NeuroTracer: Unraveling Prediagnostic Signals for Early Onset Parkinson’s Disease From Archimedean Spiral Drawings Using the 2D Wavelet Transform, Recurrence Quantification Analysis, and Convolutional Neural Networks

Shah, Diya (School: BASIS Chandler)

Parkinson's Disease (PD) is a neurodegenerative disorder that impairs motor function, making early detection crucial for slowing disease progression and managing symptoms. However, current diagnostic methods are often expensive or delayed, creating the need for accessible, affordable early screening tools. This study aims to validate the Archimedean spiral drawing as a biomarker and create a mobile pre-diagnostic app for Early-Onset PD using convolutional neural networks (CNNs). Fifty-five diagnosed PD patients in the medicated state and 55 healthy controls traced four dashed spirals (2 inward and 2 outward spirals per hand). After preprocessing these spiral images, the 2D wavelet transform (WT) was applied to the images to extract spatial frequency information for identifying tremor occurrences. Recurrence Quantification Analysis (RQA), a non-linear time series analysis, was used to find pattern recurrences in the spirals. The RQA output metrics were analyzed using a Mann-Whitney U test, which was able to capture different signs of motor dysfunction between inward and outward spirals. Two pre-trained CNNs, InceptionV3 and InceptionResNetV2, were used with an 80/20 train-test split to analyze the WT and RQA outputs. The InceptionV3 model (F1 score of 0.833, accuracy of 0.818, precision of 0.769, recall of 0.909, and ROC-AUC of 0.893) outperformed InceptionResNetV2. NeuroTracer, an accessible mobile app based on the InceptionV3 CNN, was developed in Python with Kivy for users to receive a PD likelihood score. Future research can incorporate kinematic analysis and voice biomarkers to enhance diagnostic performance.

Awards Won: