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Stability and robustness analysis of spatiotemporal delayed dynamics with application to feedback attenuation of pathological brain oscillations

ABSTRACT Several disorders are related to pathological brain oscillations. In the case of Parkinson's disease, sustained low-frequency oscillations (especially in the beta-band, 13–30Hz) correlate with motor symptoms. Among the hypotheses to explain the generation of such pathological oscillations, one is the possible pacemaker role played by two feedback-interconnected neuronal populations, one of which is excitatory whereas the other one is inhibitory. In this scenario, the abnormal increase of synaptic weights between these two populations, combined with the inherent transmission delays, gives rise to some instability which translates into sustained oscillations.

In this talk, we rely on a spatiotemporal model of the neuronal populations involved to show that a simple proportional feedback on the excitatory population is enough to attenuate pathological oscillations, provided that the internal synaptic weights within the inhibitory population are sufficiently low. The model used is a delayed nonlinear integro-differential equation know as delayed neural field. Delays are allowed to be position-dependent in order to model longer transmission delays between more distant neurons.

In order to analyze such neuronal populations networks, we extend stability and robustness tools to spatiotemporal delayed dynamics. We provide conditions under which each population is input-to-state stable (ISS) with respect to the inputs coming from the other population. Based on small-gain reasonings, we show that proportional feedback successfully suppresses pathological oscillations in the network, provided that the internal coupling inside the inhibitory population is not too strong. The use of ISS allows in turn to evaluate the robustness of the proposed feedback with respect to imperfect actuation and control delays.

Antoine Chaillet was born in Douai, France, in 1979. In 2002, he received his B.Sc. degree from ESIEE Amiens, and his M.Sc. degree in Control Engineering from Univ. Paris Sud in 2003. In July 2006, he received his Ph.D. degree cum laude in Control Theory from Univ. Paris Sud-L2S. In 2006-2007, he was a post-doctoral fellow at Univ. degli Studi di Pisa, Italy. Since Sept. 2007, he has been serving as an associate professor at L2S-Univ. Paris Sud-CentraleSupélec. His research interests include stability and robustness analysis of nonlinear systems and control theory for neuroscience.
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