SSY095 – Image Analysis

Project: Classification of Western Paintings with Haralick Features

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Abstract

In this report a method for analysing western paintings from realism, impressionism, cubism, romanticism and surrealism are presented. Haralick Features [1] are used for extracting texture-based information and use this information for classification. 80% success has been achieved with baroque paintings.

1. Introduction

Image analysis methods have been applied to arts for different purposes [2] including trying to guess the equipment used by the painters [3,4] or perspective analysis [5] or classifying paintings [6]. Traditionally, the analysis of western paintings are done by specialists that can understand a painting from its painting style, color choice, stroke techniques, the theme of the painting. However, now museums, art galleries, schools etc. can have a wide library of digital images. Thus, having a program that can classify the paintings will make the ordering, storing much easier and cheaper. In addition, the feature can be applied on robots. Today, robots that can play music have been reported [2], so why could not they have also some understanding in visual arts.

However, implementation wise there are some limitations. Some properties, which can be observed or understood by the humans easily, can be hard to decipher by computation. A well-known example is "The Treachery of Images" by René Magritte. In the painting is a pipe and under the painting is written: "This is not a pipe" [7]. In addition, one must never forget the computational force required for classifying pictures as some algorithms may not be usable, due to time spent.

2. Material and Methods

Matlab is used as the software for computation. The codes can be found in appendix A. A database of 30 images is constructed, where each type have 5 paintings. The images are downloaded from Wikipedia, thus possibly they are not professional recordings of the images. In addition, it must be noted that different images have different resolutions, thus provide different amount of detail.

Haralick Features are chosen for analysis. The reason is they define textural properties using only a gray level/intensity image. Using a gray image allows less computation since there is only 1 matrix that has the color information and simple hardware as no color cameras are needed. However, the cost is the loss of color information, which might be very important since, the investigated objects are initially color paintings.

2.a Database

The paintings that form the database can be seen below. When choosing the pictures, it has been arranged such that, no more than a single painting has been chosen from a

painter. This is done in order to avoid classifying a painter rather than an era. This is an important risk, since some painters are very influential in some movements, such as Pablo Picasso to cubism or Claude Monet to Impressionism.

2.a.1 Baroque

Baroque paintings are extension of Baroque movement, in which the arts was encouraged by the Church to do religious works and show immense power and control. Baroque paintings show an event at its most dramatic point and usually have very dark shadows and very bright spots.

Figure 1: Genoan Hauteur from the Lomelli Family by Anthony van Dyck (1623)

Figure 2: The Embarkation of the Queen of Sheba by Claude Lorrain (1648)

Figure 3: Girl with a Pearl Earring by Johannes Vermeer (circa 1665)

Figure 4: St. Joseph by Georges de la Tour (1642)

Figure 5: The Night Watch by Rembrandt Harmenszoon van Rijn (1642)

2.a.2 Cubism

Cubism is an art movement that started in the early years of 20th century, was a vital movement until the appearance of surrealism. In cubism, an object is disassembled then assembled into an abstract image where different angles or times of views are also added. In addition, in this process the depth information is also lost.

Figure 6: Nude Descending a Staircase, No. 2 by Marcel Duchamp (1912)

Figure 7: Still Life with Fruit Dish and Mandolin by Juan Gris (1919)

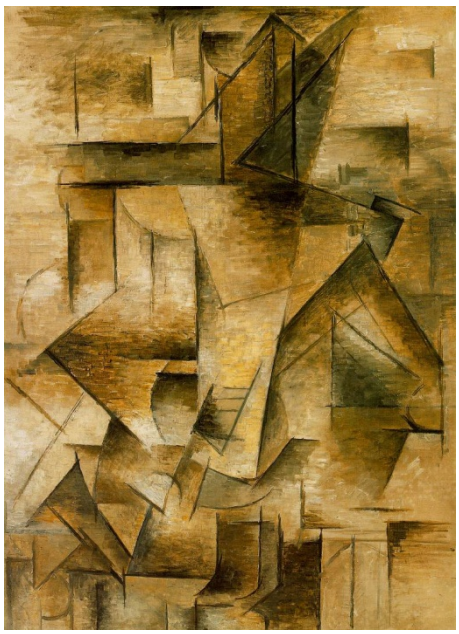

Figure 8: Le Guitariste by Pablo Picasso (1910)

Figure 9: Quarry Bibémus by Paul Cézanne (circa 1895)

Figure 10: Woman with a Guitar by Georges Braque (1913)

2.a.3 Impressionism

Impressionism is a movement that started Paris, and named after Claude Monet's painting "Impression, Sunrise". Impressionist paintings have observable brush strokes. The changing of light and the movement of objects are painted as observed by a human eye in a smooth fashion.

Figure 11: View of the Saint-Martin Canal by Alfred Sisley (1870)

Figure 12: Reading by Berthe Morisot (1873)

Figure 13: Gelee Blacnhe by Camille Pissarro (1873)

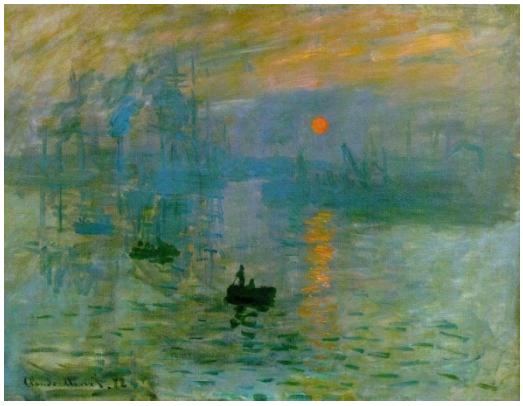

Figure 14: Soleil Levant (Impression, Sunrise) by Claude Monet (1872)

Figure 15: Paris Street; Rainy Day by Gustave Caillebotte (1877)

2.a.4 Realism

Realist paintings have two aspects, the paintings represent what the eyes can see or they can represent ordinary objects or events. The movement started in France around 1850.

Figure 16: A Burial at Ornans by Gustave Courbet (1849-1850)

Figure 17: Hiding in the Haystocks by William Bliss Baker (1881)

Figure 18: Woman Cleaning Turnips by Jean-Baptiste Siméon Chardin (1738)

Figure 19: The Gleaners by Jean-François Millet (1857)

Figure 20: Horse Fair by Rosa Bonheur (1853-1855)

2.a.5 Romanticism

Romanticism is a movement, which is a revolt against the industrial revolution, nature sciences. The paintings are based on strong emotions and show wild nature.

Figure 21: Wanderer above the Sea of Fog by Caspar David Friedrich (1818)

Figure 22: The Voyage of Life: Childhood by Cole Thomas (1842)

Figure 23: Liberty Leading the People by Eugène Delacroix (1830)

Figure 24: Shipwreck by Joseph Vernet (1759)

Figure 25: Raft of the Medusa by Theodore Gericault (1818-1819)

2.a.6 Surrealism

Surrealism is a movement that evolved in 1920 as an opposition to realism. Surrealist paintings show unexpected abstractions and philosophical thoughts.

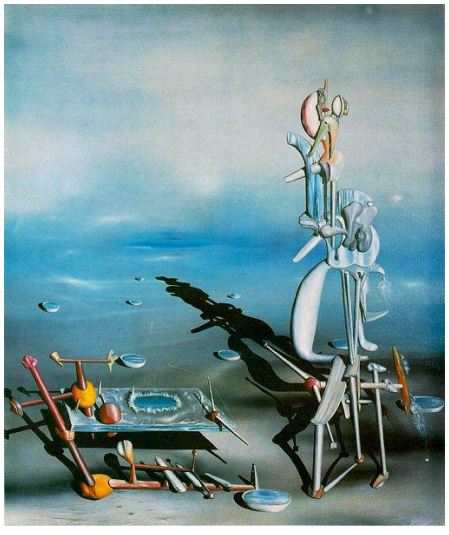

Figure 26: Indefinite Divisibility by Yves Tanguy (1942)

Figure 27: The Son of Man by René Magritte (1964)

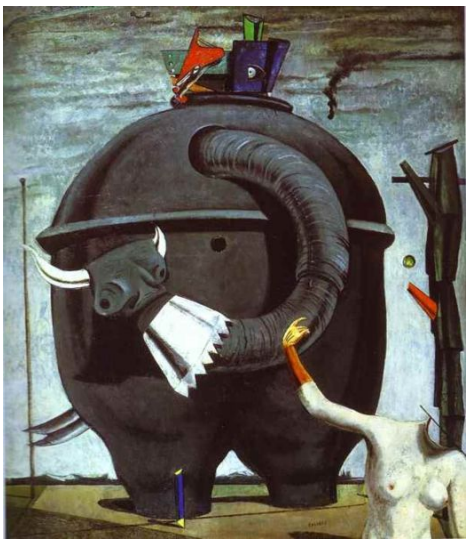

Figure 28: The Elephant Celebes by Max Ernst (1921)

Figure 29: The Persistence of Memory by Salvador Dali (1931)

Figure 30: The Red Tower by Giorgio de Chirico (1913)

2.b Haralick Features

Haralick features are used for analysing the texture of an image. In a painting, this corresponds to brush strokes. One argument against the Haralick features can be that they require mathematical computation, the amount of computational power can be adjusted by adjusting the number of gray levels. In addition, by not using a color image, the required camera might be cheaper and the acquired image as a matrix will be three times smaller. On the other hand, Haralick features offer 14 different elements that define the textural structure of a painting. Haralick features can be defined as follows [1].

Angular Second Moment:

$$f_1 = \sum_{i=1}^{Ng} \sum_{j=1}^{Ng} \{p(i,j)\}^2$$

Contrast

$$f_2 = \sum_{n=0}^{Ng-1} n^2 \left(\sum_{i=1}^{Ng} \sum_{j=1}^{Ng} p(i,j) \right) \quad when\ |i-j| = n$$

Correlation

$$f_3 = \frac{\sum_{i=1}^{Ng} \sum_{j=1}^{Ng} (ij) p(i,j) - \mu_x \mu_y}{\sigma_x \sigma_y}$$

Sum of Squares: Variance

$$f_4 = \sum_{i=1}^{Ng}\sum_{j=1}^{Ng}(i-\mu)^2 p(i,j)$$

Inverse Difference Moment

$$f_5 = \sum_{i=1}^{Ng}\sum_{j=1}^{Ng}\frac{1}{1+(i-j)^2}p(i,j)$$

Sum Average

$$f_6 = \sum_{i=2}^{2Ng} i p_{x+y}(i)$$

Sum Variance

$$f_7 = \sum_{i=2}^{2Ng}(i-f_8)^2 p_{x+y}(i)$$

Sum Entropy

$$f_8 = -\sum_{i=2}^{2Ng} p_{x+y}(i)\log\{p_{x+y}(i)\}$$

Entropy

$$f_9 = -\sum_{i=1}^{Ng}\sum_{j=1}^{Ng} p(i,j)\log(p(i,j))$$

Difference Variance

$$f_{10} = E[p_{x-y}{}^2] - E[p_{x-y}]^2$$

Difference Entropy

$$f_{11} = -\sum_{i=0}^{Ng-1} p_{x-y}(i)\log\{p_{x-y}(i)\}$$

Information Measures of Correlation

$$f_{12} = \frac{HXY - HXY1}{\max\{HX, HY\}}$$

$$f_{13} = (1-\exp[-2.0(HXY2 - HXY)])^{1/2}$$

Maximal Correlation Coefficient

$$f_{14} = (Second\ largest\ eigenvalue\ of\ Q)^{1/2}$$

where

$$p_x(i) = \sum_{j=1}^{Ng} p(i,j)$$

$$p_y(j) = \sum_{i=1}^{Ng} p(i,j)$$

$$p_{x+y}(k) = \sum_{i=1}^{Ng}\sum_{j=1}^{Ng} p(i,j) \qquad i+j=k, k = 2,3,\dots,2Ng$$

$$p_{x-y}(k) = \sum_{i=1}^{Ng}\sum_{j=1}^{Ng} p(i,j) \qquad |i-j|=k, k = 0,1,\dots,Ng-1$$

$\mu_x, \mu_y, \sigma_x, \sigma_y$ *are the means and the standard deviations of* p_x *and* p_y

$$HXY = -\sum_{i=1}^{Ng}\sum_{j=1}^{Ng} p(i,j)(\log(p(i,j)))$$

$$HXY1 = -\sum_{i=1}^{Ng}\sum_{j=1}^{Ng} p(i,j)(\log\{p_x(i)p_y(j)\})$$

$$HXY2 = -\sum_{i=1}^{Ng}\sum_{j=1}^{Ng} p_x(i)p_y(j)(\log\{p_x(i)p_y(j)\})$$

$$Q(i,j) = \sum_{k=1}^{Ng}\frac{p(i,k)p(j,k)}{p_x(i)p_y(k)}$$

More than one method is used when applying the Haralick Features. Initially the images are taken as a whole and the Gray-Level Co-Occurrence are computed for four different directions with different number of gray levels from 2 to 256 and the average of four direction is taken. Here the aim is finding the lowest amount of gray levels giving sufficient information.

Later the images are divided into sub-images with varying size from 32x32 to 256x256, and the images are analyzed with different number of gray levels again from 2 to 256.

3. Results

Before observing the results, one must remember that when a painting is stored as a digital data, it is quantized and loses

information. Thus, machines can not see the detail, a human specialist see a painting. In addition, the digital copies used in this project are downloaded from Wikipedia, thus they may not be good reproductions of the original images. In addition, it must be noted that different images had different sizes, which causes some images to have more information and some to have less information than the others do. On the other hand, downsizing every image to lowest, will cause loss of information and will decrease the overall quality of the database.

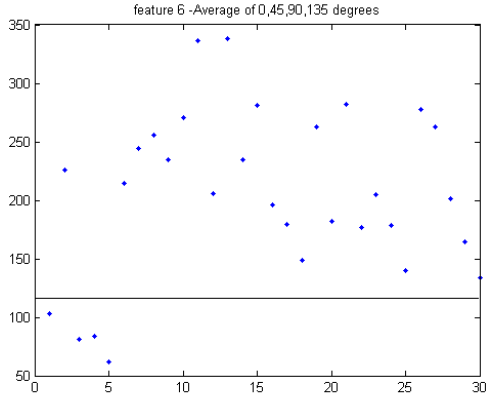

Figure 31: Sum Average with 256 Gray Levels 118.3500

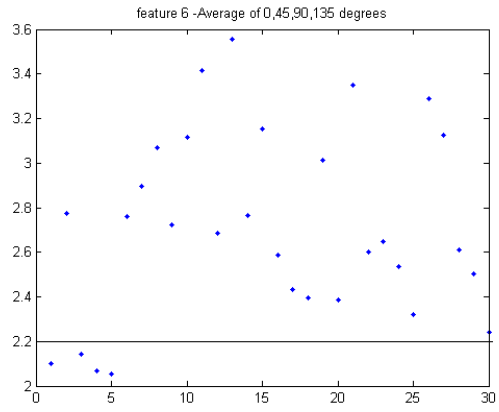

Figure 32: Sum Average with 2 Gray Levels 2.1910

The above graphs are obtained when the image are analyzed as a whole. The dots 1 to 5 belong to baroque, 6 to 10 belong to cubic, 11 to 15 belong to impressionism, 16 to 20 belong to realism, 21 to 25 belong to romanticism and 26 to 30 belong to surrealism. It can be observed from the graphs that the baroque paintings can be found with 80% even with binary images; yet other types can not detected with the 14 Haralick Features.

Because of the unsuccessful results, the method is changed to dividing images into sub-images. However, it must be added that since the computation of the Haralick Features depends on the size of the Gray-Level Co-Occurrence matrix, the number of sub-images linearly increases the computation time. With sub-image size of 32x32 and 256 number of gray-level, it takes more than 4 hours to analyze a 1.7 million-pixel image, which is not a very large image. Thus, analysis with small sub-images could not be completed. Yet, simulations are done up to the complexity of 64x64 sub-image size with 256 number of gray levels and 32x32 sub-image size with binary images. Unfortunately, the results became worse. Moreover, the variations in the sizes of images affect the simulation more as some images could not be divided into sub-images of size 256x256, or in order to have the same number of sub-images, different sizes of sub-images should be applied.

4. Conclusions

Haralick Features does not seem to be a viable method for classification of western images. Other methods such as using color information as artistic color concepts [8] or a combination of color, texture and edges [7], might used. In addition, there is a very important problem with database. The images must be digitalized with the best quality in order to keep the most of the information that exists in their counterparts. Moreover, the digital versions must be standardized, so that they have the same amount of pixel and detail. Then again, still one must take the defects such as the cracks or fading of colors due to time. Yet, the application of image

analysis on western paintings is an interesting topic if not as important as medical implementations.

If the paintings are observed with an uneducated plain eye, one can say that baroque, impressionism and cubic should be easier to detect with computer. Baroque paintings have large dark regions and very bright regions, impressionism should be found by its brush strokes and cubic should be detected by the lines that form the edges of the polygons. On the other hand, romanticism, realism and surrealism have context information where the classification is done from a different perspective than the former types.

As a final conclusion, it can be said that with 256 number of gray levels paintings that has Sum Average less than 118.35 or with 2 number of gray levels painting that has Sum Average less than 2.191 can be deciphered as baroque paintings.

References

[1] R.M. Haralick, K. Shanmugam, I. Dinsten; Textural Features for Image Classification, *IEE Transactions on Systems, Man and Cybernetics,* vol. SMC-3, No.6, November 1973, pp. 610-621

[2] F. Bartolini, V. Cappellini, A. D. Mastio, and A. Piva, "Applications of image processing technologies to fine arts," in *Optical Metrology for Arts and Multimedia*, R. Salimbeni, Ed., vol. 5146, no. 1. SPIE, 2003, pp. 12–23.

[3] D. G. Stork, M. K. Johnson, Computer Vision, Image Analysis and Master Art: Part 2, *IEEE Multimedia,* October-December 2006,p12-17

[4] P. Kammerer, M. Lettner, E. Zolda, and R. Sablatnig, "Identification of drawing tools by classification of textural and boundary features of strokes," *Pattern Recognition Letters*, vol. 28, no. 6, pp. 710 – 718, 2007.

[5] D. G. Stork, Computer Vision, Image Analysis and Master Art: Part 1, *IEEE Multimedia,* July-September 2006,p16-20

[6] A. Deac, J. van der Lubbe, and E. Backer, "Feature selection for paintings classification by optimal tree pruning," in *Multimedia Content Representation, Classification and Security*, 2006, pp. 354–361.

[7] J. Zukovic, L. Gandy, S. Friedman, B. Pardo, T. N. Pappas; Classifying Paintings by Artistic Genre: An Analysis of Features & Classifiers, *Multimedia Signal ProceMSP'09*, October 2009

[8] M. Yelizaveta, A. Irina; Analysis and Retrieval of Paintings Using Artistic Color Concepts, *Multimedia and Expo*, July 2005, pp. 1246 - 1249]

APPENDIX A

Matlab Codes

Except for the codes of the functions that calculate the gray-level co-occurrence matrix, Haralick feature 1, Haralick feature 2, Haralick feature 3 and Haralick feature 9, the Matlab codes have been written. The functions mentioned are used as they were written in the Texture Analysis and Classification lab. In addition, it must be noted that the ideas for quantization and creating sub-images are used from the given codes in Texture Analysis and Classification lab.

1. Main Codes

- The code below is used for analyzing the 30 paintings as a whole, without dividing into sub-images.

```
clear all;
close all;
clc

Ng=128;
quantize=1;


for i=1:30;

    clear I;

    %%Loading and Adjusting Image for Analysis
    if(i==1)
        %Baroque
        ImColor=imread('Genoan hauteur from the Lomelli family_Anthonis_van_Dyck.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==2)
        ImColor=imread('he Embarkation of the Queen of Sheba_Claude_Lorrain.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==3)
        ImColor=imread('Johannes_Vermeer_(1632-1675)_-
_The_Girl_With_The_Pearl_Earring_(1665).jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==4)
        ImColor=imread('Saint Joseph charpentier_Georges de La Tour.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==5)
        ImColor=imread('The_Nightwatch_by_Rembrandt.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==6)
        %Cubic
        ImColor=imread('Duchamp_-_Nude_Descending_a_Staircase.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==7)
        ImColor=imread('Juan_Gris_-_Still_Life_with_Fruit_Dish_and_Mandolin.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==8)
        ImColor=imread('Le_guitariste_PabloPicasso.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==9)
        ImColor=imread('Paul_Cézanne_Quarry Bibémus.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==10)
        ImColor=imread('woman_with_a_guitar_GeorgesBraque.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==11)
        %impressionist
        ImColor=imread('Alfred_Sisley_View of the Saint-Martin Canal,.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==12)
        ImColor=imread('Berthe_Morisot_Reading.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==13)
```

```
        ImColor=imread('Camille_Pissarro,_Gelee_blanche_(Hoarfrost),_1873.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==14)
        ImColor=imread('Claude_Monet_soleil_levant.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==15)
        ImColor=imread('Gustave_Caillebotte_-_La_Place_de_lEurope,_temps_de_pluie.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==16)
        %realist
        ImColor=imread('Gustave Courbet, A Burial at Ornans,.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==17)
        ImColor=imread('Hiding_in_the_Haycocks_(1881)_by_WIlliam_Bliss_Baker.jpeg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==18)
        ImColor=imread('Jean-Baptiste_Siméon_Chardin_Woman Cleaning Turnips.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==19)
        ImColor=imread('Jean-François Millet_The Gleaners.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==20)
        ImColor=imread('Rosa_Bonheur_horse_fair_1835_55.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==21)
        %romanticist
        ImColor=imread('Caspar_David_Friedrich_Wanderer above the Sea of Fog.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==22)
        ImColor=imread('Cole_Thomas_The_Voyage_of_Life_Childhood_1842.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==23)
        ImColor=imread('Eugène_Delacroix_-_La_liberté_guidant_le_peuple.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==24)
        ImColor=imread('Joseph Vernet,  Shipwreck.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==25)
        ImColor=imread('Theodore_Gericault_Raft_of_the_Medusa-1.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==26)
        %surrealist
        ImColor=imread('Indefinite_Divisibility_Yves Tanguy.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==27)
        ImColor=imread('RenéMagritte_TheSonOfMan.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==28)
        ImColor=imread('The_Elephant_Celebes_MaxErnst.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==29)
        ImColor=imread('The_Persistence_of_Memory_Salvador Dali.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==30)
        ImColor=imread('The_Red_Tower_Giorgio de Chirico.jpg');
        I=imgray(ImColor,Ng,quantize);
    end


%%Co-occurance Matrices

p0   =cooc(I,0,Ng,1);
p45  =cooc(I,45,Ng,1);
p90  =cooc(I,90,Ng,1);
p135 =cooc(I,135,Ng,1);


%%Results

[f0_7,f0_8]=sumve(p0,Ng);
[f0_9,f0_12,f0_13]=ent_imc(p0,Ng);
```

```
R0(i,:)=[asm(p0,Ng),cont(p0,Ng),cor(p0,Ng),sosv(p0,Ng),idm(p0,Ng),suma(p0,Ng),f0_7,f0_8,f0_9,dif
v(p0,Ng),dife(p0,Ng),f0_12,f0_13,mcc(p0,Ng)];

[f45_7,f45_8]=sumve(p45,Ng);
[f45_9,f45_12,f45_13]=ent_imc(p45,Ng);

R45(i,:)=[asm(p45,Ng),cont(p45,Ng),cor(p45,Ng),sosv(p45,Ng),idm(p45,Ng),suma(p45,Ng),f45_7,f45_8
,f45_9,difv(p45,Ng),dife(p45,Ng),f45_12,f45_13,mcc(p45,Ng)];


[f90_7,f90_8]=sumve(p90,Ng);
[f90_9,f90_12,f90_13]=ent_imc(p90,Ng);

R90(i,:)=[asm(p90,Ng),cont(p90,Ng),cor(p90,Ng),sosv(p90,Ng),idm(p90,Ng),suma(p90,Ng),f90_7,f90_8
,f90_9,difv(p90,Ng),dife(p90,Ng),f90_12,f90_13,mcc(p90,Ng)];


[f135_7,f135_8]=sumve(p135,Ng);
[f135_9,f135_12,f135_13]=ent_imc(p135,Ng);

R135(i,:)=[asm(p135,Ng),cont(p135,Ng),cor(p135,Ng),sosv(p135,Ng),idm(p135,Ng),suma(p135,Ng),f135
_7,f135_8,f135_9,difv(p135,Ng),dife(p135,Ng),f135_12,f135_13,mcc(p135,Ng)];



Ravg(i,:)=(R0(i,:)+R45(i,:)+R90(i,:)+R135(i,:))/4;

end

plotter(Ravg);
```

- The code below is used for analyzing the 30 paintings as compound of sub-images.

```
clear all;
close all;
clc

Ng=2;
quantize=1;


for i=1:30;
tic
    clear I;

    %%Loading and Adjusting Image for Analysis
    if(i==1)
        %Baroque
        ImColor=imread('Genoan hauteur from the Lomelli family_Anthonis_van_Dyck.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==2)
        ImColor=imread('he Embarkation of the Queen of Sheba_Claude_Lorrain.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==3)
        ImColor=imread('Johannes_Vermeer_(1632-1675)_-
_The_Girl_With_The_Pearl_Earring_(1665).jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==4)
        ImColor=imread('Saint Joseph charpentier_Georges de La Tour.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==5)
        ImColor=imread('The_Nightwatch_by_Rembrandt.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==6)
        %Cubic
        ImColor=imread('Duchamp_-_Nude_Descending_a_Staircase.jpg');
        I=imgray(ImColor,Ng,quantize);
    elseif(i==7)
```

```
    ImColor=imread('Juan_Gris_-_Still_Life_with_Fruit_Dish_and_Mandolin.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==8)
    ImColor=imread('Le_guitariste_PabloPicasso.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==9)
    ImColor=imread('Paul_Cézanne_Quarry Bibémus.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==10)
    ImColor=imread('woman_with_a_guitar_GeorgesBraque.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==11)
    %impressionist
    ImColor=imread('Alfred_Sisley_View of the Saint-Martin Canal,.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==12)
    ImColor=imread('Berthe_Morisot_Reading.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==13)
    ImColor=imread('Camille_Pissarro,_Gelee_blanche_(Hoarfrost),_1873.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==14)
    ImColor=imread('Claude_Monet_soleil_levant.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==15)
    ImColor=imread('Gustave_Caillebotte_-_La_Place_de_lEurope,_temps_de_pluie.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==16)
    %realist
    ImColor=imread('Gustave Courbet, A Burial at Ornans,.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==17)
    ImColor=imread('Hiding_in_the_Haycocks_(1881)_by_WIlliam_Bliss_Baker.jpeg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==18)
    ImColor=imread('Jean-Baptiste_Siméon_Chardin_Woman Cleaning Turnips.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==19)
    ImColor=imread('Jean-François Millet_The Gleaners.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==20)
    ImColor=imread('Rosa_Bonheur_horse_fair_1835_55.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==21)
    %romanticist
    ImColor=imread('Caspar_David_Friedrich_Wanderer above the Sea of Fog.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==22)
    ImColor=imread('Cole_Thomas_The_Voyage_of_Life_Childhood_1842.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==23)
    ImColor=imread('Eugène_Delacroix_-_La_liberté_guidant_le_peuple.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==24)
    ImColor=imread('Joseph Vernet,  Shipwreck.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==25)
    ImColor=imread('Theodore_Gericault_Raft_of_the_Medusa-1.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==26)
    %surrealist
    ImColor=imread('Indefinite_Divisibility_Yves Tanguy.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==27)
    ImColor=imread('RenéMagritte_TheSonOfMan.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==28)
    ImColor=imread('The_Elephant_Celebes_MaxErnst.jpg');
    I=imgray(ImColor,Ng,quantize);
elseif(i==29)
    ImColor=imread('The_Persistence_of_Memory_Salvador Dali.jpg');
    I=imgray(ImColor,Ng,quantize);
```

```
    elseif(i==30)
        ImColor=imread('The_Red_Tower_Giorgio de Chirico.jpg');
        I=imgray(ImColor,Ng,quantize);
    end

counter=1;
s=256; % sub-image size = s x s
[X,Y]=size(I);
xcoord = s:s:X-s-1; ycoord = s:s:Y-s-1;
MAXX = size(xcoord,2); MAXY = size(ycoord,2);
Rstore=zeros(1,14);

for x=1:MAXX
    for y=1:MAXY
        subimage = I(xcoord(x):xcoord(x)+s-1, ycoord(y):ycoord(y)+s-1);
        counter=counter+1;
        %%Co-occurance Matrices

        p0   =cooc(subimage,0,Ng,1);
        p45  =cooc(subimage,45,Ng,1);
        p90  =cooc(subimage,90,Ng,1);
        p135 =cooc(subimage,135,Ng,1);

        [f0_7,f0_8]=sumve(p0,Ng);
        [f0_9,f0_12,f0_13]=ent_imc(p0,Ng);


R0=[asm(p0,Ng),cont(p0,Ng),cor(p0,Ng),sosv(p0,Ng),idm(p0,Ng),suma(p0,Ng),f0_7,f0_8,f0_9,difv(p0,
Ng),dife(p0,Ng),f0_12,f0_13,mcc(p0,Ng)];

        [f45_7,f45_8]=sumve(p45,Ng);
        [f45_9,f45_12,f45_13]=ent_imc(p45,Ng);


R45=[asm(p45,Ng),cont(p45,Ng),cor(p45,Ng),sosv(p45,Ng),idm(p45,Ng),suma(p45,Ng),f45_7,f45_8,f45_
9,difv(p45,Ng),dife(p45,Ng),f45_12,f45_13,mcc(p45,Ng)];


        [f90_7,f90_8]=sumve(p90,Ng);
        [f90_9,f90_12,f90_13]=ent_imc(p90,Ng);


R90=[asm(p90,Ng),cont(p90,Ng),cor(p90,Ng),sosv(p90,Ng),idm(p90,Ng),suma(p90,Ng),f90_7,f90_8,f90_
9,difv(p90,Ng),dife(p90,Ng),f90_12,f90_13,mcc(p90,Ng)];


        [f135_7,f135_8]=sumve(p135,Ng);
        [f135_9,f135_12,f135_13]=ent_imc(p135,Ng);


R135=[asm(p135,Ng),cont(p135,Ng),cor(p135,Ng),sosv(p135,Ng),idm(p135,Ng),suma(p135,Ng),f135_7,f1
35_8,f135_9,difv(p135,Ng),dife(p135,Ng),f135_12,f135_13,mcc(p135,Ng)];

        Ravg=(R0+R45+R90+R135)/4;
        Rstore=Rstore+Ravg;
    end
end
Rfinal(i,:)=Rstore/counter;



toc
end

plotter(Rfinal);
```

2. Haralick Features

- Feature 1: Angular Second Moment

```
function ASM=asm(coc,ng)

Ng=ng;
ASM=0;
for i=1:Ng;
    for k=1:Ng;
        ASM=ASM+coc(i,k)*coc(i,k);
    end
end
ASM;
```

- Feature 2: Contrast

```
function ASM=asm(coc,ng)

Ng=ng;
ASM=0;
for i=1:Ng;
    for k=1:Ng;
        ASM=ASM+coc(i,k)*coc(i,k);
    end
end
ASM;
```

- Feature 3: Correlation

```
function CORR= cor(coc,ng)

Ng=ng;
CORR=0;
ma=0;
mb=0;
stda1=0;
stdb1=0;



for a=1:Ng
    for b=1:Ng
        ma=ma+a*coc(a,b);
        mb=mb+b*coc(a,b);
    end
end
t1=0;
a1=0;
b1=0;

for a=1:Ng
    for b=1:Ng
        t1=t1+((a-ma)*(b-mb))*coc(a,b);
        a1=a1+(a-ma)*(a-ma)*coc(a,b);
        b1=b1+(b-mb)*(b-mb)*coc(a,b);
    end
end

CORR=t1/(sqrt(a1)*sqrt(b1));


CORR;
```

- Feature 4: Sum of Squares: Variance

```
function SoSV=sosv(coc,ng)


Ng=ng;
SoSV=0;
m=0;

for a=1:Ng
    for b=1:Ng
        m=m+a*b*coc(a,b);
    end
end

for i=1:Ng;
    for k=1:Ng;
        SoSV=SoSV+(i-m)^2*coc(i,k);
    end
end
SoSV;
```

- Feature 5: Inverse Difference Moment

```
function IDM=idm(coc,ng)

Ng=ng;
IDM=0;
for i=1:Ng;
    for k=1:Ng;
        IDM=IDM+(1/(1+(i-k)^2))*coc(i,k);
    end
end
IDM;
```

- Feature 6: Sum Average

```
function SUMA=suma(coc,ng)


Ng=ng;
SUMA=0;
pxy=zeros(2*Ng,1);


for i=1:Ng;
    for j=1:Ng;
        pxy(i+j)=pxy(i+j)+coc(i,j);
    end
end

for k=2:2*Ng
    SUMA=SUMA+k*pxy(k);
end

SUMA;
```

- Feature 7: Sum Variance and Feature 8: Sum Entropy

```
function [SUMV,SUME]=sumve(coc,ng)


Ng=ng;
SUMV=0;
SUME=0;

pxy=zeros(2*Ng,1);


for i=1:Ng;
    for j=1:Ng;
```

```
        pxy(i+j)=pxy(i+j)+coc(i,j);
    end
end

for k=2:2*Ng;
    if (pxy(k)==0)
    else
        SUME=SUME-pxy(k)*log(pxy(k));
    end
end


for k=2:2*Ng;
    SUMV=SUMV+(k-SUME)^2*pxy(k);
end


SUME;
SUMV;
```

- Feature 9: Entropy and Feature 12,13: Information Measures of Correlation

```
function [ENT,IMC1,IMC2]=ent_imc(coc,ng)


Ng=ng;

px=zeros(Ng,1);
for j=1:Ng
    px=px+coc(:,j);
end

py=zeros(Ng,1);
for i=1:Ng
    py=py+coc(i,:)';
end

HX=0;
HY=0;

for i=1:Ng
    if(px(i)==0)
    else
        HX=HX-px(i)*log(px(i));
    end
    if(py(i)==0)
    else
        HY=HY-py(i)*log(py(i));
    end
end

ENT=0;
HXY1=0;
HXY2=0;

for i=1:Ng;
    for j=1:Ng;
        if (coc(i,j)==0)
        else
            ENT=ENT-coc(i,j)*log(coc(i,j));
        end
        if (px(i)*px(j)==0)
        else
            HXY1=HXY1-coc(i,j)*log(px(i)*px(j));
            HXY2=HXY2-px(i)*px(j)*log(px(i)*px(j));
        end
    end
end

IMC1=(ENT-HXY1)/max(HX,HY);
IMC2=sqrt(1-exp((-2*(HXY2-ENT))));
```

```
ENT;
IMC1;
IMC2;
```

- Feature 10: Difference Variance

```
function DIFV=difv(coc,ng)


Ng=ng;
m=0;
m2=0;

px_y=zeros(Ng,1);

for i=1:Ng;
    for j=1:Ng;
        px_y(abs(i-j)+1)=px_y(abs(i-j)+1)+coc(i,j);
    end
end

for k=1:Ng;
    m=m+(k-1)*px_y(k);
    m2=m2+(k-1)*(k-1)*px_y(k);
end


DIFV=m2-m*m;
```

- Feature 11: Difference Entropy

```
function DIFE=dife(coc,ng)


Ng=ng;
DIFE=0;


px_y=zeros(Ng,1);

for i=1:Ng;
    for j=1:Ng;
        px_y(abs(i-j)+1)=px_y(abs(i-j)+1)+coc(i,j);
    end
end


for k=1:Ng;
    if(px_y(k)==0)
    else
        DIFE=DIFE-px_y(k)*log(px_y(k));
    end
end


DIFE;
```

- Feature 14: Maximal Correlation Coefficient

```
function MCC=mcc(coc,ng)


Ng=ng;

px=zeros(Ng,1);
for j=1:Ng
    px=px+coc(:,j);
end

py=zeros(1,Ng);
for i=1:Ng
```

```
    py=py+coc(i,:);
end

Q=zeros(Ng,Ng);

for i=1:Ng
    for j=1:Ng
        for k=1:Ng
            if(px(i)*py(k)==0)
            else
                Q(i,j)=Q(i,j)+coc(i,k)*coc(k,j)/(px(i)*py(k));
            end
        end
    end
end

L=eig(Q);
[C I]=max(L);
L(I)=L(I)-C;

MCC2=max(L);

MCC=sqrt(MCC2);


MCC;
```

3. Supplementary Codes

- Gray-Level Co-Occurrence Matrix

```
function coc=cooc(Im,angle,Ng,normalize)



[M N]=size(Im);

coc=zeros(Ng,Ng);

for k=1:M
    for l=1:N
        if(angle==0)
            if(l+1>N)
            else
            a=Im(k,l);
            b=Im(k,l+1);
            coc(a,b)=coc(a,b)+1;
            end
        elseif(angle==45)
            if((l+1>N) || (k-1<1))
            else
            a=Im(k,l);
            b=Im(k-1,l+1);
            coc(a,b)=coc(a,b)+1;
            end
        elseif(angle==90)
            if(k-1<1)
            else
            a=Im(k,l);
            b=Im(k-1,l);
            coc(a,b)=coc(a,b)+1;
            end
        elseif(angle==135)
            if((k-1<1) || (l-1<1))
            else
            a=Im(k,l);
            b=Im(k-1,l-1);
            coc(a,b)=coc(a,b)+1;
            end
        end
```

```
    end
end

coc=coc+coc';




if(normalize)
    coc=coc/sum(sum(coc));
end

coc;
```

- Plotter for plotting the results

```
function plotter(R)

for i=1:14;
    figure;
    plot(R(:,i),'.');
    title(['feature ',num2str(i),' -Average of 0,45,90,135 degrees']);
end
end
```

- Gray level converter and defines the number of gray levels

```
function I=imgray(ImColor,Ng,quantize)
ImGray=rgb2gray(ImColor);
% figure
% imshow(ImGray);

if(quantize==1)
    ImGray2=double(ImGray)/max(max(double(ImGray)));
    ImGrayQ=uint8(round(ImGray2*(Ng-1))+1);
%     figure
%     imshow(ImGrayQ);
    I=ImGrayQ;
else
    Ng=256;
    I=ImGray;
end
```