Using Persistent Homology Topological Features to Characterize Medical Images: Case Studies on Lung and Brain Cancers

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Abstract:
Tumor shape is a key factor that affects tumor growth and metastasis. This paper proposes a topological feature computed by persistent homology to characterize tumor progression from digital pathology and radiology images and examines its effect on the time-to-event data. The proposed topological features are invariant to scale-preserving transformation and can summarize various tumor shape patterns. The topological features are represented in functional space and used as functional predictors in a functional Cox proportional hazards model. The proposed model enables interpretable inference about the association between topological shape features and survival risks. Two case studies are conducted using consecutive 143 lung cancer and 77 brain tumor patients. The results of both studies show that the topological features predict survival prognosis after adjusting clinical variables, and the predicted high-risk groups have significantly (at the level of 0.01) worse survival outcomes than the low-risk groups. Also, the topological shape features found to be positively associated with survival hazards are irregular and heterogeneous shape patterns, which are known to be related to tumor progression.

Keywords:
Topological Data Analysis; Tumor Shape; Functional Principal Component Analysis