Human Cyber-Physical Systems

Synopsis of Results from NSF CPS Grant #1544702

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Estimation of MSD models

MSD models include variables which are not directly measurable, such as internal states of muscle dynamics and non-physical state definitions used with certain state-space models. Muscular activations are key variables in MSD models, which can be inputs or states according to the modeling approach. While activations can be measured with electromyography (EMG) sensors, it is not practical to directly measure all muscles involved in a study. Using MSD models, it is possible to measure a small set of variables while estimating the rest.

The following topics were undertaken:

1. Tradeoff studies for state estimation for a rowing machine were conducted. The studies explored tradeoffs between state estimation performance and the number of measurements, the number of states, and the fidelity of the friction model [2]

2. Simulation studies demonstrated effective state estimation for exercise machines. Evolutionary algorithms were shown to be effective for optimizing the estimator gains [2].

3. Effective and scalable state estimation algorithms were designed for realistic human muscle model systems. Unknown muscle activations were reliably estimated. Estimator stability was mathematically proven [1, 6, 4].

4. Effective state estimation algorithms were designed for a two-joint, six-muscle human model.

5. Effective Kalman filter-based state estimation algorithms were designed for a human arm model so that both muscle states and motion states could be simultaneously estimated. The estimator works with a minimum number of sensors and eliminates the need for certain sensors, such as load cells. The filter estimates certain parameters that are not available for measurement, such as muscle states [3].

6. An extended Kalman filter augmented with unknown inputs and tuned with evolutionary algorithms was designed for a two-joint, six-muscle human, even with unknown external forces and torques, and good results were achieved with experimental data in a laboratory setting. The filter estimates variables that may not available for measurement, such as muscle activations, muscle lengths, and external forces and torques [5, 3].

7. A particle filter-based method was developed for the simultaneous estimation of the muscle states, muscle forces, and joint motion states of a dynamic human arm model.

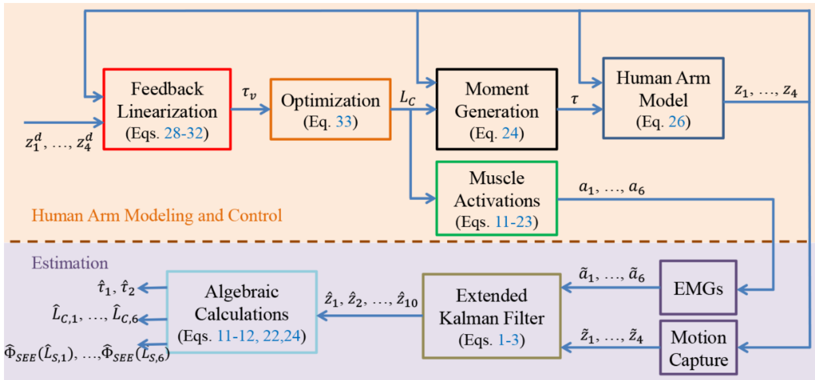

Figure 1: Estimator architecture for studies with experimental validation in [3]

References

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