**ECE1778 CREATIVE APPLICATIONS FOR MOBILE DEVICES**

# LensMeter

Power of eyeglasses measuring Application

**Final Report**

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## 1 Introduction

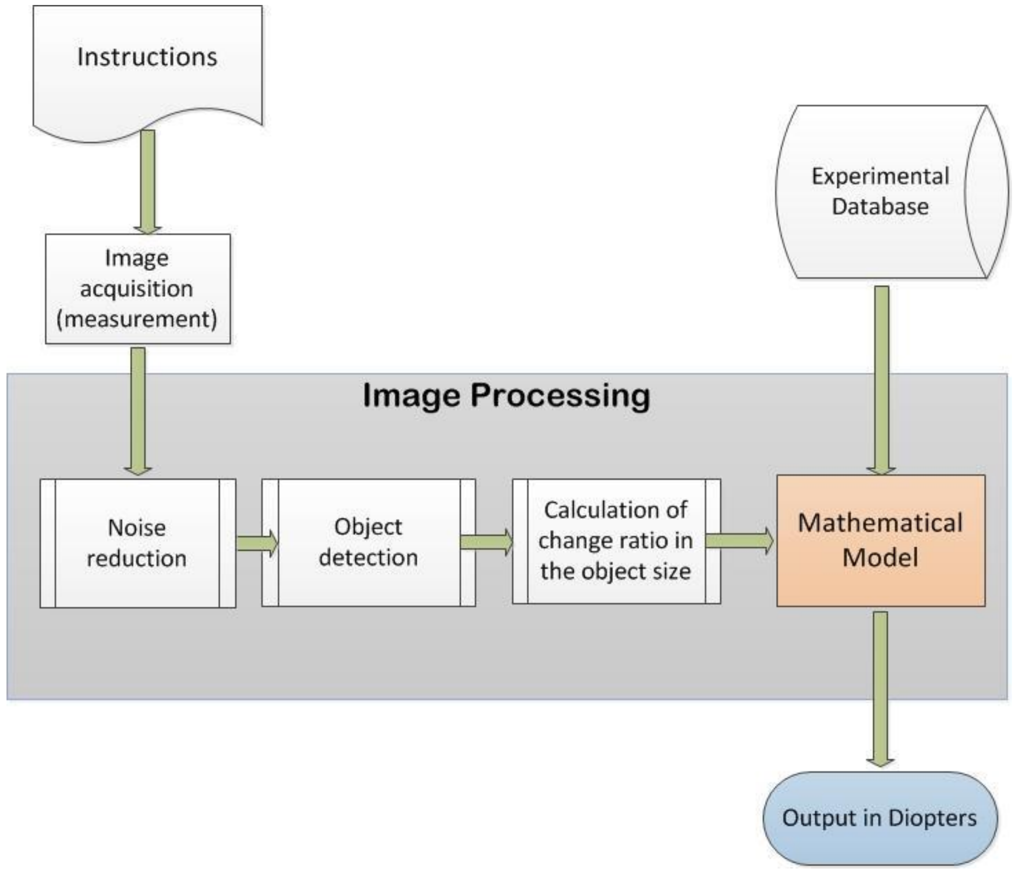
Eyeglasses are the most popular implement for the correction of ocular anomalies. One demographic study from Singapore suggests that afflictions such as myopia or other refractive anomalies may affect up to 82% of the country's population (Chow et al, 1990).

Many bespectacled may not have an understanding as to the importance of an appropriate eyeglass prescription. Presently, the accurate measurement of eyeglass prescriptions is limited to a clinical environment employing the use of an automatic or manual lens meter. Unfortunately, e-commerce has established a channel through which consumers and patients, without this knowledge, may quickly purchase eye care products that may be inappropriate to their needs for a number of important reasons. As an expert in the field of optometry and eye care with significant clinical experience, I have begun a campaign to convince my peers to challenge this problem head-on. I aim to achieve this through the use of a mobile application.

The solution my team is developing establishes a new method to estimate the prescriptive power of spectacles using handheld, personal devices. This is anticipated to have a profound impact on the eyecare industry particularly contributing to the future growth through the online sale of the eye care products.

### 2 Overall Design

**Block Diagram:**




**1- Instructions:**

First screen in the app is the instructions screen, where the user is presented with an animated explanation of the process, and how the measurements should be taken. The user can go through the instructions or skip to the next step.

**2- Measurement:**

Based on the instructions, the user should fix a black A4 paper on a light colored wall, and stand around 2 meters away. The user is then asked to take pictures of the specified object in the normal setting, then take a picture of the object through the left lens of the glasses, and a last picture through the right lens. The user is guided with instructions, and a marker to help center the image.

**3- Noise Reduction:**

The first step in the processing of the pictures taken is noise reduction. This is done by applying a gaussian blur to the image, then a threshold to convert them to binary pictures. A dilate process is then applied to fill the gaps and complete deformed shapes. Since we asked the user to use a black paper on a light colored background, most of the background pixels after the threshold will take the value 0, and the pixels of the paper will take value 1.

**4- Object Detection:**

The paper should be close to the center of the image, if the user followed the instructions correctly. The app tracks the pixels of value 1 that are close to the center to detect the boundaries of the paper object. The image is then cropped based on those boundaries to be processed separately.

**5- Calculation of ratio of change:**

After cropping each of the 3 images, the pixels having the value 1 (representing the paper object) are counted in each. The ratio of change in magnification is calculated by dividing the count of pixels from the image taken through lens over the count of pixels representing the paper in normal setting.

**6- Mathematical model:**

From our experiments, we have fit a mathematical model to the data obtained, and eventually got a function that predicts the power from a given pixel ratio. We plug the calculated ratio into our model, and get a prediction.

**7- Results:**

The value predicted by our model is then rounded to the nearest half, and returned to the user for both lenses of the glasses.

## 3 Statement of Functionality

The functionalities that our app provides can be summarized as follows:

1. User guidance and process explanation :- We present the user with slides, guiding him/her as to the steps to be followed for using our app. This functionality works satisfactorily with the user being able to go back and forth between the steps or skip the introduction altogether to go to image acquisition.

Fig.1: One of the user-guidance slides. The user can go back and forth between the slides using the navigation buttons or to the next screen via "Proceed".

2. Image Acquisition :- The user is presented with a camera preview with a guidance text at the top of the preview(in red). The text lets the user know if he is supposed to take a picture without the lens or not. The preview also has a red dot in the center to guide the user to focus the reference object for the best image processing results.

Fig.2: Camera Preview with a text at the top in red for user-guidance. A red circular dot at the center of screen is provided to focus the black rectangle.

3. Power calculation and results display :- Our accuracy measurements have shown that the results are always within +1 or -1 of the actual power. But these are subject to the realisation of some constraints. The images have to be taken by standing 2 meters from the reference object.

More importantly, the lens should be 15 centimeters from the camera. Failure of any of the above, particularly the second condition, leads to error prone results. Also the application correctly calculates the power for spherical glasses only. Glasses with astigmatic components yield inaccurate results.

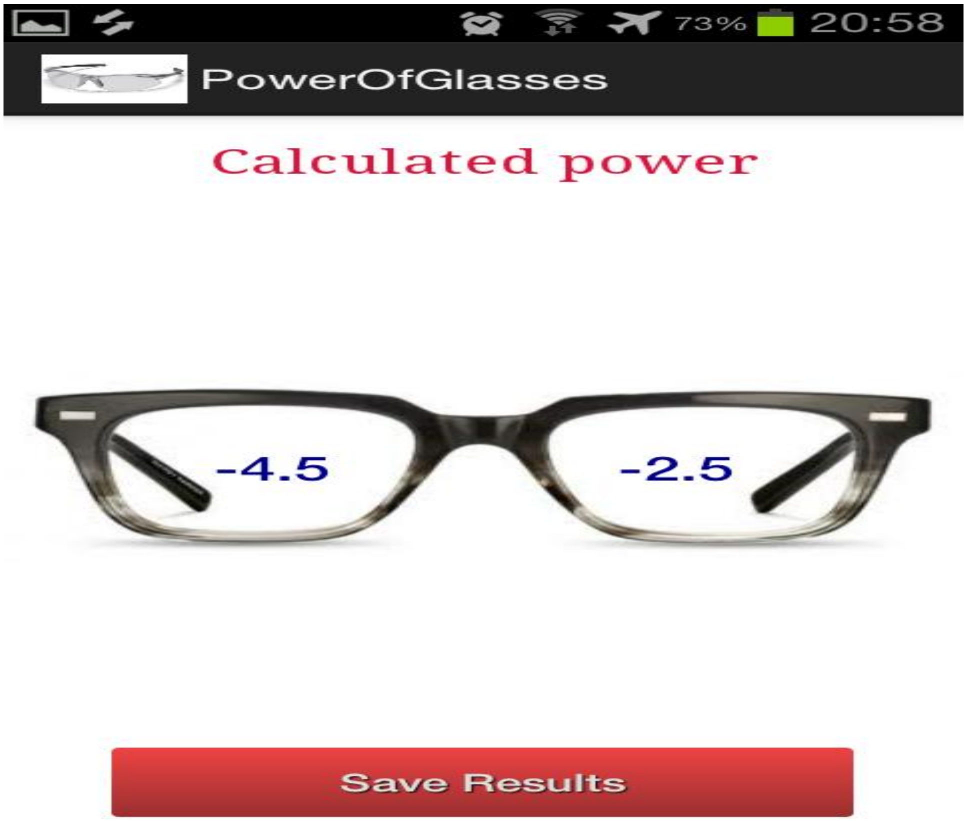


Fig.3: Results screen. The powers are shown within the lens framework in diopters.

4. Logging and History functionality :- The user is also given the option of saving the results. The name, date, time and the results can be logged. It is also possible for the user to retrieve the previous records indexed according to the date and time.


Fig.4: Results saving screen. The fields that can be changed are Name, Date and Time. You can save the results by clicking "Save Results" and see the previous loggings by clicking the history button.


Fig.5: History screen. The top half shows a list of date and timestamps on which the user has previously saved his results. Selection of any of those will result in populating the fields in the lower half of the screen with corresponding values of those records.

## 4 What did we learn ?

**Alexander Rodin**

Skills crucial to the success of this project are development of the application and web-based interface, as well the ability to communicate and present ideas clearly and thoughtfully to internal and external stakeholders. Thorough planning of individual team responsibilities has been essential to meeting timelines. The course has furthered my presentation skills and understanding of agile software development methodologies.
In addition to acquiring project management skills, it was necessary to sufficiently update my knowledge of geometrical optics. I also was able to establish connections in the field of optical engineering to ascertain knowledge relevant to the optics. Further, I learned more about the image processing algorithms that were employed by my team members in order to calculate image size and better understand the technology employed in the focusing of mobile phone cameras.

**Lubna Khader, Sreekumar Rajan**

As programmers, we had little understanding of the optics system at first, and struggled to connect the physical model to the measurements that can be obtained from images. As our project progressed, we developed a thorough understanding of the problem with the help of our Apper, we were able to participate in a real experiment and data collection process, and were able to model this data and find correlations with lens power.

At the beginning, we had different ideas on how to calculate power from images, we had to test each for reliability and feasibility. From our observations and our Apper's experience, we found that magnification is the most reliable, and relatively easy to acquire measurement to base our calculation on.

Image processing on mobile phones was new to us. We have used Opencv to do that processing, so we had to learn how to use this library and integrate it with the app. We experimented with other libraries too, and did lots of research on how to best achieve the required processing. Opencv performed the best with regards to our image processing, and had the fastest computations, we decided to use it in our application.

## 5 Individual Contribution

**Alexander Rodin**

I was responsible for generating the proposal to develop a mobile application for eye care. I thought to develop a mobile application to help people estimate eyeglass efficacy and conducted initial research on this topic to obtain a consensus and approval of the project by all team members. In an initial phase of the project, I performed a literature review and suggested different models for spectacle power estimation based on image size calculation and displacement. I also performed preliminary experiments for proof of concept examining patterns of shadows on images taken through eyeglasses in dim illumination.

I also assisted in designing a model and arranged for an optical dispensing laboratory for purposes of experimental testing of said model.  I conducted initial experiments with the trial lens set and recorded experimental data for different camera models. In a later phase of development I arranged for and conducted a second round of experiments, testing the prototype's accuracy on both trial lens' set and variable glasses. I participated in the development of the user manual for the application. Lastly, I summarized experimental results and drew conclusions on limitations.

**Lubna Khader:**

I participated in the experiments we conducted, as we all agreed on the setting and procedure. I gathered the results and wrote a matlab file to clean and process the images as a preliminary study to try to find correlations with power. Then, I prepared tables and charts summarizing our findings.

After deciding on the algorithm to be used in the app, I was responsible for the image processing part. I integrated Opencv, and wrote the noise reduction, object detection, and ratio calculation code. I also integrated our mathematical model into the app to do the prediction.

**Sreekumar Rajan:**

I helped in the acquisition of experimental data with various camera models and logging the observations in excel sheet. I suggested the idea of using a database of stored results and comparing with those for prediction of results.

I was responsible for the UI side of the app, which included setting up the camera preview, designing the activities, design and display of the introduction animation in an appropriate widget. I was also responsible for setting up the logging and history functionalities in the end.

## 6. Apper Project

An estimated 96 million people worldwide use prescription spectacles to correct ocular anomalies (Online Eyeglasses & Contact Lens Sales in the US, 2013). According to a recent study by the World Health Organization (WHO), an estimated 640 million people are unnecessarily visually impaired or blinded, worldwide (Pascolini and Mariotti, 2011). There is an increasing presence of online vendors purveying spectacles, but an extant limitation to their approach is in requiring consumers to know and provide their specific and unique eyeglasses prescription. As such, consumers may often be limited in their ability to place orders as they either do not know or have never received a spectacle prescription.
Because patients require access to eye care providers to obtain prescriptions, those persons in resource scarce environments are constrained in their capacity to do so, thus prolonging their vision impairment, leading to increased ocular morbidity (Pascolini and

Mariotti, 2011). For those with the capacity to access eye care, the provider would use a series of tools in determining a precise prescription.

If consumers had access to a mobile device, however, to determine their eye glass prescription, the need to visit a provider may altogether be precluded thus making access to these very important services more equitable. This would also have implications for the economics of eye care e-commerce, as more demand for these services would potentially increase, thus lowering prices.

Currently, the annual sale of eye care products online is a estimated $8 billion worldwide, and this number is projected to climb in coming years (Online Eyeglasses & Contact Lens Sales in the US, 2013). It is reasonably anticipated that orders from users who can manage their own prescriptions, empowered by this mobile solution, will positively affect eye glass e-commerce and thus online sales.

For eye care providers, a mobile application that measures spectacle power may become an attractive alternative to costly manual lens meters that are currently widely used in optometric practice. Lens meters are very costly, thus adversely affecting practice expenditures. An alternative, inexpensive measurement device such as one we are proposing may well decrease the overall cost of eye glass examinations, as well as fitting and production at optometric practices.

## 7. Future Work

Though the app provides accurate data on spherical lens power it may be improved in a few certain ways. The functionality could be improved if it is capable of measuring astigmatic lenses or lenses with a prismatic component. Another improvement would be if the system could more accurately measure target image distance and size variability for near- and short-sightedness. Another area for improvement could be the user interface. Additional features may include options to submit measurement results to eye glass dispensing laboratories and place orders for new prescriptions directly through the interface of the application.

## References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