Variational Autoencoder Latent Space as a Robust Clinical Classification Tool for Neurodegenerative Diseases

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The growing prevalence of neurodegenerative diseases underscores the importance of improved diagnostic accuracy. Many proposed Clinical Decision Support Systems (CDSS) have low interpretability of individual diagnosis and implementability in the clinical setting. Fluorodeoxyglucose Positron Emission Tomography (FDG-PET) is an established modality in differential diagnosis. Using a deep variational autoencoder (VAE) with a graph structure for flexibility and precision, a single, standardized brain FDG-PET image can be interpreted to support the diagnosis of neurodegenerative diseases. Through prior training from FDG-PET brain images (n=2000), 16 low-dimensional and interpretable latent features of each image are extracted, where each dimension accurately represents a pattern of brain activity and variation within. The features from the VAE were analyzed with logistic regression coefficients and aligned with known metabolic patterns from neurodegeneration. An ensemble classifier system of k-nearest-neighbors and logistic regression models was implemented to categorize images embedded in the VAE latent space and achieved high accuracy, for instance, 95% accuracy in diagnosing Alzheimer's disease, in comparison to a baseline principal component analysis architecture. The VAE latent space and graph structure provide clear visual interpretability and illustrate a latent space comparison among dementia phenotypes through a neighborhood graph. In addition to classification, interpolation among disease types uncovers the trajectories of brain metabolism through brain FDG-PET surface mappings. The use of a single brain FDG-PET allows this model to be implementable in the clinical setting and would be a robust CDSS to assist clinicians in diagnosing neurodegenerative diseases.

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