Traffic Congestion and Speed Assessment using Image Processing Technology Accessible via Internet through Smart Devices

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***Abstract* - Philippines is one of the countries that is known for its bad traffic conditions specially among urban cities such as in Metro Manila. As of today, existing application such as the "Waze" mobile app is providing information to driver and commuters of the traffic condition in a nearby area. In this study, the proponents designed a system that can compute for the actual speed and volume of vehicles in a specific area using the installed CCTVs in the streets. The components of this system are interconnected together via wire and are capable of sending updates over a website that can be viewed anywhere else in near real time manner.**

Keywords - Traffic, Internet-of-Things, Philippines

I. INTRODUCTION

The proposed device in this study lets its user know the traffic situation in a certain area/location. It uses quantitative data gathering through a device that measures the traffic count through image processing technique via the camera installed and movement speed of object that saatisfies to the size of a car to distinguish vehicles from humans and animals. The device is composed of a camera installed at a higher altitude that aim to capture the area of a street. It is set to detect vehicles only and reflect its count to interpret the congestion in an area. Moreover, another camera is used along the street that aims to determine the speed of a vehicle that pass through its vision. The information is then processed and integrated to determine the volume of vehicles in a certain area and how fast they are moving. This information is sent to the assigned domain that host the created website specific for the near real-time update of the installed devices.

As much as the government wanted to solve traffic, it will only be a pain in the neck to think of ways to end such problem. According to Transportation Sec. Arthur Tugade, "*The traffic situation in Metro Manila is now under a "state of chaos"* (Cepeda, 2016). This only mean traffic in the Philippines is uncontrollably disturbing and the Philippine government badly needed a backup to lessen the burden with regards to the problem of traffic. Philippine Senator Migz Subiri also spoked about the statistics of vehicle density in Metro Manila that is said to be 3,643 per square kilometer, and the volume of vehicles under stagnant traffic in ESDA is estimated at 520,000 per day in both directions, exceeding the capacity which should only be 280,000 per day in both directions (Romualdez, 2016) . The mere fact that traffic is getting worse, it is highly recommended to provide an advisory to avoid congestion or traffic in an area in order to supply an aid for this problem as well as to help the Philippine community.

Existing methods used by commuters to know/avoid traffic situation are through social media, news, and the mostly used GPS navigation app, Waze. Waze's method to know traffic situation is survey-based. The said application prompts a question to the user as the vehicle reduces speed, asking if there is heavy traffic in that certain area. The surveys are then being collected to serve as a record of the traffic situation which can be utilized by other users as guide/basis making it unreliable.

With the help of the proposed device in this study, people will be knowledgeable about the traffic situation in an area thus allows them to avoid choosing a route that will cause inconvenience to them which eliminates Waze's survey-based method.

A. Significance

This study will contribute greatly to the benefit of the society because traffic is a scourge of all motorists and commuters in the Philippines. Dismally, the traffic situation worsens, and it becomes ungovernable. The traffic situation in the Philippines especially in Metro Manila can be viewed in diverse pool of contexts: wasted time on longer travel, employee and student absences, squandered man-hour, and an ever-growing increase in fuel expenses.

It is not sufficing to know the current situation of traffic in the Philippines but rather be able to provide a solution. The study offers improvement of an existing knowledge such as Waze. Since Waze is a survey-based application which asks the commuters to fill up a survey to assess traffic situation in a certain area, it is not accurate.

This study will use the power of internet for the real-time accessing of the status of traffic in a specific location with minimal time discrepancy without having to be at the location itself, making it reliable and convenient. Furthermore, the proposed device in this study can optimize the use of CCTVs installed all over the country. In short, it will transform every CCTV to not just a monitoring and recording camera but also a smart camera that can assess speed and congestion of vehicles in respective areas at which the CCTVs are installed.

B. Limitations

Traffic in urban areas especially in Metro Manila, had already been evaluated and provided a solution to ease traffic congestion. In addition to the solution, this study proposed a provision of quantitative data. This mainly focuses in assessing the volume of traffic in an area through a camera installed at ahigher altitude, determining the speed allowance for vehicles in the area and then sending the data collected to the dedicated website wherein this data can be viewed remotely through a smartphone or any device connected to the internet.

Considering the factor that Manila is a congested area, Earnshaw near National University will be the target location for the evaluation of the device. It is observed that traffic situations in these areas are volatile and/or unpredictable, that makes it a good location for the pilot test.

The people who will benefit from this study are obviously the drivers as well as the commuters. The government agencies that will be involved in this study are Metro Manila Development Authority (MMDA), Land Transportation Office and Land Transportation Franchising & Regulatory Board under the Department of Transportation (DOT).

The validation will be limited by one location only and will be based on the targeted resource persons that will verify through interview wherein the level of assessment of a group of people in the area will be correlated to the assessment of the device. The qualitative data gathered from set of people will undergo statistical analysis.

The rerouting options will not be covered by this since that takes an algorithm to be accomplished beyond the limited time assigned for the completion of this study. However, the user will be guided properly by the assessment displayed by this system and can have their own evaluation on which route to take.

II. RESULTS AND DISCUSSION

A. Assessment of Congestion Level in the Location

The proponents of this study will be using a camera to capture videos of vehicles passing through the street. Ideally, it will be situated at a higher altitude to allow a better view of the whole targeted area just like what is shown in figure 1. Tthe camera can be as simple as the CCTV cameras connected to a microprocessor that will do the job of detecting vehicles regardless of its distance from the camera. Specifically, the camera will be able to detect presence of vehicle in the targeted area and count the present vehicles with respect to the covered area of the camera. The procedure on assessing the volume is described by the figure given below.

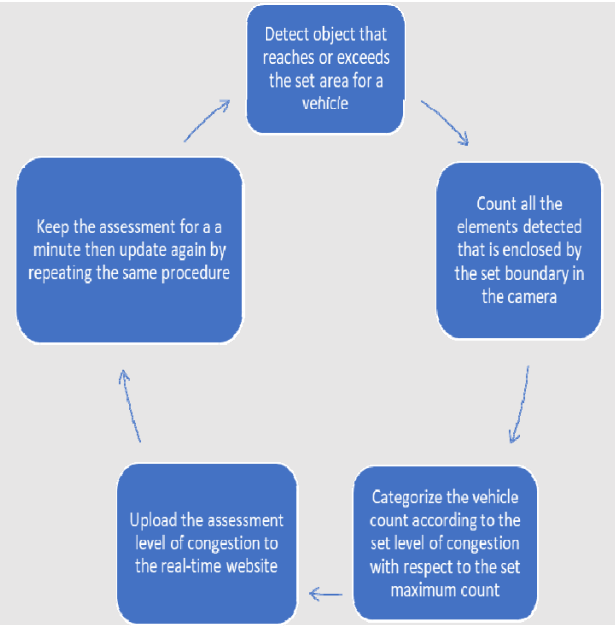

Figure 1. Procedure on Congestion Assessment

The object will only be considered vehicle if it exceeds the area assigned for vehicles. Any object with lesser area will be taken as other object such as human or animals. A set boundary will be pinpointed on the camera view. Every object enclosed by it, and with a size that of any vehicle will be counted. If there is no object that is the same size of a vehicle inside the set boundary, zero count will be stated just as shown in figure 2.

Figure 2. Boundary Perspective in Camera View (Vehicle Counter)

Initially, upon installation, a reference value for the maximum vehicle that the street can accommodate will be set in the codes of the microcontroller which reflect the maximum possible vehicles that can cover up the chosen street. Every detected vehicle per cycle will be counted and will be categorized with respect to the maximum possible vehicle that the street can accommodate. The proponents of this study will use the following range summarized in table 1.

TABLE 1. LEVEL OF CONGESTION VERSUS PERCENTAGE OF VEHICLES OVER THE MAXIMUM POSSIBLE

Level of Congestion	Percentage of vehicle count with respect to maximum possible vehicle can be accommodated	Color coding assignment
Low Congestion	30% below	Green
Moderate Congestion	50% below	Orange
High Congestion	Above 50%	Red

The assessment table was based on the perspective of random people surveyed. The participant in the survey was given different pictures of a street with cars in different percentage and was given the option to categorize the picture as whether it is showing low, moderate or high congestion.

The assessment result of the device will then be uploaded to the dedicated website. The current assessment will remain on the website and will update every minute. After a minute, the device will upload the current assessment of the congestion. This cycle will repeat infinite times. Since no server is dedicated for this device yet, the data on the website will be overwritten every day.

B. Assessment of the Flow rate in the location

Same camera will be used to calculate the speed allowance in an area. A set boundary will be the reference for the start and finish of the passing object. Once an object hit any of the red boundary of the region coming from the external region, time will be recorded. Time will again be recorded once another red boundary was hit coming from the inside of the bounded region. If in the event more than one objects enter and exit the region, the average of the speed will be calculated and displayed. Moreover, the speed will be calculated using the formula below.

TABLE 2. SURVEY ON CONGESTION LEVEL ASSESSMENT

% of street occupied	Low Congestion (weight = 1)	Moderate Congestion (weight = 2)	High Congestion (weight = 3)	Weighted Mean	Interpretation
0%	30	0	0	1.00	Low
10%	30	0	0	1.00	Low
20%	28	2	0	1.07	Low
30%	23	7	0	1.23	Low
40%	4	26	0	1.87	Moderate
50%	1	25	3	2.00	Moderate
60%	0	3	25	2.70	High
70%	0	1	27	2.77	High
80%	0	1	27	2.77	High
90%	0	0	28	2.80	High
100%	0	0	28	2.80	High

$$speed = \frac{\sqrt{(current\ y - previous\ y)^2 + (current\ x - previous\ x)^2}}{current\ time\ recorded - previous\ time\ recorded}$$

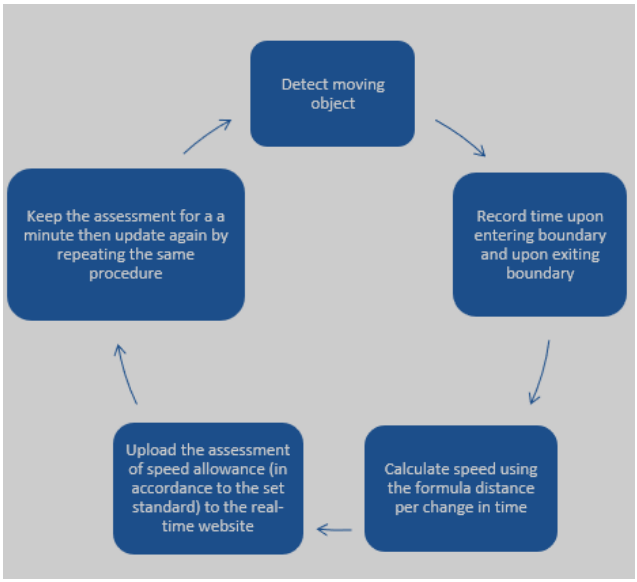

Figure 3. Procedure on Speed Assessment

Since most cars has a length of more than 3m, the set boundary is 3m away from each other. This is to ensure that one car will hit both boundaries before another car will hit the first boundary. Also, 3m is just enough distnace to be able to measure time elapse with significant difference in time upto one-thousandth of a second. Shown below in figure 4 is the sample perspective of camera when detecting speed of a vehicle.

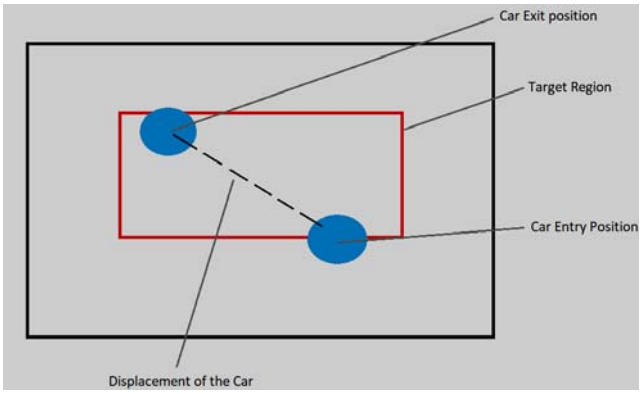

Figure 4. Methodology for Speed Allowance Assessment

Moreover, same as with the level of congestion, the speed of the vehicles is categorized as fast, moderate and slow. The proponents of this study use the following criteria in categorizing vehicles as to whether fast, moderate or slow moving, which is the same standard used by Waze mobile application.

TABLE 3. SPEED CATEGORIZATION OF VEHICLES

Speed of Vehicles	Categorization	Color Coding
20 KPH below	Slow	Red
50 KPH below	Moderate	Orange
Above 50 KPH	Fast	Green

C. Transmission of Devices Assessments to the Internet-Based Website

By utilizing the availability of internet connection everywhere in the country specially in Metro Manila, the proposed device in this study will be sending updates to a dedicated website every minute to give a near real-time updates to people from different locations. The procedure in the transmission of the device updates is summarized by the given figure below.

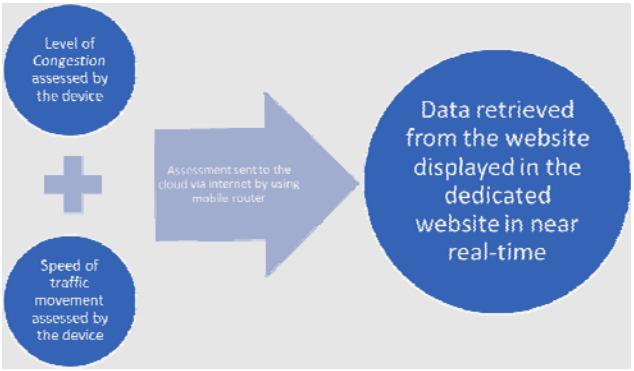

Figure 5. Assessment of the device uploaded to the cloud via internet

The idea is that the categorization of the assessment made by the device will be reflected in the dedicated website from time to time. Any devices with capability to connect to the internet and reach the website can check the updated status of an area with respect to its traffic congestion and flow rate. Shown in figure 6 is the cluster configuration of the data transmission from the assessment device to the monitoring device which in this context referred to the smart phones and computers.

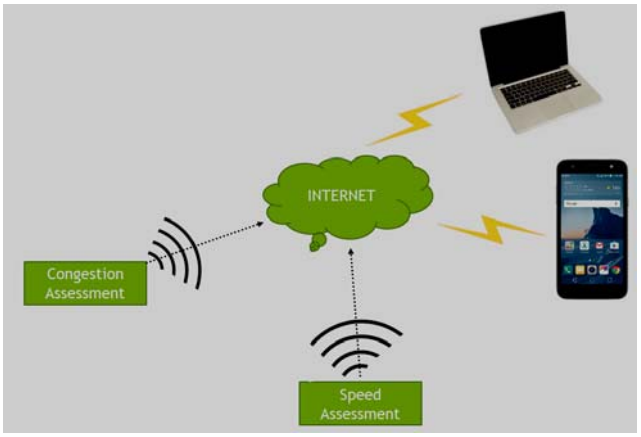

Figure 6. Cluster Configuration of data transmission

The configuration used by the user is described by the given figure above which shows that every segment of the device has its own channel to connect to the internet and are sending data to the cloud individually.

D. System Evaluation

The evaluation of the proposed system was divided into two sections. In the first section, the 18 random observers were divided into 6 groups. Every group was assigned to quantitatively assess the level of congestion (whether high, moderate or low) and the flow rate (whether fast, moderate or slow) at different schedules.

Prior to the installation of the device, a separate study of the tendency of traffic in the chosen street was conducted and summarized below are the findings.

TABLE 4. TRAFFIC CONGESTION TENDENCY IN CHOSEN LOCATION

	Morning	Afternoon	Evening
22-Jan	M	L	M
23-Jan	M	M	H
24-Jan	M	L	H
25-Jan	H	M	M
26-Jan	H	M	H
27-Jan	L	M	M
28-Jan	M	M	L
Weighted Mean	2.14	1.71	2.29
Mode	M	M	M

Assuming that for the traffic congestion, high congestion is denoted as H with a weight of 3, moderate congestion is denoted as M with a weight of 2 and low congestion is denoted as L with a weight of 1. Looking at the findings, it most probable to get a moderate congestion level in the morning, low congestion in the afternoon and high congestion in the evening.

TABLE 5. TRAFFIC FLOW RATE TENDENCY IN THE CHOSEN LOCATION

	Morning	Afternoon	Evening
22-Jan	M	F	M
23-Jan	F	M	S
24-Jan	F	F	S
25-Jan	M	F	S
26-Jan	M	M	S
27-Jan	F	F	M
28-Jan	M	S	F
Weighted Mean	1.57	1.57	2.43
Mode	M	F	S

Assuming that for the traffic flow rate, fast speed is denoted as F with a weight of 1, moderate speed is denoted as M with a weight of 2 and slow speed is denoted as S with a weight of 3. Looking at the findings, it most probable to get a moderate flow rate in the morning, fast flow rate in the afternoon and slow flow rate in the evening.

After applying the result of the prior study regarding the tendency of congestion and flow rate per time of the day, the proponents of this study conducted the test within the 3rd week of February. Shown in table 6 is the correlation result between the system's assessment and the observers' assessment using the Pearson's r correlation coefficient.

TABLE 6. CORRELATION BETWEEN OBSERVER AND SYSTEM'S ASSESSMENT

Correlation coefficient	Interpretation	Remarks
0.8333	Direct Relationship	Highly Correlated

TABLE 7. CORRELATION BETWEEN WAZE AND SYSTEM'S ASSESSMENT

Correlation coefficient	Interpretation	Remarks
0.9211	Direct Relationship	Highly Correlated

Summarized in the table above, it is clear to see that the proposed system in this study accurately assess the congestion level and flow rate of vehicles in the said location.

III. CONCLUSION

The main goal of this study is to provide a system that can assess the congestion level and flow rate of vehicles in an area and send it to a dedicated website via internet. As part of achieving this, the qualitative assessment of random observer was used as a reference of the device's accuracy. Summarized below are the conclusions formed from the study.

First, the proponents find it more efficient to transform every CCTVs to a smart CCTVs. So instead of just monitoring events 24/7, through this study, every CCTV will be having additional capability which is significant in informing people on the current condition of traffic from everywhere in Manila. Given the additional beneficial feature, not much additional cost is needed.

Second, the proponents were able to appreciate the power of image processing and concluded that this technique will be very helpful in so many more other applications such as biomedical, artificial intelligence, etc. In this study, the readers will be given ideas that they can possibly use in other applications.

Moreover, considering the system's accuracy in categorization of congestion and flow rate in an area, it is evident that high end camera is not necessary though recommended in this type of applications. In addition to this, the internet connection will be one of the major limitation of this system since the absence of internet connection will make the whole system non-functional.

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