Defense Announcement

Scalable and Robust Inference of Sparse Brain Signals via Personalized Physiological System Identification

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Location: Virtual (Please use the Zoom info below)

Zoom Link: https://uh-edu-cougarnet.zoom.us/j/97677964969?pwd=TXp2b0xrR1B4Q3ZjcTZnMm5MTmFmUT09
Meeting ID: 976 7796 4969, Passcode: 319014
One tap mobile +13462487799, 97677964969#,,,,*319014# US (Houston)

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Abstract: Electrodermal activities (EDA) are any electrical phenomena observed on the skin. Skin conductance (SC), a measure of EDA, shows fluctuations due to autonomic nervous system (ANS) activation induced sweat secretion. Since it can capture psychological and physiological information, there is a significant rise in the research for tracking mental and physiological health with SC recording. SC signal that is an observation of the EDA dynamics is representative of the class of signals generated by sparse dynamic systems. These signals can be deconvolved to uncover hidden variables. However, the current state-of-the-art of system theoretic deconvolution and consequent investigation has many challenges. The challenges include the need for a framework that incorporates prior physiological knowledge, the absence of a robust inference framework that can reliably fuse multichannel observations, and the non-convexity of the parameter estimation optimization problem. In addition to that, there is a lack of a comprehensive physiologically motivated model, the existing deconvolution method has poor scalability, and there is the presence of motion artifacts. Therefore, firstly, we model the fast varying fluctuations, i.e., the phasic component of SC using a two-dimensional state-space model representing the diffusion and evaporation processes of sweating with a sparse impulsive signal as the input representing ANS activation. We model the slow varying fluctuation, i.e., the tonic component of SC with several cubic B-spline functions. We formulate an optimization problem with physiological priors on system parameters, a sparsity prior on the neural stimuli, and a smoothness prior on the tonic component. Finally, we employ a generalized cross-validation-based coordinate descent approach to balance the smoothness of the tonic component, the sparsity of the neural stimuli, and the residual. Secondly, we propose a model that combines multichannel SC recording that relates to the impulsive sparse ANS activation. Then we introduce a generalized cross validation-based deconvolution approach utilizing this model. Thirdly, we utilize the continuous system identification technique to reformulate the cost function as a convex one for the deconvolution problem. Fourthly, we propose a comprehensive model for the SC dynamics. The proposed model is a 3D state-space representation of the direct secretion of sweat via pore opening and diffusion followed by corresponding evaporation and reabsorption. The comprehensive model enables us to derive a scalable fixed interval smoother-based sparse deconvolution approach for scalable ANS activation inference. We incorporate generalized cross-validation to tune the sparsity level. Finally, we propose a motion artifact reduction scheme that leverages multiresolution linear/nonlinear adaptive filters and three-axis accelerometer-based motion reference. We further perform experiments to obtain the motion artifact contaminated data and the corresponding motion reference signal for validating the proposed scheme. For evaluation, we utilize both experimental, publicly available, and simulated datasets to investigate the performance of our proposed schemes. Our results show that our approach is successfully recovering ANS activation from SC recordings by addressing the existing challenges. Furthermore, we validate our approaches for reliability, robustness, and scalability by evaluating their event SC response detection performance. Finally, our results validate that our physiology-motivated state-space model can comprehensively explain the EDA dynamics and outperforms all previous approaches. Our findings introduce a whole new perspective and have a broader impact on the standard practices of EDA analysis and the analysis of similar systems with sparse dynamics.