Glaucoma classification with eye-tracking data

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March 2019

1 Introduction

Glaucoma is a group of eye diseases, which affects harmfully the optic nerve and leads to vision loss. About 6 to 67 million people have glaucoma globally. It occurs more commonly among older people. [1]

Screening for glaucoma is usually performed as part of a standard eye examination performed by optometrists and ophthalmologists. Testing for glaucoma should include measurements of the intraocular pressure via tonometry, anterior chamber angle examination or gonioscopy, and examination of the optic nerve to look for any visible damage to it, or change in the cup-to-disc ratio and also rim appearance and vascular change. A formal visual field test should be performed. [1]

What is more, nowadays there is no cure from glaucoma itself, but it can be prevented on early stages of disease development. In that in case, when this disease treated early it is possible to slow down or prevent at all the progression of disease with several medicine techniques implied on patient.

In order to make diagnosis procedure easier and convenient we propose to test and use machine learning techniques on medical data of real patients, which will allow us to reduce amount of medical tests in glaucoma diagnosis, make them faster and technically easily, especially on early stages of glaucoma's development, find new bio-markers for glaucoma diagnosis. The optimization of this medical routines via applying machine learning can reduce the growth of people suffering from glaucoma disease and optimize the medical expenses, referred to diagnostics and maintaining the patient's stable condition.

Eye movements of glaucoma patients have been shown to differ from age-similar control groups when performing everyday tasks, such as reading, visual search, face recognition, driving, and viewing static images.

So the point of this project is to proof this assumption, related to eye movement, by implementing machine learning techniques on the given medical data and to propose the optimisation of this medical routines,

2 Related Work

Due to this problem importance, there were several researches on this problem. Used in this project dataset (description below) [1] was already used for classification in [5], what confirms the informativeness of data. Provided in [1] solution consists of one way feature generation method (Saccade mapping), one dimension reduction using PCA with custom kernel method and one classifier.

Some researches were devoted to eye-tracking data, where there were represented two different techniques of handling the data: analisys via Fixation and Saccade points or [2] analisys using directly eye-tracking time series data. [3]

3 Dataset Description

In our project, we use an open public dataset [1], containing of data from 76 people: 44 glaucoma patients and 32 healthy ones at the age between 50 and 80 years. For everyone there were several test, from which data executed: each participant watched three video clips (see Figure 1), for approximately 16 min in total, and clinical tests of visual function (visual acuity, contrast sensitivity, visual field examination).

Figure 1: Video time codes

The dataset contains raw gaze data (i.e duration of eye tracking, coordinates of Fixation and Saccade points, peak velocity of Saccade), clinical vision tests results and some addititonal info (i.e, age, sex). Raw gaze data was collected, using an Eyelink 1000 eye-tracker, preprocessed using a bespoke C++ program.

4 Machine Learning Methods

Implementation of Machine Learning models can be separated into 3 classes:

- **Machine learning pipeline on time series features**

  After feature generation (dataset with generated features consists of 30 features, among generated: Mean Fixations/Saccades time, Number of Fixations/Saccades, Mean Saccades velocity/amplitude for each video) and applied the following machine learning model: used Feature Selection (SelectKBest. SelectPercentile) and Dimension reduction techniques (PCA, LLA), after that for 6 Classifiers (XGBoost, GaussianNB, KNNeighbours, SVC, Logistic Regression) provided Grid Search with Repeated Stratified KFold cross validation. For best estimators we provided Leave-One-Out cross validation. The best results are represented by Logistic Regression (shown in Figure 2). Trying to improve the quality of classification, based on the data of eye tracker, so we decided to use the following 2 techniques, represented below.

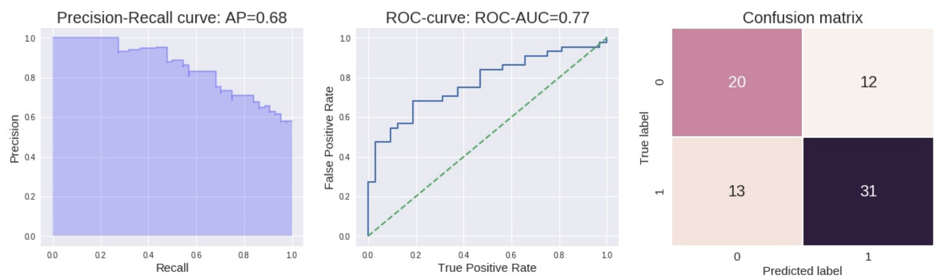

Figure 2: Visualised classification metrics

- **Feature extraction with kernel PCA with custom kernel on Saccade heat map images and change of pupil's area**

  Using a kernel PCA with represented below custom kernel to extract classifiable features from the Saccadic maps. The given idea was provided by [5]. The main point is, that we build centralised Saccade scan paths, from which we generate the Saccadic maps. After using KPCA we obtain new feature subspace, with linear separable elements. The kernel representation as follows:

$$k_{i,j} = e^{-\frac{1}{2}\frac{(maxDiff+meanDiff)^2}{0.2^2}},$$

  where $meanDiff$ and $maxDiff$ are the mean and maximum difference of all video trials between the two participants i and j respectively. The obtained results for Saccadic maps from Centralised Saccade Scan Path (Figure 3.) represented in Figure 4.

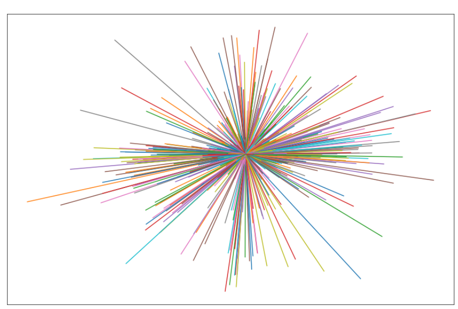

Figure 3: Centralised Saccade Scan Path for Control 20, Dad's army video

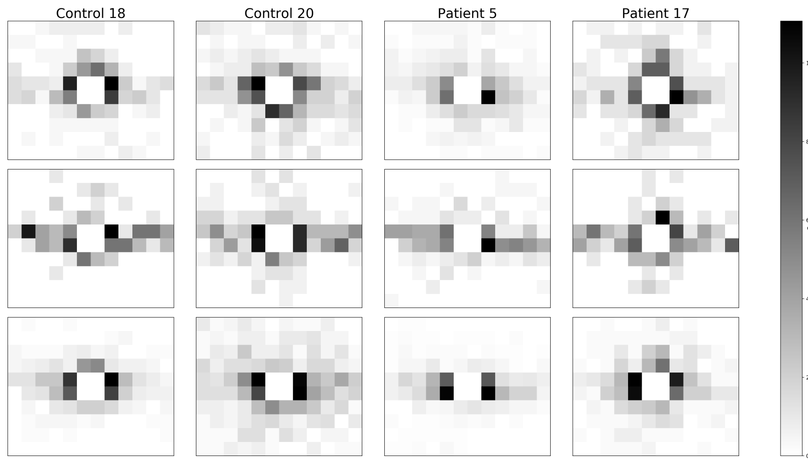

Figure 4: Obtained Saccadic maps

Kernel $k_{i,j}$ forms Gram matrix K which is then normalized and decomposed into principal eigenvectors, the importance of these is evaluated by ranking the corresponding eigenvalues. New features for each person are calculated as the projection onto these principal axes. The main hypothesis in [5] is that using this calculated features we can linearly separate features. The exact following of the ideas, given in [5], we received the similar Saccadic maps, but during the next steps, we didn't obtain the linear separation of data. The correctness of given approach in paper [5] is under question.

- **Neural Networks on Saccade scan path images**

  On the input of the neural network we inserted Cassades images. Our neural network was represented as simple 19 layers convolution network. Due to the fact, that our dataset consists of small amount of samples, neural network failed in finding hard dependencies in data. The resulting metrics were similar to classical ML approach (similar to pipeline results).

5 Discussions

Observing results from 3 Machine Learning approaches, we receive the significant quality (ROC-AUC: 0,77) using our implemented ML Pipeline approach. Comparison with other ML approaches gives the similar results. Kernel approach works, but the statement about linear separation of features for given dataset is under question and can be risen up as the question for next steps of the research.

6 Source code and Contribution

On the following link you can find our code:
https://github.com/NikolayKozyrskiy/SK-Machine-Learning-2019
Team impact:

- **Gleb Balitskiy** - Feature generation, KPCA
- **Andrei Dzis** - ML Pipeline, Visualisation
- **Nikolay Kozyrskiy** - KPCA, Neural Network research
- **Nikolay Skuratov** - Feature generation, ML Pipeline

7 Conclusion

During our project, we applied couple ML techniques for feature generation and extraction, implemented ML pipeline on time series data, applied simple convolution neural network on the generated pictures for Saccade images. The biggest merit of our project is the implementation custom (it wasn't implemented in sklearn of somewhere else) kernel for PCA feature extraction technique.

The stated approach in [5] about the usage of eye tracking data to diagnose the glaucoma isn't good enough to replace clinical diagnostics. We implemented kernel ideas of [5], but didn't obtain the similar results in data separation. What's more the were several issues in paper, which can be risen up in separate discussion.

References

[1] Daniel S.Asfaw, Pete R.Jones, Nicholas D.Smith, David P.Crabb *"Data on eye movements in people with glaucoma and peers with normal vision"* 2018

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[4] Claudio Aracena , Sebastián Basterrech , Václav Snášel†, and Juan Velásquez *"Neural Networks for Emotion Recognition Based on Eye Tracking Data"*

[5] David P. Crabb, Nicholas D. Smith and Haogang Zhu *"What's on TV? Detecting age-related neurodegenerative eye disease using eye movement scanpaths"* Front. Aging Neurosci., 11 November 2014.