World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:10, No:1, 2016

Day/Night Detector for Vehicle Tracking in Traffic Monitoring Systems

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***Abstract*—**Recently, traffic monitoring has attracted the attention of computer vision researchers. Many algorithms have been developed to detect and track moving vehicles. In fact, vehicle tracking in daytime and in nighttime cannot be approached with the same techniques, due to the extreme different illumination conditions. Consequently, traffic-monitoring systems are in need of having a component to differentiate between daytime and nighttime scenes. In this paper, a HSV-based day/night detector is proposed for traffic monitoring scenes. The detector employs the hue-histogram and the value-histogram on the top half of the image frame. Experimental results show that the extraction of the brightness features along with the color features within the top region of the image is effective for classifying traffic scenes. In addition, the detector achieves high precision and recall rates along with it is feasible for real time applications.

***Keywords*—**Day/night detector, daytime/nighttime classification, image classification, vehicle tracking, traffic monitoring

I. Introduction

RECENT years have witnessed a surge of interest in traffic monitoring systems. There is an urgent need for robust and reliable traffic monitoring systems to improve traffic control and management [1]. Thanks to the availability of low-cost hardware, as well as continuous progress in algorithmic research, computer vision has become a promising base technology for traffic monitoring systems [2]. Since vision sensors (such as video cameras) provide more information than the conventional sensors (such as loop detectors, and radar sensors), attention is now being focused on vision-based traffic monitoring systems. The employment of computer vision in traffic monitoring helps to reduce the implementation cost and to provide comprehensive traffic information such as the position of the vehicles on the lanes, their speeding status, and their travel trajectory [3]. In order to extract this type of information, it is first necessary to separate moving vehicles from the scene [4]. In this way, vehicles can be counted, and their trajectories and speeds can be estimated. Furthermore, by using these parameters, it is possible to classify the traffic state into safe, congested, or dangerous situations.

Lately, numerous research projects aiming to detect and track vehicles have been carried out in terms of measuring traffic performance [2], [3], [5]-[8]. The evaluation of traffic conditions can be represented by a set of parameters [1] including traffic flow rate, average traffic speed, queue length, and traffic density. Most of the proposed methods used to extracted traffic condition information are based on vehicle detection and tracking techniques. In these systems, robust and reliable vehicle detection and tracking is a critical step [1].

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Unfortunately, despite its undeniable interest, computer vision is not heavily used in traffic monitoring applications, since existing systems still suffer from poor reliability and unbalanced accuracy [5]. The reason is that computer vision systems are much affected by weather and illumination conditions. Not every system is able to work unattended 24 hours. Many systems cannot operate at night or in the periods between day and night. Therefore, the variety of light conditions of outdoor scenes is one of the major difficulties of automatic traffic monitoring [4]. Tracking systems that are work under daytime and nighttime cannot be approached with the same techniques, due to the extreme different illumination conditions. Some daytime traffic monitoring systems are built upon specific motion detection approaches to detect and track vehicles. However, using the same approach to detect vehicles at night has never produced desirable results. Nighttime vehicle tracking is always a complicated area within any traffic monitoring system due to the weak illumination and headlights reflection on the ground [3]. Consequently, there is an urgent need to develop efficient techniques to differentiate daytime/nighttime video frames in order to invoke the suitable tracking technique. In this paper, a HSV-based day/night detector is proposed for traffic monitoring scenes. The basic idea of the detector is based on employing two discriminant features (color feature and brightness feature) to differentiate day time and nighttime scenes. These two features are analyzed on HSV (Hue, Saturation, and Value) color space. The detector performs a thresholding process on the hue-histogram and the value-histogram constructed from the top half of the image frame.

For clarity of presentation, the paper is organized as follows: Section II explores the related work found in the literature concerning daytime/nighttime image classification. Section III presents the proposed day/time detector in detail. Section IV discusses the experimental results and the performance evaluation of the proposed detector. Finally, the conclusion is presented in Section V.

II. Related Work

Generally, image classification forms an important tool for analyzing digital images. In the literature, day/night image classification has received the attention of many computer vision researchers. Changing scene illumination is one the most critical issues in computer vision applications especially in vehicle detection and tracking [9], [10]. The absence of light makes vehicles not clearly visible. Hence, the algorithms used for daytime motion detection cannot be applied at night [11], [12]. In the nighttime, under bad-illuminated condition, the obvious features, which are effective in daytime, become invalid in nighttime environment. The image has very low contrast and a weak light sensitivity. Detecting the time of day and lighting conditions plays an important role especially for outdoor environments. Many algorithms have been proposed to address this problem. In [13], Wang and Hu present a method for hierarchical image classification using Support Vector Machines (SVMs). The image is classified with hierarchical semantics into day, night, and sunrise/sunset; close-up and non-close-up; indoor and outdoor, city and landscape classes. The classification is performed through a combination of selected features. They use RGB color histogram as the low-level feature in classifying image into day and night. However, this might wrongly classify some nighttime images with multiple cars or other lights. Empirically, approaches that adopt color histogram information as a feature vector in daytime/nighttime image classification have produced limited improvements in performance [14].

Chen et al. [15] present a method to discriminate night images from daytime images. In their method, they employ the rule of thirds about the composition of images. They divide the image into 9 equal parts with two equally-spaced horizontal lines and two equally-spaced vertical lines. The histogram of value component within the top one-third region of an image is calculated as local color feature. After thresholding, a histogram with two bins is calculated as an input to K-means clustering. The clusters are obtained by setting K as two. Finally, the cluster with higher value in a smaller bin is considered as the night scene.

Saha et al. in [16], [17] present a day night classification of images using thresholding on HSV histogram. Their approach is based on the fact that the sources of scene illumination during day and night are fundamentally different with distinctive spectral properties. During nighttime, under artificial ambient lighting conditions, there is a clear lack of color information in the blue and green spectrum. By suitable thresholding along the hue and value axes, reliable classification of images as daytime or nighttime is possible. In images with low ambient lighting, the hues are mostly in the red-yellow range while in the presence of adequate sunlight, images tend to have more contributions from blue- and green-color regions.

III. Purposed Day/Night Detector

During vehicle tracking process, the external environment around the moving vehicle varies constantly and significantly. Nighttime images of a scene from a surveillance camera have lower contrast and higher noise than their corresponding daytime images of the same scene due to low illumination. Hence, it is difficult to use only one particular feature or method to detect moving vehicles under these different environments. Therefore, there is a need to determine whether the current image is a daytime image or a nighttime image according to the lightness of the image to select the suitable detection method for the current environment.

In this section, a day/night detector is presented for vehicle tracking in traffic monitoring applications. The detector is inspired from the technique presented by Saha et al. in [16], [17]. Saha's technique is a general technique for day/night classification of images using thresholding on HSV histogram. Originally, it targets the still images not image sequences (video). When considering image sequences, real time processing is an important factor especially if real time tracking is targeted. Our proposed modification to Saha's technique is based on an observation proven by [15]. They experimentally deduce that there is no need to process the whole image to classify it into daytime or nighttime. However, the brightness within the top one-third region of the image contains color features enough to discriminate night images from others. Accordingly, we modify the Saha's technique so that it is applied on the top half of the image frame instead of the whole image frame. Fig. 1 shows a comparison of H-histogram and V-histogram results between different frames and their top half images. It noted that the results obtained on the top half keep the general properties of both H-histogram and V-histogram. Hence, it is sufficient for the detector to just operate on the upper half region instead of the whole image. Reducing the processing area has an important impact on the processing time since the classification is performed faster. This modification makes the proposed day/night detector convenient for online real time processing.

In human perception, the darkness and brightness are commonly used for recognition of daytime and night [18]. Similarly, the basic idea of the detector is based on employing two discriminant features: color feature and brightness feature. For color feature, nighttime images suffer from lack of color information compared to daytime images, specifically in the blue and green regions of the spectrum [16], [17]. This is due to the ambient illumination in nighttime images is largely from artificial sources, while the ambient illumination in daytime images is largely from natural light. In other words, nighttime images tend to be largely consisting of pixels with hues extensively in the red and yellow regions of the spectrum, while ordinarily exposed daytime images tend to have a significant number of pixels with hues extensively in the green and blue regions of the spectrum. Concerning brightness feature, daytime images tend to have a relatively great number of pixels, which are sufficiently bright or light. On the other hand, nighttime images tend to have a relatively great number of pixels, which are relatively dark or not sufficiently bright or light. Accordingly, the detector takes advantage of a combination of these parameters (i.e., pixel hue and brightness or lightness) to distinguish daytime and nighttime images.

Actually, all input video frames are encoded in the RGB color space. Therefore, it would be better to work with RGB since no conversion is needed. However, the RGB color space is inappropriate for most classification tasks based on color. The luminance information is more important to the human perception than the Chroma [19]. Different illumination will change the perceived color. This fact has to be considered when using a color space where luminance is not directly available, rather being a combination of all three channels. Accordingly, in our proposed detector, color feature and brightness feature are analyzed on HSV color space rather than RGB color space. The HSV color space represents hue, saturation and color value (brightness) in a hexagonal cone shape as shown in Fig. 2. The angle is given by the hue. The distance from the center of the cone is given by the saturation and the vertical position is given by the value.

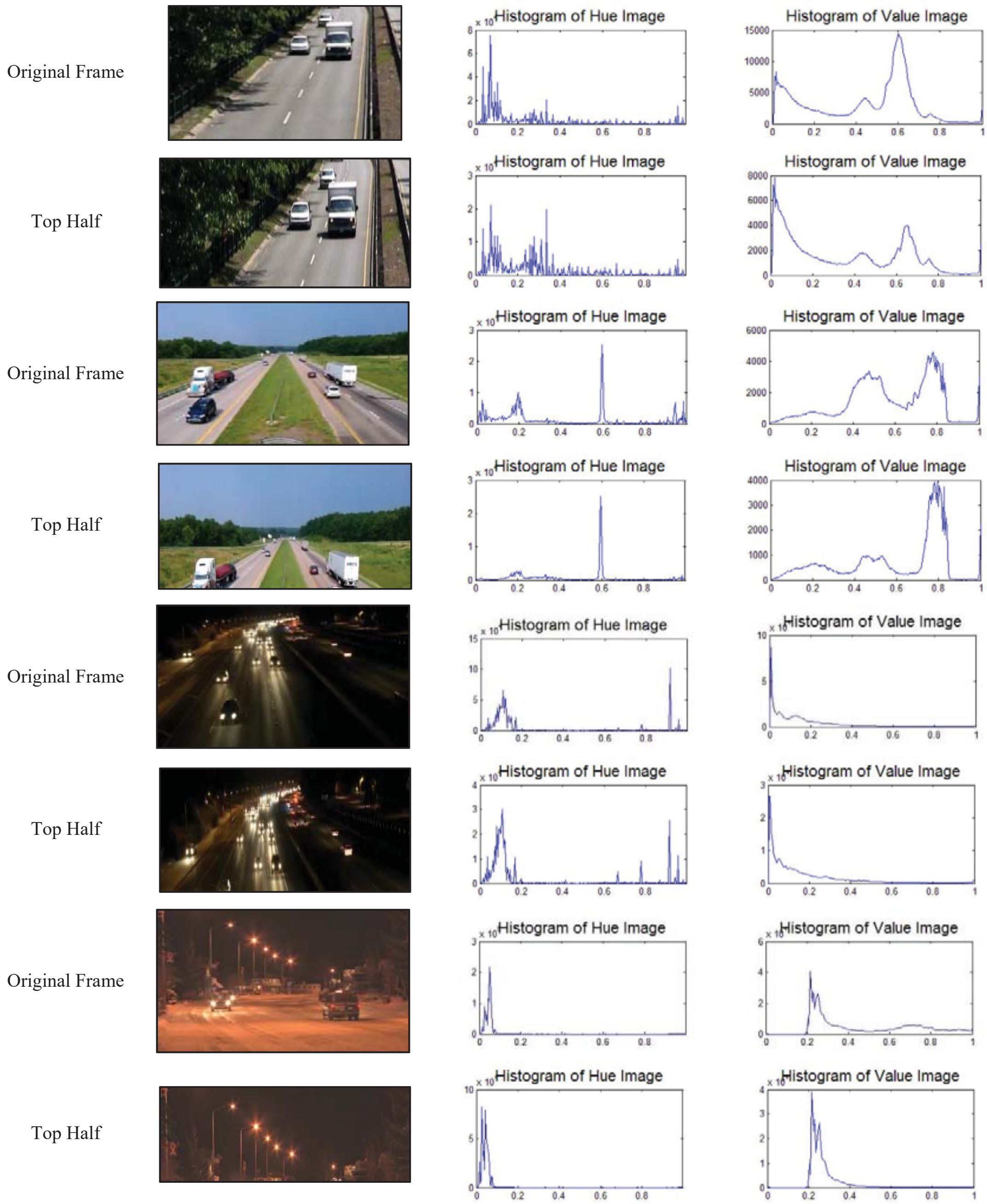


Fig. 1 Comparative H-Histogram & V-Histogram of original frame and its top half image for different daytime / nighttime traffic videos

Fig. 3 shows the block diagram of the proposed day/night detector. The detector first extracts top half of the image frame and converts it from RGB color space to HSV color space. Then, a histogram is calculated for the H and V components, by statistically binning the values of the respective components for the pixels of the image. Using H-histogram, the detector calculates the first parameter(n_H), which represents the amount of pixels in the image that are sufficiently red or yellow. That is, it counts all the pixels falling in red and yellow color hue range. As stated in [16], when the hue or H-component is on a scale from zero to 360, the red and yellow color hue range obtained from experiments are approximately less than 72 and greater than 288 as shown in Fig. 4. In other words, the thresholds essentially specify the lower 20% and upper 20% of the hue scale, i.e., the regions of the spectrum that are sufficiently red or yellow.

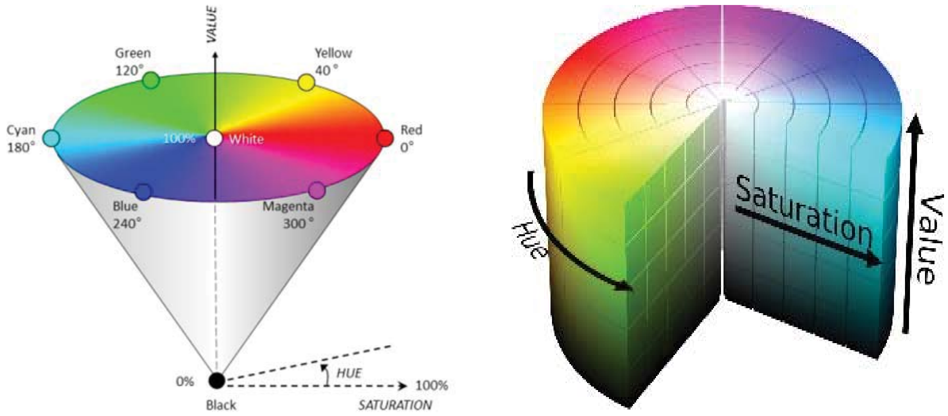


Fig. 2 HSV color space

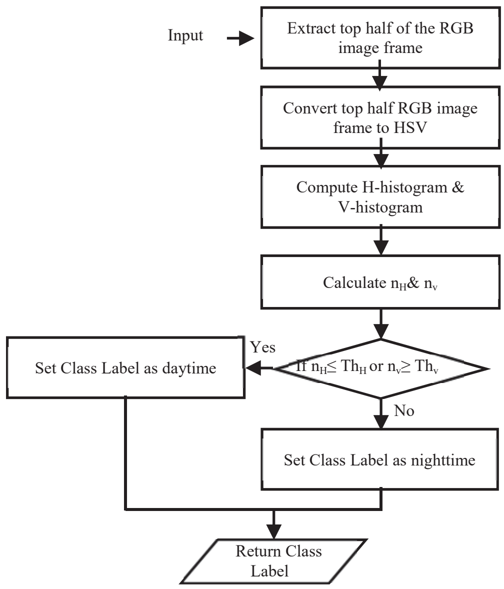


Fig. 3 The block diagram of the proposed day/night detector

Similarly using V-histogram, the detector determines the second parameter (n_V) which represents the amount of pixels in the image that are sufficiently light or bright. That is, experimentally when the V-component is on a scale from zero to 255, the detector counts all the pixels having a V-component above 150. Consequently, if (n_H) is less than a determined hue count threshold (TH_H) or if (n_V) is substantially greater than a determined value count threshold (TH_V), then the image is classified as a daytime image; otherwise if (n_H) is above (TH_H) and (n_V) is below (TH_V), then the image is suitably classified as a nighttime image.

IV. Experimental Results

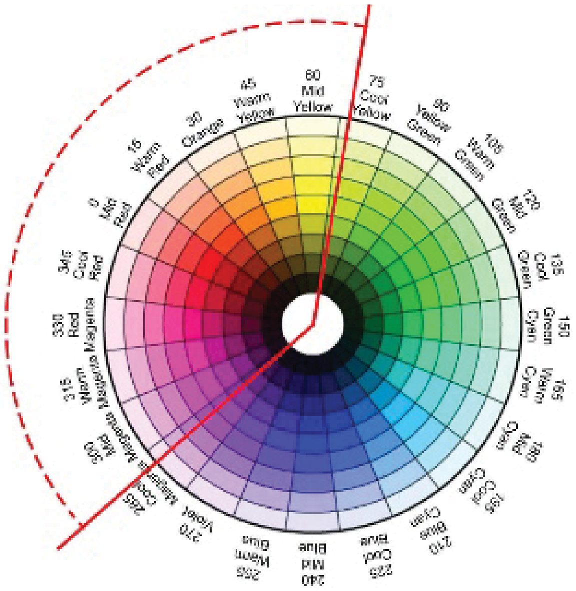
The performance of the day/night detector is evaluated with a large and varied collection of daytime and nighttime traffic monitoring videos. These video are the datasets used to evaluate the vehicle tracking techniques in [6], [20]-[22]. The videos represent different times during day and night. Some example frames are shown in Fig. 5. The class label of the tracking environment for each video sequence is manually predetermined whether it is daytime or nighttime. Then, each frame is passed to the detector and the correctness of the detector to classify the scene environment is evaluated. The standard classification metrics (precision and recall) are measured for each class using the following formulas [23]:

$$\text{Precision (P)} = \frac{\textit{No of correctly classified scenes}}{\textit{No of scenes classified as the corresponding class}}$$

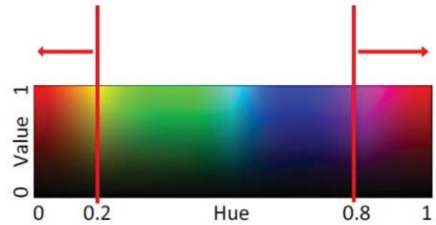
$$\text{Recall } (R) = \frac{\textit{No of correctly classified scenes}}{\textit{No of actual scenes of the corresponding class}}$$

where precision is the proportion of video scenes placed in the class that are really in the class, while recall is the proportion of video scenes in the class that are actually placed in the category.

It should be mentioned that all the experiments have been performed on a 2.27GHz Intel Core i5 PC with 4GB memory, running under Windows 8 Enterprise. The methods are coded using MATLAB 8.1.0.604 (R2013a). Table I shows the confusion matrix of day/night image detector. Each row represents the number of frames in the actual class and each column denotes the classification results. For example in the second row, 6921of the “nighttime” frames are classified correctly while 409of the frames are misclassified as “daytime”. As the table indicates, the total numbers of test frames are 16503. The total numbers of correctly classified frames are 15806, while the total numbers of incorrectly classified frames are 697. For “daytime” class, the detector achieves a recall and precision equal to 96.9% and 95.6% respectively. Also for “nighttime” scenes, it achieves a recall and precision equal to 94.4% and 96%% respectively. Table II shows the evaluation results details of daytime/nighttime detector. As the table shows, the detector recall is approximately good. Slightly better classification performance is achieved with the daytime compared with the nighttime. Fig. 6 shows a representative subset of the misclassified daytime and nighttime frames, respectively. The misclassified daytime frames, shown in Fig. 6 (a) are due to the existence of a very dark sky or being captured under very cloudy conditions. The same thing may happen for night scenes when they are taken during dusk. The two cases are ambiguous even to a human observer. However, most of the misclassified nighttime frames in Fig. 6 (b) are urban traffic scenes in downtown where there are many street lamps, illuminated advertisements, banners, flashing signs, florescent tubes inside office buildings, displays/ screens for information or advertisement purposes, and floodlighting or traffic headlights or taillights. The existence of these elements makes the illumination of the scene as if it is in daytime. Nevertheless, the misclassified frames are very small and they do not affect the whole performance of the detector. This lighting environment is rarely available in highway road traffic scenes, where the only light source available is the streetlights.



(a) Hue angle color wheel



(b) Value–Hue color chart at S = 1

Fig. 4 Red and yellow color hue range

(a) Daytime sample frames

(b) Nighttime sample frames

Fig. 5 Sample frames from test traffic monitoring videos

TABLE I
CONFUSION MATRIX OF DAYTIME/NIGHTTIME DETECTOR

	Daytime	Nighttime	Recall
Daytime (9173)	8885	288	96.9%
Nighttime (7330)	409	6921	94.4%
Precision	95.6%	96%	

In the next experiment, a comparison is made between the proposed detector and two recent methods: Saha's technique [16], [17], and Chen's technique [15]. The two techniques are coded in order to evaluate their performance on the same test set. Table III summarizes the comparative results. As it can be seen from the table, both the precision and recall of the proposed detector is comparable with the precision and recall achieved by Saha's technique. The main reason behind the superiority of Saha's technique in terms of precision and recall is that it calculates the HSV histogram overall frame while our proposed technique works only on the upper half of the frame. However, the difference in the achieved precision and recall between the two methods is so small. At the same time, Chen's technique achieves low precision and recall when compared with the other two methods. This is because it depends on applying the thresholding process on the V-component and it ignores the H-component. That is, it depends on the scene brightness and ignores the scene color information. Combining color feature with brightness feature improves the classification precision. Moreover, when considering the average processing time for each frame, we found the superiority of Chen's technique since it works only on top one-third region of the image and it calculates only V-histogram. However, Saha's technique takes a processing time almost twice the time taken by the proposed detector. To sum up, when taking into consideration both the detection precision and the processing time along with the real time constrain imposed in tracking process, the proposed day/night detector outperforms the other techniques in differentiating between the daytime and the nighttime video scenes.

TABLE II
EVALUATION RESULTS OF DAYTIME/NIGHTTIME DETECTOR

No	Video Sequence Name	No of Frames	Environment State	Correctly Detected Frames	Recall
1	bungalows	1680	daytime	1670	99%
2	highway	1700	daytime	1700	100%
3	highway I	440	daytime	426	97%
4	highway III	2227	daytime	2200	99%
5	Video 1	302	daytime	302	100%
6	Video 2	258	daytime	258	100%
7	Video 3	416	daytime	416	100%
8	City Traffic _ Seoul _ South Korea	975	daytime	863	89%
9	Champs-Elysées _ Paris _ France	550	daytime	487	89%
10	Champs-Elysées _ Advent _ France	625	daytime	563	90%
11	Above LA Highway Traffic	379	Nighttime	324	85%
12	Highway LA Overpass	332	Nighttime	318	96%
13	LA Highway Bend Traffic	404	Nighttime	404	100%
14	LA Highway Bend	394	Nighttime	394	100%
15	Slow Moving 101 North Traffic	530	Nighttime	530	100%
16	Slow Night Commute In Cali	311	Nighttime	310	100%
17	Cars On LA Highway	653	Nighttime	650	100%
18	Night Time Traffic on Snowy	812	Nighttime	779	96%
19	Slow Moving Los Angeles	586	Nighttime	533	91%
20	Nighttime Traffic in Aspen	557	Nighttime	488	88%
21	Roadway Traffic at Night	599	Nighttime	502	84%
22	Seattle Airport Control Tower	752	Nighttime	726	97%
23	Taxi Cabs and Traffic in Times sq.	490	Nighttime	490	100%
24	Traffic on Busy Times Square Street	531	Nighttime	473	89%

(a) Misclassified daytime frames as nighttime

(b) Misclassified nighttime frames as daytime

Fig. 6 Examples of misclassified frames

TABLE III
COMPARATIVE RESULTS OF THE PROPOSED DETECTOR AND SOME OF STATE OF ART METHODS

	Saha's technique		Chen's technique		Proposed Detector	
	daytime	nighttime	daytime	nighttime	daytime	nighttime
Recall	97.3%	95	89.1%	86.2%	96.9%	94.4%
Precision	95.8%	96.2%	90.2%	88.7%	95.6%	96%
Average processing time for each frame	17.6 ms		8.4 ms		9.2ms	

V. Conclusion

In this paper, a day/time detector is proposed to recognize the tracking environment whether it is daytime or nighttime. This allows the tracking system to launch the suitable technique. The basic idea of the HSV-based day/night detector is based on employing two discriminant features (color feature and brightness feature) to discriminate daytime and nighttime scenes. This is done by analyzing the HSV color space of the upper half of the image frame instead of the whole frame. Then, a thresholding process is performed a on the H-histogram and the V-histogram.

Extensive experiments are conducted to evaluate the proposed detector. The results show that the proposed detector achieves high precision and recall for both daytime and nighttime scenes. Moreover, it achieves a feasible average frame processing time, which makes it suitable for real time application.

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