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Online Traffic Density Estimation and Vehicle Classification Management System

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Abstract

This paper shows the design of an online web based traffic management system that presents the traffic density of heavy and light weight vehicles. The methodology used in this system performs object segmentation using edge detection to identify the object in video frames. Moreover, the robust object identification using feature extraction will identify the object in bad conditions i.e. night vision, shadow in daylight and occlusions occurring due to absence of gap present between two objects. The Blob analysis is the part of implementation to identify the type of vehicle (light and heavy) along with calculating the speed of vehicle. Further we are counting number of objects passed using Motion History Images (MHI) which generates the history of each object and assigns label to each object. This paper addresses the issue that there are various paths to same destination in which some of them are densely populated and others are vacant which are unknown to the travelers. Our online system traces the estimated density of heavy and light weighted vehicles of different locations at different times which will certainly help user to decide the suitable path to respective destination. Moreover, User can estimate time that it will take to reach the destination from particular path.

Keywords: Background Elimination, Blob Analysis, Edge Detection, Feature Extraction, Morphological Operations, Motion History Images, Object Segmentation, Thresholding

1. Introduction

Increase in traffic is one of the major concerns for the city development (Figure 1).

Video cameras are a relatively inexpensive surveillance tool. Manually reviewing the large amount of data and extracting useful information such as traffic density and vehicle types is often impractical from the camera systems

Figure 1. Traffic congestion.

due to the high number of cameras in use. Development of adaptive and intelligent systems that extract traffic density and vehicle classification information from traffic surveillance systems is crucial and indispensible in traffic management. It is important to present the knowledge of the traffic density of the roads in real time to the residents especially in mega cities for effective traffic management. Time estimation of reaching from one location to another and recommendation of different route alternatives using recently calculated traffic density information are very valuable for mega city residents. In addition, the system estimates the density of vehicles in accordance to vehicle type (heavy and light weight) as this classification is also significant for traffic control centers. For example, the effects of prohibiting big vehicles from a road can be analyzed using vehicle classification information in a simulation program. This paper presents the design of web

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based management system that automatically generates traffic density estimation for specific interval of time and vehicle classification method for traffic surveillance system.

Our contribution:

- We have given the algorithm for processing video, background elimination, object identification, calculating centroid and area of objects.
- We are defining the motion history image for counting the number of object along with its generated history.
- Since our main emphasis is on web based application. We have given the system architecture which is defining the online working of our paper.

2. Related Background

There are various reasons for research in the field of traffic surveillance such as losses in human lives and finance caused by vehicle accident is mainly due to lack of effective traffic management system, the availability of feasible technologies accumulated within last 50 years of computer vision and the Exponential processor speed have paved the way for running computation –intensive video processing algorithm even on a low –end PC in Real Time. In past few years, many traffic controls major have been come into play to optimize the solution to control the traffic. Various paper are published to reduce the number of frames by means of vehicle detection by eliminating the frames which do not have any object[1]. Different approaches using information about symmetry, colour, shadow, geometrical features, texture, and vehicle lights, an example-based algorithm for moving vehicle detection for adaptive background estimation[2]. Also, Implementation based on Robust Background Estimation using outdoor Mixture of Gaussians (MoG) and the Group Based Histogram (GBH) techniques has been done[3]. Various works has been done and proposed to identify objects from a video frame even in outdoor complex conditions like night vision, daylight shadow and fog etc using segmentation[4]. The work has been done to detect the edge using vertical edge detection (sobel)[5]. Multiple observations due to the fact that the blob centres of the same object in two different cameras correspond to close but different 3-D points. In order to group together all the observations that correspond to the same target, techniques are proposed, the grid-based technique and the Foreground map fusion[6]. Papers are also published using methods called combination of saturation and values or CVS for Foreground extraction and vehicle detection[7]. Robust object Identification using the Model Based tracking, Active contour based tracking and best work on Feature Extraction[3]. Various research and implementation has been done for counting the number of objects in a video[4,6,9,10]. Speed Detection is done by using the different position of object in continuous frames[1,2,5]. Traffic flow prediction using time delay based neural network and vehicle type identification[11]. Various researches have been done on occlusion using Line-based Shadow Elimination and vehicle tracking by Kalman Filter[12,13]. Research has been done for detecting lane center by analyzing vehicle histogram and lane dividing detection[8,12]. Papers are published on a prototyping development of the smart camera i.e. a scalable architecture comprised of a CMOS sensor, digital signal processor, and a network processor[5,14]. Papers are published on real time video surveillance for traffic monitoring using virtual line analysis[15]. Papers are published of using Full Search (FS) block matching algorithm for the detection motion of interest and suppress the false motion using adaptive thresholding technique[16]. These works are done for optimizing various processing in traffic surveillance but there is no such system developed that will generate the information about the traffic to the residents at regular interval of time. This paper proposes an approach for density estimation technique using motion history image and designing a web based system for providing the traffic density information of each location for the residents.

3. System Overview

The objective of the research is to identify the vehicles in accordance to the type of vehicles from the video frames of different location; count the number of vehicles which results in density estimation of the traffic at regular interval of time.

This is achieved through the sequence of steps performed on the video captured by the mounted camera. These steps which are performed by the vehicle classification and density estimation engine (see Figure 3) are depicted by the Figure 2.

The modelling of the present paper is presented in Figure 2. Initially, a video clip is read and divided into a number of frames. Next phase is the post processing phase where interference of noise is being minimised. Then, the frame consisting of only dynamic objects is obtained which is then converted into a binary image; this is achieved using morphological processing techniques (dilation), which is applied to the binary image to group the different segments of a single object into one logical object. Structuring elements for dilation are chosen based on the video sequences. Now, by using these frames as inputs, the background will be dynamically eliminated from each frame. The next phase is object identification from the foreground dynamic objects, which is obtained by performing edge detection and thresholding. Edges of objects are identified by using connected components logic in which binary image is a set of pixels that form a connected group. Next phase will justify the vehicle type and the speed of object by performing the blob analysis which computes the statistics for the labeled region in a binary region. Further, a counting algorithm is applied to the resulting image to assist in counting the number of objects according to its type. Thereafter, the estimation of density will be done on the basis of number of object passed per interval of time. The speed of the object calculated before will help in generating alarm if the speed of object of the very high in the very high density area.

3.1 Passive Sensors

Optical Sensors such as cameras are usually referred to as a passive sensor. Our work is based on Image Processing which will perform it process on the video. We are using a camera mounted on area having heavy traffic congestion. The camera present in that region will work as a sensor which will capture the video for interval of time and storing the relevant required data into the database.

Optical Sensor will capture a video to which it will first break into certain number of frames so that it can analyze its processing o individual image of the video.

I="Read Video";
[Σ (F [I]) =Pr (I)] (1)

Given equation-(1) is taking video as the input in a I, after that the Pr (I) is processing the video and breaking the video into the frames and storing the each frames into an array. After that the sensor performs its processing on grayscale image, so sensor converts each frame into grayscale which takes very less space and provide the more efficient output.

$$[\Sigma G(x, y) = (T\ (\Sigma\ (F(x, y)))] \quad (2)$$

Given equation-(2) will perform the spatial domain function for Image Enhancement. Where F(x, y) is the input frames. G(x, y) is the processed image. T is the operation performed on the set of input image. The operator 'T' is applied at each location (x, y) to yield the output G at the location. The simplest form of T is when the neighborhood is of size |x| (that is a single pixel). In case, G depends only on the value of F at (x, y) and T become a gray level.

3.2 Morphological Operation

Morphology is a broad set of image processing operations that process images based on shapes. Morphological operations apply a structuring element to an input image, creating an output image of the size. In Morphological operation, the value of each pixel in the output image is based on a comparison of the corresponding pixel in the input image with its neighbors.

3.3 Operations

Erosion and Dilation.

3.4 Dilation

Pixels beyond the image border are assigned the minimum value afforded by the data type. The Binary dilation of A by B, denoted by $A \oplus B$, is defined as the set operation

$$A \oplus B = \{z \in E \mid (B^s)_N \cap A \neq \varnothing\}$$

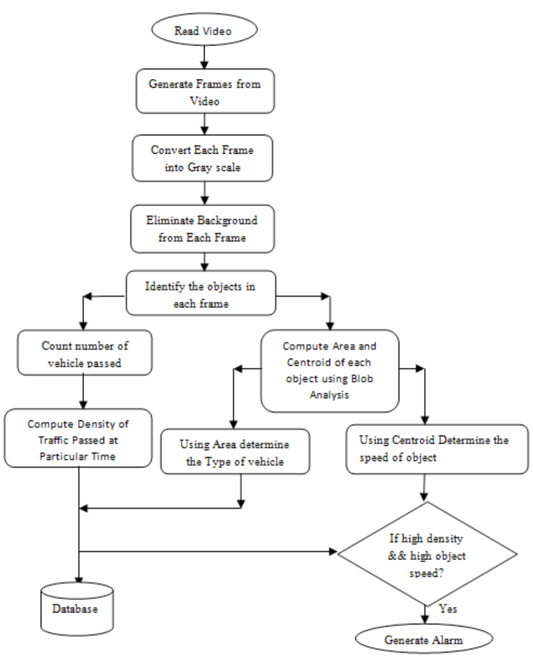

Figure 2. Flow diagram of Density estimation and Vehicle Classification system.

where, A-input image, B-structured element, z-set of all pixels, (B) set of all pixels in B.

3.5 Erosion

Pixels beyond the image border are assigned the maximum value afforded by the data type.

The Binary Erosion of A by B, denoted by AΘB, is defined as the set operation.

$$A\Theta B = \{z \in E \mid B_N \subseteq A\}$$

3.6 Background Elimination

Background elimination method uses concept of least square to compare the accuracies of current algorithm with already existing algorithm. By using the concept of background elimination the background present in each will be eliminated so that only the area of interest region should be present in the frame. The problem occurs in the background elimination is due to continuously change in background i.e. dynamic background because of bad weather condition, sun rays causing shadow of each object. To resolve this problem we are using dynamic background elimination.

$$[O(x, y) = \sum(G(x, y) - BG(x, y))] \tag{3}$$

Given equation-(3) is the difference between the two images G(x, y) (Input image) and BG(x, y) (background image), the result O(x, y) is obtained by computing difference between all pairs of corresponding pixels from G and BG.

3.6.1 Strategies to Object Identification

There are many strategies to trace the object but in non-ideal condition and bad weather it became difficult to track and identify the objects. Objects can be identified using certain methodology.

3.7 Edge Detection

Edge detection is by far the most common approach for detecting meaningful discontinuities in gray level. An edge is a set of connected pixels that lay on the boundary two regions. An edge is a local concept whereas a region boundary, owing to the way it is defined is a move global idea. Intuitively, an ideal edge has the properties of the model.

An ideal edge (Figure 3) according to this model is a set of connected pixels (in the vertical direction here). In practice, optics, sampling, and other image acquisition imperfections yields edge that are blurred with the degree of blurring determined by factors such as the quality of the image acquisition system.

In Figure 4, the slope of the ramp is proportional to degree of blurring in the edge. The most common way to look for the discontinuity is to run a mask through the image. The response of the image is given by equation – (4).

$$R = W_1Z_1 + W_2Z_2 + W_3Z3 + \dots\dots\dots + W_nZ_n \tag{4}$$
$$= \sum(W_iZ_i)$$

where, Z_i is the gray level of the pixel associated with mask coefficient $W_{i.}$

Thresholding Decision:

$$T=T\ [(x, y), (P(x, y), O(x, y)] \tag{5}$$

where, T is the thresholding perform on the image, O(x, y) is the gray level at the point (x, y) and P(x, y) denotes some local property of the point (such as the average gray level of the neighborhood centroid on (x, y)).

A threshold image is defined as:

$$G(x, y) = 1 \text{ if } O(x, y) > T \text{ or,}$$
$$G(x, y) = 0 \text{ if } O(x, y) <= T.$$

The pixel labeled 1, say corresponds to object and pixels labeled 0 say correspond to the background.

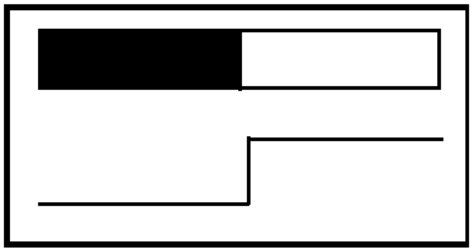

Figure 3. Model of an Ideal Digital Edge.

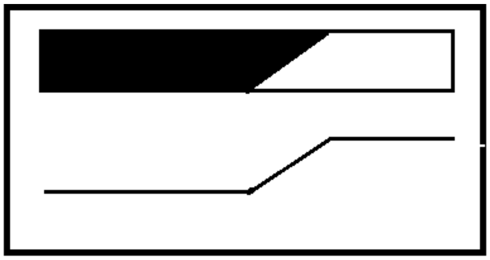

Figure 4. Model of a Ramp Edge.

The problem occurring in the Edge detection using connected component is if two or more object comes parallel then due to occlusion between those object both will assumed as a single object. This will not work in very heavy traffic.

3.7.1 Shape Based Identification

In shape based approach the detection region will be aligned in each frame, when any new object will pass through that detection region the shape i.e. contour will be inserted to that object(also called contour based tracking) so that each object will treat as an individual object.

Above Figure 5 black horizontal lines show the detection area, Red boxes are the shape assigned to each object.

But this approach is not that much effective because in case if the two object reach at the detection region parallel then due to occlusion occurring at detection region they will be treated as one object and they will be inserted into one rectangle shape.

3.8 Feature Extraction

This approach can be used in the area of image processing which is used to detect and isolate various desired portions or shapes of digitized images or video. This alternative is the best approach, instead of detecting and tracking whole object, extract only the sub feature from the object as a point, portion or line on the object. This approach resolves many non-ideal condition problems occurring in object identification, by extracting two points on the object. This will work as if the distance between those two points are same in continuous frame then they are on same object and if distance between those two points will change in next frames then those points are on different object (Figure 6).

This approach will resolve the night vision by using the light of the vehicle as a feature from object. This method will also solve the problem of shadow of day light.

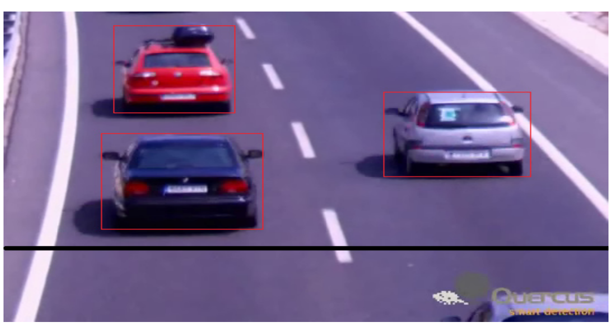

Figure 5. Contour based tracking.

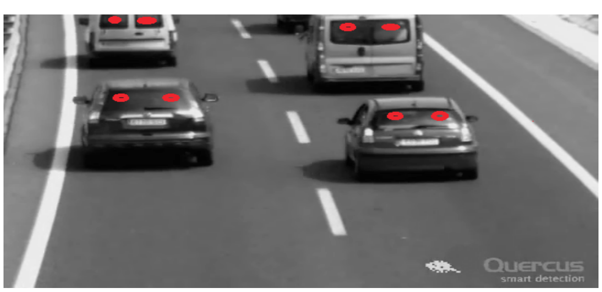

Figure 6. Representing Extraction of point on objects.

3.9 Vehicle Classification

To detect the type of vehicle passed, the blob analysis is used to calculate the area of each object which helps in distinguishing whether the passed object is heavy vehicle or light vehicle. Using Blob analysis, the centroid of the objects will be determined which is used in calculating speed of object. A blob is defined as a region of connected pixels. Blob analysis is the identification and study of these regions in an image. The typical applications that use blob analysis are the area and centroid calculation of the detected objects. The performance of a blob analysis operation depends on a successful segmentation of the image that is, separating the required blobs from the background and each other as well as eliminating everything else in the image that is not of interest. The calculated area of the objects is generating the stats which define the area for the heavy vehicle and light vehicles.

3.10 Counting Object

To count number of object passed, we are using Motion History Image methodology which generates history of an object by observing it over a given period of time. The motion history image contains numerous regions captured at different time intervals. In one method, the most recent region(s) are located and adjacent older regions are labeled with a unique identifier to perform a down fill operation. Each down fill operation can identify a single motion contained in the motion history image. If a down filled region of the motion history image contains more than one movement, separate up fill operations can be performed to help separate the movements. Each up fill operation begins at a set of oldest or lowest value regions and progresses toward the most recent region. The down fill and up fill operations can be combined to provide an image mask(s) to separate the multiple motions from the motion history image. By assigning the unique identifier we will count each object. By the help of number of object passed at particular interval of time we are generating the density at that particular time.

4. System Architecture

To implement "Online density estimation and vehicle classification Management System" several databases are required. The *Video databases* are implemented for storing the video captured from the mounted camera sensor at various locations for regular interval of time. The video databases are actually distributed systems at all the specified areas over the city. The business logic of our system is implemented in sequence of steps described in system overview and this processing is done by the *vehicle classification engine* and *density estimation engine* as shown in the Figure 7. The centralized *Information database* stores the outcome of engine in form of density of both vehicle type pertaining to the specific city and location. The business logic implemented updates the results automatically after executing the input video in the information database.

User drives the web based management system via web server and selects the city and location in order to view the information (density per hour). Administrator will have access to all the databases for monitoring of resources and authentication of results.

5. Proposed Algorithms

Pseudo code is presented to show the implementation part of the research, we have given four algorithm we shows the different implemented part of the research. Algorithms are arranged in the same manner as the steps are given in flow diagram (Figure 2).

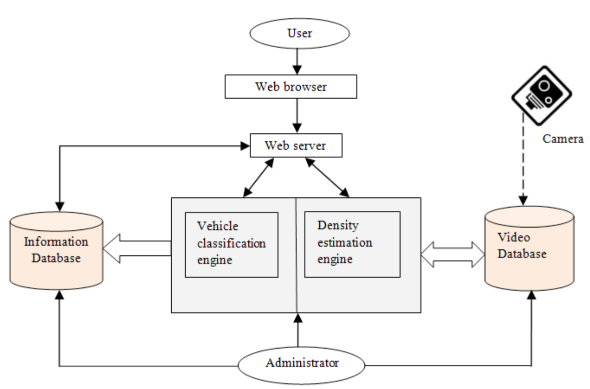

Figure 7. System Architecture.

1. First Algorithm is the pseudo code for the density estimation and vehicle classification, this code shows all the steps of the work done in the paper. This code is showing the calculation of the area of object and centroid of that object. This code is also tells the calculation of the density of object.

Density estimation and vehicle classification ( )

Step1: Process the Video to convert into frame and change into gray scale.
Step2: Performing Morphological Operation for enhancement of image.
Step3: Background Elimination.
Step4: Edge Detection using sobel.
Step5: Object Identification using 8 connected component.
Step6: Calculating Area and Centroid using Blob analysis.
Step7: Vehicle Classification is done using area.
Step8: Counting of heavy and light weighted vehicles separately using motion history image.
Step9: Calculation of density of vehicles. Density_heavyweight = Count_of_heavyweight/hour; Density_lightweight = Count_of_lightweight/hour;
Step10: Store the output information in Result database.

2. Second algorithm is the first module of the research which is processing the video and generating the frames, each frame is stored in Output folder with initialized name i.e. '0.2%d.jpg'. After that each frame is converted into grayscale image.

Process video ( )

1: *Read Video: filename='videoName.avi'.*
2: *for I=1 to number of frames.*
3: *Name all the frames of the captured video name = sprintf ('%0.2d.jpg', image).*
4: *Create a folder and file for storing frames out = fullfile (foldername, name).*
5: *Frames stored in video database imwrite (this frame, out_image,'jpg').*
6: *Initialize m, n and array image {}.*
7: *for j = m: n*
8: *Convert the frame into gray scale format*

3. Third algorithm is performing the background elimination from each frame by using the dynamic background image, the background elimination involves the variable called tolerance whose varying value from 10–100 will help in detecting small and large object

Background Elimination ( )

```
Input Bg_image
Input Input_image
Initialize tolerance=?
Calculate the size of Bg_image
for 1: col
    for 1 to row
      im=Input_image (col, row)
       bg =Bg_image (col, row)
        if ((bg == im) || (bg > im && bg <= im + tolerance) || (bg < im && bg >= im -tolerance))
            out (ch, cw) = 0;
        else
            out (ch, cw) = 1;
```

4. Fourth algorithm is identifying the object by tracking the connected components, we are using the 8 connectivity of neighbor pixels so that the masking used to track the similar components will work on the left, right, up, down and diagonal neighbors of the pixels.

Object Identification ( )

```
output=graythresh (input_image).
bw=im2bw (input_image, output).
bw=bwareaopen (bw, 700)
cc=bwconncomp (bw, 8)
Create a label matrix from connected component Structure.
Define the RGB color of element.
```

We have implemented the algorithms on sample videos and the output figures are shown in Figure 8 sequentially.

6. Result

Implementation Software: For the implementation purpose of this research we have worked on the MATLAB, Matlab having Image Processing Toolbox™ provides a comprehensive set of reference-standard algorithms, functions, and apps for image processing, analysis, visualization, and algorithm development. Many toolbox functions are multithreaded to take advantage of multicore and multiprocessor computers.

Implemented Statistics: On the basis of the vehicle type estimation (Light and heavy vehicle) Density of the particular area is calculated. We are presenting the Table 1, showing the number of heavy vehicle and light vehicle detected during the different interval of time, and on the basis of the data in a table the chart is shown which is representing the number of heavy vehicle and light vehicle passed per interval of time.

We have presented the two graphs (chart 1, chart 2) the chart: 1 is showing the graph for number of light vehicle passed per interval of time, this chart is showing the histogram of passing light vehicle in respect to time, with the increase in time the light vehicle increases. The chart: 2 is showing the number of heavy vehicle passed per interval of time, this chart is showing the histogram of heavy vehicle passing through that monitoring region.

7. Conclusion and Future Works

The anticipated product "Online density estimation and vehicle classification Management System" is a flexible

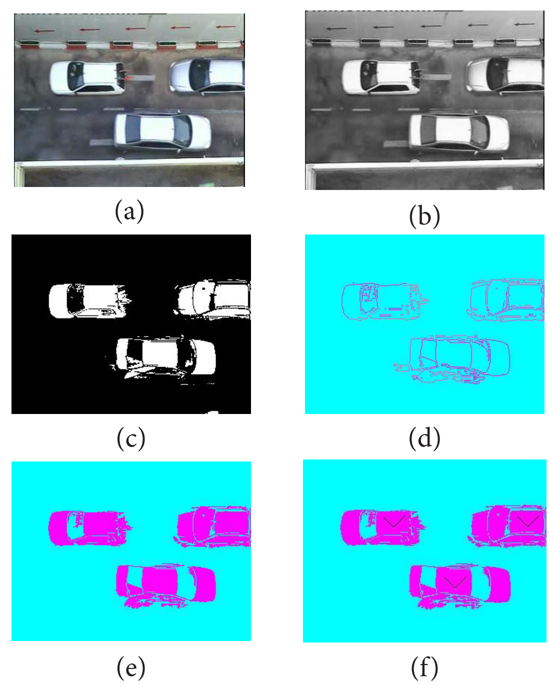

Figure 8. Detection of object from Frame #3468 (a) Shows original frame. (b) Grayscale conversion of frame. (c) Background elimination (d) Edge detection of object in a frame. (e) Vehicle identified in frame (f) Arrow showing the Centroid of the identified vehicle.

Table 1. The number of heavy vehicle and light vehicle passed per interval of time

Time Interval (min)	No. of heavy vehicle passed	No. of light vehicle passed	Total no. of object	Density Estimation (vehicles/hour)
5	1	5	6	72
10	3	12	15	92.036
15	3	15	18	72
20	4	22	26	86.66

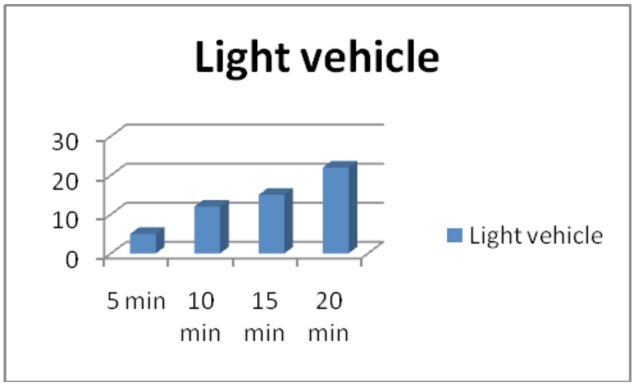

Chart 1. The number of light vehicle passed per interval of time.

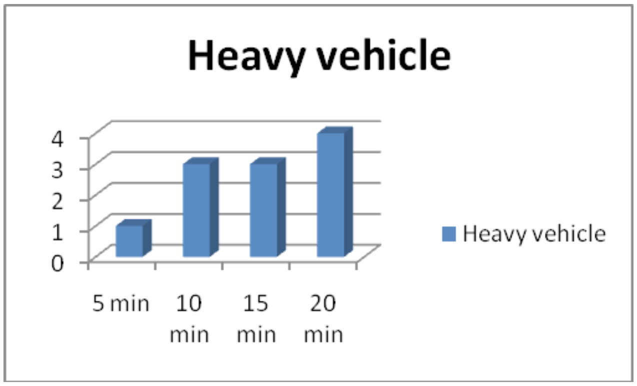

Chart 2. The number of heavy vehicle passed per interval of time.

and intelligent web based system. The complete conceptual design and sample implementation on videos has been provided.

Online traffic management system shows the density of traffic at particular location for particular interval of time. The application shows the traffic free path to reach to their destination. Web based traffic management will help public to travel easily and suitably to their destination by viewing the website. This web application will also deliver the number of heavy and light vehicle passed through the particular area. If in case there is no other path for user to reach their destination instead of going through the traffic prone area, at least user will get the prior assumption about the time before they should leave to reach their destination. While this application is still a work in progress, it is believed that the success of this project will provide a great aid for the residents of place as well as the local administration in providing easy information and effectively managing the traffic respectively. The future goal is to scale this flexible system to various densely populated cities and towns which connects them and manages the traffic density information.

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