The Center for Control, Dynamical Systems, and Computation
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Presents

Optimal Control and Tracking with Smooth Pursuit and Vergence Eye Movements

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Abstract: In this talk, the human oculomotor system is presented as a simple mechanical control system. Most of the time, such as during "smooth pursuit", eye movements obey Listing's constraint, which states that the movements consist of rotation matrices for which the axes are orthogonal to the normal gaze direction. This corresponds to the "coronal plane" when the head is not turned and the eyes are looking straight. Eye movements fail to satisfy the Listing's constraint either as a result of abnormality or when the gaze direction is sufficiently oblique, as would typically be the case when the angle of rotation is large, i.e. when the eye is rotated sufficiently to one corner of the visual field. During binocular vision, two eyes need to simultaneously focus on a target. This is achieved by what is known as a "vergence eye movement". The vergence eye movements are not actuated satisfying the Listing's constraint but instead the axes of rotation are contained in a plane spanned by the normal direction and the vertical direction. This would be called the sagittal plane. In this talk, optimal eye movements are described during smooth pursuit when the dynamics satisfy the Listing's constraint. We compare this dynamics to the case when the Listing's constraint is not satisfied. We also study "optimal vergence eye movements" which follows a smooth pursuit where these movements are assumed to satisfy the "sagittal plane constraint". The highlight of this talk is to show that "eye movement dynamics" are described by parameters that are contained in a torus and these dynamics typically have singularities. By defining suitable charts on the torus, these singularities can be removed. Thus an eye movement trajectory needs to be computed over multiple charts by switching between charts. The optimal control is posed as a two point boundary value problem posed over multiple charts of a torus. The underlying mathematics of eye rotation is amply described by "quaternion" and they are an important ingredient in describing the parameters of the eye dynamics.

About the Speaker: Bijoy K. Ghosh received the B. Tech and M.Tech degrees in Electrical and Electronics Engineering from BITS, Pilani, the Indian Institute of Technology, Kanpur, India and the PhD degree in Engineering from the Decision and Control Group of the Division of Applied Sciences, Harvard University, Cambridge, MA in 1977, 1979 and 1983, respectively. From 1983 to 2006, he was with the Department of Electrical and Systems Engineering, Washington University, St. Louis, MO, where he was a Professor and Director of the Center fro BioCybernetics and Intelligent Systems. Currently he is the Brooks Regents Professor of Mathematics and Statistics at Texas Tech University, Lubbock. His research interests are in multivariable control theory, machine vision, biomechanics and control. Bijoy is a 1988 recipient of the Donald P. Eckmann award from the American Automatic Control Council and is a Fellow of the IEEE. He also received the JSPS invitation fellowship in the year 1997.