

MultiSensor—Maintaining humidity and detecting sunrises using humidity and light sensors

Technical Report 1

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Work performed at USC

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Abstract

Using the sensors in the dongle provided, data analysis using Matlab determined characteristic signatures of certain events.

The humidity sensor was used mainly to detect the signature of a shower event. Furthermore, analysis of natural dehumidification from open doors or open windows or a dehumidifier was desired, though the humidity sensor threw errors in the humidity array very early on in data collection.

The light sensor was used to detect random spikes in luminance in a dark room with a moving flashlight shining bright light over the sensor. As expected, luminance spiked at appropriate times with minor noise, which was filtered out using a moving average to remove the higher frequencies. Next the light sensor was used to detect the signature of a sunrise on several different days including a rainy day along with some introduced noise. A moving average filtered out most irregular luminance spikes and then a polynomial fit was introduced to model the sunrise data successfully. The error between the fit and the data turned out to be quite small as the order of the polynomial grew larger, as expected, making it a sufficient model. Then slope and concavity analysis allowed a simpler identification of the signature, with the filtered slope gradually rising to approximately 0.5 before suddenly plummeting back to 0, indicating a flat line that the sun has risen. Likewise the concavity emits a similar behavior, just with larger concavity values. Detecting sunrises will help reinforce the circadian rhythm to maximize daily efficiency and energy by alarming when the sun has risen—the Circadian Rhythm Application.

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Summary

This report explores the use of the dongle sensors, particularly the Light sensor and the Humidity sensor.

The humidity sensor first tested to ensure correct working sensing of humidity values in the air. First tested was the humidity in a standard room, along with varying breaths of air. Later on the sensor and laptop were brought to the bathroom to examine the changes in humidity during a shower. An error occurred with the dongle in that after just a few minutes of gathering data, an array error was thrown. The error tends to happen between 1 minute to 3 minutes, so the data gathered was rather scarce. Also, a test of dehumidification was desired but the length of data was too short because of the dongle error.

Next tested was the light sensor. First ensured working conditions in a normally lit room at night, then a dark room at night, with some light switching on and off. Then tested was the flashlight model for detecting incoming light. This worked perfectly as the expected spikes in luminance occurred at the correct times. Lastly tested were several sunrise data. Data was gathered several times on different days around the time of sunrise for up to an hour. Some data logged had manually introduced noise, such as moving objects in front of the window to cover up the sensor or briefly shining flashlight over the light sensor. The data was then filtered with a moving average to reduce the higher frequency noise. Also, a rainy day sunrise data was gathered though starting at a later time than hoped for. The rainy day data introduced much larger amounts of noise. All filtered data then was analyzed with a polynomial fit to look for specific models of the data using polynomials of order $n=3$, 10 and 20. As expected the larger order polynomial fits were more accurate. Furthermore, slopes and concavity analysis were used to detect signatures for the sunrises. The slopes were determined from taking the difference between points and then dividing by small differentials of time. The minor noise still present in the data was greatly amplified in the graph of the slope, so a moving average was introduced to smoothen out the slope. Then the negative slopes were replaced with the previous slope, which should be positive, since negative slopes do not characterize a sunrise but rather some incidental noise such as an object moving in front of the sensor to block light. Concavity was also analyzed, and results similar to slope were detected.

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1. Introduction

Concept

The main purposes of the experiments were to detect changes in humidity and detect the signature of a shower using the humidity sensor in the bathroom. Also desired was the examination of different ways of dehumidifying and their efficiencies with respect to time—using either just an open door, open windows, and an actual dehumidifier. Unfortunately the humidity error prevented sufficient data logging for this. The light sensor was used to detect rapid changes in luminance using a flashlight. Then more importantly it was used to detect the signature of a sunrise on different days with different noise introduced. The data was fitted with a polynomial model fit accurately with orders of 3, 10 and 20. An analysis of slope and concavity was also introduced to more accurately determine the signature of the sunrise.

2. Hardware architecture

The device used is a micro-controller data acquisition module that connects to computers with a mini-USB cable and contains an accelerometer capable of detecting acceleration in the x-y-z axes, a light sensor capable of measuring luminance, a highly sensitive humidity and temperature sensor, and a pressure sensor. It also includes two digital-to-analog converters and a DC converter.

The MMA7260QT accelerometer has sensitivity settings of 1.5g and 6g in each axes.

The TPS852 light sensor photodiode draws voltage to determine the proportional luminance.

The MPXA4250A6U pressure sensor measures absolute pressure using a piezoresistive transducer.

The HTM1735 determines temperature using a negative coefficient resistor and humidity transducer.

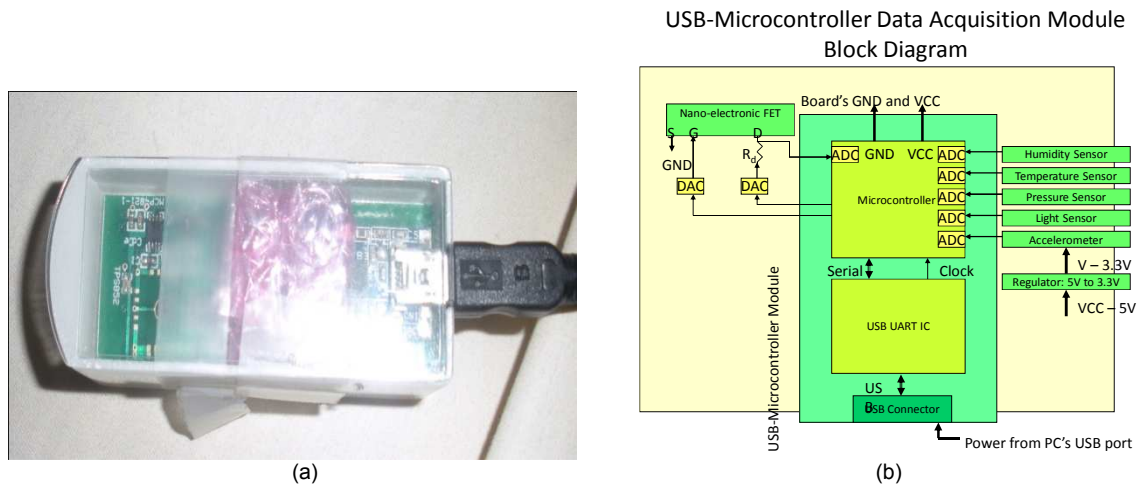


Figure 1: (a) Photograph of the dongle used from above in its protective case.
(b) Block diagram of the Dongle sensors and microcontroller and others.

3. Software

The software used in this project are Matlab code that Professor Levi supplied. Also used is Kelly Magruder's code that logs all data in real time either in an array in Matlab or in a text file. Code was written to find polynomial fits of the data and the error using the model, and plot the fit with the data as well as plot the error. Also, the code found the slopes of the graph (the derivative of the data) and filtered it to find a smoother, more characteristic graph. Concavity was examined in the same method, by taking differentials of the data and the slope and the time and dividing it accordingly and then smoothing it out. The data logging code logs any data in real time and plots it on a graph in the Matlab figure. Furthermore, the code supplies a transformed and filtered version of the respective data and outputs it in a figure. A moving average was mainly used to filter out sudden spikes of information and smooth out the graph. Rather than use a low-pass filter after a Fast-Fourier-Transform, a moving average accomplishes the same without the significant delay resulting from the transform and inverse transform. To indicate the desired events, the code searches for maintained values above a threshold and displays an output signaling a found event.

4. Performance measurements

4.1 Introduction

Humidity and Luminance data are gathered using the sensors in the dongle and stored into Matlab arrays for easy access.

4.2.1 Measurement of Humidity in a standard room

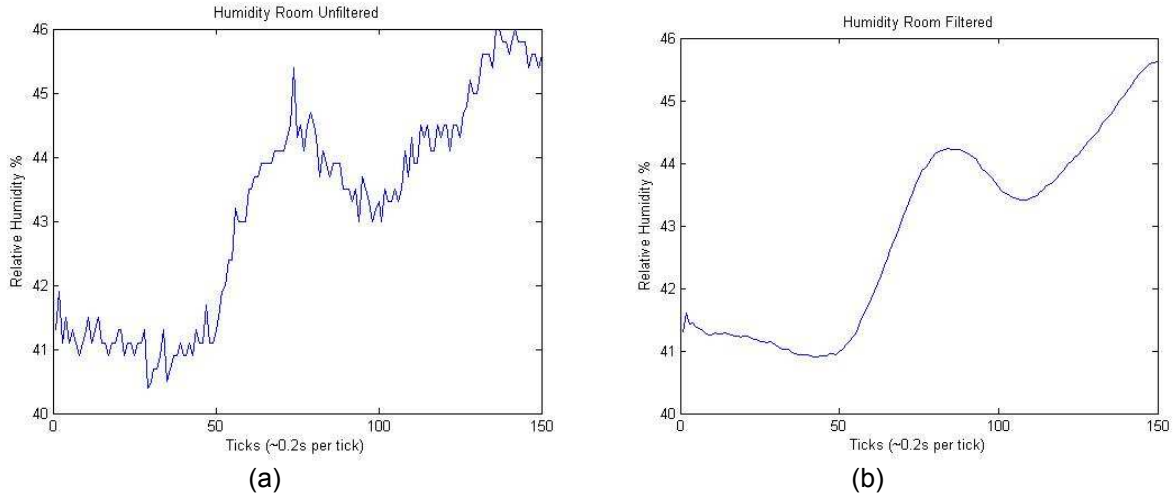


Figure (a) shows the humidity data unfiltered in a normal standard room. While it does seem to jump around a bit, it actually is relatively stable upon inspection of the values, jumping around its average of about 43-44. Figure (b) shows the moving average filtered results. As shown, it is much smoother as the higher frequency noises are removed from the averaging. Again, it jumps around its average slightly, which indicates a rather constant value which is expected in a standard room.

4.2.2 Measurement of Humidity with Varying Human Breaths

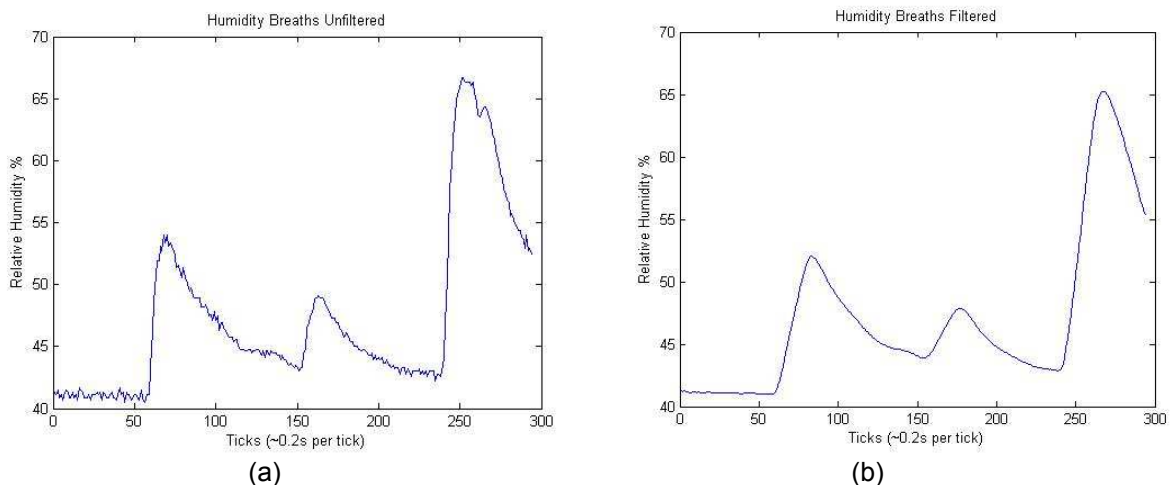
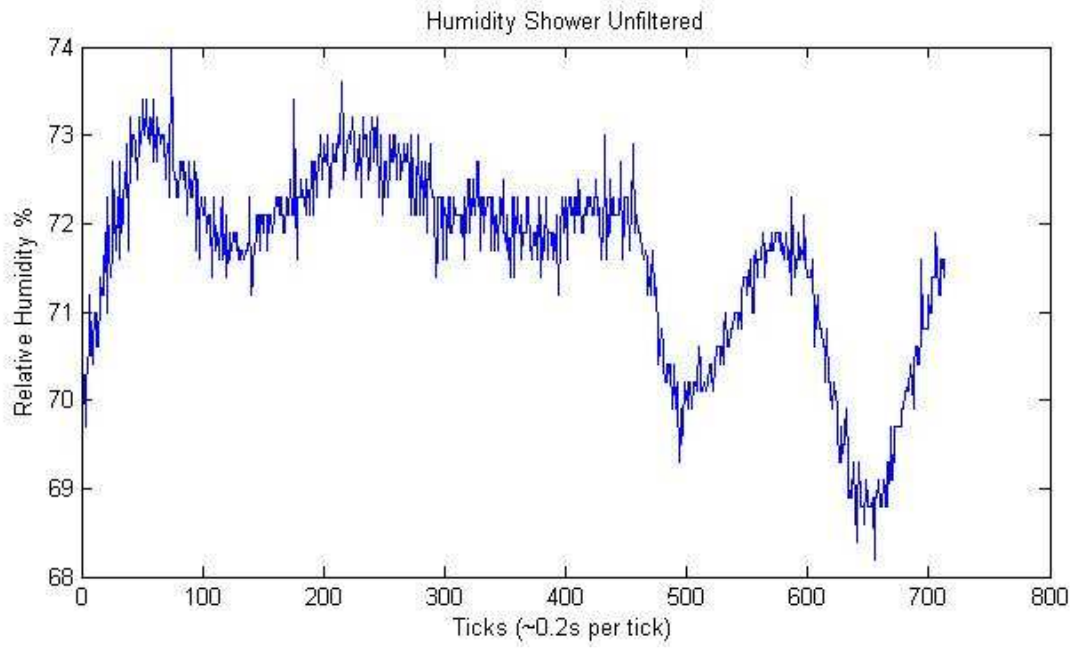
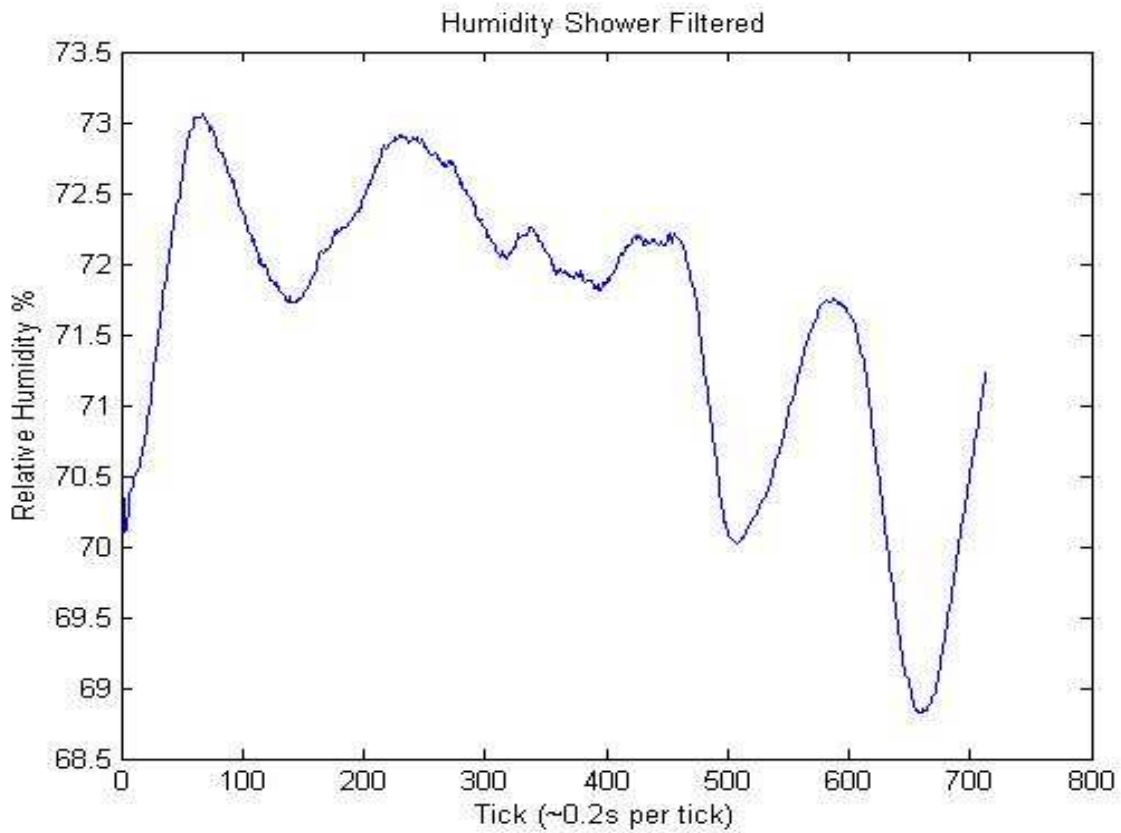


Figure (a) shows the humidity with different events. Three major stimuli were applied to the dongle during the data collection. The first is a warm breath with a large mouth about 6 to 8 inches away from the sensor. The second is a cool breath with pursed lips with greater speed at about 10 to 12 inches away from the sensor. The last spike indicates a large, warm breath with a large mouth like the first spike but at a much closer distance, nearing 1 to two inches. As expected a large spike in humidity results from such an event. Figure (b) shows the moving averaged filtered results from the data.

4.2.3 Measurement of Humidity with Varying Human Breaths



(a)



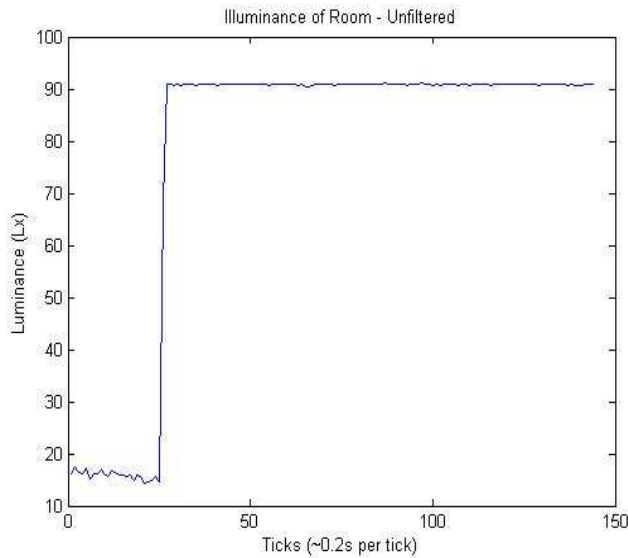
(b)

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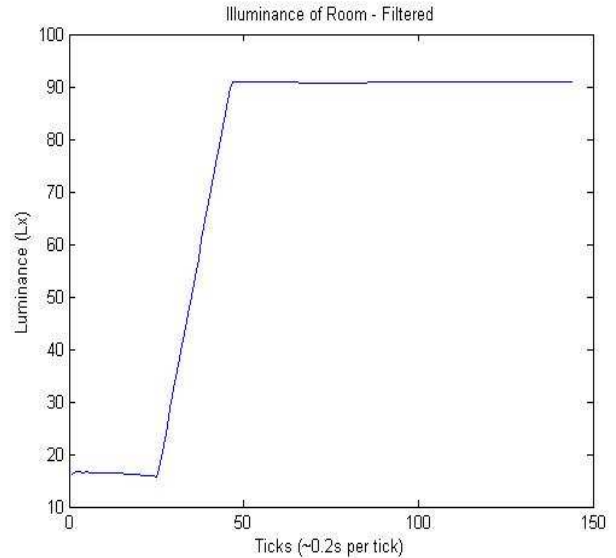
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Figure (a) shows the results of humidity in a bathroom during a shower. Because of data collection errors in the code provided, the dongle stopped logging data after a short moment. This graph shows the event of the humidity in the shower after a while, as humidity has reached a relatively stable maximum value of around 71 to 72. Figure (b) shows the moving averaged filtered results of the data, which is much smoother than the original data allowing for better inspection.

4.3.1 Measurement of Luminance in a Standard Room



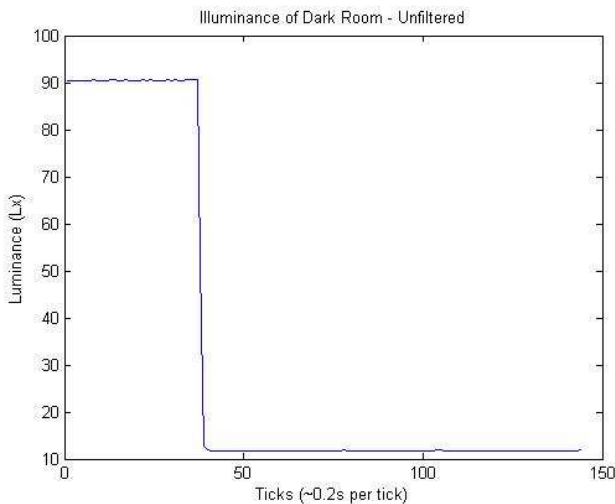
(a)



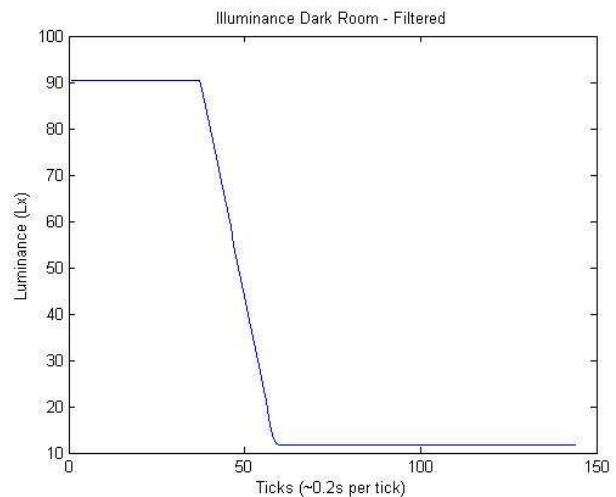
(b)

Figure (a) shows the luminance of a standard room. The low luminance in the beginning is due to the initial conditions. The sensor was covered up to ensure that as little light as possible is being read into the sensor, indicating darkness. Then when the cover was removed, luminance quickly spiked to its peak of around 92. Figure (b) shows the filtered results. The data itself was not very noisy, but it still is smoother. The sudden spike is adjusted accordingly in the moving average filter by showing a gradual increase instead.

4.3.2 Measurement of Luminance in a Dark Room



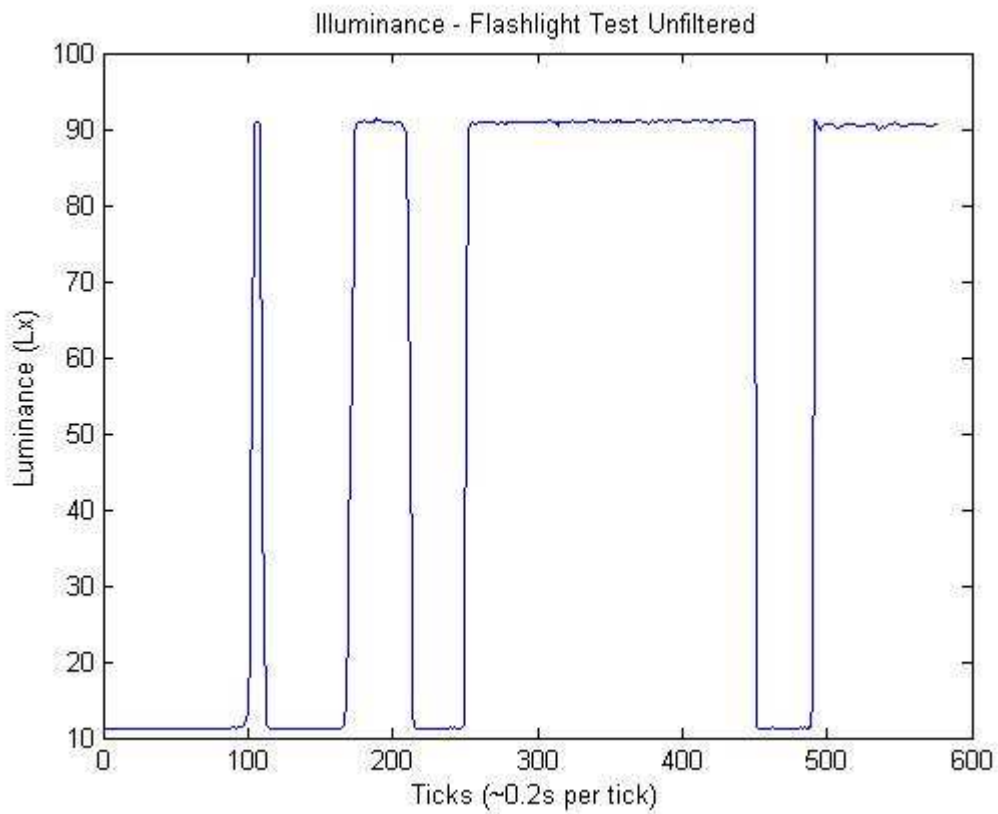
(a)



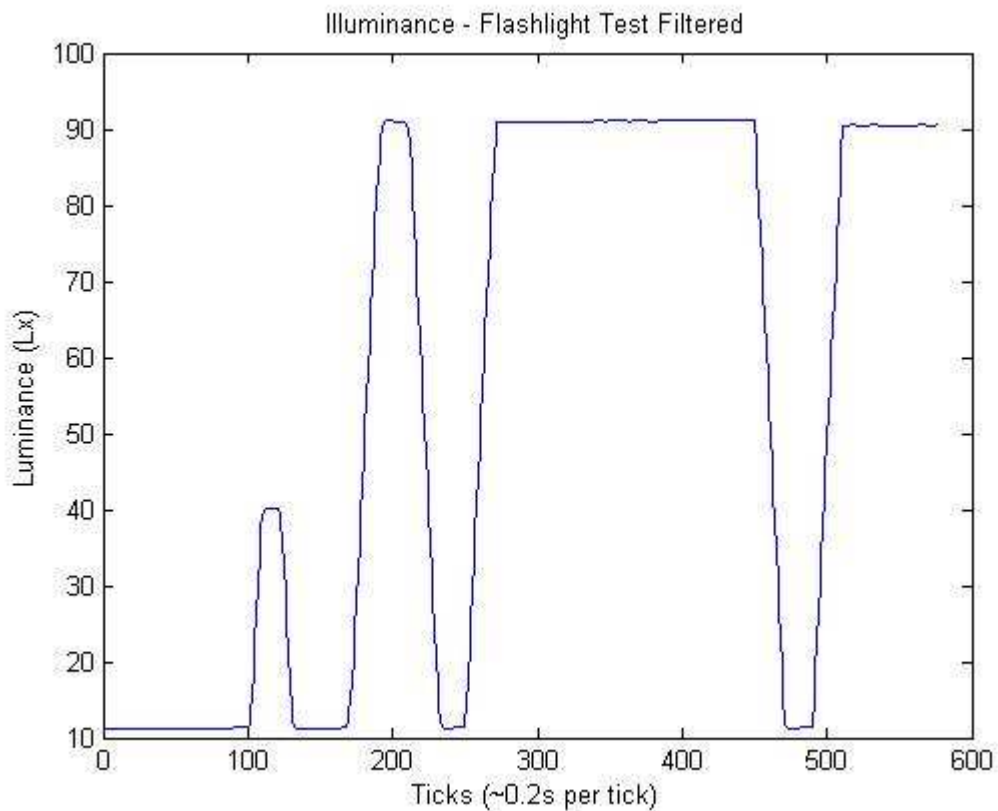
(b)

Figure (a) shows the luminance in a dark room. The initial condition was with the light turned on, then later the light switch was turned back off. Like Measurement 4.3.1, the results are similarly characteristic to its event just reversed. Figure (b) is the same idea as the previous measurement—the moving average of relatively unnoisy data.

4.3.3 Measurement of Luminance in the Flashlight Test



(a)



(b)

Figure (a) shows the flashlight test results. The setting was in a dark room with a flashlight moving back and forth across the sensor. The first spike indicates a quick sudden passing of the flashlight. The second spike indicates a slower passing of the flashlight and the last two increases indicate a slowly moving, almost constant shining of the flashlight onto the sensor. Code in the Luminance used this as a rough model to detect the signature of a sunrise, substituted by flashlight, and was alarmed once a given threshold had been reached for an extended time. In the figure, only the last two more constant levels of luminance indicated the sunrise, as hoped for, whereas the first two were labeled as random events. Figure (b) shows the filtered results. The spikes are more gradual, as expected from the moving average.

4.4.1 Measurement of Luminance in Sunrise (1) Standard Day

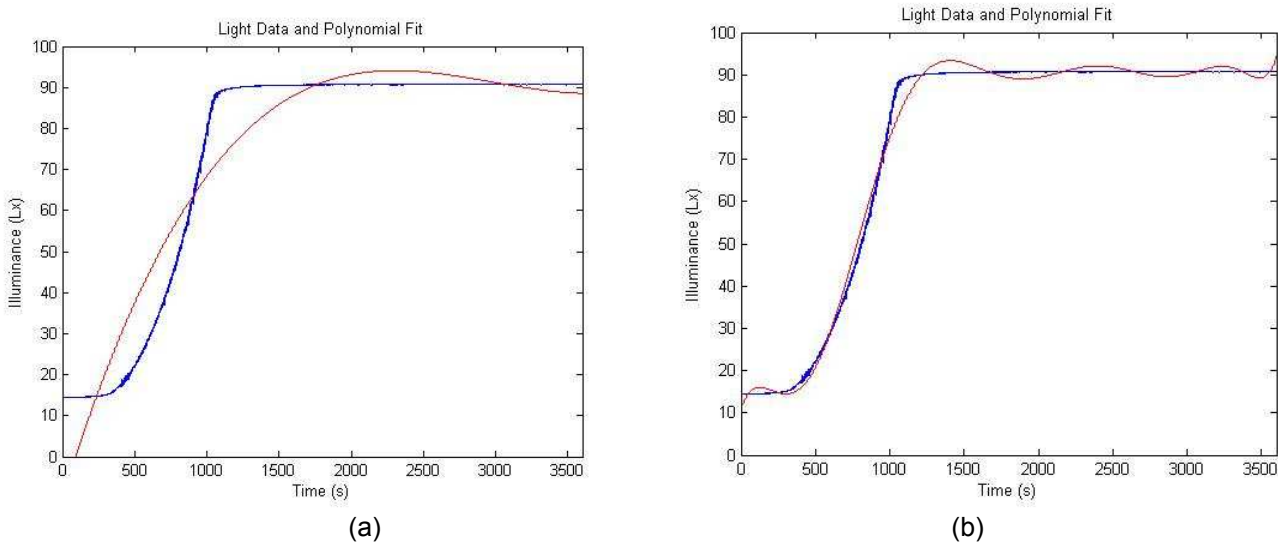
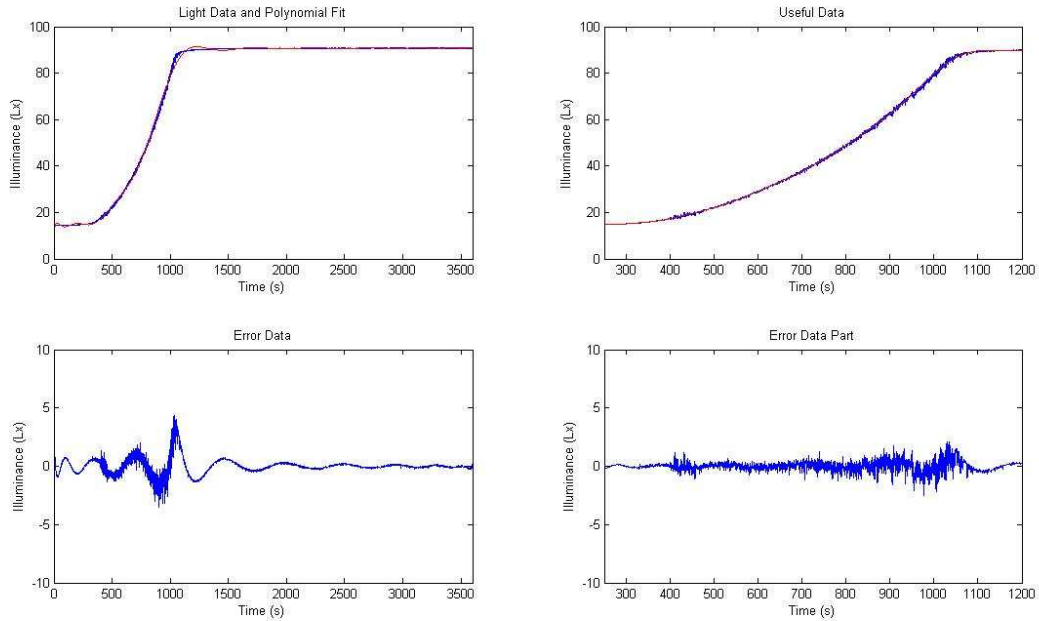
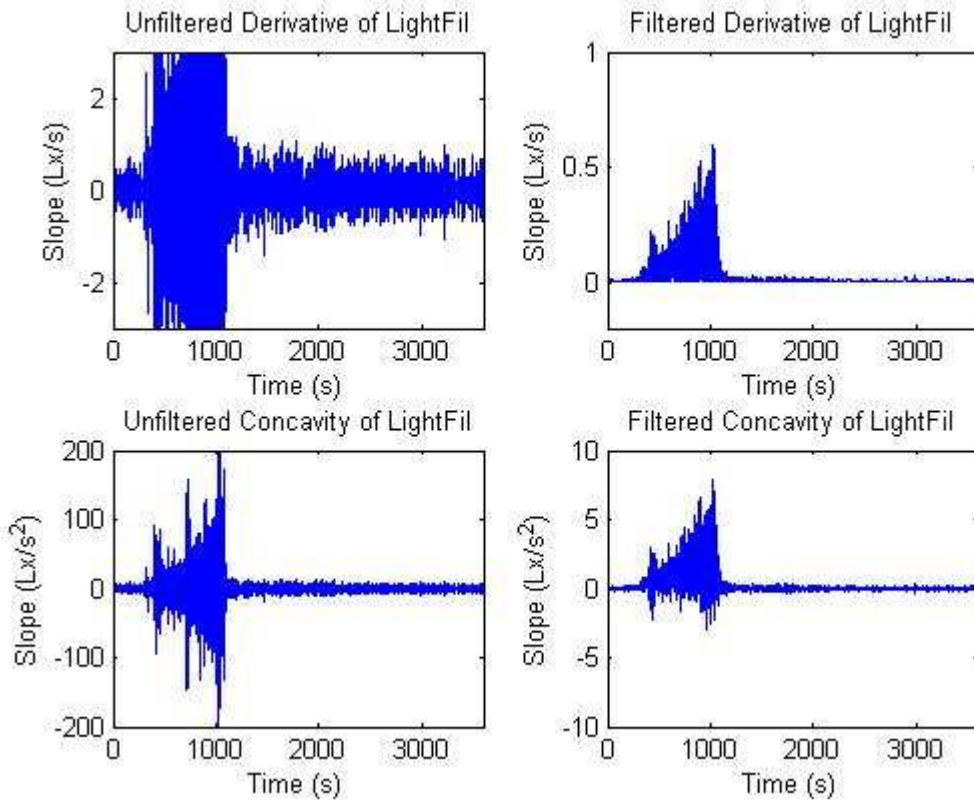


Figure (a) shows the luminance of a standard day sunrise using a polynomial fit with an order of $n=3$ indicated in red. It is not very accurate as a third order polynomial does not have enough variation to account for the characteristic shape of the data graph. Figure (b) shows the luminance of the same day using a polynomial fit with an order of $n=10$ in red. This is much more accurate, as the variations available for a 10th order polynomial can fit the graph a little better.

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(c)



(d)

Figure (c) shows various useful subplots. The polynomial fit for $n=20$ and data are in the first graph for reference. As predicted, larger orders for the polynomial greatly enhance accuracy in the graph. The

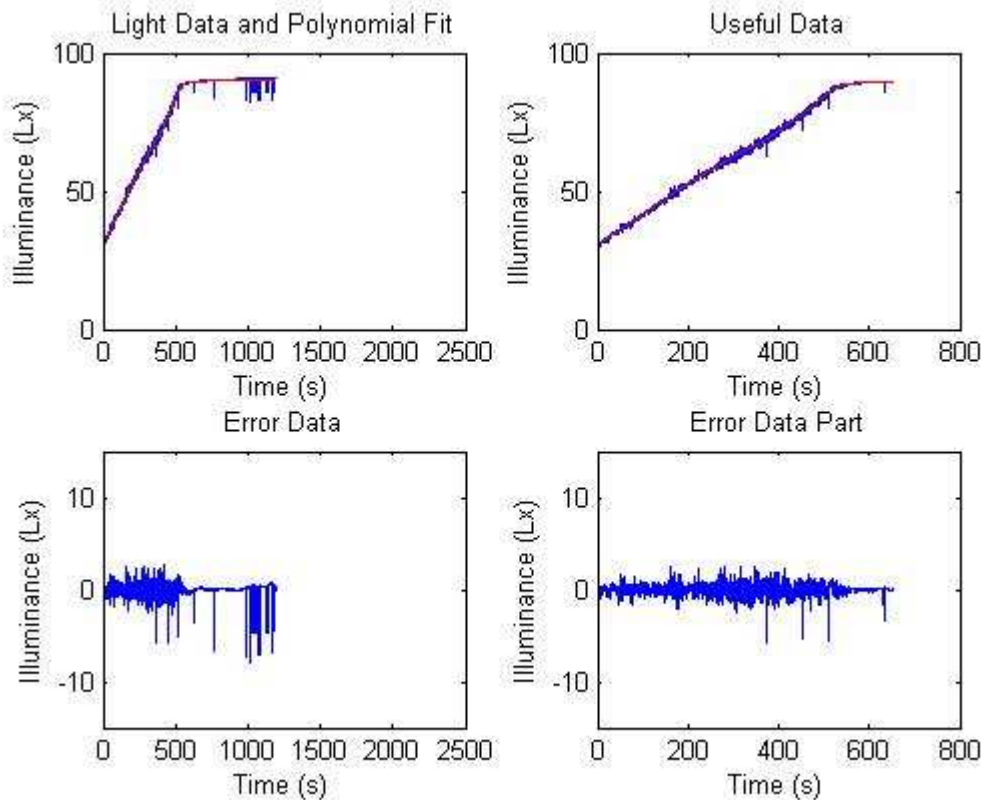
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second graph uses the useful data, mainly the region of the sun actually rising and cutting out the extremities of darkness and brightness. This allows its own polynomial fit of order 20 to be even more accurate. It is much more efficient to only look at the sun rising and removing the unneeded information on the sides. The third plot is the error plot between the polynomial fit and the data. It is not too bad, only ranging up to 5 in the sharper concavity changes. The last plot is much better, as it is the error plot between the useful data and its own polynomial fit. It reduces the error to around 2, which is 2 to 2.5 times better than using the entire domain of data.

Figure (d) shows the analysis of data slopes and concavity. The first graph shows a rough estimate of the derivative of the data by using the division of small differentials of data and time to find the rough slope. The minor noise in the original graph is amplified a great deal since the sudden changes spike when dividing by a small number. The next graph takes the moving average of the derivative plot as well as some data extraction which greatly smoothens out the noise. The extracted data were the negative slopes, since they are uncharacteristic in a sunrise and only are present in noise such as blocking the sensor from reading light. Instead of tossing them and placing a zero there, the previously indexed data in the array was repeated, so it makes the graph much more distinguished in shape by replacing noisy data with more accurate expectations. As indicated in the second graph, there is a signature rise in slope which suddenly decreases to nothing once it passes approximately 0.5, the threshold.

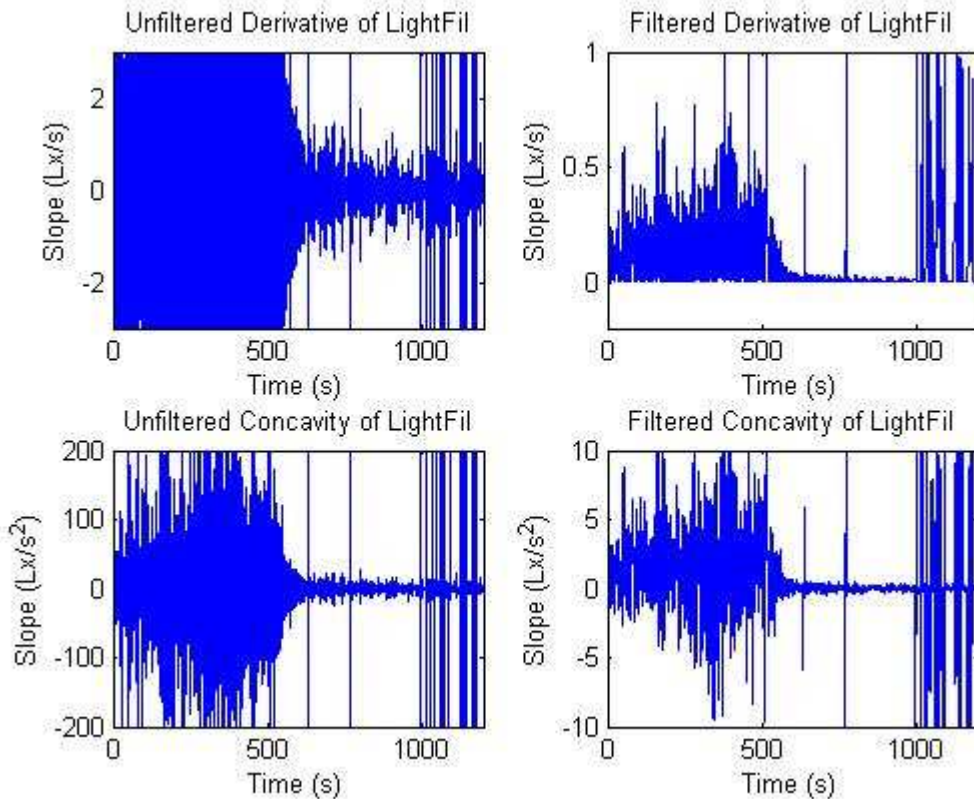
The bottom two graphs are the concavity graphs. The first is the unfiltered results of concavity and is also very noisy as expected. The second is the moving averaged results using a length of 80. 80 seemed to work the best in removing the sudden variations of concavity which should not be present everywhere but only near the actual sunrise itself. The negatives therefore could not be removed as near the sunrise, there is a specific characteristic of a sharp change in concavity to nearly 0.

4.4.2 Measurement of Luminance in Sunrise (2) Rainy



(a)

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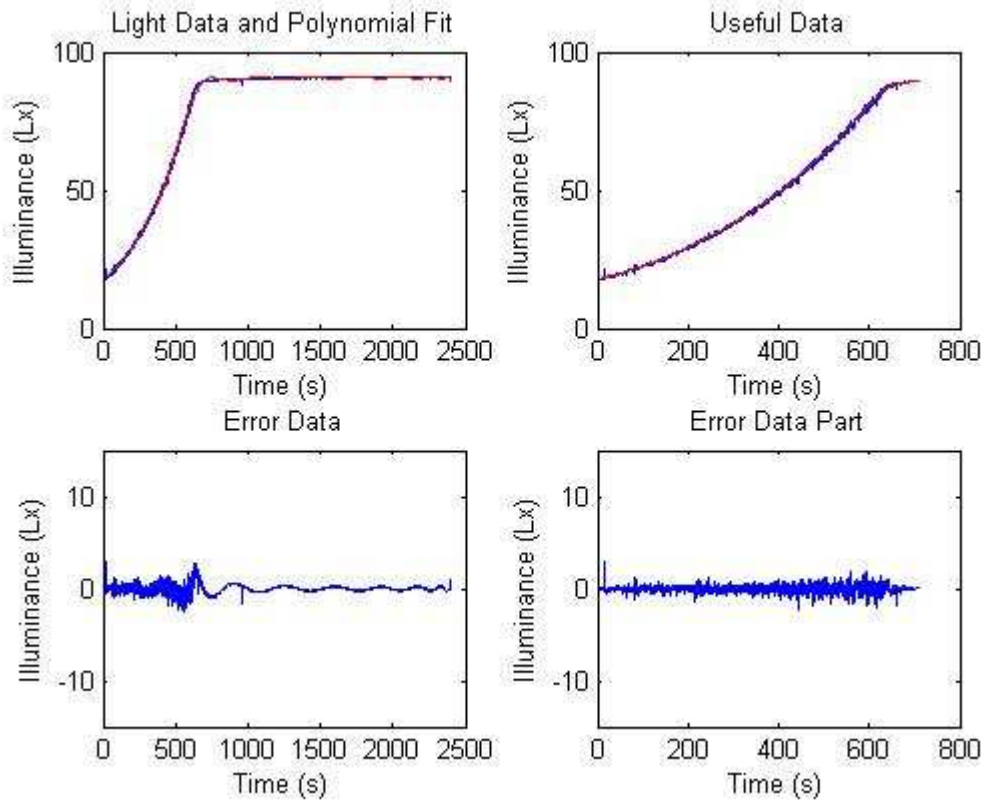
(b)

Figure (a) shows the graphs indicated by their respective titles. Because it was a rainy and windy day, the luminance had significantly greater noise even with the moving average. The polynomial fit was still a success as the noise did not affect the fit as much as its more consistent data points. The error plots because of the noise were very noisy itself, with sudden spikes at larger frequency noise.

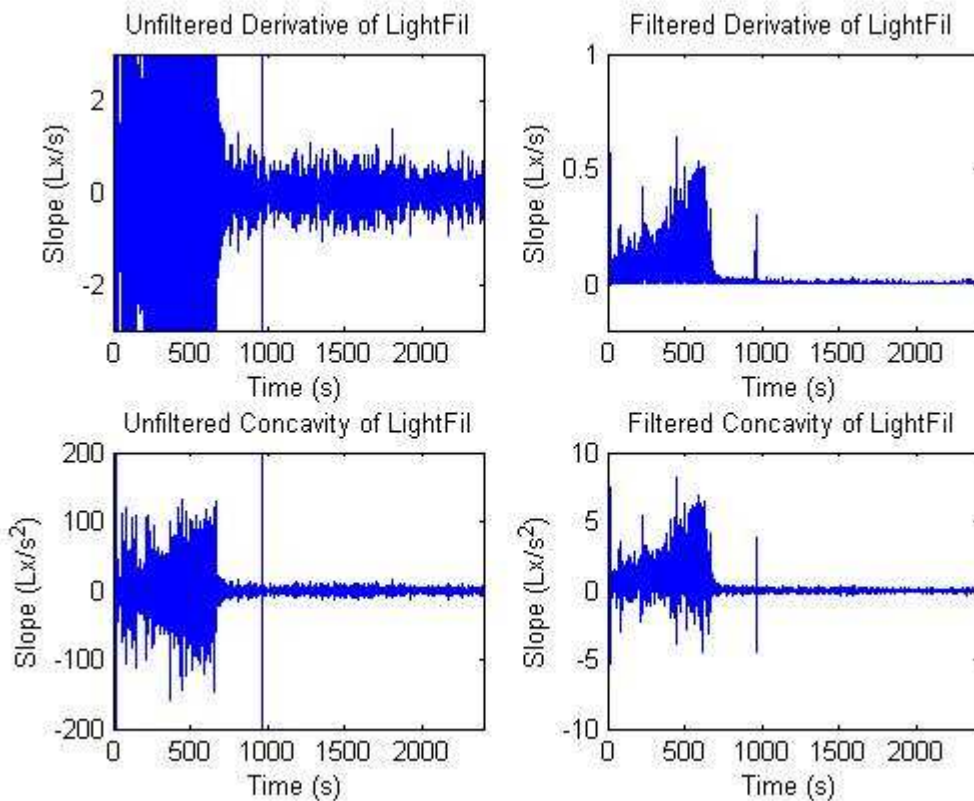
Figure (b) shows the calculus analysis of the data. As shown, the slope is widely ranging because of all the extra noise. The filtered results and the data correction did smoothen out the graph, though there were still some impulse noises. Nonetheless, the characteristic rise and drop in slope is still seen in the picture. The later spikes in noise were probably from a moving dark cloud blocking the sun as well as the rain dispersing the light. The concavity is not very accurate in depicting the signature, as the noise amplifies way too much in these graphs as the further divisions create larger variations.

4.4.2 Measurement of Luminance in Sunrise (3)

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(a)



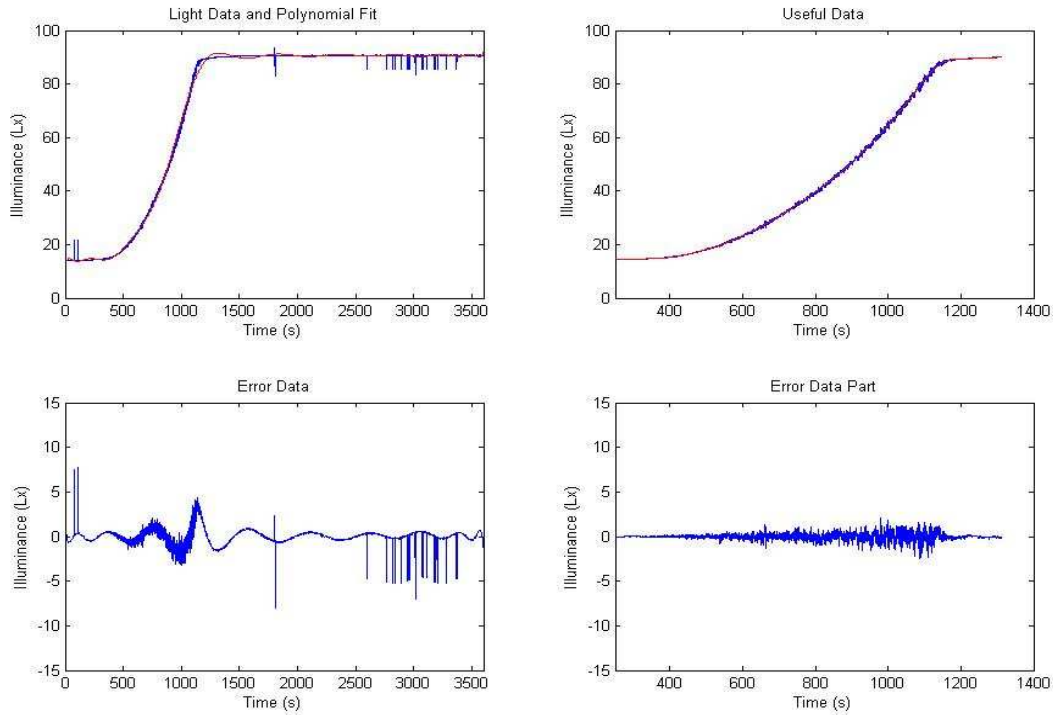
(b)

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Figure (a) shows the graphs like the previous measurements. The difference here is the data collection was started midway through the sunrise. The graphs show this characteristic effect on the initial conditions, with higher luminance. Otherwise, the fit accurately depicts the sunrise. The errors are quite small.

Figure (b) shows the calculus analysis. The filtered derivative still displayed accurate results, with the signature gradual rise and sudden drop in slope indicating the event of the sunrise. The concavity also proved to be quite accurate, though a bit more noisy as expected from the derivative plot. Still, the data analysis proved to be successful despite the initial condition change.

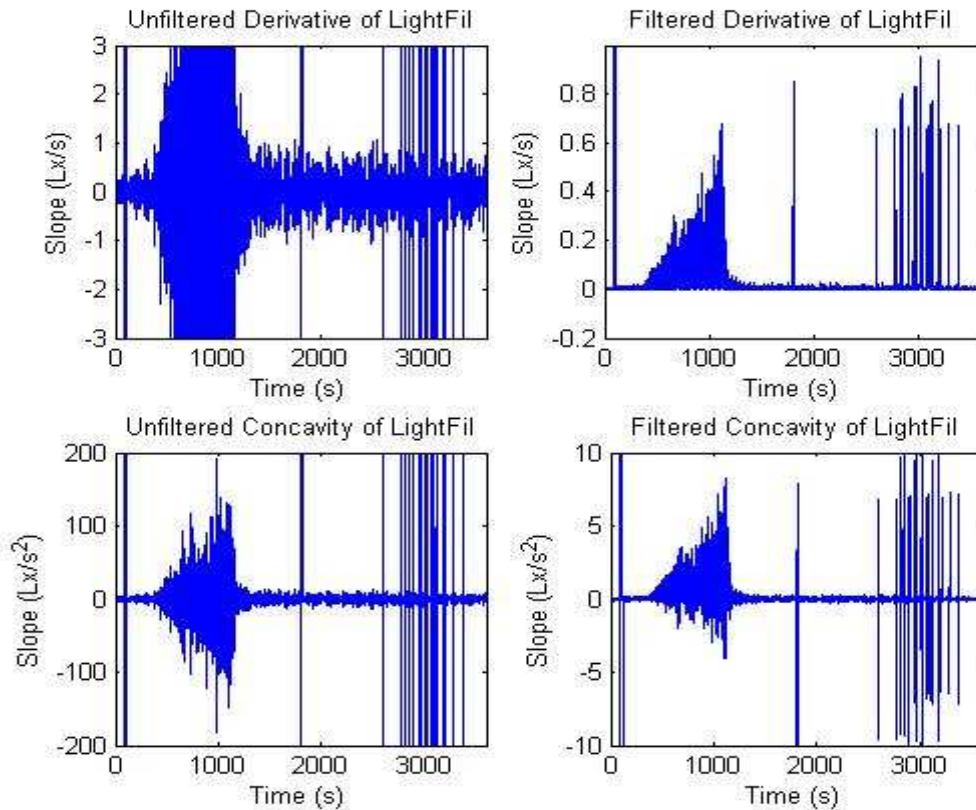
4.4.2 Measurement of Luminance in Sunrise (4) Standard Day



(a)

Figure (a) shows the indicated graphs in the title on a particularly normal day without many clouds or wind blowing objects such as leaves or branches from trees to block the sensor. The polynomial fit is quite successful, with very little noise in the useful data extraction of around 2 as its maximum. The normal data error is quite small too, except for the very noisy parts.

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(b)

Figure (b) shows the calculus analysis of a very bright day with little wind or clouds. The unfiltered slope itself is quite shapely already, but the filtering shows the gradual increase at its best. Then the steep drop indicates the sunrise signature quite well. The later spikes in the graph are the result of noise introduced into the measurements, including manual shined light or manual blocking of the sensor. The concavity is quite smooth too and characteristic of the sunrise, with concavity leveling off at 0 after the event of the sunrise with constant sunlight. The introduced noise was picked up well too, but do not correspond to the particular sunrise signature, indicating that the protocol for detecting the sunrise is effective.

5. Conclusions

The Humidity sensor worked in the aspects in which it was tested. However for the data that could not be gathered, it would require a little more signal processing in order to detect the signature for showering and dehumidifying in different methods. In order to do so the data collection code provided must be debugged in order to log more data for extended periods of time.

The Light sensor worked perfectly for the sunrise detection. The data was somewhat noisy at times but was taken care of pretty well with the moving average. In order to detect a signature, the polynomial fits of different orders $n=3$, $n=10$, $n=20$ were implemented. The $n=3$ was the least accurate as expected and the $n=20$ was most accurate. The error plot of the actual data value minus the polynomial fit showed that at $n=20$, the error was only about 2 whereas for $n=3$ the error sometimes shot to 10 or 15. On top of that, the useful data was extracted from each graph and polynomial fitted again for the three orders. The fits were much more accurate than the data graphs since we were able to remove the extraneous information of constant darkness and constant sunlight at the extremities and focus only on the sunrise itself. Errors likewise reduced with these more accurate polynomial fits, which had trouble in the unextracted data in the extremities. Overall, the polynomial fits were all rather somewhat similar and a range of polynomial coefficients can be determined to indicate sunrise events.

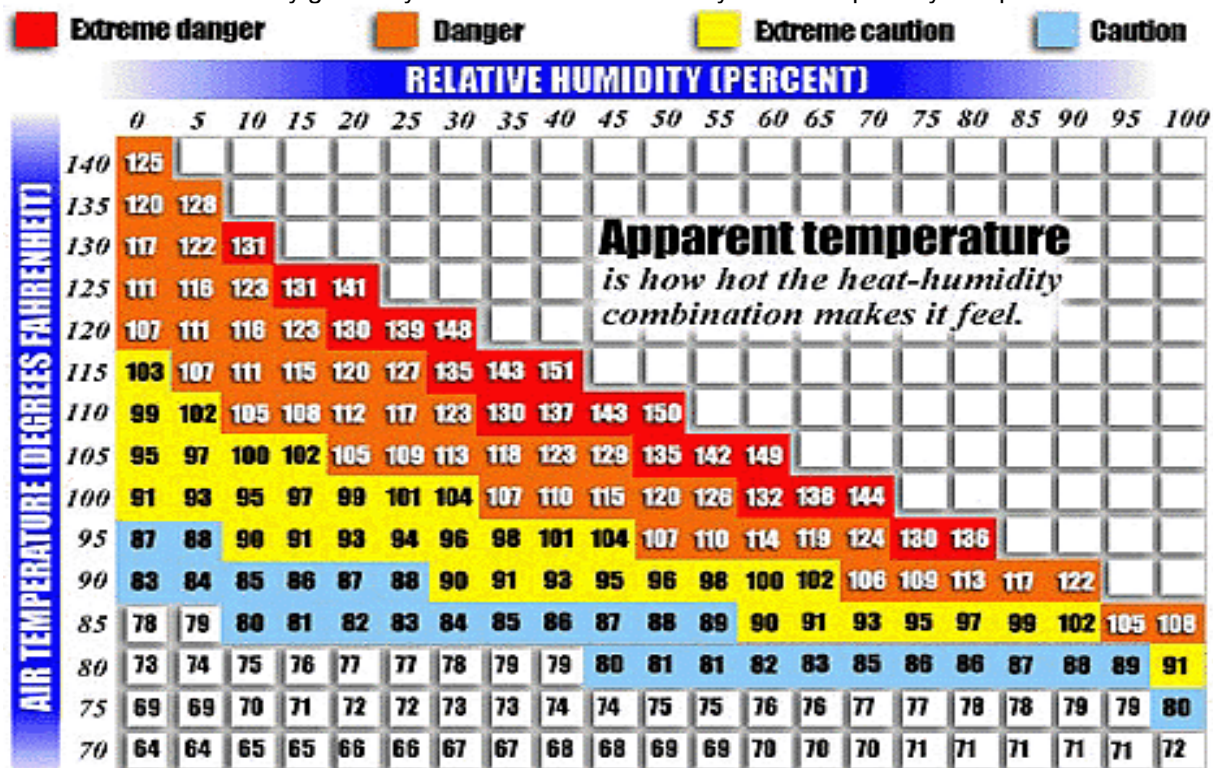
Further analysis showed clear signatures when using the calculus ideas of derivatives and concavity. Rough derivatives were calculated using the division of the differences between differentials of time and light. However, the small noises still remaining in the filtered data amplified into much larger noises when doing the division as sudden jumps are clear in the slope. Thus a moving average of the slope was implemented to smoothen out the graph. While much cleaner, there were negative slopes which do not correspond to rising luminance in a sunrise so code was further developed to replace negative slopes with the slope of the previous index in the array. This smoothened out the graph of slope even more, giving it a distinct shape of increase and then sudden drop, indicating that the sun's light was hitting the sensor constantly, meaning the sunrise had occurred. A look at concavity indicated the same event when the sunrise was up. Again, concavity just like slope had quite noisy characteristics, even more so than slope since it is the derivative of slope and thus amplifying noise by an exponential factor of two. Using the moving average again for concavity from the filtered derivative graph likewise smoothened out the graph a great deal, allowing an easy detection of the signature with its characteristic rise and drop. There were still instances of negative concavity, but those cannot be thrown out since near the sunrise, concavity should be negative rather suddenly compared to the rest of the data.

Overall, a characteristic signature had been found in these tests. The sunrise can easily be pinpointed using both the ranges in a polynomial fit and a quick analysis of the slopes and concavity of the sunrise. An implementation of this would be for the Circadian Rhythm Application, which will sound an alarm when the sunrise event had been detected, allowing people to reintroduce sleep stability and extended energy during the day into their lives after some irregular nights of poor sleeping or jet lag from traveling into different time zones.

6. Importance and Marketing

The humidity experiments could be used to detect unwanted humidities and start a dehumidification process to recalibrate to a desired humidity. This is important in delicate settings such as greenhouses or homes for the elderly, who are more sensitive to the environment. The greenhouses must keep humidity high to provide a comfortable habitat for the plants. Our target is the elderly or infants, who will have amplified reactions to changes in humidity. While we do not experience it ourselves much, poor humidity levels can have drastic effects on the human body.

- The *American Heart Association* warns seniors to limit activity when the temperature is above 70 degrees with humidity above 70%.
- 70 degrees is common indoor temperature and exercising indoors will be risky health-wise if humidity is not controlled.
- Extreme humidity generally is uncomfortable and may cause respiratory complications



When heat and humidity combine to slow evaporation of sweat from the body, outdoor exercise becomes dangerous even for those in good shape.

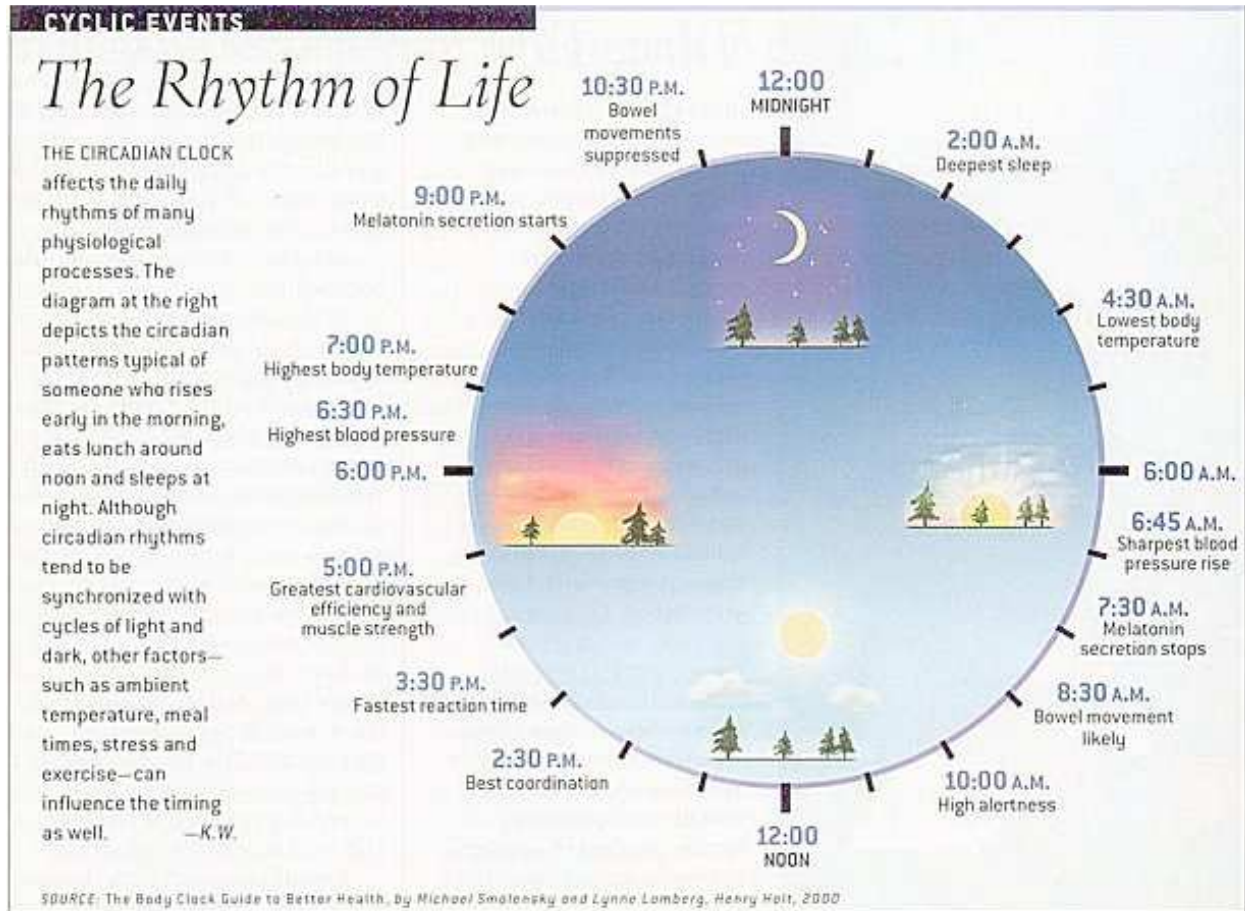
- Heat cramps, muscle cramps—imbalance of body salts
- Fainting—quick drop in blood pressure if not used to exercising in heat
- Heat exhaustion—losing fluid and salt leads to dizziness and weakness.
- Heat stroke—body temp can rise to 105 degrees +
 - Lethargy, confusion, unconsciousness
 - Fatal

Many older children of the elderly or even the elderly themselves and new parents will want to ensure safety for their families and thus consider this an appropriate and worthwhile investment. The dongle itself is about \$200 but if we can extract the only necessary components, the price can be cut down by removing the other unused sensors. A small attachment onto the necessary rooms in a home as well as engineered connections to humidifiers or dehumidifiers will maintain humidity in the sensitive environment. With the elderly population alone growing exponentially currently at roughly 10 million, there

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must be new technology to facilitate taking care of them. This sensor and further applications can be one of them.

As for the Circadian Rhythm application, people of young middle age in their mid twenties to fifties will considering investing in this, especially those with higher amounts of stress leading to worse sleep and overall lethargy and those who travel to different time zones, deflecting their natural rhythm. The benefits of good sleep on both energy in the day for working as well as health and overall happiness is worth the investment.



As long as marketing is effective in displaying the importance of good sleeping habits and the effects on health and happiness and overall energy, the large population of young adults to middle aged adults will have to consider this device. It should be relatively inexpensive, needing only just one sensor and some memory.

7. Distribution list

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