Deep Learning Accelerated Lattice Boltzmann Simulations for Multiscale Modeling of Thrombosis

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Cardiovascular disease (CVD) is the leading cause of human death, accounting for 17.8 million deaths in the past year. CVD causes dysfunction in blood proteins and cells. These dysfunctions may result in abnormal blood clotting—thrombosis—which can cause heart attack or stroke. Since thrombosis is a complex process, therapeutic design for thrombosis requires developing a fast and accurate molecular model. Existing simulation techniques, however, are unable to resolve all of the phenomena relevant to thrombosis. By combining different simulation techniques in multiscale modeling (MSM), many different aspects of thrombosis-relevant phenomena can be simulated. However, existing MSM simulations waste upwards of 90% of computational resources to simulate blood flow, which doesn't require such a high resolution. Consequently, lattice-Boltzmann models, which solve velocity distribution functions, can be used to model blood flow for thrombosis. The application of deep learning & artificial intelligence can make these models even faster. In this study, a deep learning accelerated lattice-Boltzmann model (DL-LBM) was used to accelerate MSM of thrombosis. A convolutional long-short term memory network (ConvLSTM) was used in the DL-LBM to recreate the dynamics of fluid particles. A novel architecture was designed to integrate the DL-LBM into the MSM framework for efficient computation. The DL-LBM modeled 250 platelets and blood flow, with over 30 million simulated particles. The DL-LBM accelerated physiological blood clot modeling by 569x while maintaining an average flow and stress accuracy of 96% and 97% respectively. This model can be used to test potential therapeutics and to develop a better understanding of thrombosis.

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