Using Smartphones to Take Eye Images for Disease Diagnosis in Developing Countries

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ABSTRACT

Mobile health applications can increase access to healthcare in low and middle-income countries, where the penetration of smartphones is rapidly increasing. However, despite a large amount of clinical trials of mobile health applications, there is little proof of beneficial clinical outcomes. Recent studies suggest that one of the reasons is user experience issues. The aim of our work is to improve the user experience of acquiring medical eye images with a smartphone camera. We present EyeGuide, a mobile application that assists people in taking eye images. Possible application areas are the algorithmic detection of diseases and the support of clinicians during tele-medicine examinations.

CCS CONCEPTS

• **Applied computing → Consumer health**;

KEYWORDS

Healthcare, Smartphones, Eye, Developing Countries, Image Analysis, Diagnosis, mHealth, Telemedicine

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1 INTRODUCTION

Mobile health technologies can help to increase healthcare coverage by providing accessible, easy to use and effective screening solutions for the early detection of causes for preventable blindness, such as cataract. According to the WHO, 39 million people worldwide are blind [8]. 80% of visual impairment can be prevented and 90% of the visually impaired live in developing countries [8].

After more than 500 clinical trials of mHealth applications there is very little evidence that they result in positive clinical outcomes [7]. One of the reasons, as a recent study of several tools to encourage medication adherence in older adults suggests, is that user experience factors might contribute to the low satisfaction with mHealth applications [6]. In a report for the National Health Service (the public health provider in the United Kingdom), Greenhalgh et al. mention the ease of use of mHealth applications as one of the deciding factors in innovation adoption [1].

Therefore, the goal of our work is to (1) identify user experience issues when taking smartphone images of one's eye, (2) to find out how to solve the issues and (3) to create a user-friendly application that produces images suitable for diagnosis.

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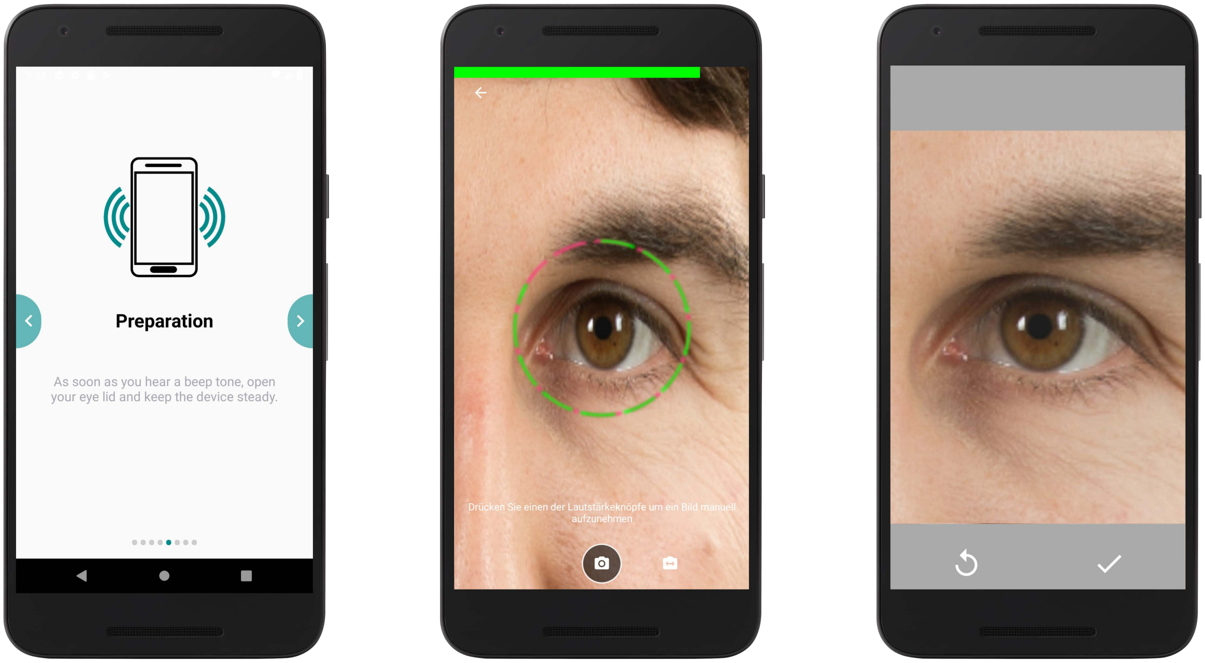
2 RELATED WORK

One area of ophthalmology where smartphones have successfully been introduced is fundus (retina) photography. Commercially available smartphone adapters that can be attached to the camera lens are sold, for example, by Peek Vision (~240 US$, http://peekvision.org). A similar product, D-Eye (435 US$, https://www.d-eyecare.com), has shown a high match rate in diagnoses when compared to a traditional slit-lamp biomicroscopy in grading diabetic retinopathy [5]. While affordable and portable adapters for retinal imaging support clinicians and nurses in areas with a low number of healthcare facilities, they are not suitable for personal use through patients. Even if the technology was easy enough to use for self diagnosis, the burden of accessing the required accessories for retinal imaging is high, in particular in developing countries.

However, there are diseases that can be detected with a smartphone camera and no additional accessories. Different approaches for cataract detection with a smartphone have been proposed [3, 4]. To measure the cholesterol level non-invasively, Kumar (2016) developed an image analysis method which requires true color images that could be acquired with a smartphone camera [2].

3 EYEGUIDE

To understand the issues related to clinical eye photography with a smartphone, we first observed four individuals who we instructed to acquire photos of their iris with their smartphone. The individuals in this prestudy used the built-in camera application with both the front and rear camera. An analysis of the resulting images revealed that lighting and positioning seemed to be the predominant causes of blurry images or images without a visible iris. Additionally, the front camera did in general not provide sufficient image quality for our purpose. Based on these fidings, we developed an Android application to guide the user through the acquisition. Our approach is to support the user at three stages: before the acquisition through a tutorial (see figure 1a), during the acquisition through positioning guidance (see figure 1b) and after the acquisition through image review (see figure 1c).



(a) Tutorial: Hold the device steady when the beep tone is played.

(b) Visual guidance for a second person or when using the front camera.

(c) Image Review: An image can be rejected if the user considers it not good enough.

Figure 1: Screenshots of the three acquisition stages: Tutorial, Positioning Guidance and Image Review.

3.1 Tutorial

Before the actual acquisition, EyeGuide supports the user in creating suitable conditions for taking eye photos. This includes lighting, where EyeGuide explains the user how to position themselves relative to light sources. Another hint refers to the distance between device and eye. Additionally, EyeGuide explains how to prepare for the acquisition (see figure 1a).

3.2 Positioning Guidance

The key challenge in providing positioning guidance is the correct detection of the eye. During the acquisition, EyeGuide analyzes the camera stream to detect eyes and gives directional guidance based on the eye position within the image. We used synthesized voice commands (e.g. "to the left") for rough positioning guidance. Additionally, the distance between the device and the eye was measured and fed back to the user through voice outputs ("nearer" or "closer"). The eye-device distance was approached through the relative size of the eye in the image (large eye area indicates small distance). As soon as the positioning is within the defined thresholds, EyeGuide plays a beep tone that increases in frequency with better positioning. After a short amount of time, usually less than two seconds, the image is automatically taken and the user is directed to the review screen.

3.3 Image Review

One of the most important image characteristics, the sharpness of the image, cannot be analyzed in real time. This is due to the computing power needed for sharpness analysis and the lower quality camera stream differing from the actual full-size photo. Therefore, after the acquisition at the review screen (see figure 1c), blurry images are rejected and the user is sent back to the acquisition screen.

3.4 Visual Guidance

The main use case of EyeGuide is the self acquisition with the rear camera, where we have to rely on the auditory guidance as the screen is not visible. However, in the case a person has someone else to take a picture for them, we also included a visual on-screen guidance. A ring in the center of the screen helps the user to position the eye and indicates when the image is acquired (see figure 1b).

3.5 Implementation

EyeGuide is an Android application written in Java. To track the eye position in the liveview screen (see figure 1b), we used the `openCV` library with the `Haar Feature-based Cascade Classifier for Object Detection`[1], which is an AI-based model for image recognition tasks. To find the optimal parameters for the eye detection (`detectMultiScale` method, parameters `scaleFactor` and `neighbors`), we took 50 sample images, 28 with eyes and 22 without, from a Samsung Galaxy S7 rear camera stream. The images without eyes showed other parts of the face around the eyes. We then analyzed the classifications (correct, false positive, false negative) for combinations of the parameters. Finally, we chose the parameters with the highest accuracy and speed.

[1] https://docs.opencv.org/3.3.0/d7/d8b/tutorial_py_face_detection.html

4 CONCLUSION & FUTURE WORK

The most important requirement EyeGuide has for the device is the camera quality. Not all cameras are able to take images with sufficient quality for disease detection. Therefore, EyeGuide needs to be tested on devices that are most used in rural areas with a lack of healthcare access.

The most promising applications are the detection of diseases in the conjunctiva and cornea. EyeGuide might also be helpful in tele-medicine exams, where a doctor could request a image of the patient's eye for a more precise diagnosis. We are discussing potential use cases of EyeGuide with ophthalmologists.

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