Normalized Model of Traffic Light Traits Based on Colored Pixels

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ABSTRACT
Nowadays, because of the growing numbers of vehicles on streets and roads, the use of intelligent control systems to improve driving safety and health has become a necessity. To design and implement such control systems, having information about traffic light colors is essential. There are the wide variety of traffic lights in terms of light intensity and color. Therefore it seems that design and practical implementation of these systems with acceptable performance is difficult. The study has been discussed extracting, Categories and the offer of a specific model for color and intensity of traffic signals based on an improved algorithm. The proposed intelligent system will detect traffic lights through images by installing camera instead of using electronic sensors. After capturing, the image sequence will then be analyzed using computer based programs for extracting of lights specifications.

KEYWORDS: Intelligent pixel detection, Traffic light, Normalized pixel.

1. INTRODUCTION

Today, it is well accepted that vision-based camera system are more flexible for traffic parameter estimation [l,2]. In addition to qualitative description of road overcrowding, image measurement can provide quantitative description of traffic status including speeds, vehicle counts, etc. Also Image tracking of moving vehicles can give us quantitative description of traffic flow [3]. Because of development on the Intelligent Vehicle Systems (IVS), many achievements have been gained in the field of vehicle driver assistance system, such as the technology of car anti-collision, road limit detection and pedestrian detection [4,5], etc. Due to many traffic accidents at intersections, IVS for these places has been studied in recent years [6,7]. For example, the traffic light recognition system can be used as assistance system for driver [8], which can create special sound to more attention when they reach an intersection and help him to make a convenient decision. 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. 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. So the main purpose of this paper to provide an acceptable model for traffic lights including red, green and yellow color light with low tolerance in intensity and color. This paper is organized as follows. In Section 2 the basic contents of the image format, Precision, Color Varity in traffic lights are presented. In Section 3 basic color, intensity and also in Section 4 improved modeling, simple model and normalized model are considered. In Section 5 Experimental and simulation results are discussed.

2. IMAGE 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. Their file extensions are bmp, cur, gif, hdf, ico, jpg/jpeg, pbm, pcx, pgm, png, pnm, ppm, ras, tif/tiff, xwd1. Four common formats are intensity, binary, indexed, and RGB.

An intensity images contains a matrix of either eight-bit integers (ranging from 0-255) or 64-bit doubles (ranging from 0.0 to 1.0) that specify the grayscale intensity of each pixel.

Fig.1. Grayscale image

Binary images are black-and-white images (either black or white pixels) composed of matrices of zeros and ones.

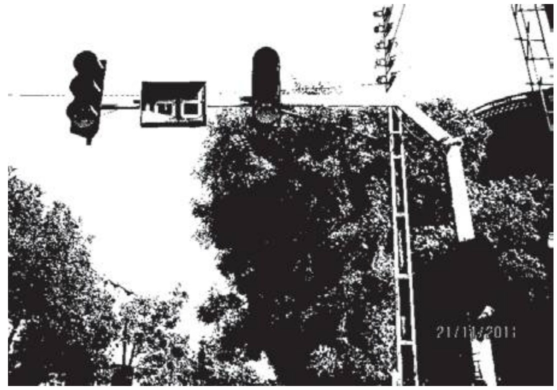


Fig.2. Black-and-white image

An indexed image consists of two matrices, not necessarily equal in size. One matrix is the color map, containing the value for each color represented in the picture. The other matrix, which is the size of the image, contains a number for each pixel. This number corresponds to a color in the color map.

Fig.3. Iindexed image

The fourth format, RGB, uses three matrices. Each matrix is the size of the image and has values corresponding to the red, green, and blue intensities for each pixel.

Fig.4. RGB image

The image processing toolbox contains functions for converting to and from each of these formats.

One of the important characteristic of the image is number of its pixels. With increase pixels, the image can be described in more detail. Commensurate with the type of application of image, it may be enough use of low details image to express a concept. The high resolution can contain additional information that will lead to better conclusions and decisions. Fig.5 shows an image with low pixel size.

Fig.5. Low pixel image (100×133)

Compared with the image shown in Fig.5, the same image with higher number of pixels is shown in Fig.6.

Fig.6. Middle pixel image (500×667)

Fig.7 also shows the picture with very high pixel

Fig.7. High pixel image (1536×2048)

By Comparing of three pictures with different pixel size, can be concluded that despite Fig.7 has more information, compared to Fig.6, but in practice it doesn't increase recognition with the proposed algorithm in this study.

As regards to the used images in this algorithm that are two-dimensional, the run time of the proposed algorithm is calculated based on image pixel as below:

$$T = \boldsymbol{\alpha}.f\left(\text{Image}_{\text{size}}\right) + \boldsymbol{\beta}.g\left(\left(\text{Image}_{\text{format}}\right)\right) \quad (1)$$

Α and β are constant coefficients appropriate to the proposed algorithm and processor Specifications. Functions f and g are interdependent to dimensions of the image and its format. As Simple, the following equation can be used as an approximation of the function f:

$$f\left(\text{Image}_{\text{size}}\right) = W_{\text{Image}}.H_{\text{Image}} \quad (2)$$

Where, H and W are the size of picture as pixel. Also the following equation can be used as an approximation of the function g:

$$\mathbf{g}(\text{Im}\mathbf{age}_{\mathbf{format}}) = \begin{cases} 2 & ; \ \mathbf{for\ MonoChrome} \\ 8 & ; \ \mathbf{for}\ 4\,\mathbf{bitColor} \\ 38 & ; \ \mathbf{for}\ 16\,\mathbf{bitColor} \\ 61 & ; \ \mathbf{for}\ 24\,\mathbf{bitColor} \end{cases} \quad (3)$$

Equation (3) shows that run time of algorithm is extremely increased for a picture with high-bit color map. According to conducted Discussions, it is concluded that for online and proper running the proposed algorithm in a real system and also for better decision-making, it is necessary to select the optimal image in term of quality and accuracy.

3. BASIC COLOR LINES

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. 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. The color vector can be expressed in terms of the three basic colors as follows:

$$\vec{C} = R.\vec{i} + G.\vec{j} + B.\vec{k} \quad (4)$$

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, to model this concept, the color vector is modified as follows:

$$\vec{C} = \tilde{R}.\vec{i} + \tilde{G}.\vec{j} + \tilde{B}.\vec{k} \quad (5)$$

Where $\tilde{R}, \tilde{G}, \tilde{B}$ are as follows:

$$\begin{aligned} \tilde{R} &= R + \Delta R \\ \tilde{G} &= G + \Delta G \\ \tilde{B} &= B + \Delta B \end{aligned} \quad (6)$$

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:

$$\vec{C} = I_0(1+\alpha)\left[\tilde{R}.\vec{i} + \tilde{G}.\vec{j} + \tilde{B}.\vec{k}\right] \quad (7)$$

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. In most color identification systems, to compensate brightness intensity affect, main colors are replaced with new define colors as below:

$$\begin{bmatrix} \hat{R} \\ \hat{G} \\ \hat{B} \end{bmatrix} = \begin{bmatrix} \frac{1}{\tilde{G}} & 0 & 0 \\ 0 & \frac{1}{\tilde{B}} & 0 \\ 0 & 0 & \frac{1}{\tilde{R}} \end{bmatrix} \begin{bmatrix} \tilde{R} \\ \tilde{G} \\ \tilde{B} \end{bmatrix} \quad (8)$$

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. Boundary values of new define colors for red light

	Min	Max
$\hat{R}_{red}$	a_{red}	b_{red}
$\hat{G}_{red}$	c_{red}	d_{red}
$\hat{B}_{red}$	e_{red}	f_{red}

Table 2. Boundary values of new define colors for green light

	Min	Max
$\hat{R}_{green}$	a_{green}	b_{green}
$\hat{G}_{green}$	c_{green}	d_{green}
$\hat{B}_{green}$	e_{green}	f_{green}

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:

$$\begin{aligned} a_{green/red} &= Max(a_1, a_2, ..., a_n) \\ b_{green/red} &= Min(b_1, b_2, ..., b_n) \\ &\vdots \\ f_{green/red} &= Min(f_1, f_2, ..., f_n) \end{aligned} \quad (9)$$

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:

$$\begin{aligned} a_{green/red} &= Min(a_1, a_2, ..., a_n) \\ b_{green/red} &= Max(b_1, b_2, ..., b_n) \\ &\vdots \\ f_{green/red} &= Max(f_1, f_2, ..., f_n) \end{aligned} \quad (10)$$

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.

4. IMPROVE THE MODELING

In practice, the use of different models leads to different results. Of course each of them have 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, at first a simple model is presented based on equation (5), so the simulation results will be used as comparison benchmark. Then the improved model is proposed and deficiencies of the initial model will be fixed until the prediction error and identify become minimum.

4.1 SIMPLIFIED MODEL

A simple model, which often it is used in image processing, is the comparison of base color and target spectrum. In this research the $\tilde{R},\tilde{G},\tilde{B}$ signals are extracted of the base color based on equation (5) and the Algorithm 1. Then Tables 1 and 2 are completed based on this signal values. To increase the detection efficiency, in Algorithm 1 have been used of the five middle lines of lights image. Finally, based on the spectra curve of color signals, the maximum and minimum values are calculated and so their specifications are given in the table.

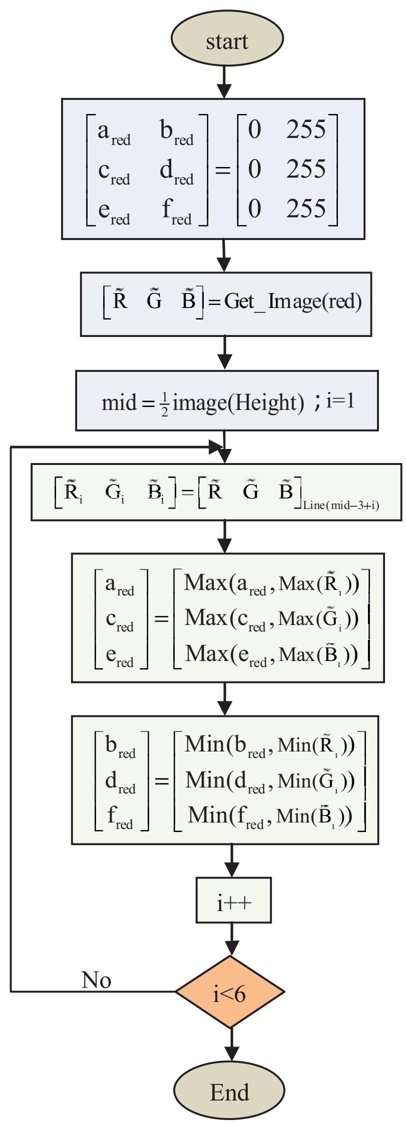
4.2 NORMALIZED MODEL

In the last section, it was said that by providing equation (8) and define the new colors, the effect of background light intensity are compensated. The conceptually, the proposed model can be used. But in practice, when one of the main signal ($\tilde{R},\tilde{G},\tilde{B}$) 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 equation (8) has been replaced with the following equation.

$$\begin{bmatrix}\hat{R}\\ \hat{G}\\ \hat{B}\end{bmatrix} = \frac{255}{|\tilde{C}|}\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix}\begin{bmatrix}\tilde{R}\\ \tilde{G}\\ \tilde{B}\end{bmatrix} \qquad (11)$$

$$|\tilde{C}| = \mathrm{sqrt}(\tilde{R}.\tilde{R} + \tilde{G}.\tilde{G} + \tilde{B}.\tilde{B}) \qquad (12)$$

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 model (5) is also resolved.



Algorithm 1. The process of color specifications extraction based on simple model

Now based on improved model, modified algorithm is proposed by replacing of function $\begin{bmatrix}\tilde{R}_i & \tilde{G}_i & \tilde{B}_i\end{bmatrix} = \begin{bmatrix}\tilde{R} & \tilde{G} & \tilde{B}\end{bmatrix}_{Line(mid-3+i)}$

With new define function as below:

$$\begin{bmatrix}\hat{R}_i & \hat{G}_i & \hat{B}_i\end{bmatrix} = \frac{255\begin{bmatrix}\tilde{R} & \tilde{G} & \tilde{B}\end{bmatrix}_{Line(mid-3+i)}}{sqrt(\tilde{R}.\tilde{R}+\tilde{G}.\tilde{G}+\tilde{B}.\tilde{B})}$$

The new algorithm has been created based on signals $\hat{R}, \hat{G}, \hat{B}$ and improved model. By run of this algorithm, new colour specifications are extracted according to Tables 1 and 2.

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.

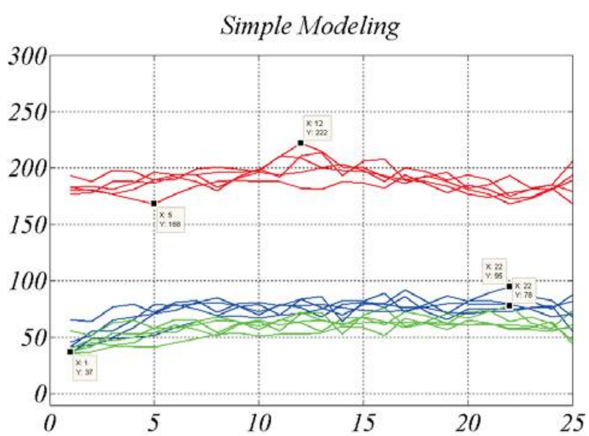


Fig.8. Simple Modeling of Normal Image (red)

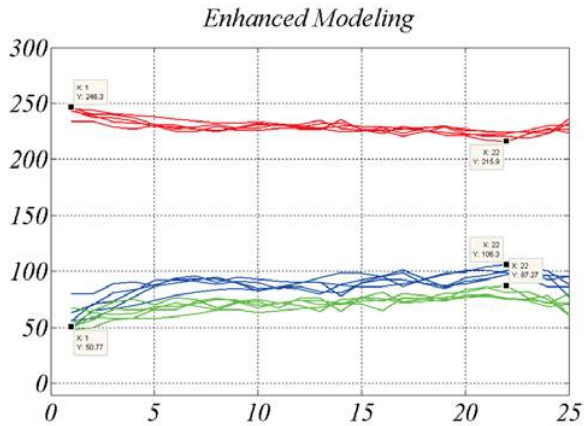


Fig.9. Enhanced Modeling of Normal Image (red)

The Selected and used images to execute algorithm are captured by cameras on several different modes of lights. The out results of the proposed algorithm, in two simple and new models, are presented in Figs. 8-11. Figs. 8 and 9 show the image of red light in normal status. Figs. 10 and 11 show the image of green light in normal positions.

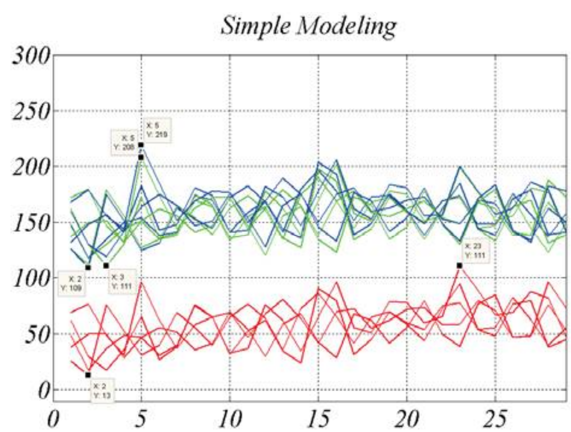


Fig.10. Simple Modeling of Normal Image (green)

The results of the simulations in Figs. 8-11 show that in general, the proposed model can reduce the allowed Bond of basic colors. This reduction on allowed Bond can reduce interval of maximum and minimum values. However, this subject will be analyzed more accurately based on the results of Tables 3 and 4.

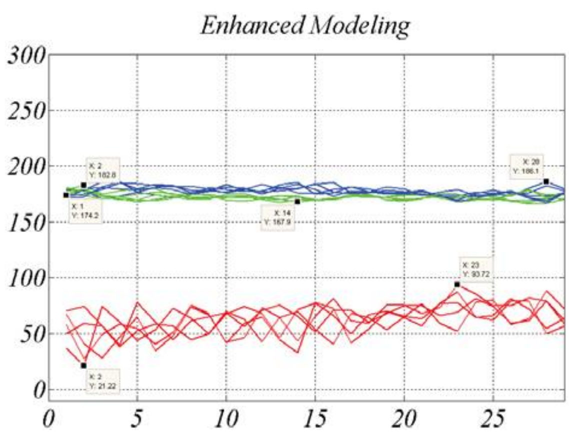


Fig.11. Enhanced Modeling of Normal Image (green)

In Tables 3 and 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.

Table 3. Effect of Modeling type on image processing for red light

	Enhanced Model	Simple Model
$Max(R)_{@R.L}$	246	222
$Min(R)_{@R.L}$	215	168
$D.R(R)_{@R.L}$	0.06	0.13
$Max(G)_{@R.L}$	87	78
$Min(G)_{@R.L}$	50	37
$D.R(G)_{@R.L}$	0.27	0.35
$Max(B)_{@R.L}$	106	95
$Min(B)_{@R.L}$	50	37
$D.R(B)_{@R.L}$	0.36	0.44

Table 4. Eeffect of Modeling type on image processing for green light

	Enhanced Model	Simple Model
$Max(R)_{@G.L}$	93	111
$Min(R)_{@G.L}$	21	13
$D.R(R)_{@G.L}$	0.63	0.79
$Max(G)_{@G.L}$	182	208
$Min(G)_{@G.L}$	168_{min}	111
$D.R(G)_{@G.L}$	0.04	0.3
$Max(B)_{@G.L}$	186	219
$Min(B)_{@G.L}$	174	109
$D.R(B)_{@G.L}$	0.03	0.33

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. 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 (9) 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 (10) and bandwidth method.

6. CONCLUSUIONS

In this work have been discussed the basic contents of the image format, Precision, Color Varity in traffic lights also basic color, intensity. So, simple model as benchmark and normalized model have been considered and discussed. The results of simulation and execution of proposed algorithm have shown the new model with proposed algorithm has ability to detect most traffic lights under various conditions.

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