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An idea of intuitive mobile diopter calculator for myopia patient

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Abstract

The diopter is the unit of measurement for the refractive power of a lens. Myopia is a form of refractive error which is a leading cause of visual disability throughout the world. The prevailing treatment of refractive errors which are commonly used in daily life are glasses and contact lenses. Although those methods can overcome myopia, many myopia patients still don't really know how to measure their current refractive error in diopter. This condition may retard the progression of refractive treatment in the myopic individual. The common methods to measure refractive error are phoropter with Snellen chart and retinoscopy, but those expensive tools need expertise to operate. This paper presents the concept of measure the face to smartphone screen distance to provide the possibility to implement a mobile application as a low-cost alternative refractive measurement tool. The main objective is to investigate the feasibility of mobile application to help patients with myopia measuring their blur line distances and evaluate their diopter levels independently. The experimental results reveal that, with 80.5 usability score the overall functionality of proposed application can be categorized as usable to users and feasible for future implementation.

Keywords: *diopter, mobile application, myopia, refractive measurement, screen to face detection*

1. Introduction

The Myopia (Nearsightedness), a form of refractive error which is a leading cause of visual disability throughout the world. Refractive errors are the inabilities of the eyes to focus on the visual images from the outside environment, which results in serious visual impairment in severe cases, blurred vision or even blindness [1]. For myopia patients, close objects look clear but distant objects appear blurred because the light is being focused in front of instead of on the retina of the eye [2]. Studies have documented a very high prevalence of myopia among urbanized Asian countries over recent decades, reaching epidemic levels of around 70–80% of young adults living in East Asian countries such as Taiwan, Japan, Hong Kong and Singapore [3-6]. The prevailing treatment of refractive errors which are commonly used in daily life are glasses and contact lenses [7]. Although those methods can overcome myopia, many myopia patients still don't really know how to measure their current refractive error. This condition may retard the progression of refractive treatment in the myopic individual.

The common method to measure refractive error is combination of a phoropter with Snellen chart [8]. Phoropter contains different lenses that can be adjusted by the optometrist to get patient's blur line [9]. This method can gives accurate outcomes, but it is still need a large platform and can only be operated by a professional optometrist. This process also requires visual acuity knowledge from the patient as well. Retinoscopy is an alternative method of measuring refractive error which does not require patients' co-operation. This method uses a tool called a retinoscope, but this expensive tool needs expertise to operate [10].

The emergence of smartphones makes these ubiquitous devices are increasingly complex, computationally powerful, and integrated with various sensors. Smartphone can collect, compute and upload various data, providing opportunities to improve quality of life in a way that not easily achievable with conventional approaches [11, 12]. Recent examples are evidence that this technology is feasible as portable diagnostic tools that offer an opportunity to decrease costs and increase the availability of healthcare [13], from self-monitoring pigmented

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moles [14], until diagnosis of infectious diseases [15]. This puts forward for consideration that mobile applications might bring a big help for myopia patients to measure blur line distance and recognize myopia before visiting an ophthalmologist.

The objective of this study is to present the concept of measure the face to smartphone screen distance to provide the possibility to implement a mobile application as a low-cost alternative refractive measurement tool. Next, we investigate the feasibility of mobile application to help patients with myopia measuring their blur line distances and evaluate their diopter levels so they can independently measure and monitoring their eye condition by only using a smartphone.

2. Research Method

Developing diopter measurement application for myopia has expanded our point of view about vision examination and monitoring systems, but it must be emphasised that these new technologies also introduce a change in the conventional eye assessment methods. Building an diopter measurement application is not simply a matter of technical wizardry. This is due to the fact that calculate the power of a lens only with a smartphone need a fancy algorithm. Additionally, develop an application that easy to use by the user is also matter.

2.1. Need Findings

We conducted a field study by exploring individual responses about their awareness of eyesight problems. Next, based on collected respondent data, we build user journey to gather the user requirements. A user journey map is a recently emerged method for designing and assessing user experience in the product design field. This map adds a third dimension feature to a traditional user persona by focusing on a diachronic outline of a user and a product [16]. Recent works prove that this approach is effective tool for rapidly gather user story in order to develop an intuitive application [17, 18].

We collected our user's personas before we conduct designing phase. A persona is a useful tool for describing user profile of a specific target group, it conveys the relevant demographic, psychographic, behavioral, and needs-based attributes [19]. Number of participants that involved in the field study and testing can be varied. Nielsen et al insists that five participants will discover as many usability problems as more test participants will do. The involvement of five participants is capable enough to give the appropriate benefit-to-cost ratio in usability testing [20]. According to the literature studies, we involve five participants in this research. They were at least familiar with Android mobile application with minimum OS version 5 (Lollipop) and good in English. They were categorized by people with normal eyes, myopia but not wear glasses and myopia with glasses. Also have basic knowledge or experienced with measuring their current refractive error and know their own current diopter level so they can confirm the correctness of the proposed application result. From our studies, we have found some insights and barriers to eye health and vision examination of common people, these are:

a. They are not aware of their eye problems.
b. They are not visiting eye doctors or ophthalmologist regularly.
c. Cost and other limitations (transport, scarcity of doctors, distance, etc.).

Based on these insights, we proposed an intuitive and low cost alternative refractive error measuring tool that can be used independently by a user only with a smartphone.

2.2. Compute Eye to Smartphone Screen Distance

The detection of user face to smartphone screen distance bring many benefits for mobile based utility applications. Many methods have developed to calculate the distance between eye to smartphone from using Infrared camera [21], combination of stereo camera and infrared [22], until using video of a monocular camera [23]. In 2014, Konig et al, proposed an algorithm to measure the screen-to-face distance based on the base length data between two eyes in a reference distance only using smartphone build-in sensor and front camera. This Screen to face distance calculations output in centimeter distance [24]. Therefore, Konig's method stands out from other approaches by providing a real time distance calculation and give natural visual experience in the way of interaction with smartphone. The usage of proposed application and illustration of eyes and smartphone screen distance (f) is depicted in Figure 1. This design only effective when the view angle is 90 degrees from smartphone screen.

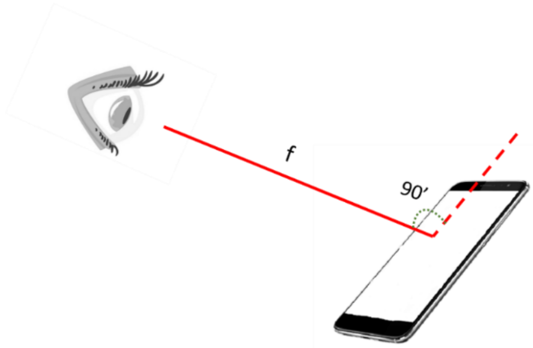

Figure 1. The design of eye-screen measurement scenario

2.3. Compute Lenses Power for Blur Line

To develop our mobile app, we used the distance of each eye's blur line. Blur line is the distance from an eye in reading position until text appears blurry [25]. User eye detection is made by using Google mobile Vision API [26]. This API provides an interface to detect the left eye, right eye, and nose as a point of interest within a face. Then based on distance that we obtained from the previous phase, we calculate the diopter using formula in [27]. Measurements were automatically obtained from each eye and averaged on each measurement occasion. Konig algorithm only effective to measure the distance from 19 centimeters to 89 centimeters, this means, an application that implemented this algorithm can only effective to calculate the diopter levels from -1.12 D to -5.26D.

2.4. System Design

In order to display a diopter level to the user accurately, this application needs to convert the raw data distance data to diopter value. This application uses front face camera to capture real-time imagery from user face then automatically determine the eye position to determine the distance of blur line. Next, with the distance data, application compute the diopter level and show the result to user. The complete process flow is shown in Figure 2.

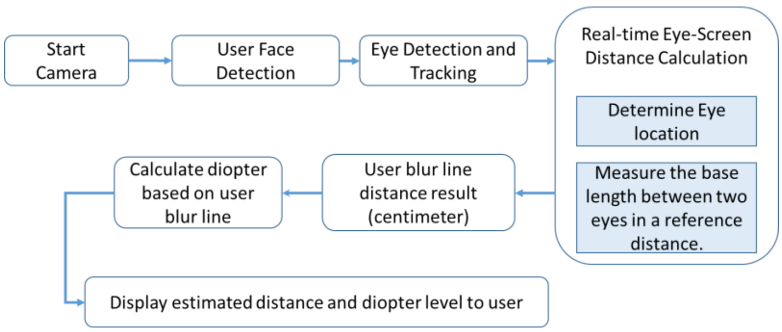

Figure 2. Process flow of proposed application

Since we are developing a mobile app, the blur line distance of the screen and the user's eyes that used to examine the patients are limited due to the used algorithm only have feasible accuracy on particular distance. Thus, we decided to take 19 centimeters as minimum distance and 89 centimeters as maximum distance.

3. Results and Analysis

As described in IEEE standards [28], validation needed to check whether all application functionalities have satisfied the requirements. To evaluate the feasibility of our approach to provide an intuitive measurement tool for myopia patients, we implemented several case studies on top of an Android platform as a minimum viable product. In the following, we introduce the main feature of proposed application prototype like calibrating the camera to real-time detection of eye position, calculate the blur line distance, and calculate the diopter level to investigate the usability of the application.

3.1. Prototype Implementation

The mobile application prototype was built for Android supported devices based on insight that we have on user journey map. We ask the participants to do some task scenarios with our prototype. Experimental condition in Figure 3 showing the measurement and calculation of diopter level in our prototype.

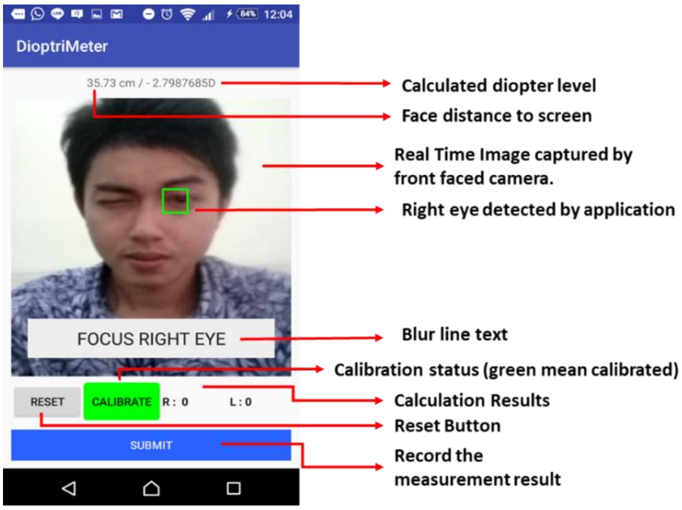

Figure 3. Experimental user interface of proposed prototype

The main feature of this app is to calculate the eye power to read some text in blur line area. When the user opens the application, the application provides step by step instruction to user so they can use this application. Each eye may have different diopter level so this prototype designed to calculate each eye power (right or left) start from the right eye and during the test, the other eye should remain closed. Then the application will measure the blur line distance and calculate the diopter level automatically, user only needs to tap the "submit button" after they see their blur line from the screen. The screen flow for this user interaction is depicted in Figure 4.

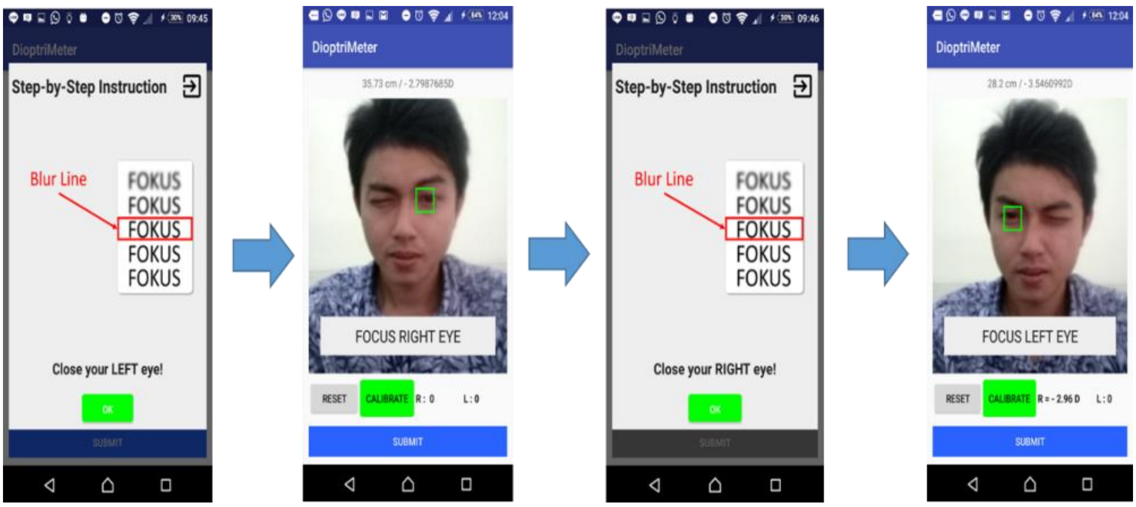

Figure 4. Screen flow design of the application

3.2. Prototype Evaluation

In evaluating the application prototype design, the resulting screen flows need to be partially implemented or physically coded. However, as this research is still in the early stage, the focus is not on how to implement the application and measure its accuracy, but evaluating how usable a mobile application as a low-cost alternative refractive measurement tool is. Therefore, we use usability testing to validate the usability of our approach. The usability testing is a most often utilized method for verifying and validating the quality of software [29].

We used the same participants as in need finding phase and ask them to do some task scenarios as described in Table 1 with our prototype. While they were performing the tasks, their performance on the tasks was observed and any problems occurred or faced by users were noted.

Table 1. Task Measure Lens Power

Task	Description
1	Start the App
2	If user wear glasses, Take off the glasses.
3	Close left eye to measure the right eye blur line.
4	Measure the distance from user eyes to the screen until get the blur line.
5	Use submit button to record the distance of blur line and diopter level.
6	Do step 3- 5 for left eye.
7	Go to the result page to see the diopter level of both eyes.

The usability testing is done with the questionnaire on participant assessment of our prototype application. The questionnaire covers three factors of usability, i.e. effectiveness, learnability, and satisfaction. In IEEE standard validation [30], time and success rate mentioned as parameter for efficiency and correctness, so time and success rate are used as efficiency indicator to evaluated the feasibility of our approach in each user task. After the participants complete all the tasks on proposed application, they were asked to answer System Usability Scale (SUS) questionnaire to measure the usability level of the application. SUS is proved as a relevant approach to conduct usability evaluations [31]. Participants were asked to score the ten modified question items that adapted from [32] to measure several usability parameters as in [33] with one of five responses that range from strongly agree to strongly disagree. Testing result of each scenario and summary of time required to measure the diopter, success rate and SUS questionnaire for proposed application are summed up in Table 2. To calculate the SUS score of each participant, for positive response questions: subtract one from the participant response. For negative response questions: subtract the user response from five. This method scales all values from 0 to 4 (with four being the most positive response). Add up the converted responses for each participant and multiply that total by 2.5 to convert the range of possible values from 0 to 100.

Table 2. Evaluation Results

Variables	*SUS Result (Mean / SD)*
Time Needed (minutes) :	2.03 / (0.40)
Success Rate (%) :	100 / 0.00
Questions (Usability Parameters) :	
Q1: I think the result is match with my condition (Satisfaction)	2.20 / (0.45)
Q2: The user interface of in giving the results are easy to understand (Learnability)	3.20 / (0.45)
Q3: The information provided is very clear and effective when measuring the diopter of each eye (Effectiveness)	3.20 / (0.45)
Q4: I feel I don't need someone else's guide to using the app (Learnability)	2.60 / (0.55)
Q5: The language and instructions provided are easy to understand (Learnability)	3.60 / (0.55)
Q6: I need another external tools to help monitoring eyes condition. (Effectiveness)	2.80 / (0.84)
Q7: The colors, icons, and other interface components used are familiar and consistent (Learnability)	3.80 / (0.45)
Q8: The button is large enough when tapped, so it efficient to select the menu (Efficiency)	3.20 / (0.84)
Q9: If I need to measure eye blur line, I would love to use this app (Satisfaction)	4.0 / (0.0)
Q10: If I make a mistake, I can quickly recover (Efficiency)	3.60 / (0.55)
Total SUS Score	80.50 / (4.11)

The results indicate a similar pattern of the user behavior, meaning that proposed apps could help user to measure the diopter level with 100% success rate, considering the total time for performing each scenario condition, participants completed the experiment task considerably fast with proposed application (Mean=2.03 minutes, Min=1.6 minutes, and Max=3.1 minutes) when compared to the average time taken when conduct clinical refraction measurement [34]. The total SUS score is more than 80, meaning that the overall performance of this prototype is excellent to user [35]. Data variability has become a prevalent issue as usability testing has extended to unstructured testing. The grater variance value will create a greater risk of violating the homogeneity-of-variance assumption. The small range of standard deviation (SD) in each the SUS questionnaire gives information that several users have similar experience with proposed application. Even though proposed application have highly rated SUS score, it is noteworthy that from Q1, the accuracy of this prototype needs further evaluation and analysis. Sometime, different diopter result between application and real eye condition has shown to participants by the application. In the effectiveness factor, the proposed idea makes users don't need many tools to calculate their current eye conditions, only using a mobile application that installed on their smartphone. Participants also made similar comments in favor of our prototype supporting the result of time and success rate. Although our proposed application was highly rated, the majority of participants made several comments about drift problem. One participant stated, "The proposed system prototype is very intuitive to use but sometime there is a mismatch between the real distance and app result", and another noted that "even the diopter level not exactly matching (on the current user condition), but with information on the screen, I could easily guess about the current eye diopter condition (increase or decrease) because eyesight may change throughout the day".

4. Conclusion

This paper proposes a design of android based mobile application which can measure the diopter level of a person only using front face camera and build-in smartphone sensors. A user can determine the blur line distance and calculate the diopter level automatically. The evaluation results show that the proposed prototype can be categorized as usable to users. In the future, with further analysis and accuracy improvement, the proposed application could provide a big help in monitoring eye conditions to detect eye diseases and visual acuity level in their early stages. Additionally, this application can be integrated with other myopia therapy and rehabilitation system.

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