Evaluation of Machine Learning Classifiers Detecting Glaucoma Based on Deep Convolutional Neural Network

Shichen Li (the author of this article)
University of Virginia, Department of Engineering Systems and Environment

XR-Driven Digital Transformation of Design, Training, and Education

Research and Working Experiences

07/2019 -- Present, Research Project on Glaucoma Detection using Color Fundus Images
Role: Team Member **Supervisor:** Postdoc Zhicheng Zhang, Stanford University

- Used Convolutional Neural Networks (CNN) and Grey Level Co-occurence Matrices (GLCM) to extract features, based on python cv2, skimage libraries
- Made evaluation of 3 machine learning algorithms in terms of image classification accuracy by sklearn

09/2019 -- 06/2020, Research Project on Mobile Health, Measuring Anxiety Level in Social Interactions
Role: Team Member **Supervisor:** Prof. Mehdi Boukhechba, University of Virginia

- Collected data from Shimmer (ECG and GSR sensors), extracted time-series features from multimodal sensors to detect social anxiety level with Jupyter Notebook, Python 3
- Made comparison of machine learning algorithms to predict social anxiety interaction scale (SIAS) score change, such as Linear Regression, Support Vector Machine Regression, K-Nearest Neighbor, Gaussian Naive-Bayes, based on a system of loss functions, using python sklearn and keras libraries

09/2019 -- 12/2019, Research Project on The Analysis and Improvement of Keppler Medical Device and Material Co. Ltd. Production System
Role: Team Member **Supervisor:** Prof. Cindy Chang, University of Virginia

- Applied of Production System Engineering Toolbox to do different manufacturing system analysis, like identification of bottleneck places and improvable places of this system
- Used Google Colab based on Python 3 to do opportunity window analysis to reallocate the workers

01/2019 -- 05/2019, Research Report for the Heuristics of Arcade Game Design

- Searched all the literatures by myself, and did survey online
- Discovered the real art of designing arcade games in a comfortable rhythm, including a decent user interface, along with the reasonable difficulty and proper hints along with the game.

03/2018 -- 07/2018, Hefei New Oriental English School
Role: Internship Student

- Used Excel to grade mock exams online, including SAT, ACT, TOEFL, AP and GRE; served as teaching assistants in English classes with size of 9 or smaller; wrote feedback for students.
- Enhanced my English reading, listening and oral communication skills.

10/2016, Project of Video Technology and Cloud Computing, Chinese Academy of Sciences

- Completed the software for video dialogue forms all by myself, perfected various of expressions and voice communication function with teammates smoothly, created a decent user interface
- Independently wrote all the codes related to .json, learned to refer to the literature online for coding. completed the Python GUI programming and designed a GUI based chatting client, debugged all by myself.
- Did the investigation report about TS, PS, and PES with other members and presented the final report by myself

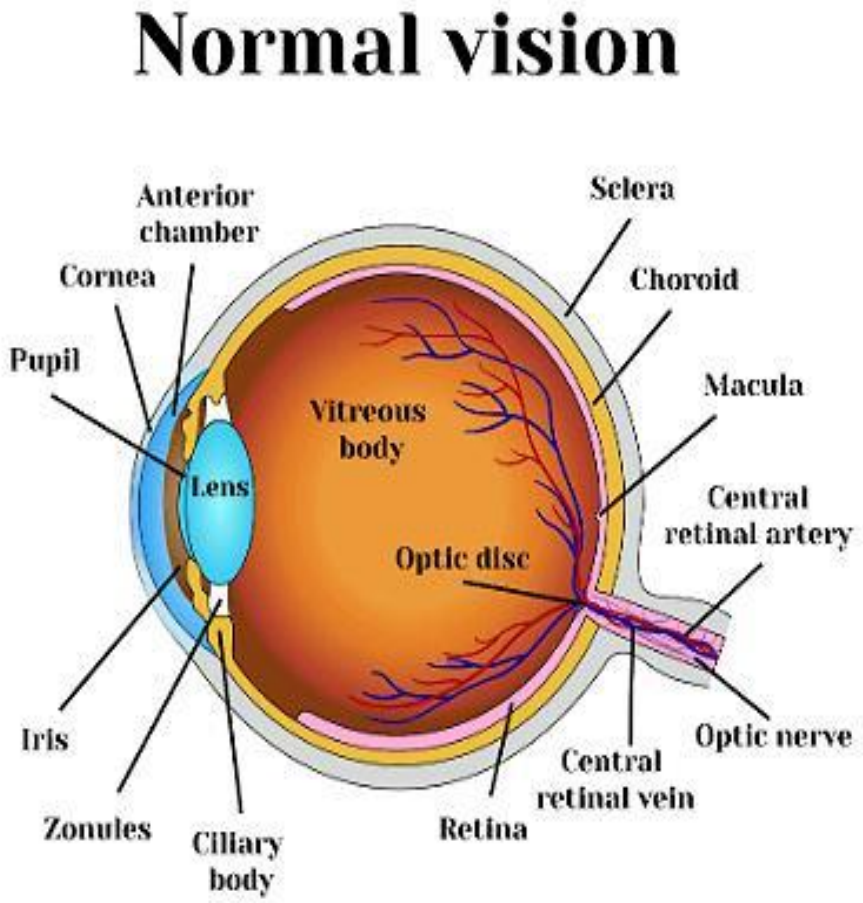
Topics Working On

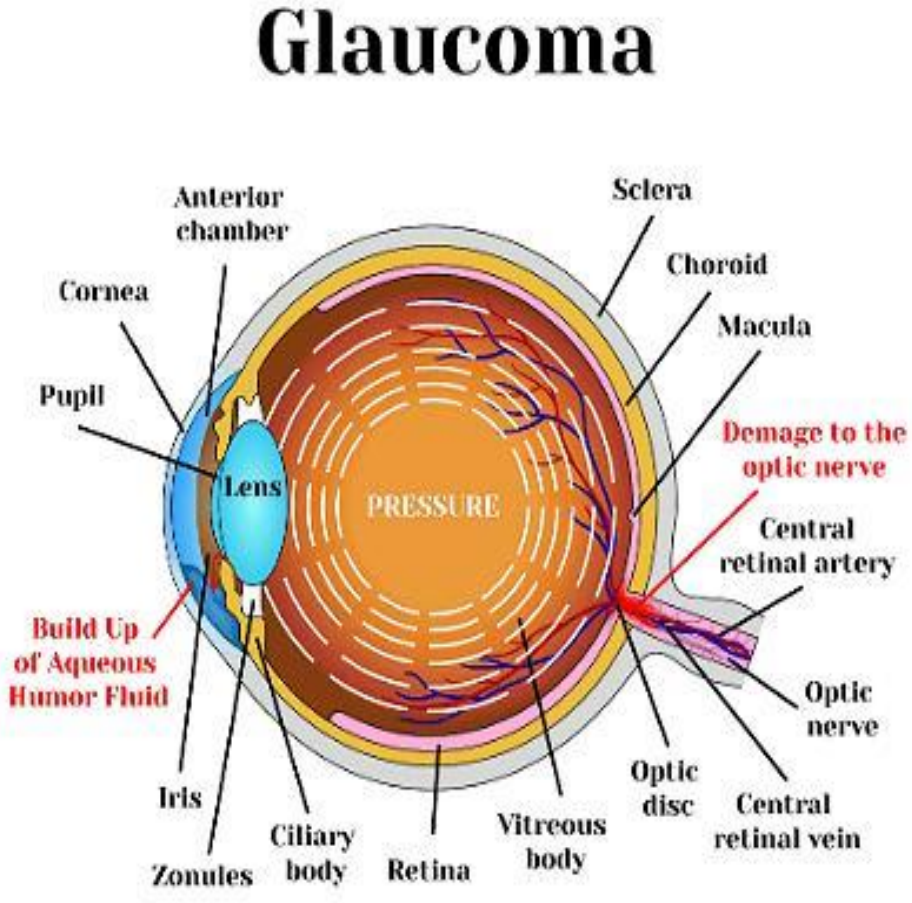
The current institution I am employed in: Zhejiang Lab

The current project I am working on:

1. The Deep Learning of EEG signals for epilepsy seizure detection (current working group)
2. The 3D game design about “Chronicles of the Earth”
3. Continuing on my current project and contribution 28004 “Social Anxiety Disorder based on Mobile Sensing”

The background for this topic





- chronic and neurodegenerative ocular disease, optic disc cupping and optic nerver fiber degeneration
- cup to disc ratio (CDR) <0.6 or the difference of two eyes' CDRs >0.2
- 30 million US, 100 million worldwide

Related Works

K. Chan et. al. [1]:

- Comparing STATPAC software with some machine learning algorithms such as Multi-layered Perceptron (MLP), support vector machine (SVM), Mixture of Gaussian (MOG), Mixture of Generalized Gaussian (MGG).
- Best machine learning better than STATPAC indices

S. J. Kim et. al. [2]:

- 399 cases training, 100 cases testing, 4 algorithms including C5.0, k-Nearest Neighbors (kNN), Random Forest (RF) and SVM.
- RF best performance, no consideration about the cases on the border between healthy and glaucomatous cases

Dey and Bandyopadhyay [3]:

- Noise removal and constrast enhancement as preprocessing, Principal Component Analysis (PCA) for feature extraction, SVM for classification.
- 90 images for training and 10 images for testing, 96% accuracy.(Too few samples)

Related Works

D. Yadav, M. P. Sarathi and M. K. Dutta [4]:

- Gray Level Cooccurence Matrices (GLCM) and PCA, along with deep learning models
- Accuracy of 72%, only 20 fundus images.

Chen et. al. [5]:

- Convolutional Neural Network (CNN) with 6 learning layers, 4 of them convolutional layers and 2 fully-connected layers, extraction of the optic disc Region of Interest on two datasets.
- The proof of feasibility of CNN for glaucoma detection

R. Hemelings et. al. [6]:

- Deep learning with CNN + transfer learning: optimized performances, minimizing the labeling cost of domain-specific mavens

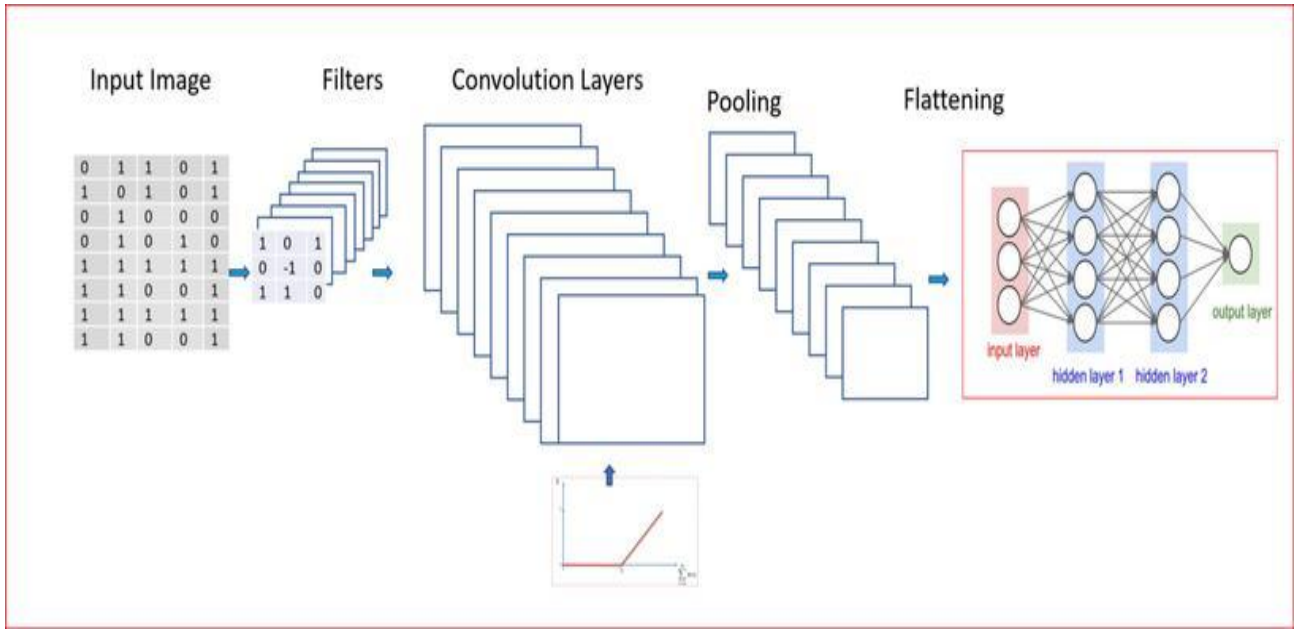
Methods: Experiment Design

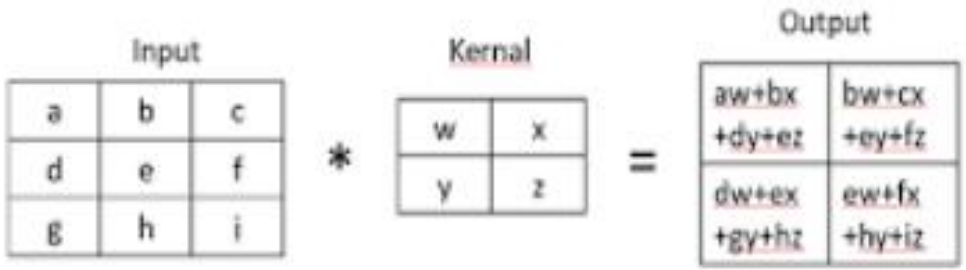
Color fundus images 400, 360 normal eyes and 40 glaucomatous eyes,
Using Convolutional Neural Network (CNN) and GLCM to extract texture features, 3 machine learning classifiers (SVM, RF and MLP) to test the accuracy
Training Set : Test Set = 80% : 20%

glaucomatous
(+)

normal
(-)

Methods: CNN





The basic principle of CNN:

Convolutional Layer: Input image with a sliding Kernel. In this study, we use the matrix of

$$\begin{matrix} 1 & 1 & 1 \\ 1 & -7.5 & 1 \\ 1 & 1 & 1 \end{matrix}$$

to extract the texture features

ReLU Layer: activation function to enhance the nonlinearity

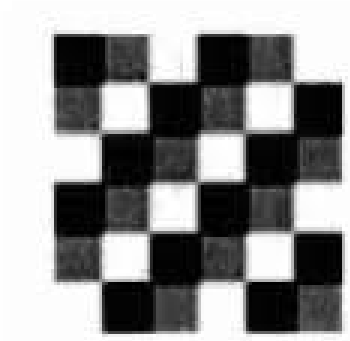
$$f(x) = \max(0, x)$$

Pooling Layer: 2-by-2 maxpooling

Finally, we will use the Fully-connected layer to yield the output

Based on Python 3, with libraries: skimage, cv2, keras

Methods: GLCM



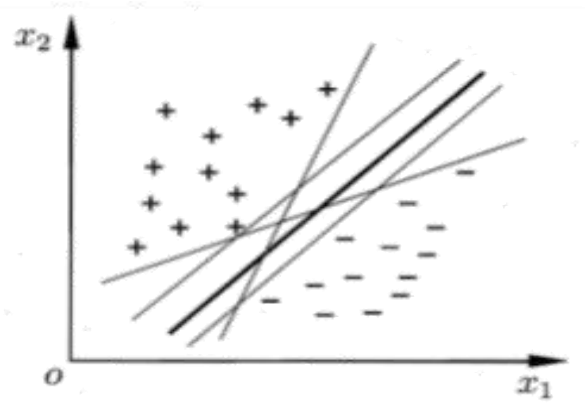
0	1	2	0	1	2
1	2	0	1	2	0
2	0	1	2	0	1
0	1	2	0	1	2
1	2	0	1	2	0
2	0	1	2	0	1

Gray-Level Co-occurence Matrices:
The calculation of correlation between the gray-level two points with specific distance and direction

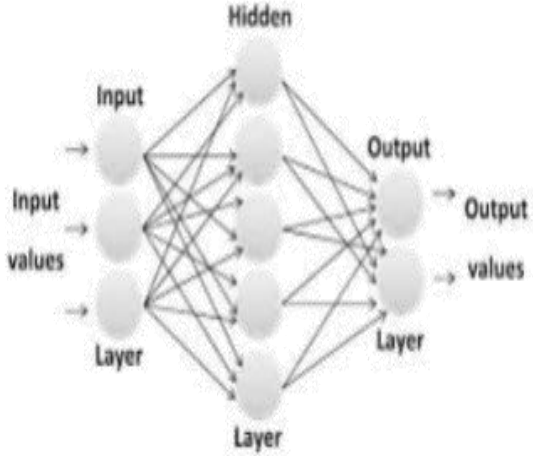
The process before feature extraction:
rgb2gray(): colored images to black and white
img_as_ubyte(): pixels of image to 0 ~ 255
numpy.digitize(): bin numbers to 0 ~ 7

The feature extraction process:
contrast/dissimilarity/homogeneity/energy/correlation/angular second moments (ASM)
In four directions: $\pi/4$, $\pi/2$, $3\pi/4$, 0

Methods: Machine Learning Classifiers



SVM



MLP

RF

Results

Algorithms	SVM	RF	MLP
Parameters	RBF kernel coefficient γ = 0.1	max_depth = 460 the number of estimators = 105 max_feature = 'sqrt'	3 layers sizes: (50,50,50) tanh activation function
Accuracy(%)	86~92	86~96	86~90
True Positives(%)	0~10%	0~33%	nearly 0

Conclusions:
Random Forest: the highest accuracy
Great improvement and more samples compared to [3] and [4] in Related Works
The main problems:
The high False Positive rate

(The RF has somewhat higher ability to detect the glaucomatous images, and the other two are often unable to identify the glaucomatous images)

Future Work

Direction 1: High False Positive Rate

- Development of new techniques of feature extraction such as ResNet, AlexNet, VGG, …, etc. (Working on it with Pytorch now)
- Other machine learning algorithms, such as Decision Trees (DT), kNN, etc.
- More images for training and testing

Direction 2: VR Technologies and Glaucoma

- Construction of spatial cognitive maps for wayfinding [7]
- The use of smartphone-based VR inside VR goggles to assess activity limitations [8]

References

[1] K. Chan et. al., ” Comparison of Machine Learning and Traditional Classifiers in Glaucoma Diagnosis”, IEEE Transactions on Biomedical Engineering, Vol.49, No.9,September 2002, pp.963-974.
[2] S. J. Kim et. al. (2017) ” Development of machine learning models for diagnosis of glaucoma”. PLoSONE12(5): e0177726. doi: https://doi.org/10.1371/journal.pone.0177726.
[3] A. Dey and S. K. Bandyopadhyay, ” Automated Glaucoma Detection Using Support Vector Machine Classification Method”, British Journal of Medicine And Medical Research 11(12): 1-12, 2016, Article no.BJMMR.19617
[4] D. Yadav, M. P. Sarathi and M. K. Dutta, ” Classification of glaucoma based on texture features using neural networks.” International Conference on Contemporary Computing IEEE Computer Society, 2014.
[5] X. Chen et. al., ” Glaucoma Detection based on Deep Convolutional Neural Network”, Engineering in Medicine & Biology Society, 2015.
[6] R. Hemelings et. al., ” Accurate prediction of glaucoma from colour fundus images with a convolutional neural network that relies on active and transfer learning”, Acta Ophthalmol. 2020: 98: e94–e100
[7] F. B. Daga et. al., ” Wayfinding and Glaucoma: A Virtual Reality Experiment”, Investigative Ophthalmology & Visual Science July 2017, Vol.58, 3343-3349.
[8] R. L. Z. Goh et. al., “Objective Assessment of Activity Limitation in Glaucoma with Smartphone Virtual Reality Goggles: A Pilot Study”,Translational Vision Science & Technology January 2018, Vol.7, 10.

Thank you!

Any Questions?