

ECE 1778: Creativity and Programming Mobile Devices **Project Report**

Apollo: Solar Measurement Application

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Introduction

Apollo is a commercial Android application designed to study the economic feasibility of roof-top solar panel installations based on user inputs and location-specific solar insolation or solar power intensity per unit area. The overall objective of this project is to give consumers (the users) the opportunity to do an on-site evaluation of a proposed project and then make this information available to installers and manufacturers so that it can be used to assess the project site for a future solar installation. This will make it possible to link the consumers with their providers in an efficient way.

There are several examples of commercial software available on the market for evaluating solar installation projects. These software packages are commonly used in industry to assess the costs and energy returns of a potential project. To our knowledge, however, there is not similar software designed around the consumer. Furthermore, most of these packages do not incorporate information obtained on site such as the inclination of the roof-top and a visual evaluation of the site surroundings. We took these facts into consideration when we were developing the concept for our application.

Initial Development

The initial concept of this application was centered on the ability to measure solar intensity using the built-in camera on the phone. Under this design, pixel information from the camera would be integrated and calibrated with known sources so that we could determine the solar intensity from a camera image. It was quickly found that the auto-exposure function of the camera interfered with these measurements. The auto-exposure adjusts the brightness of the camera view depending on the light intensity. Unfortunately, this is not a one-to-one mapping, but depends on the light intensity and thus dissimilar light intensities could potentially give similar results. This makes a relative comparison of the measured light intensity almost impossible. In an attempt to work around this issue both LG and Samsung technical services were contacted to see if a solution could be reached. Based on our correspondence with these companies there was no clear method to compensate for the auto-exposure function of the phone. Further attempts to contact more knowledgeable individuals in the respective engineering departments were not successful.

The camera approach to our design was quickly abandoned in search for methods that could be implemented more readily. Several weeks into the project we were able to procure a Samsung Galaxy S with built-in light sensor which is used to adjust the

brightness of the camera view. It was found that this sensor can be easily accessed using common Android sensor listener methods. Several free apps designed around the light sensor were obtained and their functionalities were studied. From these studies we found that often the light sensor would cut out or would fail to respond to changes in light intensity. More importantly, the sensitivity of the sensor proved to be a significant drawback. The maximum reading for the light sensor was in the neighbourhood of 10000 lx, roughly one third of average daily diffuse sunlight (25000 lx), and less than 10 percent of direct sunlight (100000 lx). It quickly became apparent that the light sensor would not be adequate to measure the intensity of sunlight either. Even using neutral density filters which could potentially scale the light intensity down to manageable values we would still face the issue of poor sensitivity to changes in solar intensity.

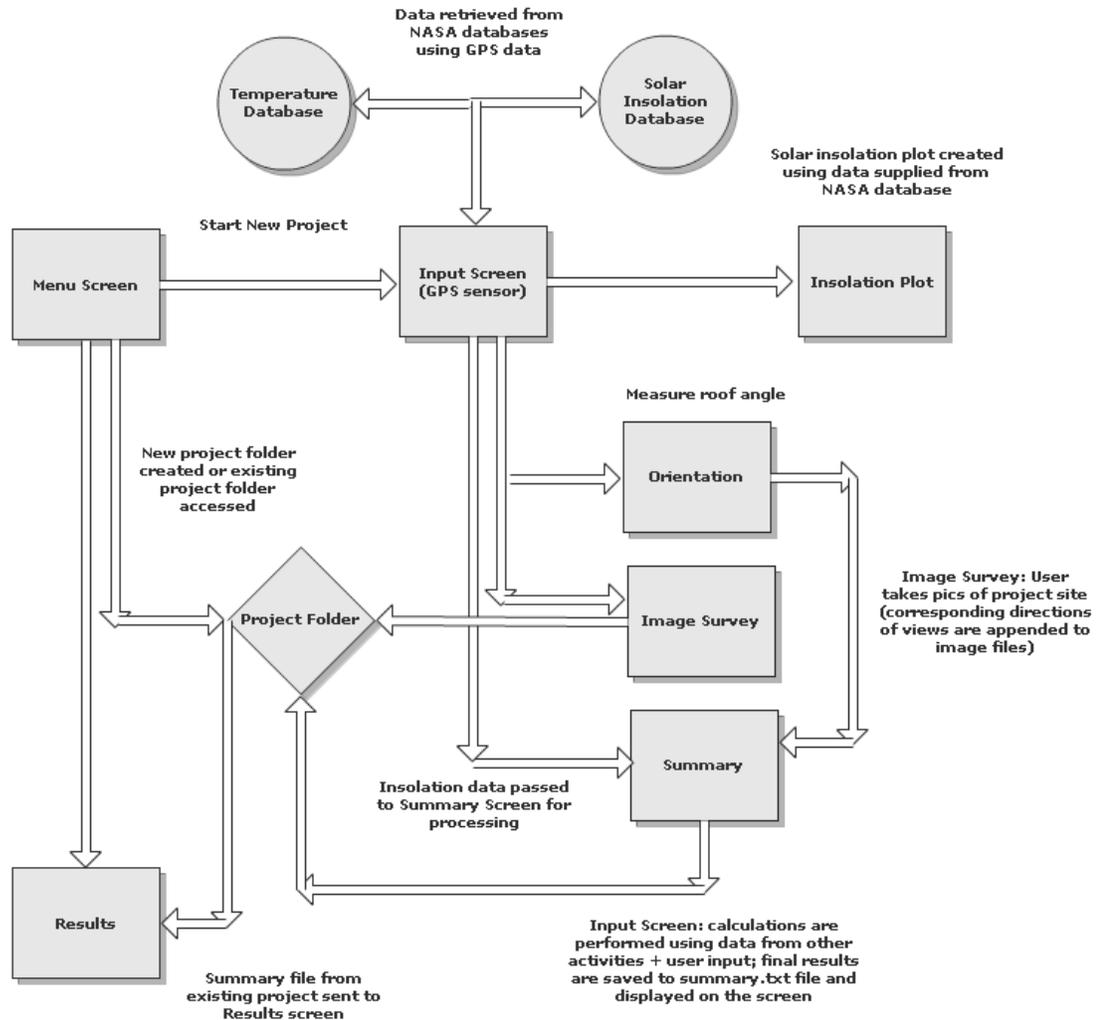
After confronting these setbacks we were able to forge ahead and design an app that implemented several of the device sensors to obtain useful information that still allowed us to fulfill the overall broad objective of our application.

Final Application Design

Our final design does not include any form of light intensity measurement using the camera or the light sensor of the mobile device. Instead we compromised on a more effective approach in which the GPS sensor was used to obtain location-specific solar insolation data from a NASA database. The application then collects orientation data to determine the inclination of the roof-top and applies the appropriate corrections to define the solar light intensity at the surface of interest. With this data collected, the user must then provide the size of the installation, the local energy costs, and choose one of three leading solar technologies from a spinner so that the financial returns can be calculated. As an added visual tool the user has the option to take as many photos as he/she would like of the project site. The direction of the view is recorded for all photos taken so that the project site can be further inspected for any obstructions that might diminish the effectiveness of the solar panels.

The final application is comprised of 7 activities that serve as user interfaces and sensor inputs with the ultimate goal of providing an accurate evaluation of the project site for a roof-top solar installation. The following is a detailed block diagram of the application followed by descriptions of each activity.

Block Diagram



Activities

Menu

This is the starting activity that is loaded when the application is first run. This activity provides the user with the option to create a new project or select a previous project from a spinner widget to view results.

To create a new project the user must specify a project name in the Edit Text widget and select **Create New Project**. A new folder, labelled with the project name, is then created and subsequently contains all project data produced by the application. Every new project is recorded in an index file that is used to populate the spinner so the user can view the results at a later date. By selecting this option the **Input** activity is initiated.

To view results from a previous project the user must select the name of the project from the spinner widget and select **Open Project**. The user is then taken to the Results activity

where the *summary.txt* file containing the results of the assessment is displayed. The picture of the installation site is also displayed here.

Results

This activity displays the results of a completed project. The *summary.txt* file contained in the project folder is displayed directly to the screen, providing the user with the pertinent results of the assessment. The *site.jpg* image of the installation site is also displayed to the screen.

Input

In this activity the GPS sensor is utilized to determine the location of the project in order to access the relevant solar insolation data for the area. Upon initiation the activity first retrieves the GPS location of the mobile device. An internet-based database (NASA) containing average monthly solar insolation and local temperature data as a function of global position is read and the appropriate values are retrieved based on the latitude and longitude returned by the GPS sensor.

From this activity the user can access most of the application's functionality to obtain further information that is important to the project. These activities include the **Image Survey**, **Orientation** as well as the final **Summary** activity where all the assessment information is compiled.

Summary

In this activity the bulk of the calculations are made. This is also where the essential project data is stored to file. This activity takes the solar insolation data from the **Input** activity as well as the orientation measurement from the **Orientation** activity for processing. Preloaded into a spinner are the names of three of the leading solar technologies (CdTe, Silicon, and CIGS). Selection of a particular technology supplies specific parameters needed to perform some of the calculations in the assessment. There are also inputs where the user must define the area of the installation (in m²) and the local electricity prices. From this information the annual revenue of the project as well as the buyback period and potential profit are calculated over the project lifetime given a rough estimate of total installation costs. (A more detailed run through of the calculations can be found in the calculations section).

Orientation

In this activity the orientation of the mobile device relative to the horizontal plane is determined. The user is prompted to place the phone on the target surface and can then choose to **Take Measurement**. The angle of inclination of the device is then set to be used later on for calculations.

Image Survey

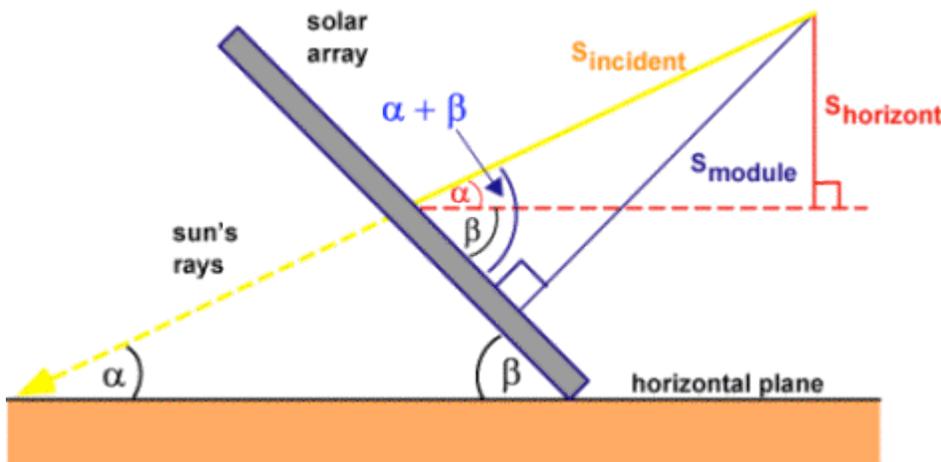
In this activity an image survey of the project location is conducted. The user can take a picture of the site location and take various skyline views around the site to identify any obstructions that might affect the solar intensity incident on the project site. The activity has a built in compass feature that allows the user to determine the direction for each skyline view and save a picture with the direction of the view. As each image file is unique there is no set limit on the number of images the user can take. These images are then saved in the project folder to provide a visual assessment of the installation site.

Insolation Plot

Using the solar insolation values from the **Input** Activity this activity implements the Google Chart API to create a plot of solar insolation as a function of the month over a period of a year.

Detailed Calculations

The data taken from the NASA database was determined for a horizontal surface. For an inclined surface such as a roof-top solar panel a geometric correction must be applied to obtain the true solar intensity that will be used to generate electricity.



For a solar panel making an angle β with the horizontal the solar power incident on the surface is given by:

$$S_{incident} = \frac{\sin(\alpha + \beta)}{\sin(\alpha)} S_{Horizontal}$$

Where α is the angle the sun's rays makes with the horizontal. This angle α is dependant on the latitudinal position and the declination angle of the sun which is seasonally dependent (monthly declination angles are stored in an array in program)

$$\alpha = (90 - Latitude + Declination)$$

A small correction must also be applied to account for temperature variations. For a solar cell, power is found to vary as a function of:

$$P_T = [1 + \gamma(T - T_0)]P_0$$

Where T_0 is the certification temperature of the device (usually 25 °C) and γ is the temperature coefficient which is technology specific.

In this part of the application average temperature and solar insolation values are taken for each month at the specified location from the database and are used to calculate the total incident solar power that can be converted to electricity. This value has already been corrected for the temperature coefficient of the selected technology for simplicity in later calculations.

Calculations for generated power, revenue, and buyback period are relatively straightforward and can be found in the provided source code. The overall profit from the installation is calculated based on technology-dependent installation costs and an assumed 25 year lifetime which is typically the industry standard.

Functionality

All elements of the final application function as presented herein. Due to problems with the screen capture in the Eclipse DDMS we were unable to obtain screen shots of the working application. This was likely due to complications with the root permissions of the mobile device. A formal demonstration of the functioning application was performed in our final presentation.

Contributions

The collaborative development of the application was done in a poorly organized fashion at the beginning. We simultaneously worked on the same function when we were attempting to use the camera to measure solar light intensity. As we began to develop a functional application based on the GPS sensor and global solar insolation data the delegation of tasks became more efficient. Kyle was tasked with developing the code for the sensors used in the application, as well as integrating the calculations for the user-input and sensor data. André was tasked with the data management of the application (file saving, project loading/creation, folder management, etc) and the aesthetic layouts of the activities. Both parties were involved in the independent research that was conducted to determine the appropriate calculations and elements required to produce an accurate assessment for a proposed project site.

What We Learned/Would Do Differently

The primary issue that plagued the development of this application was our persistence in using the camera/light sensor to measure light intensity. In retrospect, we would have saved a significant amount of time if we had split up our resources and each developed the program using different approaches (one with the light intensity measurement approach, the other using the GPS/solar insolation database approach). This would have made it easier to deal with the setbacks we experienced.

Nonetheless, we learned a great deal from this experience. Both coming from non-programming backgrounds it was initially difficult to manage the project between two programmers. Throughout the course we learned the merits of the spiral method as an effective and efficient tool for developing a large project.

Future Work

With the time at our disposal we were able to develop an application that uses GPS location information and solar insolation databases to evaluate the feasibility a given solar panel installation project. At the time of submission the application allows the use to access solar insolation data for a given GPS location, take pictures for a visual evaluation of the project, and measure the inclination angle of the installation, and assess the economic feasibility of a project based on user inputs. This application is based on actual protocols used by industry to estimate output of a proposed solar installation.

Many parameters still need to be included to form a more accurate assessment. More accurate information from suppliers has to be obtained for use as parameter inputs. Maintenance, replacement, and additional equipment costs need to be included as part of the total costs. Interest rates and electricity demand also need to be factored in to determine the overall profitability of the investment.

Finally it was always our goal to use this application to connect members of the solar industry (such as third party providers and installers) with consumers. To do this effectively we want to upload the project files to an online database that can be easily accessed and evaluated by those in the industry.

Word Count = 2345

Penalty = none