Design and Implementation of Smartphone-Based Tear Volume Measurement System

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Abstract. Evaluation of tear volume is important for diagnosing dry eye disease. At the clinical site, dedicated devices such as Slit-lamp Microscopy or Meniscometer have been used to quantify tear volume by ophthalmologist. However, these devices have access only in medical office and therefore have limited availability for the public. Tear volume changes with environmental, physical or psychological situation. For that reason, measurement of tear volume regardless of location, time or circumstances can be beneficial not only for healthcare professionals but also for patients. If tear volume could be measured by using smartphone, it is expected that the smartphone could be utilized as an IoT sensor for the healthcare application. In this study, tear volume measurement system was designed and implemented on smartphone. Further application for smartphone as an IoT device will be discussed.

Keywords: Smartphone · Tear volume · Dry eye · IoT device

1 Introduction

Dry eye patients have been reported to be increasing due to excessive use of visual display terminals (VDT), such as smartphones and personal computers. Evaluation of tear volume is indispensable for diagnosing dry eye but precise measuring is difficult because of the tiny amount and transparency of tear. Tear volume is considered to be associated with environmental, physical or psychological situation such as humidity, VDT work or mental stress. In the clinical site, tear evaluation is performed by shirmer's test, which includes placing filter paper inside lower eyelid, or by tear breakup time (BUT) measurement, which requires fluorescence instillation [1]. However, these measurements are invasive and therefore it is difficult to perform evaluation without any stimulation to the eye during measurement. Non-invasive meniscometer has been developed for measuring tear meniscus radius (TMR) which reflects tear volume [2, 3]; however, this device has been used only in medical office and therefore has limited availability for the public. If eye condition could be self-checked and controlled easily

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outside medical office whenever eye dryness or eyestrain is sensed, it could lead to the prevention of dry eye. Smartphone-based tear volume measurement system could be utilized as an IoT sensor for the healthcare application. Feasibility study of measuring TMR using the smartphone has been conducted in our former work [4]. In this study, tear volume measurement system "Meniscope" was designed and implemented on smartphone, and whether the system functions as an IoT sensor was tested.

2 Development of Tear Volume Measurement System

Tear meniscus (TM) is a thin strip of tear fluid with concave outer surfaces at the upper and lower lid margins and contains approximately 75–90% of the overall tear volume. In meniscometer, parallel black and white lines are projected horizontally to the concave surface of lower TM and reflected image from TM is captured. Then, TMR r is calculated by concave mirror formula (1) using projected line width t and measured line width i from detected image as shown in Fig. 1 [2].

$$r = 2W(i/t). \tag{1}$$

Here W, i, and t are working distance between camera and TM surface, measured line width vertically against TM, and projected line width to TM, respectively.

Following this principle, prototype of smartphone-based meniscometer "Meniscope" was developed, where iPhone 6s Plus's (Apple, Inc.) display played the role of projector and front camera the role of image detector. Macro lens was used to zoom in TM and its attachment was made using 3D printer. Magnified image of lower lid was taken adjacent to the left eye by turning smartphone's torso sideways so that the display is located on the left. White, yellow and black moving bands were displayed in the monitor and reflected image from TM surface was captured. Examinee was told to gaze at the red fixation point on the display during the measurement. This system has W of 35 mm, t of 18 mm, monitor brightness of maximum, and line velocity of 33 mm/sec, respectively. TMR was automatically calculated by image processing algorithm including use of Hough transformation [5] as shown in Fig. 2.

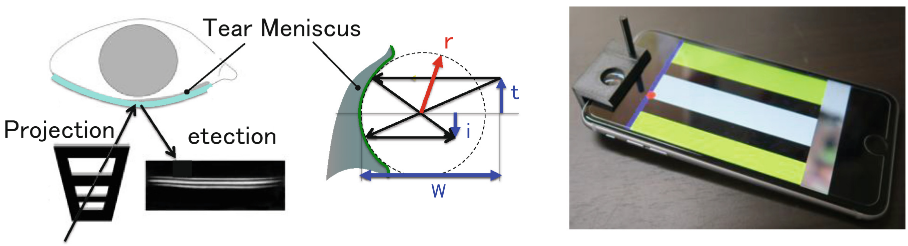

Fig. 1. Diagram of Meniscometry, edited image of [2] (left) and front view of prototype (right)

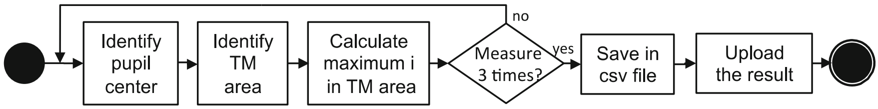

Fig. 2. Flow chart for TMR measurement algorithm.

3 Meniscope as an IoT Sensor

Preliminary study for 20 human subjects has been in progress for the purpose of confirming the feasibility of measuring TMR by using this system as an IoT sensor. A representative example of captured image during TMR calculation is shown in Fig. 3. We also have developed a system for uploading data to the server. It has become possible, with the prototype, to check the change in tear volume displayed graphically in the server, but to apply this system to IoT healthcare device, it would be necessary to combine tear volume with other data such as heart rhythm or physical activity.

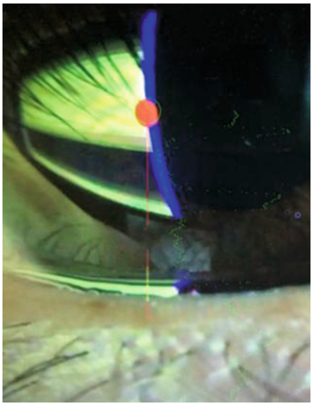

Fig. 3. A representative example of captured image during calculation of TMR.

4 Summary

Smartphone-based tear volume measurement system was developed as an IoT sensor by applying the principle of meniscometry. One limitation of this system is that it is difficult to adjust camera to the right position during self-measurement. In the preliminary study, it is expected that diurnal change of TMR will be measured using this system. The result of the study will be discussed in the conference.

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