Advancing Glaucoma Progression Prediction with Machine Learning Models

Marta Colmenar Herrera

Supervisor(s): Prof. Dr. Raphael Sznitman, Dr. Pablo Márquez Neila, Dr. Serife Seda Kucur
Institution(s): University of Bern, ARTORG Center for Biomedical Engineering Research
University Hospital Bern (Inselspital), Department of Ophthalmology

Introduction

Glaucoma is one of the leading causes of blindness worldwide. Accurate assessment of disease progression is crucial to intervene early and prevent irreversible vision loss. Traditional linear models often fail to capture the complex dynamics of glaucoma progression. This study uses machine learning (ML) techniques to improve current methods for predicting glaucoma progression.

Materials and Methods

We used three clinical datasets containing visual field (VF) data from glaucoma patients: the Bern dataset from Inselspital Eye Clinic (Switzerland) and the publicly available Rotterdam and Washington datasets. We assessed glaucoma progression in three tasks: stage classification prediction, binary classification on progression, and VF forecasting. For that, we built triplets of VFs, using the first two to forecast a property of the third. First, we compared non-linear models like the AdaBoost classifier with traditional linear models, such as Logistic Regression, to classify glaucoma stages. Next, the study explores various criteria for binary progression classification, highlighting the need for criteria independent of disease severity to reduce bias and improve prediction accuracy. Furthermore, an autoencoder (AE) model is developed to forecast glaucoma progression by reconstructing VFs (Fig. 1).

Results

In glaucoma stage prediction, non-linear models achieved high kappa metric values of 0.82 ± 0.02, 0.86 ± 0.00, and 0.85 ± 0.01 across the datasets. In comparison, Logistic Regression achieved kappa values of 0.66 ± 0.05, 0.86 ± 0.05 and 0.76 ± 0.01 for the same datasets. Binary progression classification yielded Receiver Operating Characteristic Area Under the Curve (ROC AUC) values exceeding 0.80 across all datasets. The AE model achieved Mean Absolute Error (MAE) values of 2.90 ± 3.16, 2.41 ± 2.87, and 2.56 ± 3.35, for the respective datasets.

This AE model demonstrates superior performance in capturing detailed VF changes over time, especially in progressed cases, surpassing the predictive accuracy of linear models, such as linear regression. The linear model achieved MAE values of 3.28 ± 3.47, 2.12 ± 2.49, and 2.76 ± 3.19, respectively. This AE model is also evaluated for its classification capacity, achieving kappa metric values of 0.83 ± 0.08, 0.95 ± 0.05, and 0.85 ± 0.06 for the respective datasets.

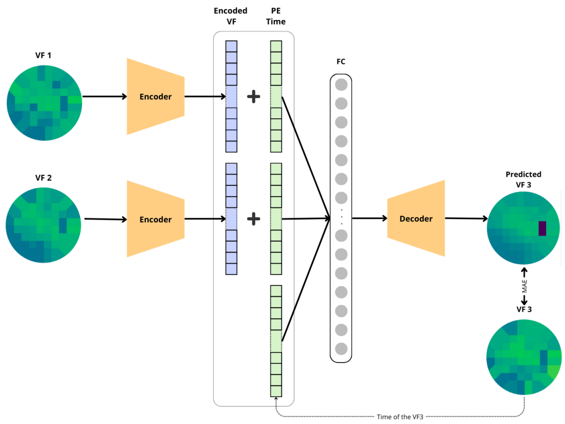

Fig. 1 Architecture of the Forecasting Visual Field Model.

Discussion

Overall, non-linear models consistently perform better than traditional ones in classifying glaucoma stages and forecasting disease progression. These findings underscore the advantages of using ML solutions for predicting glaucoma progression and reconstructing VF data, providing valuable insights that can enhance patient care and pave the way for future advancements in the field.

Acknowledgments

This research was funded by Innosuisse Grant 100.767 IP-LS.

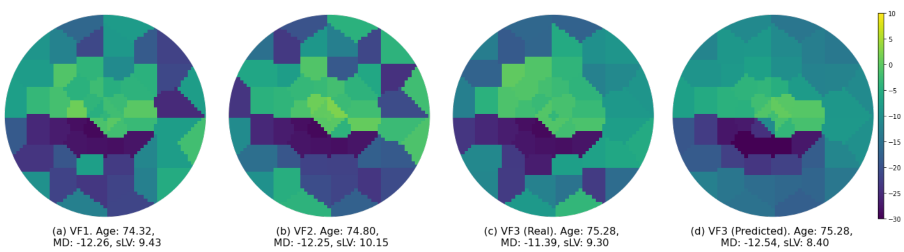

Fig. 2 Example from the Bern Dataset showing Visual Field (VF) forecasting on the test dataset, with real and predicted VF images alongside patient age, Mean Defect (MD), and Loss Variance square root (sLV).