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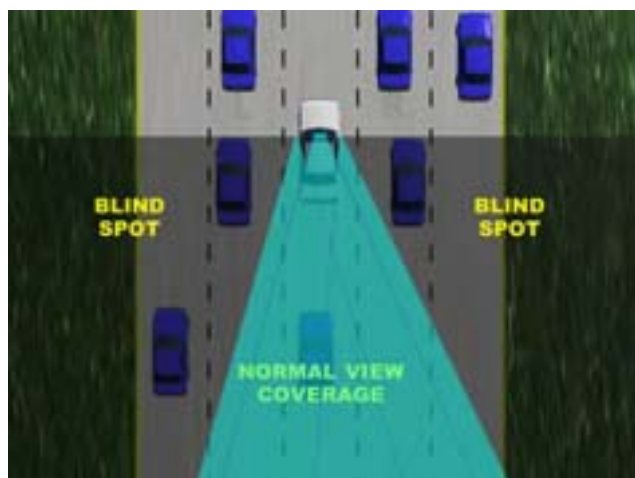
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Abstract

This project intends to use a light sensor, a single photodiode, to monitor a vehicle's surrounding environment at night such as cars in the right lane, streetlights and buildings. During at night, the lights emitted by these light sources are significant and the intensity of these lights can be easily picked up by the light sensor. For the experiment, the light sensor is attached to a GPS stand which is attached to the window to the right of the passenger seat. The dongle is placed to face the blind spot of a driver as the picture shows below.



A light sensor is provided in a USB interfaced dongle that can stream the light intensity data directly to a computer where a software program is written in Matlab to display the light intensity in real time. Another program is written to analyze the acquired data. Because the luminance data contains excessive noise, a low pass filter – moving average filter – and a band pass filter are used to facilitate the signal analysis. Three major signatures have been identified: when the car drove by series of street lights, when the car drove pass other cars in the right lane, and when the car made a left turn.

There is a significant amount of information in each of the signatures identified. By differentiating these signatures using signal processing techniques, single photodiodes can potentially be used to monitor a vehicle's surrounding environment

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Summary

Statistics shows that about half of all car accidents occur during at night. The chance of getting into an accident can be roughly calculated by dividing number of accidents occurred by amount of traffic flow at that time. Because there is less traffic flow at night than during the day and same amount of accidents at night and in the day, the probability of car accidents at night is higher than during the morning. This is largely due to the low visibility at night which significantly reduces the driver's awareness of surrounding cars. Therefore a system that can monitor a vehicle's surrounding objects can assist drivers to make safer driving decisions such as when drivers change lanes.

There is an existing technology that uses a camera to monitor the surrounding vehicles. However, it requires high production cost and complex image signal processing. The purpose of this project thus is to examine if a single photodiode light sensor can achieve the same functioning as the camera monitoring technology. Single photodiode is one of the simplest semiconductor devices which is extremely cost efficient. Also, the data acquired by the light sensor is one dimensional which is far less complex than multi dimensional image data.

The light sensor is provided in a USB interfaced dongle that streams the data into a Matlab program which displays the light intensity in real time. The raw data acquired by the light sensor contains excessive high frequency noise as shown in figure 1. This is because most of the light sources such as street lights and headlights are made of incandescent light bulbs which fluctuates the light intensity in a small range and a high frequency. However these small and high frequency fluctuation is not important for the purpose of this project because only the general trend of the light intensity graph is significant to identify the signatures. Therefore another matlab program was written to filter the raw data using a low pass filter – moving average filter. Figure 2 shows the filtered data which cut out the useless fluctuations and made the curve much smoother and cleaner for analysis. Moving average filter is used throughout the analysis of the data.

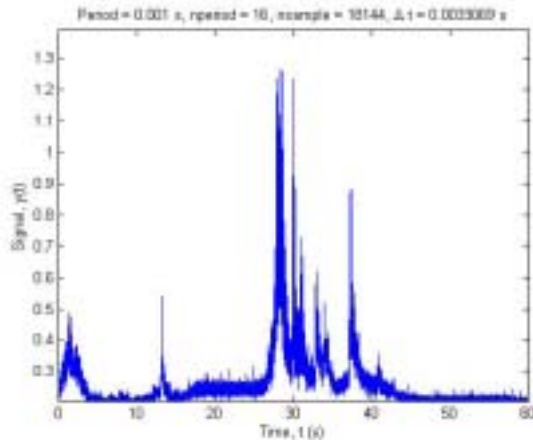


Figure 1 Raw light intensity data

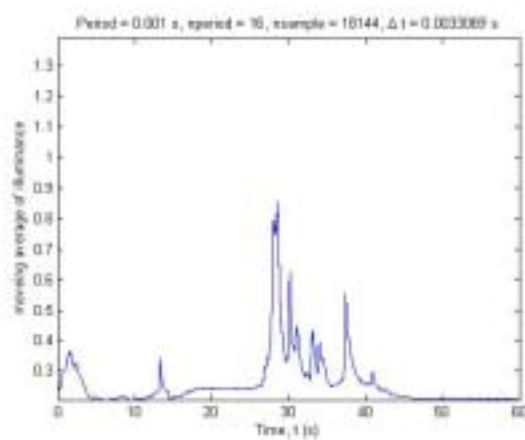


Figure 2 filtered data

1. Introduction



Figure 3 Experiment set up

Figure 3 shows the experiment set up. The dongle is attached to a GPS stand by paper tapes. The dongle was placed to face backwards with a certain angle to “observe” a driver’s blind spot. A webcam is attached above the dongle so that the webcam can “see” what the dongle is observing. Both the webcam and the dongle are connected to a laptop via USB ports, so that the real time data from the dongle and the video capture from the webcam can be displayed on the laptop screen simultaneously side by side. For analytical purposes, a camera is used to record the laptop screen where webcam video and real time data were being displayed. Most of the data is acquired from driving down the Figueroa street and the second street.

The analysis is done through the video recorded by the camera. By playing the video of webcam video capture and real-time light intensity data, the light source and the corresponding light intensity can be matched. Three major incidents occurred during the drive. First incident occurred when the car was driving by series of street lights. Second incident occurred when the car was passing two other cars in the right lane and the last incident occurred when the car was making a left turn. Each incident had different light intensity signal that can be differentiated using signal processing techniques.

2. Hardware architecture

Figure 4(a) shows the schematic of the light sensor used for this project. The light sensor was manufactured by Toshiba (Toshiba Photo IC Silicon Epitaxial Planar, model TPS852). Figure 4(b) shows the device dimension. The device is a rectangular chip with dimension of 1.2 mm by 1.6mm by 0.1mm and has 6 pins of which Pin 1 is connected to the Vcc, Pin 2-5 are connected to the ground, and Pin 6 is the output. The shaded area is the light-receiving area which is 0.51mm by 0.12mm. The weight of the device is 0.003 g.

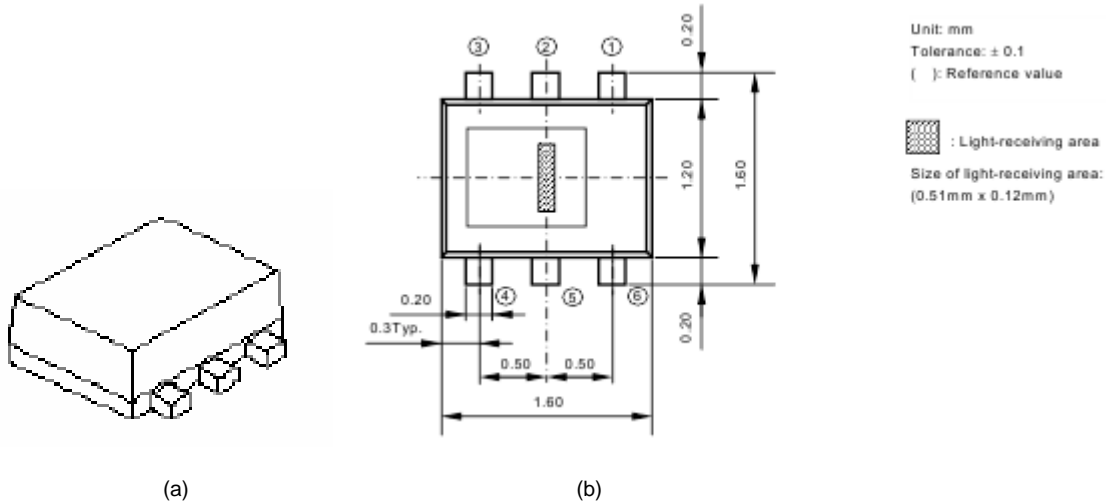


Figure 4: (a) Schematic of Toshiba TPS 852 light sensor (b) The top view of the device and its dimensions.

Figure 5 shows the block diagram of the light sensor which consists of a pn junction photodiode and a current amplifier. The maximum light current is 5 mA. The photodiode converts light to current which is amplified by the current amplifier. The current then is measured by a series of a resistor and a voltmeter. The measurement then goes through an analog-to-digital converter, a microcontroller and a USB device that serves as an interface to a computer and MATLAB.

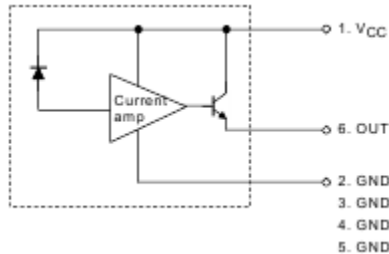


Figure 5: Block diagram of the light sensor

3. Software

Matlab is used as the software to process the light intensity data. There are two major programs written, one is for data acquisition and the other is for signal processing of the data. For the first program, the user is asked to input the length of time for data acquisition, and the program will run until the time is out. The program displays the graph of the light intensity with respect to real time. It also displays moving average of the raw data and the frequency domain of the data side by side. At the end of the program execution, it outputs a text file of all the data values with respect to each time value. For the second program, it loads the data file that is produced by the first program, and outputs a static graph of light intensity data with respect to time. It also outputs a graph of the moving average of the data and a graph of the data in frequency domain. The program also has a functionality of band pass filter which filter out frequencies that is not in the range indicated.

4. Performance measurements

4.1 Introduction

Through analysis of webcam capture and the data simultaneously, three major signatures have been identified. Unique signals were found when a car is passing by series of street lights, when a car is passing by other cars, and when a car is making a turn.

4.2 Measurement section one – streetlights

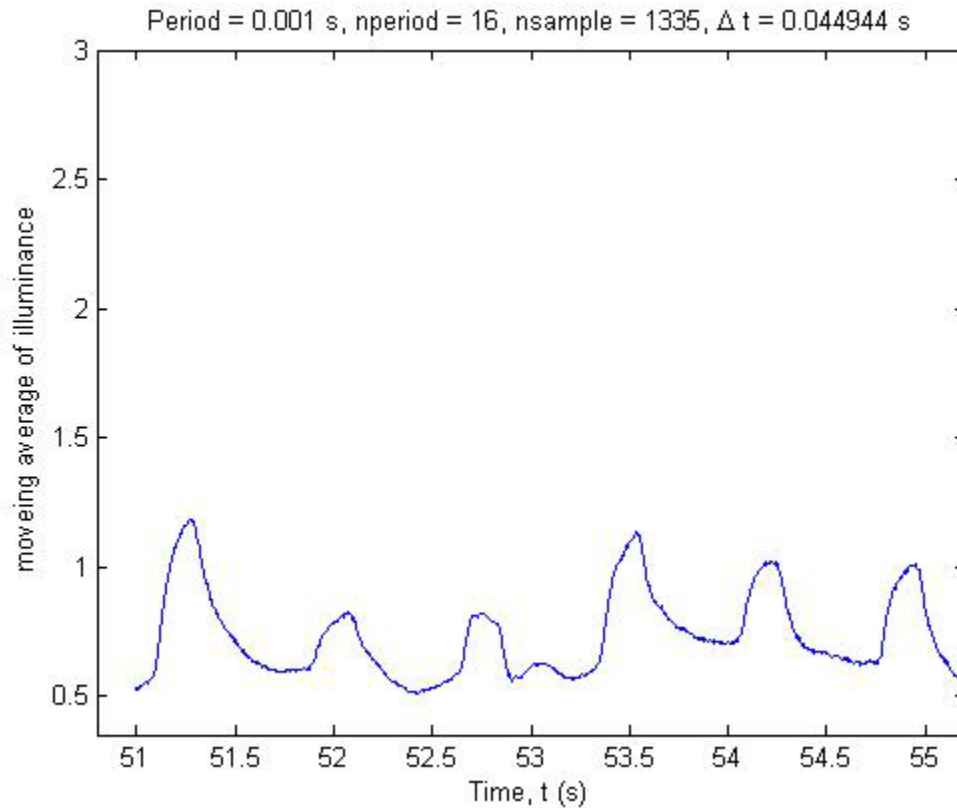


Figure 6 Moving average of luminance data acquired when passing streetlights

The graph above was acquired when the car is passing by series of streetlights. There are periodic spikes because when a car is approaching a streetlight pole, the light intensity increases and when a car is moving away from a streetlight, the light intensity decreases. Except the third spike, these spikes have a particular shape of a sharp increase followed by a sharp decrease.

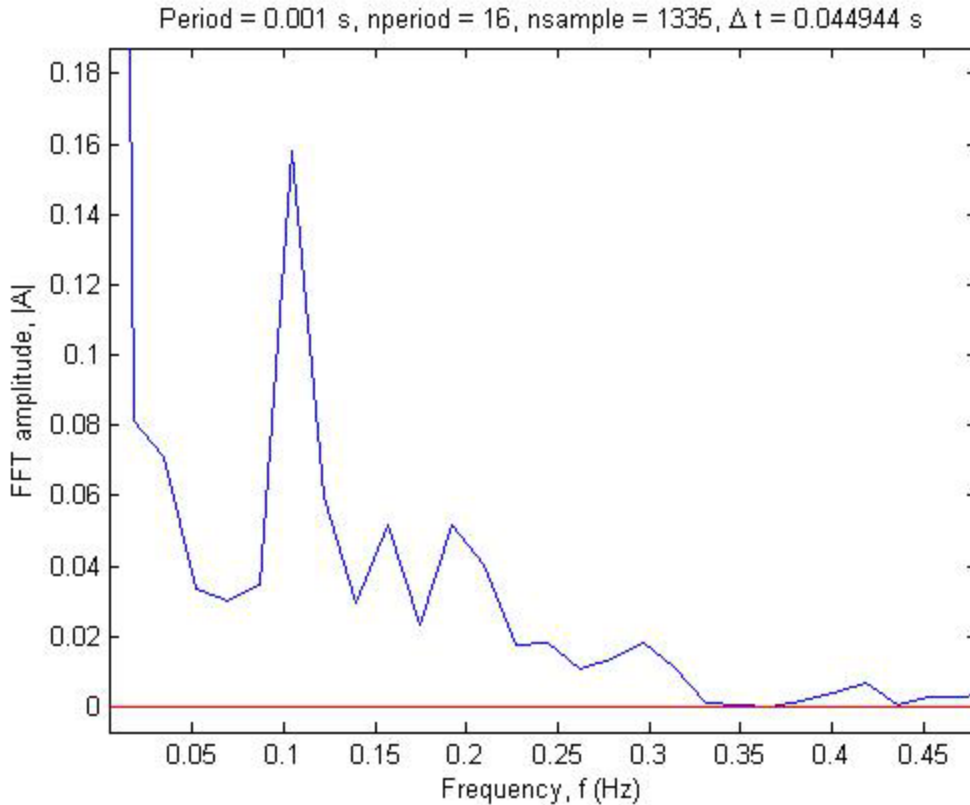


Figure 7 Previous data in the frequency domain

Because the spikes are periodic, there are harmonics in the frequency domain. The first harmonic is observed at 0.1 Hz and other harmonics are found at 0.15 Hz and 0.2 Hz with smaller magnitude.

The particular shape of the spikes may be a result of the direction that the light sensor was facing. The light sensor was placed in an angle to observe the cars at the driver's blind spot, which is in an opposite direction to cars' travelling direction. Therefore, another set of data was collected when the light sensor was placed to face the direction that is perpendicular to the direction of travelling.

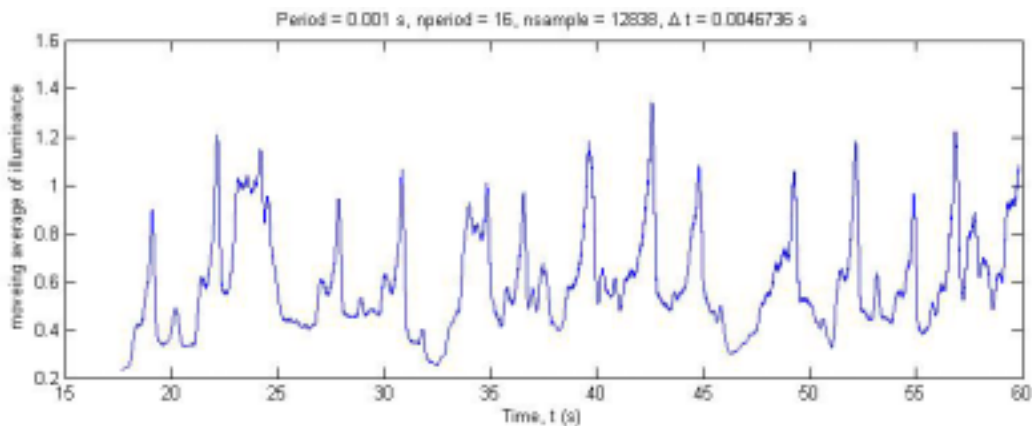


Figure 8 A graph of light intensity with respect to time (light sensor faced perpendicular to direction of travel)

Figure 8 shows the data acquired for the experiment where the light sensor faced in a direction that is perpendicular to the direction of travel. As the graph shows, most of the spikes resemble to a triangle waves. Some exceptions include the data points around time 23s to 25s, and 34s to 35 s, where the light

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intensity is relatively constant with fewer fluctuations. According to the video analysis these happened at intersections or a restaurant complex where multiple intensive light sources contributed to the light sensor readings.

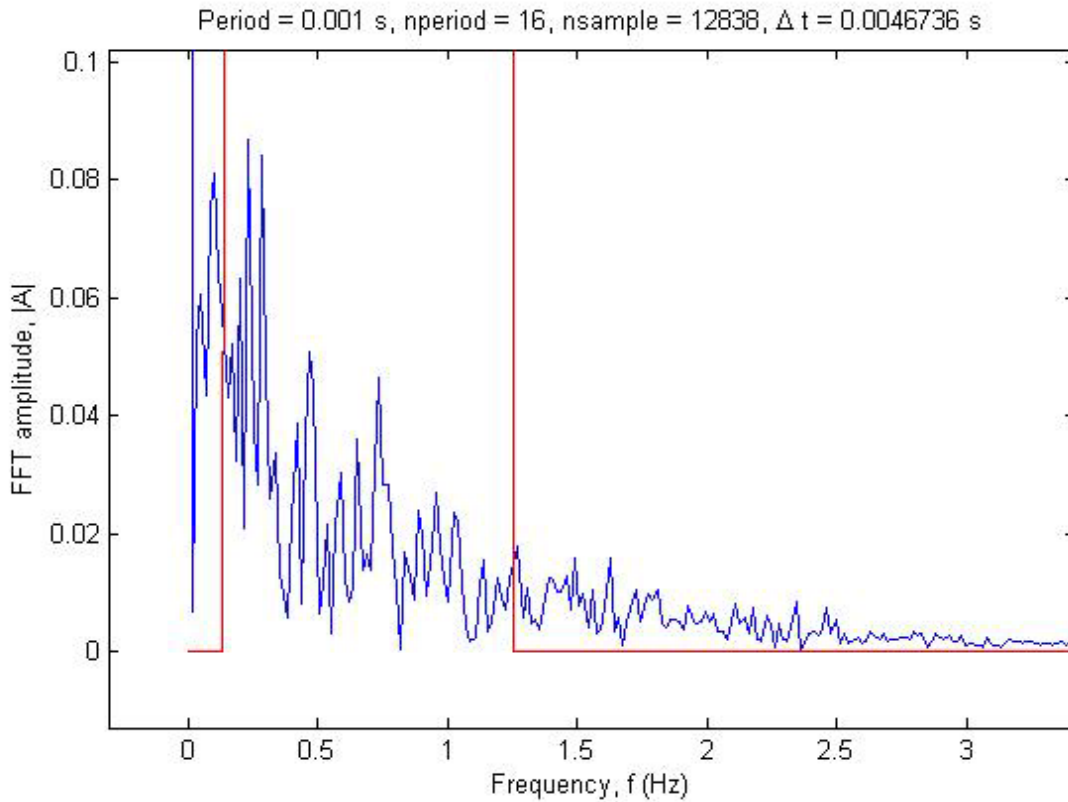


Figure 9 Previous Data in frequency domain

The graph above shows the data of streetlights in frequency domain. Most of the meaningful frequencies are between 0.2Hz and 1.25 Hz, therefore, a band pass filter is used to extract more useful information.

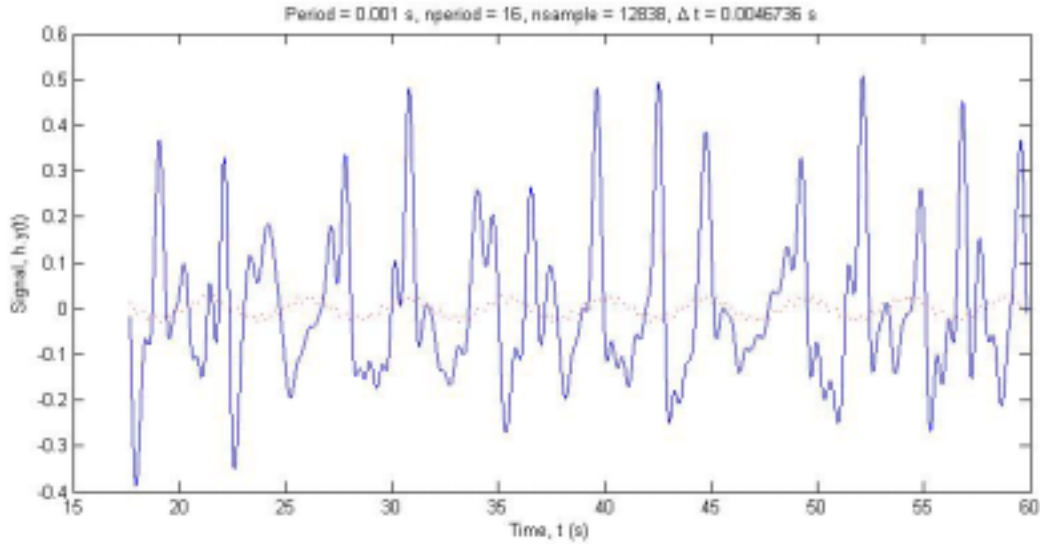


Figure 10 Graph of filtered data

Figure 5 shows the graph the data that is filtered by a band-pass filter. As the figure shows, there are some phase modulations which can be important in determining the signatures.

4.3 Measurement section two – passing other cars

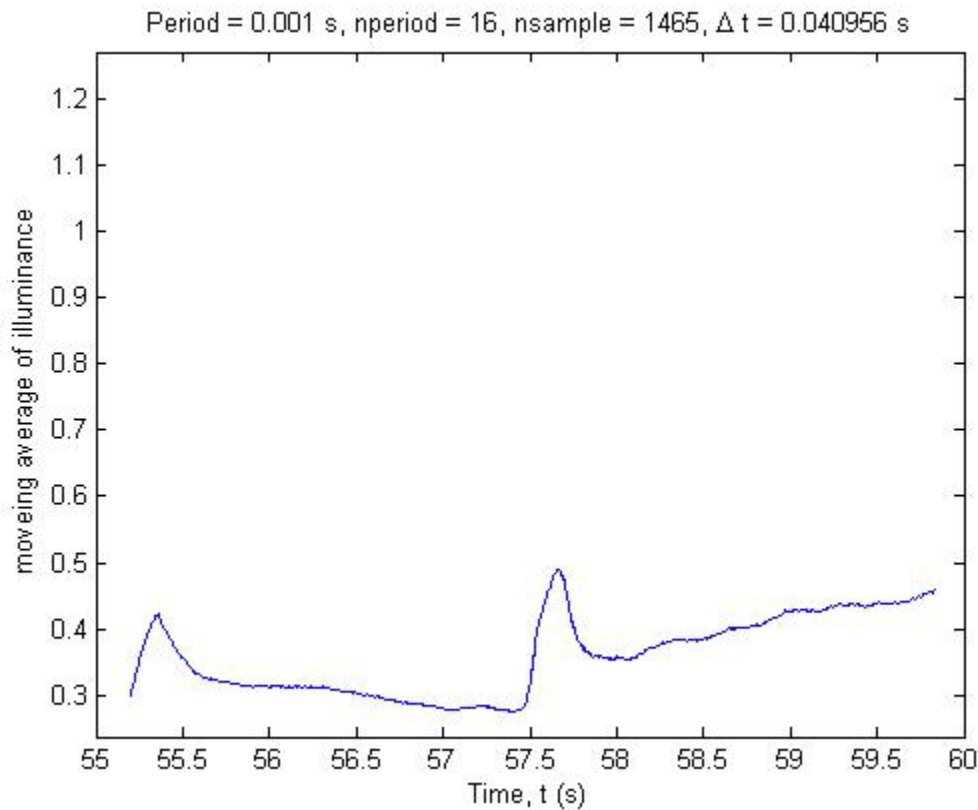


Figure 11 Data acquired when passing two cars

The figure above shows the light intensity when the car passed two other cars on the right lane. There are two spikes which indicate that the light sensor has picked up the light intensity from headlights of the two

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cars. The general shape of the two cars resembles a triangle wave. The first spike is followed by a gradual decrease meaning that the car was slowly driving ahead of the other car. The second spike is followed by a gradual increase meaning that while the car has passed the other car, the other car was catching up.

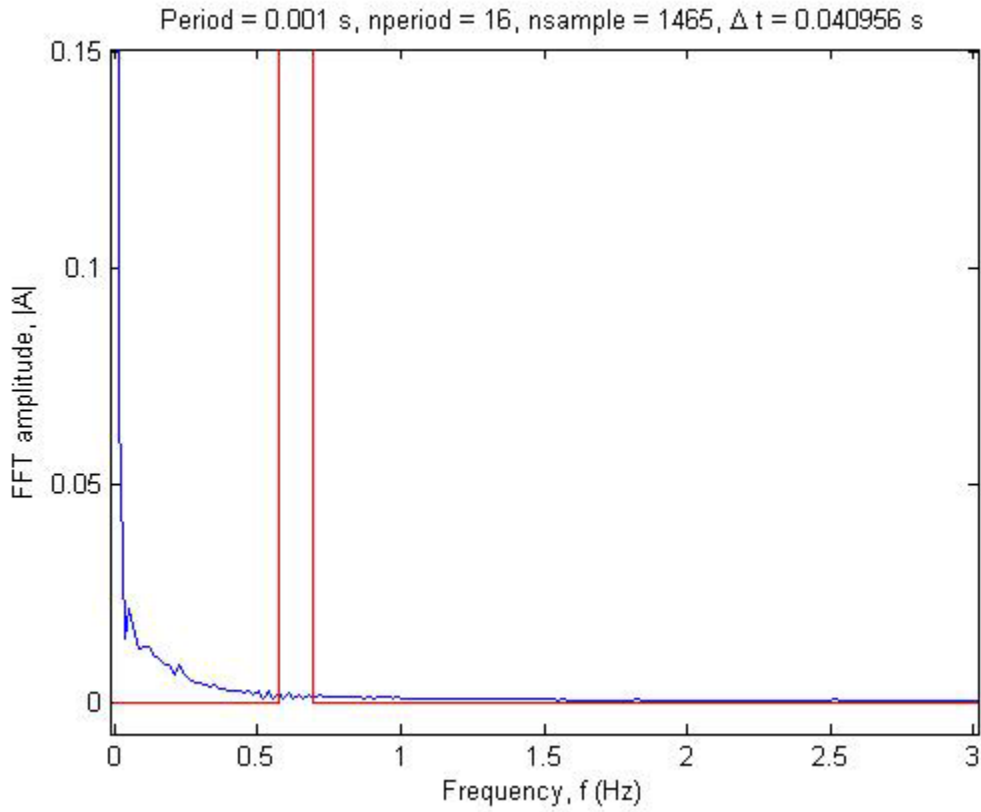


Figure 12 Previous data in frequency domain

4.4 Measurement section three – making a turn

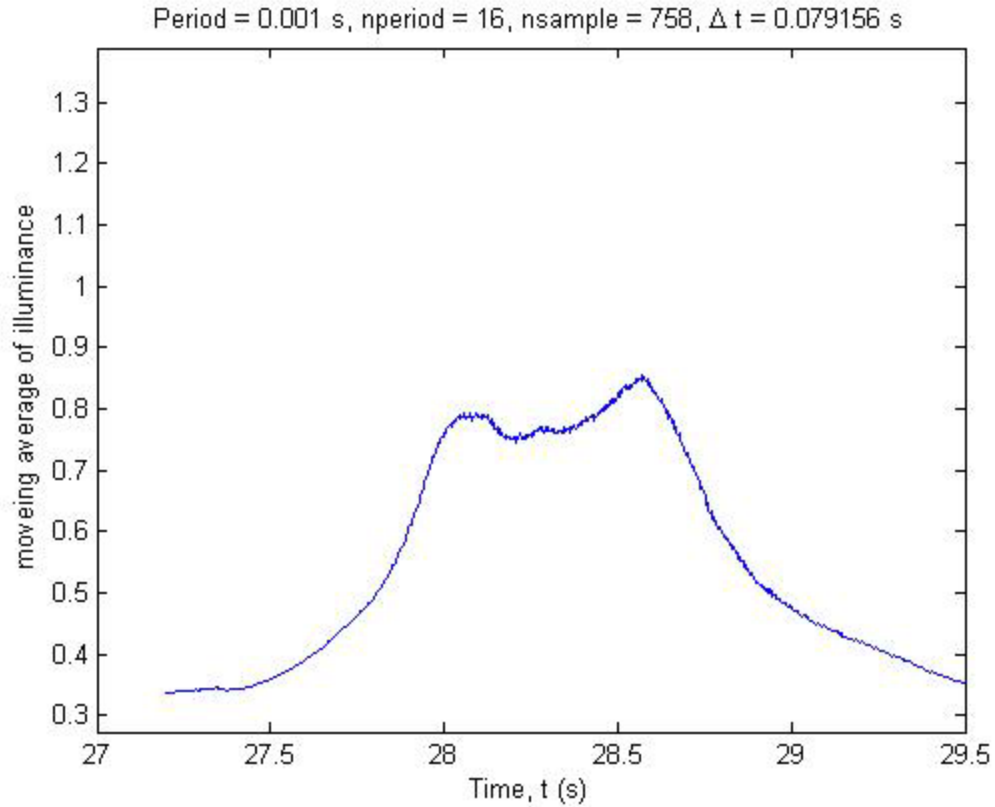


Figure 13 Light sensing data when making a turn

The graph above shows the light intensity when the car was making a left turn. At an intersection, cars going in the horizontal directions are on red and are stopped. Therefore, when the car was making a left turn, the light sensor sensed the headlight of the stopped cars on the right at the intersection. As the graph shows, the shape of the signal is different from the other signatures. It began with a slow increase, followed by a relatively flat region, and slowly decreased.

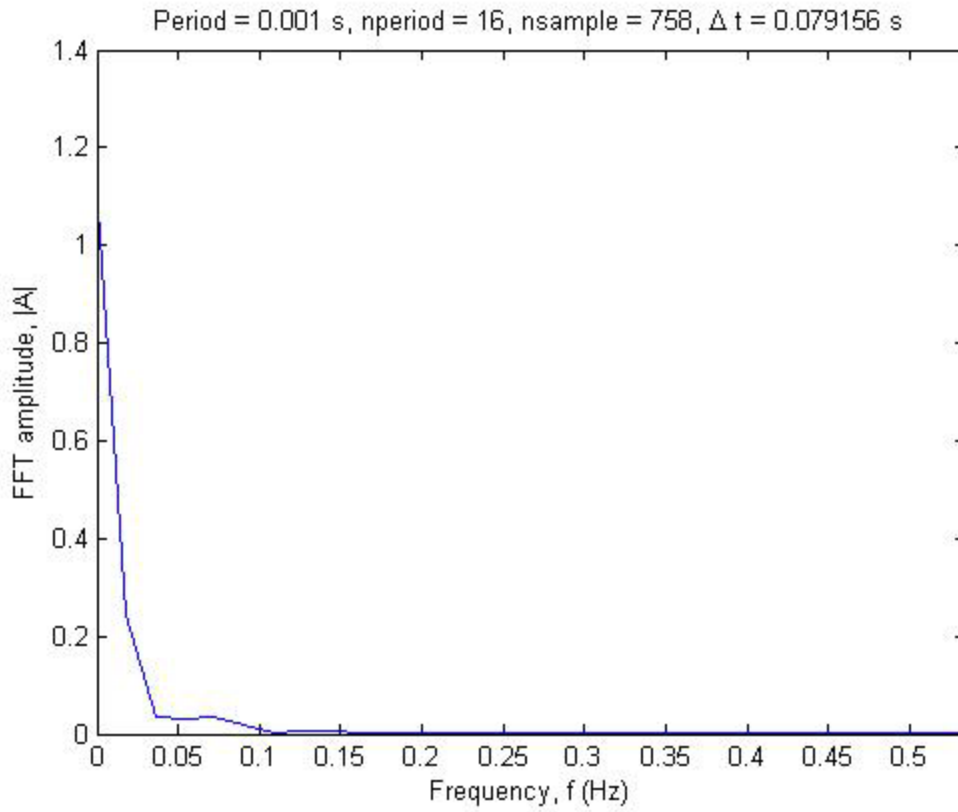


Figure 14 Previous data in the frequency domain

5. Conclusions

It can be concluded from data analysis that the light sensor could monitor a vehicle's surrounding environment at night by detecting light from various light sources such as other vehicles' headlights and street lights. Three major signatures were identified to have their unique signals. When a vehicle passes by a series of street lights, there are periodic spikes of light intensity with respect to time. Each individual spikes has a shape of a sharp increase followed by a sharp decrease. When a vehicle passes other vehicles, there is a spike for every car it passes. The shape of the spike resembles a triangle. After the spike is formed, the light intensity may gradually increase or decrease depending on the relative speed of the vehicle and cars passed. When a vehicle makes a left turn, the light intensity increases gradually and stays relatively constant for a little, and comes back down gradually. By differentiating these major signatures, some conditions and surrounding environment of a vehicle can be determined.

Though the light sensor was successful to obtain the light intensity data in different situations, some limitations prohibited the light sensor to examine the surroundings fully. Ideally the light sensors can be evenly distributed around the car to have a 360 degree view of the surroundings. For example 4 light sensors can be installed in the front and back, and 6 can be installed on the left and right. However, the car that was used for the experiment has darkly tinted rear and second row windows which significantly reduced the light intensity, and as a result signatures from the back view were hard to be observed. Moreover, the light sensor could not pick up the signal from the headlights when it is placed to face the direction that is perpendicular to the direction of travel. During the experiment, light sensor was placed in a certain angle to better observe the cars at a driver's blind spot. When the angle is adjusted so that the light sensor faced straight out of the window, it easily picked up the light signals from the streetlights and buildings, but failed to observe the headlights. This happened because the light sensor was mounted too high to receive the light signals from the low beam headlights. Lastly, the light sensor could not be placed to face the front. There is an option of manually holding the light sensor, but this may cause significant error because it is not fixed. For future experiment improvement, the dongle should be firmly placed on the outside surface of a car to overcome the limitations with the dongle placed inside the car.

Future goal of the project is to place 20 light sensors around the car to have a 360 view of a vehicles' surrounding environment. All the data, if possible, should be streamed simultaneously into a software program for risk analysis. LEDs or Sound systems can be integrated to the system to alert drivers when they make an unsafe driving decision. Due to high advantages signal processing speed and production cost, the system can become competitive to other existing technologies.

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