Abstract

Encoded fluorescent proteins, such as the green fluorescent protein (GFP), have changed and revolutionized the way scientists use microscopes. Today high resolution live cell fluorescence imaging is used to study intracellular traffic, which was not possible before. One of the modern microscopy methods for visualization of transport processes in living cells is Fluorescence Loss In Photobleaching (FLIP). In FLIP a high-intensity laser is used to bleach a small cellular area, while images are taken between the bleaches.

This thesis presents several methods, which can be used to model the intracellular transport observed on FLIP images. A reaction-diffusion system that models both free and hindered molecules and different models for nuclear membrane transport have been proposed. In the interest of the development of an automated analysis of the FLIP images, the cell geometry was extracted from the FLIP image by use of the Active Contours Without Edges or merely Chan-Vese algorithm.

To our knowledge, it is the first time a quantitative computational FLIP (cFLIP) method used to determine transport parameters from the FLIP image data is presented. The method have been used to determine the diffusion constant, membrane permeability, local binding rates and bleaching rates for eGFP. Further, the method is expanded to model intracellular protein aggregates, which is related to various age-associated neurodegenerative diseases, such as Alzheimer's disease, Chorea Huntington, Ataxia and Parkinson disease.

Additionally, an adaptive E-scheme for viscous balance laws originated from the work on an analysis for the cFLIP method is presented in the thesis. Numerical experiments are performed to show the improved accuracy of the adaptive scheme. Moreover, it is proved that E-schemes are monotone and TVD.

The polyglutamine protein aggregates considered in this thesis do not move, which makes it possible to apply the cFLIP method on a fixed mesh. However, recent developments in FEniCS makes it possible to have multiple meshes, which can move independently. The MultiMesh implementation is explored and used to simulate wind flow and view of a settlement layout, which thus gives a measure on how well the houses are placed, in order to find and design the optimal settlement layout.