COLLEGE OF ENGINEERING AND COMPUTER SCIENCE
FLORIDA ATLANTIC UNIVERSITY

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for the degree of Doctor of Philosophy (Ph.D.)

"Deep Learning Regression Models for Limited Biomedical Time-Series Data"

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ABSTRACT OF DISSERTATION
Deep Learning Regression Models for Limited Biomedical Time-Series Data

Time-series data in biomedical applications are gaining an increased interest to detect and predict underlying diseases and estimate their severity, such as Parkinson's disease (PD) and cardiovascular diseases. This interest is driven by advances in wearable sensors and deep learning models to a large extent. In the literature, less attention has been paid to regression models for continuous outcomes in these applications, especially when dealing with limited data. Training deep learning models on raw limited data results in overfitted models, which is the main technical challenge we address in this dissertation. An example of limited and\or imbalanced time-series data is PD's motion signals that are needed for the continuous severity estimation of Parkinson's disease (PD). The significance of this continuous estimation is providing a tool for longitudinal monitoring of daily motor and non-motor fluctuations and managing PD medications.

The dissertation objective is to train generalizable deep learning models for biomedical regression problems when dealing with limited training time-series data. The goal is designing, developing, and validating an automatic assessment system based on wearable sensors that can measure the severity of PD complications in the home-living environment while patients with PD perform their activities of daily living (ADL). We first propose using a combination of domain-specific feature engineering, transfer learning, and an ensemble of multiple modalities. Second, we utilize generative adversarial networks (GAN) and propose a new formulation of conditional GAN (cGAN) as a generative model for regression to handle an imbalanced training dataset. Next, we propose a dual-channel auxiliary regressor GAN (AR-GAN) trained using Wasserstein-MSE-correlation loss. The proposed AR-GAN is used as a data augmentation method in regression problems.

The developed algorithms were evaluated on an imbalanced synthetic dataset and two real-world datasets in Parkinson's disease (PD) and affect applications. Subject-based, leave-one-out cross-validation (LOOCV) demonstrated that these algorithms provided an excellent generalizability. For instance, a high correlation of r=0.79 (p<0.0001) and a low MAE of 5.95 (5.5%) were achieved using an ensemble algorithm based on three deep models in estimating total severity of PD measured using part III of the unified Parkinson disease rating scale (UPDRS III). The high performance

indicates that each model learns different aspects of the PD motor complications from the movement data. Also, a high correlation of r=0.87 (p<0.001) and a low MAE of 1.74 (6.2%) were achieved using an algorithm based on bidirectional long short-term memory (LSTM) with feature engineering in estimating dyskinesia measured using modified abnormal involuntary movement scale (mAIMS). Similar performance was achieved by the proposed cGAN using the raw signals without the need for feature engineering. The proposed dual-channel AR-GAN overcome the limitation of cGAN in generated plausible time-series data while precisely maintaining the condition-related patterns. Also, the proposed AR-GAN showed the ability to interpolate and extrapolate for conditions not seen during training.

BIOGRAPHICAL SKETCH
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Published Papers:

Hssayeni, M. D., Jimenez-Shahed, J., Burack, M. A., and Ghoraani, B. (2021). Ensemble deep model for continuous estimation of Unified Parkinson's Disease Rating Scale III. Biomedical engineering online, 20(1), 1-20.

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