

SIMPLIFIED METHODS FOR REAL-TIME TRAFFIC SIGNS RECOGNITION

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This paper presents an approach for a detection and classification algorithm of traffic signs, and in same time highlights the encountered problems that appeared in the process of software development.

The methods that were utilized could be classified into color and black white segmentation, and the process of traffic sign recognition has tree stages of detection that are segmentation, detection dimensioning and recognition. In the paper it was presented an approach that would find the sign even if those would not be detected after the first stage extraction from the color matrix.

1. Introducere

Safety became an important part when carefully analyzing the roads and car users, making Traffic Sign Recognition to reach top expectations while researchers try now to improve the applications that do sign recognition and exceed maximum identification level of a human driver without any mismatch made.

Traffic signs provide important information to the drivers and with the information from the sign they can proceed accordingly and not have any type of incident even if it is first the time that a driver uses a road.

Traffic signs are created to be easy noticed, because they are designed to have a high contrast in RGB field and on normal atmospheric condition even during the night time when they are lighted with the headlights.

Human drivers use in a high percent the visual information to take decisions for acceleration, breaking and turning the steering wheel. The problems come when a driver is not careful or is distracted, tiered and misses a traffic sign or does not adapt the speed to the recommended one and so on.

In [1] segmentation is used as a first step for their traffic sign detection and recognition algorithms, and they slightly outline the problem where the signs are not identifiable because of degradation, as it is described in [2], or other obstructions that could be in front of the sign.

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2. Related work

The first known research on the traffic sign recognition in real time goes back to 1987, when Akatsuka and Imai proposed this approach [3]. Since then until now a lot of other techniques have been studied. Some of these suggestions do share only the computing capacity [4], as it is described in [5] where filters are applied for color segmentation to find the areas of interest and avoiding to process a high amount of data.

There are two used approaches that are developed today: one is based on neuronal networks that are more accurate even than humans drivers, and that can detect traffic signs with 99.4% accuracy, like it is exposed in [6] and the other one is segmentation that uses candidate detection, classification and tracking as exposed in [2] and has a lower rate of detection.

This paper underlines an approach to traffic sign recognition by structuring the steps that could be followed to achieve a better recognition and exposing the problems that are encountered in the software development. It utilizes segmentation, color detection and segregation in an algorithm that uses color and black/white thresholds. The tests were made on a library of eight traffic signs and this library was specially created from the traffic signs that can be found on Romanian roads. The input images were extracted from video frames and after running the recognition software, the considered traffic signs are detected with accuracy.

The traffic sign recognition systems that use segmentation are based on three steps like as described in [7]. The first step would be the color segmentation or thresholds which isolates the areas of interest from the frame, as in [8]. These areas are obtained by extracting certain thresholds of the RGB, as in [9] or HSV matrix, the second step would be shape detection, and the third step is the search for the library specific signs that match or not with the candidate. The third step could be replaced by a neuronal network that could search with much higher precision and speed the candidate areas [10].

The detection rate of classic color segmentation and library matching candidates would be higher than 95%, with a minimum size of detectable traffic sign at 25 pixels and a low rate alert of false positives lower than 0.1% [11].

3. Methods used in traffic sign recognition application

Usual algorithms for shape extraction start with a segmentation analysis to obtain the objects from an image, and this compound works fairly well until trying to extract for example circles from a video frame of a usual city road. The complexity of these images makes shape detection becomes useless because of the textures and colors diversity in every frame captured, for example at a traffic light from a town (see Fig.1).

Blocks, houses and all objects that generate complex textures after segmentation, like you can see in Fig.2, and this make the edges of a sign impossible to be highlighted, the sign holder can also generate a segmentation problem, because the sign is extracted as a geometric shape with an incomplete perimeter portion and in combination with the support bracket, the further analysis will not extract an usual shape, and we can't use a shape extraction based algorithm.



Fig.1 Video frame



Fig.2 Image obtained after Sobel filter applied

A system that is based on common traffic sign recognition usually has three steps: detection of the region of interest, determining the dimension of the region of interest and recognition, as you can see from Fig.3.

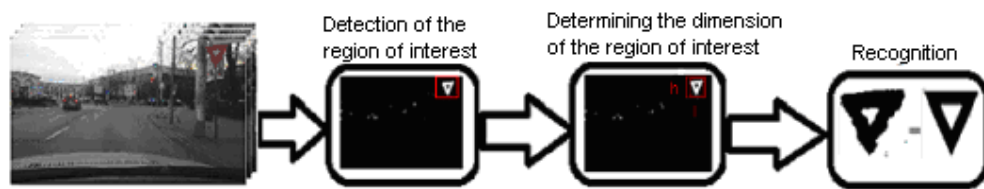


Fig.3 Structure of the traffic sign recognition

The approach that I used was to make a library containing the traffic signs, search and extract them from analyzed frames until having a positive confirmation for every region of interest, otherwise all library signs are confirmed as not present.

In the Fig.4 we can see the restriction and alert signs that are considered as library for this algorithms.



Fig.4 Signs from the library that was considered

1.1. Detection of the regions of interest where a traffic sign can be found

The algorithm is written in Matlab and has as input a video frame and a library sign. The video frame is filtered to the color of the library sign from RGB color channels, and then the channels are extracted in three different matrices as red, blue and yellow. For every channel we set the region of interest and we modify the library sign to the size of the region of interest.

From the captured video frame I managed to find experimentally, by measuring the traffic signs at different distances from the camera, and I found that the detection could be made rigorously only when the traffic signs arrive at least at 30 pixels in size. At this size the signs are situated somewhere around 80 to 70 meters distance from the recording camera.

The library signs have the initial size of 70x70 pixels and are resized to the dimension of the extracted region of interest to calculate the correlation between them.

1.2. Determining the dimension of the regions of interest

From the frame we identify the normalized cross correlation function, from Formula (1), the best area where the sign of the library could be found. From the generated matrix of this function we get the highest match as an area of interest. For each possible area where a sign could be present, a contour detection filter is applied in order to measure the exact sign dimension, resize the library sign, and compare them after a conversion to black and white.

I proposed the normalized cross correlation approach for a better detection rate in case that the window color matrix extraction would not return the presence of any traffic sign and at least one would be present in the image. This approach

would make it possible to correctly detect the library sign when the sign from the image will reach the correct size.

The normalized cross correlation function has the mathematical formula [12]:

$$\gamma(u, v) = \frac{\sum_{x,y} [f(x, y) - \bar{f}_{u,v}] [t(x-u, y-v) - \bar{t}]}{\left\{ \sum_{x,y} [f(x, y) - \bar{f}_{u,v}]^2 \sum_{x,y} [t(x-u, y-v) - \bar{t}]^2 \right\}^{0.5}}, \quad (1)$$

where:

- f is a segmented image.
- t is a segmented sign from the library.
- \bar{t} is the mean of $t(u, v)$
- $\bar{f}_{u,v}$ is the mean of $f(x, y)$ in the region under the template.

1.3. Recognition

At this step, after the conversion in black and white of both images the returned region of interest is compared with the library traffic sign. If the correlation presented in formula (2) returns after comparison a percent greater than 70%, the sign is marked as found in the library and is overlapped on the original image in the exact place where it was initially placed. If the percent is lower then the step we display the percentage of correlation and a proper message that the sign is not one from the library.

The correlation coefficient is computed using the formula [12]:

$$r = \frac{\sum_{m,n} (A(m, n) - \bar{A})(B(m, n) - \bar{B})}{\sqrt{\left(\sum_{m,n} (A(m, n) - \bar{A})^2 \right) \left(\sum_{m,n} (B(m, n) - \bar{B})^2 \right)}}, \quad (2)$$

where:

- A is the image resulted after applying the normalized cross correlation from function (1)
- B is a sign from the library filtered in black and white
- \bar{B} is the mean of B
- \bar{A} is the mean of A

After running the algorithm the results can be seen in the following images. In Fig.9 the result of the normalized cross correlation of Fig.6 with the library sign from Fig.8 is plotted, so we can see the highest correlation point where the library sign could be found. The image from Fig.6 is obtained from

Fig.5, after applying a sobel filter, and the image from Fig.8 is obtained in the same way from Fig.7.

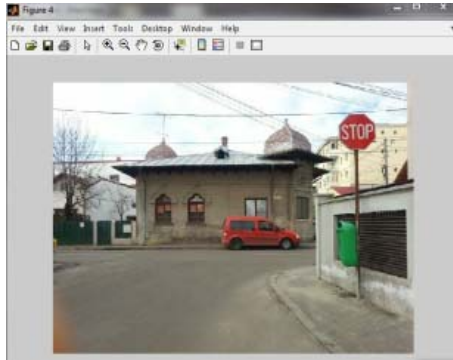


Fig.5 Video Frame

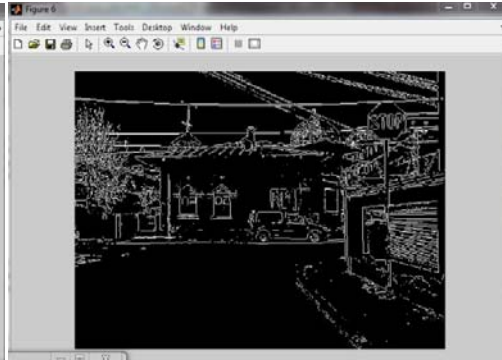


Fig.6 Segmented frame from Fig. 6



Fig.7 Library traffic sign



Fig.8 Segmented library sign

The search for the library sign in Fig.5 returns an area where the sign would match, and the result is further analyzed in comparison to confirm its existence. Passing all the signs from the library through the algorithm will increase searching time with the size of the library.

The final correlation result is computed by the presented function from (2), between the library sign converted to black and white from Fig.10 and the region of interest from Fig.11 also converted to black and white. The match is a 78% in this case, so the sign would be considered found, because the percent is higher than the threshold set to 70%. In this case where the sign is found the initial image from Fig.5 is converted in gray scale and on it is overlapped the found sign, as you can see in Fig.12.

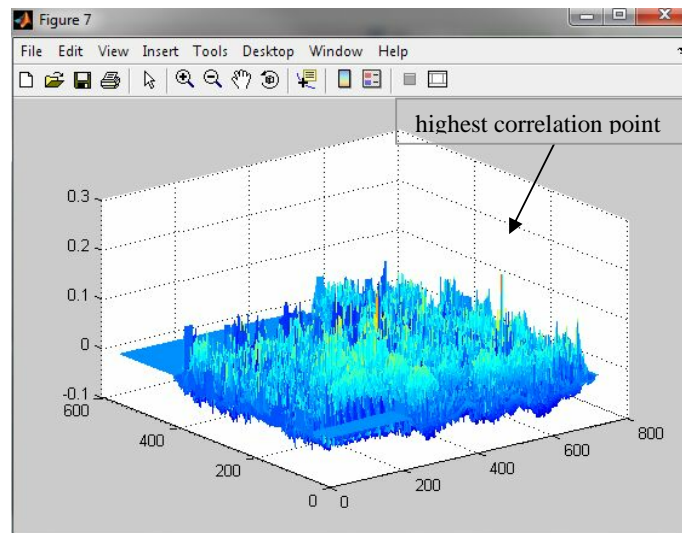


Fig.9 Correlation matrix of the coefficients resulted after applying function (1) on Fig.6 and Fig.8



Fig.10 Library sign with red color window applied.



Fig.11 Image returned by the function (1) from Fig.5, with a color window on red spectrum.



Fig.12 A mask with the library traffic sign overlapped on Fig.5 applied after match found.

The red color window that is applied to obtain Fig.14 from Fig.13 is presented in function (3):

$$Red(i, j) = \begin{cases} true, & if (Frame(:, :, 1) > 98 \wedge Frame(:, :, 3) < 90 \wedge Frame(:, :, 2) < 90) \\ false, & else \end{cases} \quad (3)$$

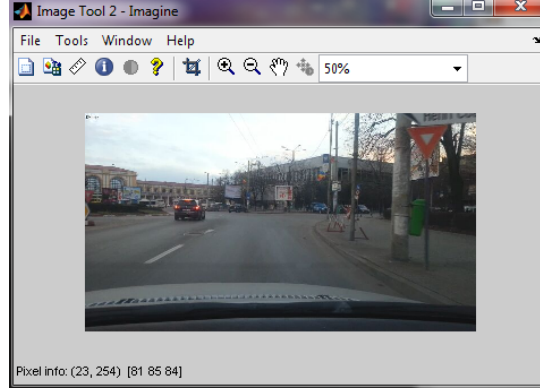


Fig.13 Video Frame

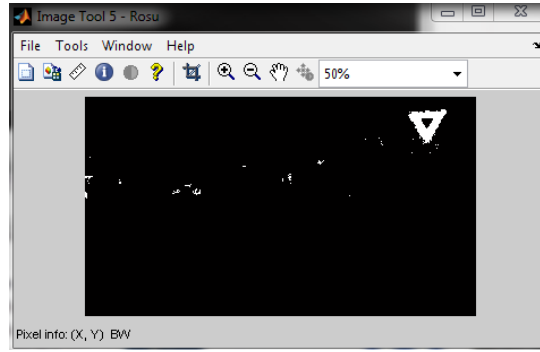


Fig.14 Red color window applied on Fig.13

The problems occur after setting the color window limits of the color red, blue and yellow from where we can extract the sign, because in other light conditions this color limits will not be good. Without analyzing the brightness the strict window limits will not detect any sign even in an environment with just a shadow or low light, which would lead to an incorrect sign extraction. In Fig.16 the same filter like in Fig.14 can be seen, but the result is not the expected one and you can see that the light is lower and the sign is no longer detectable within the previous color limits.

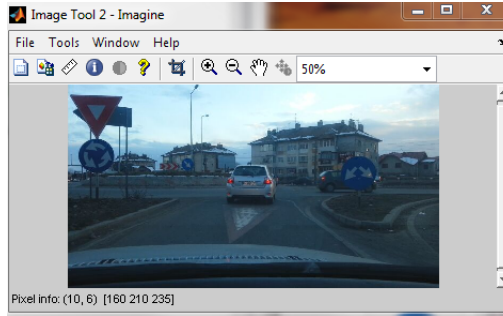


Fig.15 Video Frame

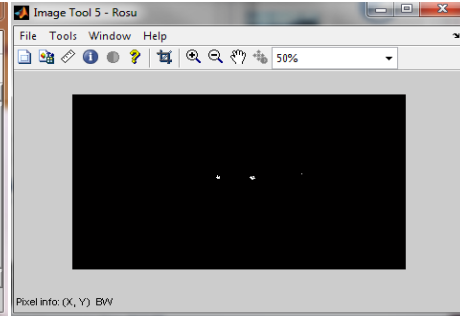


Fig.16 Extraction from Fig.15 with same Red window color filter from function (3)

Another common problem would be that our library needs to contain each model of traffic sign that can be encountered. Other issues highlighted that some signs with the same indicative are slightly different, not only in color but also in structure and will require another representation in the library. An obvious example would be the latest sign of blue crosswalk with yellow signal lights in the upper corners, as you can see in Fig.17, which is structurally different from the old one from Fig.18.



Fig.17 Pedestrian crossing with lights



Fig.18 Pedestrian crossing

The advantage of video sign recognition is that it could be applied at a very large scale because the sensors are not expensive and could be used in the older vehicles too without large modifications. With this kind of detection it is no need to modify the structure of the route infrastructure.

The video recognition could be turned on when the vehicle is moving and when a sign is detected for example a pedestrian crossing sign, then it starts a detection algorithm for pedestrians and if the driver does not take the correspondent action the vehicle can automatically break.

When we have little obstacles in front of a sign like a branch, the algorithm will detect the sign with a lower correlation, but the important part is that the sign will still be detected. The problem is when we have a large obstacle that blocks the view of the sign because here the detection of the sign will occur in a very late stage.

During night time with public lighting we can detect signs without problems, but we have a problem when the roads do not have public illumination because in this situation the colors of the sign are visible very late because of the camera sensor. This problem could be easily surpassed by using a camera with the

new generation sensors High Dynamic Range (HDR), which can keep the colors of the objects even in powerful light, caused by the cars headlights.

Traffic sign recognition is one of the systems that will help drivers, as covered in [13], and in which they will be more confident than in themselves, therefore these systems need a very strong conception and reliability and finally should be one of the basic systems that will sustain self drive vehicles.

4. Experimental results

After analyzing the colors from different videos, the windows for the usual color were set to the values from table 1.

Table 1

The setting for usual colors from HSV matrix			
Color	HSV Values		
	Hue	Saturation	Value
Red	0 to 98	0 to 90	0 to 90
Blue	0 to 60	0 to 107	98 to 255
Yellow	100 to 140	80 to 90	0 to 65

Table of the mismatched traffic sign after the second filter applied is zero as you can see from the table 2.

Table 2

Mismatched traffic signs				
Sign Color	Inputs	Results		
		Detected	Different patterns	Mismatches percent
Red	72	39	33	0%
Blue	85	47	38	0%

The result of the correct traffic sign recognition is present in the table 3

Table 3

Result of Traffic Sign Recognition after running the algorithm			
Sign Color	Results		
	Inputs	Correct Detection	Correct percentage
Red	40	39	97.5%
Blue	50	47	94%

With this simplified algorithm approach can be realized a good detection rate as you can see from the results from table 3.

5. Conclusions

Video analysis to detect road signs is in an early stage even if there are market cars equipped with this feature. Today it is implemented on more and more brands but only in the top range of the manufacturers, like a detection of speed restriction signs, but even here where it is supposed to be a rigorous safety it is offered only as complementary systems, because correct detection is low.

Although this system may be functional, libraries need to be developed for local signs, which is why some brands of cars can't deliver functional systems for Romania.

The obstacles that could be in front of a sign, erroneous mounting or wrong positioning that interfere with the straight detection of traffic signs algorithms are still problems that should be taken into consideration. This problem could lead to wrong decisions, even for the human drivers, but they can assume that there is a sign and take complementary decisions.

The necessity of a sign library for each country makes this problem even more difficult and testing is needed for every traffic sign because each as a different reflective material.

Best programs developed until now in this field use neural networks for learning signs and the detection rate reached up to more than 99.46% of all the signs possible and the detection was in real time like it is described in [9].

In conclusion detection of road signs is more and more accurate and will not take long until the implementation of these systems will be on all our new cars.

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