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Eye Fundus Image Processing System for Automated Glaucoma Classification

INTRODUCTION AND VISION

Glaucoma is an eye disease that threatens the eyesight of the patients. As the disease progresses, nerve fibers in the retina die, which, if left untreated, leads to blindness. In Germany around 5% of the population (5 mill.) live with a glaucoma risk while around 800.000 people suffer from glaucomatous damages [1]. Although glaucoma cannot be healed, the progression can be stopped. Therefore, early detection of the disease is essential for preventing one of the most common causes of blindness. Glaucoma screenings based on digital images of the retina have been performed in the past few years in the clinics but they still lack robust automated assistance.

We devised an automated system that detects glaucomatous eyes based on acquired fundus images. In contrast to other approaches [2-5], we use image-based features of fundus photos that do not depend on exact measurements gained by segmentation techniques. This appearance based approach is new in the field of retina image processing.

Our vision is to establish a screening system that allows fast, robust and automated detection of glaucomatous changes in the eye fundus. Such a system could even be deployed in everyday environments, like shopping malls, to reach many people. It helps to discover suspected glaucomatous cases and warn the subject, so that careful evaluation can be done in time to control disease progression. This would not only reduce health care costs of treating glaucoma but would also prevent affected patients from vision loss. An acquisition device (Kowa NonMyd digital fundus camera) and an example image of the retina are shown in Figure 1.

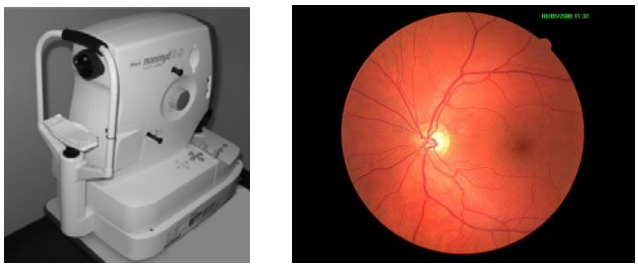

Figure 1 Kowa Digital Fundus Camera and an acquired image example.

First, we briefly describe our processing system and the used methods. It is followed by an evaluation based on 200 images. By applying a 2-stage classification scheme we achieve a total classification correctness of 86 %.

SYSTEM OVERVIEW

We devised a system for **c**omputer **a**ided de**t**ection of **eye** diseases (called **CatEye**). It is a database driven framework to process, analyze and classify retina images. Existing functionality from tools, such as the ITK image processing toolkit [6] or Matlab can be easily integrated while the C++ framework provides image (and derived) data access (read and write) to the retina database. There are interfaces to implement image processing filters or methods to compute classification features. Programs can be fairly easily created to process large image sets from the database by applying certain filters or to visualize results.

The image processing pipeline follows the standard three-stage structure of (i) pre-processing, (ii) image-based feature extraction, and (iii) classification (see Figure 2). A brief description of the methods used in each step follows.

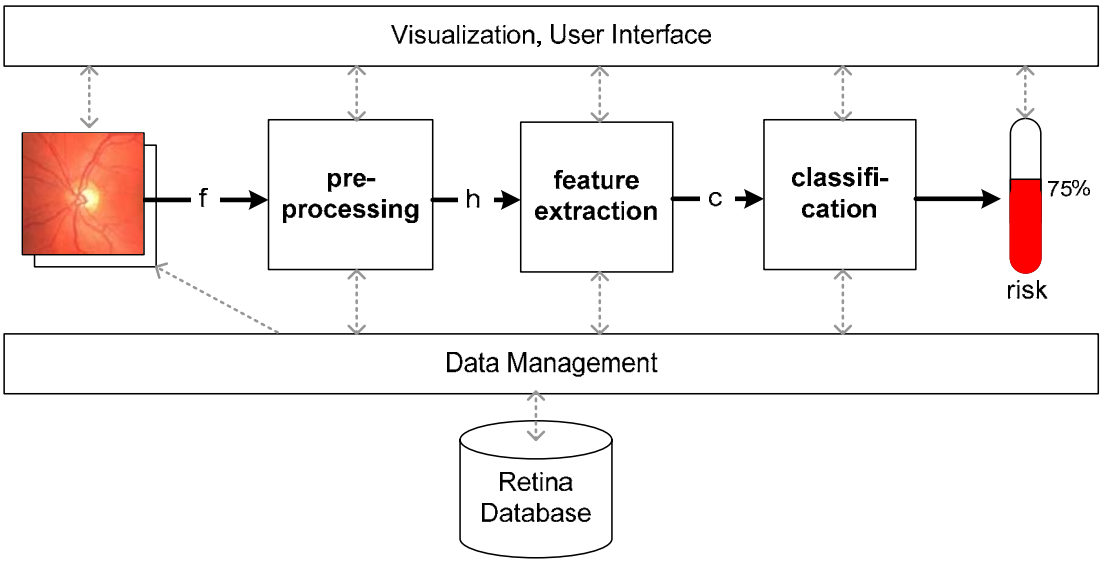

Figure 2 CatEye (Computer Aided Detection of Eye Diseases): System Overview.

PREPROCESSING

On one hand, nonuniform illumination is a general problem in retina image analysis. It is due to the small size of the objects and the complexity of the optical system (including both the camera and the eye) involved in the imaging process. Such inhomogeneities are corrected by robust homomorphic surface fitting [7].

On the other hand, blood vessels introduce a high variation in retina images which seems to be a distracting feature when diagnosing glaucoma. In our study, blood vessels are removed by computing a vessel mask and interpolating the missing pixel values by morphological inpainting [8].

The neuroretinal rim around the optic disc (papilla) is the most important region for glaucoma detection [9]. We normalize the images such that the papilla is centered and appears in the same size. This normalized input is required for the feature computation by appearance based approaches. Localization and size estimation is done by the method of [5]. Finally, all images are scaled to a fixed size of 128x128 pixels for feature extraction. Figure 3 shows example images after all steps are done except the final scaling step.

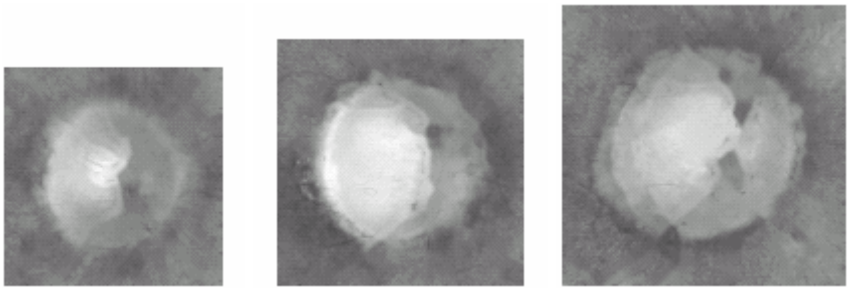

Figure 3 Examples of images after preprocessing (illumination corrected, cropped ROI, and excluded vessels) showing different papilla sizes. First: a healthy retina, second: a glaucomatous optic disc, third: a healthy retina with macro papilla.

FEATURE EXTRACTION

To capture different aspects of the image information, we use four types of feature extraction. (i) The first set of features is obtained by taking the pixel values directly as input to principal component analysis (PCA) which is used here as a dimensionality reduction technique. (ii) The second feature group comes from 28 Gabor texture filter responses [10] that represent spatial and spatial-frequency information of the data. The filter output is also compressed using PCA. (iii) The third set of features is computed from the coefficients of the Fast Fourier Transform (FFT) which contains translation invariant global frequency information. Again, PCA is used for data reduction. (iv) Histograms provide a compact summary of the intensity distribution in an image. In this application, they also show structural parts of the images (background, papilla rim, optic cup). A tri-modal Gaussian mixture is fitted to the histogram using maximum likelihood estimation and then the found distribution parameters, such as the mean and the variance values, serve as features.

CLASSIFICATION

We found that a 2-stage classification scheme performs better than classification using any of the four feature sets alone or using a single pooled feature set. First, the four sets of feature values are classified separately by support vector machines (nu-SVM [11]). Then, the probability score of belonging to the glaucoma class, obtained from each of the four classifiers is taken as a new feature vector input to another classifier. This final SVM-classifier decides whether the sample is considered glaucomatous or not.

EVALUATION AND RESULTS

For evaluation, we took 200 images (50 images each of healthy and glaucomatous eyes for training and a similar mixture for separate testing; age of the subjects: 57±10 years) randomly selected from the Erlangen Glaucoma Registry (EGR) that contains thousands of records of the eye ground of healthy subjects and patients having glaucoma. Diagnosis was done by an ophthalmologist using anamnesis, image data and other measurements. The images were acquired by a Kowa NonMyd digital fundus camera.

We computed the overall classification correctness and also the F-measure, which is the harmonic mean of sensitivity and precision, for healthy and glaucomatous eyes. The experiments where performed with a cross-validation on the separated test set. The performance of the classifications using one feature set only varies: total correctness of 73% with the histogram features, 76% with the FFT coefficients, 80% with the Gabor

textures and 83% with the pixel intensities. When applying the second classification step, 86% classification correctness is achieved with an F-measure of 83% for healthy and 88% for glaucomatous samples. This is similar to what was achieved by experienced human observers. According to [12], experts achieved by qualitative assessment of optic disc stereo photographs (63 normal and 29 glaucomatous subjects) an average F-measure of 91% for detecting normals and 79% for detecting glaucoma.

CONCLUSION

We presented our automatic system for computer aided detection of eye diseases (CatEye) used to identify glaucomatous eyes in fundus photographs. The images can be acquired quickly and without any inconvenience to patients. The classification success rate of the system is comparable with that of experienced human observers. Thus, such a system can be deployed in large scale screening examinations for early detection of the disease. To our knowledge this is the first data-driven feature computation and classification system for glaucoma detection from retina images.

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