Low back pain (LBP) and neck pain (NP) are two major musculoskeletal disorders that cause disability. Changes in motor control are associated with LBP and NP. These changes can be revealed by designing motor control tasks to test healthy and pain groups. The very first research question is whether subjects’ performance is reliable during the test.

Once a test is deemed reliable, further investigations of motor control can be conducted. First, we devised an approach that infers the control intent (motor control strategy) by solving inverse Model Predictive Control (iMPC) problems using input/output data. Model Predictive Control (MPC) allows us to model physiological constraints in motor control. For a subject who performed the seated balance test, the iMPC solution suggests that the subject’s control intent was dominated by minimizing the squared sum of the upper-body and lower-body angles.

Motor control utilizes several physiological pathways: visual, vestibular, proprioceptive, and intrinsic. Parametric models of these pathways provide insight into the relative contributions of various pathways. However, estimating model parameters is challenging because (1) there are many parameters to be estimated, (2) the information in experimental data is limited since subjects do not tolerate long testing periods before fatiguing, and (3) non-invasive external sensors are not available to measure all signals of interest.

Therefore, we devised a systematic method of selecting sensitive parameter subsets to be estimated, while fixing the remaining parameters to values obtained from preliminary estimation. Our method, based on the Fisher Information Matrix (FIM), was applied on a rotational head position tracking test. Our method (1) reduced model complexity by only requiring five out of twelve parameters to be estimated, (2) significantly reduced parameter variability (95% confidence intervals) by up to 89% of the original confidence interval, (3) maintained goodness of fit (variance accounted for) at 82%, (4) reduced computation time, where our FIM method was 164 times faster than the existing nonlinear Least Absolute Shrinkage and Selection Operator (LASSO) method, and (5) selected similar sensitive parameters to the LASSO method, where three out of five selected sensitive parameters were shared by FIM and LASSO methods.

We investigated the feasibility of incorporating parameter reliability and model diversity in our FIM method to narrow down the solution space from sensitive parameters to key parameters of motor control. First, we incorporated parameter reliability as a third selection criterion besides parameter variability and goodness of fit. Then, we incorporated model diversity as a fourth optional criterion. We applied this approach to head position tracking in axial rotation and flexion/extension. With variability and reliability measures ≤0.35 and ≥0.75 respectively, we selected three key parameters out of twelve. The key parameters were associated with at least two physiological pathways out of four modeled pathways which is a measure of model diversity. The average goodness of fit was >69%.