. Most investigations into identification of haptic systems offer methods that have at least one of the following restrictions: linearity of the model in parameters; availability of joint velocities and accelerations; and, non-extendibility to online settings. To overcome all the aforementioned restrictions, a nonlinear recursive scheme is introduced that exploits a joint state-parameter formulation for simultaneous estimation of the states (e.g. joint angles and rates) and uncertain parameters (e.g. inertial and friction parameters), out of noisy measurements (e.g. joint angles). Unscented Kalman filtering has been employed to resolve restrictions such as linearity in the parameters and the linearization problems associated with extended Kalman filtering. Owing to the unscented transform concept which requires only input-output evaluations of the dynamic model, a more general and modular implementation is realizable. This also allows for the utilization of computational modeling tools without the requirement of symbolically manipulating or even deriving the equations of motion. The practical performance of the proposed scheme was verified through an experiment involving a five-bar linkage based haptic device, the end-effector (EE) of which is made to interact with a virtual box. The human operator releases the EE from an arbitrary point inside the virtual box with an arbitrary initial velocity, leading to consecutive collisions of the EE with the virtual walls. Torque pair commands generated by the haptic controller, and the encoder angular measurements have been recorded and used as input-output data. A mass parameter and joint frictional coefficients were used as represantative uncertain parameters. A satisfactory converging behavior of parameter estimates was observed while running the UKF from an initial guess for these parameters. These initial results demonstrate successfulness of the scheme for recursive estimation/identification purposes, as well as promising potential applicability to indirect adaptive model-based control and some specialized haptic applications.

Keywords: haptic robotic systems, state-parameter estimation, unscented Kalman filtering