

Modeling of Biodynamic Feedthrough in Backhoe Operation

*Heather Humphreys
Graduate Research Assistant
Georgia Institute of Technology*

An advanced backhoe user interface has been developed which uses coordinated position control with haptic feedback, using a SensAble Omni six degree-of-freedom haptic display device. Results indicate that the coordinated control provides more intuitive operation that is easy to learn, and the haptic feedback relays meaningful information back to the user in the form of force signals from digging forces and system limitations. However, they also show that the current system has significant problems with biodynamic feedthrough. Biodynamic feedthrough refers to the phenomenon where the motion of the controlled device excites motion of the operator, resulting in undesirable forces applied to the input device and control performance degradation. According to the literature, and to industry backhoe and excavator interface designers, this is also a significant problem in state-of-the-art user interfaces. This unwanted input is difficult to decouple from the intentional operator input in experiments. This research presents an investigation on the effects of biodynamic feedthrough on this particular backhoe control system. This approach uses system identification to empirically define transfer functions to represent each component, including the valve/cylinder dynamics, tractor/backhoe structure dynamics, the human body dynamics, and the input device. For the nominal case, the input device dynamics are negligible, since it has very low inertia and little damping; the dynamics of the input device can be modified as desired for biodynamic feedthrough compensation using its force display capability. For the purposes of simplifying the modeling, the system is limited to a single degree of freedom, using fore-aft motion only. For biodynamic feedthrough testing, the control setup is reconfigured such that the fore-aft axis of the SensAble Omni controls the stick joint of the backhoe; by appropriately configuring the backhoe and using small angle approximations, fore-aft cab excitation is achieved. The human body dynamics are modeled by two methods. First, human subject tests were performed, using the backhoe as excitation and the input device for measurement. Second, the human operator is modeled using LifeMOD™ and MSC.Adams dynamic modeling software. These transfer functions are assembled into full system simulations in Simulink, for both position control and velocity control. This model is used for a preliminary simulation study on potential methods for biodynamic feedthrough compensation. Simulation results are shown using both position control and velocity control, with nominal system parameters. Tests also include modifications to the input device dynamics, including adding a damping force and spring return force, as well as a few other simple modifications to the system and corresponding parameter studies.