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## **From the Editor**

*International Journal of Electronics, Mechanical and Mechatronics Engineering (IJEMME), is an international multi-disciplinary journal dedicated to disseminate original, high-quality analytical and experimental research articles on Robotics, Mechanics, Electronics, Telecommunications, Control Systems, System Engineering, Biomedical and Renewable Energy Technologies. Contributions are expected to have relevance to an industry, an industrial process, or a device. Subject areas could be as narrow as a specific phenomenon or a device or as broad as a system.*

*The manuscripts to be published are selected after a peer review process carried out by our board of experts and scientists. Our aim is to establish a publication which will be abstracted and indexed in the Engineering Index (EI) and Science Citation Index (SCI) in the near future. The journal has a short processing period to encourage young scientists.*

**Prof. Dr. Hasan HEPERKAN**  
**Editor**





## Multiclass Cancer Diagnosis using Firefly Algorithm and K- Nearest Neighbor

Elnaz PASHAEI<sup>1</sup>

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**Abstract** - Among a large number of genes in microarray data sets that characterize the samples, many of them may be irrelevant to the learning tasks. Thus there is a need for reliable methods for gene representation, reduction, and selection, to speed up the processing rate, improve the classification accuracy, and to avoid incomprehensibility due to the high number of genes investigated. Classifying multiclass data sets is usually more difficult than classifying microarray datasets with only two classes. In this paper, we propose a new gene selection and classification strategy based on Firefly Algorithm (FFA) and K- Nearest Neighbor (KNN), suitable for multiclass microarray data sets. This approach is associated with Kruskal-test pre-filtering technique. The FFA is utilized to evolve gene subsets whose fitness is evaluated by a KNN classifier with leave-one-out-cross-validation (LOOCV) schema. The experimental results on three multiclass high-dimensional data sets show that the proposed method simplifies gene signatures effectively and obtains approximately higher classification accuracy compared to the best previously published results.

**Keywords:** *Gene selection, firefly algorithm, kruskal-test, k- nearest neighbor.*

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### 1.Introduction

The DNA microarray technology simultaneously allows for monitoring and measuring the expression level of a great number of genes in tissue samples. In microarray data sets the number of samples is much smaller than the number of genes. The classification of such data results with the known problem of “curse of dimensionality” and data overfitting. Therefore, for a successful disease diagnosis, it is necessary to select a small number of discriminative genes that are relevant for classification. Gene selection in microarray data analysis, not only increases the classification accuracy, but also decreases the processing time in the clinical setting. Hence, it is quite important to determine a minimum subset of genes for developing a successful disease diagnostic system. There are different methods developed for gene selection in recent years. These methods can be categorized into two main groups as the filter (ranking) and wrapper (gene subset selection) approach. The filter approach assesses each gene individually and ranks the genes from the most relevant to the less relevant using a certain 'filter' criteria. The filter approaches that can be used without restriction in the multiclass case are F-test, Kruskal-test, Random Forest (RF), and boosting. Multiclass generalization to the Wilcoxon rank sum test and the nonparametric pendant to the F-test is known as Kruskal-test. Wrapper approaches evaluate the goodness of each found gene subset by the estimation of the accuracy percentage of the specific classifier.

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The classifier is trained only with the found genes. Wrapper approaches, when compared to the filter approaches, obtain better classification performance, however they are more of a computational cost. Evolutionary algorithms such as Genetic Algorithm (GA), Particle Swarm Optimization (PSO) [1-3], Ant Colony Optimization (ACO) [4], Binary Black Hole Algorithm (BBHA) [5], and Firefly Algorithm (FFA) [6] are some wrapper based approaches that have been provided and widely applied in bioinformatics. Since these approaches simultaneously evaluate many points on the search space, they can obtain excellent performance in gene expression data analysis. FFA has been used effectively to solve various NP-hard problems such as image processing, shape, and size optimization, set covering problem, manufacturing cell problem and gene selection [6-9]. However, combining FFA with 1NN classifier and applying it as gene selector on gene expression datasets has rarely been investigated by previous researchers. Gene selection and classifier design are known as two crucial factors in determining the performance of gene expression classification problem. In fact, the gene expression classification results depend on selected relevant gene subsets and performance of the classifiers. In classifier design, classification of multiclass (class >2) microarrays are usually more difficult than the classification of microarray datasets with only two classes. The support vector machines (SVMs) [6], nearest Shrunken Centroids Discriminant Analysis (SCDA) [10], Random Forest, and K-nearest neighbor (K-NN) [1] are three prevalent classifiers, which have been found useful in handling classification tasks in the case of the high dimensionality and multiclass data. The K-NN is one of the most popular nonparametric methods that were introduced by Fix and Hodges in 1951. K-NN is invariant to noisy data and not negatively affected when the training data is large. For error estimation on the classifier, the leave-one-out-cross-validation (LOOCV) schema can be utilized. The LOOCV technique is a straightforward and unbiased estimator that is widely used in small sample-sized data sets. In this paper, we are interested in gene selection and the classification of multiclass microarray data. For this purpose, we proposed a hybrid model that uses two techniques: LOOCV Kruskal-test and Firefly Algorithm (FFA) combined with one nearest neighbor (1-NN). First, to cope with the difficulty related to high-dimensional data, we use a Multi-class generalization to the Wilcoxon rank sum test as a pre-filtering step which ranks the genes from the most relevant to the less relevant for gene reduction. From each data set, 1000 tops ranked genes are selected. Second, the FFA combined with a 1NN classifier is used for final gene selection and classification. The gene subsets were measured by the LOOCV mean absolute error of one nearest neighbor (1-NN). Neighbors are calculated using their Euclidean distance.

The proposed approach is experimentally assessed on three long-familiar multiclass microarrays (9-Tumors, 11-Tumors, and Lung-Cancer). Comparisons with eight well-known classifiers and six state-of-the-art demonstrate that our proposed approach yields a minimum number of genes with high prediction performance. The remainder of this paper is organized as follows; we introduce the general scheme of our hybrid model in Section 2. Experimental results and Comparisons are presented in Section 3. Finally, conclusions are given in Section 4.

## 2. Gene Selection and Classification by FFA/1NN

In this section, we describe the hybrid FFA/1NN algorithm for performing gene selection and classification of multiclass microarray data. The FFA is designed both for identifying optimal gene subsets (solutions) and for final gene selection and classification. The 1NN-based classifier is used to ensure the fitness evaluation of each candidate solution as part of the firefly based wrapper algorithm.

### a) The Firefly Algorithm

The Firefly Algorithm (FFA) is a novel nature-inspired algorithm which was presented by Xin-She Yang in 2008 [7] and applied for solving the linear design problem and multimodal optimization problem. The idea of the FFA is to mimic the behavior of flashing lights of fireflies. The FFA was developed by utilizing the following three idealized rules:



- All fireflies are unisex and are attracted to other fireflies regardless of their sex.
- The degree of the attractiveness of a firefly is proportional to its brightness, and thus for any two flashing fireflies, the dimmer firefly is attracted by the brighter one and moves towards it. The fewer distance between two fireflies means more brightness. Fireflies move randomly if there are no brighter fireflies nearby.
- The brightness of a firefly is determined by the value of the objective function.

Based on these three rules the pseudo code of FFA is shown in Figure 1.

---

```
Objective function  $f(x), x = (x_1, x_2, \dots, x_d)^T$ 
Generate an initial population of n fireflies  $x_i(1, 2, \dots, n)$ 
Light intensity  $I_i$  at  $x_i$  is determined by  $f(x)_i$ 
Define a light absorption coefficient  $(\gamma) = 0.001$ ;
Define mutation Coefficient ( $\alpha$ )=0.01;
while ( $t < \max\ generartion$ )
  for  $i = 1:n$ 
    for  $j = 1:n$ 
      if  $I_i < I_j$ 
         $r_{ij} = \|x_i - x_j\| = \sqrt{\sum_{k=d}^1 (x_{i,k} - x_{j,k})^2}$ ;
         $\beta = \beta_0 e^{-\gamma r_{ij}^2}$ ;  $\beta_0 = 0.33$ ;
         $x_i^{t+1} = x_i^t + \beta (x_j^t - x_i^t) + \alpha \epsilon_i^t$ ;
         $\epsilon_i^t$  is a vector of random numbers drawn from a uniform distribution
      end if
      Evaluate new solutions and update light intensity
    end for  $j$ 
  end for  $i$ 
  Rank the fireflies and find the current global best  $g^*$ 
end while.
```

---

**Figure 1. Pseudo code of the firefly algorithm.**

#### **b) Fireflies and initial population.**

The Fireflies are binary-encoded; each allele (a bit) of the fireflies represents a gene. If an allele is “1” it indicates that this gene is kept in the gene subset and “0” means that the gene is not included in the subset. Thus, each firefly represents a gene subset. The firefly length is equal in the number of genes pre-selected by the Kruskal test pre-processing (i.e. 1000 for each data set). The initial population of the FFA is randomly generated according to a uniform distribution.

**c)Objective function.**

The fitness of a firefly, i.e. a subset of genes, is evaluated by LOOCV classification mean absolute error of 1NN classifier. In other words, the lower fitness value is gotten; the better gene subset may be obtained.

**d)Stopping criterion.**

The evolution process ends when a pre-defined number of generations (200) is reached.

**3.Evaluation****a)Parameters Settings**

Table 1 summarizes three multiclass gene expression data sets that are used for this study. These data sets have thousands of genes (high-dimensional data). They were downloaded from <http://www.gems-system.org>. All the experimental results reported in this article was acquired using WEKA open source machine learning software and R packages. Firstly, a Kruskal-test was applied for pre-processing in order to pre-select 1000- tops-ranked genes. For performing Kruskal-test, “CMA” package in R [11] was used. The genes were then applied in FFA. Next, the LOOCV mean absolute error of gene subsets that were produced by FFA, was measured by using KNN. Generally, in LOOCV, one sample among all samples is evaluated as testing data while the others are used as training data. This is repeated so that each observation in the sample is used once as the test data. The sizes of population and iterations for all data sets are set to 50 and 200, respectively. These parameters are same for cuckoo search. For FFA, except mutation type that must be set to bit-off, the remaining parameters are set as default.

**b)Results and Comparisons**

Firstly, in order to accelerate the speed of convergence and alleviate the burden of computation, 1000 top ranked informative genes were selected by Kruskal-test approach. Then to further reduce the number of marker genes and improve the classification accuracy, the FFA/1NN algorithm was applied on these 1000 genes.

Table 2 reports the LOOCV classification accuracy of the five classifiers without using any gene selection approach on 9-Tumor, 11-Tumors, and Lung cancer data sets. The results presented in this table imply that without using any gene selection approach, we cannot be able to capture the patterns that underlie the gene expression profiles.

Table 3 shows the LOOCV classification accuracies of eight different classifiers on 1000 top ranked genes which were obtained by filter-based feature ranking approach (Kruskal-test). We compared the LOOCV classification accuracy of the FFA/1NN algorithm proposed in this paper with the following eight most popular algorithms; Cuckoo search/Naive Bayes, PART, 1NN, Boosted C5.0, Correlation-based Feature Subset selection (CFS)/Multinomial logistic regression, SVM with the polynomial kernel, Random Forest (RF), and SCDA. Experimental results show that our method resulted in higher averages of the classification accuracies on all data sets compared to the eight methods in Table 3.

To carry out our experiments, our FFA/1NN algorithm is run 5 times on each of the 9-Tumor, 11-Tumors, and Lung cancer multi-class microarray data sets (Table 4). Table 5 summarizes our results (Column 2) for these data sets with the results of six state-of-the-art methods from the literature (Columns 3-8). Two criteria are used to compare the results: the classification accuracy (first number) and the number of used genes (the number in parenthesis).

For all the data sets, the averages of the number of the selected genes for our work were smaller than the previous works [1-3, 12, 13]. As it can be observed, for the 9-Tumor data set, we obtained a classification rate of 90.66% using 43.2 genes, which is much better than that reported in [1-3, 12-14]. The study [13] has shown better classification accuracy than our work on Lung cancer data set but with a greater number of genes (99.52% with 6958 genes). Our approach offers the correct classification rate as 98.32% with only 21.8 genes. For 11-Tumors data set, our approach has achieved the highest (averaged) classification accuracy with the minimum number of genes. The same performance is achieved by [13], with a high number of selected genes.

Table 4 shows the detailed results of five independent runs of our FFA/INN algorithm. As it can be observed, these results are quite stable in all data sets based on the standard deviations. For the 11-Tumors and Lung cancer data sets, each of the five runs obtains a classification rate of 97% and 98 % while for the 9-tumor data set, the best run gives a classification rate of 93.33. Even the worst obtains a classification rate of 88.33.

Experimental results show that our proposed Kruskal-test/FFA/INN algorithm may select a smaller gene subset with better LOOCV classification accuracy than many other methods in almost all data sets. Therefore, it is more effective for gene subset selection and pattern classification on multiclass data sets.

#### 4. Conclusion

In this paper, a new hybrid algorithm was presented for gene selection and classification of multiclass high dimensional microarray data. The FFA Algorithm employed KNN classifier to intelligently select the most convenient genes that could maximize the classification accuracy while ignoring the redundant and noisy genes. The proposed approach, compared to the existing methods, achieves better classification accuracy with significantly fewer numbers of genes.

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## Least Significant Bit Gaped: A New Method for Image Steganography

Waleed TUZA<sup>1</sup>, Dr. Öğr. Üyesi N. Gökhan KASAPOĞLU<sup>2</sup>

---

**Abstract** - Steganography is an information security technique that provides a solution for hiding information. There are different types of cover mediums that can be used in steganography such as text or image steganography. We chose image steganography as our domain of work where the images are used as cover mediums to be our basis of experiments for the proposed LSBG method. One of the main well-known steganography methods is the least significant bit (LSB), however it has its limitations and therefore many approaches have been proposed to improve it. We propose a new improvement method defined as Least Significant Bit Gaped (LSBG) where the aim is to improve steganography imperceptibility compared to LSB by comparing the histogram analysis of LSB with LSBG methods and MSE measures. The proposed LSBG method will also offer a new key structure that will increase the complexity in secret data extraction and the level of information security.

**Keywords:** *Steganography, Least Significant Bit, Least Significant Bit Gaped*

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### 1. Introduction

Steganography is the art of hiding data. It is an information security method that can be applied to secure the information by hiding it in a medium where the secret information cannot be observed. Steganography methods, in recent years, have been applied in the digital world where we deal with different digital media such as images, audio, or video data. Digital steganography works by using those digital mediums as cover mediums where the secret message is required to be in a digital data form too. The application of steganography simply consists of embedding secret information data in a selected cover medium to produce a stego medium where it holds the hidden data.

There are wide applications where steganography can be used. Secret and covert communication systems, for instance, the military communications systems need to possess a high level of information security during transmission where steganography takes a place as one of the possible solutions [2]. Some of the widely used applications for steganography are watermarking and fingerprinting, which are used for protecting the copyrights and data property for the owners.

Another possible application area of steganography is the secure storage of information [12]. Steganography can be considered as a useful method to save information data in an undetectable way which is an important element for securing the data.

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As mentioned before, steganography can use different types of cover mediums such as text medium, image medium, audio medium, and other types of mediums [7]. Also for secret messages, messages can be any kind of data medium like a text or an image.

### **1.1. Steganography Elements**

As a system, the steganography method can be divided into four main elements as listed below:

- Secret message: it is the message that will be embedded in the cover medium. It is actually the crucial element to be secured by hiding so that it cannot be detected. The secret message can be any type of data such as a simple text message or an image.
- Cover object: it is the medium that will be used as a carrier of the embedded secret data. Selecting a suitable cover medium is very important for concealing the secret based on the steganography method requirements.
- Steganography key: the key can be considered as the control data part that you need when you want to apply the inverse operation of steganography method and extract the secret message. Without the knowledge of the key, you will not be able to extract the secret message from the cover medium.
- Stego object: it is the result carrier medium that contains the embedded secret message hidden inside it.

### **1.2. Steganography in Communication Systems**

In covert communication systems, the most important parameter for steganography to be considered is imperceptibility. The main objective for the hidden data is to raise no suspicion regarding the cover medium being edited [4]. That is why the designer will try to maximize the level of imperceptibility on the expense of having reduced levels of capacity and robustness [3]. Improving imperceptibility can be done by reducing the amount of changes in the data values (pixel intensities) in the cover medium during the embedding of the secret data.

Using steganography as an information security technique can be very useful in communication systems. Especially in communication systems that are used for military applications where the communication of information is considered to be confidential and is very important not to be received and analyzed by third parties. That is why it is important to secure the information so that in case received by a third party, the data cannot be analyzed and that is where encryption and steganography come into play. Those information security techniques can be used as pre-stages in the communication system in order to secure the information signal from being used by a third party.

Using lossless compression as a pre-stage operation of steganography in the communication systems provides the capability of extracting and reconstructing the secret message 100% accurately [5]. Moreover, it is a great solution for reducing the capacity of the secret message. Error detection and correction (EDC) coding is used for ensuring the correct reconstruction of the embedded data. Below, Figure 1 shows a block diagram of the communication system that has encryption and steganography methods used for securing the secret data before transmitting it:

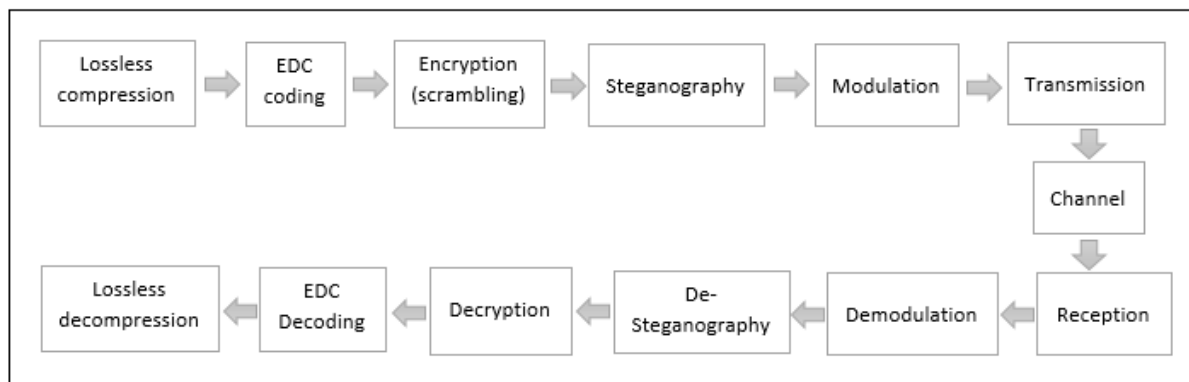


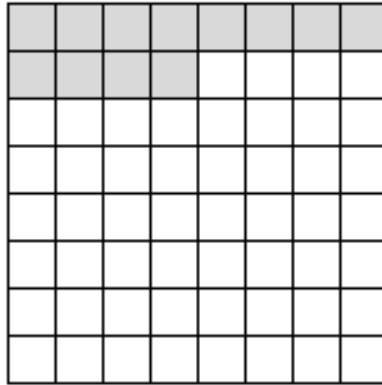
Figure 1: Covert communication system block diagram.

## 2. Least Significant Bit (LSB)

Least Significant Bit is a steganography method of embedding hidden data by using the least significant bits of the cover medium data bytes (image pixels). To simply summarize the way of embedding data in LSB method, LSB is located as the last bit from the right side of any binary value [7]. In LSB embedding, it is possible to use the last bit, last two bits, or the last three bits in the binary value of the byte or pixel for data embedding. Therefore, if we have a 1-byte pixel size, the minimum LSB capacity is 1 bit per pixel (bpp) [7]. For example, if we have a byte binary value of (11110101), the last LSB is (1), and the last two LSB bits are (01), also if one wants to know, the last three LSB bits are equal to (101).

For instance, let's have three pixels of the cover image with binary values of (11110001 11110000 11110011) and if we want to embed a message of 3 bits as (110) in those three pixels then 1 bit is needed for LSB embedding in each pixel. By that, the result stego pixels are (11110001 11110001 11110010). As you can see for the first pixel, the secret bit is equal to last bit in the pixel and that is why the pixel LSB value is still the same. While in the second and the third pixels, the LSB bits were changed to the value of the second and third bits of the message as seen in red color.

In Figure 2, we have another example to demonstrate the locations of the LSB pixels in a cover image. It is assumed that we have an (8x8) size cover image and we have a secret message that has a capacity of 24 bits. If we have used LSB with embedding two bits in each selected pixel, then we need a total of 12 pixels to carry the secret message. Therefore, the first 12 pixels in the cover image that are highlighted in grey, are used for LSB embedding. The remaining pixels that are highlighted in white in the cover image will be left untouched.



**Figure 2:** An 8x8 pixel size stego image where the highlighted pixels in gray are the pixels used for LSB method.

### 3. Least Significant Bit Gapped (LSBG) Methodology

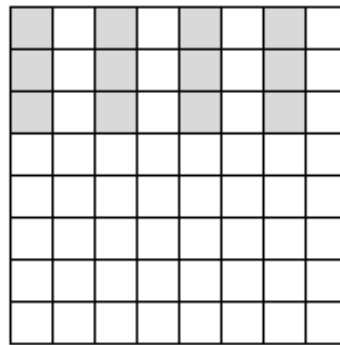
Basically, the concept covers embedding the secret message in certain pixels with a certain rate using LSB method. Also, LSBG method requires gap pixels with a certain rate where there are no data embedded in these pixels. Hence, in the stego medium, the pixels are divided into two parts. First, the LSB pixels that are to be used for LSB embedding are selected. The other part includes the gap pixels which can be defined as the pixels that are not selected for LSB embedding. The reason behind the name “gap pixels” originates from the fact that those pixels not being used for containing any data of the secret message, and that is why they can be considered as gaps. The gapping rate can vary from one LSB pixel to one gap pixel (1LSB to 1G), one LSB pixel to two gap pixels (1LSB to 2G), one LSB pixel to two gap pixels (1LSB to 3G), and so on. The main idea of applying such a method is to have the ability to distribute the secret embedded LSB pixels in the majority of the cover medium area (image pixel area) as much as possible. The ratio of LSB pixels to gap pixels depend on two main factors:

1. The capacity of the secret message to be hidden. The smaller the capacity of the secret message, the more possible gapping rates can be applied in the cover medium.
2. The capacity of the cover medium (cover image). The larger capacity of the cover image offers the capability of applying high variety of (LSB to G) rates.

Studying the previous two factors, we can select a suitable LSB to gap rate based on the capacity of the secret message and the capacity of the chosen cover image to apply LSBG method.

In LSBG method, the ratio of LSB pixels to gap pixels can be performed in either horizontal or vertical axes in the cover image. The selection of the axis can be made by the designer. In Figure 3, same as before, we assume having 12 pixels to carry the secret message. LSBG method is applied with horizontal gapping and the LSBG gapping rate is 1LSB to 1G.



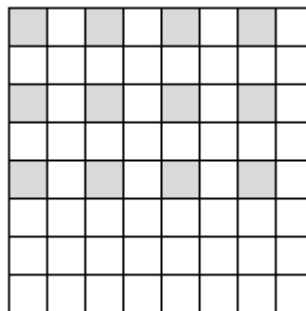


**Figure 3:** An 8x8 pixel size stego image where highlighted pixels in gray are the ones used for LSBG method with 1LSB /1G ratio in horizontal access.

### 3.1. Two-Dimensional LSBG (2D LSBG)

The LSBG gapping can be applied in the vertical or in the horizontal axes as explained previously. However, there is also the possibility of applying (two dimensional) LSBG gapping in both vertical and horizontal axes. The 2D LSBG provides a greater LSB pixels distribution in the cover medium.

In Figure 4, we have the same cover image with a size of 8x8 pixels and 2D LSBG method is applied with 1LSB to 1G rate where the gapping is done in both vertical and horizontal axes and the 12 LSB pixels are distributed as shown in the figure below.

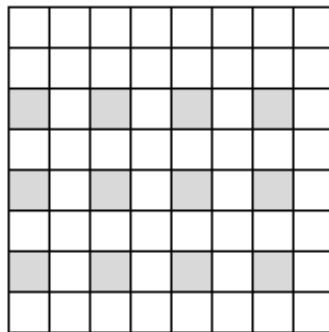


**Figure 4:** An 8x8 pixel size stego image where highlighted pixels in gray are the ones used for 2D LSBG method with 1LSB /1G ratio.

### 3.2. Shifting Property for LSBG

Shifting property can be applied to either LSB or LSBG method where the aim is not to apply the steganography technique from the beginning of the cover medium but to shift the starting point (starting LSB pixel) with a certain number that is chosen by the designer. Applying this method will increase the difficulty of extracting the secret information from the LSB pixels by third parties since the starting point is only known by the designer. The shifting property can be used as an additional element to the steganography LSBG key elements.

In Figure 5 where the 2D LSBG method is used with the ratio of 1LSB to 1G, an additional shifting property was applied for placing the start point from the third row from up in the cover image as seen in the figure.



**Figure 5:** An 8x8 pixel size stego image where highlighted pixels in gray are the ones used for 2D LSBG method with 1LSB /1G ratio and shift property.

### 3.3. LSB and LSBG capacity

The formula for finding the maximum possible capacity of LSB method in a cover image is shown in formula (1) below:

$$Max \{C_{LSB}\} = n_p \cdot n_b \tag{1}$$

Where  $n_p$  is total number of pixels and  $n_b$  is total number of bits used per pixel. While the maximum possible capacity of LSBG method in a cover image is shown in formula (2) below:

$$Max\{C_{LSBG}\} = \frac{n_p \cdot n_b}{(n_g + 1)} \tag{2}$$

Where  $n_g$  is the number of gaps in the gapping rate. Finally, the maximum possible capacity of 2D LSBG method in a cover image is given in formula (3) below:

$$Max\{C_{2D\ LSBG}\} = \frac{n_p \cdot n_b}{(n_g + 1)^2} \tag{3}$$

For a cover image of a selected pixel size of 256 x 256, Table 1 demonstrates the maximum capacity of the secret data to be embedded when using LSB and LSBG at different possible gapping rates for 1 byte pixel capacity for LSB and LSBG.

**Table 1.** Maximum capacity for cover image with 256x256 pixel size.

Method	Max. capacity
LSB (2 bpp)	131,072 bits (16,384 byte)
LSBG (2 bpp) (1LSB to 1G)	65,536 bits (8,192 byte)
LSBG (2 bpp) (1LSB to 3G)	32,768 bits (4,096 byte)
LSBG (2 bpp) (1LSB to 7G)	16,384 bits (2,048 byte)
LSBG (2 bpp) (1LSB to 15G)	8,192 bits (1,024 byte)
LSBG (2 bpp) (1LSB to 31G)	4,096 bits (512 byte)
LSBG (2 bpp) (1LSB to 63G)	2,048 bits (256 byte)
LSBG (2 bpp) (1LSB to 127G)	1,024 bits (128 byte)

As it can be noticed that the more you increase the gapping rate the less capacity it can support for embedding the secret message. From the given secret message capacity, a suitable gapping rate that supports a greater embedding capacity is selected for carrying the secret message .

### 3.3. LSBG Key Elements

One of the main improvement points of LSBG over LSB is the complexity of the key elements of LSBG method. In LSBG method, the length of the secret message and the LSB method's embedding rate per pixel are not enough alone. One actually needs to have all the elements of the LSBG key to be able to extract the embedded secret message successfully. The LSBG key elements can be defined as follows:

- The capacity of the secret message (Total number of the bits of the secret bit stream).
- The selection of number of bits to be embedded in each pixel by the designer.
- The selection of the ratio of LSB pixels to gap pixels to be used for data embedding.
- The selection of the start point of LSBG embedding. An additional applicable element by using shifting property.
- The LSB sequence number in the LSB to G ratio. (In case multiple messages multiplexing is used).
- The possible usage of encryption (scrambling) before applying LSBG method as pre-stage. Adding the key of encryption will cause the secret bits to be embedded in a non-sequential way in the selected LSB pixels.
- The possible usage of Lossless compression method for the secret message before applying LSBG method. Adding the key of compression as a pre-stage will help reduce the capacity of the secret message and also the secret message cannot be analyzed during extraction from LSBG unless it is decompressed
- Band selection for LSBG method. This is applicable certainly; if multiple bands colored images are used like RGB images. This way one band would be selected while the other band will remain the same.

## 4. Designed Experiments and Results

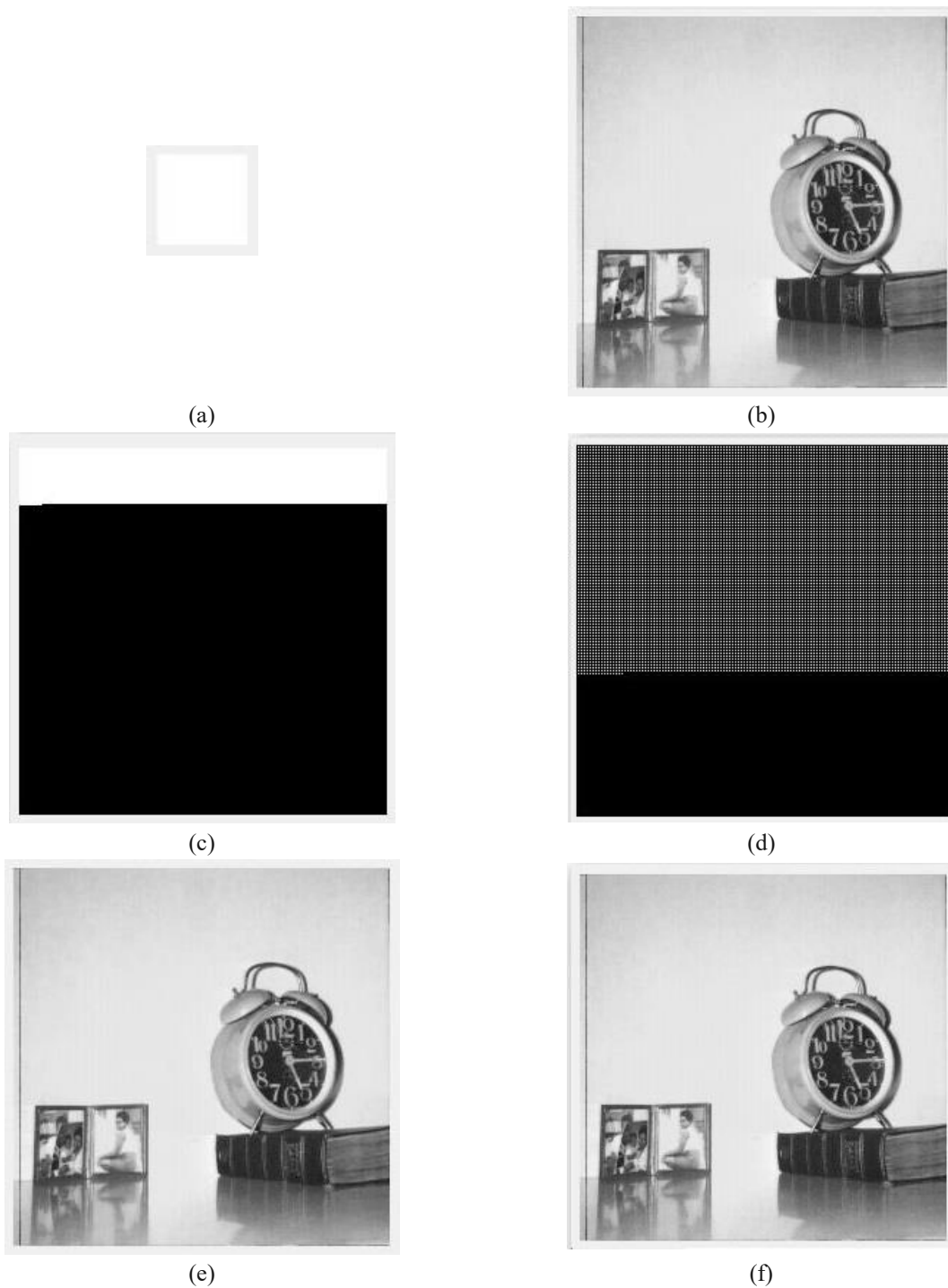
The used secret image is a 50x50 pixel size white background image with fixed pixel value of 255 (the binary value of 11111111). This secret image was selected as a severe case as it causes a high amount of deviation in the stego histogram which is important since it requires applying different methods that are used in the experiments, demonstrating the great difference clearly in the stego histogram between the each embedding method used. The used cover image is a grayscale watch image with the size of 256x256 pixels.

Embedding methods used in this case:

- Least Significant Bit method, (LSB) (2 bpp).
- Least Significant Bit Gaped method, (2D LSBG) (2 bpp) (1LSB to 1G).

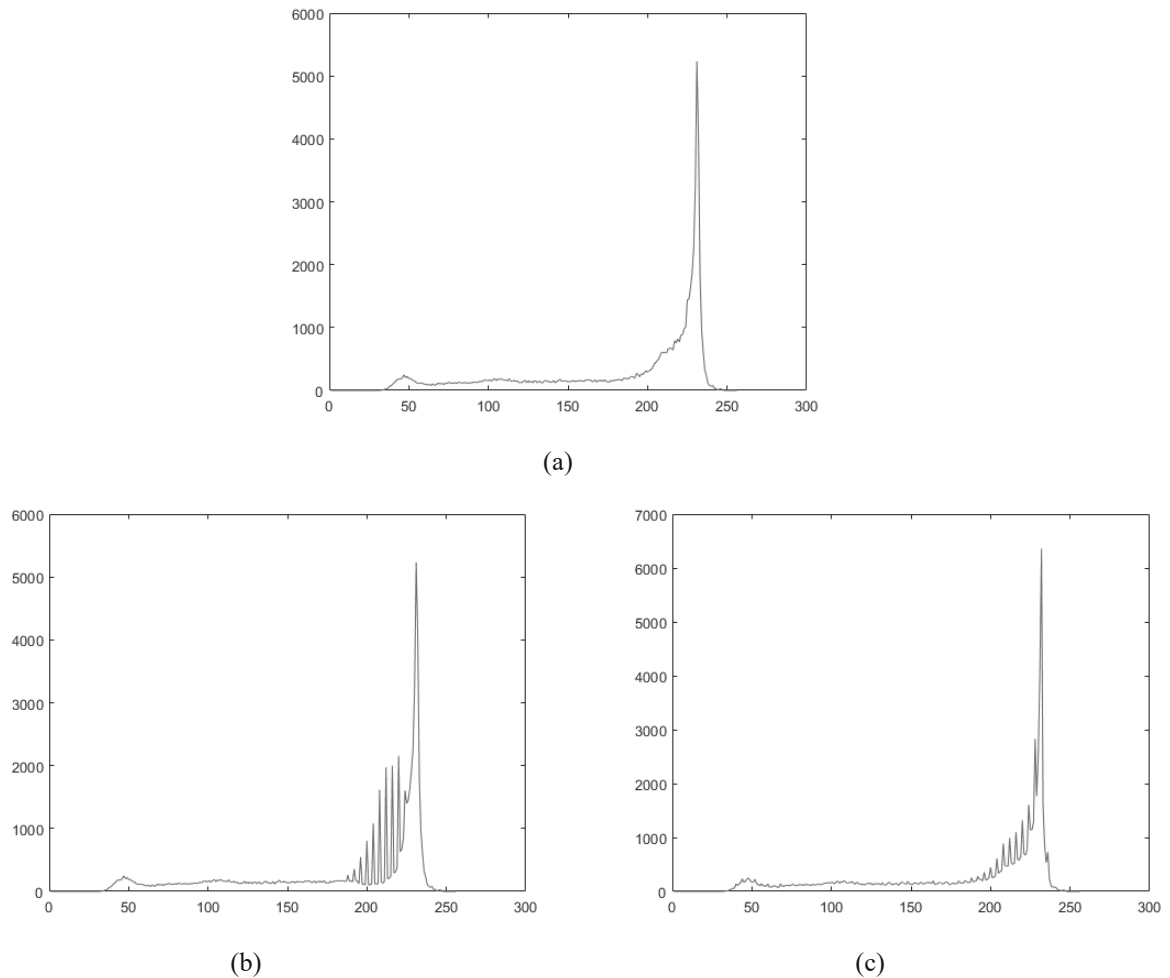
The evaluation process is conducted by analyzing the histograms of the stego images and making a comparison of the histograms of LSB and LSBG methods. Mean square error (MSE) and Peak Signal to Noise Ratio (PSNR) are measured to determine the amount of change between the cover and stego mediums for both LSB and LSBG methods. The less MSE value indicates less difference between the cover image and stego image and by that the imperceptibility level is increased.

The following figure is composed in six subfigures, the selected secret white image is shown in Figure 6 (a). Watch image is the selected cover image in the experiment as seen in Figure 6 (b). A demonstration figure with the cover image pixel size was generated to highlight the selected pixels for embedding in white and remaining unchanged pixels in black. In Figure 6 (c) we can see the demonstration figure of selected pixels for LSB embedding and in Figure 6 (d) the demonstration figure of selected pixels for 2D LSBG embedding. Figure 6 (e) shows the result stego image after using LSB embedding and Figure 6 (f) shows the result stego image using 2D LSBG method.



**Figure 6:** (a) Secret image; (b) cover image before embedding; (c) a demonstration figure of the selected pixels for embedding in white for LSB method (d) a demonstration figure of the selected pixels for embedding in white for 2D LSBG (1LSB to 1G) method; (e) the stego image using LSB (f) the stego image using LSBG (1LSB to 1G).

In Figure 7 which is composed of three subfigures, the histogram is generated for the selected cover image before embedding as seen in Figure 7 (a). The generated histogram of the resulting stego image acquired by using LSB method is shown in Figure 7 (b). Finally, in Figure 7 (c), we can observe the generated histogram of the resulting stego image acquired by the 2D LSBG method.



**Figure 7:** (a) Histogram of the cover image before embedding; (b) Histogram of the stego image after LSB embedding; (d) Histogram of the stego image after 2D LSBG (1LSB to 1G) embedding.

From the analysis of the histogram results with the cases applied, we can see the stego histogram having a high deviation that is in a specific range of the histogram and can only be noticed when compared to the cover histogram in a simple LSB method. In 2D LSBG method, on the other hand, the deviation in stego image histogram spreads in a higher range and the range cannot be accurately defined.

The MSE and PSNR measurements of the given cases are listed below in Table 2:

**Table 2.** MSE & PSNR Results.

Secret	Cover image	Method	MSE	PSNR
White image	Watch image	LSB (2 bpp)	0.5467	50.7528
White image	Watch image	2D LSBG (2 bpp) (1LSB to 1G)	0.5011	51.1307

If we study the MSE and PSNR results above, we notice the improvement achieved by LSBG method by reducing the MSE value and increasing the PSNR value compared to the applied LSB method.

### 5. Conclusion

Compared to LSB, applying LSBG method distributes and spreads deviation in a higher range in the histogram of the stego image. The interesting improvement is that the deviation effect is getting reduced since the deviation itself has been stretched and distributed in the histogram range.

For MSE and PSNR results of the given case, we can conclude that the LSBG method improved the system performance compared to LSB method by reducing the MSE value and logically increasing the PSNR value. As mentioned before, MSE improvement indicates an imperceptibility improvement in the stego image. For some other cases and experiments using other cover images, we did not have the same improvement in the MSE and PSNR values. This specific point shows the importance of selecting a suitable cover image for LSBG method which ensures the MSE and PSNR improvement.

According to our study, we recommend selecting a cover image with a narrow dynamic range histogram in order to ensure the improvement of the performance in applying LSBG method. We suggest using multiple options for cover images and applying multiple LSBG rates to them and analyzing the results, the case with the best result can be chosen. One recommendation that can be made is to apply the highest LSBG rate possible to ensure a greater distribution of LSB embedded pixels in the selected cover image. Another recommendation is to apply the shifting property of LSBG to enhance the key complexity of the used steganography method.

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## Identification of Vehicle Design and Transition of Traffic Signs with Image Processing Method

Metin BILGIN<sup>1</sup>, Zekeriya ZEYBEK<sup>2</sup>

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**Abstract** - Automobiles which are the most intensive and preferred means of transportation in all time, have many innovations and features based on the comfort, security and satisfaction of the users. It would be an ideal solution to develop a system that can alert drivers and intervene when needed given the sudden illness seizures that drivers experience in case of an accident. With the object recognition method, traffic signs, warning flashers and passages on the route are detected and the back panel is processed in milliseconds to warn the driver.

In this study, image processing methods are applied in order to create a prototype of an autonomous vehicle by establishing a fast and stable decision making mechanism.

**Keywords:** *Traffic sign recognition and detection, color segmentation, HSV color filtering, image processing*

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### 1.Introduction

Traffic signs are the symbols and flashers that are designed to alert and direct the vehicle drivers in motion. It is possible to collect traffic signs under four main categories which are prohibition, warning, information and obligation. Signs are specified according to their types, colors and shapes. Prohibition signs are formed on a white background within a red frame. Symbols are formed within a white frame on a blue background or within a red frame on a triangular white background. The information plaques are generally rectangular and formed on a white background in thick blue frames with black symbols and shapes. There are two signs that are different from the rest of the signs, these are "Stop" and "Cannot be entered" signs. The unmarked sign consists of a white horizontal line on a red background. The stop sign, on the other hand, consists of the word "STOP" written in white with capital letters within the shape of a hexagon on a red background.

Traffic sign recognition has become popular in recent years and accordingly the number of methods has also increased. In this project, first, a snapshot will be taken using a camera. This image will then be converted to grayscale in order the desired shape and color to be determined. Then, the designated symbol will be identified, and the vehicle will perform the necessary physical operation. All these scan and recognition operations will protect the vehicle's course by defining the signs in the order of operation.

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People are constantly faced with recognition problems in image processing based operations that they use in everyday life. Many recognition situations such as face recognition, finger recognition, disease diagnosis, etc. are needed in different forms and areas. In each case, there are characteristics to be examined due to obligation and examination techniques are available depending on these references.

When the previously written studies are examined, the image processing method and the sign detection and recognition systems have been applied using different methods. There are very few applications available as a tool capable of deciding what to do by recognizing traffic signs. Current study aims to create a tool that can move autonomously utilizing image processing techniques with the aid of a camera.

The main purpose of recognizing and determining the traffic signs is to warn and intervene in cases of loss of sensitivity due to environmental or personal problems, where the driver's reflexes are weakened. The camera that forms the entrance to the system is located on the front of the vehicle. The camera captures live images and continuously generates instantaneous input. These inputs are processed in the processor in order to perform detection, recognition and classification operations. As can be seen in Figure 1, the detected object is determined. As an output, control is provided by sending necessary signals to the related components of the vehicle.



**Figure 1.** Signal Recognition System

## 2. Method

Techniques in related fields such as pattern detection, machine language, artificial intelligence, and others are used in the processing of the data that the camera captures. The basic technical pattern used in this project is the process itself.

### 2.1. Visual Object Detection

The input of the instant video viewing program from the test camera that is located on the ceiling of the vehicle is created. The snapshots taken from the videotape have significant blurriness. This is due to the fact that the vehicle is in motion and pixel shifts occurring while images are being taken. The snapshots that are taken for minimizing this blur are used in rows and columns. Signs are detected after multi-stage operations.

Then, a color range is determined, and then the image with the RGB color space captured from the camera device is converted to the related hue, saturation and value (HSV) color space.

On the image, the thresholding, grinding and expansion operators are applied. Using methods such as edge detection, colors are distinguished and objects are marked.

HSV space will be used for color detection; shaving in RGB color space is insufficient compared to shaving in HSV color space. Since the value of H (HUE) in HSV is changed more discernibly, the detection of different colored objects is much easier.

#### 2.1.1. Histogram Synchronization

The images taken from the camera do not always look very good. The image quality can be distorted due to various factors, such as light reflections. Therefore, the method of histogram equalization is a very suitable method of healing [1,2]. Histogram equalization is used for improving low visibility in images where color values are not uniformly distributed. This method is applied locally, only to a specific region. Global histogram equalization, on the other hand, is applied when the entire image is at stake whereas local histogram equalization can be applied to a certain region of the image. Non-linear transformation is performed depending on the probability distribution. On this count, when the probability of high probability is high, the low probability levels become closer to each other.

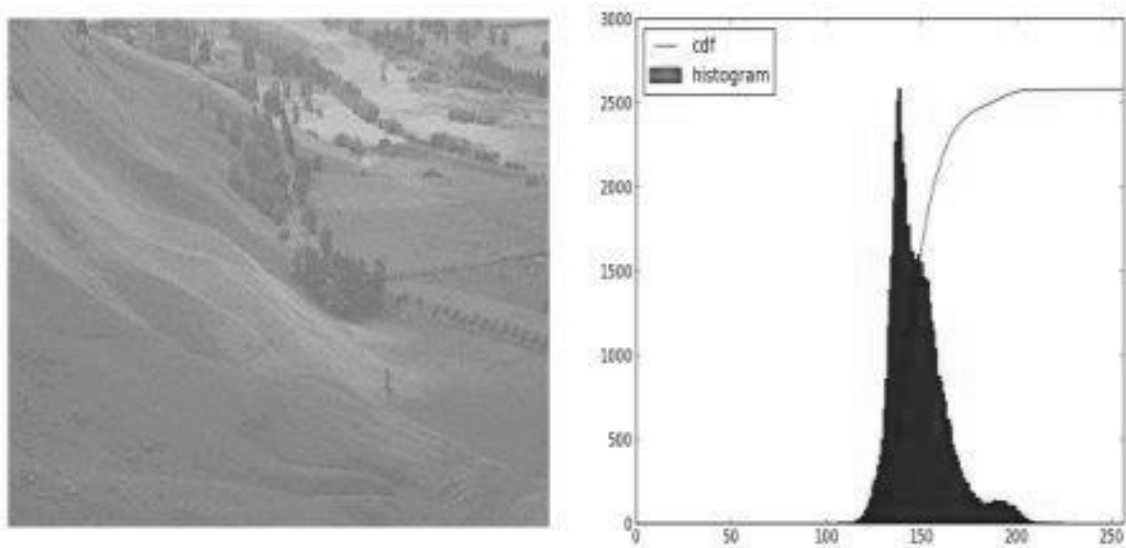


Figure 2. Before Histogram Equalization [3]

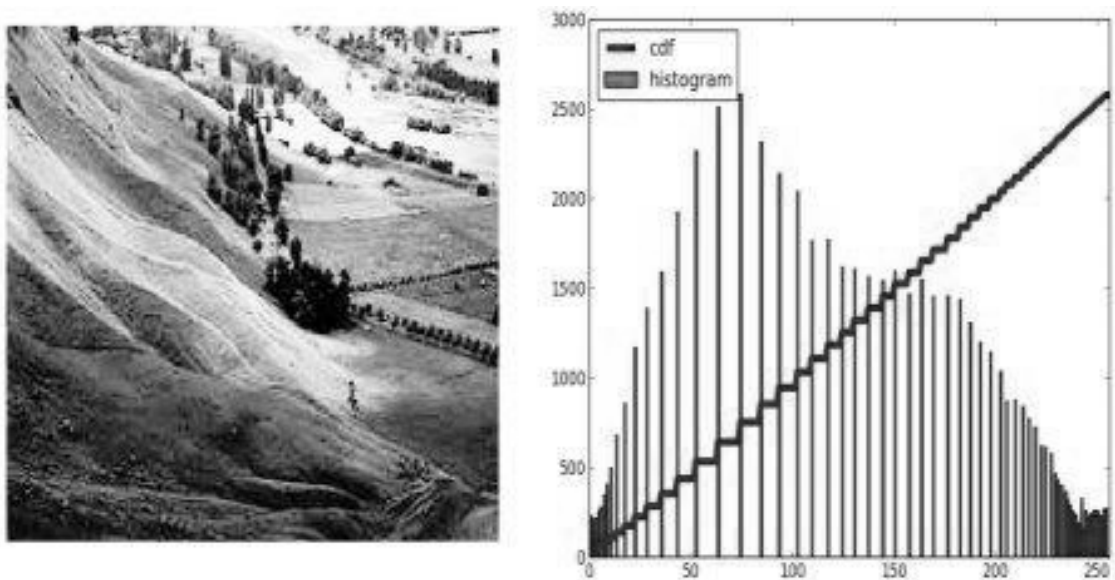


Figure 3. After Histogram Equalization [3]

### 2.1.2. HSV Color Filtering Method

The R (Red), G (Green) and B (Blue) color space is defined by a mixture of three main colors (red, green, blue). The HSV color space defines the color Hue, Saturation and Value [4]. Color, saturation, and brightness values are used in the HSV color space, although the mixture of colors is used in the RGB color space. Saturation refers to the brightness of color when determining the vitality of color. The brightness value is zero while the color and saturation values for the black color in HSV space can take anywhere from 0 to 255. For the color white, the brightness value is 255.

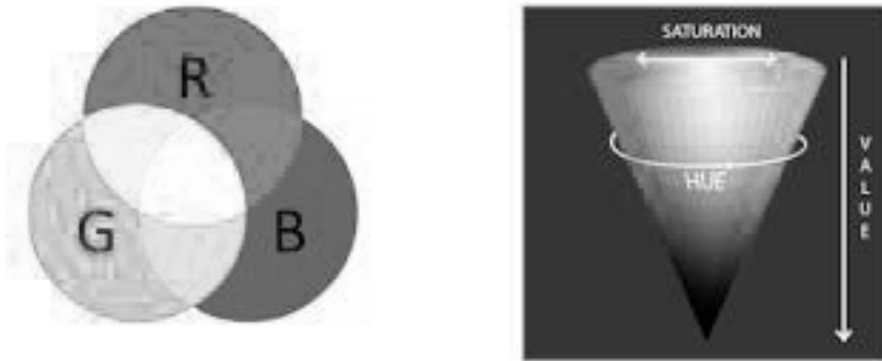


Figure 4. RGB - HSV scales [4]

Accordingly, in any image processing application, it is more convenient to use the HSV color space when we want to distinguish a particular color object. Due to contrasting with RGB, only the hue value can be used for clearly distinguishing colors by applying a threshold value.

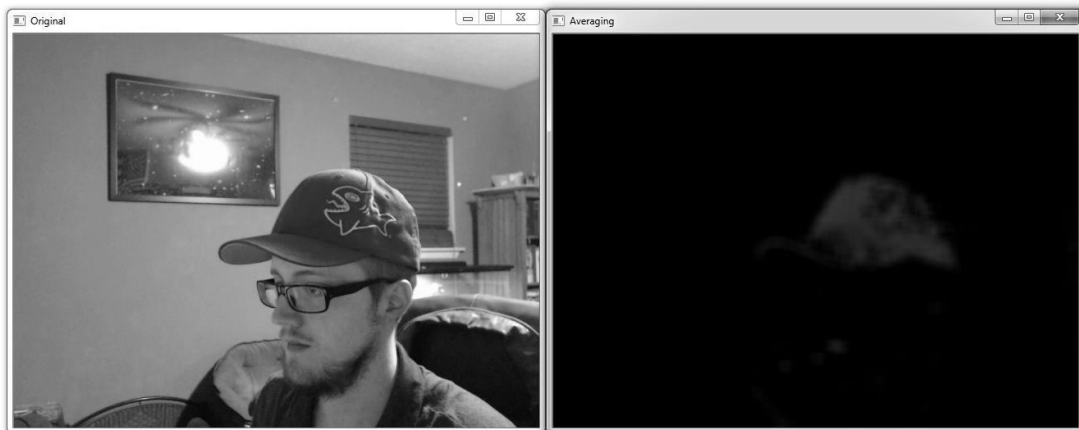


Figure 5. HSV Filter Application [5]

## 2.2. Object Recognition

Object recognition is very important for image processing. Different algorithms have been developed for this subject, which have been working for a long time. The guideline for this field was the Viola Jones algorithm developed by Paul Viola and Michael Jones in 2001. This algorithm has been announced in the article titled "Rapid Object Detection using a Boosted Cascade of Simple Features" [6]. In the following process, many algorithms have been developed, and many developed methods are available in OpenCV.

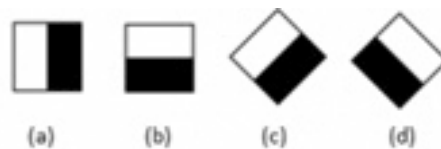
There are four different methods for object recognition and detection:

- Template Matching [7] [8]
- HAAR Cascade [9]
- LBP - Local Binary Pattern [10]
- HOG - Histogram of Oriented Gradients [11]

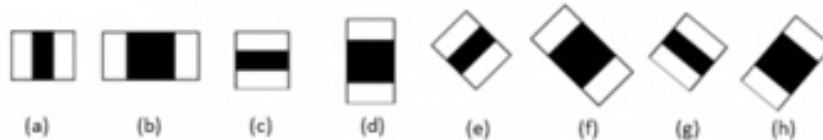
**2.2.1. HAAR Cascade Classifier**

The HAAR Cascade Classifier is a very functional feature. The classifier is primarily trained with examples and then it recognizes the object. The training consists of the steps of forming positive and negative samples of any object to be perceived, marking positive samples, educating the classifier in this direction and perceiving the object using positive images.

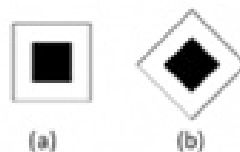
Positive and negative pictures are needed for training the classifier. Positive pictures are the images that contain the target object to be detected whereas the negative images are the images in which the object to be detected is absent. In classifier training, objects in positive pictures are scanned with frames set at certain sizes, as shown in Fig. 6, Fig. 7 and Fig. 8, and the dark luminance values are summed up by adding the pixel values in the black region and the white region in the frame.



**Figure 6.** HAAR Cascade - Edge Classifier



**Figure 7.** HAAR Cascade - Line Classifier



**Figure 8.** HAAR Cascade - Center and Environment Classifier

These frames, named Feature, are called weak classifiers. Since a weak classifier cannot provide a correct result on its own, there are many weak classifiers found in an object. The object that is searched with a great accuracy will be detected at the point where the classifiers are gathered. For the areas of reference, dark spots are created on the object to be detected. Target values are generated from each of these regions.

When these frames (weak classifiers) are considered for each image size; hundreds of thousands of nuclei will form. Negative images will be scanned so that the majority of the frames that are not going to be used are eliminated as there are no objects in these images.

In positive images, objects will be selected and the frames to be used in the object will be determined. Therefore, the desired object to be detected in the positive images is truncated in millimetric order, and full values are entered in order to facilitate the operation. The large number of positive and negative image samples is important to obtain better results regarding the desired object.

If there are too many pictures, it may cause the processor to think that it will spend a lot of time. One of the most important aspects of image processing is that it is real-time. Therefore, as the number of transactions increases, the latency also increases. However, in the haar cascade classifier, the integrals of the pictures are taken first. Thus, rather than calculating individual sums of pixel values, it is calculated with an integral. At this point, the processor gets faster by getting rid of the individual account.

Instead of being repeatedly scanned by each frame at the stage of object detection, only the parts that match the previous step are scanned in the next step, reducing the processing load. Although the Haar cascade method is very fast in terms of these aspects, it slows down at certain stages in the application phase, hence it appears as if there are slight deviations in real time. The real-time delays vary depending on parameters such as the classifier's training pattern, sample number, and number of repetitions.

The minimum hit rate, maximum false rate, and alarm rate values that the classifier takes as a reference for the detection of the desired objects are available. The classifier tries to reach these values with the algorithm determined at each stage of the training.

When the training is completed, a file with an ".xml" extension is created which will be used as the source. With this source file created, the desired object is detected using OpenCV library.

### 2.2.2. Template Matching

Other methods, apart from Template Matching, are the Machine Learning algorithms which are defined as classifiers. These algorithms are used to recognize a learned object, and these algorithms are the most commonly used methods for object recognition. Objects for classifiers can be taught with Deep Learning methods. The template mapping method carries out the matching process by searching the image template in all the pixels on the source image. There are two components required for this method:

- a) Source Image: A snapshot of the video.
- b) Template Image: The template to search for in the source image.



Figure 9. Template Matching Example: (a) Source Image, (b) Template



Figure 10. Template Matching Example Result

To match the template image, the source image is checked pixel by pixel from left to right and from top to bottom. I matrix is stored in R matrix for each T position on the matrix. Each position (x, y) in the R matrix contains the matching components.



Figure 11. Template Source Searching in the Image



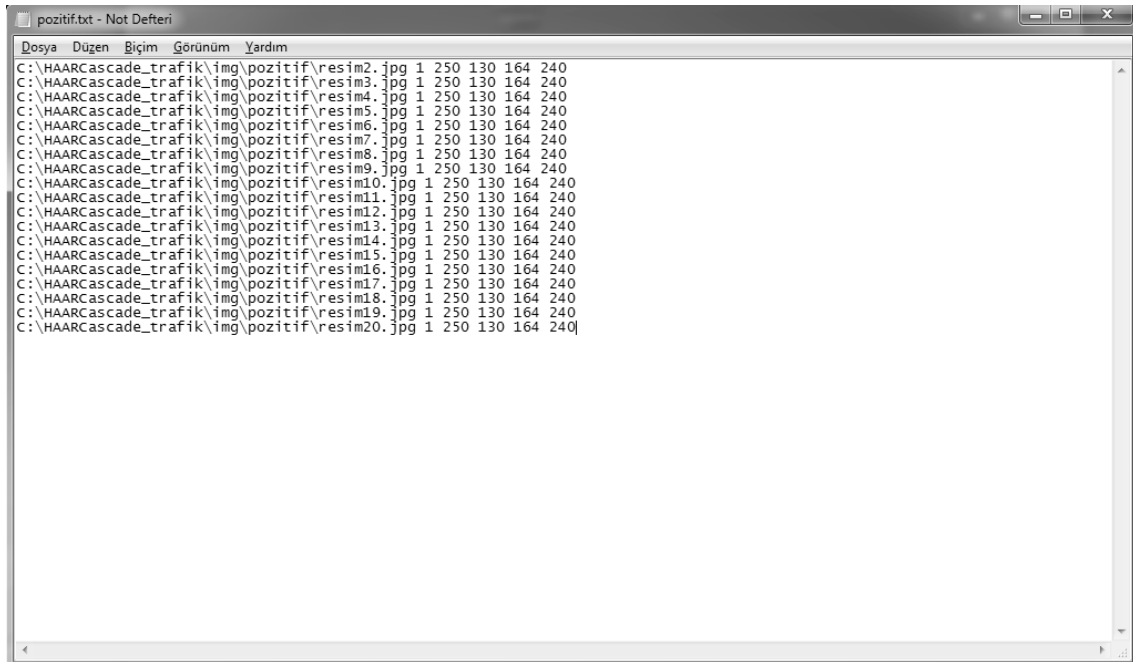
### 3. Method Used

Positive images are the example images of the objects that we want our classifier to find. In case these samples have different brightness values and different angles, a more effective classifier can be formed. A good classifier needs to be trained with thousands of examples, though with fewer examples a classifier can be created.

In this project, 250 positive and 100 negative pictures were used for each sign. The total number of used positive samples is 1500 and the number of used negative samples is 600.

#### 3.1. Haar Cascade Training

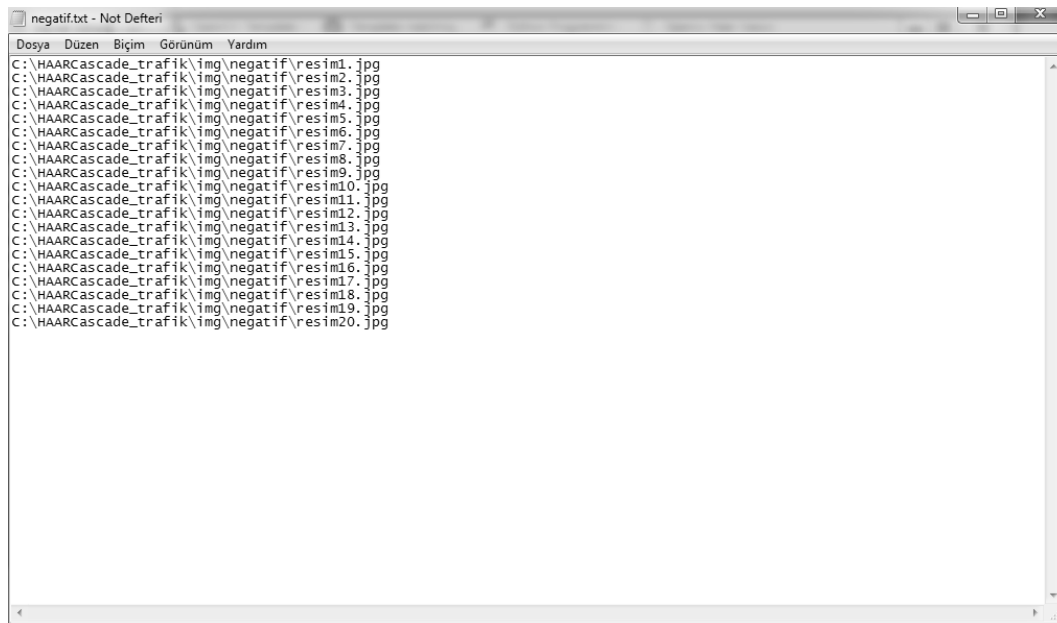
Cascade training requires utmost care [12]. Otherwise, the detection process fails. In order to avoid complicated training, related folders are created in the C directory and different files are created in this folder including the positive and negative images. Positive images should be placed in the positive folder, and negative images should be placed in the negative folder. Within the main folder, a text document is created for both positive and negative images and picture extensions, coordinates and pixels are written in it.



```
pozitif.txt - Not Defteri
Dosya Düzen Biçim Görünüm Yardım
C:\HAARcascade_trafik\img\pozitif\resim2.jpg 1 250 130 164 240
C:\HAARcascade_trafik\img\pozitif\resim3.jpg 1 250 130 164 240
C:\HAARcascade_trafik\img\pozitif\resim4.jpg 1 250 130 164 240
C:\HAARcascade_trafik\img\pozitif\resim5.jpg 1 250 130 164 240
C:\HAARcascade_trafik\img\pozitif\resim6.jpg 1 250 130 164 240
C:\HAARcascade_trafik\img\pozitif\resim7.jpg 1 250 130 164 240
C:\HAARcascade_trafik\img\pozitif\resim8.jpg 1 250 130 164 240
C:\HAARcascade_trafik\img\pozitif\resim9.jpg 1 250 130 164 240
C:\HAARcascade_trafik\img\pozitif\resim10.jpg 1 250 130 164 240
C:\HAARcascade_trafik\img\pozitif\resim11.jpg 1 250 130 164 240
C:\HAARcascade_trafik\img\pozitif\resim12.jpg 1 250 130 164 240
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C:\HAARcascade_trafik\img\pozitif\resim17.jpg 1 250 130 164 240
C:\HAARcascade_trafik\img\pozitif\resim18.jpg 1 250 130 164 240
C:\HAARcascade_trafik\img\pozitif\resim19.jpg 1 250 130 164 240
C:\HAARcascade_trafik\img\pozitif\resim20.jpg 1 250 130 164 240
```

Figure 12. Cascade Training Positive Pictures

The images will be clipped and processed by the "createSamples" function in the OpenCv library according to the values indicated on their sides.



**Figure 13.** Cascade Training Negative Pictures

The images of the environments that look similar to the environment we want our classifier to detect and the objects we are looking for are also recorded as negative images. The image extensions valid for positive images are also valid for negative images and one must be careful of the samples are of the same sizes.

For the classifier to work effectively, the number of positive images must be very large. The number of negative images should be less than the number of positive images, not exceeding the half-time if possible. The cause will be understood in the form that we will calculate in the progressive lines.

After filling the Positive and Negative folders with examples and saving the names and paths of these examples in txt files, we need to gray scale them for use in the cascading classifier of the positive images, and we need to create a vector file by trimming the object part.

A text document with .bat extension is created for sending the vector file to "OpenCV\_CreateSamples.exe" file. "OpenCV\_CreateSamples.exe" file path is written in the edited file with the necessary parameters.



```
vec olustur.bat - Not Defteri
Dosya Düzen Biçim Görünüm Yardım
D:\opencv\build\x64\vc11\bin\opencv_createsamples.exe -info pozitif.txt -num 3400 -vec el.vec -w 24 -h 24
```

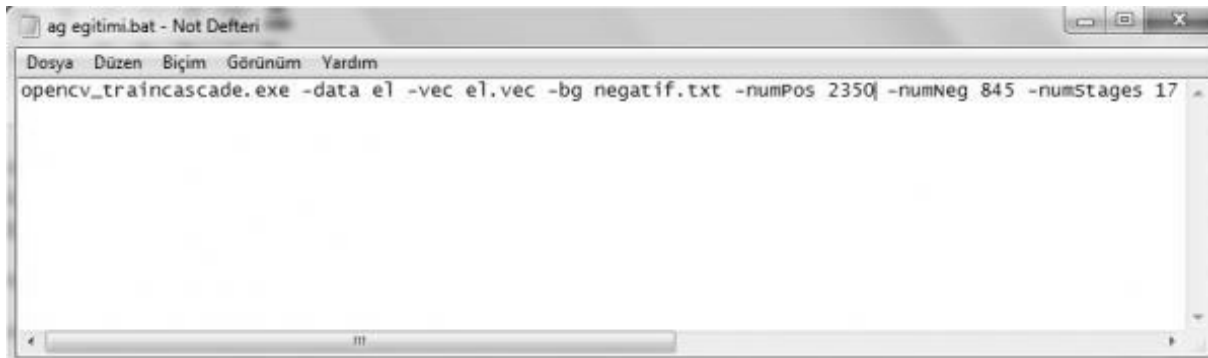
**Figure 14.** Cascade Training vector file

"OpenCV \ build \ x86 \ vc11 \ bin \ opencv\_createsamples.exe" section of your OpenCv directory is the path to the file "OpenCV\_CreateSamples.exe". When the command window sees this command, it executes the "exe" file located in the specified path.

The "-info positive.txt" section is used for taking the txt file that we created as a parameter, which holds the information that the file "OpenCV\_CreateSamples.exe" will find the required images and the way to crop them. In the "-num 3400" section, the "positive.txt" file contains the number of sample images that has been saved. The vector file contains information on how many images are created. The picture number from 2000 to 4000 is ideal for an effective detection.

In the "-vec el.vec" part, the name of the created vector file is entered. "-w 24 -h 24" -w specifies the width, and -h specifies the height. This section resizes the picture width and height so that the picture is cropped in the specified coordinates. This classifier makes it easy to work if you need to work with thousands of pixels; working on 24 \* 24 pixels will be faster and easier. The vector file with ".bat" extension runs automatically and it is automatically closed after the necessary data is collected.

Training can be done with two exe files located in OpenCv library. These files are "OpenCV\_Haartraining.exe" and "OpenCV\_Traincascade.exe" files. "OpenCV\_Haartraining.exe" only uses old algorithms that use the haar method. "OpenCV\_Traincascade.exe" is the most up-to-date classifier training file and can be trained with both haar method and local binary method. In this project, we are training with "OpenCV\_Traincascade.exe". This exe file tries to process the positive images on the negative images until the specified minhitrate and maxfalsealarmrate values are reached. In each step, positive images are scanned with different frames and values are created. When the specified stage value is reached, an xml file is created which can be used to find the object to be detected.



**Figure 15.** Creating a Cascade Training xml file

With the bezier steps of the previous process, the above file is created and executed, and our library with xml extension is created.

#### 4. Identification of Traffic Signs

Since the created xml file only detects the object, a separate xml file is created for each sign in order to classify the detected object.

traffic\_cascade = cv2.CascadeClassifier ('haarcascade\_traffic.xml') is written in the form of codes. Then a snapshot is taken from the camera and a Gray Scale filter is applied.

Signs = traffic\_cascade. detectMultiScale (gray, 1.3, 5)

The plates are determined by command. Then, rectangle parameters are entered in order to get the plates detected in the for loop into a frame.

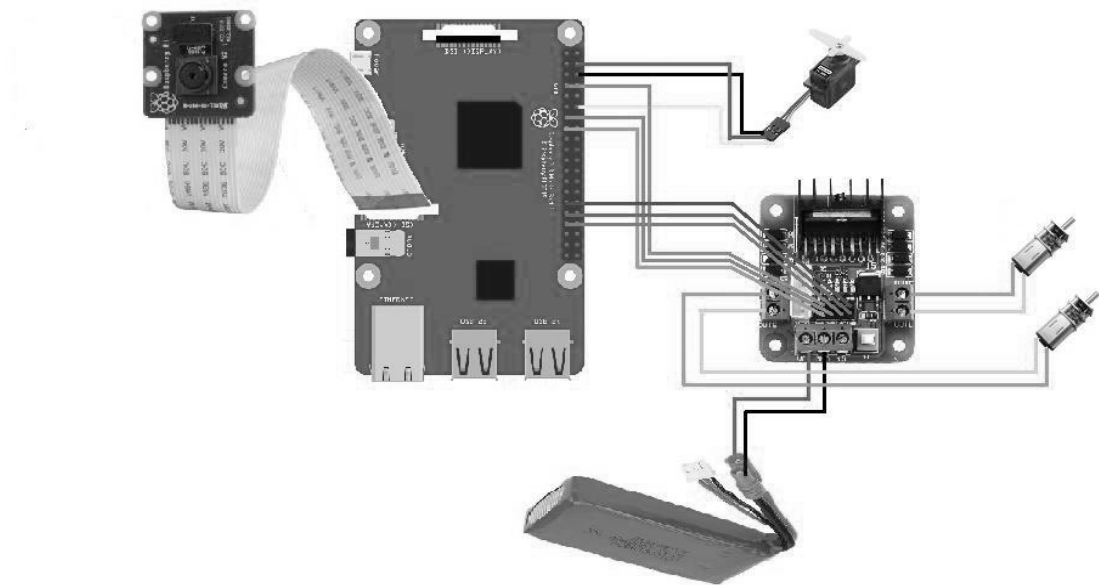


**Figure 16.** Sign Detection

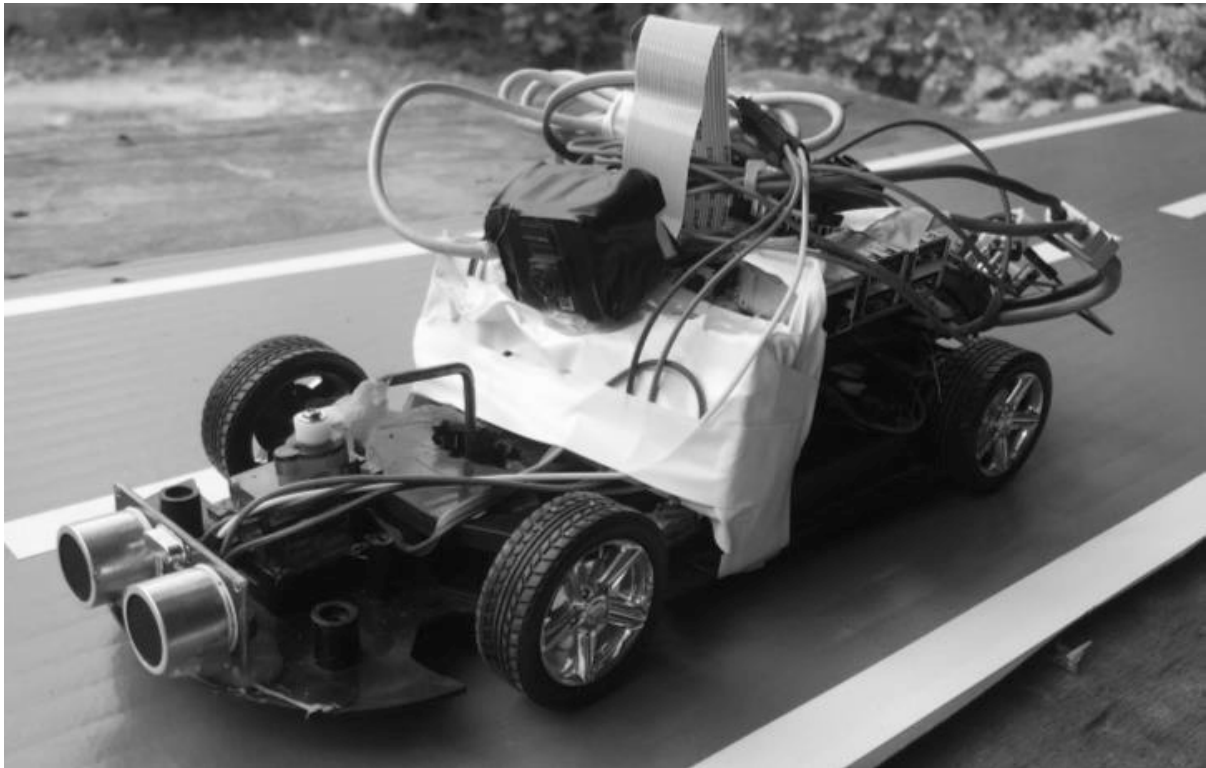
## 5.Designed Vehicle

The vehicle to be used in the project is a toy car model. It also checks whether pedestrians are pedestrian crossing, whether there is a vehicle in front of them, or whether there is an external stationary object that could put traffic flow on the road in danger. Ultrasonic distance sensors are used for this control.

RaspberryPi 3 motherboard is used as a control mechanism. The camera module is connected to the motherboard and the output generated to control the vehicle as a result of the processes are sent to the motors via the "output" on the card. Continuous input values are read from sensors, such as cameras. All control of the vehicle is provided by this card. Reducing dc motor is preferred for the vehicle to be able to move steadily even at low speeds. Thus, driving stability is increased by increasing vehicle traction. A total of two reducer dc motors are used, one for the rear and one for the wheels.



**Figure 17.** Vehicle connection diagram



**Figure 18.** Vehicle View

## **6.Results and Discussion**

Template Matching and Haar Cascade methods that are described in the study are both used. It has been determined that the efficiency of the template matching method is very low as it is very sensitive. In this method, the sample template sought in the environment must have the same maturity. A tolerance value can be given, however this value is very limited. False objects are detected more as the value increases.

The Haar Cascade method has been found to be much more efficient. There are many examples of tablets in terms of different environment, light intensity and position. Thus, the system becomes more stable. Image processing operations are 90-95% successful with the usual positions of the labels.

Since the motherboard used in the project did not have enough capacity, the intensive processes deviate from real time. More efficient algorithms and quality enhancements should be used in order to avoid these deviations and to reduce the worst case scenario. The project can be developed with the improvements in the required calculations and adapted to today's vehicles. In addition, the project can be passed on, not only as a car, but also as an autonomous application for production plants and transport systems in factories.

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