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Stochastic models of cell invasion with fluorescent cell cycle indicators

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Fluorescent cell cycle labelling in cell biology experiments provides real time information about the location of individual cells, as well as the phase of the cell cycle of individual cells. We develop a stochastic, lattice-based random walk model of a two-dimensional scratch assay where the total population is composed of three distinct subpopulations which we visualise as red, yellow and green subpopulations. Our model mimics FUCCI technology in which cells in the G1 phase of the cell cycle fluoresce red, cells in the early S phase fluoresce yellow, and cells in the S/G2/M phase fluoresce green. The model is an exclusion process so that any potential motility or proliferation event that would place an agent on an occupied site is aborted. Using experimental images and measurements we explain how to parameterise the stochastic model, and we apply the stochastic model to simulate a scratch assay performed with a human melanoma cell line. We obtain additional mathematical insight by deriving an approximate partial differential equation (PDE) description of the stochastic model, which leads to a novel system of three coupled nonlinear reaction diffusion equations. Comparing averaged simulation data with the solution of the continuum limit description shows that the PDE description is accurate for biologically-relevant parameter combinations.

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