Indian Institute of Science
Centre for BioSystems Science and Engineering

BSSE Doctoral Defense

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A CONTROL SYSTEMS APPROACH TO UNDERSTAND THE PRINCIPLES OF SACCADIC EYE MOVEMENTS

Speaker: Varsha V, Ph.D. student
Advisors: Prof. Aditya Murthy (CNS)
Prof. Radhakant Padhi (AE)

ABSTRACT

Movements are critical building blocks of goal-directed behavior that have evolved to support survival. A robust motor system is hence essential for movements to be carried out efficiently. Although biological descriptions of the structure and function of the motor system are abundant, many fundamental principles underlying motor control remains elusive. Research in motor control has extensively used control system approaches like optimal control, feedback control, and predictive control to understand the motor system. These studies have largely been restricted to investigating the central tendencies of movements like mean kinematics. However, owing to the inherent noise in the motor system, behavioral movements exhibit considerable variability even when carried out repeatedly to the same goal. Hence, it is imperative to study variability in movements and consider it an important aspect of motor control.

Saccades which are a type of voluntary eye movement have been studied in this thesis, with emphasis on mean trajectories as well as inter-trial variability. By investigating natural variability in saccade behavior and modeling the saccadic system in the presence of noise, more insights have been gained into principles of the saccadic system that enables it to be successful despite the noise. Firstly, it is shown using a trajectory tracking stochastic optimal control framework that the saccadic system may have an explicit velocity plan. This is an important finding given that the dominant view in the field is that saccades are planned based on target displacement only. Secondly, using a stochastic saccade generation model with internal feedback that predicted behavioral variability in saccades, it is established that saccadic system uses both displacement and velocity information. This generalized model proposed resolves the ambiguities that exist in the saccade control literature over whether saccades are based on only displacement or velocity. This new generalized dual model framework is also validated for an oblique saccade generation system with noise.

Taken together, this work emphasizes that variability in behavior is an important tool for investigating the principles of movement generation in a stochastic system like the oculomotor system. The aim is to provide deeper insights into the principles of the motor system and enable the development of therapy and technology that can improve the rehabilitation of patients with movement disorders.