DEVELOPMENT OF COLOR CODING FROM DATA COMBINATION TO PERCEPT TRAFFIC CONGESTION

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In the era of traffic engineering an important element for transportation system operations is traffic information which is the determinant of the level of performance of the traffic network. Color code developed through a proper method may provide a clear perception of the prevailing traffic condition. With a view to develop a better color coding method in the proposed research data fusion method has been used. To get continuous information of the traffic condition sparse probe car and continuous video data from a fixed position has been combined to produce trajectory of the each vehicle by car following theory with some alternation. Then by relating speed with some color band and using time-distance area condition of the traffic was visually represented through color coding.

Keywords: *color coding***,** *time space diagram, trajectory of vehicles, intelligent transportation systems (its).*

1. INTRODUCTION

Originating from optical engineering and electrical engineering, data combination or fusion from multiple data sources have been using particularly in the fields of traffic operation and control, traffic and incident management, and intelligent transportation systems (ITS). The ability of providing richer information from multiple data sources, it has the advantages of providing higher reliability, robustness and credibility, faster and more accurate estimation and prediction, and broader spatial and temporal coverage in many traffic management and control applications and for this reason data fusion technique from two or multiple sources has drawn the attraction of the transportation researchers.

Here in order to develop an accurate color coding a data combination method has been proposed to estimate the road traffic condition to evaluate the prevailing traffic state and congestion situation based on the traffic engineering principal. Here data from the two sources are combined to develop the vehicle trajectory for each and every vehicle in the desired link. These two data sources are probe car data and video data where the video data collects the entering time of the each vehicle from the upstream. Then using the developed trajectory a color coding method is developed for the same analysis period to percept the traffic congestion through the speed as designated by the color coding.

2. BACKGROUND

Color coding developed only from a little number of samples may provide wrong information about the condition of the prevailing traffic. For example if only from the probe data, color coding is predicted and the congestion measurement of the links is

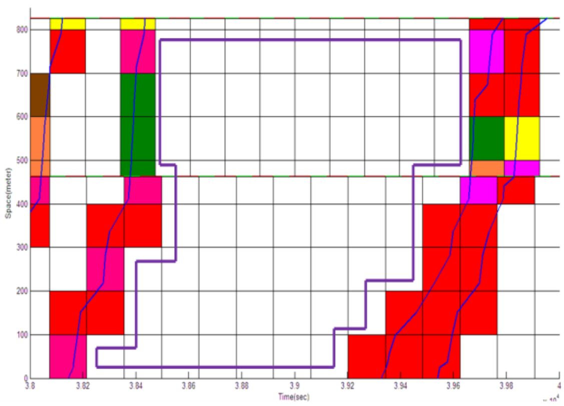

Figure 1 : Indefinable Portion Only From the Probe Car Data

demonstrated then most of the portion of the link is unpredictable as like the Figure 1.

On the other hand, existing data fusion techniques are mainly based on the statistical concept and probabilistic approach and do not benefit from the principles of traffic engineering. They normally used the weighted combination of travel time from different sources but the delay due to the fixed traffic signal at the intersection and delay due to the various factors and facilities in urban roads are not considered.

Different researchers developed data fusion method to have an estimation of the traffic condition of the existing road network. For example Westman et al. (5) explored the integration of probe vehicle and loop detector data for travel time estimation and incident detection and Thomas (9) proposed several multi-state multi-sensor data fusion models for arterial incident detection. Probe vehicle travel times, number of probe vehicle reports, and detector occupancy and volume as inputs are combined. Bayesian score rule is applied to detect incidents as making a multiple attribute decision. Klein et al. (10) introduced and tested the Dempster-Shafer theory for data fusion in support of advanced traffic management. Dempster-Shafer inference is a statistical data classification technique for detecting and identifying traffic events that affect normal traffic operations. It can deal with the conditions in which data sources provide discontinuous and incomplete information, and no single data source can produce a high probability of certainty for identifying the most probable event. The algorithm captures and combines any certainty existing in the object discrimination or event classification capability of the sensors and other information, as contributed by the data sources using Dempster's rule.

Berkow et al. (12) recently used the graphical method to fuse the data from the loop detectors data and the transit bus probe as sectional data. Specially, the two sources data were collected at the same time simultaneously by taking the consideration of the transition of the traffic state which was absent in the previous works of data fusion. But using the transit vehicle as probe has several drawbacks like stopping due to passenger serving and may provide flawed result and they also did not take into account the delay due to traffic signal at the intersection. They used sections speed data which they showed by some color point. Then they extended the color in the upstream and the downstream. But the method was relying on some uncertainty as this color coding they used was only applicable for some portion of the total section in the distance and for the time coverage it provided the data only of some point.

3. OBJECTIVE

Considering the short coming of the former researches and to develop a color coding with the full utilization of the traffic data, following objectives were set in the research:

To find a methodology to combine the data from the Probe car and video recording and thus supplement the sparse number of probe data by producing the estimated trajectory of all entering vehicles recorded from the video data positioned at the upstream with considering the traffic engineering principles.

By using this traffic data develop a color coding to visually percept the traffic congestion level in terms of speed.

4. METHODOLOGY

The proposed methodology is comprised of two portions. The first one is to produce the estimated trajectory by using the car following theory with the addition of the concept of Observed Free Flow Speed for combining data from the two sources considering the cases evolved. Then by checking the accuracy of the proposed methodology the second step is to develop a color coding which depends on the accuracy of the of the prior method.

In the first portion to estimate the trajectory of the vehicles captured by the video data two cases may be involved. Case 1 is when the headway between the two consecutive vehicles is very small .e. less than 5 seconds and former case is the headway is large.

Case 1 is the condition when the movement of the following car is influenced by the movement of the leader. Such case can be handled by the car following theory one of the microscopic theories of the traffic flow.

For the case 2 when the time headway between two consecutive vehicles is higher, then the motion of the follower is not influenced by the leader vehicles motion. In such case car following theory cannot handle the traffic flow condition. In order to incorporate such condition which is very common to the actual field the proposed method has included the term Observed Free Flow Speed (OFFS) in the proposed method. So the vehicle coming after the leader vehicle will follow the trail of the probe car if there is not so much space for the driver to speed up.

But if the headway between this two consecutive vehicle such that there is room for the driver to speed up then the following vehicle will not exactly follow the leader vehicle as it will get the free space in front of it and speed up. The speed that the following car will attain in this case will be similar to the OFFS according to the assumption of this proposed method and will cruise the link. But if the following vehicle finds that it has again reached very near to the leader than again it will start to follow the trail of the leader and from that point again car following theory can be applied. Taking this consideration it was assumed that every vehicle will maintain at least minimum 2second headway with its leader vehicle and then will again follow its leader maintaining that headway. So to accommodate the stochastic behavior of the vehicle's headway it was taken that if the driver gets enough spacing or headway between it and its leader then it will go with the observed free flow speed which is the maximum speed in the link that the driver can attain, and passes the link.

(1) Calculation of OFFS

As stated earlier that this research methodology has used simplified car following theory with some modification. The concept here used as an addendum is the Observed Free Flow Speed (OFFS). Observed Free flow speed of the vehicle is the speed which was the maximum for the desired link. But in this research desired links were divided into some sections according to the positions of some landmarks. Along the links probe car's time of passing that landmarks were extracted from the probe car data. Thus each links was divided into several sections according to the position of the landmarks. For instance the link A1 which is the upstream of the desired links was divided into eleven sections according to the positions of the landmark. For each section the data of all probe cars were compared and the smallest value was taken for each section of the link. Then all smallest time for the eleven sections

Figure 2: Map of the study area

were summed up. Thus free flow speed of the desired link was manipulated by dividing the sum total of the smallest time for the sections to the length of the link. Suppose s_i is the length of the ith link. According to the designated landmark points along the link, it is divided into n number of sections. If the smallest travel time along the n_1 , n_2, n_3, n_4, n_5 …..n sections are $t_{1,} t_2, t_3, t_4 \ldots . t_n$ etc. then the Free flow speed of the link can be expressed by the following equation:

$$V_{OFFS} = \frac{s_i}{[t_1 + t_2 + t_3 + t_4 + \cdots \ldots . t_n]}$$

Where s_i is the length of the specific link. After calculating the OFFS for the study links A1 and A2 the value became 7.5 and 10.5 m/s respectively. It is the highest speed that the vehicle can attain for the specific link calculated by sampling the probe data for the sampling period of 10:00 to 11:30 am of the data for the September 18th .

(2) Data processing framework

As both the video and the probe car have their respective drawbacks both data will be combined to produce a reliable and robust result to estimate the traffic state. The procedures comprised of the following procedure:

1. Conduction of the video recording at the upstream of the study links
2. Driving of the probe car through the link at the same time of the video recording for designated links of the network was in operation.

3. After extracting the data, drawing of the vehicle trajectory (Times-pace diagram) and calculation of the Observed Free Flow Speed from the probe car data was made.
4. Combination of data from the two sources was performed using the car following theory and the concept of the observed free flow speed. Thus the trajectory of all entering vehicles was drawn.
5. Then a color band was developed relating to the speed and with the data of each vehicle trajectory the color coding was developed.

5. DATA SOURCE

Data was collected from Omiya, Saitama prefecture, Tokyo, Japan. It is a city center of the Saitama ward embellished by high rise buildings, shopping malls etc. Many business opportunities draw the attention of people and also offices of different types are situated here. Due to a lot of mixed activities encircling the place and easiness of connectivity through roads and train system it is a

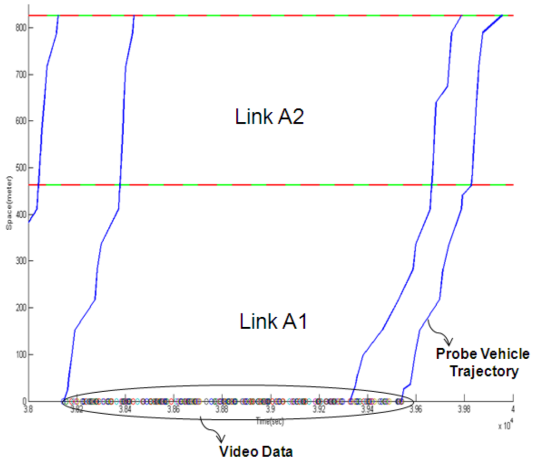

Figure 3 : Demonstration of the two data sources together

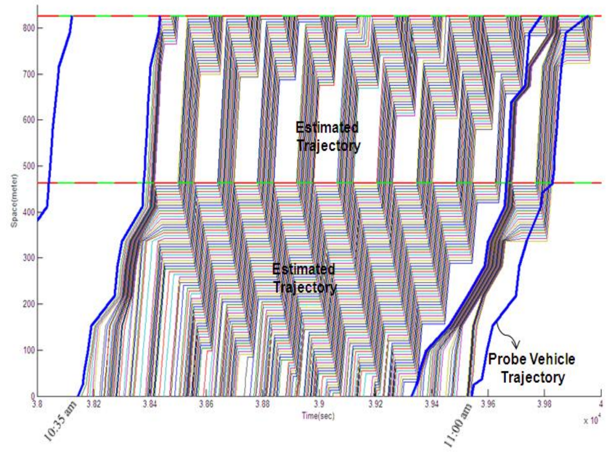

Figure 4 : Data combination and the overall traffic condition

very business intensive and commuting place for people on regular basis. During the weekday and especially on holiday the surrounding roads and streets become very congested due to heavy traffics. As a part of the experiment conducted in the title "Saitama Car Free Day" this research has chosen some existing streets from Omiya and has conducted the experiment for the collection of the requisite data and the data for the analysis were collected both for morning and afternoon for the month of September. But for the data analysis by the proposed method data of 10:30 to 11:00 am on the September 18th will be utilized and demonstrated for the highlighted portion of the section A in the Figure2.

6. CALCULATION AND ANALYSIS OF THE REAL FIELD DATA

Combination of the both data sources

In this research the fixed placed video camera positioned at grade at the upstream of the portion A to link A1 and the entrance time of the each vehicle was recorded. Then this video recorded data which is time data in the real sense of the term was plotted in the time-space plane as shown in the Figure 3 .Then taking the prior probe car as reference proposed methodology was considered and the estimated trajectory was developed for each vehicle for the analyzing period.

By considering the both concept in the methodology section data of probe vehicle and video were placed in the time-space plane shown by the Figure 6 for the sampling period 10:35 to 11:00 am for the study link A1 and A2.Now after the combination the two data sources and by manipulating the estimated trajectory the traffic condition can be represented by the Figure 4.

Evaluation of the method

The proposed methodology thus developed and manipulation of the estimated trajectory using this methodology was then evaluated to measure its performance in the real world. For the evaluation number plate survey data was used as representative of the actual field data. As the number plate survey was conducted along the same time it can be used as a source of the realistic traffic information of the field like the probe car data concerning the travel time of the vehicles. The sample number is compared between the number plate and the estimated trajectory in terms of travel time.

Table 1: Comparison table between proposed method and field sample

	Estimated Travel Time(sec)	Number Plate Travel Time(sec)	Error Percentage
Link A1	273.85	257.91	**6.2**
Link A2	132.16	124.45	**6.5**
Section A	406.55	380.65	**6.8**

Table 1 shows the primary comparison between the number plate survey data and the estimated trajectory data for the sampling period. So for the link A1, the estimated average travel time is 273.85 second for the sampling period while that of the number plate survey is about 258 second. The percentage of error is 6.2. On the other hand for the link A2 travel time of the number plate and the estimated trajectory are 132.16 and 124.5 second respectively and the percentage of error is 6.5.For the total portion A that contains the both links A1 and A2 which are in the consideration altogether the travel time is 406.55 second for the estimated trajectory and number plate survey provides the average travel time 380.7 second the error percentage is 6.8.

As the number of samples are not the same for the number plate and the estimated trajectory another process were used to evaluate the methodology. The total number of sample for the samples for the total portion A is demonstrated. As shown total number of samples from the estimated trajectory was 230, 55 for the number plate survey. These 55 samples from the number plate survey are matched against the 230 number of samples of the estimated trajectory and 30 samples are matched from the both samples. In Table 2 the result of the matched samples has been summarized. The average travel time of the estimated and number plate survey is 392 and 367second respectively and error percentage is 6.86.

Table 2 : Result for the exact matched samples

	Travel Time(second)	Error Percentage
Estimated Trajectory	392	**6.86**
Number Plate Data	367	

7. DEVELOPMENT OF THE COLOR CODING

Color band used

In the proposed research in order to relate the speed of the urban link a color code was developed which used some designated color. The color code used here contains 6 types of color. They are red, pink, purple, orange, yellow and green according to the hierarchy of the lower to higher speed of the both links. The speediest condition that means the lowest travel time is reflected by the green and the most congested condition i.e. the forced flow condition is reflected by the red color.

Color band and speed relationship establishment

As stated earlier the free flow speed is the maximum speed on the designated links which is minimum travel time along that link. Here in order to describe the congestion level of the prescribed links a universal color code for the portion A should have to be included in the development of the color code. However the methodology has used the maximum free flow speed of the two links labeled A1 and A2 which is 10.5 meter per second and designated as the green color band. It is done with a view to depict the congestion level of the each link with perspective to each other with time. Such thing will have to be considered when developing the color coding for any number of intersections and for that maximum speed among the links will have to be taken into the taken as green color band as a threshold value for higher one.

In this way after fixing the maximum threshold value for the color coding the minimum speed threshold for the color code was developed from the minimum speed of the probe car. Although the probe car has been used here for determining the threshold values of the color coding but historical data will be the best choice to be used for fixing the threshold values. However after determining the maximum and the minimum values then the middle threshold were determined heuristically. The range was divided into some time boundary taking the consideration of the maximum red cycle time between the two links. For the link A1 at downstream signal the red time is 79 second which is higher than that of 77 second for the link A2. Table 3 shows in the tabular form the range of the speed and their relationship with the color band. The 3rd column here shows the travel time of the vehicle if it passes the total 826 meter urban links without the signal delay.

Developing the time-distance area

Table 3 : Color Band and Speed Relationship

	color	**Speed(m/s)**	**Travel Time(sec)**
	Red	<2.75	>300
	Pink	<5.5 to 2.75	>150 to 300
	Purple	<7 to 5.5	>120 to 150
	Orange	<9 to 7	>90 to 120
	Yellow	<10.5 to 9	>78 to 90
	Green	>10.5	< 78

Now consider the Figure 4 where the combination of the data from the mobile and the fixed source have been performed. Then the total time-space plane has been divided into some rectangular blocks as shown in the Figure 5. These blocks are given the name ‘Time-Distance Area’. This time distance area is spaced vertically which is the line of time, according to the signal cycle of the each links. For instance for the link A1 the total cycle length of the signal is 141 second. So the spacing of the vertical lines is 141 seconds. In the case of horizontal lines as it is the distance line the spacing between the lines is normally 100 meter. With a view to show the variation of the congestion along the 100 meter to

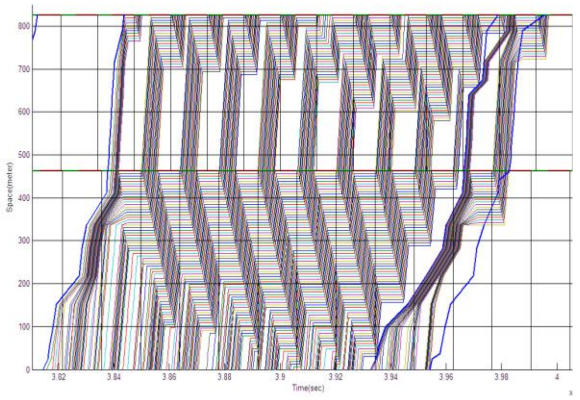

Figure 5 : Time-space Plane Divided into Some Rectangular 'Time-Distance' Blocks

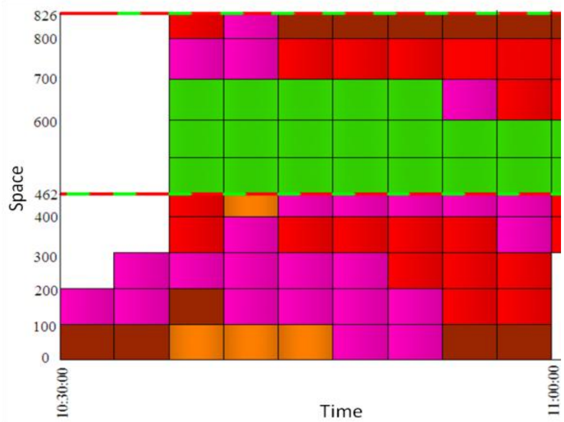

Figure 6 : Congestion Measurement for Overall Links by Color Code

100 meter this spacing has been chosen. But in the last horizontal line for the link A1 the distance is 62 meter to cover the last 62 meter length of the link. Such is the case also for the last horizontal line of the link A2. Here the time-distance area chosen for the specific purpose but it is changeable. For example it is possible to divide the time-distance rectangular blocks in 1 or 2 or 3 minutes vertically and 50 or 150 or 200 meter along the horizontal axis according to the required level.

Estimation of the congestion level

Then for the each rectangular box the entering time and the exiting time of the each vehicle are extracted and also their passing distance is recorded. After the completion of this task for the each block the total number of vehicles and their passing distance data is used to find the speed of the each vehicle. Then they were averaged for the each block to find the speed of the each time-distance area block. Thus average speed of the each blocks are manipulated.

After manipulating of the travel time and the speed average for all the time-distance area have been extracted and according to the color table relating the speed and the color band the block is colored. Thus speed in turns travel time which is the main traffic factor for the congestion measurement is related with the color band the congestion condition of the highlighted links are represented in the Figure 6.

8. CONCLUSION

Color Coding thus developed through the utilization of rich vehicle trajectory developed from fusing the data from fixed video data and probe car sampling, provide a uninterrupted and reliable information of the congestion in terms of the speed and visually helps to understand the situation of the traffic at a glance.

The data fusion method proposed here produces the estimated trajectory of the all vehicles and various traffic information like the speed of the individual vehicles as well as their travel time, the condition of the traffic in each signal cycle, the length of the queue, the transition of the traffic state form one to another etc can be deployed easily. Performance of the proposed methodology is evaluated regarding travel time estimation with number plate survey data from the field and it was found that the proposed method can provide the travel time as well as speed of the links reliably.

Still there are some limitations are associated with the proposed methodology. The incoming and outgoing vehicles from the midsection were not taken into consideration in this research. Again here to collect the data of the number plate from the real world special type of audio recorder were used which reduces the sample size retrieved in comparison of the total amount of sample in the real sense. The use of AVI equipment could be used instead to collect a large number of samples from the real world for compare precisely as this could increase the sample size. This method is still incapable of handling the condition where there are multilane facilities as the overtaking may take place in that case. These issues mentioned above if incorporated can provide a more reliable method of estimation and are considered as the future direction of the research.

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