Abstract

The purpose of this experiment was to test the effect of random noise in an image on the effectiveness of an edge detection algorithm. The hypothesis stated that if the amount of noise increases, the effectiveness of the algorithm will decrease because it will not be able to detect the true edges due to the reduced image contrast, which is reflected in the reduced variation in the contrast derivative. The edge detection algorithm was implemented using the Java programming language in the Eclipse development environment. The main procedures in the edge detection algorithm use loops, lists, derivatives, signal to noise ratio and other simple math functions. The data collected in the experiment was taken from calculating the signal to noise ratio after noise was added and the guessed edges were detected. An ANOVA test showed that each experimental group was significantly different. The means of effectiveness for each percent noise were found and graphed to clearly support the hypothesis and explain how the effectiveness of the edge detection algorithm decreased as the noise increased.

Introduction

Image processing is the manipulation and analysis of digital images by means of image blurring, image enhancement, color inversion, image filtering, image distortion, edge detection and many more methods (Day, 1998). Edge detection is a process that identifies boundaries in a digital image by detecting the change in brightness; enabling a computer to detect shapes and patterns used in shape recognition. The human mind is capable of differentiating shapes by drawing inferences about distance, direction, volume, and area consequently allowing humans to be able to “guess” the shape by summarizing the information in which they observe. Computers, on the other hand, have to be programmed to be able to “see” the way a human can. Shape recognition is used for games, biomedical and investigative applications, art and design software, and robotics. It is found on radar systems, surveillance and forensics, and is used to create robots more human-like (Levine, 1985). Image processing is implemented in machine vision, which is a process by which a computer-driven device optically senses external objects. From the analysis of the sensed data, the device infers information about objects it senses or “sees”. The device is usually a type of camera connected to a computer that digitizes the images and then analyzes them. Machine vision is used for small tasks such as checking size and shape for automobiles, x-rays, photographs, chromosome slides, and cancer smears ("Machine Vision", 1991).

For this project, an image is imported and processed through a computer. The computer uses image processing, manipulating data in the form of an image, in order for the computer to “read” or interpret the image. An image is usually interpreted as a two-dimensional array of numbers, which resemble the image’s brightness values. Each point, or pixel, has a number according to the color that is shows. A pixel is a number that represents the brightness value of the image at a particular location.

1	0	1	0	0	0	0	1	0	0	
0	0	67	151	227	225	155	60	1	0	This shows the color values of a circle in matrix form
1	67	206	252	253	256	249	209	63	1	
0	151	252	256	252	256	256	254	154	0	
0	227	253	252	256	256	254	254	222	1	
0	225	256	256	256	254	256	256	224	0	
0	155	249	256	254	256	254	256	153	0	
1	60	209	254	254	256	256	203	64	0	
0	1	63	154	222	224	153	64	0	0	
0	0	1	0	1	0	0	0	0	0	

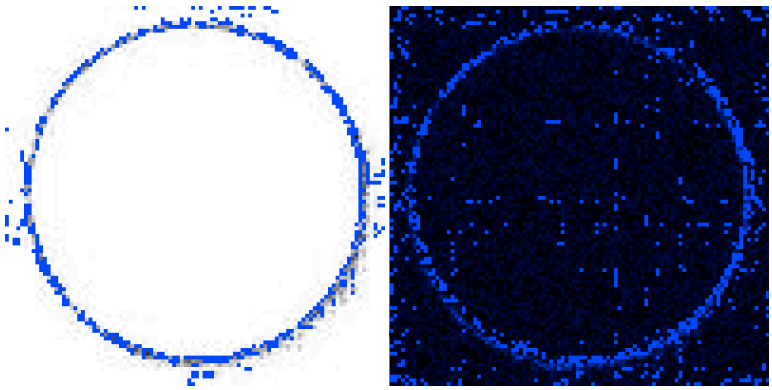
11	27	29	0	23	17	5	20	13	27	
1	24	76	154	214	227	140	54	13	19	This shows the color values of a circle in matrix form with noise added
12	55	231	231	230	244	233	213	66	7	
10	144	233	251	242	240	247	241	148	16	
7	210	232	229	244	244	250	233	196	28	
9	196	253	242	249	224	228	252	218	2	
7	156	222	240	240	254	230	230	134	17	
21	38	231	223	242	231	238	228	72	0	
19	10	84	134	235	211	133	42	15	11	
15	22	31	22	5	1	29	18	23	29	

Another important aspect of this project is noise, which is the independent variable. Image noise is the random variation of brightness or color in images creating the image to look fuzzy and grainy. It affects pattern recognition by making it more difficult for the program to decipher the edges because of the random brightness values (McHugh, 2010). To create noise, a random number is generated from -1 to +1. This generated number is then multiplied by 256, which is the largest color value and represents the blackest black, because the color value should be between -256 and +256. This number is then multiplied by the desired percentage change and is added to the original value of the pixel (Smith, 2008).

For example:

Original color = 100
Random generated number = 0.5293719173
Noise Level = 25%

0.5293719173 x 256 = 135.519211
135.519211 x 0.25 = 33.8798028
100 + 33.8798028 = 133.8798028



The image on the left is an image of a circle that has its edge detected with no noise added. The image on the right is the same image of the circle with its edge detected and with noise added.

Edge detection is the process when a computer detects a change in brightness representing the edges in an image or of a particular shape. To detect edges in this experiment, derivatives are found to identify the edges. A derivative is the slope of a line that is tangent to a curve at a single point. The slope is calculated by taking two points close together on the curve and determining the slope of the line that passes through those two points. As the two points on the curve get very close together, the slope of the line becomes numerically equal to the derivative at a single point on the curve.“ To find all of these, a simple algorithm is written to scan the image horizontal and vertical finding the slope between every point that lay next to each other. To find the effectiveness of the algorithm, the signal to noise ratio is calculated. The signal to noise ratio (S/N ratio), a unitless ratio, is the contrast between the signal, which is what is being measured without variation, to the undesired signal known as the noise. More noise in the image results in a lower signal to noise ratio, correspondingly, less noise results in a higher signal to noise ratio (TopBits.com, 2010).

The purpose of this experiment was to test the effect of random noise in an image on the effectiveness of an edge detection algorithm. The independent variable was the noise level on the image; the dependent variable was the effectiveness of the algorithm. The effectiveness was

calculated by the signal to noise ratio. The hypothesis reads that if the amount of noise increases, the effectiveness of the algorithm will decrease because it will not be able to detect the shape due to the high and low derivative becoming closer.

Materials and Methods

The only thing needed for this experiment is a computer with a Java development system, in this case Eclipse. An edge detection algorithm, written on a MacBook Pro, was used in this experiment. Three shapes were chosen to be tested, a circle, square, and triangle, each 100x100 pixels; refer to Appendix A for the shapes. Different methods are used in the algorithm for the program to work properly. The main methods, which will be explained later on, include: loading the image, adding noise, detecting the edges, and evaluating the effectiveness. For more algorithm details refer to Appendix B. For each shape a percent noise was chosen, the effectiveness was shown and recorded, then repeated five times for each percent noise. The effectiveness values for each percent noise for each shape were then averaged and graphed.

Load Image

To load the image a string file is sent to a method that reads the file and displays the image. It then sends the image to save each color value in the form of a two dimensional matrix so it can be manipulated later.

Add Noise

Noise is added randomly in the image. The original color can either be increased, to be brighter, or decreased, to be darker. To add noise, a random number is calculated from 0 to 1. 0.5 is then subtracted from this number in order for it to be positive or negative. Then, it is multiplied by 256 to correct the range to all visible colors and multiplied by the desired percentage to find the value that should be added to the pixel. This number is added to the value

of a specified integer “color” which equals the original color at a specific point of the image.

Detect Edges

This method finds the edges of the image and turns those pixels light blue. To find the edges, it runs through the picture first horizontally and then vertically through each pixel finding the derivation of that pixel. To find the derivation, it grabs the pixels in one line of pixels and calls another method to find the derivatives. Two different methods were created for this. The “XDerivative”, which calculates the derivatives horizontally and the “YDerivative” which calculates the derivatives vertically. To find the derivative, the color value of the current pixel is subtracted by the last color value pixel. This number is then saved in the list “slope”. Each derivative value in the slope list is compared to the max multiplied by the “maxpercent”, which is .80. If the number is larger than the max times the “maxpercent”, then it is an edge. The coordinates that go with the derivative value are then added to a list called “edgepoints”

Evaluate Effectiveness

The second to last step is to find the effectiveness of the edge detection when a certain amount of noise is added. To find the effectiveness, the signal to noise ratio is calculated. To do this, the amount of edge pixels without noise, the signal, is divided by the current amount of edge pixels subtracted by the edge pixels without noise, the noise.

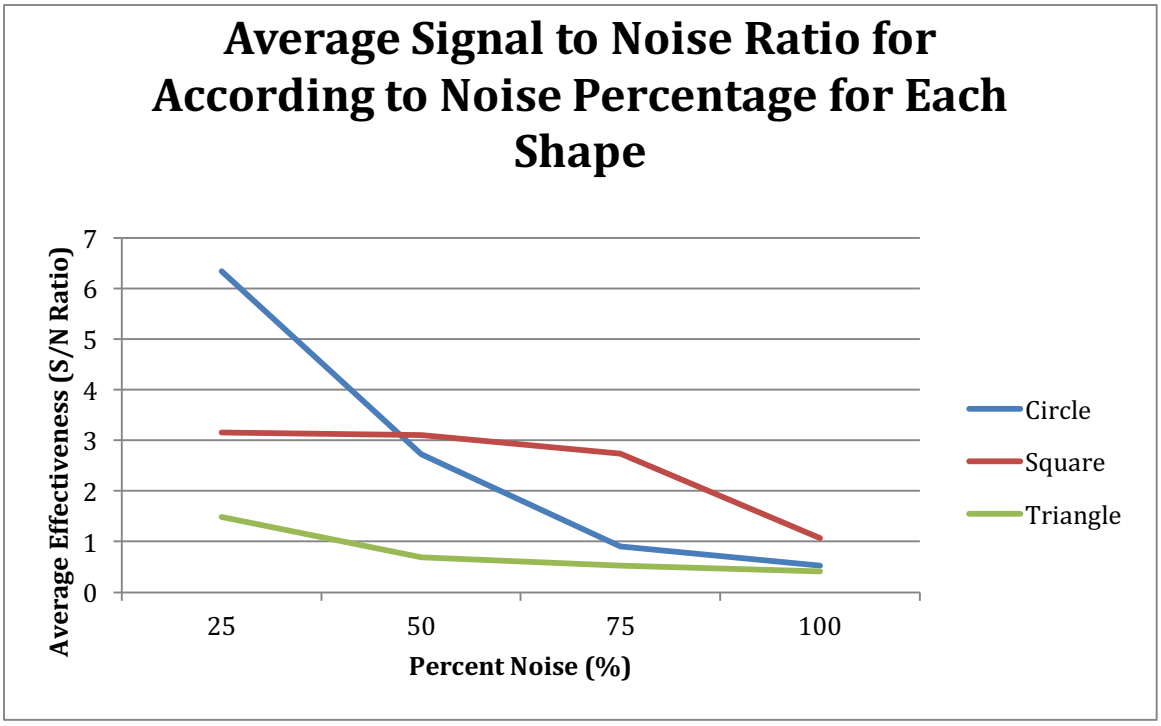
To keep the process clean and organized a window is set up for a user to choose a shape and a noise percentage (See Appendix I). The control for each shape will be the amount of edges the program finds with no noise added. Since the noise is random, it should change each time the program runs. The program will run 5 times for each shape for each noise level, finding its signal to noise ratio. These ratios are then averaged in each shape category to find the average signal to noise ratio for each shape in each noise percentage.

Results

Average Signal to Noise Ratio According to Noise Percentage for Each Shape

	0	25% Noise	50% Noise	75% Noise	100% Noise
Circle	∞	6.34267178207346	2.72700963433947	0.904223256522195	0.528796696429223
Square	∞	3.1594824636076	3.10534638439943	2.74022693757858	1.06926545770273
Triangle	∞	1.49150683382595	0.690224258668032	0.526968100010168	0.407327687803635

After five trials, the mean effectiveness was found for each noise percentage and shape to determine which noise percentage allowed the algorithm to work the best. Each shape at 0% noise had an effectiveness of infinity because there was no noise to make the signal offset.



The graph clearly shows the effectiveness of each noise percentage for each shape and how when more noise is added, the effectiveness decreases.

Summary of ANOVA Test Results for The Effect of Noise on Edge Detection Algorithm

Comparisons	Degrees of Freedom	Alpha Level of Significance	P Value	Significant or Not Significant
25% vs. 50% vs. 75% vs. 100%	3	.05	2.5459888 X 10^-6	Significant

The variability was shown significant from the ANOVA because the P value was much less than the alpha level.

Conclusion

The purpose of this experiment was to test the effect of noise on the effectiveness of an edge detection algorithm. The hypothesis was that if the amount of noise increases, then the effectiveness of the algorithm will decrease. With 3 degrees of freedom and a 0.5 alpha level of significance, the differences in the mean effectiveness of each experimental group were statistically significant as shown in the results from the ANOVA test. Each mean effectiveness value was less than the control and continued to decrease as more noise was added for each shape used. There was a larger difference in effectiveness for the circle, than there was for the square or triangle. With only 25% noise, the algorithm was most efficient on the circle, however with 100% noise, the circle and triangle had the least effectiveness. **The research data supported the hypothesis that as noise increased, the effectiveness of the algorithm decreased.**

An increase of the amount of noise affected the algorithm because it increased the noise value while the signal remained the same, so the s/n ratio decreased. With more noise in the image, the change of the color value caused the non-edge points and the edge points to be less differentiated, reducing the contrast so that edges were more difficult to detect. Each time the program ran, a random number was used for the noise at each pixel; these results were averaged over five trials for the estimated s/n ratio. The increase in noise percentage reduced the distinction between edge and non-edge pixels. Adding random noise obscures true edges, and creates false ones. This happens when the random noise between two points causes an increase in color in one point and a decrease in the next, so the algorithm interprets that variation as an edge.

Other researchers have found it difficult to find edges in images with a high noise level. To solve this problem, complex algorithms are created to find the edges more efficiently or to reduce the amount of noise. Additional studies could include shape detection, where the program uses the edges to detect what shape it is. This experiment could be improved by using a more sophisticated algorithm that includes noise smoothing and convolution. Noise smoothing is a method that averages pixel by using surrounding pixels to guess the actual color of the center pixel. This would have improved the effectiveness as the noise increased because averaging cancels out the random noise. Convolution is a more complicated process that is used to find the edges, and would be used instead of simply finding the derivatives.

Literature Cited

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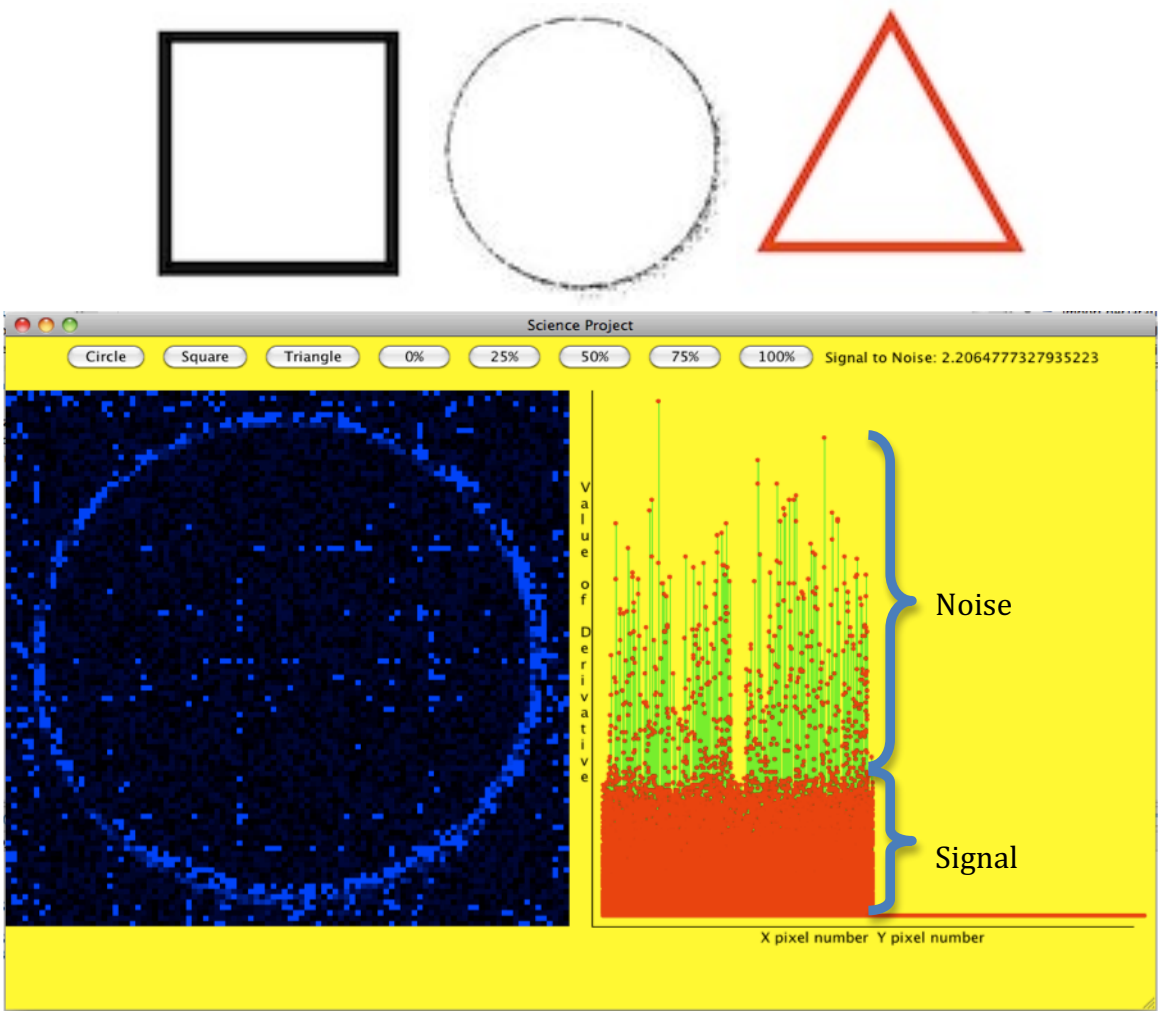
Appendix A



This is an image of the window display showing buttons for choosing shape and noise percentage. It shows the shame with noise and edge detection as well as the value of the derivatives and the signal to noise ratio.

Shape	Trial	%Noise	SNR	Shape	Trial	%Noise	SNR
Circle	C	0	∞	**Square**	C	0	∞
Circle	1	25	4.2578125	**Square**	1	25	3.6989247311828000
Circle	2	25	5.923913043478260	**Square**	2	25	2.6259541984732800
Circle	3	25	6.337209302325580	**Square**	3	25	2.9783549783549800
Circle	4	25	9.39655172413793	**Square**	4	25	3.1705069124424000
Circle	5	25	5.797872340425530	**Square**	5	25	3.323671497584540
AVERAGE			6.34267178207346	**AVERAGE**			3.1594824636076
Circle	1	50	1.8664383561643800	**Square**	1	50	2.8666666666666700
Circle	2	50	3.40625	**Square**	2	50	2.991304347826090
Circle	3	50	3.1142857142857100	**Square**	3	50	2.8666666666666700
Circle	4	50	2.3491379310344800	**Square**	4	50	3.2
Circle	5	50	2.898936170212770	**Square**	5	50	3.602094240837700
AVERAGE			2.72700963433947	**AVERAGE**			3.10534638439943
Circle	1	75	0.9511343804537520	**Square**	1	75	2.8786610878661100
Circle	2	75	0.8346094946401220	**Square**	2	75	3.0442477876106200
Circle	3	75	0.9628975265017670	**Square**	3	75	2.5864661654135300
Circle	4	75	0.8790322580645160	**Square**	4	75	2.8907563025210100
Circle	5	75	0.8934426229508200	**Square**	5	75	2.301003344481610
AVERAGE			0.904223256522195	**AVERAGE**			2.74022693757858
Circle	1	100	0.4972627737226280	**Square**	1	100	1.0766823161189400
Circle	2	100	0.5444555444555440	**Square**	2	100	1.2531876138433500
Circle	3	100	0.5126999059266230	**Square**	3	100	1.1505016722408000
Circle	4	100	0.5079217148182670	**Square**	4	100	0.9234899328859060
Circle	5	100	0.5816435432230520	**Square**	5	100	0.9424657534246580
AVERAGE			0.528796696429223	**AVERAGE**			1.06926545770273

Shape	Trial	%Noise	SNR
Triangle	C	0	∞
Triangle	1	25	1.6015831134564600
Triangle	2	25	1.5524296675191800
Triangle	3	25	1.5251256281407000
Triangle	4	25	1.4050925925925900
Triangle	5	25	1.3733031674208100
AVERAGE			1.49150683382595
Triangle	1	50	0.6692392502756340
Triangle	2	50	0.7082847141190200
Triangle	3	50	0.7183431952662720
Triangle	4	50	0.640295358649789
Triangle	5	50	0.7149587750294460
AVERAGE			0.690224258668032
Triangle	1	75	0.4967266775777410
Triangle	2	75	0.4963205233033520
Triangle	3	75	0.6112789526686810
Triangle	4	75	0.5409982174688060
Triangle	5	75	0.48951612903225800

AVERAGE			0.526968100010168
Triangle	1	100	0.40066006600660100
Triangle	2	100	0.41746905089408500
Triangle	3	100	0.4118046132971510
Triangle	4	100	0.40683646112600500
Triangle	5	100	0.39986824769433500
AVERAGE			0.407327687803635

These tables represent the raw data. They show each shape, the trial number, the percent noise, and the signal to noise ratio.

Appendix B

```
import javax.swing.JFrame;


public class FinalScienceProject extends JFrame {

        public FinalScienceProject() {
            add(new FinalScienceProjectPart2()); //ShowPictures

           setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
           setSize(500*2+20, 650);
           setLocationRelativeTo(null);
           setTitle("Science Project");
           setResizable(true);
           setVisible(true);
        }
            public static void main(String[] argv){
                    FinalScienceProject i = new FinalScienceProject();
            }


}

import java.awt.Color;
import java.awt.Graphics;
```

```
import java.awt.Graphics2D;
import java.awt.RenderingHints;
import java.awt.Toolkit;
import java.awt.event.ActionEvent;
import java.awt.event.ActionListener;
import java.awt.image.BufferedImage;
import java.io.File;
import java.util.Random;
import javax.imageio.ImageIO;
import javax.swing.JButton;
import javax.swing.JLabel;
import javax.swing.JPanel;


public class FinalScienceProjectPart2 extends JPanel {
	BufferedImage inputSourceImage;
	String stringSource, status, stringShape;
	Random generator = new Random();
	int[][] processedImage;
	int[] edgepoints, rgbs;
	int[] totaldata, xDerivativeList,yDerivativeList; //derivatives
	int wpixel, hpixel, average, numofaverages, numofedges,numNoNoisePoints;
	int i = 0;
	int derivativeCounter = 0;
	int edgecounter = 0;
	double efficiency;
	double percentNoise; // Noise value. Total value is usually 256.
	int edgeColor = 255;
	double maxpercent = .70;
	Boolean noiseOn = false;
	//SCREEN SETTINGS
	int titleHeight=20, buttonHeight=30, screenWidth, screenHeight, graphStartX, space=20,
mag=5,
	buttonWidth = 12, PAD = 10;

	//buttons
	JButton circle = new JButton("Circle");
	JButton square = new JButton("Square");
	JButton triangle = new JButton("Triangle");
	JButton zero = new JButton("0%");
	JButton twentyFive = new JButton("25%");
	JButton fifty = new JButton("50%");
	JButton seventyFive = new JButton("75%");
	JButton oneHundred = new JButton("100%");
	JLabel efficiencyLabel = new JLabel();
```

```
public FinalScienceProjectPart2(){
        setFocusable(true);
        setBackground(Color.yellow);
        setDoubleBuffered(true);
        setVisible(true);
        generateButtons();
        setInputImage("/Users/kyla/Desktop/SHAPES/blank.jpg",percentNoise);
        setStringSource("/Users/kyla/Desktop/SHAPES/blank.jpg");
        stringShape = "Circle";
}

public void setInputImage(String file, double n){
        try {
                inputSourceImage = ImageIO.read(new File(file));
        }
        catch (Exception e) {
                e.printStackTrace();
        }

        percentNoise = n;
        wpixel = inputSourceImage.getWidth(null); //num of pixels
        hpixel = inputSourceImage.getHeight(null); //num of pixels

        screenWidth = wpixel*mag;
        screenHeight = (hpixel*mag + buttonHeight + titleHeight);
        setSize(screenWidth*2+space, screenHeight+100);
        graphStartX = screenWidth + space; //maybe *mag or (screenWidth+space);
        i=0;
        edgecounter =0;

        totaldata = new int[(wpixel*hpixel)*4]; //////////////
        edgepoints = new int[(wpixel*hpixel)*4]; ////////////

        processedImage = pixelArray();
        FindEdge(processedImage);

        //printPoints(edgepoints); THIS IS CALLED IN FINDEDGE()
        //printDerivative(totaldata); THIS IS CALLED IN FINDEDGE()



        //              System.out.println("totaldatalength: " + totaldata.length);
        //              System.out.println("edgepoints: " + edgepoints.length);
        //              System.out.println("w: " + wpixel);
        //              System.out.println("h: " + hpixel);
```

```
        efficiency = findEfficiency();
        status = "Signal to Noise: " + efficiency;
        efficiencyLabel.setText(status);
        System.out.println("E:" + efficiency);

}

public void setStringSource(String s){
        stringSource = s;
}

public void setNoiseOn(boolean o){
        noiseOn = o;
}

private void generateButtons(){
        circle.setBounds(buttonWidth, screenHeight, buttonHeight, buttonHeight);
        circle.addActionListener(new ActionListener() {
                public void actionPerformed(ActionEvent event) {
                        stringShape = "Circle";
                        System.out.println(stringShape + " w/ " + percentNoise + "%");

setInputImage("/Users/kyla/Desktop/SHAPES/circle_jpg.jpg",percentNoise);
                        setStringSource("/Users/kyla/Desktop/SHAPES/circle_jpg.jpg");
                }
        });

        square.setBounds(buttonWidth*2, screenHeight, buttonWidth, buttonHeight);
        square.addActionListener(new ActionListener() {
                public void actionPerformed(ActionEvent event) {
                        stringShape = "Square";
                        System.out.println(stringShape + " w/ " + percentNoise + "%");

setInputImage("/Users/kyla/Desktop/SHAPES/square7.jpg",percentNoise);
                        setStringSource("/Users/kyla/Desktop/SHAPES/square7.jpg");
                }
        });

        triangle.setBounds(buttonWidth*3, screenHeight, buttonWidth, buttonHeight);
        triangle.addActionListener(new ActionListener() {
                public void actionPerformed(ActionEvent event) {
                        stringShape = "Triangle";
                        System.out.println(stringShape + " w/ " + percentNoise + "%");

setInputImage("/Users/kyla/Desktop/SHAPES/goodtriangle.jpg",percentNoise);
```

```
setStringSource("/Users/kyla/Desktop/SHAPES/goodtriangle.jpg");

                }
        });

        zero.setBounds(buttonWidth*5, screenHeight, buttonWidth, buttonHeight);
        zero.addActionListener(new ActionListener() {
                public void actionPerformed(ActionEvent event) {
                        System.out.println(stringShape + " w/ " +" 0%");
                        setInputImage(stringSource,0);
                        setNoiseOn(false);
                }
        });

        twentyFive.setBounds(buttonWidth*6, screenHeight, buttonWidth,
buttonHeight);
        twentyFive.addActionListener(new ActionListener() {
                public void actionPerformed(ActionEvent event) {
                        System.out.println(stringShape + "w/" + "25%");
                        setInputImage(stringSource,25);

                        setNoiseOn(true);
                }
        });

        fifty.setBounds(buttonWidth*7, screenHeight, buttonWidth, buttonHeight);
        fifty.addActionListener(new ActionListener() {
                public void actionPerformed(ActionEvent event) {
                        System.out.println(stringShape + " w/ " +" 50%");
                        setInputImage(stringSource,50);
                        setNoiseOn(true);
                }
        });

        seventyFive.setBounds(buttonWidth*8, screenHeight, buttonWidth,
buttonHeight);
        seventyFive.addActionListener(new ActionListener() {
                public void actionPerformed(ActionEvent event) {
                        System.out.println(stringShape + " w/ " +" 75%");
                        setInputImage(stringSource,75);
                        setNoiseOn(true);
                }
        });

        oneHundred.setBounds(buttonWidth*9, screenHeight, buttonWidth,
```

```
buttonHeight);
		oneHundred.addActionListener(new ActionListener() {
			public void actionPerformed(ActionEvent event) {
				System.out.println(stringShape + " w/ " +" 100%");
				setInputImage(stringSource,100);
				setNoiseOn(true);
			}
		});

		add(circle);
		add(square);
		add(triangle);
		add(zero);
		add(twentyFive);
		add(fifty);
		add(seventyFive);
		add(oneHundred);
		add(efficiencyLabel);
	}

	public int[][] pixelArray() {
		rgbs = new int[wpixel*hpixel];
		//		System.out.println("rgbs length: " + rgbs.length);
		int[][] pixelArrayData = new int[wpixel][hpixel];
		int colorcounter = 0;

		/*		24 bit color
		16777216 = 2^24

		16 bit color
		65536 = 2^16

		(2^24)/(2^24) = 1bit --> 0 or 1
		(2^24) / (2^16) = 2^8bits --> 0-225
		 */

		inputSourceImage.getRGB(0, 0, wpixel, hpixel, rgbs, 0, wpixel);
		for (int r=0;r<wpixel;r++) {
			for (int c=0;c<hpixel;c++) {
				pixelArrayData[r][c] = -(rgbs[colorcounter])/65536; //greyscale
				colorcounter++;
				//			System.out.print(pixelArrayData[r][c]+ "
");
			}
			//			System.out.println();
		}
```

```
        if (noiseOn){
                pixelArrayData = addNoise(pixelArrayData,percentNoise);
        }

        /*              System.out.println("WITH NOISE");

        for (int r=0;r<wpixel;r++){
                for (int c=0;c<hpixel;c++){
                        //                      System.out.print(pixelArrayData[r][c] + "
");
                }
                //              System.out.println();
        }*/

        return pixelArrayData;
}

public int[][] addNoise(int[][] data, double percent){
        double random;
        int color;
        int[][] noiseImage = data;

        for (int y=0;y<noiseImage.length;y++){
                for(int x=0;x<noiseImage.length;x++){
                        random = generator.nextDouble() - 0.5; //256*(percent/100)
                        random *= 256*(percent/100);
                        color = noiseImage[x][y];
                        if (color + (int)random > 256){
                                color -= (int) random;
                                noiseImage[x][y] = color;
                                inputSourceImage.setRGB(x,y,color);
                        }
                        else if (color + (int)random < 0){
                                color -= (int)random;
                                noiseImage[x][y] = color;
                                inputSourceImage.setRGB(x,y,color);
                        }
                        else{
                                color += (int)random;
                                noiseImage[x][y] = color;
                                inputSourceImage.setRGB(x, y, color);
                        }
                }
        }
        return noiseImage;
}
```

```
	public void FindEdge(int[][] list){ //list of whole image (may include noise)
		//		System.out.println("listSizeFindEdge(): " + list.length);
		//each list of Z values in one row of Y need a derivative.

		//		System.out.println("YDERIVATIVE...");
		for (int y = 0; y<list.length;y++){
			yDerivativeList = new int[list.length];
			for (int x=0;x<list.length;x++){
				yDerivativeList[derivativeCounter] = list[y][x];
				derivativeCounter++;
			}
			YDerivative(yDerivativeList,y);
			derivativeCounter = 0;
		}

		//		System.out.println("XDERIVATIVE...");
		derivativeCounter = 0;
		for (int x = 0; x<list.length;x++){
			xDerivativeList = new int[list.length];
			for (int y=0;y<list.length;y++){
				xDerivativeList[derivativeCounter] = list[y][x];
				derivativeCounter++;
			}
			XDerivative(xDerivativeList,x);
			derivativeCounter = 0;
		}

		if (noiseOn == false){
			numNoNoisePoints = edgecounter;
		}
//		System.out.println("numNoNoisePoints: " + numNoNoisePoints);
//		System.out.println("edgecounter: " + edgecounter);

		printPoints(edgepoints);
		printDerivative(totaldata);



	}

	public void YDerivative(int[] list, int yvalue){
		int[] slope = new int[list.length];
		int counter = 0;
		int sum = 0;
```

```
		//		System.out.println();
		for(int x=0;x<list.length;x++){
			//			System.out.print(list[x] + ", ");
		}
		//		System.out.println();
		for (int y=1;y<list.length;y++){
			slope[counter] = Math.abs(list[y]-list[y-1]);
			counter++;
		}
		/*		System.out.println("SLOPE...");
		for (int i =0; i<list.length;i++){
			//			System.out.print(slope[i]+ ", ");
		}*/

		for (int k=0;k<list.length;k++){
			sum += slope[k];
		}
		average += Math.abs(sum/slope.length);
		numofaverages++;
		//		System.out.print("AverageD " + sum/slope.length);

		int max = findMax(slope);
		//		System.out.println("    max: " + max);

		counter = 0;
		for (int j=0;j<slope.length;j++){
			if (slope[j] > max*maxpercent){
				inputSourceImage.setRGB(j, yvalue, edgeColor);
				edgepoints[edgecounter] = j;
				edgecounter++;
				edgepoints[edgecounter] = yvalue;
				edgecounter++;
			}
		}

		addToTotalData(slope);
	}

	public void XDerivative(int[] list, int xvalue){
		int[] slope = new int[list.length];
		int counter = 0;
		int sum = 0;

		//		System.out.println();
		for(int x=0;x<list.length;x++){
			//			System.out.print(list[x] + ", ");
```

```
		}
		//			System.out.println();
		for (int y=1;y<list.length;y++){
			slope[counter] = Math.abs(list[y]-list[y-1]);
			counter++;
		}
		/*					System.out.println("SLOPE...");
		for (int i =0; i<list.length;i++){
					System.out.print(slope[i]+ ", ");
		}*/

		for (int k=0;k<list.length;k++){
			sum += slope[k];
		}
		average += Math.abs(sum/slope.length);
		numofaverages++;

		//			System.out.print("AverageD " + sum/slope.length);

		int max = findMax(slope);
		//			System.out.println("slopemax: " + max);

		counter = 0;
		for (int j=0;j<slope.length;j++){
			if (slope[j] > max*maxpercent){
				inputSourceImage.setRGB(xvalue, j, edgeColor);
				edgepoints[edgecounter] = xvalue;
				edgecounter++;
				edgepoints[edgecounter] = j;
				edgecounter++;
			}
		}
		addToTotalData(slope);
}

public void addToTotalData(int[] data){
		for (int x=0;x<data.length;x++){
			totaldata[i] = data[x];
			i++;
		}
}

public int findMax(int[] list){
		int max;
		max = list[0];
		for (int x=0;x<list.length;x++){
```

```
                if (list[x] > max){
                        max = list[x];
                }
        }
        return max;
}

public int findMin(int[] list){
        int min;
        min = list[0];
        for (int x=0;x<list.length;x++){
                if (list[x] < min){
                        min = list[x];
                }
        }
        return min;
}

public int findAverage(){
        int a = average/numofaverages;
        return a;
}

public void printPoints(int[] list){
        /*System.out.println("PRINTEDGEPOINTS");
        for (int x=0;x<list.length;x+=2){
                System.out.print("(" + list[x] + "," + list[x+1] + ")");
        }*/
}

public void printDerivative(int[] d){
        /*      System.out.println();
        System.out.println("PRINTDERIVATIVE");
        for (int x = 0;x<d.length;x++){
                System.out.print(d[x] + ", ");
        }*/
}

public double findEfficiency(){
        double efficiency;
        //              System.out.println();
        //              System.out.println("max: " + max);
        //              System.out.println("average: " + totalAverage);
        //              efficiency = (max-totalAverage)/totalAverage;
        efficiency =(double) numNoNoisePoints/(edgecounter - numNoNoisePoints);
        return efficiency;
```

```
	}

	public void paint(Graphics g){

		super.paint(g);
		Graphics2D g2 = (Graphics2D)g;

		g.drawImage(inputSourceImage, 0, buttonHeight+titleHeight, screenWidth,
screenHeight-buttonHeight-titleHeight, this);

		g2.setRenderingHint(RenderingHints.KEY_ANTIALIASING,
				RenderingHints.VALUE_ANTIALIAS_ON);

		// Draw Y axis.
		g.drawLine(graphStartX,buttonHeight+titleHeight,graphStartX, screenHeight);
		//draw X axis
		g.drawLine(graphStartX,screenHeight,screenWidth*2, screenHeight);

		// Draw labels.

		// Y label.
		int xCounter = 115;
		String[] s = "Value of Derivative".split("");
		for ( int x=0; x<s.length; x++) {
			xCounter +=15;
			g.drawString(s[x], graphStartX-10, xCounter);
		}
		//		g.drawString(s, graphWStart, i);
		// X label.
		String s2 = "X pixel number		Y pixel number";

		g.drawString(s2, graphStartX+150, screenHeight+15);

		// Draw lines.
		// The space between values along the x axis.
		//		System.out.println("totaldatalength: " + totaldata.length);

		double xInc = (double)(screenWidth - 2*PAD)/(totaldata.length-1);
		///////		double xInc = (double)(screenWidth-PAD-space)/(totaldata.length-
1);
		//		System.out.println("xInc: " + xInc);
		// Scale factor for y/data values.

		double scale = (double)(((screenHeight-buttonHeight-titleHeight)) -
2*PAD)/findMax(totaldata);
```

```
                //drawLines
                g.setColor(Color.green);
                //                  g2.setPaint(Color.green.darker());
                for(int i = 0; i < totaldata.length-1; i++) {
                        double x1 = graphStartX+ PAD + i*xInc;
                        double y1 = (screenHeight) -PAD- scale*totaldata[i];
                        double x2 = graphStartX +PAD+ (i+1)*xInc;
                        double y2 = (screenHeight)- PAD-scale*totaldata[i+1];
                        g.drawLine((int) x1, (int)y1, (int)x2, (int)y2);
                        //                              g2.draw(new Line2D.Double(x1, y1, x2, y2));
                }
                // Mark data points.
                g.setColor(Color.red);
                //                  g2.setPaint(Color.red);
                for(int i = 0; i < totaldata.length; i++) {
                        double x = graphStartX +PAD+ i*xInc;
                        double y = (screenHeight)-PAD- scale*totaldata[i];
                        g.fillOval((int) x-2,(int) y-2, 4, 4);
                        //                              g2.fill(new Ellipse2D.Double(x-2, y-2, 4, 4));
                }


                Toolkit.getDefaultToolkit().sync();
                g.dispose();

                requestFocusInWindow(true);
        }

        public void actionPerformed(ActionEvent e) {
                FindEdge(processedImage);
                add(efficiencyLabel);
                repaint();

        }

}
```