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A fast GPU Simulations of Multicellular Response to Radiation Effects on Cell Populations

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We a present novel multiscale simulation framework for describing and predicting radiation-induced biological damage considering both the slow biological and the fast chemical scales.
Building upon the Generalized Stochastic Microdosimetric Model (GSM2) [1] a fully probabilistic model for DNA damage formation and kinetic evolution, we develop a hybrid mesoscopic methodology that include cell proliferation and division besides the already existing description of DNA lesion formation and repair
The code, developed in Julia, is designed to adapt easily to various cell population geometries and arbitrary 3D cell distributions. It uses Monte Carlo sampling to simulate cell damage induced by radiation including proton, helium or carbon, beams and calculates the survival probability and the time of repaire or apoptosis, for each individual cell.
We bridged this code with CellSim3D [2], an open-source code developed in CudaC, to simulate cells evolution and division. The radiation Julia module establishes an initial state, which will then serve as input of a modified version of CellSim3D, integrating a reparation mechanisme.
We then build a simulation pipeline allowing use to study temporally fractionated radiotherapy. This simulation pipeline enables the study of temporally fractionated radiotherapy allowing to include any temporal and spatial fractionation schemes and radiation quality. We are now able to simulate radiation exposure and three days of cellular evolution in a millimeter-scale volume of densely packed cells in under 20 minutes.
[1] Generalized stochastic microdosimetric model: The main formulation, F. Cordoni, M. Missiaggia, A. Attili, S. M. Welford, E. Scifoni, and C. La Tessa, Phys. Rev. E 103, 012412, 2021.
[2] CellSim3D: GPU Accelerated Software for Simulations of Cellular Growth and Division in Three Dimensions Madhikar, P., Åström, J., Westerholm, J., & Karttunen, M. (2018). Computer Physics Communications, 232, 206–213

Authors: CORDONI, Francesco; LATTANZI, Gianluca; BORDIERI, Giulio; MORAND, Jules; BATTESTINI, Marco; KARTUNEN, Mikko

Presenter: MORAND, Jules