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Comparative Study Of Traffic Flow Models And Data Retrieval Methods From Video Graphs

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Abstract
Traffic engineering pertains to the analysis of the behavior of traffic and to design the facilities for the smooth, safe and economical operation of traffic. Understanding traffic behavior requires a thorough knowledge of traffic stream parameters and their mutual relationships. To figure out the exact relationship between the traffic parameters, a great deal of research has been done over the past several decades. The results of these researches yielded many mathematical models named Traffic flow models. They are basically microscopic models, Mesoscopic models and macroscopic models. Macroscopic modeling studies traffic flow from a global perspective. This models deal with macroscopic parameters such as speed, flow and density. Microscopic model gives attention to the details of traffic flow and the interactions taking place within it.ie microscopic details related to individual vehicle characteristics such as headways, individual vehicle speeds and acceleration of vehicles etc. Video recordings appear as a more detailed, more complete and more accurate observational technique. They are more reliable since they allow data analysis independent of the person who collected the data. This technique is widely used in transportation engineering, traffic and planning. Many attempts are done earlier for data retrieval from videos.

Key words: Data Retrieval Techniques, Macroscopic Model, Microscopic Model, Video Graphic Data Collection.

I. Introduction

Traffic stream is non-uniform in nature. It is influenced not only by the individual characteristics of both vehicle and human but also by the way a group of such units interacts with each other. Thus a flow of traffic through a street of defined characteristics will vary both by location and time corresponding to the changes in the human behavior. The traffic engineer, but for the purpose of planning and design, assumes that these changes are within certain ranges which can be predicted.The traffic stream itself is having some parameters on which the characteristics can be predicted. The parameters can be mainly classified as: measurements of quantity, which includes density and flow of traffic and measurements of quality which includes speed.

The traffic stream parameters can be macroscopic which characterizes the traffic as a whole or microscopic which studies the behavior of individual vehicle in the stream with respect to each other. As far as the macroscopic characteristics are concerned, they can be grouped as measurement of quantity or quality as described above, i.e. Flow, density, and speed. They are known as fundamental stream characteristics. While the microscopic characteristics include the measures of separation, i.e. the headway or separation between vehicles which can be either time or space headway.

Longitudinal spacing of vehicles are of particular importance from the points of view of safety, capacity and level of service. The longitudinal space occupied by a vehicle depend on the physical dimensions of the vehicles as well as the gaps between vehicles. For measuring this longitudinal space, two microscopic measures are used- distance headway and distance gap. Distance headway is defined as the distance from a selected point (usually front bumper) on the lead vehicle to the corresponding point on the following vehicles. Hence, it includes the length of the lead vehicle and the gap length between the lead and the following vehicles. To figure out the exact relationship between the traffic parameters, a great deal of research has been done over the past several decades which many mathematical models.it include both macroscopic models and microscopic models. Some important models among them will be discussed in this paper.

Very early on, the advantages of video as an observational technique proved to be quite obvious compared to observations made by the naked human eye, video recordings appear more detailed, more complete and more accurate. In a technical sense, they are more reliable since they allow data analysis independent of the person who collected the data. Video now is widely used in transportation engineering, traffic and planning. Many attempts are done but very few discussions are done regarding data retrieval from video. So this paper also discuss about the different methods and techniques adopted by researchers for data retrieval from collected videos in transportation point of view. i. e., macroscopic and microscopic traffic data retrieval from video.

II. Traffic Flow Model

2.1. Macroscopic models

Several macroscopic models have been investigated in this. Some of the popular steady state speed-density functional forms include Greenshield's model, Greenberg's model, underwood model, drake model, modified green shield model, pipe's generalized model, underwood model with Taylor series expansion, drake model with Taylor series expansion. These models speed-density relationships are also shown

2.1.1. Single regime model

Single regime models are the models based on assumption that same speed-density relation valid for entire range of densities seen in traffic streams.

- *Green shield's model (1935)*

Macroscopic stream models represent how the behavior of one parameter of traffic flow changes with respect to another. Most important among them is the relation between speed and density. The first and most simple relation between them is proposed by green shield. This is the general model of uninterrupted traffic flow that predict and explain the trends observed in real traffic flow.In this he assumed speed – density are linearly related and proposed the following linear speed-density relationship.

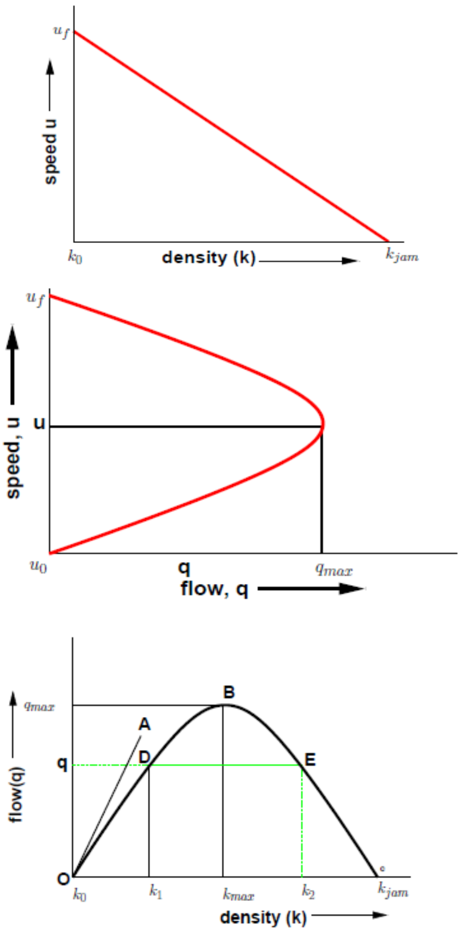

Fig.1.fundemental traffic flow diagram

$$v = v_f - \frac{v_f}{k_j} * k$$

$$q = k * v$$

$$k_0 = \frac{k_j}{2}$$

$$v_0 = \frac{v_f}{2}$$

$$q_{max} = v_f \frac{k_j}{4}$$

Where,

v_f - Free flow speed.

k_j - jam density.

K - Field density.

k_0 - Optimum density

v_0 - Optimum speed

q_{max} - Maximum flow

The parameters to be calibrated in this model are free speed and jam density.

In field we can hardly find the linear relationship between speed and density as assumed by green shield. So validity of that model was questioned and many other models came up. Prominent among them are discussed below.

- *Greenberg's logarithmic model (1959)*

Greenberg used a fluid-flow analogy concept and proposed a logarithmic speed-density relationship.

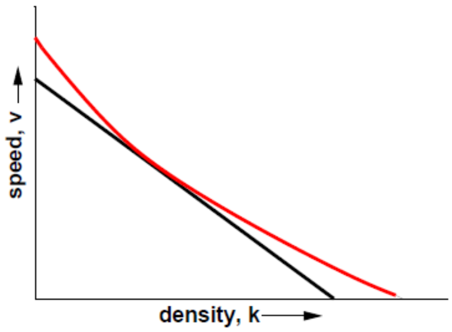

Fig.2. speed density relationship by Greenberg

$$v = v_0 * \mathrm{Ln} \frac{k_j}{k}$$

Where, v_f - free speed,

k_j- jam density

The parameters to be calibrated in this model are free speed and jam density.

This model has gained good popularity. Because this model can be derived analytically. Also model shows better goodness of fit as compared to green shield's model. The main criticism of this model is its inability to predict speed at lower densities. Because as density approaches zero, speed tends to increase to infinity. Another drawback is it violates boundary conditions. Zero density can only be attained at an infinitely high speed.

- *Underwood exponential model (1961)*

Underwood proposed an exponential speed-density relationship and derived an exponential model that attempted to overcome the limitation of the Greenberg model.

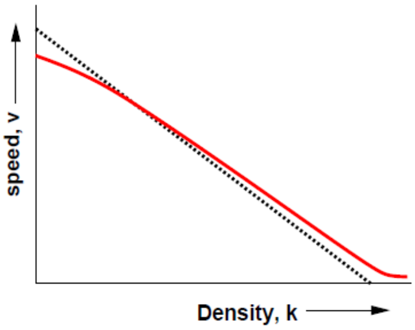

Fig.3.speed density relationship by underwood

$$v = v_f * e^{(-k/k_{cri})}$$

Where, vf is free speed, kcri is critical density.

The parameters to be calibrated are free speed and critical density Underwood model tends to underestimate speed free-flow phase but overestimate in congested portion. The main drawback of the model is speed becomes zero only when density reaches infinity .hence this cannot be used for predicting speeds at high densities. Model shows a better fit than Greenshield and Greenberg Models for uncongested condition. But it does not present a good fit to the congested condition.

- *Pipe's generalized model*

Introduced a new parameter n and provide a more generalized modeling approach. Pipes proposed the model shown by the following equation.

$$v = v_f[1 - \left(\frac{k}{k_j}\right)^n]$$

When "n" is set to one, pipe's model resembles green shield's model. Thus by varying the value of "n", a family of models can be developed.
"n" is set to two will give polynomial and quadratic models

- *Drake model/ bell-shaped curve model (1967)*

This model works in a manner opposite to the underwood model.

$$v = v_f * e^{[-1/2(k/k_{cri})2]}$$

It tends to overestimate speed in the free flow region while underestimating speed in the congested region. Drake estimate density from speed and flow data, fitted speed versus density functions and transformed to a speed flow functions.it showing best fit than Green Shield ,Greenberg And Under Wood models for uncongested, but not a good fit for congested condition.

- *Modified Greenberg model (2008)*

Ardekani and Ghandehari developed this model by considering "even under very light traffic conditions there are always some vehicles on the freeway ".this model introduces a non-zero average minimum density k_0 in the green berg model.

$$q = kv_c \text{ Ln} \frac{k_j + k_0}{k + k_0}$$

Where
k_0 – Average minimum density
v_c – Speed at capacity
When density approaches to zero, the modified version yields a finite free flow speed of

$$v_f = v_c \text{ Ln}(1 + \frac{k_j}{k_0})$$

Also density at capacity $k_c = 0.4\, k_j$ .which is close to greenberg's model ($k_c = 0.368\, k_j$)

- *Underwood model with Taylor series expansion*

Underwood's model doesn't yield a solution for jam density when speed approaches zero. But exponential function can be expanded in a Taylor series obtaining a numerical approximation for jam density. Taking power up to k^3 will give the following formula.

$$v = v_f * e^{[-1/2(k/k_{cri})2]} = v_f(1 - \frac{k^2}{2 * k_{cri}{}^2} + \frac{k^4}{8 * k_{cri}{}^4} \frac{k^6}{48 * k_{cri}{}^6})$$

So, here we will get jam density k_j at v=0

- *Drake model with Taylor series expansion*

Drake model doesn't yield a solution for jam density when speed approaches zero. So, Taylor series expansion will be used to obtain numerical approximation for k_j

$$v = v_f * e^{(-k/k_{cri})} = v_f(1 - \frac{k}{k_{cri}} + \frac{k^2}{2*k_{cri}{}^2} - \frac{k^3}{6*k_{cri}{}^3})$$

So, here we will get jam density k_j at v=0

2.1.1. *Multi-regime models*

Human behavior is different at different densities. This is corroborated with field observations shows different relations at different range of densities. Therefore speed density relation is different at different zone of densities. Model based on this concept is generally called multi-regime models. The simplest one is called a two-regime model, where separate equations are used to represent speed-density relation at congested and uncongested traffic.

2.2. Microscopic models

A microscopic model of traffic flow attempts to analyze the flow of traffic by modeling driver-driver and driver-road interactions within a traffic stream which respectively analyzes the interaction between a driver and another driver on road and of a single driver on the different features of a road. Many studies and researches were carried out on driver's behavior in different situations like a case when he meets a static obstacle or when he meets a dynamic obstacle. Several studies are made on modeling driver behavior in another following car and such studies are often referred to as car following theories of vehicular traffic.

2.2.1. Car following models

Car following theories describe how one vehicle follows another vehicle in an uninterrupted flow. Various models were formulated to represent how a driver reacts to the changes in the relative positions of the vehicle ahead

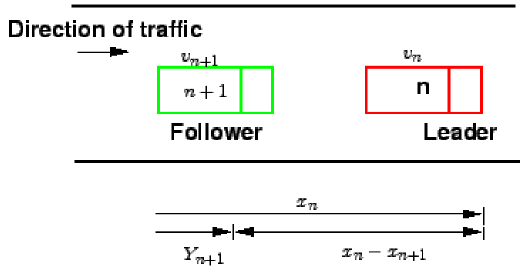

Fig.4.car following concept

Several theories have been proposed to model car following behavior, which can be divided into four classes based on behavioral assumptions namely,

- Stimulus response models,
- Safety distance or collision avoidance models,
- Action point models or psycho-physical models,
- Optimal velocity models

The earliest car following model was proposed as a stimulus-response concept based on the assumption that the driver of the following vehicle accurately perceives and reacts appropriately to the spacing and speed differential between the following and the lead vehicles.

The second class of models is based on the driver's tendency to keep a safe following distance (Gipps, 1981). The main advantage of these models is that it explicitly accounts for differences between acceleration and deceleration phases of driving. Further, the parameters can be calibrated using common assumptions about driver behavior like maximum acceleration or deceleration rates.

The third class of models is known as psycho-physical or action point models. This class aims to provide a more realistic driving behavior, by allowing for imperfect perception and discontinuous response based on thresholds on visual angle, speed, spacing etc. In these models, a driver can be in different driving modes like free driving, approaching, following and braking. The driver switches from one mode to another as soon as he reaches a certain threshold that can be expressed as a function of speed difference, space headway etc. (Wiedemann, 1974). The main challenge of these models is estimating and calibrating the individual threshold values.

The fourth class of models is optimal velocity models based on the assumption that the driver following the lead vehicle accelerates or decelerates depending on the difference between his/her speed and the optimum or target speed he/she can attain. In general, optimal velocity models have the disadvantage of being not completely crash free and give unrealistically large accelerations in some circumstances. Response-Stimulus Models (RSModel), Intelligent Driver Model (IDM,1999), Van Aerde Model,Velocity Difference Model (VDIFF), WiedemannModel (1974)And GIPPS(1981)Model are the some of popular microscopic models.

III. Data Collection

Traffic data collection through video recording has been widely applied due to its ability to collect data of all the traffic flow characteristics simultaneously and facilitate data extraction at both microscopic as well as macroscopic levels. Vehicles occupy any possible lateral position on the entire width of the road and move without any strict lane discipline. Under this circumstance, it will be inappropriate to consider and analyze the traffic flow based on lane, as followed in homogeneous traffic conditions. Hence, the entire width of the road was considered(Area occupancy concept) for data collection and analysis purposes.

IV. Data Retrieval

Microscopic and macroscopic data can be extracted from a database like collected traffic video. These are different methods, which has are still in use for finding both microscopic and macroscopic data from video.

Different methods used for data retrieval from videographs:

1 Tuladhar (1987): studied lateral and longitudinal spacing maintained by different types of vehicles using a video camera based technique. Using this technique, nagaraj*et al*. (1990) carried out extensive data collection studies. Lateral and longitudinal gaps has been collected with the help of a grid placed on a television monitor while playing back the video film.

2 Singh (1999):used a video recording technique to collect microscopic traffic data under heterogeneous traffic conditions. Using calibrated image size & distance relationship -speeds, time headways and lateral spacing data were obtained.

3 Hoogendoorn (2003):used a sequence of aerial images to collect trajectory data along with vehicle dimensions which were then put to extract the lateral positions of the vehicles.

4 Vehicle count manually from the video and speed by noting time taken by each vehicle to cover a

particular known length say 100 m .distance/time will give speed.

5 Naveen(2013)plot grid lines using AutoCAD and created an image file which suits to the road in the traffic video. The image file is then superimposed over the video Using Ulead Video Studio Editor and converts this new video with grid file into frames using Irfan View Software. Analysis of the frames will give the different coordinates of the subjective and surrounding vehicle and finally lateral position of each vehicle and there by lateral gap between vehicles.

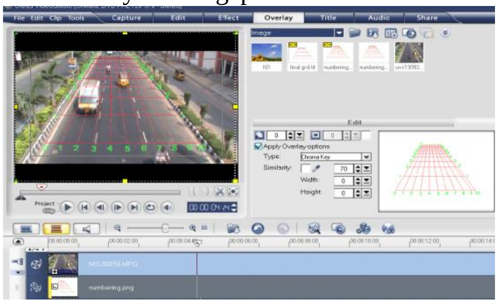

Fig.5.overlaying of grid lines on video using Ulead Video Studio Editor

Fig.6.converting video into frames using Irfan View Software

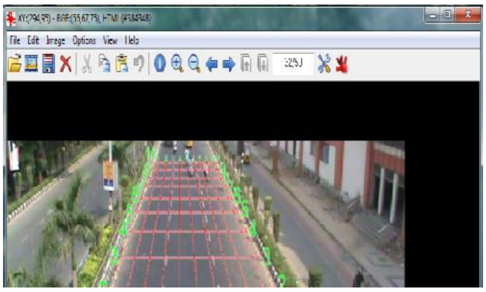

Fig.7.finding vehicle position in terms of x y coordinates

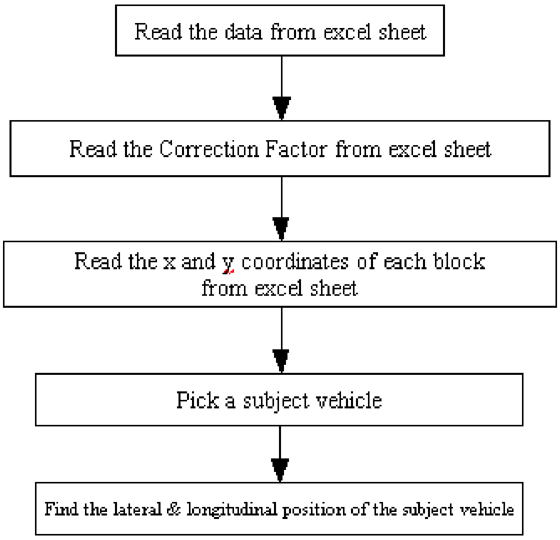

Fig.8.flowchart showing conversion of row vehicle coordinates into lateral and longitudinal positions.

Using TRAZER software:The classified data on vehicle trajectory collected using video image processing software called TRAZER have been utilized by MallikarjunaChunchu in 2010 for Data analysis, carried out to understand relationships between vehicle characteristics and longitudinal and lateral gap maintaining behaviour.This software is specially developed for Indian traffic condition. Software has to run for the entire duration till which data is required.Results will show as one minute interval data. Vehicle frame size has to input.TRAZER generates an output consisting of classified count,classified speed,classified occupancy. Software will read the video having frame rate -25fps, video size-640*480 vga and video having focus across to traffic flow as shown in figure.

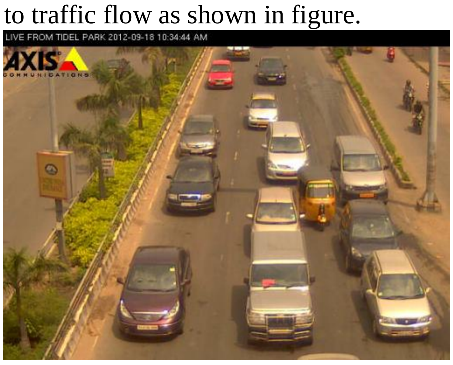

Fig.9.traffic video

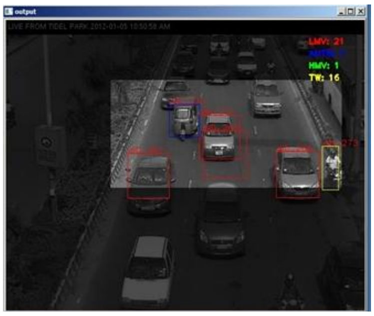

Fig.10.video while running in TRAZER software

Accuracy of the software is 70% for vehicle count and 80% for speed. Accuracy can be increased even above 90% by doing manual correction by deleting and proper shifting of wrong frames of vehicle.

			Counts			
S. No.	StartTime	EndTime	LMV	3W	HMV	2W
1	30-05-201	30-05-201	29	2	4	59
2	01:00.0	02:00.0	2	0	3	16
3	02:00.1	03:00.1	4	0	1	25
4	03:00.1	04:00.1	11	4	1	57
5	04:00.2	05:00.2	27	3	0	69
6	05:00.2	06:00.2	22	3	2	68
7	06:00.2	07:00.2	8	1	3	22
8	07:00.3	08:00.3	4	4	1	25
9	08:00.3	09:00.3	13	4	4	60
10	09:00.4	30-05-201	3	1	3	9
		Total	123	22	22	410

Fig.11.excell output by TRAZER Software for classified vehicle count

6 Vehicle count using MCME (Manual Count Made Easy) software:this software is introduced by Dr.GitakrishnanRamadurai, Asst. Professor, Civil Dept., IITM. MCME is a powerful tool for data extraction .It is a graphical user interface which works on the principle of speech recognition. It makes data extraction simpler and easier. Classified vehicle count can be obtained more easily and with greater accuracy with the use of MCME. It is developed in the programming language c sharp(c#). Another major advantage with this application is that it is portable. System requirements are windows 7 with.net framework (4.0 and above).

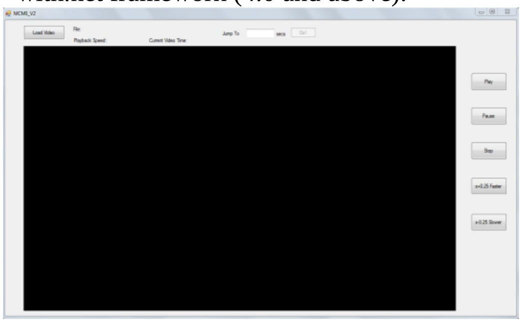

Fig.12.MCME software window

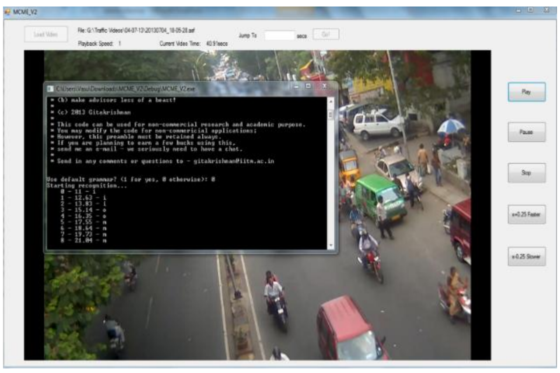

Fig.13.running video in MCME software

Open the mcme_v2 executable file and load the video. Data extraction will carried out by just speaking the mentioned keywords for different vehicle classes using a headphone with a mic in a less noisy environment. Increasing and decreasing the video playback speed is also possible.After detection is over, the key words spoken as well as the time of detection are stored in a text file named “vehcount.txt”. It can be easily transferred to excel or other suitable software for further analysis.

V. Conclusion

Green shield model, the general model of uninterrupted traffic flow that predict and explain the trends observed in real traffic flow model. In field we can hardly find the linear relationship between speed and density as assumed by green shield. So validity of that model was questioned and many other models came up. Greenberg proposed a logarithmic speed-density relationship which shows better goodness of fit as compared to green shield’s model. But model is unable to predict speed at lower densities. Underwood derived an exponential model showing better fit than other two models but cannot be used for predicting speeds at high densities due to speed becomes zero only when density reaches infinity. Modified Greenberg model introduces a non-zero average minimum densityk_0. Car following theories describe how one vehicle follows another vehicle in an uninterrupted flowand the model can be divided into four classes based on behavioral assumptions.

Videography technique is widely used in transportation engineering, traffic and planning for data collection. Many attempts are done earlier for data retrieval from videos. Earlier micro data’sretrieved by placing a grid on a television monitor while playing back the video film. Later technology developed and grid overlaid on video. TRAZER and MCMEsoftware are latest.MCMEworks on the principle of speech recognition. It makes data extraction simpler and easier.It will give classified vehicle count easily and with greater accuracy.TRAZER generates an output in excel consisting of classified count, classified speed, classified occupancy by simple running of video.

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