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# Abstract

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# Introduction

## Detection of neurodegenerative diseases

Late onset Alzheimers Disease: PET & MRT

## Currently no early detection CSIRO and retinal image analysis

Vessel properties (width), correlation with diseases

Previously applied only on single images, expand into sequence

## Motivation

Develop new diagnosis method

Research vessel properties, measure vessel elasticity in IR sequence

# Methods

For the first time ever, a procedure had to be developed at the eHealth research center of the CSIRO in order to collect and evaluate information on the back of the eye, which was intended to be applied to a sequence of retinal images. The aim was to investigate whether the change in vessel width caused by the pulse was optically measurable. The basis for measuring the width of vessels in a single image was developed by Phd. Shaung Yu, so that this solution could be integrated.

The medium that is evaluated is a monochromatic infrared image of the human retina with a resolution of 1600x1200 pixels. To process a sequence of such images, a pipeline with three main steps and many sub steps has been developed. It is used to extract many different parameters from the image sequence, one of them being the change in vessel thickness over time. In addition, other pipeline-relevant methods are also implemented, which are mandatory for their regular flow as well as very helpful for the evaluation and verification of the intermediate step results.

In the following paragraphs, the most important methods of the pipeline for evaluating and analyzing vessel width are explained.

## Quality preprocessing

The individual frames of the image series sometimes have strong differences in quality. These quality differences range from small contaminants or particles that hover over a certain area during the series and cover some vessels, up to large distortions of the entire image through rapid movement and blinking. Such frames must be identified and excluded beforehand so that the analysis can be applied to a series of images that are as undistorted and uncovered as possible. Therefore, it is very difficult to develop an automated method because of the different nature of the distortions that can occur. The estimation of when a frame of a series should be excluded must, therefore, be done manually and at one's own judgment. To do this, several frames are taken into account before and after a blinking or abrupt movement of the eye and identified where distortion such as stretching of the whole or part of the image can be seen. This step is of highest priority, as distortion changes the vessel width enormously and can ultimately lead to completely wrong measurement values. Removing individual frames from a series has no effect on the following pipeline except that fewer records are available and everything related to it. This could possibly cause inaccurate readings, as important events such as the systolic peak of a vessel could be overlooked. However, given the consequences of distortion and the fact that affected frames cannot be analyzed anyway, the influence of remote frames is neglected.

## Stabilize movement of the eye

If the image series is as undistorted as possible, it must be stabilized, because for an exact measurement of the parameters the vessels should be at a fixed position in the series. The reference is the optical disc, which can be easily recognized as the origin of the retinal vessels and by the dark circle. There is always a slight movement of the retina in every series of pictures. However, a wide range of movements is usually observed, be it simple movements such as the slow, continuous drifting of the retina from one point to another, or complicated movement patterns such as sudden twitching of the eye from one point to another in different directions. The latter can also result from the removal of individual frames from the quality selection, so that due to missing frames the retina suddenly appears at a different location in the image. Any kind of movement can interfere with the measurement and the resulting measurement values. Therefore, the series should always be stabilized. Several methods have been used and investigated to achieve the best possible result.

1. Python feature matching using OpenCV

This is an own implementation of image stabilization using OpenCV in Python. A brute force matcher with the SIFT descriptor is implemented for this purpose. The first frame of a series is the reference frame, on which all other frames are aligned. First, all features are identified in the reference image and in the frame which is to be stabilized and then paired with each other using the cnnMatch function. The paired features of the two frames can then be used to determine their coordinates. The difference between the X and Y positions can then be used to determine how strongly and in which direction the frame which is to be stabilized deviates from the reference image. This displacement is applied inversely to the frame being aligned so that all vessels and the optical disc are in the same position as in the reference frame.

Evaluation tool to compare movements

## Single Image Width Measurement

### Optic disc detection

Resize image

Make b&w mask

Illuminate green channel

Detect disc? = disc center, disc radius

Vessel segmentation

Vessel skeleton, remove branches

Partition eye into zones A, B, C

Vessel width measurement

Spline along the skeleton

Gradient points along the spline, averaging

## Extracting parameters from a Sequence of images

* + 1. Trace the vessel width (FrameTime, remove NaN)
    2. Get vessel parameters
       1. Curve fitting = frequency, bpm, phase
       2. Vessel width = estimate min, max
       3. Vessel elasticity

## Post processing of parameters

* + 1. Outlier identification
       1. By hierarchical clustering (bpm, phase, elasticity)
       2. By thresholds (bpm, elasticity, fitting score)
          1. Reject outliers
    2. Vessel classification
       1. Arteries/Veins by largest phase shift
    3. SQL Database for gathering data
       1. SQL Browsing tool
       2. Verification of vessel parameters (elasticity, plot, vessel class)
    4. Estimate vessel elasticity change across vessels
       1. Vessel width-elasticity plot for each zone
       2. Linear regression through points
       3. Compare plots of zones B and C, esp. of both eyes
       4. Average both zones

1. Classification of elasticity data
   * 1. Big six => prioritize thicker vessel elasticity (threshold for low elasticity)
     2. slope of the function for overall elasticity

# Results

1. Dataset
2. Select from 32 subjects with ca. 2 sequences each (both eyes)
   * 1. Final amount of subjects, vessels etc.
3. Blind dataset (not known, which condition)
4. Task supervision
   * 1. Movement translation
     2. Optic disc detection
     3. Result verification
5. Elasticity
   * 1. …
     2. accuracy
6. Classification
   * 1. …
     2. Comparison with clinical data
     3. Accuracy
7. Runtime
8. Discussion
   1. Does the vessel elasticity measurement support the correlation to diseases?
   2. What is the impact/future of this research project?