RETCAD SYSTEM

The RetCAD software is a system to detect AMD and DR related abnormalities in color fundus images. The final outputs of the system are heat maps indicating the locations of detected abnormalities related to AMD and DR and two image abnormality scores; one for the presence of AMD and one for the presence of DR. The higher the score, the more likely that the patient should be referred to a health care specialist, i.e. ophthalmologist.

INPUT

Input for the RetCAD system: a color fundus image in the RGB color space taken at an angular resolution between 30 and 45 degrees and having even illumination across the retina. Furthermore, the image should have a minimal resolution of 1024x1024 pixels and the macula should be visible in the image. The input image should be in one of the following file formats: .dcm, .jpeg, .tif, or .png.

OUTPUTS

Outputs of the RetCAD system:

Score Outputs:

- Quality check system:
  - Computed image quality score
- AMD and DR analysis system:
  - DR Score: score indicating the likelihood that the patient should be referred for DR
  - AMD Score: score indicating the likelihood that the patient should be referred for AMD

Heat Map Outputs:

The outputs of the AMD and DR analyses are, next to the analyses scores, heat maps indicating locations in the image which are suspicious for abnormalities. These heat maps are shown as a color overlay on top of the contrast enhanced image. Figure 1 shows an example input image with DR (A), contrast enhanced image (B) and the corresponding heat map for DR with its color coding (C). Figure 2 shows an example input image with AMD (A), contrast enhanced image (B) and the corresponding heat map for AMD with its color coding (C).

Figure 1: (A) Input color fundus image   **(B) Contrast enhanced image**   **(C) DR heat map**

Figure 2: (A) Input color fundus image   **(B) Contrast enhanced image**   **(C) AMD heat map**

The heat map for DR shows lesions related to DR that include so called 'red lesions' i.e. microaneurysms and hemorrhages. Exudates and cotton wool spots are not highlighted in the heat map. However, the DR score does take other lesions (e.g. microaneurysms, hemorrhages, exudates, cotton wool spots, neovascularization etc.) into account and the DR score should thus be leading for the decision on DR referral.

The heat map for AMD focusses on drusen, the early signs of AMD. Other abnormalities are not highlighted in the AMD heat map. However, the AMD score does take other lesions (geographic atrophy, pigmentary changes, neovessels, etc.) into account and the AMD score should thus be leading for the decision on AMD referral.

PDF Report Output:

RetCAD composes a standardized PDF report out of the RetCAD results, including the Score Outputs and Heat Map Output. An example of such a report can be found in Figure 3.
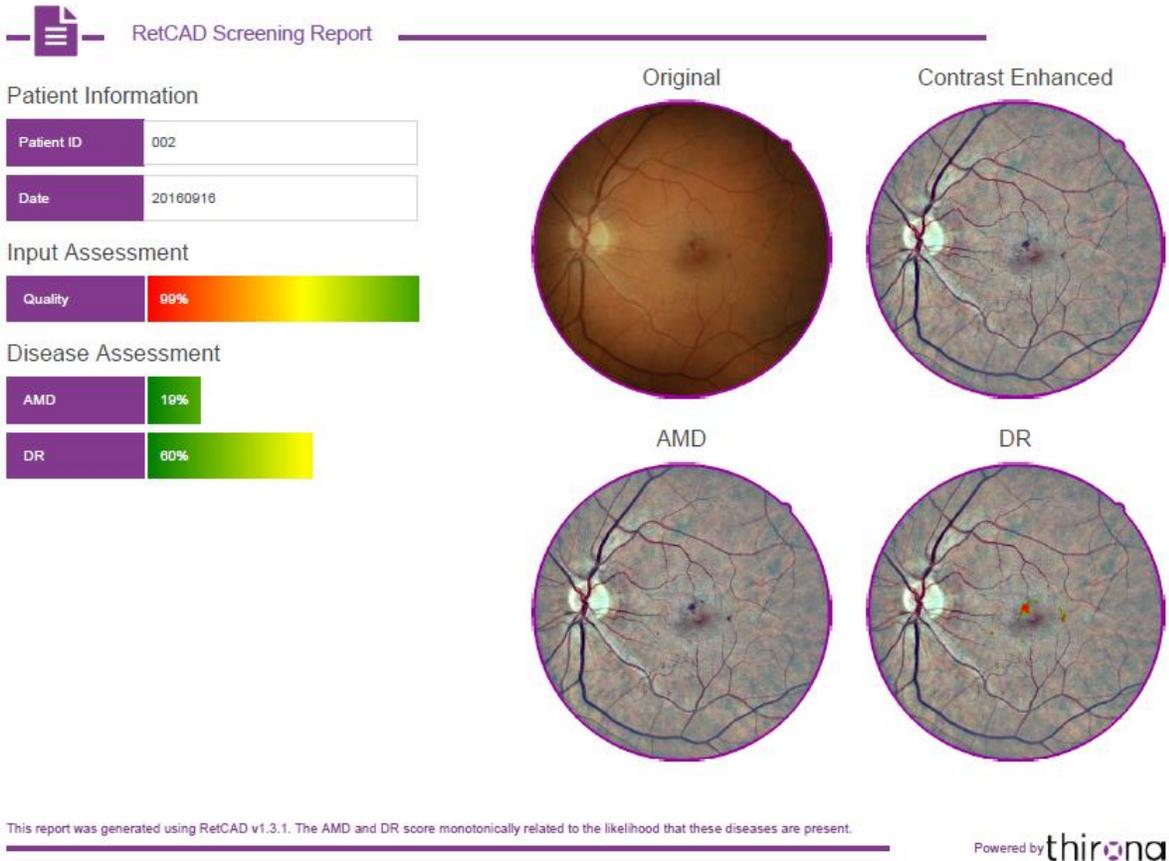
Figure 3: Example output PDF report by RetCAD.

In the Report, the output scores (quality, AMD score, DR score) are shown using a color coded bar. The higher the score, the larger the bar. For the image quality, the bar is color coded from red (bad quality) to green (good quality), whereas for AMD and DR, the bar is color coded from green (no referral) to red (referral). The color of the bar depends on the value of the score (e.g. a high AMD score results in a large color bar reaching the red color)

INTERPRETATION OF SCORES AND HEAT MAPS:

- Quality check system: The analysis of images with a low image quality score might be less reliable than analysis of images with a high image quality score.
- AMD and DR analysis system: the abnormality score is monotonically related to the likelihood that the color fundus image contains signs of AMD and/or DR and should be referred to a health care specialist, e.g. an ophthalmologist. The user should take these score as leading score for his/her decision.
- Heat maps: the heat maps can be used as a visual aid when the AMD or DR scores are high, i.e. to check where abnormalities are present in the image.

Users can take these outputs into account in their clinical work: they can decide if a new image should be acquired, in case the quality assessment indicates suboptimal image quality; they can decide that the subject should undergo further testing for the presence of AMD, DR or other retinal diseases, in case the heat maps display suspicious regions or when the scores are above a certain threshold. The choice for the thresholds should be made by the user and will depend on the conditions under which the software is used.

RETCAD OPERATION THRESHOLDS:

The values of the AMD score and DR score are in a range between 0 (no referral) and 100 (definite referral). A value of 50 can be used as a cut-off point for the referral-no referral decision, where patients with scores above 50 should be referred. The value of the threshold determines how many patients will be send for referral: A high threshold (e.g. 60) means that only the most suspicious patients will be referred and a high overall specificity will be obtained (at the cost of false negative referrals). A low threshold (e.g. 30) means that more patients will be referred and a higher sensitivity will be obtained (at the cost of more false referrals). In order to not miss any patients that should be referred, we advise to use a threshold 'on the safe side' which is somewhere between 30 and 50.

The scores are based on the AREDS (AMD) and ICDR (DR) grading protocols and can be roughly divided into the following classes:

AMD (according to the AREDS grading protocol)

- 0-25: No AMD
- 25-50: Early AMD
- 50-75: Intermediate AMD
- 75-100: Advanced AMD

DR (according to the ICDR grading protocol)

- 0-25: No DR
- 25-50: Mild DR
- 50-67: Moderate DR
- 67-84: Sever DR
- 84-100: Proliferative DR