Modeling and Simulation of Traffic Lights on the High Contrast and Brightness Conditions and Structure Technology

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ABSTRACT

Nowadays, the use of intelligent control systems to reduce human error is one of the most popular research fields. Design and implementation of such controllers requires to actual knowledge of the environment conditions. Traffic lights as one of the inputs of intelligent control systems are significant. usually the traffic lights have the various physical structure. also, generally in image processing images is provided by a digital camera therefore having similar characteristics of images is a necessity. The light of environment conditions as backlight can lead to different results in the image processing. It seems, design and practical implementation of this system with acceptable performance will be hard achievable without a proper model for different lighting conditions. In this study we propose a consistent and comprehensive model for traffic lights in various lighting conditions, such as day and night conditions.

KEYWORDS: Local image processing, Traffic light, Lighting conditions, Normalized model

1. INTRODUCTION

With the growing number of vehicles, the traffic congestion and transportation delay on urban arterials are increasing worldwide; hence it is imperative to improve the safety and efficiency of transportation. Subsequently, several research teams focus their attention on the area of Intelligent Transportation System (ITS) [1, 2]. In addition, they applied advanced communication, information, and electronics technology to solve transportation problems such as traffic congestion, safety, transportation efficiency [3]. It is an important issue in traffic light control systems for two main reasons: (1) the traffic light control systems exhibit a high degree of concurrency (2) the systems might make the shared resources (*i.e.*, intersection area) conflict and cause a tendency to deadlock and overload. The currently available methods and strategies utilising traffic-light controls may be classified into two categories [4-9]. First: fixed-time strategies,

which consider a given time of day and determine the optimal green times and optimal cycle times, based on the historical constant demands over the considered signalised urban area. Second: traffic-response strategies, which are based on constructing real-time control systems with optimum signal settings. The most used strategies for urban traffic control are fixed-time strategies [6, 7], nevertheless, nowadays; more interest is being given to developing control strategies in which the control system is fully responsive [12]. Many traffic-response strategies have been developed and are based on dynamic programming optimisation procedures, which allow continual incremental adjustments in real-time of cycle lengths, splits, and offsets [6]. In general, for both fixed-time and traffic-response strategies, a modelling of the urban traffic network is essential either for simulation purposes or for the implementation requirements of a real time control system. Moreover, it is crucial to consider real parameters in any work of modelling or development of an optimisation method.

The information of traffic signal can be obtained through wireless communication technology, but installing wireless communication equipment has high price and also it raise cost of the hardware services [10,11]. In order to simplify on the hardware, the image processing technology can be applied to identify traffic lights. This system has some advantages, such as high efficiency, low price, and easy upgrade. Today, in more places Light Emitting Diodes (LEDs) have replaced with conventional lighting devices. Because, The LEDs have more advantages such as high effective power consumption, longer lifetime, lower response time, smaller size and weight. However, these intelligent systems should be able to recognize the traditional and LEDs lights. So the main purpose of this paper to provide an acceptable model for traffic lights including red and green color light with low tolerance in environment lightening condition.

2. IMAGE IN HIGH CONTRAST AND BRIGHTNESS FORMAT

Analysis of an image involves processing of the construction of the image's format. This is mainly true when using Matlab, where the user has the capability of working with the binary level image, from the point at which the image is read into the program to the final processed image. Matlab requires the user to import manually images, on the other hand Matlab handles the actual images bits into a variable array or matrix, and performing image operations by referencing that variable. For image processing methods, MathLink provides the Image Processing Toolbox, a Matlab add-on utility comprised of many powerful functions for image acquisition, analysis, transformation, filtering, exporting, etc. Matlab has ability of importing several image formats.

While, images are taken by digital automatic camera they may have different contrast and brightness for identical location on different times and lightening conditions because of auto gain camera. This problem can lead to different result of image processing. Fig.1 shows a normal contrast and brightness picture of a square.

Fig.1. Normal image

The High Contrast picture of traffic light situation is shown in Fig.2

Fig.2. High Contrast image

Also, Fig.3 shows a High brightness picture of the other situation

Fig.3. High Brightness image

It is obvious that results of image processing for these pictures can be more distinct

2.1 COLOR VARITY IN TRAFFIC LIGHTS

For many years, colored lights have been used as traffic signs. Often, in the automatic systems unknown problem occurs Because of extend of used color for traffic lights and also absence of convenient standards to select of their color and intensity in the decision-making step. Some red and green light for traffic light are shown in Figs.4 and 5.

Fig.4. Red Signs

this problem can be more complex by Use of traffic signs with LED and lamps structure

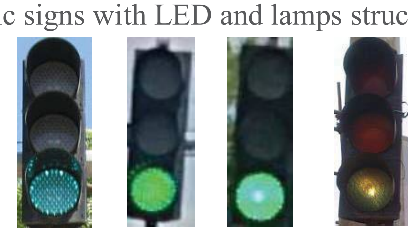


Fig.5. Green Signs

As can be seen, the used colors have high range of color specification, so that in practical it can be decrease the efficiency of intelligent automatic driver assistance systems.

2.2 DAY AND NIGHT CONDITIONS

It is well known, in practice The effect of environmental conditions can affect on the intelligent driver systems. An Example for this subject is the difference of environment light intensity in the day and night conditions. Certainly, The effect of synthetic light on the night and the darkness of the environment because of cloudy conditions can be modeled by day and night conditions. In Most cases, the special cameras are used to compensate such conditions, so that have ability to adjust brightness of captured image for environment with different light intensity. But in practice, because of constant intensity of traffic lights for different conditions, use of this technique can be lead to change ratio of traffic light intensity to the overall picture. The red light in the night is shown In Fig.6 , where the gain of camera is fixed for different modes.

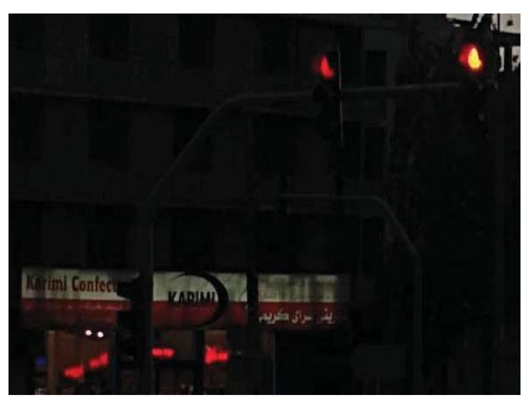


Fig.6. Red Sign on the Night (Fix Gain)

Fig.7 shows the night where by increasing of camera gain the overall Light intensity was increased so that leads to too much permissible coruscation and unreal green light.

Fig.7. Green Sign on the Night (Auto Gain)

Certainly, another problem occurs at the night because of generated red and green lights by non-traffic systems so that often it is leads to wrong make decisions.

3. BASIC COLOR SIGNAL VECTOR

Considering the variety of used colors in traffic signals, for having benchmark to compare and recognition, it is necessary to be reviewed and analyzed their information. In this study, Identification has been done based on type and structure of the color spectrum. Therefore it is necessary, the Range of Variation of optical signals are calculated In terms of the structure of color, intensity, contrast and brightness. Then a convenient algorithm is proposed to create a Data Bank. Undoubtedly, one of the parameters that must be considered is the spectrum of colored Signal.

$$\vec{C} = R\vec{i} + G\vec{j} + B\vec{k} \qquad (1)$$

Where R, G, B express the energy of red, green and blue colors respectively. Now, according to done survey on the provided images, we know that the value of R, G, B have some tolerance in different localities corresponding to construction technology. Therefore, for modeling this concept, the color vector is modified as follows:

$$\vec{C} = \begin{bmatrix} \vec{i} & \vec{j} & \vec{k} \end{bmatrix} \begin{bmatrix} R+\Delta R \\ G+\Delta G \\ B+\Delta B \end{bmatrix} \qquad (2)$$

In these equations $\Delta R, \Delta G, \Delta B$ are the maximum deviations from nominal value based on the original reviewed colors. Another characteristics that often needs to model the effect, is the signs with different intensity but similar spectrum of color. In order to model this characteristic, the color vector is modified as following:

$$\vec{C} = I_0(1+\alpha) \begin{bmatrix} \vec{i} & \vec{j} & \vec{k} \end{bmatrix} \begin{bmatrix} R+\Delta R \\ G+\Delta G \\ B+\Delta B \end{bmatrix} \qquad (3)$$

Where α is a negative or positive coefficient which is selected to minimum and maximum brightness. Also I_0 is a positive coefficient which is calculated for normal brightness of image. By applying the max and min value of $\Delta R, \Delta G, \Delta B$ for worst conditions, the Range of new define colors are created as Table 1 and Table 2 for red and green lights. As needed to identify the yellow color light, another table can be created respectively. These Tables will be used as the important section of the proposed algorithm in modeling discuss.

Table 1. Min – Max values for base colors of red light

Red	Min	Max
$(R+\Delta R)_{@Red}$	R_{min}	R_{max}
$(G+\Delta G)_{@Red}$	G_{min}	G_{max}
$(B+\Delta B)_{@Red}$	B_{min}	B_{max}

Table 2. Min – Max values for base colors of green

Green	Min	Max
$(R+\Delta R)_{@Green}$	R_{min}	R_{max}
$(G+\Delta G)_{@Green}$	G_{min}	G_{max}
$(B+\Delta B)_{@Green}$	B_{min}	B_{max}

Practically, the intelligent system should have ability to recognize the colors of the lights in terms of their color variety. For example, if characteristic of "n" traffic light are given as Tables 1 and 2, minimum and maximum values can be chosen by following two methods.

Narrowband method:

In this method, the maximum and minimum values are calculated using the following relations:

$$\begin{aligned}[R_{min}, R_{max}] &= \underset{i=\text{Number of Traffic Light}}{\text{Min}}[R_{min-i}, R_{max-i}]\\ [G_{min}, G_{max}] &= \underset{i=\text{Number of Traffic Light}}{\text{Min}}[G_{min-i}, G_{max-i}]\\ [B_{min}, B_{max}] &= \underset{i=\text{Number of Traffic Light}}{\text{Min}}[B_{min-i}, B_{max-i}]\end{aligned} \quad (4)$$

This method has some advantages such as fine recognition and non-Mistake on recognition. But it may not recognize right because of Narrowband.

Widthband method:

In this method, the maximum and minimum values are calculated using the following relations:

$$\begin{aligned}[R_{min}, R_{max}] &= \underset{i=\text{Number of Traffic Light}}{\text{Max}}[R_{min-i}, R_{max-i}]\\ [G_{min}, G_{max}] &= \underset{i=\text{Number of Traffic Light}}{\text{Max}}[G_{min-i}, G_{max-i}]\\ [B_{min}, B_{max}] &= \underset{i=\text{Number of Traffic Light}}{\text{Max}}[B_{min-i}, B_{max-i}]\end{aligned} \quad (5)$$

In this method, the color recognizing is done almost completely. But it may recognize irrelevant points as target because of to be Width-band color area overlaps.

3.1 CONTRAST AND BRIGHTNESS

Contrast and brightness Mismatch problem in the captured pictures, occurs mostly because of the use of cameras with miscellaneous technologies. This problem occurs severely, while the camera adjusts automatically brightness and contrast according to default algorithm. In this case, because of fixed out energy for color signals in most lighting conditions, with decreasing intensity of background in the darker environments, the intensity of the color traffic signals increases and lead to shining colored points. Certainly, this problem can model as brightness affect. The second problem is contrast. According to equation (3), it can be concluded the contrast problem has been solved by use of the new define color instead of main colors. Of course values of α and I_0 should be modified to compensate the brightness and contrast.

4. NORMALIZED MODEL

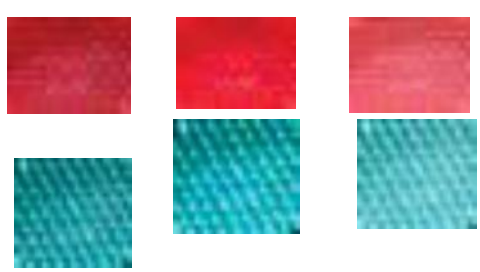
In practice, the use of different models leads to different results. Of course each of them has special advantages and disadvantages. Simple models, despite the simplicity can result faster algorithms. The other hand, more complex models can lead to more precisely decision-making ability and usually have less error. In this research, simple model has been used as comparison benchmark. In the last section, it was said that by providing equation (3) and define the new colors, the effect of background light intensity, brightness and contrast are compensated. The conceptually, the proposed model can be used. But in practice, when one of the main signal $(\tilde{R}, \tilde{G}, \vec{B})$ on the pixel of the image has zero value, the new define signal of pixel will be singular point. In this research to solve this problem, the basic color vector has been defined with the following equation.

$$\begin{bmatrix}\hat{R}\\ \hat{G}\\ \hat{B}\end{bmatrix} = \frac{255}{\left|\mathrm{sqrt}(\tilde{R}.\tilde{R}+\tilde{G}.\tilde{G}+\tilde{B}.\tilde{B})\right|}\begin{bmatrix}\tilde{R}\\ \tilde{G}\\ \tilde{B}\end{bmatrix} \qquad (6)$$

Of course these calculations are not vector operations and done for each pixel independent. Thus, the singularity problem does not happen. In addition to solving the main problem the other defects of simple model is also resolved.

5. EXPERIMENTAL AND SIMULATION RESULTS

In this section the results of the proposed model, on images in different modes, are presented. Comparing of the results of simple model and the proposed model is shown improved model performances. The most important characteristic which are obtained by image processing as follows: minimum and maximum value of basic colors and also their dynamic variation range.



Normal | High Contrast | High Brightness

Fig.8. Pattern for normal and un-normal contrast and brightness

5.1 IMAGE ON AUTO ADJUST MODE

The Selected and used images to execute algorithm are captured by cameras on several different modes of lights. To investigate the effect of brightness and contrast, a few images are provided which have different adjusting. The out results of the proposed algorithm, in two simple and new models, are presented in Figs.9-14. Figs.9-11show the image of red light in normal, high contrast and high brightness status.

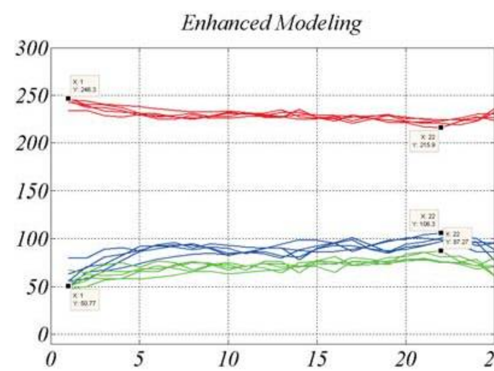


Fig.9. Normal image (red)

Fig.10 show the result of simulation for High contrast red image

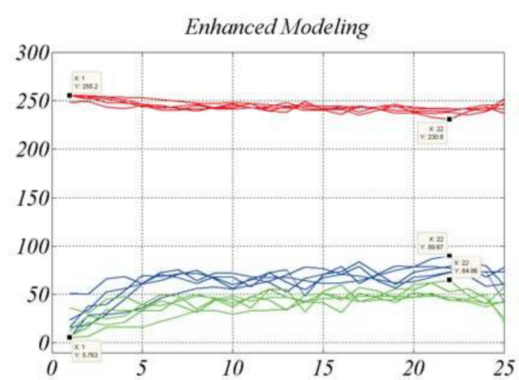


Fig.10. High contrast image (red)

Fig.11 shows the result of simulation for High brightness red image

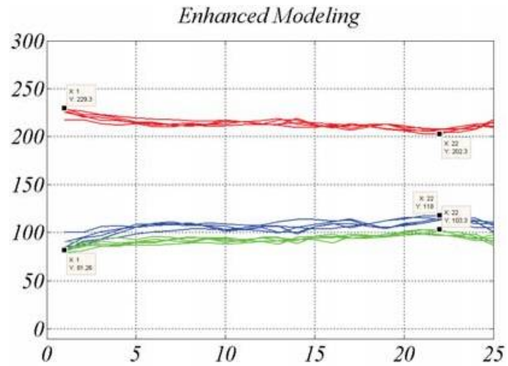


Fig.11. High Brightness image (red)

Figs.12-14 show the image of green light in normal, high contrast and high brightness positions

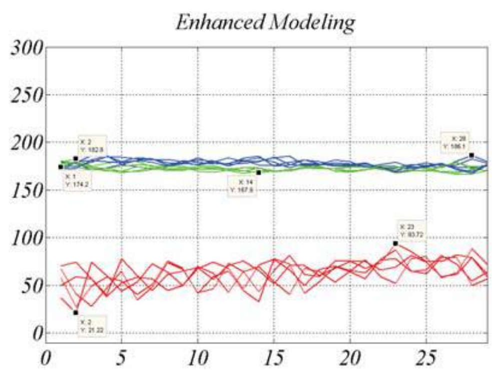


Fig.12. Normal image (green)

Fig.13 shows the result of simulation for High brightness green image.

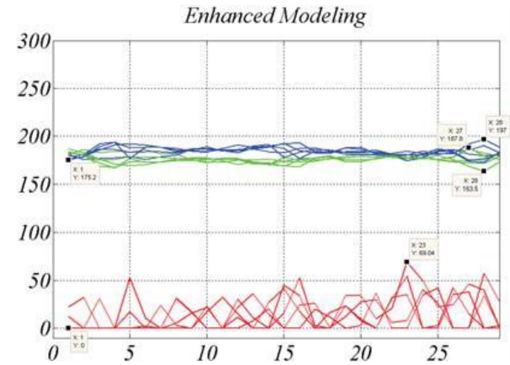


Fig.13. High contrast image (green)

Fig.14 shows the result of simulation for High brightness green image

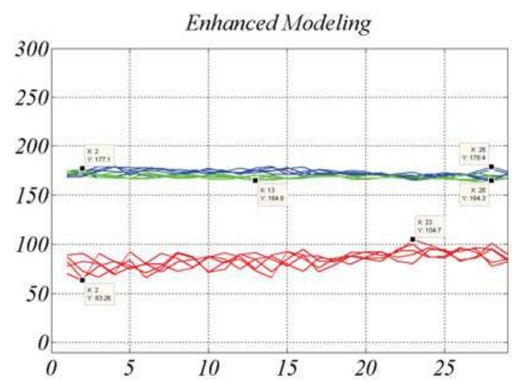


Fig.14. High Brightness image (green)

The results of the simulations in Figs.9-14 show that in general, the proposed model can reduce the allowed Bond of basic colors.

Table 3. Effect of contrast and brightness on image processing of red light

	Normalized Model			Simple Model		
	Original Image	High contrast	High brightness	Original Image	High contrast	High brightness
$Max(R)_{@R.L}$	246	255	229_{max}	222	255	255
$Min(R)_{@R.L}$	215	230_{min}	202	168	204	210
$D.R(R)_{@R.L}$	0.06	0.05	0.06	0.13	0.11	0.09
$Max(G)_{@R.L}$	87	64_{max}	103	78	68	120
$Min(G)_{@R.L}$	50	5	81_{min}	37	6	79
$D.R(G)_{@R.L}$	0.27	0.85	0.12	0.35	0.88	0.26
$Max(B)_{@R.L}$	106	90_{max}	118	95	94	137
$Min(B)_{@R.L}$	50	5	81_{min}	37	6	79
$D.R(B)_{@R.L}$	0.36	0.89	0.18	0.44	0.88	0.26

Table 4. Effect of contrast and brightness on image processing of green light

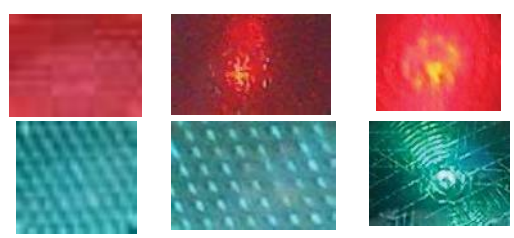
	Normalized Model			Simple Model		
	Original Image	High contrast	High brightness	Original Image	High contrast	High brightness
$Max(R)_{@G.L}$	93	69_{max}	104	111	101	153
$Min(R)_{@G.L}$	21	0	63_{min}	13	0	55
$D.R(R)_{@G.L}$	0.63	1	0.24	0.79	1	0.47
$Max(G)_{@G.L}$	182	187	177_{max}	208	223	250
$Min(G)_{@G.L}$	168_{min}	163	164	111	101	153
$D.R(G)_{@G.L}$	0.04	0.06	0.04	0.3	0.43	0.24
$Max(B)_{@G.L}$	186	197	178_{max}	219	255	255
$Min(B)_{@G.L}$	174	175_{min}	164	109	97	151
$D.R(B)_{@G.L}$	0.03	0.06	0.04	0.33	0.44	0.25

This reduction on allowed Bond can reduce interval of maximum and minimum values. As Another result, the proposed model had no significant effect on reducing brightness and contrast variations. However, this subject will be analyzed more accurately based on the results of Tables 3 and 4. In Tables 3,4 are presented the maximum and minimum of basic colors of traffic lights. But the important Characteristic, which has most roles on proposed algorithm and also shows the percent of variation of basic colors, is D.R. The less D.R can result to better diagnosis. Of course, this Characteristic must use to compare for similar basic colors. The comparison of D.Rs in Table 3 shows that use of new model can lead to narrower band of basic color variation. Also the D.Rs of basic red and green colors show that using of proposed model leads to Improvement except contrast variation condition. The results in Table 4 expresses that generally use of proposed model can lead to high accurate identify. Certainly, D.R would not be usable if it's minimum value is zero.

The D.Rs, which has min or max index, have been selected based on equation (4) and narrowband method. As so the results of Table 3 show, this model would not be used to identify two basic colors (red and green) of red traffic light. In these cases, the proposed algorithm must be executed based on equation (5) and bandwidth method.

5.2 EFFECT OF LAMP TECHNOLOGY

One of the important problems is the use of different technologies for lamp structure. Usually, color and brightness in older lamps are changed with time and applied voltage variation, because they are built based on vacuum tube and filament.



Lamp 1 Lamp2 Lamp3

Fig.15. Selected lamp for simulation

Today new traffic lamps, which have long life, are made based on LED technology. These lamps have disadvantages against the voltage variations as colored changing. Also, LED lamps produce discrete signals which have high peak to peak value because of point Structure. Fig.15 shows some

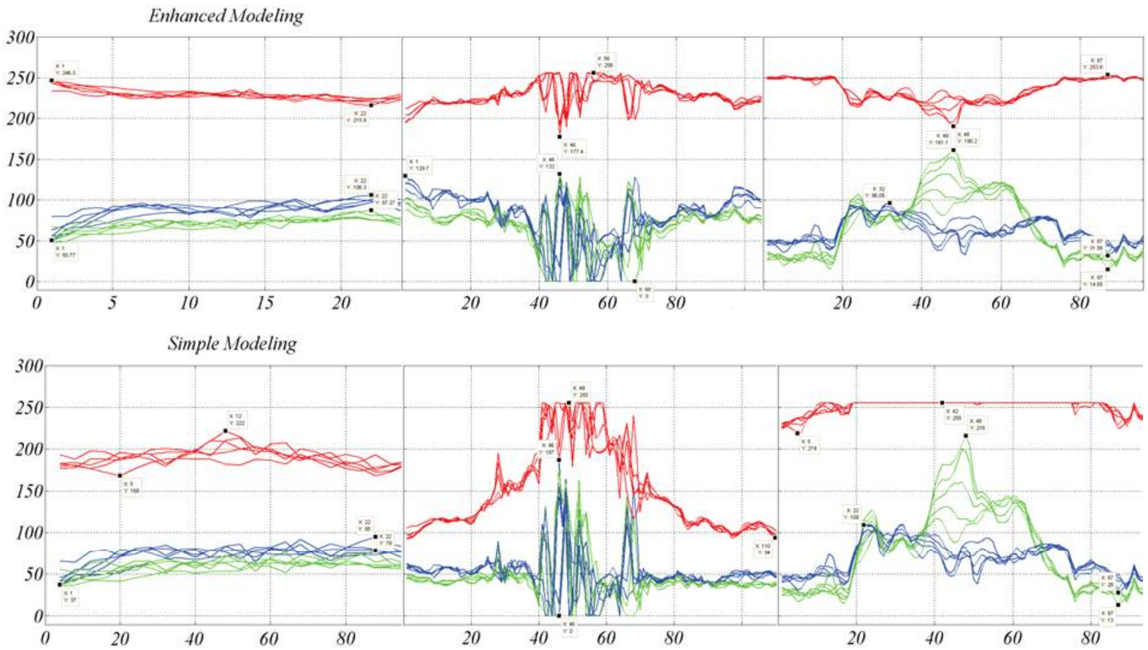


Fig.16. Effect of lamp Technology on image (red)

Table 5. Effect of lamp technology on processing of red light

	Normalized Model			Simple Model		
	Lamp1	Lamp2	Lamp3	Lamp1	Lamp2	Lamp3
$Max(R)_{@R.L}$	246_{max}	256	253	222	255	255
$Min(R)_{@R.L}$	215_{min}	177	190	168	94	219
$D.R(R)_{@R.L}$	0.06	0.18	0.14	0.13	0.46	0.07
$Max(G)_{@R.L}$	87_{max}	132	161	78	187	216
$Min(G)_{@R.L}$	50_{min}	0	15	37	0	13
$D.R(G)_{@R.L}$	0.27	1	0.83	0.35	1	0.88
$Max(B)_{@R.L}$	106	129	96_{ma}	95	187	109
$Min(B)_{@R.L}$	50_{min}	0	31	37	0	28
$D.R(B)_{@R.L}$	0.36	1	0.51	0.44	1	0.59

selected most used lamp as traffic light. Fig.16 shows the result of simulation for the effect of lamp technology on red. Fig.17 shows the result of simulation for the effect of lamp technology on green. Table 5 shows that use of new model decrease D.Rs for overall basic colors. D.Rs of lamp3 has least improvement because of vacuum tube Structure.

Table 6. Effect of lamp technology on processing of green light

	Normalized Model			Simple Model		
	Lamp1	Lamp2	Lamp3	Lamp1	Lamp2	Lamp3
$Max(R)_{@G.L}$	93_{max}	100	138	111	133	231
$Min(R)_{@G.L}$	21	53_{min}	0	13	34	0
$D.R(R)_{@G.L}$	0.63	0.3	1	0.79	0.59	1
$Max(G)_{@G.L}$	182	176_{max}	198	208	233	255
$Min(G)_{@G.L}$	168_{min}	162	155	111	108	40
$D.R(G)_{@G.L}$	0.04	0.04	0.12	0.3	0.36	0.72
$Max(B)_{@G.L}$	186	182_{max}	189	219	233	255
$Min(B)_{@G.L}$	174_{min}	165	152	109	108	40
$D.R(B)_{@G.L}$	0.03	0.05	0.1	0.33	0.36	0.72

The results in Table 6 show, precision of decision making has increased (less D.Rs) for all lamps. In general, it is concluded that the use of enhanced model increases identification of the color of traffic light (red or green) in an intelligent driver assistance systems. The D.Rs, which has min or max index, have been selected based on equation (4) and narrowband method.

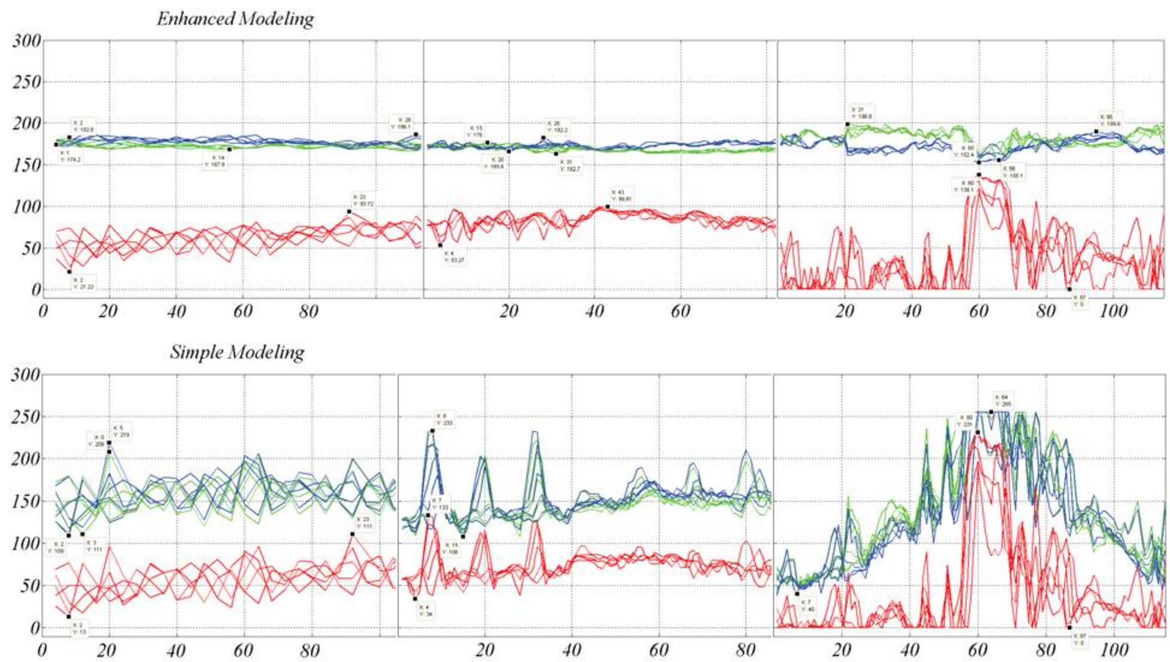


Fig.17. Effect of lamp Technology on image (green)

As so the results of Tables 5 and 6 show, this model would be used to identify.

6. CONCLUSIONS

In this work have been discussed the basic contents of the color variety in traffic lights, day and night conditions, also basic color, intensity, contrast and brightness. So, simple model as benchmark and normalized model have been considered and discussed. The simulation have shown the normalized model has ability to detect most traffic lights under various conditions such as different contrast, brightness, day and night.

AKNOWLEGMENT

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