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VEHICLE MODEL RECOGNITION BASED ON USING IMAGE PROCESSING AND WAVELET ANALYSIS

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Abstract— Today, using intelligent transport systems such as identifying vehicle type for monitoring traffic in urban areas can advantage a lot. In this paper, a new method has been presented to detect vehicle type with only one reference image per class. Our algorithm is based on searching mean gradients and analysing these changes by Daubechies wavelet transformation. Firstly, a feature vector is obtained based on the car boundary changes of the side view image in proposed system. This vector is then analyzed by Daubechies wavelet transformation and three statistical criteria; variance, norm-1 and norm-2 are extracted from wavelet coefficients. Finally, a similarity factor is defined to detect the same type of vehicles. The proposed algorithm is resistant against car edge negligible changes and the experimental results indicate the high performance of system in detecting the vehicle types.

Index terms: Image Processing, Wavelet Transform, Feature Vector, Similarity Factor.

I. INTRODUCTION

Nowadays, the intelligent control systems have entered the human life in different areas. These systems far have reduced the number of human resources and resulted in the improvement of industries towards automation process. Introduction of making intelligent solutions is very efficient due to increasing population spread [1]. For instance many vision based intelligent Transport Systems are used for detecting vehicle [2], license plate [3] and car model [4]. Besides, diversity kind of sorting systems have been improved by implementing image processing for product quality evaluation [5]. Furthermore, among machine vision based systems, face and fingerprint recognition [6, 7], are very applicable for security regions as they used for distinctive identification purposes. Today, due to increase of population and complexity of the traffic control and laws enforcement and due to low labor available, traffic control intelligently has a lot of merits such as minimum cost and time is dealt with this important matter. Meanwhile, the intelligent transportation systems, especially based on image processing will be very efficient.

Auto detection and its type is of issues that many researchers have researched about it until now. For example in 2000 Paragios et al., have used a Gaussian statistical model in detecting mobile objects border. They have actually achieved this fact by detecting the boundary movement objects and connecting points that have the minimum distance together [8]. Three years later, Mahmoudi and et al., deal with the objects edge images retrieval. They achieved this important fact by applying two features of correlation and relation at the edges [9]. Besides, In 2007 Ambardekar took advantages of a spatial wired model for the vehicle detection. He used the color comparison and background gradient as preprocessing [10].

In this paper we developed a new method for detecting car type from side view by employing image processing. It should be noted that the car mask is obtained in the input image by applying some morphology processes on the database images. In this regard some preprocessing operation such as noise reduction and the mean retention filters are applied on the input image. Then the car mask is obtained from the side view pre-mentioned input image. In this stage the vehicle mask boundary is extracted and car shadow is removed from mask image approximately and we compute the boundary image contour by using the proposed algorithm. After describing the boundary of existing vehicle we have dealt with establishing proper feature vector, then three statistical characteristics is obtained by using Daubechies wavelet transformation from the proposed feature vector. Finally the similarity factor is defined based on three statistical criteria that we will explain it in the last part of the article. Experimental results show that the method presented in this paper has been resistant against the transmission of vehicle location and expresses similar description for them against the vehicles minor changes.

This paper is organized as follows. The next two parts discuss about System Architecture and Image Processing algorithms that was done on image for obtaining unique feature vector for each vehicle type. In Section IV the wavelet analyzing is described, followed by introducing statistical criteria and Experimental results. Finally conclusion is presented in section VI.

II. SYSTEM ARCHITECTURE

The three major modules of this vehicle type detection system are image processing, wavelet analysis and statistical feature selection. Fig.1 illustrates the steps of our proposed vehicle recognition system.

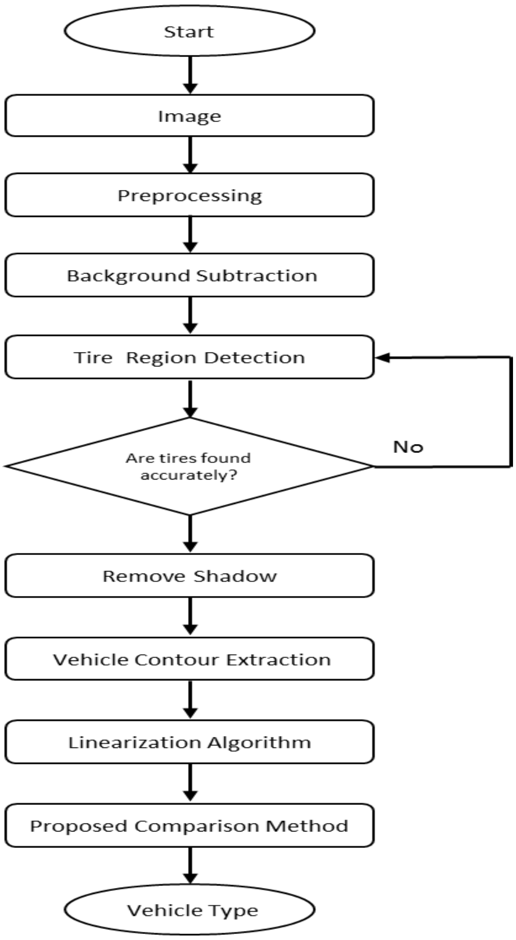


Figure 1. The scheme of the proposed vehicle detection model

III. IMAGE PROCESSING

a. Image capturing

At first we capture image with Sony 8 Mega pixel camera. Regarding to this issue that most digital cameras have the automatic correction options of color and light, in this paper all of the automatic correction options in the camera put in silent condition and rate of light and contrast set in normal condition. Due to the sizes or resolution required, in this paper images have been used with 640 × 480 dimensions which these size and camera characteristics have been similar in every imaging such as instantaneous and non-instantaneous.

b. Pre-processing operation

At this phase, processes are performed on the images available in the database that result in establishing more proper images for processing in the later stages. Considering that the images have been used with the same light conditions in this article, we confine ourselves to a few simple preprocessing. Firstly, the pixels data type has been converted to double type and is located in the ranges of zero and one. Then, the input image that is usually in the form of three channels or RGB turns into a gray level or one channel image. For noise decrement we use rotationally symmetric Gaussian low pass filter of size 3*3 with standard deviation calculated in OpenCV image processing toolbox [11, 12]. In OpenCV standard deviations through the x and y axis are considered in (1) and (2).

$$\sigma_x = \left(\frac{n_x}{2} - 1\right) \times 0.3 + 0.8 \qquad (1)$$

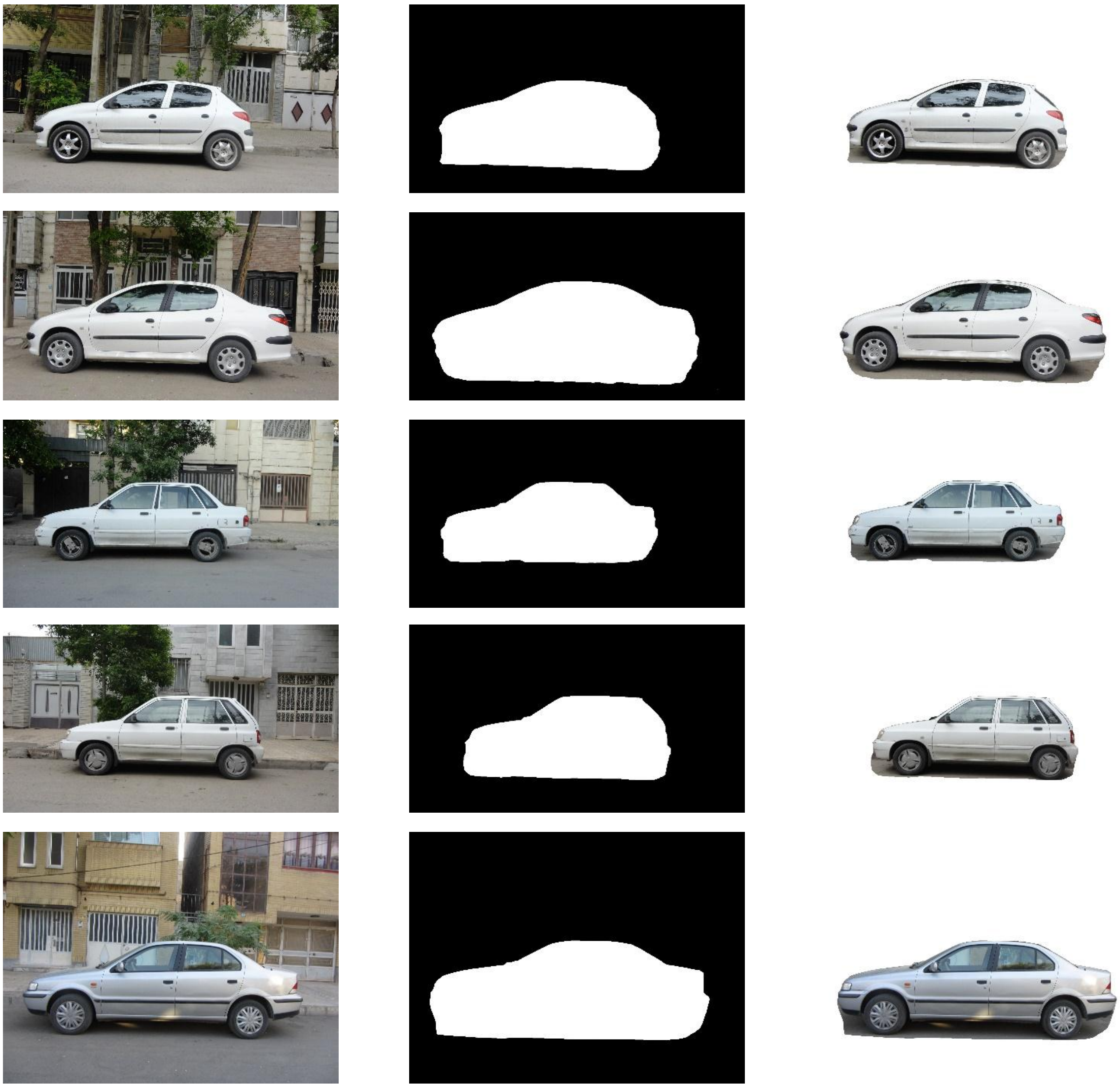
$$\sigma_y = \left(\frac{n_y}{2} - 1\right) \times 0.3 + 0.8 \qquad (2)$$

c. Background Subtraction

In the tracking systems with a fixed camera always a pre-processing algorithms use for detecting moving regions in each frame. Generally this type of methods is known as changes detection algorithms. In fact it can be said that these algorithms make decision for identifying moving areas in each frame according to the previous frames. Their main objective is classification of image pixels into two categories, moving and background.

These algorithms do processes on different features of an image such as the pixel level, edge or higher-level features such as boundary, lines and corners, in which for this paper the characteristic of pixel level and background subtraction are used. For this purpose, after reviewing the images resulting from subtraction operation of the three color components of image (R, G and B), grey image resulting from subtraction of the blue color component was selected for subsequent processing. Then, the pixel data quantity is mapped to zero and one to increase the selected image light intensity and improve its quality. For obtaining the vehicle binary mask the threshold value of 0.2 was chosen empirically.

At this stage, in order to provide a more accurate shape of car, some of the morphology process was done on afore-mentioned mask as follows: At first, areas from binary image that have been surrounded by white pixels and have the zero amounts have filled and change to white color. Then, we obtain ultimate mask of the car by applying open and close conversions on output binary image. Result mask of some sample cars are depicted in Fig. 2.



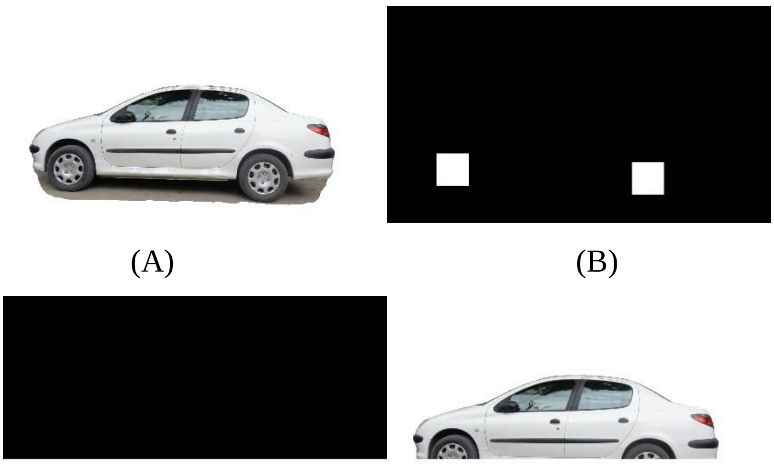
(A) (B) (C)

Figure 2. (A): Sample images of car side view. (B): Background subtraction Mask. (C): Output images of background subtraction algorithm.

d. *Shadow Removal*

Since shadows bring errors in the performance of computer vision algorithms such as tracking and object recognition, different methods of shadow composition and removal have been proposed in recent years [13]. As indicated in Fig. 3-A shadow boundaries have connection with tires, so for having an accurate feature detection module, we omit part of tires that connected with shadow. For this purpose, first the image has been segmented by using the mean shift clustering algorithm [14]. Then, according to the radial interval, 18 to 30, searching tire circles is done and accuracy of detection is confirmed by the user.

Doing the search process is by using the Hough transform on the segmented image [15]. By applying this transformation and moving on image, the tire circles are marked with a special radius and its place is created in a white square shape on Mask image. Now we obtain the center coordinates of two squares in the y direction to remove the shadow, then from the center which has a lower y coordinate or in other words, from the middle of the square which is higher, we set equal to one until end of the vehicle image. Finally, the mask is created and result of the shadow elimination process is displayed to the user. If it was desirable, the process is terminated manually. Otherwise, the stages are repeated. Fig.3 shows this procedure for sample image.



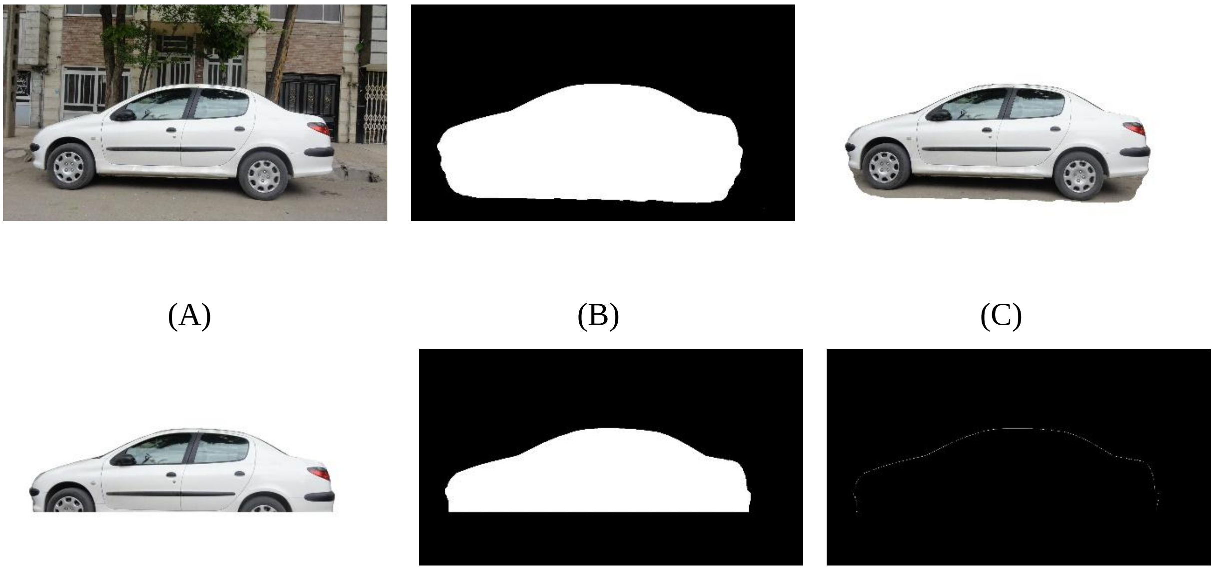
(A) (B)

(C) (D)

Figure 3. (A) A resulting image of background subtraction (B) Tire Mask
(C) Shadow Removal Mask (D) Output image of shadow removing algorithm.

e. Boundary Detection

In the proposed algorithm the boundary of the image objects are used which is the most important low-level features for shape description. For obtaining boundary of image first non-shadow image is converted to gray scale then we perform background subtraction with threshold value of 0.95. Besides, some morphological operation on output image has done in order to enhance the quality of its boundary. At this stage, we extract the boundary by doing simple search .The outcome of this edge detection operation is shown in Fig. 4.



(A) (B) (C)

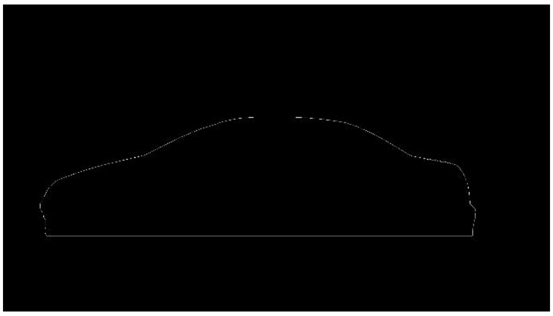
(D) (E) (F)

Figure 4. (A): Original image. (B): Background Subtraction Mask.
(C): Vehicle Image segmented by multiplying Background Subtraction Mask and Original Image. (D): Result of shadow removing. (E): Non shadow binary image after performing some morphological operation. (F): Boundary of the non-shadow image.

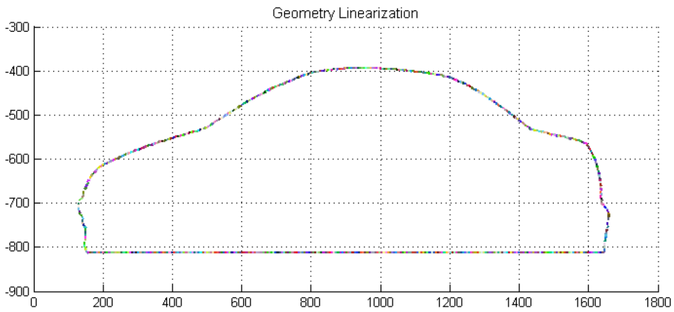
f. Linearized boundary operation

Actually our proposed algorithm is a method for describing a binary image in which the binary edges available in image are replaced by lines which their slope is relevant with objects boundary. In fact, lower points on boundary images will being processed by performing this operation; also a geometric approximation is done on the boundary of objects that reduces the margin noise. This algorithm was done on boundary image as express below:

We move on each of boundary point coordinates and consider them as a center of a circle with a predefined radius (In this article we defined r =5 empirically) [16]. There are other points inside this circle which are the neighborhood of the center point and indicate the boundary of the object in a binary image. We should replace these existence points inside a circle with a line or lines. For this purpose, the distance of all points located inside the circle is measured from center of the circle; then the points that have the maximum distance from the center, or their distance is slightly less than the maximum distance quantity, are chosen. This selection method leads to less discontinuity in the final linearized image. After selecting the appropriate points in the circle, lines are considered from the center of the circle to the selected points that are representative of the boundary points located inside the circle. Now we remove all the points which are processed in the previous stage and set center of the circle on other border point arbitrarily. This processes are being repeated until all the points on the border are eliminated, see Fig. 5.



(A)



(B)

Figure 5. (A) A border of non-shadow image. (B) Result of proposed algorithm in Linearized section.

g. Feature vector Extraction

Regarding to the image 5B, after extracting lines which describe the boundary of the car, we derived the center coordinates for each line and save the data in a matrix. Then we earn the centroid of the boundary image and transfer the image coordinates to that point. Finally we divide the image into regions of equal angular from the new center coordinate and move from the positive part of the axis in a clockwise direction and consider the average of the lines slope which have been located in each region as one of the feature vector columns. According to the values considered in this article the proposed feature vector has 14 (The number of regions created in the image coordinate) members. Fig. 6 illustrates feature vector of sample car.

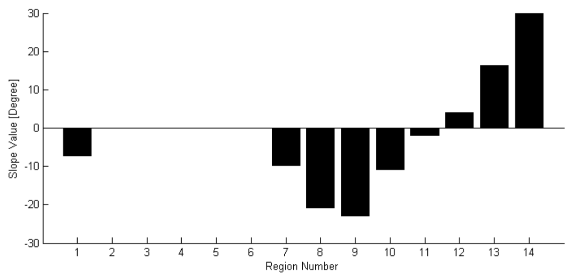


Figure 6. Feature vector for linearized image.

IV. WAVELET ANALYSIS

a. Introduction

Wavelet analysis is one of the relatively new and exciting achievements in pure mathematics which is based on several decades' research in harmonic analysis. Today this application becomes important in many fields of science and engineering; as new possibilities for understanding its mathematical aspects and improving its manipulation are provided.

From a historical point of view, the first reference to the wavelet was in Haar’s dissertation [17]. The properties of the Haar wavelets are range compression, non-differentiable and continuous form. After that, in 1970, a Frenchman geo-physicist named John Morlet found that Fourier bases aren’t the best possible tool for the underground explorations, this issue led to introducing of wavelets by Grossman and Morlet. Actually they developed the technique of scaling and shifting of the analysis window functions in analysing acoustic echoes [18]. After the scientific formation of the wavelet transform which was first proposed by Grossmann [18], Malta created wavelets analysis and reconstruction algorithms using multi-differentiation analysis in 1985 [19].

In this paper we earn statistical characteristics of each vehicles boundary by employing 2D Daubechies Wavelet Transform. The Daubechies wavelets are one of the most commonly used set of discrete wavelet transformation and can be performed with using simple digital filtering techniques; Belgian mathematician Ingrid Daubechies is the person who formulated these Orthogonal wavelets in 1988 [20].

b. Wavelet Theory

In wavelet analysis like Fourier analysis, we deal with functions extension. Although the goal of this conversion is similar to Fourier analysis which is signal transmission from one base to another, we can achieve more accurate information from signal in comparison to the Fourier transformation.

Wavelet is a specific function with zero mean and unit energy which in this function extension is performed based on transitions and dilatations. As wavelets are studied in space locally, thus closer relationship between some functions and their coefficients is possible and greater numerical stability is provided in reconstruction and calculations. Regarding to these features of wavelets, greater spatial information (or time local) can be gained by reformulating any application that is based on fast Fourier transform. In general, this advantage causes the calculation of the integral operators be done through fast numerical algorithms and improves signal and image processing.

For a function the continuous wavelet transform is obtained in (3) and (4), the result of this transform is wavelet coefficients c which are a function of the scale and location [19]:

$$c(scale, position) = \int_{-\infty}^{\infty} f(t)\psi(scale, position)dt \tag{3}$$

$$c(a,b) = \int_{-\infty}^{+\infty} f(t)\frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right)dt \tag{4}$$

Where $\psi(t)$ is mother wavelet, a and b called Dilation and translation parameters respectively which are employed for transforming wavelet mother. A factor $1/\sqrt{a}$ is used for keeping wavelet norm one for all a values. This equation depicts that wavelet analysis has frequency domain localization capability. Since selecting continues variable for $\boldsymbol{a}$ and **b** increases the amount of computation, $\boldsymbol{a}$ and **b** are usually considered discretely. Therefore, one suitable choice for $\boldsymbol{a}$ and **b** is:

$a = 2^{-j}, b = k2^{-j}$ (k and j are integer values).

In this case, the relationship of the wavelet conversion which is known as dyadic conversion has been a function of j and k. The following formulate shown in (5) describes this relationship:

$$w_f\,(j,k) = \int_{-\infty}^{+\infty} f\,(t)\,2^{j/2}\psi^*\left(2^j t - k\right)dt \quad (5)$$

Regarding to the structure of the filter bank, discrete wavelet transform is implemented according to (6) and (7) by scaling filter h (n) which is a low pass filter related to the scale function $\phi(t)$ and wavelet filter g (n) which is a high-pass filter related to the wavelet function $\psi(t)$ [19].

$$\phi_j\,(t) = \sum_k h\,(k)\,2^{\frac{j+1}{2}}\,\phi\left(2^{j+1}t - k\right) \quad (6)$$

$$\psi_j\,(t) = \sum_k g\,(k)\,2^{\frac{j+1}{2}}\,\phi\left(2^{j+1}t - k\right) \quad (7)$$

As we can see in Fig. 7, substantial step of wavelet analysis could be done in two different direction; decomposition and Reconstruction. Regarding to this figure cA1 and cD1 are known as sequence and detail coefficients respectively, these vector elements are obtained by passing discrete signal **f** from low-pass (L) and high-pass (H) filters in the analysis phase. Also, sign $\downarrow 2$ indicates a decrease in the sampling rate with factor of 2 [21].

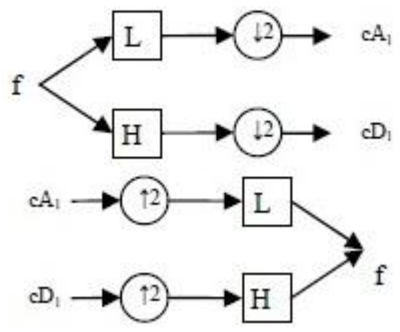


Figure 7. Basic stages of wavelet transformation: Decomposition and Reconstruction.

c. Wavelet Selection

As shown in continuous wavelet transform equation (3)-(4), many wavelet transforms can be created by scale change and displacement in the mother wavelet time. For instance, we can named Daubechies wavelets, which for each integer r is defined in (8) [20].

$$\phi_{r,j,k}(x) = 2^{j/2}\phi_r\left(2^j x - k\right), j, k \in z \quad (8)$$

Features that make the results of image analysis and synthesis remarkable by using Daubechies' wavelets are described in (9).

$$\int_{-\infty}^{\infty} \psi_r(x)dx = \ldots = \int_{-\infty}^{\infty} x^r \psi_r(x)dx = 0 \quad (9)$$

(1) According to the above equation, since the details of the signal are determined by the mother wavelets; their integral should be zero. So the changing trend of information is stored in the coefficients obtained by father wavelet.

(2) Mother wavelet (ψ_r) has ability to compress signal in the interval [0, 2r +1], this feature provides a possibility to display signal with finite length based on wavelet basis functions with limit length. This finite length reduces the number of local wavelet coefficients at the signal indication, so is important for spatial domain localization.

(3) Diversity range of studies and experiments [22] have proved that Daubechies' wavelets are better for dealing with general enhancement in images.

d. Proposed Algorithm

For analyzing feature vector which is obtained in section 3, 1D Daubechies Wavelet Transform is employed. The reason for this choice is that Daubechies wavelet members store useful information from analysis of images. Even if a member does not have sufficient information, another member has effective signal information. Besides, selecting a wavelet function which closely matches the processed signal is of utmost importance in wavelet applications [23].

So, in this paper, coefficients extracted from the Level 4 and 5 of Daubechies wavelet are evaluated for feature vector and all its elements are compared with each other. Then, we create identification vector by putting together details coefficients resulting from two pre-mentioned level. Fig. 8 shows the schema of our proposed comparison method in more detail.

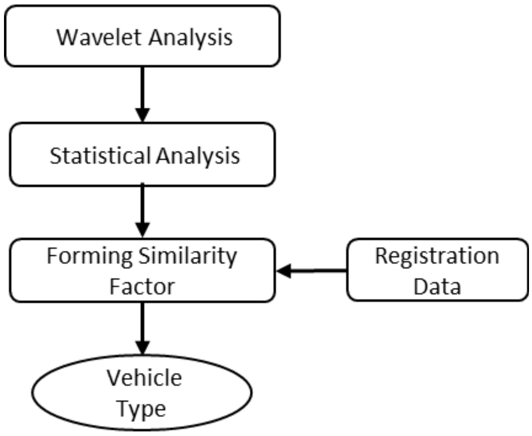


Figure 8. Schema of Proposed Comparison Algorithm.

V. STATISTICAL CRITERIONS AND SIMILARITY FACTOR

a. Statistical features Selection

In this paper, three statistical criteria: norm-1, norm-2, Variance; have been used experimentally to analyze coefficients resulting from Daubechies wavelet transform. We explain these three criteria on the following.

1) P-norm: P-norm defined in (10).

$$\|x\|_p = \left(|x_1|^p + \ldots + |x_n|^p\right)^{(1/p)} \quad (10)$$

In this equation $1 \leq p < \infty$ and if we set P=1 and P=2 we acquire norm-1 and norm-2 respectively.

2) Variance: Variance is a measure type of dispersion and its value is calculated by averaging the squared differences from the mean .Moreover, variance is a measure that shows how the data have been spread around the mean. If μ = E (X) be an average of random variable x, the variance of x is equal to (11).

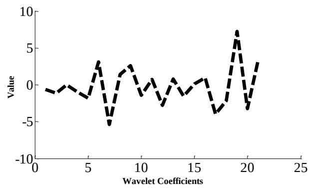
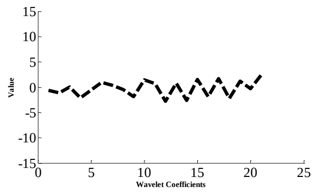
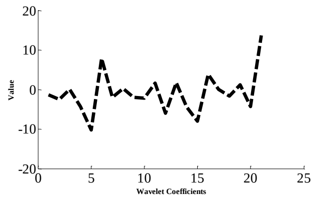
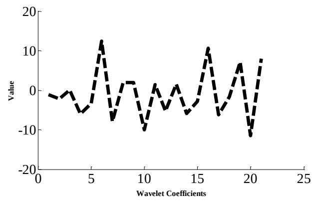
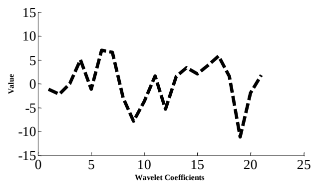
$$Var(\mathrm{X}) = E\left[(X - \mu)^2\right] \quad (11)$$

The dominant distribution on data is not known in most cases. In this case, the variance is estimated as (12):

$$S_N^2 \equiv \frac{1}{N} \sum_{i=1}^{N} \left(x_i - \bar{x} \right)^2 \quad (12)$$

Values that achieved by performing these statistical factors on wavelet coefficients along with vector identification of each vehicle are shown in Table 1.

Table 1: Result of statistical factors and identification vector for 5 car model.
(A): Vehicle Model. (B): Identification vector. (C): Variance. (D): L1-norm. (E): L2-norm.

(A)	(B)	(C)	(D)	(E)
		**8.32**	**46.30**	**13.02**
		**15.91**	**69.33**	**17.84**
		**63.29**	**131.93**	**35.79**
		**46.48**	**104.52**	**30.73**
		**22.36**	**76.66**	**21.30**

b. Similarity Factor

The type of vehicles can be detected by using the proposed similarity factor defined in (13).

$$S = abs\left(\sum_{i=1}^{3} DSF_i - \sum_{i=1}^{3} UIF_i \right) \Big/ 3 \quad (13)$$

In this equation DSF is the statistical factors of images which are available in the dataset and UIF is statistical factors of unknown image which the camera captures in real time. According to the proposed equation, the system calculates a similarity value for each image in a dataset in which the minimum value of S shows the type of unknown vehicle.

c. Experimental Results

In this paper all the simulation is performed by using a personal computer with an Intel (R) Core (TM) i7 processor and 6GB of memory. For evaluating the performance of the proposed algorithm we have used 8 car models in the dataset and the system identified 5 unknown car models through these datasets correctly. Our dataset was filled by the most popular vehicles used in many cities of Iran.

Table 2(A-E) shows experimental results of the similarity value of 5 unknown vehicles which indicts in columns by A-E. These cells show lower similarity value for unknown image that similar to our vehicle library. As table2 shows all of unknown images could be matched to the known vehicle model in dataset where the similarity value for these unknown vehicles are calculated 5.0881, 0.6094, 4.0405, 2.5605 and 6.0683, respectively.

In fact, by extracting three statistical characteristics of the unknown vehicle and doing a comparison process based on defined similarity factors, among vehicles which exist in the dataset, the lowest values of similarity factor indicate the type of vehicle. The final results show high and acceptable performance of the proposed algorithm in spite of some minor errors in the border of images.

Table 2: similarity value for unknown car type

vehicle Library					
	A	**B**	**C**	**D**	**E**
	43.1176	**0.6094**	7.7712	57.0133	23.6279
	31.3060	11.0223	**4.0405**	45.2016	11.8163
	11.3352	53.8434	46.6816	**2.5605**	30.8249
	**5.0881**	37.4201	30.2583	18.9838	14.4015
	25.5580	16.9503	9.7885	39.4536	**6.0683**
	25.9502	68.4584	61.2966	12.0545	45.4399
	29.5843	12.9239	5.7622	43.4799	10.0946
	26.4288	16.0795	8.9177	40.3244	6.9391

VI. CONCLUSION

In this article a similarity factor for detecting car model based on side view image has been presented. In the proposed method, the characteristic of the vehicle boundary lines' slope and three statistical features from wavelet coefficients Daubechies are used to identify the type of vehicle. Although the acquiring results indicate the great efficiency of the proposed method to detect vehicle type, the final similarity factor will be closer to zero if the vehicle boundary is extracted more precisely. Therefore, using better methods to detect changes in the picture and identifying the vehicle mask like what in [24] has been expressed is recommended to increase the performance of the presented system in this paper.

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