ECE 1778

Final Report

IllumiSmart

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Word Count: 2463

Introduction

Most people receive the majority of information through the sense of sight. Therefore, lighting is an extremely important factor in the workplace, and poor lighting damages workers' health, reduces productivity and leads to safety issues. Physiological requirements of lighting are different from occupations. Due to the social distance, many people have started to work from home. There is an increasing need for ergonomic tools that help people improve workplace settings. Therefore, the objective of IllumiSmart is to measure and assess the user's workplace lighting conditions and give advice regarding issues identified.

Description of Functionalities

In this section, we will discuss our 4 major functionalities of IllumiSmart. We will also introduce some side features which help to provide a complete user experience. Here is the home page of the app:

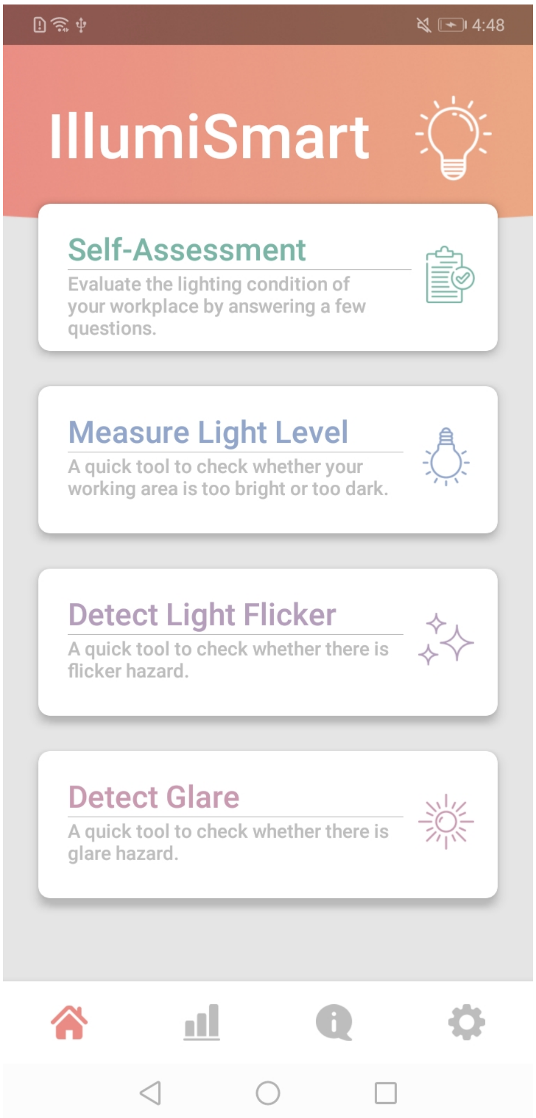


Figure 1 - Homepage

Self-Assessment

The first function that users could access through the homepage is self-assessment, which is to evaluate the lighting condition of the user's workplace. To use it, users should select the answers that best describe their situation according to the questions, then the suggestions will be provided if necessary. It is a key feature that could identify many cause-specific issues that are not easily addressed by the light measurement and detection. The questions and feedback in the assessment are modified from the guidelines of Canadian Centre for Occupational Health & Safety. We now only provide 10 questions all regarding the office setting since office workers contribute to the most work-from-home scenarios. The selected questions are designed to cover the most common lighting problems in the daily working environment, including monitor positioning, natural light, paper documents, vision transitions, light bulb replacement, and light fixture maintenance, etc. The questions are generated correspondingly based on the users' answer to the previous questions. The proposed feedback would include lighting context knowledge and practical actions that users could take in order to address the problems. After finishing the assessment, users could save the results and review them at any time.

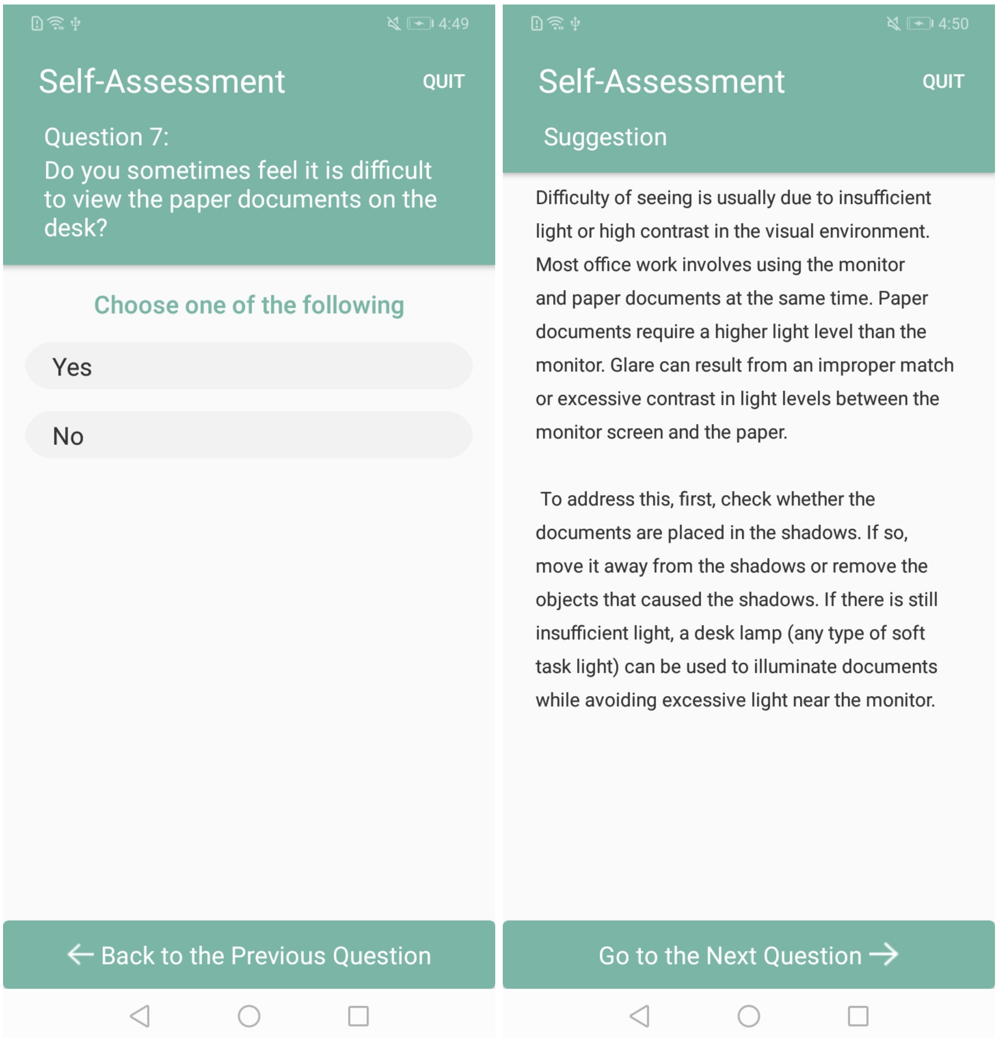


Figure 2, 3 - Self-Assessment (Question and Suggestions)

Light Level Measurement

The second function on the home page is the light level measurement. Illuminance level is a primary lighting requirement. A high level illuminance increases the risk of troublesome reflections, deep shadows and excessive contrasts. A low level illuminance will reduce the visibility and cause fatigue. This functionality utilizes light sensors to check whether the user's working area is over-exposed or too dark. Users could either view the instantaneous illuminance, or record an average lighting level for a period of time. There is instruction given on how to correctly use this function, and additional information of light level is also provided. If the measurement result is considered as inappropriate based on users' occupation and age, solutions and lighting advice would be proposed to the users. Similar to the self-assessment, the data recorded can be saved.

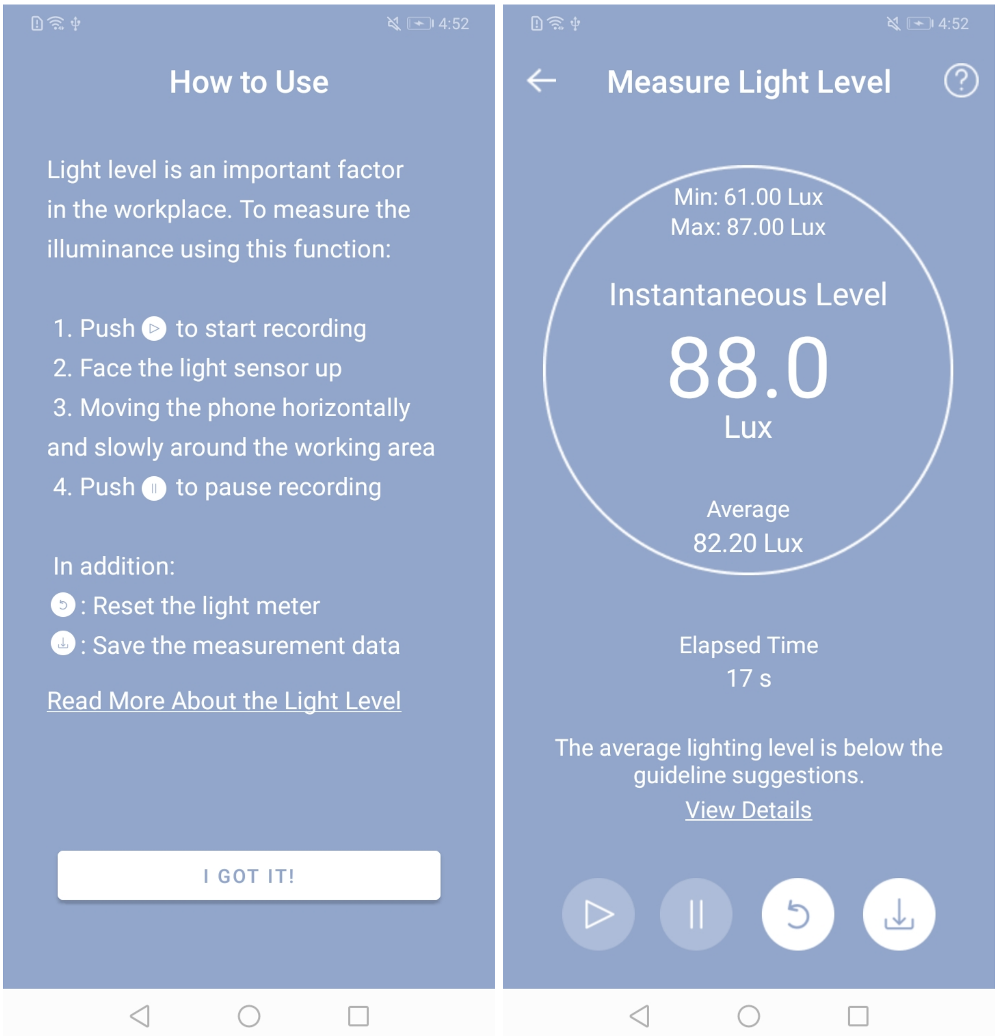


Figure 4, 5 - Light Level Measurement (Instruction and During Measurement)

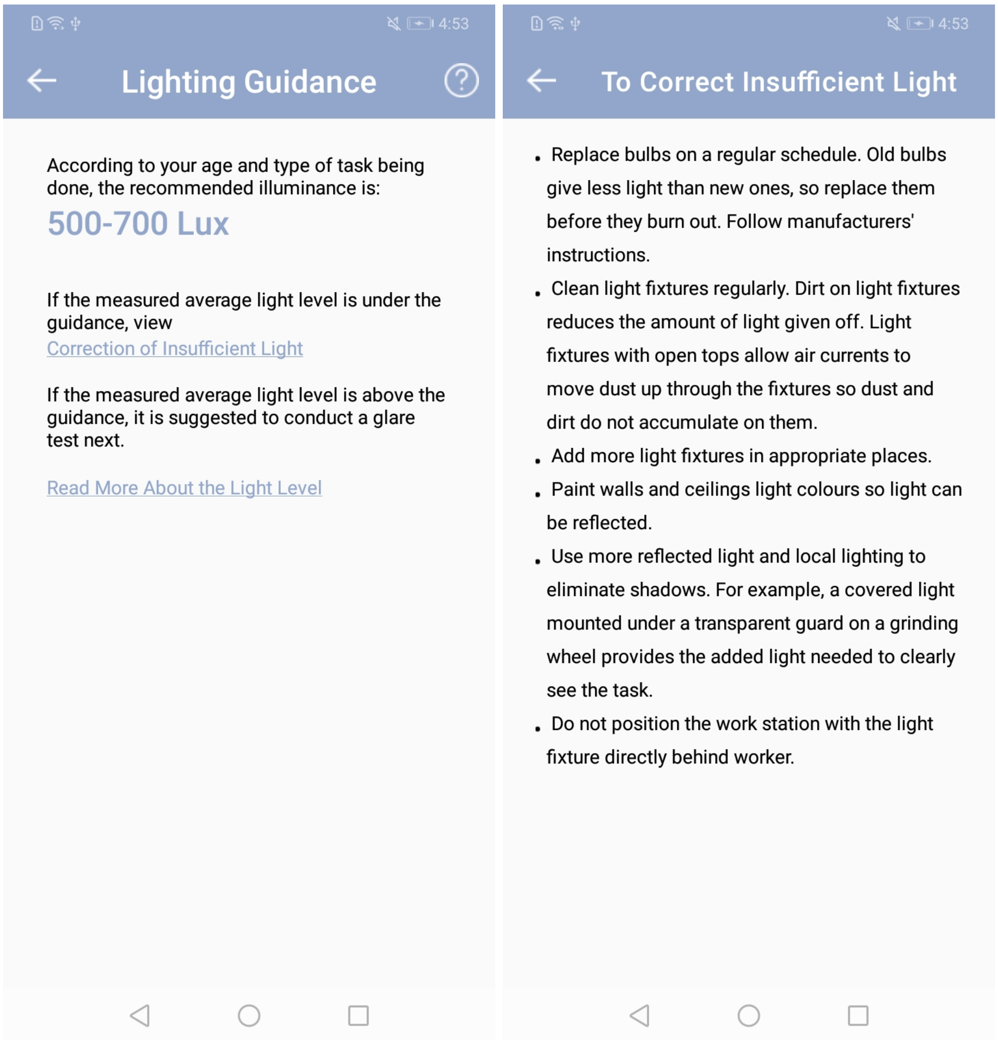


Figure 6, 7 - Light Level Measurement (Result and Suggestions)

Flicker Detection

The third function is flicker detection. We define flickers as visible and repeatedly rapid changes in the brightness of light over time, which may cause eye strain and headaches. To check whether or not a light source could be a potential flicker, the user needs to face the light sensor directly to the light source and wait for ten seconds. If there are any flicker events detected, warning signs and suggestions will be displayed. Again, similar to other functions, instructions for usage and data saving features are also available in flicker detection.

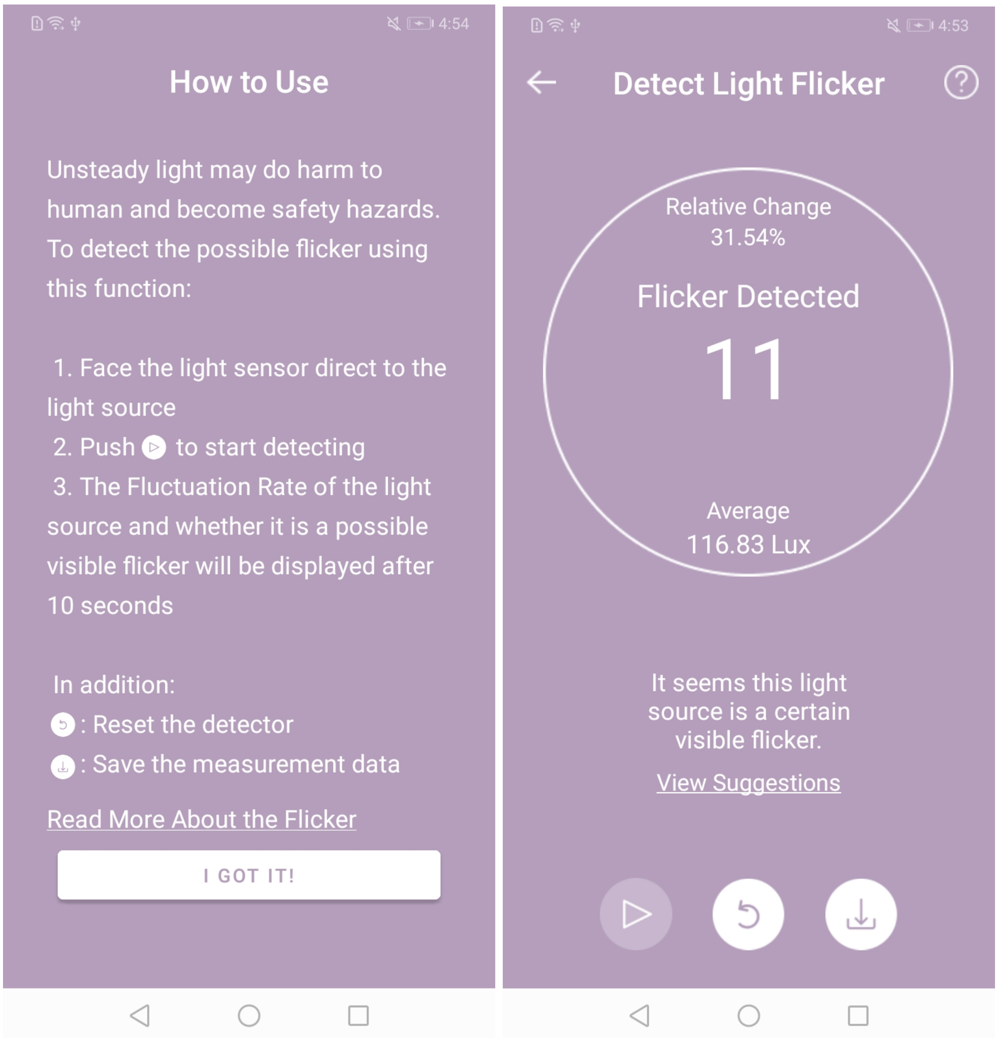


Figure 8, 9 - Flicker Detection (Instruction and Result)

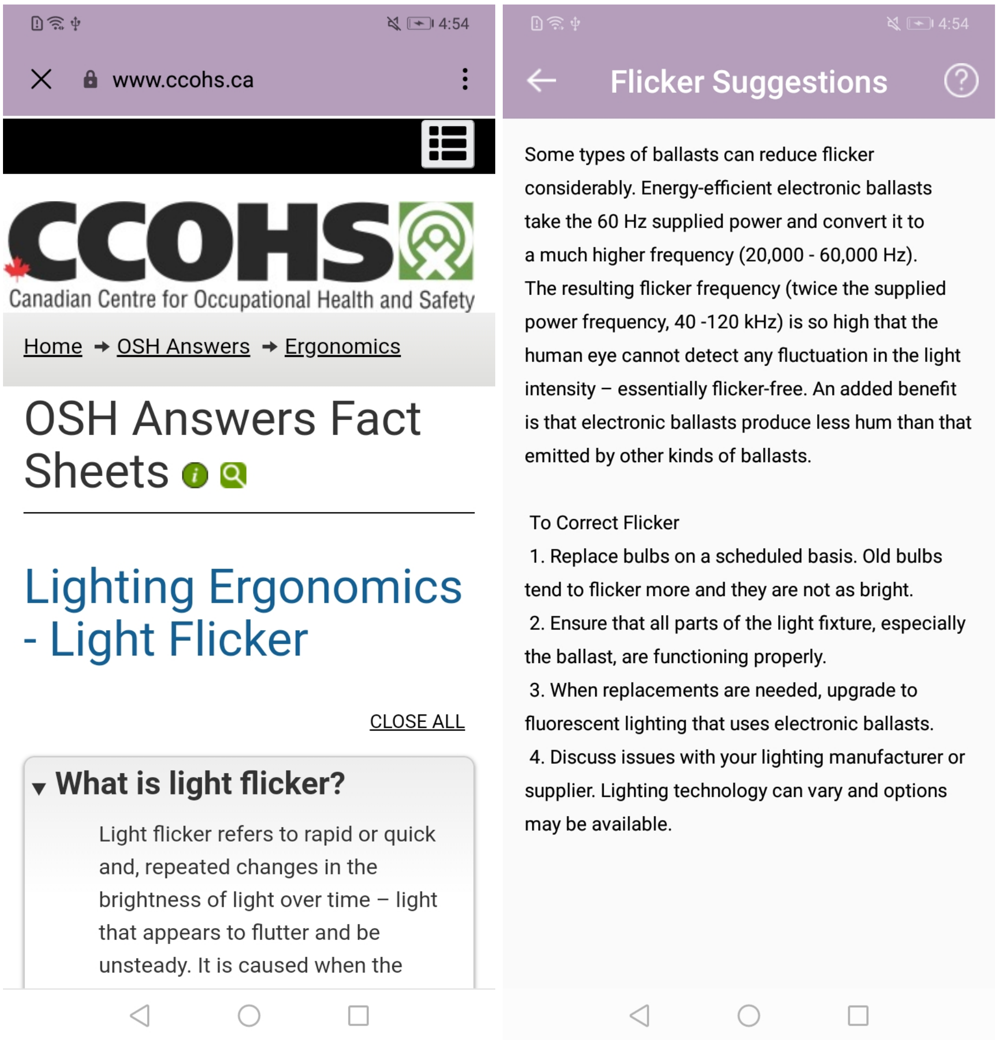
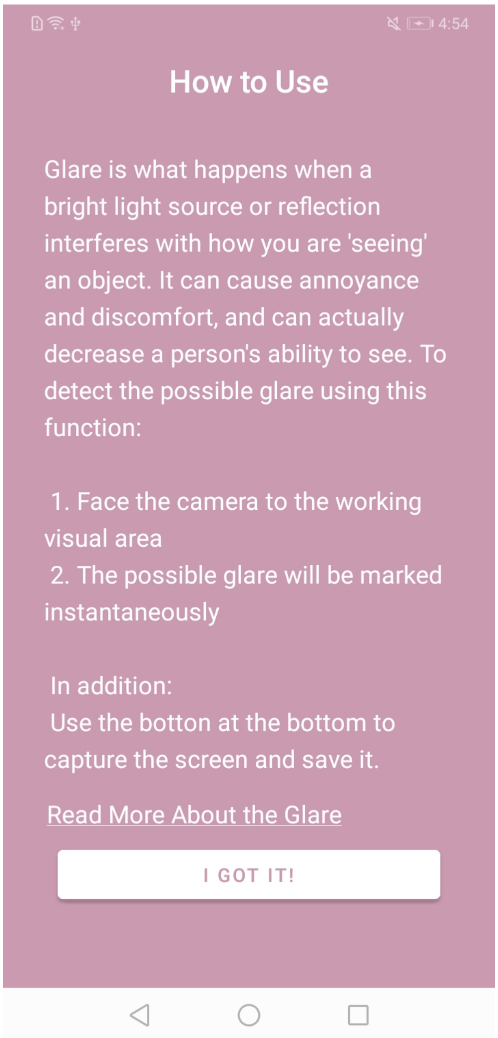


Figure 10, 11 - Flicker Detection (Supplement Readings and Suggestions)

Glare Detection

The last function from the homepage is glare detection. Glare happens when a bright light source or reflection interferes with vision. It is a common lighting problem that could cause annoyances and discomfort, and reduce visibility. Following the instruction, the user needs to face the camera to the working area in the position where they normally conduct their work. Then, any possible glare sources in the visual area will be marked and displayed. After detection, the user may read the proposing advice and save detection results.



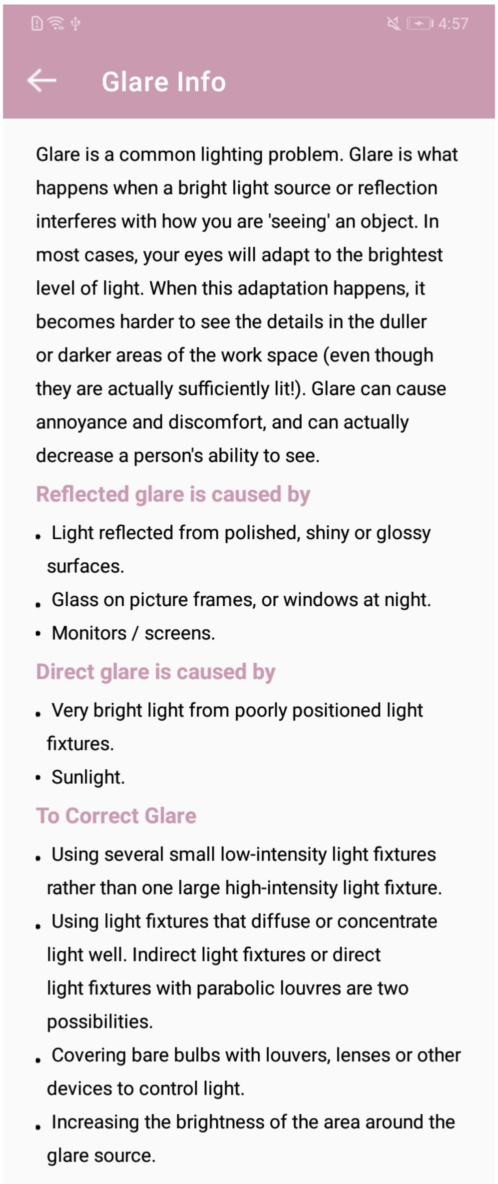


Figure 12, 13 - Glare Detection (Instruction and Info)

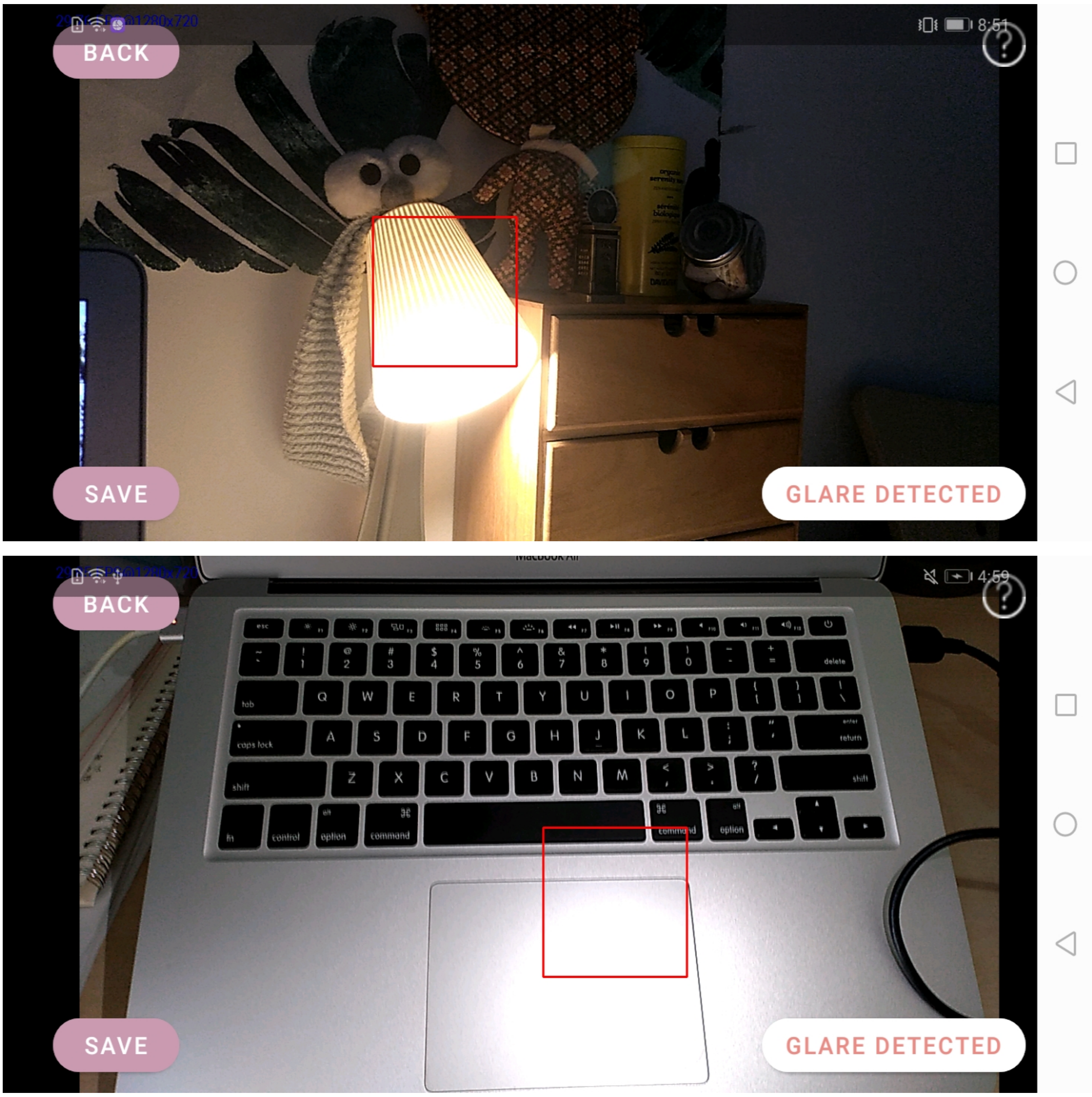


Figure 14, 15 - Glare Detection (Direct Glare and Indirect (i.e. Reflective) Glare)

History Data

All locally saved data could be accessed through the data function in the bottom navigation bar. It enables users to review recommendations and keep track of the lighting conditions at different times (for the temporal uniformity of lighting).

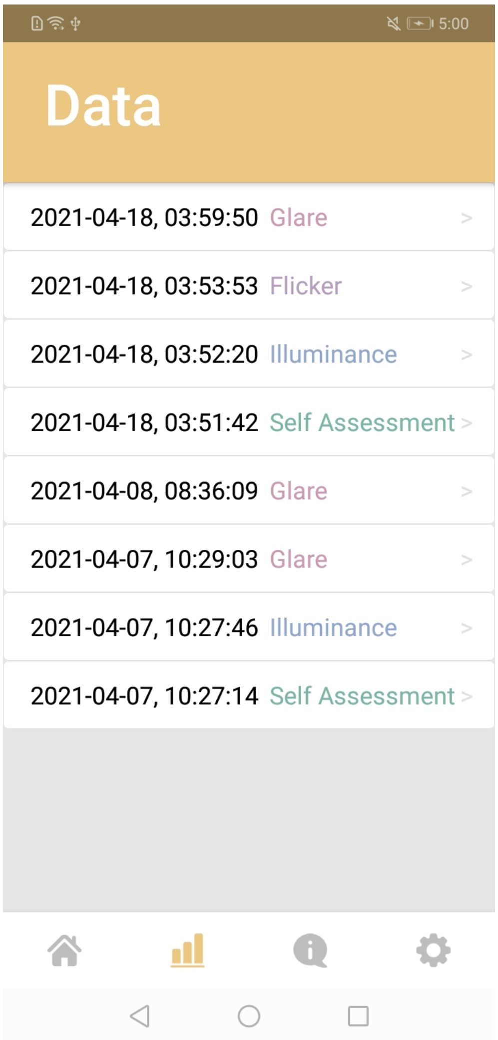


Figure 16 - Data Function

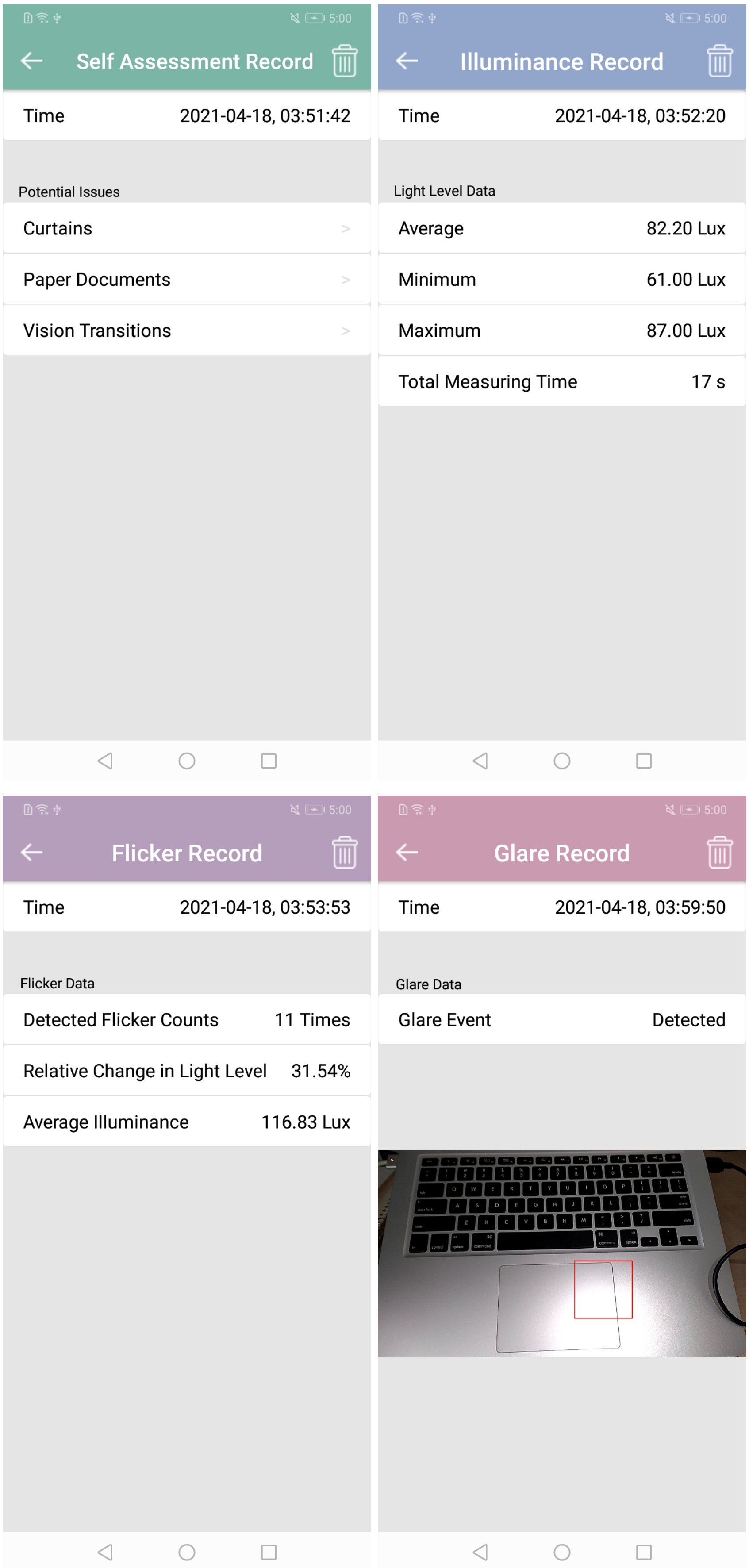
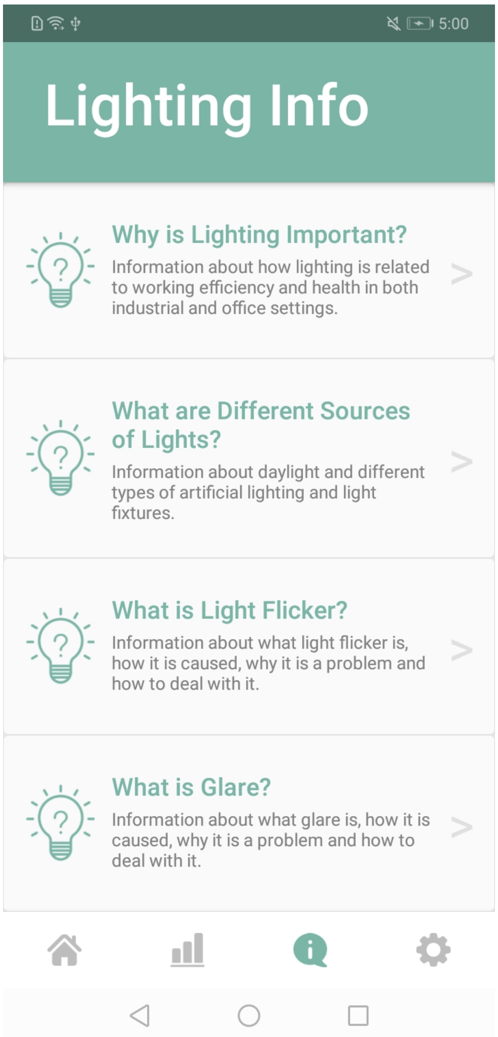


Figure 17, 18, 19, 20 - Data Function (Different Records)

Lighting Information

Accessing via bottom navigation bar, this function provides the user with educational information on lighting ergonomics, including articles and web pages selected from Canadian Centre for Occupational Health and Safety (CCOHS) official sites. It is a collection of and supplement to the knowledge covered in other functionalities, which helps to emphasize the importance of workplace lighting and calls for more attention to the visual perspective of occupational health.



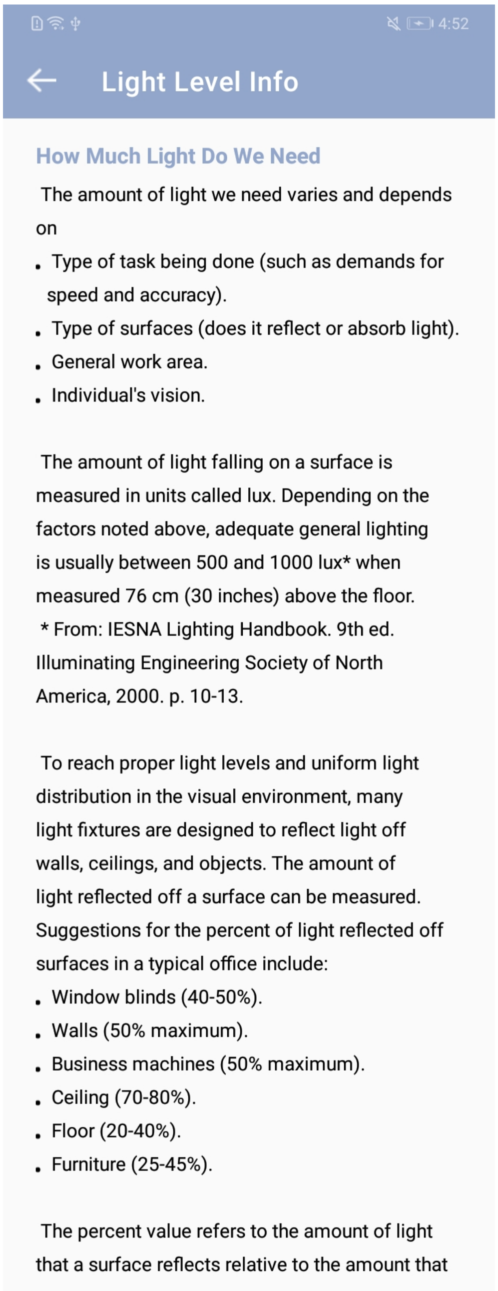


Figure 21, 22 - Lighting Information (Reading List and Article)

Profile and Settings

The setting function grants the access to additional features, including user profile, reminder and app settings, etc. The "About" functions are not implemented as time was not permitted. When users first open the app, they will be asked to select their occupation type and age range. They could add or edit this information in the profile feature under settings.

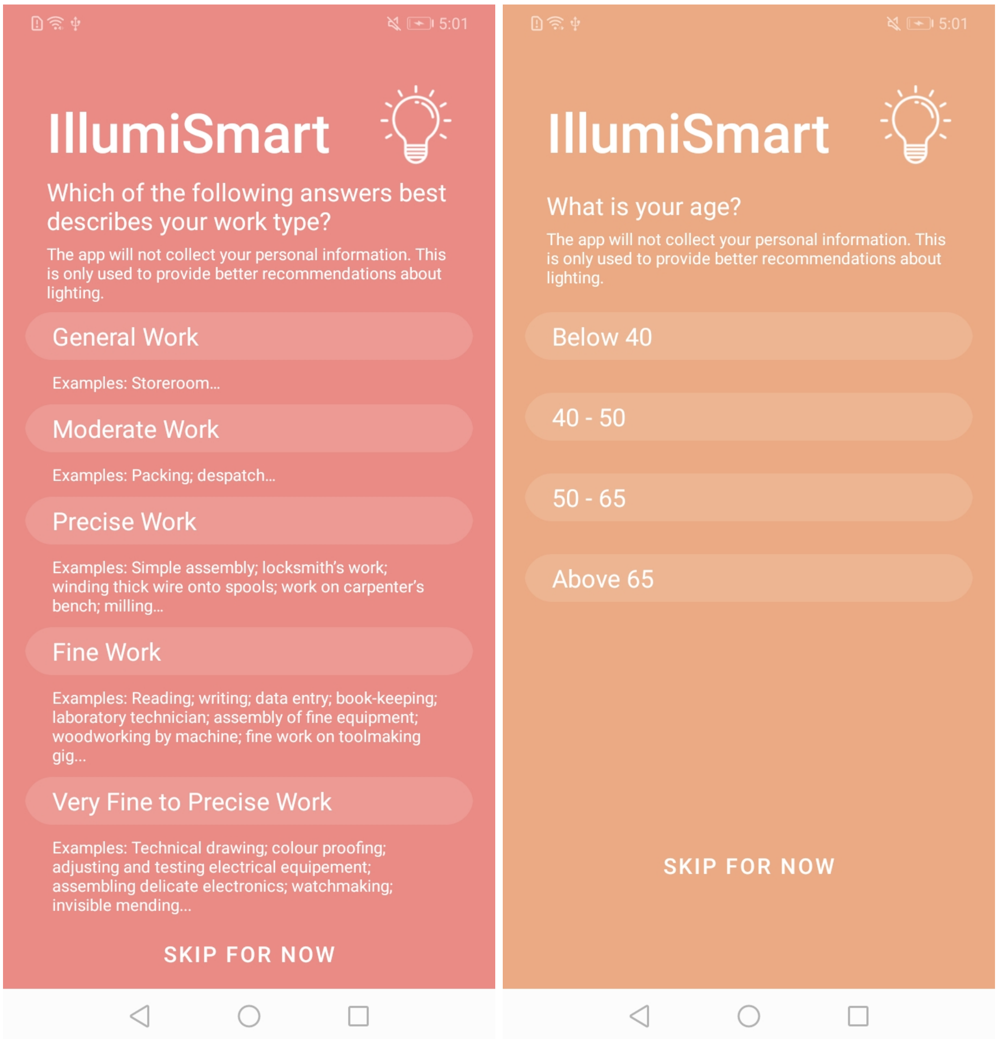


Figure 23, 24 - Occupation and Age Information

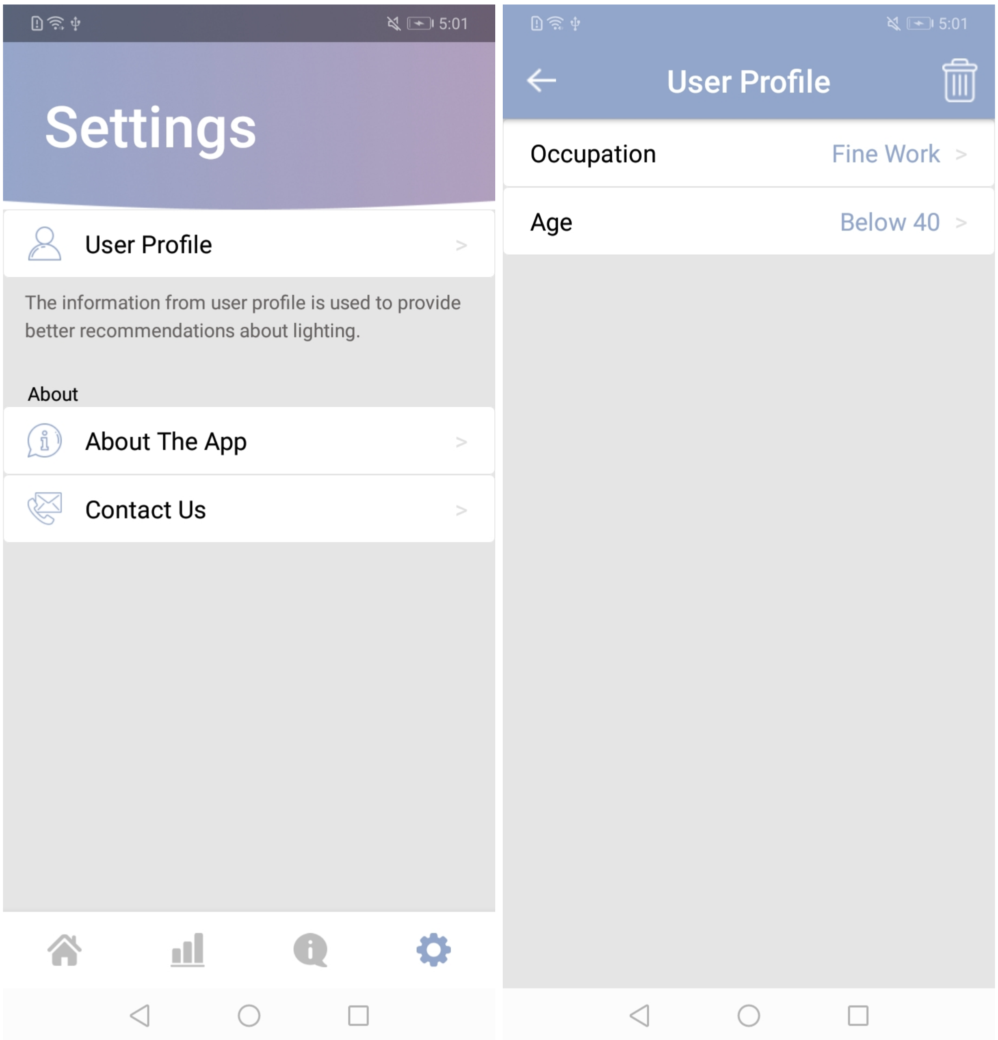


Figure 25, 26 - Settings and User Profile

Overall Design

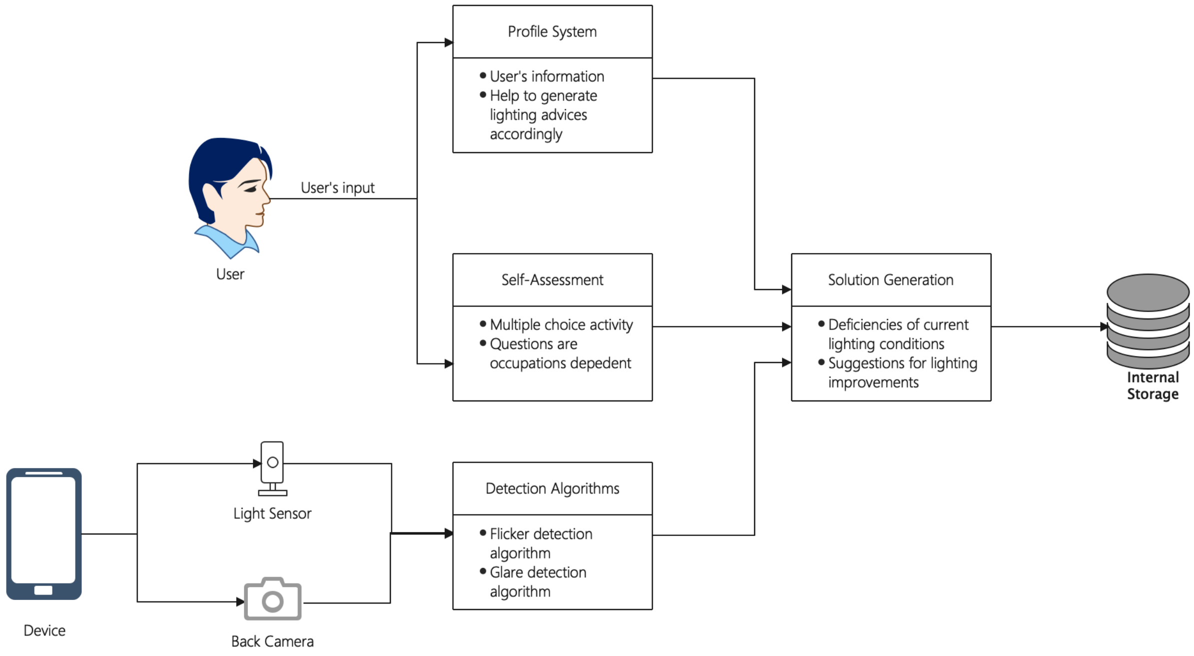


Figure 27 - The Block Diagram

<u>Block Diagram Overview</u>

The block diagram shown in Figure 27 presents our application structure from a high-level view. There are four major modules in the application, which are profile system, self-assessment, detection algorithms, and solution generation respectively. Our application requires running on an Android device with front light sensor, back camera, and storage being available. The module of detection algorithms relies on the input captured from the device sensors and camera, including real-time illuminance values and live image frames; the modules of profile system and self-assessment require information from the end users. Once the user's information and detection results are ready, they would be processed inside our solution generation module, which is to report any potential deficiencies regarding current lighting conditions and propose fixing advice to users accordingly. The solutions are able to be saved into the device's internal storage, and they are available to be fetched and displayed at any time.

<u>Module specifications</u>

Detection Algorithms

There are two detection algorithms being implemented in this module. The first one is the flicker detection that requires real-time illuminance values captured from the light sensors. We define flicker as a visible change in brightness of light source. Therefore, we are able to identify a flicker event by observing whether or not there are any fluctuations happening in the light source illuminance values. Our flicker detection algorithm runs as follows: We collect an array of real-time illuminance values from a consecutive period of time, then we slide through the entire array with a small window size. For each window, we consider a flicker event happening if the delta of maximum and minimum illuminance value exceeds a certain threshold. Once we slide through the entire array, we are able to identify how many potential flicker events happened during our measurement period. Due to the on device light sensor refresh rate limit and the delay on code executions, we are not able to detect any invisible flicker events. The second algorithm is glare detection, which requires the input of live image frames captured from the back camera. Glare is an extreme direct light source or reflection that impedes people's vision, and a glare on an image usually shows with high intensity values. Thus, our glare detection algorithm is to analyze an image frame region by region to see if there are any regions of pixel intensity values that are extremely high. If it exceeds our threshold, we crop the region as a potential glare source. The auto gain control (AGC) would be automatically enabled on some devices when an extreme light source is placed directly in front of the camera. We are not able to control the AGC effect programmatically, and it certainly affects the accuracy of our glare detection. One way to bypass this issue is to manually adjust the camera focus by clicking on the region beside the light source when AGC is enabled.

Self-Assessment
The module of self-assessment is to construct a text based multiple choice activity that needs to be performed by users. First, the type of questions are occupation dependent, which the system would generate different questions based on the occupation information given by users. Moreover, the order and flow of questions are also dependent on the user's answers to the previous questions. We internally maintain a state machine inside this module in order to preserve the order of questions.

Profile System
The module of the profile system simply stores the user's basic information, including age, gender, working context, and etc. Although this module is simple and easy to implement, it is significant in our application because the solution generation relies on the information given by this module.

Solution Generation
This is the module that reports lighting deficiencies and generates lighting advice. We pre-store many text-based lighting information educated by the specialist. The proposed suggestions and deficiencies of current lighting conditions would be displayed to our users accordingly based on the input from other modules.

Reflection

For most of us, this is our first time to work as part of a multidisciplinary team involving application development, project management, and research in human factoring engineering. As a result, we learned many important elements of how to develop an application efficiently, including conducting complete communication between the specialist and programmers, how to break a large project into small pieces and accomplish them in a rational sequence as well as the ability to think and solve problems in a more user-friendly way.

If we start again, there is something that we would like to do differently. First, we would more carefully assess the risk of device capabilities before we started working on the project. Auto Gain Control (where the image dims in the presence of excessive light) is a special function that exists in almost all of the phones' cameras. This behavior would affect the performance of glare detection. However, we did not realize this risk when we implemented the function of glare detection. In addition, we could do better in time management, which we could allocate more time on the final stage for UI optimization, screen adaptation and Android version adaptation. Moreover, we should recruit more participants to test on the app and collect sufficient feedback which will be beneficial to improve the user experience of the app. Finally, there is still room for our presentation skills to be improved. Based on the peer reviews, we learned that we should explain the use-cases while demonstrating each feature explicitly for better understanding to the audiences.

Contribution by Each Group Member

	Spiral 2	Spiral 4	Final
Changchang Cai (Specialist)	Designed app functionalities, UI, light level suggestions, flicker suggestions, app instructions, and conducted the usability test, and issue tracking	Designed suggestion logic, assessment contents, glare suggestions, profile information, and conducted issue tracking	Proposed UI modifications, organized Lighting Info articles, and conducted testing and issue tracking
Dongqing Zhu (Programmer)	Home/Data/Illuminance Record page UI and functions implementation, Database design and implementation, Light Level/Flicker functions UI implementation	Settings/Profile page UI and functions implementation, Self-Assessment function UI implementation, Glare function UI optimization	Lighting Info function implementation, Functional integration and improvement
Zhe Su (Programmer)	Light level measurement/Flicker detection implementation, Data storage implementation	Glare detection implementation by OpenCV, Self-Assessment function implementation	Resolve issues marked by specialist, Resolve issues marked by Spiral 2/4 demo feedback

Specialist Context

Industrial engineering is an applied science about the design and improvement of integrated systems. Under this scope, human factor engineering is a subject regarding human capabilities, and limitations in relation to machines, products, and environments. Based on the specialist's expertise in the field, IllumiSmart is concerned with occupational ergonomics from the perspective of lighting.

Poor lighting could lead to safety issues such as injuries when the driver misjudged the position, shape, or speed of an object. Improper contrasts could potentially reduce the productivity of work especially when precision is required. Exposing the eyes to too much or too little light when working might cause eye discomfort and headaches. Physiological requirements of lighting are different for different occupations and ages. For example, very precise work such as polishing and engraving glass, needs additional task lighting to supplement the general illumination, while lighting in computerized offices should consider the background contrasts and reflections on the screens. All of these factors are taken into account when designing our app functionalities.

Therefore, we are expecting two meaningful things that IllumiSmart would achieve. First, it will conveniently help the users adjust their workplace lighting and mitigate potential risks to their health, especially for those who are changing their workplace due to the covid-19 pandemic and do not have any knowledge about designing the visual environment. Moreover, the app will help to emphasize the importance of workplace lighting and calls for more attention to the visual perspective of occupational health. Nowadays, most people are not aware of the vital role that lighting plays in their working environment. By using this app and reading about the lighting information it provides, people will have a chance to learn basic but important knowledge that they hardly get known to in their daily life, and are motivated to take better care of their working environment.

Future Work

Although we successfully implemented all core features, there is still room for improvement of the app based on the peer reviews. First, a score to the overall light conditions based on all assessments and measurement results will better interpret users' workplace light conditions. Also, we could provide more pictures for an ideal desk setup in the self-assessment function in order to make users better understand the proposed solutions. In addition, the glare detection feature still needs optimization, where we could try to adapt any existing glare object detection models for better performance.

We also come up with some additional features that could make the app better. The first one is the sharing feature, which allows users to share their assessments and measurement results to the others. Secondly, a reminder feature will improve the user experience by reminding users to regularly conduct an assessment to check their lighting conditions. Community forum is also a nice to have feature, where users could share their lighting experiences and give support to each other.

Statement of Permission

	Video of final presentation	Report	Source code
Changchang Cai	yes	yes	yes
Dongqing Zhu	yes	yes	yes
Zhe Su	yes	yes	yes