Algorithm to determine the scenic beauty of images

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Abstract

The United States Forestry Service (USFS) wishes to determine the scenic quality of the images to preserve recreation and aesthetic resources in forest management. They want to determine a predefined pattern to cut the trees so as to still retain the scenic beauty even after cutting the forest by timber loggers. The scenic beauty will be determined on a scale from “0” to “1”. We have in our database 679 unique PPM images of different vegetations taken during all the seasons of the year. Each of the image is of 4.7 Mb. We have the subjective ratings available for all the images. These ratings are taken by showing each of the images to different groups of people and then converting them to a standardized scores by using Scenic Beauty Rating. We attempt to develop a systematic approach to determine the scenic quality and correlate them to the subjective ratings available. Some of the parameters to be considered are color, size of the trees etc. The effect of the color can be determined by doing histogram analysis of the image. The effect of the size of the trees can be studied by doing edge detection and computing the number of vertical lines in the image. Forest scenery that is undisturbed and having variety of natural features is preferred while scenery which obstructs the view of the forest with lot of foliage and bushes is not considered as scenic.and images which doesn’t obstruct the view are preferred as compared to the ones with more foliage and bushes. The evaluation is performed by running the program through the images in the database.

1. Introduction

We attempted to develop an algorithm to determine the scenic quality of the image on a scale from “0” to “1”. The importance of forest recreation and landscape scenic quality is being recognized and thus efforts are made to preserve the scenic quality of the image.The statistical models suggest that the density and sawtimber-sized trees and the proportion and visual penetration are positively associated with scenic beauty while foliage, twig, small stem screening and the density of small-diameters tree are negatively associated with scenic beauty. Histogram analysis and edge detection methods were used to analyses the parameters such as color and the size of the trees in the image. The results from the subjective ratings showed that scenic beauty increases with the level of the hardwood retention and the summer, fall and spring views were preferred over those taken during winter. Effort was made to correlate the output of the algorithm with the subjective ratings. We have the database with 679 unique images. The database has the scenic beauty rating for each of the image. Scenic beauty rating is a scaling procedure used to correlate the ratings from different groups of sessions. Baseline slides are used as reference for all the rating sessions.

2.PPM Images

The images given by the forestry department were in Kodak PhotoCD(PCD) format. The PCD format is a proprietary format and it could not be viewed with the imagetools available hence it was required to convert it into more familiar formats such as gif or ppm.We chose PPM format for this purpose. The PCD images were converted into PPM format through public domain software "hpcdtoppm" available in the net. This software tool is used to convert pcd files to ppm files. hpcdtoppm stands for "Hadmuts pcd to ppm" The software is available at the URL "*http://www.boutell.com/lsm/lsmbyid.cgi/000746*". This software also needs some netpbm utilities which are also available as public domain utilities. The netpbm utilities can be downloaded from the ftp site at "*ftp://ftp.cs.ubc.ca/ftp/archive/netpbm/*".Various resolutions of the ppm files can be obtained. Basically Base/16, Base/4, Base,4Base and 16 Base are available. We have taken the 4 Base option for our requirement.Any of the resolution can be obtained by adjusting the options while executing the "hpcdtoppm" software. The resolution of each of these options is given below.

1. Base/16, size 128 x 192 pixels

2. Base/4, size 256 x 384 pixels

3. Base, size 512 x 768 pixels

4. 4 Base, size 1024 x 1536 pixels

5. 16 Base, size 2048 x 3072 pixels

The format of the PPM images is described below:

- A "magic number" for identifying the file type. A PPM file magic number is the character string *P6*. It should be the first line of the PPM file.
- Whitespace characters such as blanks, TABs, carriage returns (CR), line feeds (LF) etc.
- The image width in number of pixels, formatted as ASCII characters in decimal.
- Whitespace characters.
- The height again in number of pixels, formatted as ASCII characters in decimal.
- Whitespace characters.
- The maximum color value which each of the colors in the pixels can have. This value is again in ASCII decimal. The maximum value which it can have is 255.
- Whitespace characters.
- Width x height pixels, each three ASCII decimal values having value between 0 and the specified maximum color value which it can take, starting at the top-left corner pixmap, proceeding in normal English reading order. The three values for each pixel represent red, green, and blue, respectively. A value of 0 means that the color is off, and the maximum value means that the color is at saturation level.
- Comments are also allowed in the

ppm file and they are indicated by the character “#”. Any line starting with the character “#” to the next end-of-line are ignored.

- There is also a restriction that the line should not be longer than 70 characters.

Various resolutions of the ppm files can be obtained. Basically Base/16, Base/4, Base, 4Base and 16 Base are available. We have taken the 4 Base option for our requirement. The resolution of each of these options is given below.

1. Base/16, size 128 x 192 pixels

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5. 16 Base, size 2048 x 3072 pixels

Any of the resolution can be obtained by adjusting the options while executing the hpcdtoppm software.

3. Histogram Analysis

Color is one of the noticeable features of a forest environment. It is affected by the temporal rhythm of seasons. Color variation by season is one of the most notable changes in forest vegetation. Summer, Fall and Spring views are judged as significantly more scenic than winter views. The preference is related to seasonal color patterns.As human preferences vary with color change, change of season is an important factor in determining the quality of an image.

Our approach was to extract the mean of each of the color in the image. Color has a major effect in determining the scenic quality of the image. The variation of seasons changes the colors in the image. It was observed from the subjective ratings that summer and spring are preferred over winter. This is based on the fact that people prefer green and blue color as compared to red and yellow which comes from the inclination of the people towards natural colors.

Each pixel in PPM is represented by three bytes one byte for each of the color of red. green and blue. Algorithm was developed to compute the mean of each of the three fundamental colors in the image and to correlate the mean of the colors to the scenic beauty of the image. For constructing the histogram the image is scanned in a single pass and a running count of the number of pixels found at each intensity value is kept. Some of the factors of the image like the naturalness of the image can be determined from the color as color is an aid in distinguishing between what is “natural” and what is “built in”. In particular, a natural setting’s continuous gradation in color is often very different from the sharper contrasts that are found in the built-in environment. Graph is drawn for the variation of the number of pixels for each value of the color from “0” to the maximum value of color in the image.

4. Edge Detection Overview

Edge detection is an important part in image analysis. Edges characterize object boundaries and are therefore useful for segmentation and identification of objects in scenes. Edge is defined as the boundary between two regions with relatively distinct gray-level discontinuity and the abrupt transition between two regions can be determined on the basis of gray-level discontinuity. The magnitude of the first derivative is used to detect the presence of an edge and the direction of the edge is determined by the sign of the derivative. Thus the two important properties for establishing similarity of edge pixels are the strength and the response of the gradient operator used to produce the edge pixel and the direction of the gradient.

Our approach was to extract the number of long trees in the image. We believed that computing the number of vertical lines in the image would indicate the presence of the long trees and also the approximate length of the tree. We used the algorithm of canny-edge detector to compute edge detection.

The input to the canny edge detector is a PGM image hence we converted the PPM image to PGM image. The header of the PGM image is similar to the PPM file except for the magic number which is “P5” and there are width x height pixels each of 8 bytes representing the gray value. Edge detection was done to properly detect the edges and then thresholding them through a thresholding tracker to obtain both the horizontal and vertical lines. Algorithm was written to calculate the number of vertical lines after edge detection. By this way both the smaller as well as longer vertical lines are obtained. Hence to get the number of longer lines a threshold was considered to eliminate the shorter lines which correspond to foliage or small bushes in the image.

4.1 Conversion of PPM image to PGM image

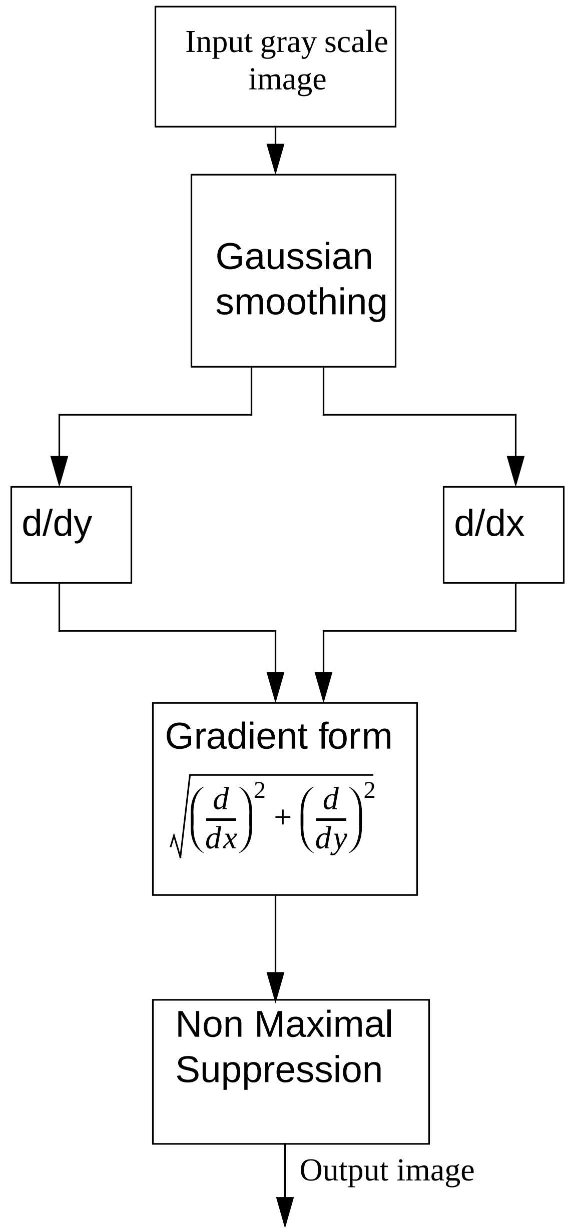
The first step of edge detection was to convert the PPM color image to the gray scale PGM image. This was done by applying the following matrix to each of the pixel of the PPM image.

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.523 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (22)$$

The “Y” value in the above matrix represents the “luminance” or brightness of each pixel. The “RGB” represents the red, green and blue intensity of each pixel for the PPM image. Each pixel in the PPM file is read converted it into a gray scale value using the above relation and was written into the PGM file.

4.2 Doing edge detection

The canny-edge detector was used to perform the edge detection on the gray scale image. It first applies the masks in the horizontal and the vertical direction to retrieve the horizontal and vertical edges. These edges are then connected together to obtain the horizontal and vertical lines. A threshold value is used both for the magnitude and the orientation to detect an edge. The image after the edge detection contains only two color levels. The block diagram of the edge detection is shown below. Two masks which can



be used for the detection of edges in the horizontal and vertical direction are shown below. The mask matrix as well as the image matrix ar given

$$\begin{bmatrix} I1 & I2 & I3 \\ I4 & I5 & I6 \\ I7 & I8 & I9 \end{bmatrix} \qquad \begin{bmatrix} W1 & W2 & W3 \\ W4 & W5 & W6 \\ W7 & W8 & W9 \end{bmatrix}$$

Where I is the image matrix and W is the mask matrix. The responses in the x and y direction can be obtained by applying the respective matrix. The mask matrix for the response in the x direction is given by the matrix [1] and the mask matrix for the response in the y direction is given by the matrix [2]. Gx and Gy, the gradients in the respective directions are calculated by the formulas shown below and the resultant gradient can be computed by the relation $\sqrt{G_x^{\ 2} + G_y^{\ 2}}$. The mask for calculating G_x is given by

$$\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \qquad [1]$$

and the mask for calculating G_y is given by

$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

The G_x and G_y are given by the equations:

$$G_x = (W_7 + 2W_8 + W_9) + (W_1 + 2W_2 + W_3$$

$$G_y = (W_3 + 2W_6 + W_9) + (W_1 + 2W_4 + W_7$$

The angle gradient is given by the relation $\alpha(x, y) = tan^{-1}\left(\frac{G_x}{G_y}\right)$. The masks are moved through the entire image and the gradient for magnitude and orientation are obtained. We experimented the algorithm with various threshold values and it has been found to give a good edge detection at a threshold value of 120 for the orientation.

5. Vertical lines

The output of the canny edge detection algorithm is a combination of vertical as well as horizontal lines smoothened representing line segments. Algorithm was developed to compute the number of vertical lines. The total number of the vertical lines and the length of each of the line was computed. As the length of the lines is directly proportional to the length of the trees in the image they are useful in determining the number of tall trees and the short bushes.

Apparently tall trees have a positive effect on the scenic quality whereas the small bushes have negative effect. In calculating the length of the vertical lines care was taken of the deviation of the tree from the vertical by considering certain amount of deviation in the horizontal direction also. Also there might be a discontinuity in the length of the tree due to the presence of some obstacle before it. Care was taken for this also by giving a tolerance limit of about 5 pixels in the vertical direction.

6. Computing the scenic beauty

We had to obtain a relation for the scenic beauty from the analysis of the histogram and the edge detection. This has to be done so as to correlate the scenic beauty with the actual mean value of the rating available from the forestry department. The mean of each of the color in the image was obtained from the histogram analysis and the number of vertical lines in the image was obtained from the edge detection.

The mean of each of the color has been normalized inorder to get an exact percentage of the color in each of the image. The percentage of the long lines as well as the percentage of the short lines in relation to the total number of lines were computed. The facts that green color and tall trees has a positive impact on the scenic beauty and the red color and the short bushes has a negative impact on the scenic beauty is used for computing the weights of different parameters to be used for determining the scenic beauty.

7. Evaluation

The relation which we have developed by observing the dependency of the various parameters on the actual scenic rating was used for evaluating the scenic beauty on some other images in the database.We have taken about 20 images from the database and tried to adjust the weights of various parameters. After deriving a relation we implemented the relation on another 30 images. Though there was deviation from the actual scenic value they seem to be varying with the same proportion for all the images. We evaluated the program on plots 1 and 3 of block 1. We provide the results for all the images in plot 3 and some images in plot 1.

8. Database

An important aspect is the availability of extensive well organized database of the forestry images. These images are the pictures taken of the Ouachita forest in the Winona range. We have in our database 680 unique images. These are the images taken of four blocks in the range with each block having five plots. Each of the image is taken during all the seasons of the year and also with different angles so as to see the effect of the season.

There are also subjective scenic beauty ratings available for each of the images. These subjective ratings were obtained by showing the images to people from different walks of life and asking them to rate the images on a scale from 1 to 10. “1” indicating less scenic and “10” indicating the most scenic image. These scores are then converted into standard ratings using Scenic Beauty Rating technique.

Rating scales offer an efficient and widely used means of recording judgements about many kinds of images. Scenic Beauty Estimation(SBE) is one of the scaling procedure used. The main reason for the scaling procedures are that people will use the rating scale differently from one to another in the process of recording their perceptions of the images presented for assessment.

Scaling procedures are effective for adjusting some of these differences. All the information regarding the images such as the block number, plot number, SBE rating, angle and the time at which it is taken is included in the ppm file as comments. There are 4 blocks and 5 plots per block.The distribution of the plots in the blocks and the number of images is given in the following tables.

Directory b01 (block 1)	
Sub Directory	Number of Images
p001	32
p002	32
poo3	40
p004	39
p020	32

Directory b02 (block 2)	
Sub Directory	Number of Images
p005	40
p006	32
p007	32
p008	32
p019	32

Directory b03 (block 3)	
Sub Directory	Number of Images
p009	32
p010	32
p011	32
p012	32
p018	40

Directory b04 (block 4)	
Sub Directory	Number of Images
p013	32
p014	32
p015	40
p016	32
p017	32

There are 32 images of each plot. This relation comes as there are 4 angles per plot and the picture is taken 4 times in a year, we have 16 images of the same plot per year. As in the database we have the images for 2 years there are 32 images for each plot. Some of the plots have 40 images. These additional images are the baseline slides which are used as reference.

9. Results

This section contains charts and graphs of the various programs run on the images. For convenience sake we are including only the images from plots 3 and 1 in the website. The mean values of the color provided in the following chart are given in the same order as the images in the corresponding plots. We have taken the readings for 32 images from the plot 1 and the first ten images in the plot 3. Since the image names are long we have not included them here.We will just indicate them by numbers.

Number of the image	Red mean	Green mean	Blue mean
1	55	62	30
2	83	85	69
3	45	65	36
4	85	97	75
5	33	49	16
6	37	52	24
7	52	57	29
8	80	84	70
9	37	54	31
10	81	91	63
11	27	30	15
12	78	91	69
13	52	62	23
14	32	40	15
15	64	77	36
16	66	72	54
17	46	52	27
18	55	61	59
19	38	53	17
20	29	43	16
21	47	56	20
22	43	52	22
23	59	69	30
24	56	62	51
25	75	82	40

Number of the image	Red mean	Green mean	Blue mean
26	69	73	59
27	70	84	49
28	94	105	75
29	64	73	33
30	64	72	60
31	67	83	49
32	96	108	78
33	58	65	32
34	64	68	56
35	57	72	44
36	97	108	84
37	42	52	21
38	43	50	22
39	71	79	43
40	58	62	51
41	66	72	36
42	85	79	63
42	46	62	36
43	87	99	66
44	45	57	18
45	41	53	19
46	71	79	33
47	87	83	66
48	89	84	69
49	57	64	33

Number of the image	percent of long lines	percent of short lines
1	2.51	70.34
2	0.94	80.56
3	3.45	68.45
4	2.47	76.10
5	1.19	90.41
6	3.24	73.89
7	5.42	64.88
8	2.04	79.84
9	3.72	67.64
10	1.56	76.14
11	3.98	66.77
12	3.47	69.21
13	.0.88	82.04
14	2.12	74.21
15	2.95	68.72
16	3.08	72.24
17	3.75	70.34
18	0.84	81.12
19	0.52	83.30
20	2.10	74.34
21	2.70	78.88
22	2.21	72.02
23	2.51	71.13
24	4.99	68.42
25	4.30	66.81

Number of the image	percent of long lines	percent of short lines
26	2.78	78.39
27	4.43	67.57
28	2.17	71.71
29	2.50	74.30
30	3.56	69.98
31	4.36	65.62
32	2.29	73.66
33	2.95	70.72
34	1.41	77.89
35	3.31	68.18
36	2.67	73.08
37	1.97	77.13
38	2.45	72.03
39	2.46	72.57
40	2.03	77.37
41	2.74	72.93
42	2.34	74.79
43	3.05	70.30
44	1.10	77.98
45	1.42	77.13
46	2.57	69.58
47	2.69	68.00
48	2.28	75.70
49	3.24	71.04
50	1.96	76.23

Number of the image	Derived SBE	Actual SBE(mean)
1	0.42	4.68
2	0.33	4.64
3	0.50	6.59
4	0.37	4.27
5	0.56	7.25
6	0.51	7.58
7	0.40	4.15
8	0.33	3.94
9	0.49	6.35
10	0.38	7.21
11	0.41	4.58
12	0.33	3.76
13	0.46	6.41
14	0.48	6.00
15	0.45	5.19
16	0.36	4.81
17	0.41	3.22
18	0.33	2.63
19	0.54	6.17
20	0.55	6.73
21	0.46	6.95
22	0.46	6.38
23	0.44	5.49
24	0.35	6.02
25	0.41	4.47

Number of the image	Derived SBE	Actual SBE(mean)
26	0.34	4.15
27	0.43	4.75
28	0.38	4.13
29	0.43	5.72
30	0.36	5.00
31	0.44	5.00
32	0.38	4.41
33	0.42	5.25
34	0.34	4.15
35	0.44	5.74
36	0.36	5.24
37	0.47	6.65
38	0.44	6.61
39	0.40	5.85
40	0.34	6.04
41	0.47	4.37
42	0.35	4.47
43	0.54	4.80
44	0.46	4.65
45	0.57	6.09
46	0.57	5.94
47	0.50	4.76
48	0.36	3.60
49	0.50	5.16
50	0.48	5.05

The plots for the first five of the images in the table are given below. The first plot is the histogram plot which shows the number of pixels present in the image of each value of the color from zero to the maximum value of color in the image. The other plot shows the number of lines for each length of the line. The length of the line is on the X-axis and the number of lines with such length is on the Y-axis.

10. Future Work

10.1 Evaluating Scenic Beauty

The evaluation of scenic beauty has been done by only observing the various parameters computed and figuring out a relation between the actual scenic beauty and these parameters. The parameters are the mean value of the colors and the percentage of the vertical lines in the image. A better and efficient method would be to use the neural network as decision box. The parameters should be given as the input and the neural network should be trained with a fair amount of database to output the actual scenic beauty. It can then be used to test on the remaining images.

Also some other parameters like texture of the ground and frequency characteristics can be used to determine the scenic beauty. The effect of these parameters can be determined using various image analysis methods and their effect on the scenic beauty should be evaluated.The determination of more parameters helps in the effective determination of the scenic beauty and a better correlation to the actual scenic value.

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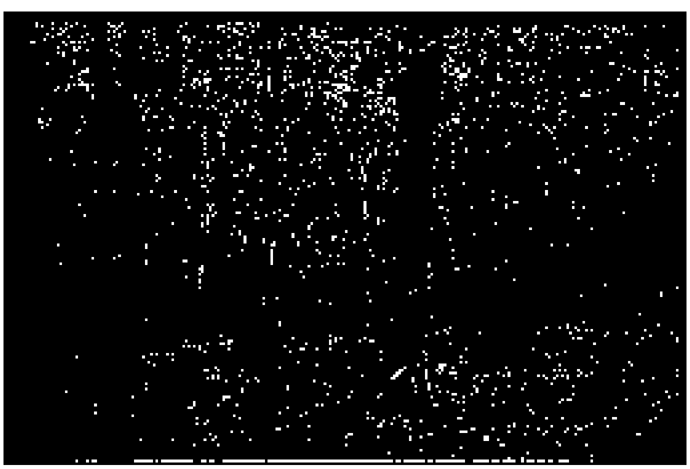
Appendix A: Images Tested:

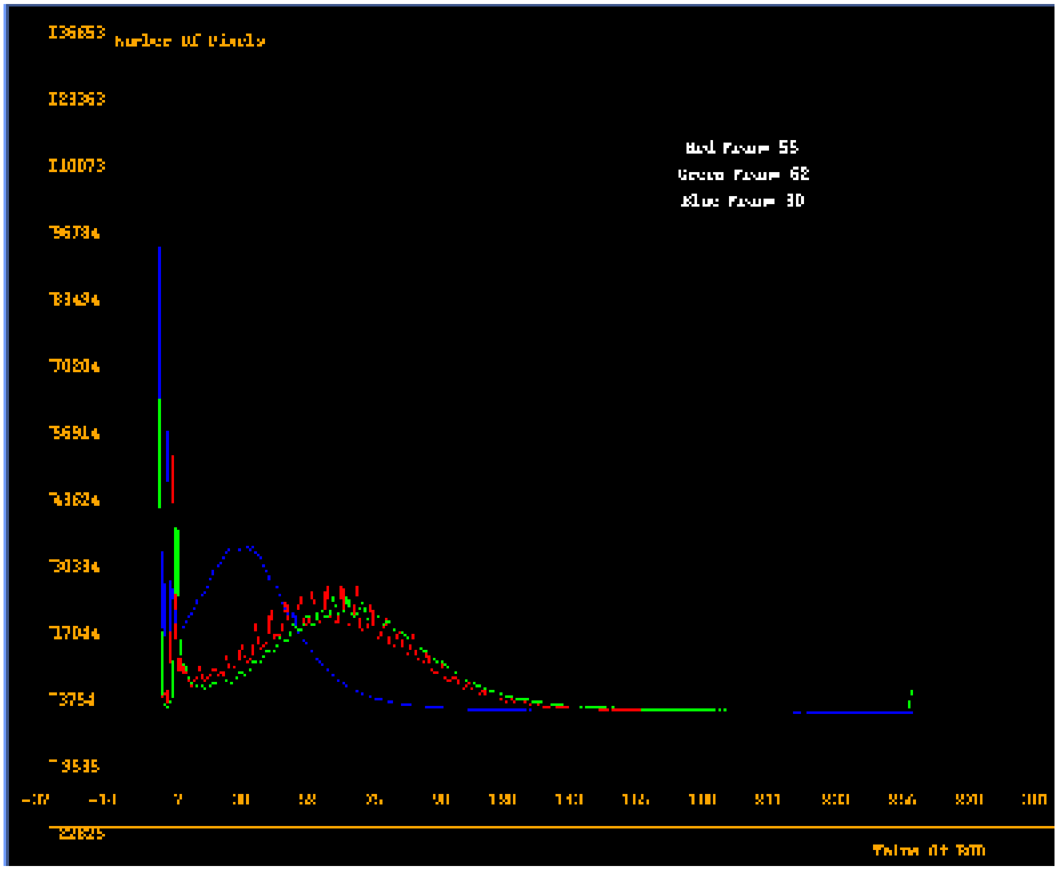
Red mean = 55
Green mean = 62
Blue mean = 30
% long lines = 2.51
% short lines = 70.34
SBE = 0.42

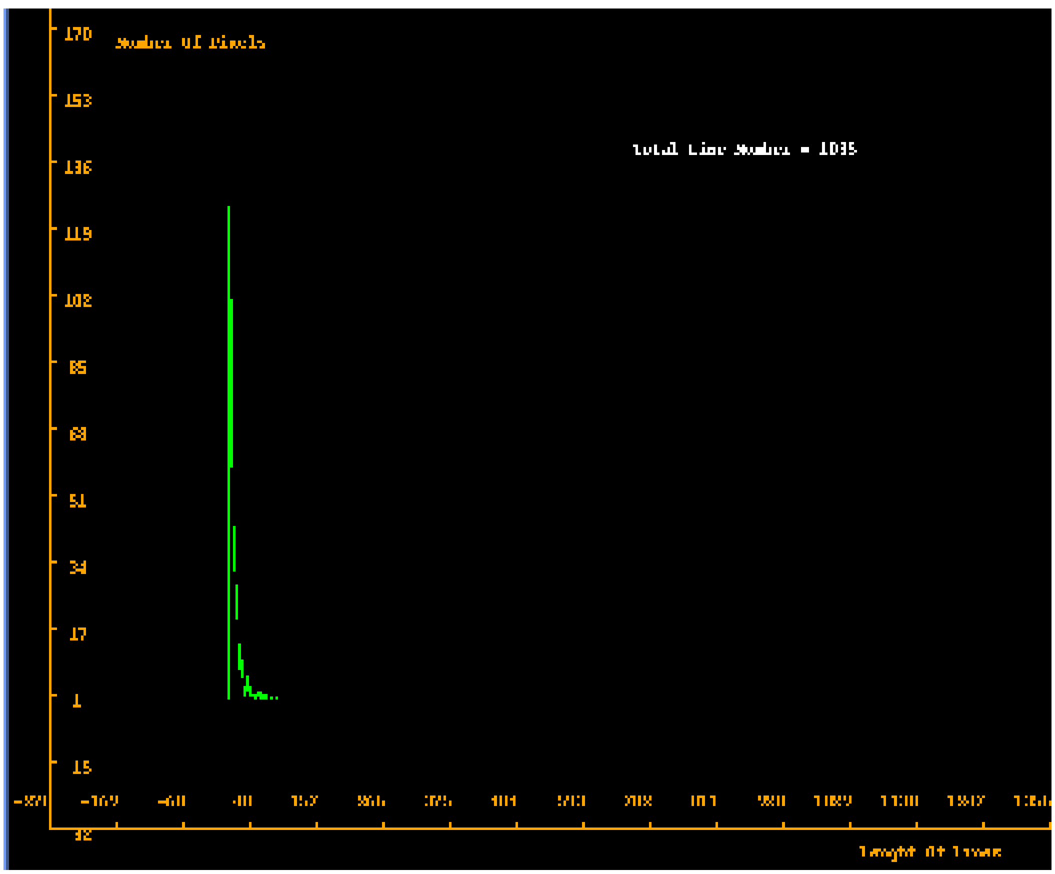
Gray scale image



Edge detected image

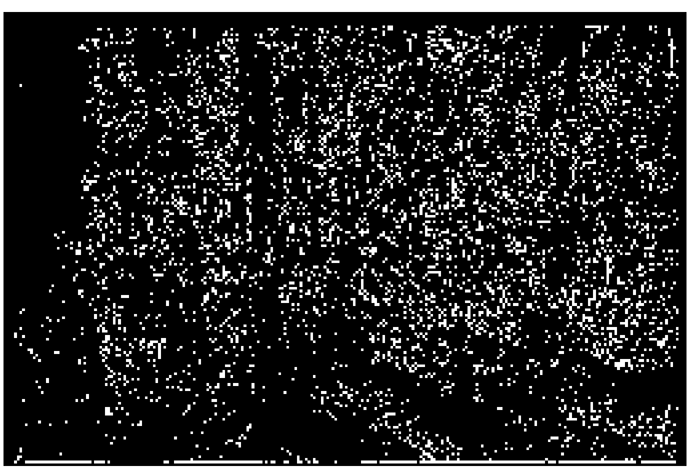
Plots showing the number of pixels of each color and the number of vertical lines





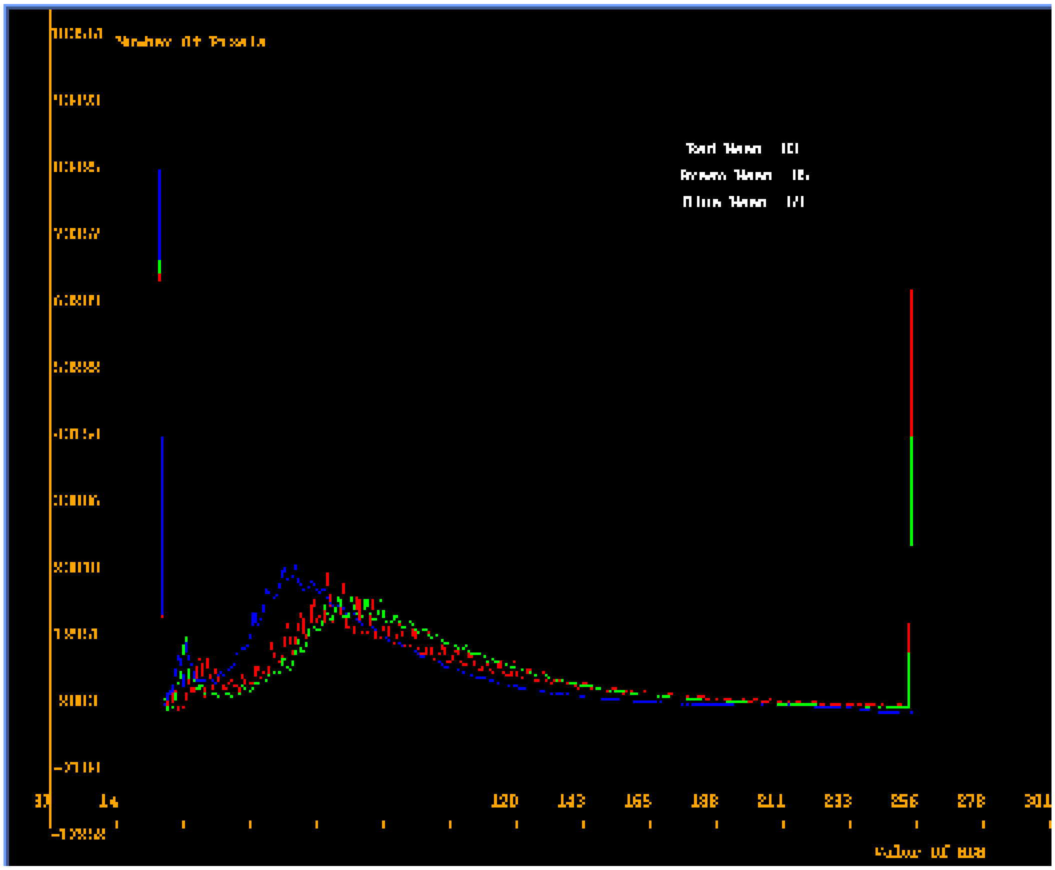
Red mean = 83
Green mean = 85
Blue mean = 69
% long lines = 0.94
% short lines = 80.56
SBE = 0.33

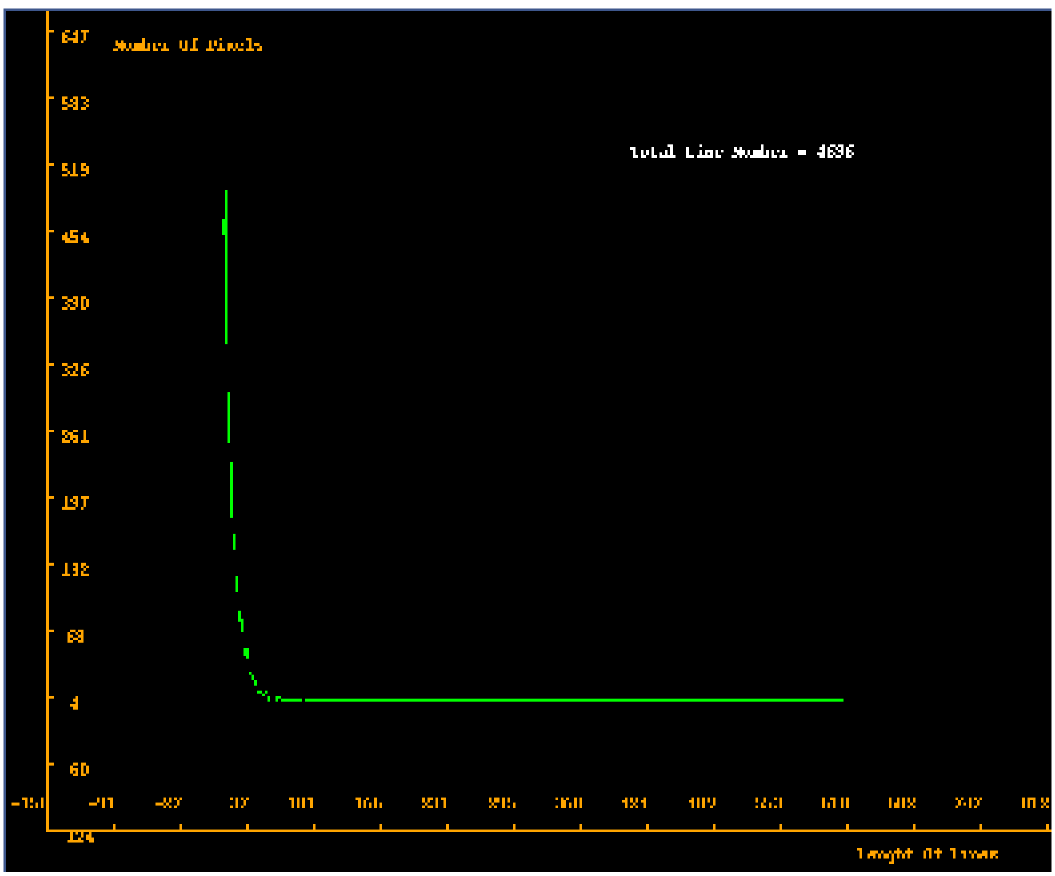
Gray scale image



Edge detected image

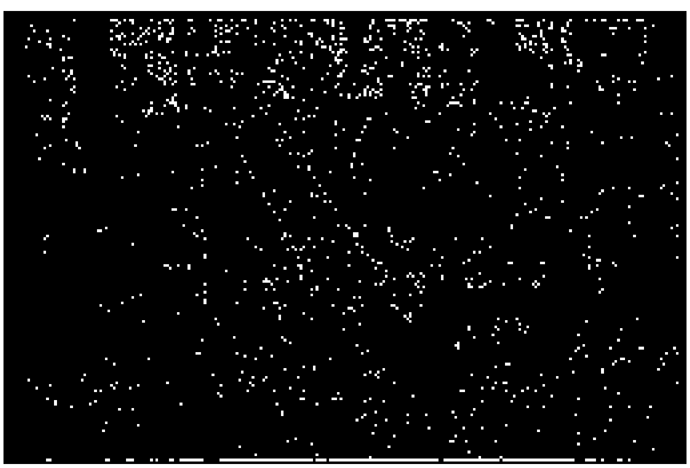
Plots showing the number of pixels of each color and the number of vertical lines





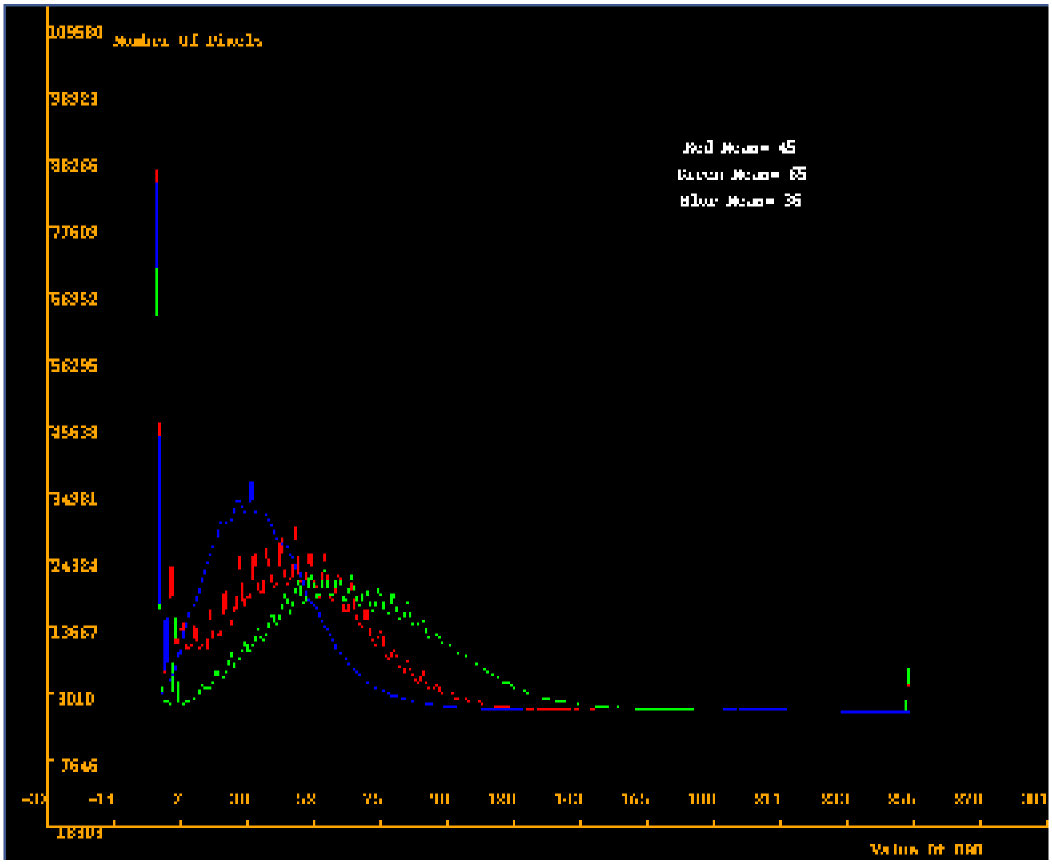
Red mean = 45
Green mean = 65
Blue mean = 36
% long lines = 3.45
% short lines = 68.45
SBE = 0.50

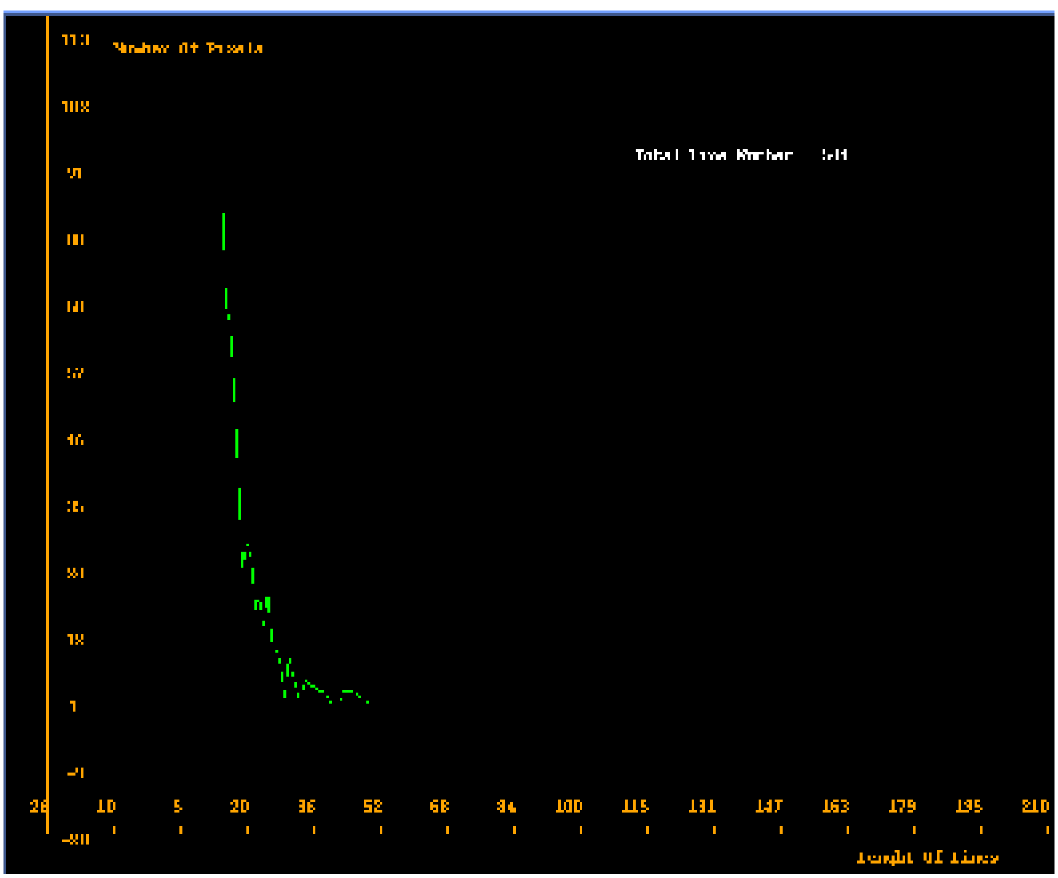
Gray scale image



Edge detected image

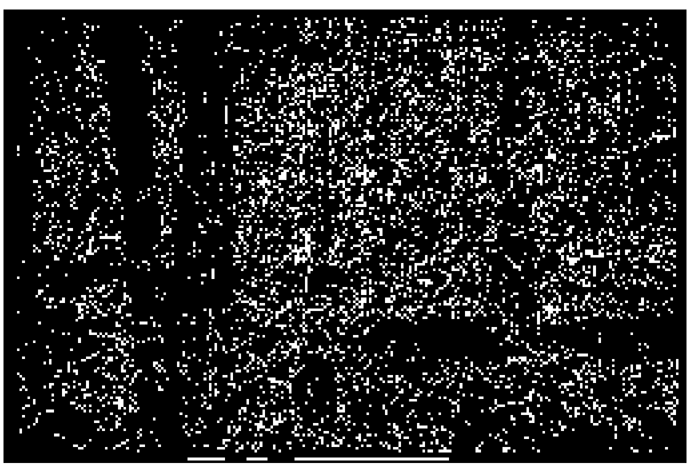
Plots showing the number of pixels of each color and the number of vertical lines





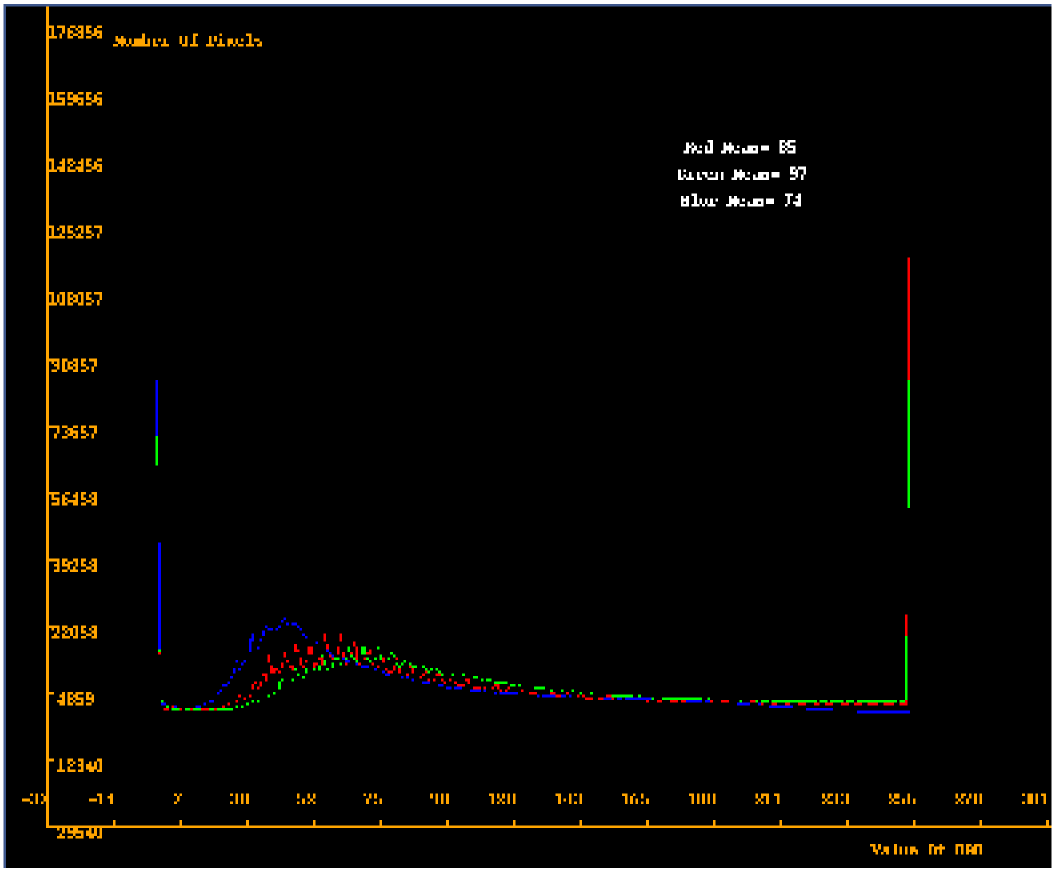
Red mean = 85
Green mean = 97
Blue mean = 16
% long lines = 2.47
% short lines = 76.10
SBE = 0.37

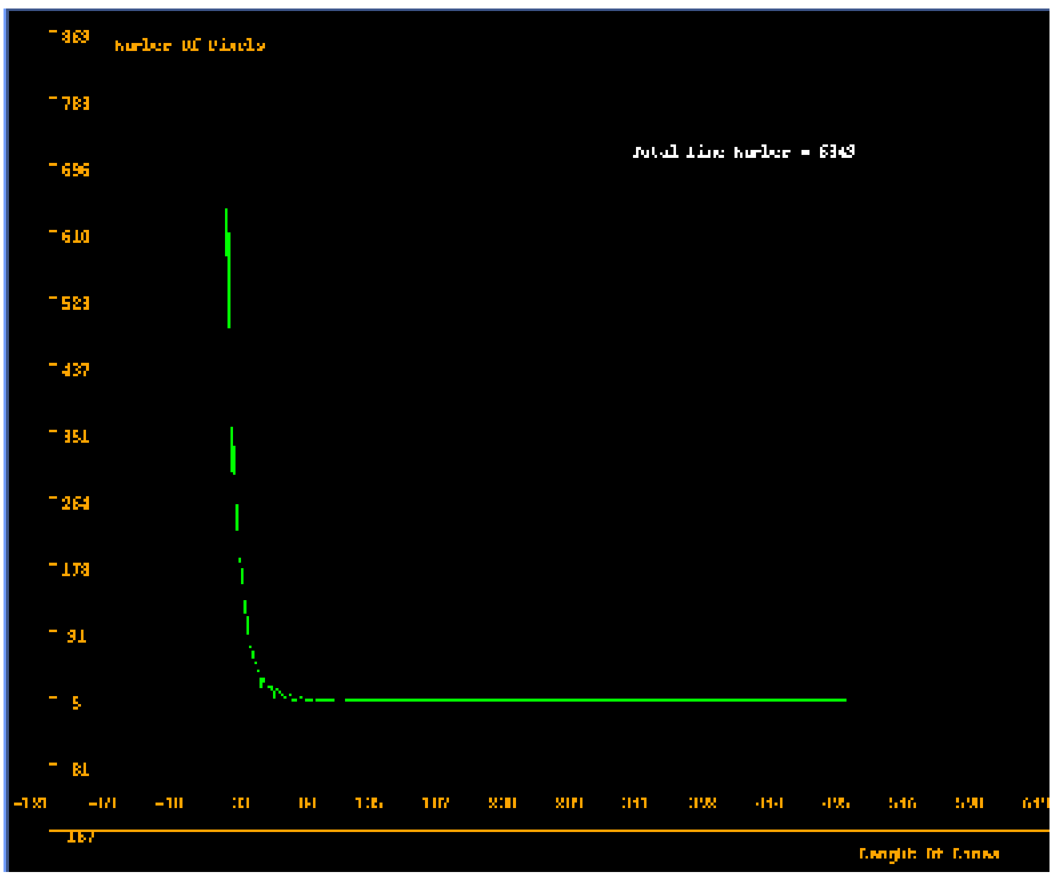
Gray scale image



Edge detected image

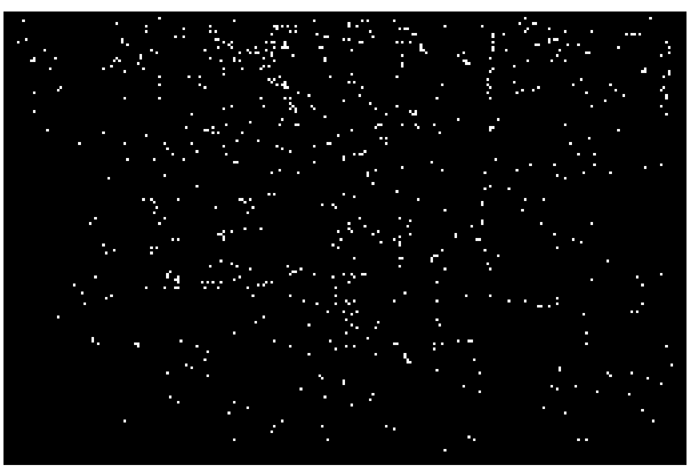
Plots showing the number of pixels of each color and the number of vertical lines





Red mean = 37
Green mean = 52
Blue mean = 24
% long lines = 3.24
% short lines = 73.89
SBE = 0.56

Gray scale image



Edge detected image

plots showing the number of pixels of each color and the number of vertical lines