Modeling of Age-related Macular Degeneration evolution using unsupervised deep learning approaches

Project
Age-related Macular Degeneration (ARMD) is an eye disease that slowly causes the atrophy of the retinal pigment epithelium causing the patients to ultimately go blind. The disease can be diagnosed and monitored using eye fundus images (cSLO in infra-red) that are available in large quantities due to the non-lethal aspect of the pathology.

The study of these series of eye fundus images is an active field for 20 years now [1][2] as it may lead to break through in predicting how the pathology evolves and may help to determine the efficiency of experimental cures to slow or stop the lesion growth.

However, due to various defects present in the images, tasks as simple as segmenting the lesions on individual images or following the lesions evolution remain difficult both for expert doctors and algorithms. It is our goal to use the recent advances in Deep Learning, in particular applied to change detection or times series using unsupervised methods to be able to make a break through that may: first help to properly detect the evolution of the lesion through full series of ARMD images with little to no annotated data. Second, using these observations proposing a model (neural network based, statistical, or otherwise) that can predict the evolution of ARMD lesions based on the first images of a series.

Challenges
Despite the high number of available images and the perceived possibility to model the lesion growth process, eye fundus images suffer from many flaws that make them difficult to study: These images present heterogeneous quality levels, lighting and contrasts defects that make the simple segmentation of potential lesions on single images an already difficult process both for humans and machines. Standard segmentation algorithms, such as region growing [3] or variational methods [4,5] fail to reach the expected level of accuracy. Supervised classifiers applied to features extracted from the images may show better performances but require labeled data [6,7]. The difficulty is further increased when it comes to studying series of images as the aforementioned defects are not the same through the series, and additional alignment and angle issues may come into play. Finally, the last difficulty comes from the lack of reliably annotated or labeled data thus making it difficult to use the trendy supervised neural networks that have great performances for segmentation, classifications and predictions tasks.

During the first part of the thesis, using tools such as convolutional neural networks, coupled with Autoencoders and times series analysis models such as LSTM or GRU, which have shown to be effective with similar problems in Remote Sensing [8][9], the successful candidate will propose an unsupervised deep learning approach that can detect the lesion evolution through the ARMD images time series.

Then, the second part of the thesis will focus on predictive and modeling approaches for the evolution of the lesions. The first predictions could be made using the neural networks used to follow the lesion evolution. However, due to the “black box” nature of such algorithms, it may be difficult to derive explainable models that could be linked with underlying medical conditions. As such, the Ph.D. candidate may choose between working on the interpretability of the neural networks he used, or turn to statistical approaches to try to reproduce the evolution of the lesions based on the neural network models while keeping a good level of interpretability.
It is worth mentioning, that while the PhD candidate will be a computer scientist working on a Machine Learning problem, finding reliable and interpretable models for the evolutions of ARMD may lead to break through in finding more effective medical treatments for ARMD as a successful model may help to determine whether or not a treatment changes the course of the lesion evolution.

References:


Collaborations

This project will be done within the context of a collaboration between ISEP and the Ophthalmology department of the Quinze-Vingts Hospital whose head Pr. Michel Pâques provides us with our times series and will help in defining the medical objectives and validate the proposed methods.