Spatiotemporal-Aware Glioblastoma Multiforme Tumor Growth Modeling With Deep Encoder-Decoder Networks

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Glioblastoma multiforme is an aggressive brain tumor with the lowest survival rate of any human cancer due to its invasive growth dynamics. These dynamics result in recurrent tumor pockets hidden from medical imaging, which standard radio-treatment and surgical margins fail to cover. Mathematical modeling of tumor growth via partial differential equations (PDE) is well-known; however, it remains unincorporated in clinical practice due to prolonged run-times, inter-patient anatomical variation, and initial conditions that ignore a patient's current tumor. This study proposes a glioblastoma multiforme tumor evolution model, GlioMod, that aims to learn spatiotemporal features of tumor concentration and brain geometry for personalized therapeutic planning. A dataset of 6,000 synthetic tumors is generated from real patient anatomies using PDE-based modeling. The model employs image-to-image regression using a novel encoder-decoder architecture to predict tumor concentration at future states. GlioMod is tested in its simulation of forward tumor growth and reconstruction of patient anatomy on 900 pairs of unseen brain geometries against their corresponding PDE-solved future tumor concentrations. We demonstrate that spatiotemporal context achieved via neural modeling yields tumor evolution predictions personalized to patients and still generalizable to unseen anatomies. Its performance is measured in three areas: (1) regression error rates, (2) quantitative and qualitative tissue agreement, and (3) run-time compared to state-of-the-art numerical solvers. The results demonstrate that GlioMod can predict tumor growth with high accuracy, being 2 orders of magnitude faster and therefore suitable for clinical use.

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