Indonesian Journal of Electrical Engineering and Computer Science
Vol. 29, No. 2, February 2023, pp. 890~898
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v29.i2.pp890-898

Evaluation of object detectors in recognizing crossroad intersection triangle sign

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Article Info

Article history:

Received Jul 12, 2022
Revised Oct 8, 2022
Accepted Oct 18, 2022

Keywords:

Cascade object detector
Crossroad intersection triangle sign
Precision
Speed up robust features
labeling
Training

ABSTRACT

Variations in perspective, illumination, occlusion, motion blur, and weatherworn degeneration of signs could all be crucial in identifying road signs. The goal of this work is to evaluate the technique's performance for image processing in detecting and recognizing triangle sign, as well as determine the optimum threshold value range for doing so. Cascade object detector and speed up robust features (SURF) are tested here to detect and recognize the triangle sign through Palestine and Al-Rubaie streets during daytime in Baghdad city. Results showed the effectiveness of cascade object detector over SURF in detecting triangle sign with precision lies in the range (0.98-0.9) and (0.54-0.46) for cascade and SURF techniques respectively. At Final, the highest precision was recorded at fifteen and twenty-five threshold values for cascade and SURF approaches respectively.

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1. INTRODUCTION

Based on computer vision and pattern recognition, traffic sign detection (TSD) and recognition are being studied for several purposes, like autonomous and assisted driving. The ability to recognize traffic signs helps a driver to be alerted to potentially dangerous circumstances and inappropriate conduct [1]. In any object detecting system, there are two key processes. The first is detection, and the second is recognition. Based on colors, the traffic signs are categorized by the use of the big database obtained by training the video after detection. As a result, training is an essential component of any object detection system. The color distinguishes the road signs from each frame in the detection stage. The traffic signs are classified using a large database created by training the footage after color detection took place [2]. As a result, any object detection system must include training as a component. Developing a system that can independently navigate a vehicle becomes a more fascinating topic. For monitoring the environment, the vehicle is outfitted with sensors such as radar, laser, GPS, and camera. The most widely used method for developing such a system is to combine a camera with computer vision technology. In comparison to other sensors, a camera gives a lot of information and is a low-cost instrument [3].

A degraded decision tree with rising complexity stages is referred to as a cascade object detector and SURF detector. The first stage (training stage) consists of a classifier that is used to recognize practically all objects of interest before triggering the evaluation of the system. The second-stage classifier, which has been tweaked as well achieves a high rate of detection. If the outcome is favorable, the third stage is initiated, and so on. If there is a negative consequence at any moment, the sub-window will close and promptly reject [4].

In traffic-sign detection, several problems may be involved like variations in perspective, illumination, occlusion, motion blur, and weatherworn deterioration of signs [5]. Some of the challenges that drivers confront are during time day, overcast weather day, and poor visibility [6]. The majority of the time, drivers are unaware of traffic signs. However, one of the biggest causes of accidents is negligence on the part of the drivers. On many occasions, accidents happen when the weather is terrible or when people are intoxicated. Accidents have become a big social problem in recent years. Every day, human lives become more and more unpredictable. The need to create an automatic system to cope with traffic congestion is critical [7].

Based on the observation filter, Savitha and Ramesh [8] proposed multi-observational detection and tracking approach (MoDTA) and tested it on different groups of the upper motor neuron (UMN) dataset. Their model produced a value for the area under the curve equal to 99.62%. Razali *et al.* [9] improved the model of food recognition by the use of a combination method of fuzzy encoding and maximum pooling techniques. Their results showed a noteworthy classification performance in comparison with the traditional approaches. Utomo *et al.* [10] used integration of digital image processing technique with sobel canny edge detector to estimate the instance water levels in the real world. The experiment showed the technique's validity in detecting an immersing object and the whole system at final can be used in future for flood disasters. Many researchers adopted various techniques for detecting and recognizing road signs. Bali *et al.* [11] used a single shot detector (SSD) in addition to a faster region convolutional network (Faster R-CNN) upon small traffic lights. Their results achieved a higher value of mean average precision which was equal to 94% for faster R-CNN ResNet50 V1 in comparison to SSD ResNet50 FPN V1.

A basic image processing technique for automatically recognizing two different traffic signs-stop signs and speed signs in an image used by Revathi *et al.* [12]. The proposed method detects the location of the sign in the image and the processing methods included RGB domain thresholding, dilation of an image, mapping of the region, and thresholding. The algorithm recorded an accuracy of over 80%. Mohammad *et al.* [13] used a driver assistance system located on board the vehicle monitor to detect the traffic signs, alert the driver about the environment ahead and help in preventing possible accidents. They used the lucy-Richardson filter to pre-process the corrupted frame and to identify and extract potential symbols, they performed eight connected component analyses with a multi-class support vector machine (SVM) classifier to classify them [13]. A system for large-scale automatic traffic sign recognition and mapping is used by Chigorin and Konushin [14]. The system trained on synthetically generated data and did not require labor-intensive labeling of the training data. The authors evaluated the proposed system on the Russian traffic sign. Their result showed that the usage of a deep neural network upon cascade detector yielded an improvement to the hit rate of the detector on average by 7% in comparison to cascade trained on dipole features.

The researchers Shahbaz *et al.* [15] used a speed up robust features (SURF) object detector in recognizing different samples of road signs through daylight. Results showed that the highest precision occurs in the threshold range (20-25) for all used signs except for the cross sign symbol which witnessed its highest precision under lower levels of the threshold value (i.e 5). Other researchers like Wang *et al.* [16] supposed one of the most essential functions in intelligent transportation; the advanced driver-assistance system (ADAS). ADAS outperforms traditional modes of transportation in terms of passenger safety. Their results showed that color recognition of the traffic cones was extremely accurate, with success rates of 85%, 100%, and 100% for red, blue, and yellow cones, respectively. Additionally, by combining color and depth photos, 90% of the traffic cones' distance was correctly perceived [16]. Wali *et al.* [17] introduced a method that is insensitive to the changes in lighting, rotation, translation, and viewing angle, and yielded a short processing time with a low false-positive rate. The utilized system which included RGB color segmentation and form matching, as well as a(SVM classifier, yielded good results in terms of accuracy (95.71%), false-positive rate (0.9%), and processing time (0.43 s). The system's accuracy was good, and its processing time is relatively short, which will be useful for identifying traffic signs, particularly on Malaysia's highways.

The determination of vehicle speed is very important, especially on city streets, highways, and external roads. As the process of detecting traffic signs helps drivers take the right decision to reduce road risks and avoid violations. The speed in the internal streets and highways in the city of Baghdad is limited so that it does not exceed 60 km/h or 100 km/h respectively, so the traffic signs installed on the sides of the roads when the vehicle is traveling near it will be well and seen by the driver with a distance of up to 100 meters or less. For the car to move this distance, it takes about 3s or 6s respectively, or more. So the driver must decide within this time. The proposed system in this study uses a video recording system with a frame rate equal to 30 frames per second, meaning that the number of frames that can be recorded during a period of 3s or 6s are 90 frames or 180 frames, respectively. Therefore, the proposed system must detect at least one road sign reliably and correctly during this time, so, the correct detection and identification of the traffic sign in at least one of the 90 consecutive frames is sufficient for the driver to take the right decision. Therefore, any confirmed and correct detection of the traffic sign every 3 seconds will be sufficient and appropriate for drivers to take the right decision. The presented work aims to detect triangle road sign by adopting a cascade object detector in addition to speed up robust features (SURF) under different car speeds throughout the daytime to investigate the best circumstances for reaching the goal of obtaining robust road sign identification.

2. THE COMPREHENSIVE THEORETICAL BASIS

The cascade object detector system comes with several pertained classifiers for detecting frontal faces, profile faces, noses, eyes, and the upper body. However, these classifiers are not always sufficient for a particular application [18]. A cascade of classifiers is a degenerated decision tree made up of stages of increasing complexity, with the first stage training a classifier to detect almost all objects of interest (traffic signs) and then triggering the evaluation of the second stage classifier, which has also been adjusted to achieve a high detection rate [4]. Each sub-window is subjected to a series of classifiers. The number of sub-windows has drastically decreased after numerous phases of processing [19]. The detection process takes the shape of a degenerate decision tree and is depicted in Figure 1 as a "cascade" detector. Several integrated (nested) layers, each containing a boosted classifier, make up a cascade of boosted classifiers. The cascade function works as a single classifier that combines the results of the previous steps [20].

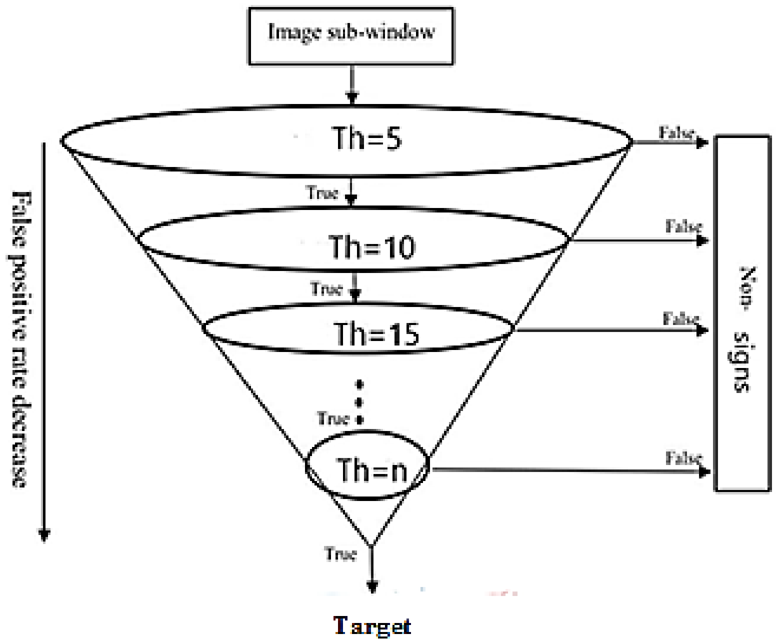

Figure 1. Schematic depiction of the cascade detection [21]

The SURF is a feature-based algorithm that has been widely utilized in computer vision applications and is one of the best techniques [22]-[24]. The SURF technique is a scale- and rotation-invariant approach that extracts Hessian matrix-based interest points and generates a distribution-based descriptor. These characteristics make it ideal for item detection and matching. SURF is made up of three steps; feature extraction, description, and matching [6]. SURF is computationally intensive due to its feature-based techniques. As a result, the frame rate is frequently very low. To work, SURF is a real-time program for driving assistance in portable vehicles, platforms, parallel processing architectures, and systems to be taken into account by examining the parallelism in each step [25].

3. METHOD

In the current work, the captured video is recorded with the aid of a mobile camera of type iPhone 12 pro max of 12 MP resolution. Six videos captured Triangle traffic sign as shown in Figure 2 which do not exceed five seconds long for each video. Such sign located at different positions with various orientations in Baghdad city (Palestine and Al-Rubaie Streets). The condition of video shooting is executed here in the daytime under different car speeds at a height 1.5-1.6 m above the ground as shown in Figure 3. A laptop with unique features was used with the following specifications; Core i7-8550U, RAM 8 GB and 64-bit architecture, CPU mode on 1.99 GHz Intel(R), and the software program executed here by using MATLAB (R2020a).

For one frame that contains the specified road sign, the first step in the cascade technique involves labeling road signs manually by a rectangle box by the use of an image labeler after dividing the captured video into several frames and the labeling process can be presented in Figure 4. The results can be saved in (mat. file) named (A) for an example to go ahead toward the next part (i.e. training stage) wh ere the saved file (A) is summoned to use the cascade approach then to process the training process. The training process consists of twenty steps toward getting an XML.file and then saving it in a specified folder (B) to use later in the differentiation process. Additional videos not included in the training process and the marking process could be included in such a file. So, the images in the final will be identified as real or false detected targets (dit). And the sequential steps can be shown in algorithms I and II for Cascade and SURF detectors respectively. The two techniques can be best summarized in Figure 5.

Figure 2. Triangle sign symbol [26]

Figure 3. Video acquisition setup

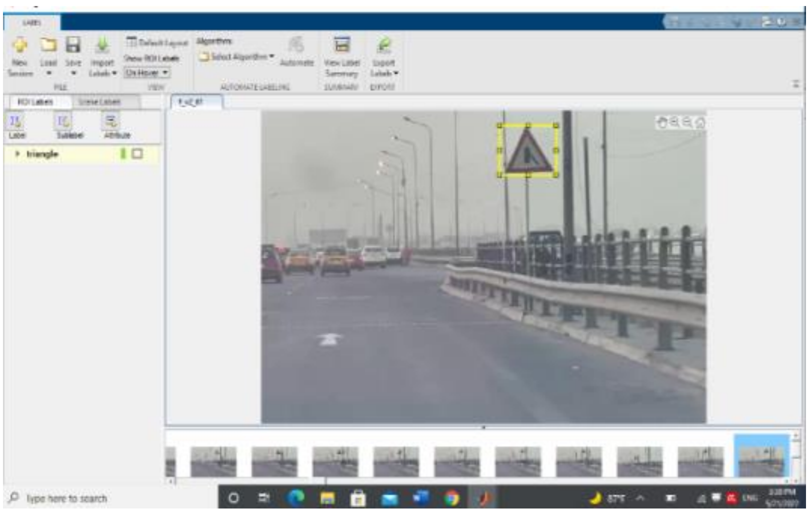

Figure 4. Labeling stage

Algorithms for (a) cascade object technique (b) SURF technique

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Algorithm I
Input: 1-Training file (B.xml file).
2-Folder (Fold1) contains N-images to be tested.
3-Merge Threshold (Mth).
Output:detected traffic sign images (Bimg)
Steps:
1- Open Folder (Fold1).
2- for i = 1 to N
 i- Read image (Im_i), detected traffic sign. Boxes in image(Im_i) using (B.xml)file
  and (Mth)
 ii-Display the annotated target for the traffic sign with the position for the
rectangles B Box as [x y width height].
 iii-Cropping target for an image using BBox from (Im_i), then saving the resulting
images (Bimg).
iv- End for
3- End algorithm.
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Algorithm II
Input:
   1.  the image (Ii), where i=1,2,…, N.
   2.  training file (B.xml)
   3.  Detection threshold (thd).
   4.  Data base (DB) contains  m=20 traffic sign images.
Output: the resulted recognized target (To)
Start algorithm:
           1.  for i=1 to N.
           2.  Read image (Ii).
           3.  Detect and configure the target with road sign using the input custom
               classification model (B.xml) to determine (BBox)
           4.  Inserts a rectangle (BBox) and label it at the location in image(Ii)
           5.  Crops the target image (Ti) according to (BBox) from image (Ii)
           6.  Convert (Ti) to gray scale (Tg).
           7.  Detect SURF Interest Points (SIP1) in (Tg).
           8.   for j=1 to m, where 'm' represents the number of traffic sign images in
               database DB, and read all image (Ij).
           9.  Detect SURF Interest Points (SIP2) in (Ij).
           10. Cr= number of matched points (SIP1) and (SIP2).
           11. If Cr > 2 then
                   i-  Display corresponding feature points.
                   ii- Estimate geometric transform from matching point pairs.(To=true)

           12. Else
               No target recognized (To=False)
               End if
           13. End algorithm.
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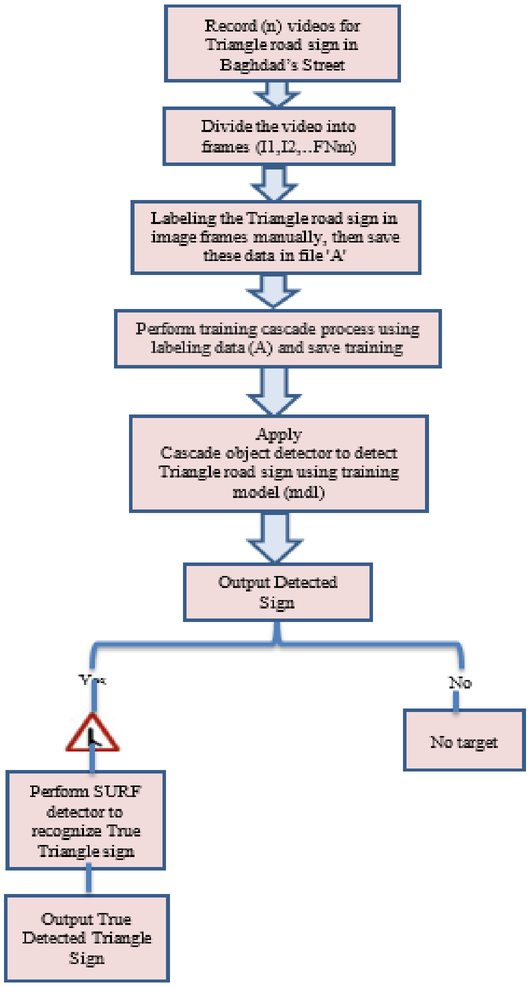

Figure 5. Block diagram for the proposed techniques

Occasionally, the computer reveals the target. But the target is undefined, as shown in Figure 6 as an example. The false-positive detection process by the use of Cascade object detector is shown in Figure 6(a) while for SURF detector's application is depicted in Figure 6(b).

Figure 6. False-positive detection by using (a) cascade object detector and (b) SURF detector

4. RESULTS AND DISCUSSION

To measure the performance of cascade, and SURF techniques, the precision estimator can be evaluated as (1) [27], [28].

$$P = \frac{T_P}{T_P+F_P} \quad (1)$$

Where T_P and F_P are the correct and misclassified positive instances respectively.

The importance of the threshold's value was highlighted here to occupy an accurate detection and hence recognize the triangle sign at the final. Figure 7 shows the result of triangle detection for the two used detectors; one by using Cascade detector as in Figure 7(a), and the other by SURF technique as shown in Figure 7(b) while Tables 1 and 2 describe the estimator's variation (dit, T_P, F_P, and P) with increasing threshold values where 'th, dit, Tp, Fp, non, and P' represents threshold value, total detected instances, true positive, false positive, non-detected targets and precision values respectively. The variation of parameters with increasing threshold values can be depicted in Figure 8. By the use of Cascade object detector, the results for parameters' variations with increasing threshold values are presented in Figure 8(a) and for SURF detector is depicted in Figure 8(b).

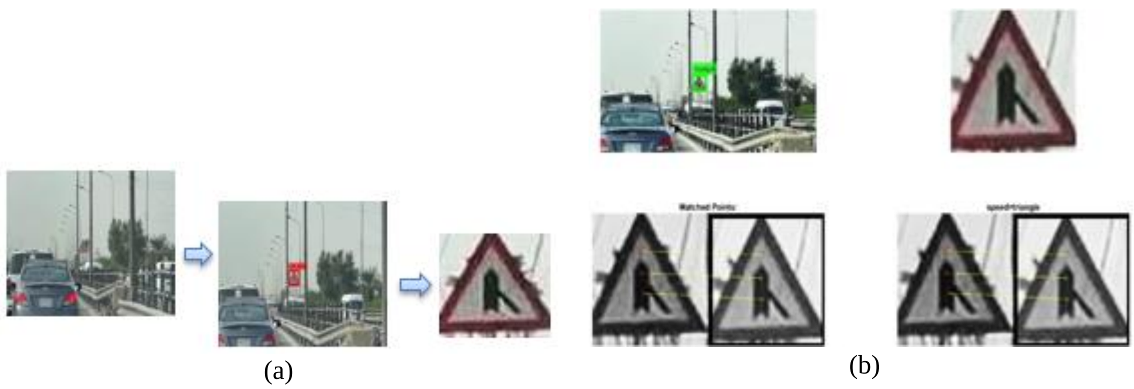

Figure 7. Results of recognizing triangle sign by using (a) cascade object detector and (b) SURF detector

Table 1. The variation of parameters with increasing threshold values for triangle sign by using cascade object detector

th	dit	Tp	Fp	non	p
5	418	371	33	14	0.918317
10	418	354	13	51	0.964578
15	418	300	6	112	0.980392
20	418	242	6	170	0.975806
25	418	180	20	218	0.9

Table 2. The variation of parameters with increasing threshold values for triangle sign by using SURF detector

th	dit	Tp	Fp	non	P
5	418	172	198	48	0.464865
10	320	145	131	44	0.525362
15	418	148	152	118	0.493333
20	418	130	118	170	0.524194
25	294	100	84	110	0.543478

For both techniques, increasing the values of the threshold affects the detection process to yield a reverse relationship for SURF approach while stable state results for the cascade object detector. In addition to that, both Tp's and Fp's values vary with an inverse state while increasing threshold values recorded their highest values at threshold value equal to five (i.e th=5). From the previous tables and by increasing threshold values, non-detected targets increased with positive relationships. In the precision-threshold relationship shown in Figure 9, and according to its highest precision value, the cascade approach seems to be better than SURF in detecting triangle road sign. Its precision lies in the range (0.98-0.9) with a nearly steady-state while SURF introduced a precision in the range (0.54-0.46) by a positive relationship at the final.

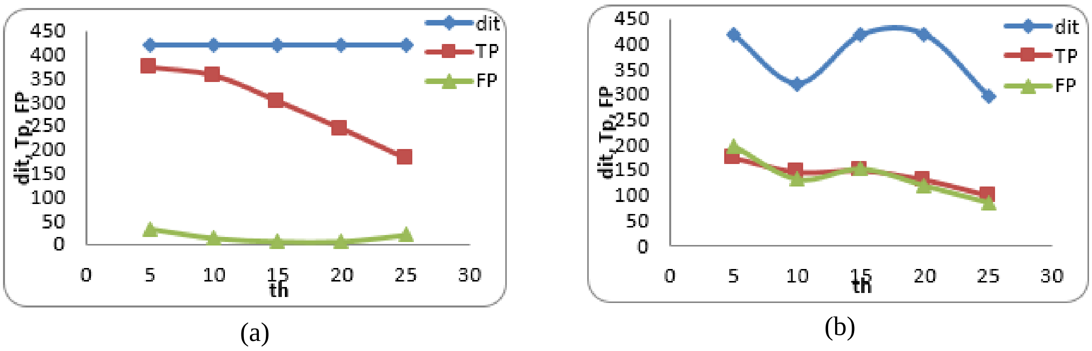

Figure 8. Result for parameters' variations with increasing threshold values by using (a) cascade object detector dan (b) SURF detector

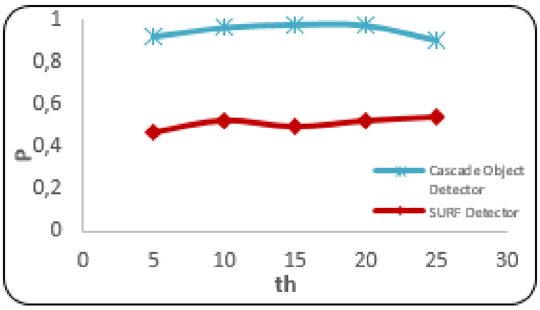

Figure 9. Precisions' variations with increasing threshold values for triangle sign for the two used detectors

5. CONCLUSION

The essential problem of automatic traffic sign detection and recognition has been solved by adopting a cascade detector and SURF approach in detecting triangle sign which was accurately recognized with a high degree of precision recorded in the application of the cascade object detector. The highest Tp's detection occurs for the cascade detector followed by SURF. One can conclude that the highest precision occurs at fifteen and twenty-five threshold values for cascade and SURF approaches respectively.

ACKNOWLEDGEMENTS

The authors would like to thank Mustansiriyah University, Baghdad, Iraq for its support in the presented work (www.uomustansiriyah.edu.iq).

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