Image Classification Schemes Based on Sliced Radial Energy Distribution of DFT and the Statistical Moments of Haar Wavelet

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Abstract

Texture recognition is used in various pattern recognition applications and texture classification that possess a characteristic appearance. This research paper aims to provide an improved scheme to provide enhanced classification decisions and to decrease processing time significantly. This research studied the discriminating characteristics of textures by extracting them from various texture images using discrete Haar transform (DHT) and discrete Fourier transform (DFT). Two sets of features are proposed; the first set was extracted using the traditional DFT, while the second used DHT. The features from the Fourier domain are calculated using the radial distribution of spectra, while for those extracted from Haar Wavelet the statistical distribution of various relative moments was adopted. Four types of Euclidean distance metrics were used for classification decision purposes. The considered method was applied on 475 classes of textures belong to 32 sets from Salzburg Texture Image Database, each set holding 16 images per class, so the a total of 7600 images were tested. Each image was separated into seven bands of color component (i.e., red, green, blue, and gray….). Concepts of average and standard deviation were calculated to determine the inter/intra scatter analysis for each feature to find out the best discriminating features that can be used. The final result of DHT was 99.98 for the testing sets and 99.71 for the training sets, while the final result of DFT was 98.63 for the testing sets and 93.74 for the training sets.

Keywords: Texture Pattern recognition; Haar transforms; energy feature; Statistical moment; Euclidean measure.

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1. Introduction

Texture is the expression used to describe the surface of a given object or region, and it is one of the main features used in image processing and pattern recognition; it refers to the shape, structure and arrangement of the parts of things within the image. One can intuitively associate several image characteristics such as smoothness, coarseness, depth, regularity etc. with texture [1]. Image textures may be synthesized by visual patterns composed of entities or regions with sub-patterns with the properties of brightness, colour, structure, size, etc. Texture can be regarded as a uniformity grouping in an image [2]. There are many definitions to the texture, some of which are perceptually stimulated, while the others are driven completely by the experience in which the definition will be used [3].

In recent years, researchers studied variant types of features for texture classification and pattern recognition. Many of these features represent the local behaviour of the texture. Vandana et al. [4] applied different transforms such as DCT (Discrete Cosine Transform), Haar, Hartley, Walsh and Kekre in combination for creating 20 different hybrid wavelets. These hybrid wavelets are used on the database images to create feature vector coefficients, they are then put through to Intra Class testing and Inter Class testing, and their performance is evaluated and matched. Yu et al. [5] suggested a novel ear recognition approach by applying wavelet transforms and ULBPs. At the same time, they used the block division and multiresolution ideas in this approach. Their results suggested that the wavelet transform and uniform local binary patterns (ULBPs) were valuable methods to reveal the texture features of ear images. Panchal et al. [6] improved a low cost and fast computing system for the identification and verification of the fingerprint by utilizing a wavelet-based approach and compared the results with the traditional discrete Fourier transform (DFT), FFT, and FRIRV techniques which made the system simple and less space and time-consuming. Singha et al. [7] Proposed a system and demonstrated a promising and faster retrieval method to extract the texture and colour features by applying wavelet transformation and colour histogram. The combination of these features is robust to the scaling and translation of objects in an image. As a result, there is a substantial boosting in the retrieval speed. The whole indexing time for the 1000 image database is 5-6 minutes. Also, Busch et al. [8] Developed and improved classification rates by analysing the image with more than one wavelet which provided additional information about the texture. Experimental evidence provided support to this theory, showing that, for simple energy features, error rates are halved when multiple wavelets are employed. The next sections are organized as follows; in the next section, an overview of the texture analysis methods used in this research is presented by clarifying some of the concepts related to the used methods and the attributes that can be derived from them. Section 3 explains the adopted methodology in this study. In the fourth section the attained results are presented. Finally, in the last section, the main conclusions are presented.

In this stage, two separate sets of features were used to generate the feature vectors and tested for the verification purpose; they are the energy-based features using DFT and the statistical moments using DHT.
2.1 Haar Wavelet Transform

Haar wavelets are being exceedingly used since their origination by Haar [9][10][11]. Haar used these functions to provide an example of a countable orthonormal system for the space of square-integrable functions on the real line. In this paper, we have used Discreet Haar wavelets (DHW) to compute the feature vector, which produces a good result and have been found to perform well in classification. DHW allows to speed up the wavelet calculation phase for thousands of sliding windows of various sizes in an image. The DHW transform computation of a two-dimensional image is decomposed into four frequency sub-bands, namely LL, LH, HL, and HH, where L denotes low frequency and H denotes high frequency [12]:

**Top left:** 2-D lowpass filter (L-L), approximation subband.

**Top right:** horizontal highpass and vertical lowpass filter (H-L).

**Lower left:** horizontal lowpass and vertical highpass filter (L-H).

**Lower right:** 2-D highpass filter (H-H).

The wavelet decomposition could be repeated on all sub-bands (approximation and detail subbands) or on the approximation subband; these two schemes are called packet & dyadic schemes, respectively. There are lots of popular wavelets to be selected, such as Daubuchies, Mexican Hat and Morlet, etc. These wavelets possess a good resolution and smooth traits, but they are not useful because of the common disadvantage of being considerably time-consuming. Compared with these wavelets, Haar wavelet is easy to perform, fast, has a shorter filter, and easily describe small texture structure [13] [14] [15]. Thus, this paper selects DHT to make wavelet decomposition. After applying this transform on the complete image, the LL-subband output from any stage can be decomposed further. Figure -1 shows the result of one and two levels DHT based on the pyramid decomposition [1].

![Figure 1- Pyramid decomposition using Haar wavelet filter.](image)

After transforming the input image into a two-level wavelet transform, the following statistical moment is proposed to extract main features from the output of wavelet transforms, as shown in Figure- 2. They are described by the following equation:

\[
Mom(n) = \frac{1}{k} \sum_{i=0}^{p-1} [S(i) - \bar{S}]^n
\]

Where: \(S(i)\) is the \(i^{th}\) sample, \(k\) is the image length, and \(\bar{S}\) is the mean which is determined as:
Figure 2- DWT technique.

The power \( n \) is taken as 0.25, 1.5 and 3, and the extracted feature vector goes to the next step which is matching stage.

2.2 DFT

The discrete Fourier transform (DFT) is one of the most important tools which has been extensively used not only for understanding the nature of an image and its formation but also for processing the image [16][17]. Power spectra consist of the sine and cosine components and different frequencies. High frequencies are concentrated at the end of the transformed components, while the low frequencies at the beginning of the signal. Hence, in this paper DFT algorithm has been used to the task to transform from spatial to the frequency domain (i.e., DFT). The transform using DFT to an image \( f(x, y) \) of a size of \( M \times N \) was applied using the following general equation (3) [1].

\[
F(u, v) = \frac{1}{NM} \sum_{x=0}^{N-1} \sum_{y=0}^{M-1} f(x, y) e^{-j2\pi (\frac{ux}{M} + \frac{vy}{N})} \tag{3}
\]

Where \( F(u,v) \) is the coefficient of the DFT. Then, the power spectra can be obtained using the following equation:

\[
F(u, v) = \sqrt{R^2(u,v) + I^2(u,v)} \tag{4}
\]

Where, \( R(u,v) \) represents the real part and \( I(u,v) \) the imaginary part of DFT. After calculating the power spectra, the result are shown in Figure-3. Next, the central slice theorem was used to obtain the feature by different angle, repeating this process for all values of \( \theta \) between 0 and \( \pi \), and using five angles to get as much powerful features as possible to use them to generate the feature vector.

Figure 3- DFT for image
3. MATERIALS AND METHODS

3.1 Data Description

The applied examination methods for DHW and DFT features have been tested on various color images in 32 data sets. Seven combinations of color images were used, each is a BMP with 256 gray levels, while the size of each image is 128x128 pixels. The sets are shown in Table- 1 below, with each set consisting of the different number of classes and 16 samples into each class. The used sets are loaded from Salzburg Texture Image Database (STex); it is a large collection of color texture images that have been captured around Salzburg, Austria. The images have been selected to be used in texture analysis experiments. Some of these samples are presented (see Figure-1).

Table 1- The Tested Salzburg Texture Image Database (STex).

| Class    | Sub Class | Total image |
|----------|-----------|-------------|
| Porcelain| 2         | 32          |
| Track    | 2         | 32          |
| Straw    | 3         | 48          |
| Tire     | 3         | 48          |
| Tree     | 3         | 48          |
| Grass    | 4         | 64          |
| Rattan   | 4         | 64          |
| Sponge   | 4         | 64          |
| Tiles    | 4         | 64          |
| Building | 5         | 80          |
| Leaf     | 5         | 80          |
| Styrofoam| 6         | 96          |
| Leather  | 7         | 112         |
| Plastic  | 8         | 128         |
| Food     | 10        | 160         |
| Paper    | 10        | 160         |

| Class    | Sub Class | Total image |
|----------|-----------|-------------|
| Floor    | 11        | 176         |
| Rubber   | 11        | 176         |
| Bark     | 13        | 208         |
| Flower   | 13        | 208         |
| Marble   | 13        | 208         |
| Technic  | 14        | 224         |
| Hair     | 15        | 240         |
| Paint    | 15        | 240         |
| Bush     | 18        | 288         |
| Gravel   | 20        | 320         |
| Stone    | 29        | 464         |
| Wall     | 30        | 480         |
| Metal    | 31        | 496         |
| Wood     | 41        | 656         |
| Misc     | 44        | 704         |
| Fabric   | 77        | 1232        |

Figure 4- Samples of the classes of data sets used in this research.
3.2 Methodology
This section presents the performed steps and consists of the following stages:
- Prep-processing stage.
- Features vector extraction stage.
- Classification stage.

3.2.1 Prep-processing stage
The first stage in any recognition system is preprocessing. In this stage, a sequence of image processing operations is utilized to make the image (that is loaded to the system as an input) appropriate for extracting the related information to obtain the best recognition results. In this research, the following pre-processing steps were applied; to read images and color decomposition as a first step, the loaded images were decomposed into seven color bands (or channels). The basic color components are Red, Green, Blue, (Gray1, Gray2, PU and Pv) and these gray color values were evaluated by the equations 5-8. The second step divides the images into four sub-images, each sub-image has a size 64x64 pixels.

\[
p_{\text{Gry}1}(X,Y) = \text{Red}(X,Y) + \text{Grn}(X,Y) + \text{Blu}(X,Y) \quad (5)
\]
\[
p_{\text{Gry}2}(X,Y) = 0.299*\text{Red}(X,Y)+0.587*\text{Grn}(X,Y)+0.11*\text{Blu}(X,Y) \quad (6)
\]
\[
p_{U}(X,Y) = -0.147*\text{Red}(X,Y)-0.289*\text{Grn}(X,Y)+0.436*\text{Blu}(X,Y) \quad (7)
\]
\[
p_{V}(X,Y) = 0.615*\text{Red}(X,Y)-0.515*\text{Grn}(X,Y)-0.1*\text{Blu}(X,Y) \quad (8)
\]

3.2.2 Features Extraction Stage
After performing the previous steps (reading the image, color decomposition, splitting), the feature extraction stage was applied to extract some of the textural attributes. The aim of the feature extraction is to obtain a set of texture measures that can be used to distinguish among different texture pattern classes. In this paper, one of the most important texture analysis methods was used to extract a certain kind of feature vector by utilizing the DHT and DFT. From each sub-image, 420 features for DHT and 840 features for DFT were extracted. Also, some variants for this method are introduced to develop more efficient sets of discriminating features.

3.2.3 Features Analysis and Selection Stage
A training set of samples was applied to train the classifier and to address the feature list. While, the test set was applied to assess the recognition accuracy of the system (after the training phase). To obtain a robust recognition performance, this step is claimed to reduce the feature size and to choose the most related and discriminative features companion with the lowest intra-distance and highest inter-distance among the discriminations, then combining the best set of features that led to the best verification result [18].

3.2.4 Classification Stage
In this research, the classification of those attributes was complete due to their inter-class stability. Through the practicing phase, certain features were selected from the overall set of features; the selection was due to the comprehensive tests which were proceed on the set of samples to find out the best features that can be utilized to yield highest matching results.

3.2.4.1 Matching
The matching steps determine the match outcome (or in other words, the similarity measure) between the feature vectors extracted from the input samples and the stored templates. The similarity result should be high for samples categorized to the same class and least for those categorized to different classes. Sample matching is usually a difficult pattern recognition task due to large intra-class variations (i.e., variations in sample images for the equivalent class) and large inter-class similarity (i.e., the similarity between sample images from the altered class). In this paper, the features extracted in the preceding stage have been used to match either the tested samples data previously stored in the database (i.e., belong to training set) or other samples (i.e., testing set). To accomplish matching, the features of the samples that belong to the training set were used to yield the template mean feature vector for each class. The mean feature vector (\(F\)) of each class and the corresponding standard deviation vector (\(\sigma\)) were determined and saved in a dedicated database during the training phase. These parameters were used as template vectors. They were determined using the following equations [19]:

```plaintext
S_d = \| F_{\text{sample}} - F_{\text{class}} \|_2 \quad (9)
\]
```
$$F(c, f) = \frac{1}{s} \sum_{i=1}^{s} F(c, f i) ,$$  \hspace{1cm} (9)$$

$$\sigma(c, f) = \sqrt{\frac{1}{s} \sum_{i=1}^{s} F(c, f i) - F(c, f i)^2} ,$$  \hspace{1cm} (10)$$

Where c, f, s are the classes number, feature number and sample number, respectively.

While, in the matching stage, their similarity degrees were computed with the feature vector extracted from the samples. The similarity distance measure for feature (f) was computed using the feature value determined from the sample and the corresponding feature template mean value as well as the standard deviation (determined for each class). The most commonly used similarity measure is the Euclidean distance measure (D1), but, the main weakness of the basic Euclidean distance function is that if one of input features has a relatively large range, then it can overpower the effectiveness of other features. The considered matching problem here is dynamic; that is every feature may not have similar behaviors like the others. Hence, another type of similarity distance measures (such as D2, D3 and D4) were computed. The results of using these four distance measures were compared and revealed that the results of measure D4 are always better than those of the others; thus, the normalized Euclidean distance (D4) was used to evaluate the similarity degree between the extracted feature vectors of the samples (fi) and the templates representing the classes [19]:

$$D_1(\bar{T}_i, \bar{F}_j) = \sum_{k=1}^{m} \left| T_i(k) - f_j(k) \right|$$  \hspace{1cm} (11)$$

$$D_2(\bar{T}_i, \bar{F}_j) = \sum_{k=1}^{m} \left( T_i(k) - f_j(k) \right)^2$$  \hspace{1cm} (12)$$

$$D_3(\bar{T}_i, \bar{F}_j) = \sum_{k=1}^{m} \left| T_i(k) - f_j(k) / \sigma_i(k) \right|$$  \hspace{1cm} (13)$$

$$D_4(\bar{T}_i, \bar{F}_j) = \sum_{k=1}^{m} \left( T_i(k) - f_j(k) / \sigma_i(k) \right)^2$$  \hspace{1cm} (14)$$

Where $\bar{T}_i$ is the template (mean) of class i, and $\sigma_i$ is the standard deviation of class i. In order to maximize the probability of the match classification and minimize misclassification rate, the efficiency of classification was calculated for each distance using the following equation [20]:

$$\eta(\%) = \left( \frac{\text{total no. of samples - no. of misclassified samples}}{\text{total no. of samples}} \right) \times 100\%$$  \hspace{1cm} (15)$$

4. EXPERIMENT RESULTS

Salzburg Texture Image Database (STex) was used for the classification of about 6700 images. Each image was divided into four sub-images, and each image vector had 420 features in DHW and 840 features in DFT. The tables below (2-9) show DFT results, with each table representing the results of how many features were used to perform the classification; for example, Table-1 represents the D1, D2, D3 and D4 of one feature. Some classes had 100% classification efficiency and the others improved by adding features until the feature seven. Table- 9 represents the final result of DFT while Tables- 10-16 represent the results of DFW. When we compared between two results, as in Figure-5, it is clear that the Haar transform has batter results. It is fast and computationally inexpensive to perform the robust method of feature classification and pattern recognition. Our results show that 23 classes had 100 scores, 7 classes had above 99 scores, and the rest had above 98.87 scores. Furthermore, Tables-(18 and 19) show the combination of seven unique features that led to this result. Each class has different combination features, so that the first feature in Table-18 is related to the result of Table- 2, the combination of the first and second features led to Table-3, and so on until all the seven features led to the final result in Table-9 for DFT, while Table- 19 is related to DHW. We can say that the DHW could extract better features than DFT. These seven features represent the discriminated features that led to the result of each class. In other words, they are the identification of each class.
Table 2- The results of DFT using single feature.

| Feature No. | Type | Sub Class | D1   | D2   | D3   | D4   |
|-------------|------|-----------|------|------|------|------|
| 1           | Porcelain | 2         | 99.21 | 99.21 | 98.43 | 98.43 |
| 1           | Track     | 2         | 100   | 100   | 100   | 100   |
| 1           | Straw     | 3         | 96.87 | 96.87 | 96.87 | 96.87 |
| 1           | Tire      | 3         | 81.77 | 81.77 | 82.29 | 82.29 |
| 1           | Tree      | 3         | 83.85 | 83.85 | 82.81 | 82.81 |
| 1           | Grass     | 4         | 78.9  | 78.9  | 80.07 | 80.07 |
| 1           | Rattan    | 4         | 91.01 | 91.01 | 89.06 | 89.06 |
| 1           | Sponge    | 4         | 84.76 | 84.76 | 86.71 | 86.71 |
| 1           | Tiles     | 4         | 92.96 | 92.96 | 93.35 | 93.35 |
| 1           | Building  | 5         | 65.93 | 65.93 | 66.25 | 66.25 |
| 1           | Leaf      | 5         | 74.37 | 74.37 | 75.62 | 75.62 |
| 1           | Styrofoam | 6         | 84.63 | 84.63 | 85.15 | 85.15 |
| 1           | Leather   | 7         | 66.21 | 66.21 | 59.37 | 59.37 |
| 1           | Plastic   | 8         | 62.5  | 62.5  | 57.03 | 57.03 |
| 1           | Food      | 10        | 50.31 | 47.81 | 47.81 | 47.81 |
| 1           | Paper     | 10        | 64.84 | 64.84 | 63.12 | 63.12 |
| 1           | Floor     | 11        | 52.65 | 52.65 | 51.87 | 51.87 |
| 1           | Rubber    | 11        | 52.03 | 52.03 | 43.43 | 43.43 |
| 1           | Bark      | 13        | 45.46 | 45.46 | 45.46 | 45.46 |
| 1           | Flower    | 13        | 41.71 | 41.71 | 40.31 | 40.31 |
| 1           | Marble    | 13        | 52.96 | 52.96 | 47.81 | 47.81 |
| 1           | Technic   | 14        | 48.59 | 48.59 | 46.25 | 46.25 |
| 1           | Hair      | 15        | 36.71 | 36.71 | 36.09 | 36.09 |
| 1           | Paint     | 15        | 54.84 | 54.84 | 49.84 | 49.84 |
| 1           | Bush      | 18        | 53.59 | 53.59 | 52.18 | 52.18 |
| 1           | Gravel    | 20        | 53.75 | 53.75 | 52.96 | 52.96 |
| 1           | Stone     | 29        | 44.21 | 44.21 | 43.59 | 43.59 |
| 1           | Wall      | 30        | 59.06 | 59.06 | 56.87 | 56.87 |
| 1           | Metal     | 31        | 51.71 | 51.71 | 46.4  | 46.4  |
| 1           | Wood      | 41        | 69.21 | 69.21 | 67.96 | 67.96 |
| 1           | Misc      | 44        | 66.4  | 66.4  | 63.43 | 63.43 |
| 1           | Fabric    | 77        | 55.15 | 55.15 | 51.25 | 51.25 |
Table 3- The results of DFT using two features.

| Feature No. | Type  | Sub Class | D1  | D2  | D3  | D4  |
|-------------|-------|-----------|-----|-----|-----|-----|
| 2           | Porcelain | 2         | 100 | 100 | 100 | 100 |
| 2           | Track   | 2         | 100 | 100 | 100 | 100 |
| 2           | Straw   | 3         | 98.95 | 98.95 | 98.95 | 98.95 |
| 2           | Tire    | 3         | 92.7 | 92.18 | 93.22 | 92.7 |
| 2           | Tree    | 3         | 96.35 | 96.87 | 95.31 | 96.35 |
| 2           | Grass   | 4         | 89.84 | 92.57 | 91.79 | 91.79 |
| 2           | Rattan  | 4         | 96.09 | 96.48 | 96.48 | 96.48 |
| 2           | Sponge  | 4         | 95.31 | 94.92 | 96.87 | 97.65 |
| 2           | Tiles   | 4         | 100 | 99.21 | 100 | 100 |
| 2           | Building| 5         | 79.06 | 80 | 83.43 | 84.06 |
| 2           | Leaf    | 5         | 90.31 | 90.62 | 88.75 | 89.68 |
| 2           | Styrofoam| 6         | 98.95 | 98.95 | 99.73 | 100 |
| 2           | Leather | 7         | 84.37 | 80.85 | 80.85 | 81.64 |
| 2           | Plastic | 8         | 84.57 | 85.15 | 85.15 | 85.93 |
| 2           | Food    | 10        | 70 | 71.71 | 70.31 | 72.03 |
| 2           | Paper   | 10        | 92.03 | 91.87 | 94.84 | 94.37 |
| 2           | Floor   | 11        | 80.62 | 80.15 | 82.03 | 82.96 |
| 2           | Rubber  | 11        | 77.5 | 78.12 | 70 | 70.6 |
| 2           | Bark    | 13        | 78.28 | 79.68 | 79.53 | 79.68 |
| 2           | Flower  | 13        | 60 | 58.9 | 59.06 | 57.5 |
| 2           | Marble  | 13        | 77.34 | 77.18 | 77.5 | 79.37 |
| 2           | Technic | 14        | 74.53 | 73.59 | 72.96 | 72.65 |
| 2           | Hair    | 15        | 56.25 | 56.09 | 56.4 | 57.65 |
| 2           | Paint   | 15        | 79.37 | 79.37 | 80.31 | 82.34 |
| 2           | Bush    | 18        | 80.46 | 81.71 | 81.25 | 82.81 |
| 2           | Gravel  | 20        | 84.37 | 84.37 | 86.4 | 86.25 |
| 2           | Stone   | 29        | 67.81 | 68.43 | 65.78 | 67.65 |
| 2           | Wall    | 30        | 85.93 | 86.4 | 85.31 | 86.87 |
| 2           | Metal   | 31        | 74.21 | 73.43 | 68.43 | 70.4 |
| 2           | Wood    | 41        | 91.25 | 91.71 | 92.34 | 93.28 |
| 2           | Misc    | 44        | 92.81 | 91.4 | 91.09 | 91.71 |
| 2           | Fabric  | 77        | 84.06 | 84.37 | 84.53 | 85.46 |
Table 4- The results of DFT for three features.

| Feature No. | Type  | Sub Class | D1  | D2  | D3  | D4  |
|-------------|-------|-----------|-----|-----|-----|-----|
| 3           | Porcelain | 2        | 100 | 100 | 100 | 100 |
| 3           | Track    | 2        | 100 | 100 | 100 | 100 |
| 3           | Straw    | 3        | 100 | 99.47| 100 | 100 |
| 3           | Tire     | 3        | 95.31| 96.35| 95.83| 95.83|
| 3           | Tree     | 3        | 98.43| 98.43| 99.47| 97.91|
| 3           | Grass    | 4        | 92.96| 95.31| 94.14| 95.31|
| 3           | Rattan   | 4        | 97.26| 98.04| 98.82| 98.82|
| 3           | Sponge   | 4        | 96.48| 96.48| 97.65| 98.43|
| 3           | Tiles    | 4        | 100 | 100 | 100 | 100 |
| 3           | Building | 5        | 85.31| 86.25| 90.31| 90.62|
| 3           | Leaf     | 5        | 91.25| 92.5 | 89.68| 90.31|
| 3           | Styrofoam| 6        | 99.47| 100 | 100 | 100 |
| 3           | Leather  | 7        | 88.28| 88.86| 87.5 | 89.06|
| 3           | Plastic  | 8        | 88.08| 88.67| 91.21| 93.16|
| 3           | Food     | 10       | 76.25| 78.12| 74.53| 76.25|
| 3           | Paper    | 10       | 96.71| 97.18| 98.43| 98.9 |
| 3           | Floor    | 11       | 83.75| 85.15| 85.93| 87.03|
| 3           | Rubber   | 11       | 83.12| 84.21| 79.84| 83.28|
| 3           | Bark     | 13       | 87.34| 89.06| 87.96| 90.93|
| 3           | Flower   | 13       | 64.53| 65.31| 62.65| 62.96|
| 3           | Marble   | 13       | 82.65| 84.68| 82.96| 85.65|
| 3           | Technic  | 14       | 79.21| 78.75| 79.37| 81.56|
| 3           | Hair     | 15       | 67.5 | 67.18| 67.65| 69.53|
| 3           | Paint    | 15       | 86.09| 86.09| 88.59| 91.4 |
| 3           | Bush     | 18       | 89.21| 90.46| 89.06| 91.56|
| 3           | Gravel   | 20       | 93.12| 92.34| 95   | 95.15|
| 3           | Stone    | 29       | 75.46| 76.25| 79.06| 80.93|
| 3           | Wall     | 30       | 89.68| 90   | 88.28| 91.25|
| 3           | Metal    | 31       | 78.59| 78.12| 73.43| 75.31|
| 3           | Wood     | 41       | 96.71| 97.03| 96.56| 97.34|
| 3           | Misc     | 44       | 95.93| 95.62| 94.37| 93.9 |
| 3           | Fabric   | 77       | 93.9 | 95   | 95.46| 97.03|
Table 5- The results of DFT for four features.

| Feature No. | Type | Sub Class | D1  | D2  | D3  | D4  |
|-------------|------|-----------|-----|-----|-----|-----|
| 4           | Porcelain | 2       | 100 | 100 | 100 | 100 |
| 4           | Track     | 2       | 100 | 100 | 100 | 100 |
| 4           | Straw     | 3       | 100 | 99.4| 100 | 100 |
| 4           | Tire      | 3       | 95.83 | 97.39 | 97.39 | 97.39 |
| 4           | Tree      | 3       | 98.43 | 98.43 | 98.43 | 97.91 |
| 4           | Grass     | 4       | 96.48 | 97.26 | 95.7 | 96.09 |
| 4           | Rattan    | 4       | 98.43 | 98.82 | 98.82 | 99.21 |
| 4           | Sponge    | 4       | 96.48 | 96.48 | 98.04 | 98.43 |
| 4           | Tiles     | 4       | 100  | 100  | 100  | 100  |
| 4           | Building  | 5       | 87.81 | 89.06 | 91.25 | 93.12 |
| 4           | Leaf      | 5       | 91.25 | 92.81 | 89.37 | 89.68 |
| 4           | Styrofoam | 6       | 99.47 | 100  | 100  | 100  |
| 4           | Leather   | 7       | 88.86 | 90.23 | 88.08 | 90.23 |
| 4           | Plastic   | 8       | 89.64 | 91.4 | 93.16 | 96.28 |
| 4           | Food      | 10      | 76.25 | 78.12 | 74.53 | 76.25 |
| 4           | Paper     | 10      | 98.12 | 98.9 | 99.68 | 100  |
| 4           | Floor     | 11      | 87.81 | 89.21 | 87.5 | 89.06 |
| 4           | Rubber    | 11      | 84.84 | 85.93 | 85.46 | 89.53 |
| 4           | Bark      | 13      | 90.62 | 91.56 | 91.25 | 94.06 |
| 4           | Flower    | 13      | 67.34 | 69.21 | 65.64 | 67.65 |
| 4           | Marble    | 13      | 86.09 | 86.25 | 84.84 | 87.18 |
| 4           | Technic   | 14      | 80.78 | 80.78 | 82.65 | 83.59 |
| 4           | Hair      | 15      | 71.4  | 72.96 | 74.84 | 76.56 |
| 4           | Paint     | 15      | 87.65 | 90.93 | 90.93 | 93.28 |
| 4           | Bush      | 18      | 90.15 | 91.25 | 91.09 | 92.65 |
| 4           | Gravel    | 20      | 95    | 94.68 | 95.62 | 96.09 |
| 4           | Stone     | 29      | 84.21 | 84.53 | 83.43 | 86.4 |
| 4           | Wall      | 30      | 91.71 | 91.71 | 89.68 | 92.18 |
| 4           | Metal     | 31      | 80.62 | 80.93 | 76.87 | 78.12 |
| 4           | Wood      | 41      | 96.87 | 97.18 | 97.5 | 98.12 |
| 4           | Misc      | 44      | 96.25 | 95.93 | 95.78 | 95.46 |
| 4           | Fabric    | 77      | 95.46 | 95.93 | 98.12 | 98.9 |
Table 6- The results of DFT for five features.

| Feature No. | Type    | Sub Class | D1   | D2   | D3   | D4   |
|-------------|---------|-----------|------|------|------|------|
| 5           | Porcelain | 2         | 100  | 100  | 100  | 100  |
| 5           | Track    | 2         | 100  | 100  | 100  | 100  |
| 5           | Straw    | 3         | 100  | 99.47| 100  | 100  |
| 5           | Tire     | 3         | 96.35| 98.43| 97.91| 98.43|
| 5           | Tree     | 3         | 98.43| 98.43| 98.95| 98.43|
| 5           | Grass    | 4         | 97.26| 97.65| 96.09| 96.48|
| 5           | Rattan   | 4         | 99.21| 98.82| 99.6 | 99.21|
| 5           | Sponge   | 4         | 96.48| 96.48| 98.04| 98.43|
| 5           | Tiles    | 4         | 100  | 100  | 100  | 100  |
| 5           | Building | 5         | 89.68| 90   | 92.18| 93.43|
| 5           | Leaf     | 5         | 91.25| 92.81| 88.75| 90   |
| 5           | Styrofoam| 6         | 100  | 100  | 100  | 100  |
| 5           | Leather  | 7         | 89.25| 91.01| 87.69| 91.21|
| 5           | Plastic  | 8         | 90.62| 91.79| 94.72| 97.26|
| 5           | Food     | 10        | 80.4 | 82.34| 77.96| 80.31|
| 5           | Paper    | 10        | 98.21| 99.06| 99.84| 100  |
| 5           | Floor    | 11        | 88.59| 90   | 89.06| 90.4 |
| 5           | Rubber   | 11        | 85.93| 86.71| 89.06| 90.93|
| 5           | Bark     | 13        | 92.18| 92.65| 92.34| 95.62|
| 5           | Flower   | 13        | 68.5 | 69.68| 66.25| 69.21|
| 5           | Marble   | 13        | 87.03| 87.65| 86.09| 87.65|
| 5           | Technic  | 14        | 82.03| 81.87| 83.28| 85.46|
| 5           | Hair     | 15        | 74.37| 75.93| 76.09| 78.9 |
| 5           | Paint    | 15        | 88.28| 89.21| 92.65| 94.53|
| 5           | Bush     | 18        | 90.31| 91.87| 92.03| 94.06|
| 5           | Gravel   | 20        | 95.62| 96.25| 95.46| 96.4 |
| 5           | Stone    | 29        | 86.71| 87.18| 85.62| 87.81|
| 5           | Wall     | 30        | 92.34| 92.34| 90.15| 92.81|
| 5           | Metal    | 31        | 82.34| 81.87| 79.68| 82.34|
| 5           | Wood     | 41        | 97.03| 97.5 | 97.96| 98.43|
| 5           | Misc     | 44        | 96.4 | 95.93| 95.93| 96.25|
| 5           | Fabric   | 77        | 96.25| 96.4 | 99.06| 99.37|
Table 7- The results of DFT for six feature.

| Feature No. | Type  | Sub Class | D1  | D2  | D3  | D4  |
|-------------|-------|-----------|-----|-----|-----|-----|
| 6           | Porcelain | 2         | 100 | 100 | 100 | 100 |
| 6           | Track   | 2         | 100 | 100 | 100 | 100 |
| 6           | Straw   | 3         | 100 | 99.47 | 100 | 100 |
| 6           | Tire    | 3         | 97.39 | 98.43 | 98.43 | 98.34 |
| 6           | Tree    | 3         | 98.43 | 98.43 | 99.47 | 98.43 |
| 6           | Grass   | 4         | 97.65 | 98.43 | 96.09 | 96.48 |
| 6           | Rattan  | 4         | 99.6 | 98.82 | 99.21 | 99.21 |
| 6           | Sponge  | 4         | 96.48 | 96.48 | 98.04 | 98.43 |
| 6           | Tiles   | 4         | 100 | 100 | 100 | 100 |
| 6           | Building | 5         | 90 | 90.31 | 93.12 | 94.37 |
| 6           | Leaf    | 5         | 91.25 | 92.81 | 89.06 | 90.31 |
| 6           | Styrofoam | 6         | 100 | 100 | 100 | 100 |
| 6           | Leather | 7         | 90.03 | 91.4 | 88.86 | 91.01 |
| 6           | Plastic | 8         | 91.01 | 91.99 | 95.5 | 97.65 |
| 6           | Food    | 10        | 80.78 | 83.12 | 79.37 | 81.25 |
| 6           | Paper   | 10        | 98.59 | 99.06 | 100 | 100 |
| 6           | Floor   | 11        | 89.37 | 90.31 | 90 | 90.93 |
| 6           | Rubber  | 11        | 86.56 | 87.03 | 90 | 92.65 |
| 6           | Bark    | 13        | 92.5 | 92.96 | 93.28 | 96.09 |
| 6           | Flower  | 13        | 69.37 | 70.15 | 70 | 72.03 |
| 6           | Marble  | 13        | 87.5 | 87.96 | 85.65 | 88.28 |
| 6           | Technic | 14        | 83.28 | 82.34 | 83.59 | 85.78 |
| 6           | Hair    | 15        | 75.93 | 77.18 | 77.81 | 80.15 |
| 6           | Paint   | 15        | 88.75 | 89.53 | 92.03 | 95.46 |
| 6           | Bush    | 18        | 90.78 | 92.18 | 93.43 | 94.68 |
| 6           | Gravel  | 20        | 96.25 | 97.03 | 96.25 | 96.56 |
| 6           | Stone   | 29        | 87.81 | 88.9 | 88.9 | 89.68 |
| 6           | Wall    | 30        | 92.65 | 92.5 | 90.15 | 93.12 |
| 6           | Metal   | 31        | 82.96 | 82.96 | 81.4 | 83.9 |
| 6           | Wood    | 41        | 97.03 | 97.65 | 98.28 | 98.9 |
| 6           | Misc    | 44        | 96.4 | 96.25 | 97.03 | 96.71 |
| 6           | Fabric  | 77        | 97.03 | 97.81 | 99.84 | 100 |
### Table 8- The results of DFT for seven features.

| Feature No. | Type     | Sub Class | D1     | D2     | D3     | D4     |
|-------------|----------|-----------|--------|--------|--------|--------|
| 7           | Porcelain| 2         | 100    | 100    | 100    | 100    |
| 7           | Track    | 2         | 100    | 100    | 100    | 100    |
| 7           | Straw    | 3         |        |        |        |        |
| 7           | Tire     | 3         | 97.39  | 98.43  | 98.43  | 98.95  |
| 7           | Tree     | 3         | 98.43  | 98.43  | 99.49  | 98.95  |
| 7           | Grass    | 4         | 98.04  | 98.82  | 96.09  | 96.48  |
| 7           | Rattan   | 4         | 99.6   | 98.82  | 99.6   | 99.21  |
| 7           | Sponge   | 4         | 96.48  | 96.48  | 98.04  | 98.43  |
| 7           | Tiles    | 4         |        |        |        |        |
| 7           | Building | 5         | 90.31  | 90.31  | 93.43  | 94.37  |
| 7           | Leaf     | 5         | 91.25  | 92.81  | 90     | 90.31  |
| 7           | Styrofoam| 6         | 100    | 100    | 100    | 100    |
| 7           | Leather  | 7         | 90.03  | 91.6   | 89.45  | 91.21  |
| 7           | Plastic  | 8         |        |        |        |        |
| 7           | Food     | 10        | 80.93  | 84.21  | 80.15  | 82.18  |
| 7           | Paper    | 10        | 98.59  | 99.06  | 100    | 100    |
| 7           | Floor    | 11        | 70.31  | 70.62  | 71.4   | 72.96  |
| 7           | Rubber   | 11        | 86.71  | 87.81  | 91.09  | 92.34  |
| 7           | Bark     | 13        | 92.5   | 93.43  | 94.06  | 96.4   |
| 7           | Flower   | 13        | 80.93  | 84.21  | 80.15  | 82.18  |
| 7           | Marble   | 13        | 87.65  | 88.43  | 86.71  | 88.43  |
| 7           | Technic  | 14        | 83.43  | 82.96  | 84.37  | 86.09  |
| 7           | Hair     | 15        | 76.4   | 77.34  | 78.75  | 81.4   |
| 7           | Paint    | 15        | 88.9   | 90     | 92.65  | 95.93  |
| 7           | Bush     | 18        | 90.93  | 92.34  | 94.06  | 94.84  |
| 7           | Gravel   | 20        | 96.56  | 97.65  | 96.25  | 97.03  |
| 7           | Stone    | 29        | 88.43  | 89.53  | 90     | 90     |
| 7           | Wall     | 30        | 92.65  | 92.5   | 91.25  | 93.12  |
| 7           | Metal    | 31        | 83.12  | 83.75  | 82.81  | 85.31  |
| 7           | Wood     | 41        | 97.03  | 97.81  | 98.9   | 98.9   |
| 7           | Misc     | 44        | 96.4   | 96.25  | 96.56  | 96.71  |
| 7           | Fabric   | 77        | 97.34  | 98.59  | 99.84  | 100    |
Table 9- The finals result of DFT for seven features.

| Feature No. | Type    | Sub Class | Training Data | Testing data | Total Data |
|-------------|---------|-----------|---------------|--------------|------------|
| 7           | Porcelain | 2         | 100           | 100          | 100        |
| 7           | Track    | 2         | 100           | 100          | 100        |
| 7           | Straw    | 3         | 100           | 100          | 100        |
| 7           | Tire     | 3         | 98.95         | 100          | 99.475     |
| 7           | Tree     | 3         | 98.95         | 100          | 99.475     |
| 7           | Grass    | 4         | 96.48         | 100          | 98.24      |
| 7           | Rattan   | 4         | 99.21         | 100          | 99.605     |
| 7           | Sponge   | 4         | 98.43         | 100          | 99.215     |
| 7           | Tiles    | 4         | 100           | 100          | 100        |
| 7           | Building | 5         | 94.37         | 99.8         | 97.085     |
| 7           | Leaf     | 5         | 90.31         | 94.3         | 92.305     |
| 7           | Styrofoam| 6         | 100           | 100          | 100        |
| 7           | Leather  | 7         | 91.21         | 97.99        | 94.6       |
| 7           | Plastic  | 8         | 98.04         | 100          | 99.02      |
| 7           | Food     | 10        | 82.18         | 97.35        | 89.765     |
| 7           | Paper    | 10        | 100           | 100          | 100        |
| 7           | Floor    | 11        | 72.96         | 92.91        | 82.935     |
| 7           | Rubber   | 11        | 92.34         | 97.71        | 95.025     |
| 7           | Bark     | 13        | 96.4          | 99.37        | 97.885     |
| 7           | Flower   | 13        | 82.18         | 98.5         | 90.34      |
| 7           | Marble   | 13        | 88.43         | 95.14        | 91.785     |
| 7           | Technic  | 14        | 86.09         | 97.32        | 91.705     |
| 7           | Hair     | 15        | 81.4          | 96.79        | 89.095     |
| 7           | Paint    | 15        | 95.93         | 99.98        | 97.955     |
| 7           | Bush     | 18        | 94.84         | 98.87        | 96.855     |
| 7           | Gravel   | 20        | 97.03         | 100          | 98.515     |
| 7           | Stone    | 29        | 90            | 96.54        | 93.27      |
| 7           | Wall     | 30        | 93.12         | 98.36        | 95.74      |
| 7           | Metal    | 31        | 85.31         | 96.45        | 90.88      |
| 7           | Wood     | 41        | 98.9          | 100          | 99.45      |
| 7           | Misc     | 44        | 96.71         | 99.06        | 97.885     |
Table 10- The results of DHT for single features.

| Feature No. | Type  | Sub Class | D1   | D2   | D3   | D4   |
|-------------|-------|-----------|------|------|------|------|
| 1           | Porcelain | 2      | 99.21 | 99.21 | 99.21 | 99.21 |
| 1           | Track     | 2      | 99.21 | 99.21 | 99.21 | 99.21 |
| 1           | Straw     | 3      | 98.95 | 98.95 | 98.95 | 98.95 |
| 1           | Tire      | 3      | 86.97 | 86.97 | 87.5  | 87.5  |
| 1           | Tree      | 3      | 94.79 | 94.79 | 97.91 | 97.91 |
| 1           | Grass     | 4      | 93.75 | 93.75 | 95.31 | 95.31 |
| 1           | Rattan    | 4      | 99.6  | 99.6  | 99.6  | 99.6  |
| 1           | Sponge    | 4      | 91.01 | 91.01 | 90.62 | 90.62 |
| 1           | Tiles     | 4      | 90.23 | 90.23 | 95.7  | 95.7  |
| 1           | Building  | 5      | 71.25 | 71.25 | 68.43 | 68.43 |
| 1           | Leaf      | 5      | 81.56 | 81.56 | 80    | 80    |
| 1           | Styrofoam | 6      | 95.31 | 95.31 | 97.65 | 97.65 |
| 1           | Leather   | 7      | 80.07 | 80.07 | 77.92 | 77.92 |
| 1           | Plastic   | 8      | 90.62 | 90.62 | 88.67 | 88.67 |
| 1           | Food      | 10     | 58.43 | 58.43 | 53.59 | 53.59 |
| 1           | Paper     | 10     | 78.12 | 78.12 | 75.93 | 75.93 |
| 1           | Floor     | 11     | 59.21 | 59.21 | 59.37 | 59.37 |
| 1           | Rubber    | 11     | 62.96 | 62.96 | 62.34 | 62.34 |
| 1           | Bark      | 13     | 60    | 60    | 57.18 | 57.18 |
| 1           | Flower    | 13     | 60.62 | 60.62 | 53.43 | 53.43 |
| 1           | Marble    | 13     | 61.4  | 61.4  | 56.25 | 56.25 |
| 1           | Technic   | 14     | 70.46 | 70.46 | 72.81 | 72.81 |
| 1           | Hair      | 15     | 50.62 | 50.62 | 45.78 | 45.78 |
| 1           | Paint     | 15     | 82.5  | 82.5  | 79.06 | 79.06 |
| 1           | Bush      | 18     | 64.84 | 64.84 | 63.43 | 63.43 |
| 1           | Gravel    | 20     | 73.75 | 73.75 | 72.34 | 73.34 |
| 1           | Stone     | 29     | 54.84 | 54.84 | 53.43 | 53.43 |
| 1           | Wall      | 30     | 72.65 | 72.65 | 70.31 | 70.31 |
| 1           | Metal     | 31     | 61.87 | 61.87 | 59.37 | 59.37 |
| 1           | Wood      | 41     | 78.12 | 78.12 | 71.4  | 71.4  |
| 1           | Misc      | 44     | 82.18 | 82.18 | 77.5  | 77.5  |
**Table 11**- The results of DWH for two features.

| Feature No. | Type     | Sub Class | D1     | D2     | D3     | D4     |
|-------------|----------|-----------|--------|--------|--------|--------|
| 2           | Porcelain| 2         | 99.25  | 99.25  | 99.25  | 99.25  |
| 2           | Track    | 2         | 99.6   | 99.6   | 99.6   | 99.6   |
| 2           | Straw    | 3         | 98.5   | 98.5   | 98.5   | 98.5   |
| 2           | Tire     | 3         | 93.22  | 93.75  | 93.22  | 93.75  |
| 2           | Tree     | 3         | 99.47  | 99.47  | 99.47  | 99.47  |
| 2           | Grass    | 4         | 99.6   | 99.6   | 99.6   | 99.6   |
| 2           | Rattan   | 4         | 99.5   | 99.5   | 99.5   | 99.5   |
| 2           | Sponge   | 4         | 99.6   | 99.6   | 99.6   | 99.6   |
| 2           | Tiles    | 4         | 99.6   | 99.6   | 99.6   | 99.6   |
| 2           | Building | 5         | 90.31  | 90.62  | 94.68  | 95     |
| 2           | Leaf     | 5         | 95.62  | 95.62  | 96.87  | 97.5   |
| 2           | Styrofoam| 6         | 99.3   | 99.3   | 99.3   | 99.3   |
| 2           | Leather  | 7         | 94.14  | 94.14  | 93.75  | 94.33  |
| 2           | Plastic  | 8         | 99.6   | 99.8   | 99.8   | 99.8   |
| 2           | Food     | 10        | 87.18  | 86.09  | 88.28  | 88.43  |
| 2           | Paper    | 10        | 96.4   | 95.62  | 99.37  | 99.37  |
| 2           | Floor    | 11        | 81.71  | 80     | 86.25  | 87.5   |
| 2           | Rubber   | 11        | 95.31  | 95.15  | 96.25  | 96.4   |
| 2           | Bark     | 13        | 91.4   | 91.4   | 94.84  | 96.56  |
| 2           | Flower   | 13        | 83.59  | 82.96  | 80.46  | 81.09  |
| 2           | Marble   | 13        | 89.37  | 87.03  | 91.87  | 92.81  |
| 2           | Technic  | 14        | 87.65  | 88.12  | 91.87  | 93.28  |
| 2           | Hair     | 15        | 75.78  | 75     | 74.37  | 74.21  |
| 2           | Paint    | 15        | 93.75  | 93.28  | 94.84  | 95.78  |
| 2           | Bush     | 18        | 89.06  | 89.53  | 91.4   | 91.09  |
| 2           | Gravel   | 20        | 96.4   | 95.46  | 97.81  | 97.5   |
| 2           | Stone    | 29        | 86.71  | 86.4   | 84.21  | 86.09  |
| 2           | Wall     | 30        | 90.46  | 90     | 93.75  | 93.59  |
| 2           | Metal    | 31        | 87.34  | 87.96  | 89.06  | 90.31  |
| 2           | Wood     | 41        | 96.71  | 96.4   | 97.65  | 99.21  |
| 2           | Misc     | 44        | 96.71  | 97.03  | 98.75  | 99.21  |
Table 12- The results of DWH for three features.

| Feature No. | Type   | Sub Class | D1   | D2   | D3   | D4   |
|-------------|--------|-----------|------|------|------|------|
| 3           | Porcelain | 2       | 100  | 100  | 100  | 100  |
| 3           | Track    | 2       | 100  | 100  | 100  | 100  |
| 3           | Straw    | 3       | 100  | 100  | 100  | 100  |
| 3           | Tire     | 3       | 94.79| 97.39| 96.35| 96.87|
| 3           | Tree     | 3       | 100  | 100  | 100  | 100  |
| 3           | Grass    | 4       | 100  | 100  | 100  | 100  |
| 3           | Rattan   | 4       | 100  | 100  | 100  | 100  |
| 3           | Sponge   | 4       | 100  | 100  | 100  | 100  |
| 3           | Tiles    | 4       | 100  | 100  | 100  | 100  |
| 3           | Building | 5       | 98.43| 98.12| 99.68| 99.68|
| 3           | Leaf     | 5       | 96.87| 95.93| 99.37| 99.06|
| 3           | Styrofoam| 6       | 100  | 100  | 100  | 100  |
| 3           | Leather  | 7       | 96.28| 95.7 | 95.7 | 96.48|
| 3           | Plastic  | 8       | 99.8 | 99.8 | 99.8 | 99.8 |
| 3           | Food     | 10      | 91.25| 91.4 | 95.15| 95.62|
| 3           | Paper    | 10      | 99.84| 99.84| 99.84| 99.84|
| 3           | Floor    | 11      | 93.28| 92.18| 93.9 | 94.68|
| 3           | Rubber   | 11      | 99.37| 99.37| 99.06| 99.21|
| 3           | Bark     | 13      | 97.03| 97.65| 98.28| 99.21|
| 3           | Flower   | 13      | 92.65| 92.34| 89.68| 92.5 |
| 3           | Marble   | 13      | 92.96| 91.71| 96.56| 97.34|
| 3           | Technic  | 14      | 95.46| 96.4 | 98.28| 98.75|
| 3           | Hair     | 15      | 82.96| 83.12| 86.25| 87.5 |
| 3           | Paint    | 15      | 98.59| 98.59| 99.06| 98.9 |
| 3           | Bush     | 18      | 93.9 | 93.43| 96.56| 97.5 |
| 3           | Gravel   | 20      | 98.12| 98.12| 99.53| 99.68|
| 3           | Stone    | 29      | 92.03| 92.81| 93.59| 96.4 |
| 3           | Wall     | 30      | 94.53| 94.21| 95.78| 96.71|
| 3           | Metal    | 31      | 94.68| 93.59| 95.62| 95.93|
| 3           | Wood     | 41      | 99.37| 99.68| 99.84| 99.84|
| 3           | Misc     | 44      | 98.43| 99.21| 99.84| 99.84|
| Feature No. | Type      | Sub Class | D1   | D2   | D3   | D4   |
|------------|-----------|-----------|------|------|------|------|
| 3          | Fabric    | 77        | 99.68| 99.53| 99.53| 99.53|

**Table 13-** The results of DWH for four features.

| Feature No. | Type      | Sub Class | D1   | D2   | D3   | D4   |
|------------|-----------|-----------|------|------|------|------|
| 4          | Porcelain | 2         | 100  | 100  | 100  | 100  |
| 4          | Track     | 2         | 100  | 100  | 100  | 100  |
| 4          | Straw     | 3         | 100  | 100  | 100  | 100  |
| 4          | Tire      | 3         | 96.35| 97.91| 97.39| 98.95|
| 4          | Tree      | 3         | 100  | 100  | 100  | 100  |
| 4          | Grass     | 4         | 100  | 100  | 100  | 100  |
| 4          | Rattan    | 4         | 100  | 100  | 100  | 100  |
| 4          | Sponge    | 4         | 100  | 100  | 100  | 100  |
| 4          | Tiles     | 4         | 100  | 100  | 100  | 100  |
| 4          | Building  | 5         | 99.68| 99.68| 99.68| 99.68|
| 4          | Leaf      | 5         | 98.43| 96.25| 99.68| 99.68|
| 4          | Styrofoam | 6         | 100  | 100  | 100  | 100  |
| 4          | Leather   | 7         | 97.26| 96.48| 97.65| 97.85|
| 4          | Plastic   | 8         | 100  | 100  | 100  | 100  |
| 4          | Food      | 10        | 93.28| 92.81| 97.03| 98.43|
| 4          | Paper     | 10        | 100  | 100  | 100  | 100  |
| 4          | Floor     | 11        | 95.62| 95.93| 97.81| 97.34|
| 4          | Rubber    | 11        | 99.53| 99.84| 99.53| 99.68|
| 4          | Bark      | 13        | 98.59| 99.37| 99.84| 99.84|
| 4          | Flower    | 13        | 94.84| 95.46| 93.59| 94.06|
| 4          | Marble    | 13        | 95.15| 93.9 | 97.81| 99.06|
| 4          | Technic   | 14        | 96.87| 97.96| 99.84| 99.84|
| 4          | Hair      | 15        | 85.46| 85.15| 92.34| 93.28|
| 4          | Paint     | 15        | 99.37| 99.37| 99.84| 99.84|
| 4          | Bush      | 18        | 96.25| 95.46| 97.81| 99.21|
| 4          | Gravel    | 20        | 99.37| 99.68| 99.84| 99.84|
| 4          | Stone     | 29        | 96.25| 96.09| 97.65| 98.9 |
| 4          | Wall      | 30        | 95   | 95.31| 97.65| 97.65|
| 4          | Metal     | 31        | 95.93| 95.78| 97.18| 98.12|
| 4          | Wood      | 41        | 99.84| 99.84| 99.84| 99.84|
| 4          | Misc      | 44        | 100  | 100  | 100  | 100  |
Table 14: The results of DWH for five features.

| Feature No. | Type     | Sub Class | D1   | D2   | D3   | D4   |
|-------------|----------|-----------|------|------|------|------|
| 5           | Porcelain| 2         | 100  | 100  | 100  | 100  |
| 5           | Track    | 2         | 100  | 100  | 100  | 100  |
| 5           | Straw    | 3         | 100  | 100  | 100  | 100  |
| 5           | Tire     | 3         | 96.87| 97.91| 97.39| 99.47|
| 5           | Tree     | 3         | 100  | 100  | 100  | 100  |
| 5           | Grass    | 4         | 100  | 100  | 100  | 100  |
| 5           | Rattan   | 4         | 100  | 100  | 100  | 100  |
| 5           | Sponge   | 4         | 100  | 100  | 100  | 100  |
| 5           | Tiles    | 4         | 100  | 100  | 100  | 100  |
| 5           | Building | 5         | 100  | 100  | 100  | 100  |
| 5           | Leaf     | 5         | 98.75| 96.25| 99.68| 99.68|
| 5           | Styrofoam| 6         | 100  | 100  | 100  | 100  |
| 5           | Leather  | 7         | 97.65| 96.87| 99.02| 99.02|
| 5           | Plastic  | 8         | 100  | 100  | 100  | 100  |
| 5           | Food     | 10        | 94.21| 93.75| 98.12| 98.75|
| 5           | Paper    | 10        | 100  | 100  | 100  | 100  |
| 5           | Floor    | 11        | 97.34| 97.34| 98.28| 98.75|
| 5           | Rubber   | 11        | 100  | 100  | 100  | 100  |
| 5           | Bark     | 13        | 99.84| 100  | 100  | 100  |
| 5           | Flower   | 13        | 95.15| 96.56| 95.93| 96.09|
| 5           | Marble   | 13        | 97.03| 95.46| 98.75| 99.68|
| 5           | Technic  | 14        | 98.12| 98.43| 100  | 100  |
| 5           | Hair     | 15        | 87.81| 87.03| 94.68| 95.46|
| 5           | Paint    | 15        | 99.5 | 99.68| 100  | 100  |
| 5           | Bush     | 18        | 97.5 | 96.87| 98.59| 99.84|
| 5           | Gravel   | 20        | 100  | 100  | 100  | 100  |
| 5           | Stone    | 29        | 96.87| 97.18| 99.06| 99.68|
| 5           | Wall     | 30        | 95.31| 96.25| 97.81| 98.12|
| 5           | Metal    | 31        | 98.12| 97.03| 98.59| 99.21|
| 5           | Wood     | 41        | 99.6 | 99.6 | 99.6 | 99.6 |
| 5           | Misc     | 44        | 100  | 100  | 100  | 100  |
Table 15- The results of DWH for six features.

| No. Feature | Type  | Sub Class | D1   | D2   | D3   | D4   |
|-------------|-------|-----------|------|------|------|------|
| 6           | Porcelain | 2         | 100  | 100  | 100  | 100  |
| 6           | Track    | 2         | 100  | 100  | 100  | 100  |
| 6           | Straw    | 3         | 100  | 100  | 100  | 100  |
| 6           | Tire     | 3         | 97.39| 97.91| 97.91| 100  |
| 6           | Tree     | 3         | 100  | 100  | 100  | 100  |
| 6           | Grass    | 4         | 100  | 100  | 100  | 100  |
| 6           | Rattan   | 4         | 100  | 100  | 100  | 100  |
| 6           | Sponge   | 4         | 100  | 100  | 100  | 100  |
| 6           | Tiles    | 4         | 100  | 100  | 100  | 100  |
| 6           | Building | 5         | 100  | 100  | 100  | 100  |
| 6           | Leaf     | 5         | 98.75| 96.25| 99.68| 100  |
| 6           | Styrofoam| 6         | 100  | 100  | 100  | 100  |
| 6           | Leather  | 7         | 97.56| 96.87| 99.21| 99.41|
| 6           | Plastic  | 8         | 100  | 100  | 100  | 100  |
| 6           | Food     | 10        | 94.68| 95.31| 98.21| 99.37|
| 6           | Paper    | 10        | 100  | 100  | 100  | 100  |
| 6           | Floor    | 11        | 97.96| 97.5 | 99.06| 99.21|
| 6           | Rubber   | 11        | 100  | 100  | 100  | 100  |
| 6           | Bark     | 13        | 100  | 100  | 100  | 100  |
| 6           | Flower   | 13        | 95.15| 96.56| 95.93| 96.09|
| 6           | Marble   | 13        | 98.12| 96.4 | 98.9 | 99.84|
| 6           | Technic  | 14        | 99.37| 99.06| 100  | 100  |
| 6           | Hair     | 15        | 88.75| 88.28| 96.25| 97.5 |
| 6           | Paint    | 15        | 100  | 100  | 100  | 100  |
| 6           | Bush     | 18        | 97.96| 97.18| 99.06| 100  |
| 6           | Gravel   | 20        | 100  | 100  | 100  | 100  |
| 6           | Stone    | 29        | 97.96| 98.12| 99.84| 99.84|
| 6           | Wall     | 30        | 95.93| 96.87| 97.96| 98.12|
| 6           | Metal    | 31        | 98.12| 97.81| 98.9 | 99.37|
| 6           | Wood     | 41        | 100  | 100  | 100  | 100  |
| 6           | Misc     | 44        | 100  | 100  | 100  | 100  |
Table 16- The results of DWH for seven features.

| No. Feature | Type     | Sub Class | D1  | D2  | D3  | D4  |
|-------------|----------|-----------|-----|-----|-----|-----|
| 7           | Porcelain| 2         | 100 | 100 | 100 | 100 |
| 7           | Track    | 2         | 100 | 100 | 100 | 100 |
| 7           | Straw    | 3         | 100 | 100 | 100 | 100 |
| 7           | Tire     | 3         | 97.39 | 97.91 | 97.91 | 100 |
| 7           | Tree     | 3         | 100 | 100 | 100 | 100 |
| 7           | Grass    | 4         | 100 | 100 | 100 | 100 |
| 7           | Rattan   | 4         | 100 | 100 | 100 | 100 |
| 7           | Sponge   | 4         | 100 | 100 | 100 | 100 |
| 7           | Tiles    | 4         | 100 | 100 | 100 | 100 |
| 7           | Building | 5         | 100 | 100 | 100 | 100 |
| 7           | Leaf     | 5         | 98.75 | 96.25 | 100 | 100 |
| 7           | Styrofoam| 6         | 100 | 100 | 100 | 100 |
| 7           | Leather  | 7         | 97.65 | 96.87 | 99.6 | 99.8 |
| 7           | Plastic  | 8         | 100 | 100 | 100 | 100 |
| 7           | Food     | 10        | 94.84 | 95.93 | 98.75 | 99.37 |
| 7           | Paper    | 10        | 100 | 100 | 100 | 100 |
| 7           | Floor    | 11        | 98.43 | 97.96 | 99.21 | 99.21 |
| 7           | Rubber   | 11        | 100 | 100 | 100 | 100 |
| 7           | Bark     | 13        | 100 | 100 | 100 | 100 |
| 7           | Flower   | 13        | 96.25 | 97.65 | 96.56 | 96.87 |
| 7           | Marble   | 13        | 98.21 | 96.87 | 98.9 | 99.84 |
| 7           | Technic  | 14        | 99.53 | 99.37 | 100 | 100 |
| 7           | Hair     | 15        | 89.68 | 89.21 | 96.87 | 97.96 |
| 7           | Paint    | 15        | 100 | 100 | 100 | 100 |
| 7           | Bush     | 18        | 98.12 | 98.12 | 99.37 | 99.84 |
| 7           | Gravel   | 20        | 100 | 100 | 100 | 100 |
| 7           | Stone    | 29        | 97.96 | 98.75 | 100 | 100 |
| 7           | Wall     | 30        | 95.93 | 97.03 | 97.96 | 98.28 |
| 7           | Metal    | 31        | 98.12 | 98.43 | 99.06 | 99.68 |
| 7           | Wood     | 41        | 100 | 100 | 100 | 100 |
| 7           | Misc     | 44        | 100 | 100 | 100 | 100 |
Table 17- The final result of DWH for seven features.

| No. Feature | Class | No. of Sub Class | Training Data | Testing Data | Total Data |
|-------------|-------|------------------|---------------|--------------|------------|
| 7           | Fabric| 77               | 100           | 100          | 100        |

| No. Feature | Class  | No. of Sub Class | Training Data | Testing Data | Total Data |
|-------------|--------|------------------|---------------|--------------|------------|
| 7           | Porcelain | 2               | 100           | 100          | 100        |
| 7           | Track   | 2                | 100           | 100          | 100        |
| 7           | Straw   | 3                | 100           | 100          | 100        |
| 7           | Tire    | 3                | 100           | 100          | 100        |
| 7           | Tree    | 3                | 100           | 100          | 100        |
| 7           | Grass   | 4                | 100           | 100          | 100        |
| 7           | Rattan  | 4                | 100           | 100          | 100        |
| 7           | Sponge  | 4                | 100           | 100          | 100        |
| 7           | Tiles   | 4                | 100           | 100          | 100        |
| 7           | Building| 5                | 100           | 100          | 100        |
| 7           | Leaf    | 5                | 100           | 100          | 100        |
| 7           | Styrofoam| 6               | 100           | 100          | 100        |
| 7           | Leather | 7                | 99.8          | 100          | 99.9       |
| 7           | Plastic | 8                | 100           | 100          | 100        |
| 7           | Food    | 10               | 99.37         | 100          | 99.685     |
| 7           | Paper   | 10               | 100           | 100          | 100        |
| 7           | Floor   | 11               | 99.21         | 100          | 99.605     |
| 7           | Rubber  | 11               | 100           | 100          | 100        |
| 7           | Bark    | 13               | 100           | 100          | 100        |
| 7           | Flower  | 13               | 96.87         | 99.42        | 98.145     |
| 7           | Marble  | 13               | 99.84         | 100          | 99.92      |
| 7           | Technic | 14               | 100           | 100          | 100        |
| 7           | Hair    | 15               | 97.96         | 100          | 98.98      |
| 7           | Paint   | 15               | 100           | 100          | 100        |
| 7           | Bush    | 18               | 99.84         | 100          | 99.92      |
| 7           | Gravel  | 20               | 100           | 100          | 100        |
| 7           | Stone   | 29               | 100           | 100          | 100        |
| 7           | Wall    | 30               | 98.28         | 100          | 99.14      |
| 7           | Metal   | 31               | 99.68         | 100          | 99.84      |
| 7           | Wood    | 41               | 100           | 100          | 100        |
Table 18- The combination of features of DHW.

| Class     | No. of Sub Class | No of image | Feature 1 | Feature 2 | Feature 3 | Feature 4 | Feature 5 | Feature 6 | Feature 7 |
|-----------|------------------|-------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Porcelain | 2                | 32          | 0         | 50        | 3         | 4         | 5         | 5         | 3         |
| Track     | 2                | 32          | 0         | 1         | 0         | 0         | 0         | 0         | 87        |
| Straw     | 3                | 48          | 0         | 373       | 0         | 0         | 0         | 0         | 0         |
| Tire      | 3                | 48          | 307       | 405       | 136       | 404       | 362       | 132       | 2         |
| Tree      | 3                | 48          | 0         | 365       | 0         | 7         | 22        | 27        | 27        |
| Grass     | 4                | 64          | 13        | 120       | 0         | 0         | 3         | 5         | 5         |
| Rattan    | 4                | 64          | 0         | 148       | 0         | 0         | 5         | 0         | 5         |
| Sponge    | 4                | 64          | 7         | 300       | 0         | 0         | 300       | 0         | 0         |
| Tiles     | 4                | 64          | 5         | 408       | 0         | 5         | 0         | 5         | 3         |
| Building  | 5                | 80          | 4         | 415       | 10        | 5         | 300       | 0         | 2         |
| Leaf      | 5                | 80          | 76        | 322       | 403       | 305       | 362       | 308       | 308       |
| Styrofoam | 6                | 96          | 1         | 78        | 2         | 0         | 2         | 1         | 5         |
| Leather   | 7                | 112         | 345       | 361       | 78        | 316       | 187       | 110       | 120       |
| Plastic   | 8                | 128         | 303       | 365       | 0         | 0         | 0         | 0         | 0         |
| Food      | 10               | 160         | 315       | 369       | 124       | 53        | 361       | 74        | 47        |
| Paper     | 10               | 160         | 150       | 328       | 315       | 0         | 0         | 0         | 0         |
| Floor     | 11               | 176         | 146       | 374       | 50        | 324       | 7         | 366       | 166       |
| Rubber    | 11               | 176         | 58        | 404       | 313       | 32        | 9         | 10        | 26        |
| Bark      | 13               | 208         | 134       | 378       | 410       | 3         | 70        | 53        | 75        |
| Flower    | 13               | 208         | 164       | 363       | 253       | 157       | 378       | 334       | 367       |
| Marble    | 13               | 208         | 49        | 384       | 335       | 139       | 379       | 309       | 369       |
| Technic   | 14               | 224         | 39        | 402       | 151       | 333       | 46        | 3         | 10        |
| Hair      | 15               | 240         | 58        | 318       | 400       | 353       | 340       | 111       | 375       |
| Paint     | 15               | 240         | 126       | 380       | 316       | 51        | 5         | 0         | 17        |
| Bush      | 18               | 288         | 85        | 375       | 122       | 351       | 382       | 349       | 139       |
| Gravel    | 20               | 320         | 303       | 370       | 93        | 0         | 45        | 0         | 1         |
| Stone     | 29               | 464         | 14        | 319       | 349       | 173       | 344       | 227       | 413       |
| Wall      | 30               | 480         | 5         | 373       | 171       | 259       | 364       | 229       | 132       |
| Metal     | 31               | 496         | 9         | 214       | 333       | 404       | 314       | 45        | 369       |
| Wood      | 41               | 656         | 251       | 384       | 303       | 5         | 10        | 9         | 15        |
Table 19- The combination of feature of the DFT.

| Class     | No. of Sub Class | No of image | Feature 1 | Feature 2 | Feature 3 | Feature 4 | Feature 5 | Feature 6 | Feature 7 |
|-----------|------------------|-------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Porcelain | 2                | 32          | 2         | 192       | 0         | 0         | 0         | 0         | 0         |
| Track     | 2                | 32          | 0         | 1         | 0         | 0         | 0         | 0         | 0         |
| Straw     | 3                | 48          | 17        | 676       | 600       | 1         | 16        | 9         | 152       |
| Tire      | 3                | 48          | 728       | 771       | 90        | 280       | 10        | 67        | 601       |
| Tree      | 3                | 48          | 603       | 795       | 81        | 0         | 746       | 28        | 58        |
| Grass     | 4                | 64          | 136       | 675       | 728       | 194       | 737       | 1         | 10        |
| Rattan    | 4                | 64          | 269       | 794       | 617       | 320       | 656       | 76        | 640       |
| Sponge    | 4                | 64          | 668       | 810       | 9         | 600       | 256       | 600       | 632       |
| Tiles     | 4                | 64          | 258       | 651       | 0         | 3         | 98        | 0         | 120       |
| Building  | 5                | 80          | 637       | 763       | 72        | 368       | 651       | 755       | 40        |
| Leaf      | 5                | 80          | 596       | 796       | 188       | 235       | 789       | 189       | 475       |
| Styrofoam | 6                | 96          | 33        | 745       | 33        | 41        | 41        | 24        | 27        |
| Leather   | 7                | 112         | 10        | 723       | 616       | 744       | 618       | 1         | 32        |
| Plastic   | 8                | 128         | 96        | 787       | 736       | 743       | 650       | 755       | 828       |
| Food      | 10               | 160         | 676       | 758       | 632       | 32        | 776       | 65        | 651       |
| Paper     | 10               | 160         | 416       | 746       | 625       | 18        | 144       | 289       | 688       |
| Floor     | 11               | 176         | 9         | 783       | 623       | 60        | 328       | 59        | 769       |
| Rubber    | 11               | 176         | 60        | 673       | 824       | 32        | 288       | 632       | 636       |
| Bark      | 13               | 208         | 316       | 798       | 373       | 752       | 137       | 480       | 792       |
| Flower    | 13               | 208         | 284       | 646       | 76        | 800       | 448       | 330       | 733       |
| Marble    | 13               | 208         | 17        | 797       | 668       | 608       | 697       | 276       | 675       |
| Technic   | 14               | 224         | 39        | 784       | 272       | 284       | 721       | 314       | 269       |
| Hair      | 15               | 240         | 376       | 676       | 115       | 737       | 716       | 757       | 696       |
| Paint     | 15               | 240         | 253       | 677       | 787       | 58        | 249       | 635       | 747       |
| Bush      | 18               | 288         | 74        | 636       | 834       | 130       | 672       | 240       | 121       |
| Gravel    | 20               | 320         | 744       | 797       | 36        | 636       | 168       | 632       | 136       |
| Stone     | 29               | 464         | 624       | 795       | 557       | 264       | 752       | 2         | 280       |
| Wall      | 30               | 480         | 29        | 798       | 288       | 656       | 48        | 554       | 17        |
| Metal     | 31               | 496         | 724       | 761       | 404       | 676       | 244       | 196       | 721       |
| Wood      | 41               | 656         | 26        | 316       | 756       | 775       | 252       | 608       | 665       |
| Misc      | 44               | 704         | 76        | 755       | 678       | 752       | 56        | 795       | 16        |
| Fabric    | 77               | 1232        | 17        | 678       | 356       | 737       | 648       | 376       | 456       |

5. CONCLUSIONS

Within this paper, two methods are introduced; DHW and DFT. The introduced methods were applied to texture image such that each belongs to a certain class, with a need to handle the problems that occurred due to overlapping and shadowing. The gray, red, blue, and green bands have the major attained recognition rate and they are very important bands since they participate to over 90% of the results, while the other three bands present in the preprocessing stage participate to the rest. Also, the distance four shown in the Tables-(2-15) represents the best recognition rate result. The best recognition rates of the proposed method were %100 for the classification accuracy rate. The DHW is better than DFT because smooth edges and image boundary effects can prevent accurate texture analysis. DHW was found to be suitable for high periodic textures.
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