Computational modeling techniques applied to the study of the eye

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Glaucoma is a leading cause of blindness worldwide. Loss of vision in glaucoma is due to the deterioration of retinal ganglion cell axons, which carry visual information from the eye to the brain. It is generally believed that axonal degeneration initiates in the posterior pole of the eye, more specifically within the optic nerve head (ONH). The main risk factor, and only proven method of preventing the onset of glaucoma, is an elevated pressure of the fluid inside the eye (the intraocular pressure, or IOP). However, how an elevated IOP leads to glaucomatous vision loss or why there is such a wide range of sensitivities to IOP remains unknown. The goal of our research is to understand how the characteristics of an individual eye determine its sensitivity to IOP and risk of vision loss.

In this seminar we will review the results obtained using computational finite element models of humans and monkey eyes. Parametric and sensitivity studies indicate that the mechanics of the posterior pole of the eye depend strongly on the properties of the ocular shell, mainly the sclera. Multivariate analysis indicates that there are strong interactions between the parameters, that is, the effects of one parameter often depend on a second parameter. We will demonstrate the application of stochastic modeling and dimensionality reduction techniques and how these can be used to bring clarity to a complex multivariate nonlinear problem in ways that would have been impossible through experiments.