

CAUSALITY-ENHANCED SPATIAL TRANSFORMATION MODEL FOR GLIOBLASTOMA PROGRESSION DIAGNOSIS

Author's: G. Kalaivani¹, R. Surendiran², K. Sujith³, N. Vanjulavalli⁴

Abstract

Glioblastoma is the most aggressive and rapidly progressing primary brain tumor, characterized by high heterogeneity, invasive growth, and poor prognosis. Accurate and early diagnosis of glioblastoma progression remains a critical clinical challenge, particularly in distinguishing true tumor progression from treatment-related effects such as pseudoprogression. This study proposes a Spatial-Transformation-Based Causality-Enhanced Model for Glioblastoma Progression Diagnosis, designed to improve diagnostic robustness, alignment consistency, and causal interpretability in multi-modal MRI analysis. The proposed framework integrates a 3D Spatial Transformer Network (STN) with a deep convolutional backbone to automatically correct geometric variations and patient-level misalignment in volumetric MRI scans. By learning affine transformations in a data-driven manner, the spatial transformation module ensures standardized anatomical representation before feature extraction, thereby reducing variability caused by acquisition differences or patient positioning. Following spatial normalization, a compact 3D convolutional neural network extracts high-level structural and texture-based tumor features relevant to progression patterns. To address the challenge of spurious correlations and scanner-induced biases, the model incorporates a causality-enhanced training mechanism. Specifically, label-preserving interventions such as intensity shifts and modality perturbations are introduced during training to simulate real-world distribution shifts. A causal consistency regularization term enforces invariant predictions under these interventions, encouraging the network to focus on clinically meaningful tumor morphology rather than non-causal intensity artifacts. This approach improves generalization across imaging conditions and enhances robustness against domain variability.