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A Unified Framework for Signal Processing and Analysis of Multimodal Biomedical Data

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Abstract

Heterogeneous and multimodal data are acquired from diverse sensors and stored in different formats such as text, audio, images, LiDAR, or biomedical signals, offering complementary perspectives that can significantly enrich analysis and model accuracy. Their integration enables a wide range of applications, from healthcare, where imaging, genomic, and clinical data contribute to diagnostics and personalised medicine, to traffic monitoring and simulation with LiDAR, cameras, radar, and GPS, as well as computer graphics scenarios involving 3D motion and scene understanding. However, such data present several challenges, including interoperability across acquisition systems, missing or incomplete measurements, high computational demands for real-time processing, and the need for domain specialists to interpret the results. We address these issues by developing a unified and real-time framework for noise and artefact reduction, enhancement of low-resolution data, multimodal data fusion, and predictive analysis based on robust feature extraction. Our multimodal data processing pipeline deep learning and high-performance computing modules. In particular, we introduce a learning-based approach for tumour classification that integrates ultrasound segmentation and feature extraction, techniques for action recognition in 3D depth-sensor videos using kinematic descriptors, and a novel method for graph recovery and prediction via graph convolutional networks. Our results are validated through quantitative metrics on international benchmarks, such as the TUS-REC dataset. As future work, we plan to validate the results with industrial and clinical experts to support the technological transfer of our framework in hospitals and clinical centres.

Keywords

Biomedical Data, Artificial Intelligence, Multimodal Data, Real-time Processing