CHAPTER 5
IMPLEMENTATION AND TESTING

5.1 Implementation

This project is developed in Java language. There are two part of program implementation: Otsu Method and Manual Thresholding.

5.1.1. OTSU METHOD

```
1. BufferedImage image = ImageIO.read(selectedFile);
2. BufferedImage imageOutputOtsu = ImageIO.read(selectedFile);
3. image = histogramCalc(image);
4. otsuRed(image);
5. otsuGreen(image);
6. otsuBlue(image);
7. imageOutputOtsu = otsuSegmentation(image, imageOutputOtsu);
```

The code above executed after choosing an image file which will be segmented with Otsu method. There is **histogramCalc** function to calculate histogram of original image. There are three functions of Otsu calculation (**otsuRed**, **otsuGreen**, **otsuBlue**) which return the value of optimal threshold from each RGB channel. Then all of optimal thresholds are used in **otsuSegmentation** function to segment the image on all RGB channel.

```
1. for (int x = 0; x < 256; x++) {
2.   sumRedMeanFg += x * valR[x];
3.   sumGreenMeanFg += x * valG[x];
4.   sumBlueMeanFg += x * valB[x];
5. }
```

While counting histogram, sum of foreground mean also calculated on each color channel to be used in Otsu method.

```
1. public int otsuRed(BufferedImage image) {
2. for (int rh = 0; rh < 256; rh++) {
3.   weightRedBg = weightRedBg + valR[rh];
4.   weightRedFg = totalPixel - weightRedBg;
5.
6.  sumRedMeanBg += (float) (rh * valR[rh]);
7.
8.  meanRedBg = sumRedMeanBg / weightRedBg;
9.  meanRedFg = (sumRedMeanFg - sumRedMeanBg) /  weightRedFg;
10.
11. float betweenVar = weightRedBg * weightRedFg * (meanRedBg -
   meanRedFg) * (meanRedBg - meanRedFg);
12.   if (betweenVar > maxVar) {
13.     maxVar = betweenVar;
14.     optimalRedThreshold = rh;
15.   }
16.
17.   return optimalRedThreshold;
18. }
```

This is function of Otsu calculation using histogram data in red channel. Otsu method calculation is consists of background weight (**weightRedBg**), foreground weight (**weightRedFg**), sum of background mean (**sumRedMeanBg**), sum of foreground mean (**sumRedMeanFg** in previous code), background mean (**meanRedBg**), foreground mean (**meanRedFg**), and the final calculation is between class variance (**betweenVar**). There is conditional statement to search maximum value of between class variance and optimal threshold:

If current value of between class variance is greater than temporary variable (**maxVar**), then current loop iteration (**rh**) which same as color value is set as optimal threshold of red channel.

```
1. public BufferedImage otsuSegmentation(BufferedImage image,
   BufferedImage imageOutputOtsu){
2.    int ort = otsuRed(image);
3.    int ogt = otsuGreen(image);
4.    int obt = otsuBlue(image);
5.
6.    for (int i = 0; i < h; i++) {
7.      for (int j = 0; j < w; j++) {
8.         Color c = new Color(image.getRGB(j,i));
9.         int red = (int)(c.getRed());
10.        int green = (int)(c.getGreen());
11.        int blue = (int)(c.getBlue());
12.
13.        if(red < ort) { red = 0; }
14.        if(green < ogt) { green = 0; }
15.        if(blue < obt) { blue = 0; }
16.        if(red >= ort) { red = 255; }
17.        if(green >= ogt) { green = 255; }
18.        if(blue >= obt) { blue = 255; }
19.
20.        Color newColor = new Color(red,green,blue);
21.        imageOutputOtsu.setRGB(j,i,newColor.getRGB());
22.    }}
23.    return imageOutputOtsu;
24. }
```

This is function of Otsu segmentation. Optimal threshold values from three color channel are retrieved with these functions: **otsuRed**, **otsuGreen**, **otsuBlue**. These optimal threshold values are used as comparation with color value of original image. Then individual binarization is done in each RGB channel to make colored segmentation. So these binarization consists of three conditional statement to change RGB value to 0 & three others to change RGB value to 255.

5.1.2. MANUAL THRESHOLDING

```
redSlider.addChangeListener(new ChangeListener(){
public void stateChanged(ChangeEvent e) {
   currRedT = redSlider.getValue();

for (int i = 0; i < h; i++) {
for (int j = 0; j < w; j++) {
  Color c = new Color(image1.getRGB(j,i));
  int red = (int)(c.getRed());
  int green = (int)(c.getGreen());
  int blue = (int)(c.getBlue());

  if(red < currRedT) {
  newRed = 0; }

  if(red >= currRedT){
  newRed = 255; }

  Color newColor = new Color(newRed,green,blue);
  image2.setRGB(j,i,newColor.getRGB());
}}
   }
});
```

This is threshold slider for the red channel. The binarization in red channel: If red value of image < current value of red threshold slider, then red = 0. If red value of image >= current value of red threshold slider, then red = 255.

```
1. public void monochromeThreshold() {
2.    int currMonoT = monochromeSlider.getValue();
3.
4.     for (int i = 0; i < h; i++) {
5.       for (int j = 0; j < w; j++) {
6.         Color c = new Color(image1.getRGB(j,i));
7.         int red = (int)(c.getRed());
8.
9.         if(red < currMonoT){
10.            red = 0;
11.          }
12.
13.          if(red >= currMonoT){
14.            red = 255;
15.          }
16.
17.          if(red == 0){
18.            freqBlack++;
19.          }
20.
21.          if(red == 255){
22.            freqWhite++;
23.          }
24.          Color newColor = new Color(red,red,red);
25.          image2.setRGB(j,i,newColor.getRGB());
26.       }}
27.        percentB = (float) (freqBlack * 100) / totalPixel;
28.        percentW = (float) (freqWhite * 100) / totalPixel;
29.  }
```

This is function to convert image to monochrome using threshold slider. The monochrome threshold here is only based on red channel. Its binarization has same code with colored manual thresholding in previous code. The frequency of black pixels (0) and white pixels (255) are calculated. Then frequency data and total pixel of image are used to calculate the background percentage (black pixels) and object percentage (white pixels).

5.2 Testing

5.2.1. OTSU METHOD

This part is Otsu method testing on discrete and camouflage images.

Comparison 1

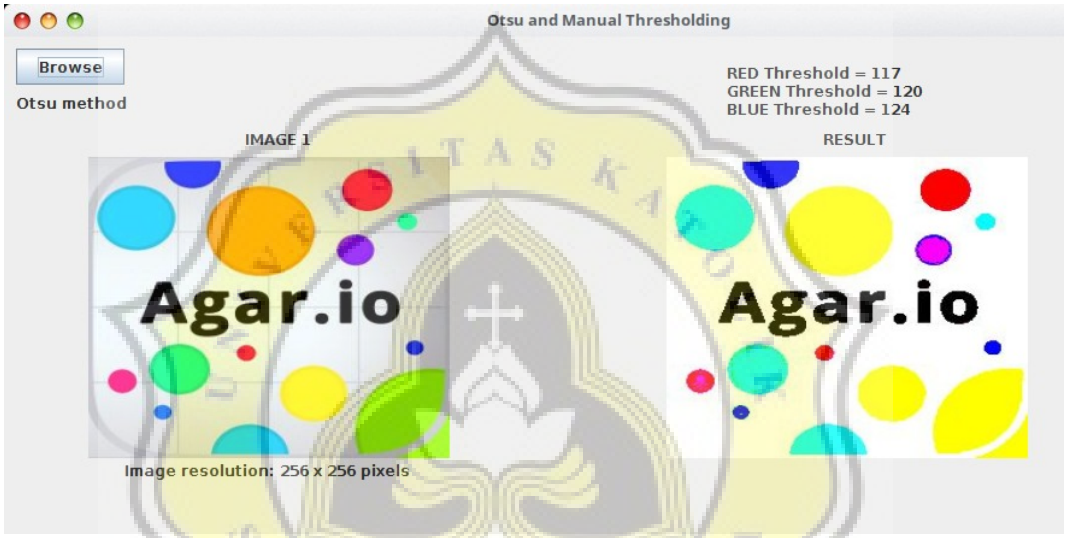


Illustration 5.1: Discrete image 1 - Otsu

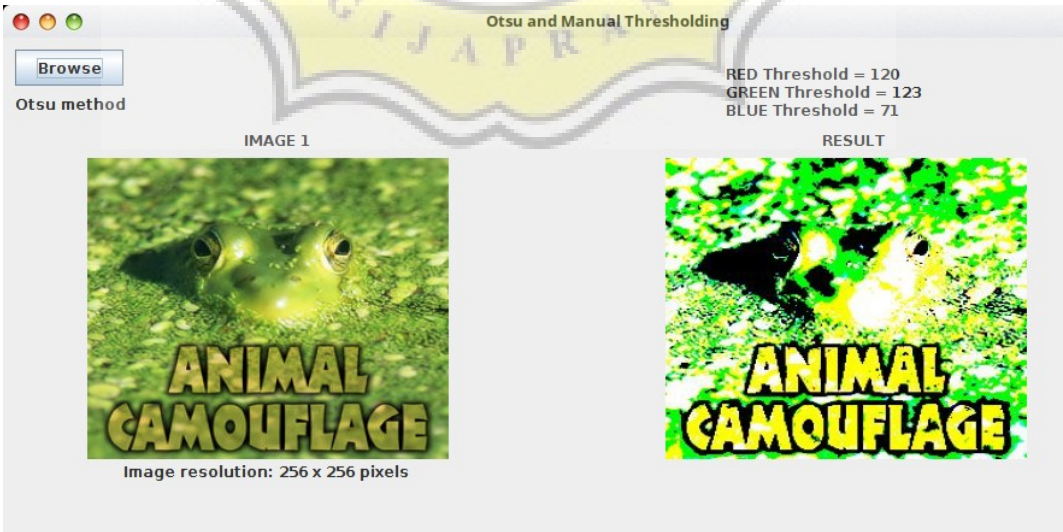


Illustration 5.2: Camouflage image 1 - Otsu

Discrete image 1 is Agar.io icon which has contrast color between background, circles, and text. While camouflage image 1 is green frog with its surrounding that also has similar green color. These two images are data sample of Otsu comparison between discrete and camouflage image.

Histograms of RGB channel are used for Otsu data analysis. In order to simplified the data, each histogram is divided into 5 zones from left to right on each graph: zone 1 (0-50, darkest color), zone 2 (51-101), zone 3 (102-152), zone 4 (153-203), zone 5 (204-255, lightest color).

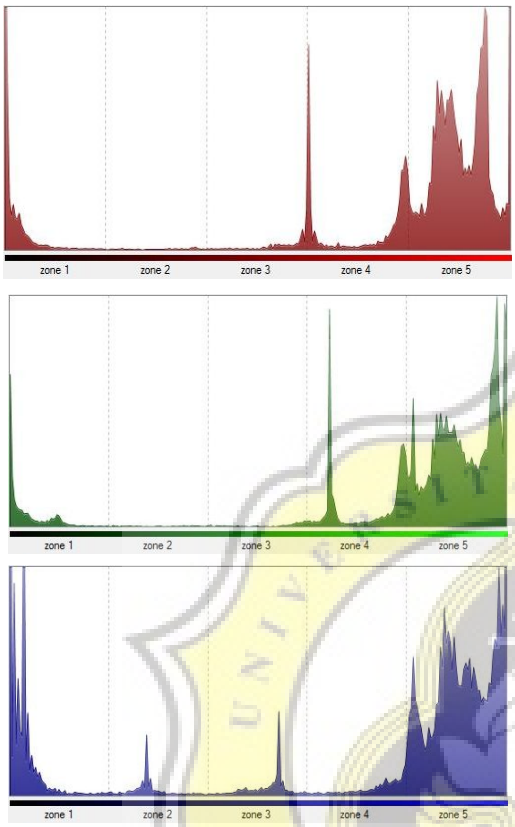


Illustration 5.3: Histogram of discrete image 1

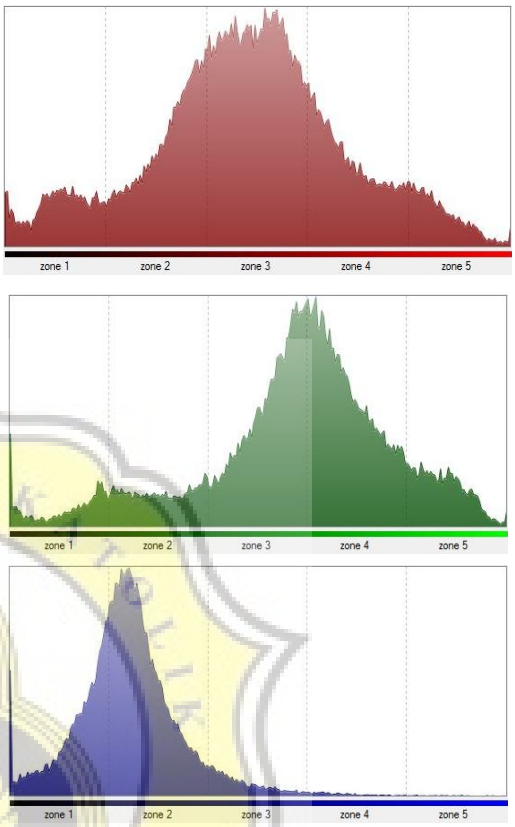


Illustration 5.4: Histogram of camouflage image 1

On the left side there are histograms of discrete image 1. Highest peaks of frequency histogram on discrete image 1 are 5262 pixels (Red), 2470 pixels (Green), 8437 pixels (Blue). All of these peaks are located in zone 5 of histogram. The optimal threshold found in discrete image 1 are 117 (Red), 120 (Green), 124 (Blue), which all of it located in zone 3.

On the right side there are histograms of camouflage image 1. While highest peaks of frequency histogram on camouflage image 1 are 645 pixels (Red) in zone 3, 844 pixels (Green) in zone 4, 1443 pixels (Blue) in zone 2. The optimal threshold found in camouflage image 1 are 120 (Red) in zone 3, 123 (Green) in zone 3, 71 (Blue) in zone 2.

All comparison results are summarized in these table:

Table 5.1: Table of highest peaks zone

Comparison	Zone of Highest peaks					
	Discrete image			Camouflage image		
	R	G	B	R	G	B
1	5	5	5	3	4	2
2	5	5	1	2	2	2
3	1	3	4	2	2	1
4	5	5	5	1	2	1
5	5	1	1	1	1	1
6	1	5	5	3	4	3
7	1	1	1	4	4	3
8	5	5	5	1	1	1
9	1	1	1	3	4	1
10	1	1	1	1	1	1

Table 5.2: Table of optimal threshold zone

Comparison	Zone of Optimal Threshold					
	Discrete image			Camouflage image		
	R	G	B	R	G	B
1	3	3	3	3	3	2
2	3	3	5	2	2	2
3	2	3	4	2	2	2
4	5	5	4	1	2	1
5	4	3	2	3	3	2
6	1	4	5	3	4	3
7	4	4	4	3	3	2
8	5	4	5	3	2	2
9	2	1	1	3	3	1
10	1	1	1	1	3	1

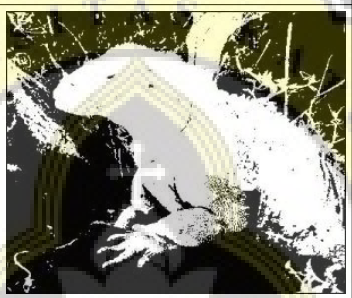
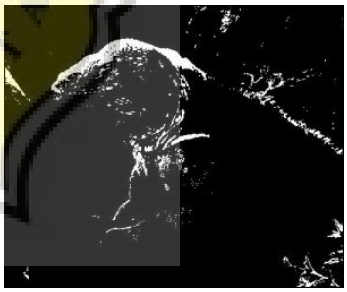
Based on the first and second table in camouflage images part, there was no highest peaks and optimal threshold which located in zone 5 (lightest color of RGB). Most of its data were in zone 1, 2, 3, and less in zone 4. While in discrete images there were more varied data which located in zone 1 until 5.

Therefore, based on tested Otsu method and its comparison results proven that discrete images usually have better segmentation between object and background than camouflage images.

5.2.2. MANUAL THRESHOLDING

This part is manual threshold testing on camouflage images. If compared to Otsu method, this method does not require histogram data for its segmentation process. So, the analysis for manual thresholding is based on median value of these threshold range: 100-120 (T = 110), 120-140 (T = 130), 140-160 (T = 150), 160-180 (T = 170), 180-200 (T = 190). In order to simplify in differentiate object and background, the color images are converted to monochrome images.

Table 5.3: Camouflage image 2 – Manual

Original image	**T = 110**	**T = 130**
		
T = 150	**T = 170**	**T = 190**
		

Camouflage image 2 is gray iguana with its surrounding that also has similar gray color. This image is a data sample of Manual thresholding on camouflage image.

Those five threshold values become comparative variable on each segmented image. The segmentation results are calculated how many its black and white pixels, then summarized in these table:

Table 5.4: Table of Manual Threshold (Camouflage image 1-10)

Camouflage image	Threshold	Frequency (pixels)		Percentage (%)		Total Pixels
		Black	White	Black (Background)	White (Object)	
1 – Frog	110	24.592	40.944	37,52	62,48	65.536
	130	36.372	29.164	55,5	44,5	
	150	47.796	17.740	72,93	27,07	
	170	55.199	10.337	84,23	15,77	
	190	59.316	6.220	90,51	9,49	
2 - Iguana	110	87.532	72.468	54,71	45,29	160.000
	130	109.456	50.544	68,41	31,59	
	150	130.388	29.612	81,49	18,51	
	170	144.265	15.735	90,17	9,83	
	190	152.904	7.096	95,57	4,43	
3 - Stingray	110	74.466	246.534	23,20	76,80	321.000
	130	143.266	177.734	44,63	55,37	
	150	231.473	89.527	72,11	27,89	
	170	283.999	37.001	88,47	11,53	
	190	305.121	15.879	95,05	4,95	
4 - Snake	110	104.119	203.081	33,89	66,11	307.200
	130	134.531	172.669	43,79	56,21	
	150	169.172	138.028	55,07	44,93	
	170	209.989	97.211	68,36	31,64	
	190	251.923	55.277	82,01	17,99	
5 – Leopard	110	23.980	283220	7,81	92,19	307.200
	130	43.167	264.033	14,05	85,95	
	150	74.676	232.524	24.31	75,69	
	170	124.180	183.020	40,42	59,58	
	190	187.152	120.048	60,92	39,08	
6 – Owl	110	169.820	137.380	55,28	44,72	307.200
	130	201.805	105.395	65,69	34,31	
	150	228.728	78.472	74,46	25,54	
	170	251.404	55.796	81,84	18,16	
	190	271.247	35.953	88,30	11,70	
7 - Cat	110	333.795	350.845	48,75	51,25	684.640
	130	410.861	273.779	60,01	39,99	
	150	509.282	175.358	74,39	25,61	
	170	592.184	92.456	86,50	13,50	
	190	653.145	31.495	95,40	4,60	
8 – Chameleon	110	145.834	126.270	53,59	46,41	272.104
	130	189.966	82.138	69,81	30,19	
	150	219.248	52.856	80,58	19,42	
	170	238.210	33.894	87,54	12,46	
	190	249.643	22.461	91,75	8,25	
9 – Leafbug	110	465.812	14.188	97,04	2,96	480.000
	130	476.419	3.581	99,25	0,75	
	150	479.978	22	100	0	
	170	480.000	0	100	0	
	190	480.000	0	100	0	
10 – Chameleon	110	415.091	64.909	86,48	13,52	480.000
	130	436.752	43.248	90,99	9,01	
	150	452.322	27.678	94,23	5,77	
	170	463.008	16.992	96,46	3,54	
	190	470.121	9.879	97,94	2,06	

Table 5.5: Table of Manual Threshold (Camouflage image 11-20)

Camouflage image	Threshold	Frequency (pixels)		Percentage (%)		Total Pixels
		Black	White	Black (Background)	White (Object)	
11 – Tiger	110	338.285	448.147	43,02	56,98	786.432
	130	455.629	330.803	57,94	42,06	
	150	563.644	222.788	71,67	28,33	
	170	661.388	125.044	84,10	15,90	
	190	738.686	47.746	93,93	6,07	
12 – Ladybug	110	393.639	392.793	50,05	49,95	786.432
	130	551.835	234.597	70,17	29,83	
	150	698.480	87.952	88,82	11,18	
	170	767.801	18.631	97,63	2,37	
	190	778.826	7.606	99,03	0,97	
13 – Lizard	110	206.205	580.227	26,22	73,78	786.432
	130	272.280	514.152	34,62	65,38	
	150	360.664	425.768	45,86	54,14	
	170	465.051	321.381	59,13	40,87	
	190	567.484	218.948	72,16	27,84	
14 – Lizard	110	452.765	468.835	49,13	50,87	921.600
	130	516.507	405.093	56,04	43,96	
	150	576.974	344.626	62,61	37,39	
	170	643.770	643.770	69,85	30,15	
	190	716.881	204.719	77,79	22,21	
15 – Leafbug	110	326.154	595.446	35,39	64,61	921.600
	130	405.867	515.733	44,04	55,96	
	150	499.817	421.783	54,23	45,77	
	170	613.757	307.843	66,60	33,40	
	190	742.447	179.153	80,56	19,44	
16 – Snake	110	343.615	81.185	80,89	19,11	424.800
	130	364.658	60.142	85,84	14,16	
	150	383.346	41.454	90,24	9,76	
	170	397.783	27.017	93,64	6,36	
	190	411.070	13.730	96,77	3,23	
17 – Fish	110	253.767	188.601	57,37	42,63	442.368
	130	286.754	155.614	64,82	35,18	
	150	321.523	120.845	72,68	27,32	
	170	356.113	86.255	80,50	19,50	
	190	387.730	54.638	87,65	12,35	
18 – Chameleon	110	644.325	404.763	61,42	38,58	1.049.088
	130	733.943	315.145	69,96	30,04	
	150	810.348	238.740	77,24	22,76	
	170	883.032	166.056	84,17	15,83	
	190	944.920	104.168	90,07	9,93	
19 – Turtle	110	752.346	296.742	71,71	28,29	1.049.088
	130	839.170	209.918	79,99	20,01	
	150	904.068	145.020	86,18	13,82	
	170	953.097	95.991	90,85	9,15	
	190	989.970	59.118	94,36	5,64	
20 – Raccoon	110	666.127	382.961	63,50	36,50	1.049.088
	130	819.246	229.842	78,09	21,91	
	150	924.171	124.917	88,09	11,91	
	170	986.477	62.611	94,03	5,97	
	190	1.025.235	23.853	97,73	2,27	

Based on five different threshold which applied on twenty sample of camouflage images, threshold value which effective in differentiate object and background is T = 110. It was caused by percentage of object (white pixels) and

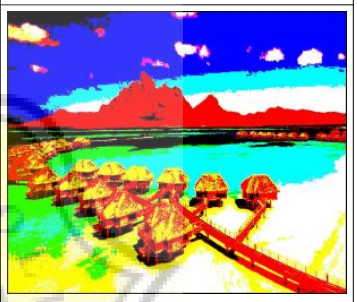
background (black pixels) on each camouflage image are tend to be relevant when compared with its original image. While in other thresholds which greater than 110, the results are background dominates over the object. In other words, proven that the greater the threshold value, the background is more dominating object, so that it generates worse segmentation.

5.2.3. OTSU METHOD & MANUAL THRESHOLDING

This part has purpose to compare Otsu method and Manual thresholding on 20 discrete images and 20 camouflage images.

Results of Otsu method:

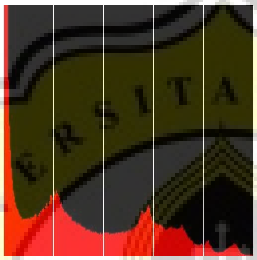
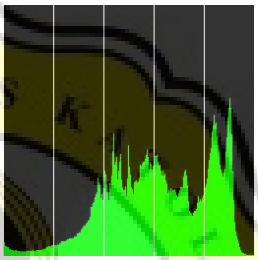
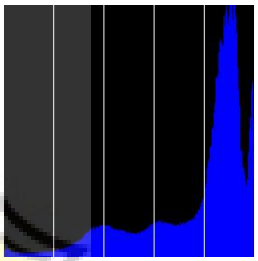
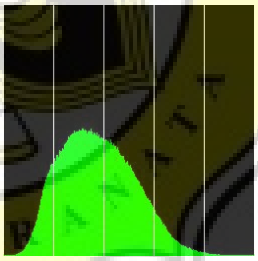
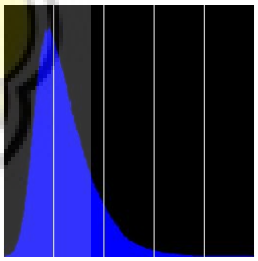
Table 5.6: Result Table of Otsu method

Original image (Discrete)	**Trial 1**	**Trial 2**
 3 - Bora-Bora		
Original image (Camouflage)	**Trial 1**	**Trial 2**
 11 – Tiger		

Discrete image 3 is Bora-Bora island which has contrast color between background (beach & sky) and object (water bungalows & mountain).While camouflage image 11 is a tiger with its surrounding that also has similar color. These two images are data sample of Otsu comparison between discrete and camouflage image.

Histograms of original images are divided into 5 zones of pixel value from 0-255 on each graph: zone 1 (0-50), zone 2 (51-101), zone 3 (102-152), zone 4 (153-203), zone 5 (204-255).

Table 5.7: Table of Histogram

Original image (Discrete)	**Red**	**Green**	**Blue**
 3 - Bora-Bora			
Original image (Camouflage)	**Red**	**Green**	**Blue**
 11 – Tiger			

These histograms from each original image are data sample which compare between discrete and camouflage image.

Otsu results are summarized in these table:

Table 5.8: Table of Maximum Frequency - Otsu

Type	Image name	Max Frequency (pixels)						Value of Max Frequency			Zone of Max Frequency		
		Trial 1			Trial 2			Trial 1 & Trial 2			Trial 1 & Trial 2		
		R	G	B	R	G	B	R	G	B	R	G	B
Discrete	1 – Agar.io	5262	2470	8437	10.524	4940	16.874	255	250	255	5	5	5
	2 - Birds	18.307	20.704	21.857	36.614	41.408	43.714	217	219	216	5	5	5
	3 - Bora-Bora	191.873	11.238	19.713	383.746	22.476	39.426	0	230	235	1	5	5
	4 - Car	71.484	31.766	27.985	142.968	63.532	'55.970	0	0	0	1	1	1
	5 - Cinema	37.364	224.634	89.501	74.728	449.268	179.002	15	0	10	1	1	1
	6 - Lake	33.187	5080	8809	66.374	'10.160	17.618	0	103	158	1	3	4
	7 - Flixbus	14.303	14.979	27.422	28.606	29.958	54.844	246	247	252	5	5	5
	8 - Golf	3344	6682	21.587	6688	13.364	43.174	245	235	0	5	5	1
	9 – Latte Art	1654	2687	2838	3308	5374	5676	221	0	37	5	1	1
	10 - Linus Torvalds	119.557	167.121	174.386	239.114	334.242	348.772	0	0	0	1	1	1
	11 - Monas	34.987	9297	'12.500	69.974	18.594	'25.000	0	115	191	1	3	4
	12 - Office	13.035	8503	12.068	'26.070	17.006	24.136	255	147	0	5	3	1
	13 – Oil Rig	3775	1949	2244	7550	3898	4488	0	202	255	1	4	5
	14 - PC	6689	4447	6458	13.378	8894	12.916	8	6	9	1	1	1
	15 - People	108.984	58.937	'58.770	217.968	117.874	'117.540	255	255	255	5	5	5
	16 - Pizza	6255	7832	10.174	'12.510	15.664	20.348	17	12	20	1	1	1
	17 - Rubic	6908	24.959	13.742	13.816	49.918	27.484	0	255	0	1	5	1
	18 – Shark Archipelago	1865	1058	2934	3730	2116	5868	51	149	223	2	3	5
	19 - Skyscraper	120.532	16.328	9851	241.064	32.656	19.702	0	67	174	1	2	4
	20 – Social Media	563.977	'559.270	562.212	1.127.954	'1.118.540	1.124.424	255	255	255	5	5	5
Camouflage	1 – Frog	645	844	1443	1290	1688	2886	131	157	50	3	4	2
	2 – Iguana	2056	2064	1974	4112	4128	3948	86	83	50	2	2	2
	3 – Stingray	4893	5358	5008	9786	10.716	10.016	132	153	116	3	4	3
	4 – Snake	3153	4646	28.382	6306	9292	56.764	0	0	0	1	1	1
	5 – Leopard	5003	3645	3701	10.006	7290	7402	255	169	120	5	4	3
	6 – Owl	2143	2254	2367	4286	4508	4734	83	60	44	2	2	2
	7 - Cat	6327	8269	8006	12.654	16.538	16.012	25	44	42	1	1	1
	8 – Chameleon	3047	2734	4461	6094	5468	8922	104	153	25	3	4	1
	9 – Leafbug	11.635	6347	15.541	'23.270	12.694	31.082	23	85	0	1	2	1
	10 – Chameleon	'53.400	7201	'150.835	'106.800	14.402	'301.670	0	2	0	1	1	1
	11 – Tiger	5835	7797	13.965	'11.670	15.594	'27.930	113	89	46	3	2	1
	12 – Ladybug	9256	10.455	'28.070	18.512	'20.910	'56.140	124	174	0	3	4	1
	13 – Lizard	9847	5498	13.175	19.694	10.996	'26.350	255	146	0	5	3	1
	14 – Lizard	28.687	22.598	17.194	57.374	45.196	34.388	101	141	0	2	3	2
	15 – Leafbug	7688	6729	14.731	15.376	13.458	29.462	186	137	0	4	3	1
	16 – Snake	24.543	23.702	114.979	49.086	47.404	229.958	1	1	0	1	1	1
	17 – Fish	7577	7454	7416	15.154	14.908	14.832	14	14	19	1	1	1
	18 – Chameleon	8314	8155	28.782	16.628	'16.310	57.564	42	56	0	1	2	1
	19 – Turtle	10.672	9871	10.824	21.344	19.742	21.648	55	51	45	2	2	1
	20 – Raccoon	10.527	10.601	12.197	21.054	21.202	24.394	88	83	49	2	2	2

Table 5.9: Table of Optimal Threshold - Otsu

Type	Image name	Value of Optimal Threshold						Zone of Optimal Threshold					
		Trial 1			Trial 2			Trial 1			Trial 2		
		R	G	B	R	G	B	R	G	B	R	G	B
Discrete	1 – Agar.io	117	120	124	222	224	225	3	3	3	5	5	5
	2 - Birds	85	55	16	207	206	203	2	2	1	5	5	4
	3 - Bora-Bora	238	24	9	12	156	219	5	1	1	1	4	5
	4 - Car	218	247	252	27	41	45	5	5	5	1	1	1
	5 - Cinema	183	167	154	53	8	12	4	4	4	2	1	1
	6 - Lake	220	34	25	67	114	156	5	1	1	2	3	4
	7 - Flixbus	215	161	209	100	132	101	5	4	5	2	3	2
	8 - Golf	120	130	232	93	116	7	3	3	5	2	3	1
	9 – Latte Art	31	114	191	159	107	69	1	3	4	4	3	2
	10 - Linus Torvalds	237	242	239	56	50	35	5	5	5	2	1	1
	11 - Monas	246	14	20	126	142	174	5	1	1	3	3	4
	12 - Office	24	6	249	165	141	98	1	1	5	4	3	2
	13 – Oil Rig	155	202	41	56	90	155	4	4	1	2	2	4
	14 - PC	221	226	245	57	57	39	5	5	5	2	2	1
	15 - People	19	34	92	244	236	224	1	1	2	5	5	5
	16 - Pizza	87	230	235	145	62	32	2	5	5	3	2	1
	17 - Rubic	28	252	232	171	125	51	1	5	5	4	3	2
	18 – Shark Archipelago	125	173	146	57	141	218	3	4	3	2	3	5
	19 - Skyscraper	230	245	15	46	90	174	5	5	1	1	2	4
	20 – Social Media	91	2	11	252	251	251	2	1	1	5	5	5
Camouflage	1 – Frog	120	123	71	122	151	59	3	3	2	3	3	2
	2 – Iguana	172	169	168	101	98	98	4	4	4	2	2	2
	3 – Stingray	208	83	50	132	153	113	5	2	1	3	4	3
	4 – Snake	23	18	185	140	147	78	1	1	4	3	3	2
	5 – Leopard	79	67	42	178	161	126	2	2	1	4	4	3
	6 – Owl	228	218	209	100	84	74	5	5	5	2	2	2
	7 - Cat	227	204	203	111	89	86	5	5	4	3	2	2
	8 – Chameleon	222	32	217	105	151	49	5	1	5	3	3	1
	9 – Leafbug	110	163	186	32	81	35	3	4	4	1	2	1
	10 – Chameleon	222	251	149	39	111	3	5	5	3	1	3	1
	11 – Tiger	222	201	176	122	93	56	5	4	4	3	2	2
	12 – Ladybug	216	50	202	108	160	81	5	1	4	3	4	2
	13 – Lizard	33	1	249	156	136	114	1	1	5	4	3	3
	14 – Lizard	3	1	230	112	136	84	1	1	5	3	3	2
	15 – Leafbug	12	242	221	142	127	77	1	5	5	3	3	2
	16 – Snake	212	239	101	37	61	2	5	5	2	1	2	1
	17 – Fish	251	233	249	88	88	81	5	5	5	2	2	2
	18 – Chameleon	245	243	230	87	104	28	5	5	5	2	3	1
	19 – Turtle	237	229	238	76	89	76	5	5	5	2	2	2
	20 – Raccoon	228	212	180	92	85	72	5	5	4	2	2	2

Based on two trials of Otsu method which applied on 20 discrete images and 20 camouflage images, the frequency of histogram zone in maximum frequency and optimal threshold are calculated and its results are compared in these table:

Table 5.10: Comparison Table of Maximum Frequency

Zone of Max Freq.	Frequency (zones)	
	Discrete	Camouflage
1	26	25
2	2	17
3	4	10
4	4	6
5	24	2

The first comparison table is zone frequency of maximum frequency which known as histogram's highest peak. The zone frequency of discrete images are dominated by zone 1 (darkest color of RGB, total = 26 zones) and zone 5 (lightest color of RGB, total = 24 zones). While zone frequency of camouflage images also dominated by zone 1 (total = 25 zones), but it have less frequency in zone 5 (only 2 zones).

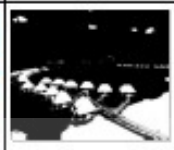
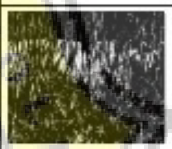
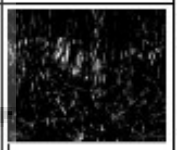
Table 5.11: Comparison Table of Optimal Threshold

Zone of Optimal Threshold	Frequency (zones)			
	Discrete		Camouflage	
	Trial 1	Trial 2	Trial 1	Trial 2
1	17	12	11	8
2	5	16	5	27
3	8	10	4	20
4	8	9	11	5
5	22	13	29	0

The second comparison table is zone frequency of optimal threshold. There were varied increase or decrease in zone frequency between trial 1 and trial 2 of both image type. However there was extreme frequency decrease from 29 to 0 in zone 5 of camouflage images, and also extreme frequency increase 5 to 27 in zone 2 of camouflage images. The change of optimal threshold and its zone frequency have important role in many tested discrete and camouflage images, which its segmentation results could be better in Trial 2 than Trial 1.

Result of Manual thresholding:

Table 5.12: Result Table of Manual thresholding

Original image (Discrete)	T = 110	T = 130	T = 150	T = 170	T = 190
 3 - Bora-Bora					
Original image (Camouflage)	**T = 110**	**T = 130**	**T = 150**	**T = 170**	**T = 190**
 11 – Tiger					

Discrete image 3 is Bora-Bora island which has contrast color between background (beach & sky) and object (water bungalows & mountain).While camouflage image 11 is a tiger with its surrounding that also has similar color. These two images are data sample of Manual threshold comparison between discrete and camouflage image.

Manual threshold results are summarized in these table:

Table 5.13: Table of Manual Threshold (Discrete image 1-10)

Discrete image	Threshold	Frequency (pixels)		Percentage (%)		Total Pixels
		Black	White	Black (Background)	White (Object)	
1 – Agar.io	110	'9107	'56.429	'13,90	'86,10	'65.536
	130	'9392	'56.144	'14,33	'85,67	
	150	'10.298	'55.238	'15,71	'84,29	
	170	'13.828	'51.708	'21,10	'78,90	
	190	'14.717	'508.19	'22,46	'77,54	
2 - Birds	110	'15.953	'464.047	'3,32	'96,68	'480.000
	130	'28.020	'451.980	'5,84	'94,16	
	150	'41.498	'438.502	'8,65	'91,35	
	170	'64.734	'415.266	'13,49	'86,51	
	190	'129.610	'350.390	'27,00	'73,00	
3 - Bora-Bora	110	'719.926	'201.674	'78,12	'21,88	'921.600
	130	'752.896	'168.704	'81,69	'18,31	
	150	'806.588	'115.012	'87,52	'12,48	
	170	'850.502	'71.098	'92,29	'7,71	
	190	'887.311	'34.289	'96,28	'3,72	
4 - Car	110	'873.569	'175.519	'83,27	'16,73	'1.049.088
	130	'901.270	'147.818	'85,91	'14,09	
	150	'928.255	'120.833	'88,48	'11,52	
	170	'956.347	'92.741	'91,16	'8,84	
	190	'994.541	'54.547	'94,80	'5,20	
5 - Cinema	110	'650.985	'270.615	'70,64	'29,36	'921.600
	130	'701.501	'220.099	'76,12	'23,88	
	150	'730.960	'190.640	'79,31	'20,69	
	170	'750.708	'170.892	'81,46	'18,54	
	190	'766.596	'155.004	'83,18	'16,82	
6 - Lake	110	'191.527	'115.673	'62,35	'37,65	'307.200
	130	'214.546	'92.654	'69,84	'30,16	
	150	'238.419	'68.781	'77,61	'22,39	
	170	'262.989	'44.211	'85,61	'14,39	
	190	'284.319	'22.881	'92,55	'7,45	
7 - Flixbus	110	'516.591	'405.009	'56,05	'43,95	'921.600
	130	'574.872	'346.728	'62,38	'37,62	
	150	'616.211	'305.389	'66,86	'33,14	
	170	'642.011	'279.589	'69,66	'30,34	
	190	'699.387	'222.213	'75,89	'24,11	
8 - Golf	110	'84.720	'75.280	'52,95	'47,05	'160.000
	130	'91.040	'68.960	'56,90	'43,10	
	150	'97.351	'62.649	'60,84	'39,16	
	170	'105.032	'54.968	'65,64	'34,35	
	190	'112.236	'47.764	'70,15	'29,85	
9 – Latte Art	110	'30.688	'129.312	'19,18	'80,82	'160.000
	130	'50.522	'109.478	'31,58	'68,42	
	150	'70.379	'89.621	'43,99	'56,01	
	170	'87.003	'72.997	'54,38	'45,62	
	190	'104.502	'55.498	'65,31	'34,69	
10 - Linus Torvalds	110	'834.667	'86.933	'90,57	'9,43	'921.600
	130	'863.123	'58.477	'93,65	'6,35	
	150	'879.895	'41.705	'95,47	'4,53	
	170	'888.030	'33.570	'96,36	'3,64	
	190	'894.399	'27.201	'97,05	'2,95	

Table 5.14: Table of Manual Threshold (Discrete image 11-20)

Discrete image	Threshold	Frequency (pixels)		Percentage (%)		Total Pixels
		Black	White	Black (Background)	White (Object)	
11 - Monas	110	'349.927	436.505	'44,50	'55,50	'786.432
	130	'411.549	'374.883	'52,33	'47,67	
	150	'485.279	'301.153	'61,71	'38,29	
	170	'572.172	'214.260	'72,76	'27,24	
	190	'650.767	'135.665	'82,75	'17,25	
12 - Office	110	'120.169	'539.831	'18,21	'81,79	'660.000
	130	'155.832	'504.168	'23,61	'76,39	
	150	'235.095	'424.905	'35,62	'64,38	
	170	'361.626	'298.374	'54,79	'45,21	
	190	'474.521	'185.479	'71,90	'28,10	
13 – Oil Rig	110	'124.800	'35.200	'78,00	'22,00	'160.000
	130	'128.111	'31.889	'80,07	'19,93	
	150	'140.764	'19.236	'87,98	'12,02	
	170	'152.820	'7180	'95,51	'4,49	
	190	'155.868	'4132	'97,42	'2,58	
14 - PC	110	'207.503	'99.697	'67,55	'32,45	'307.200
	130	'235.374	'71.826	'76,62	'23,38	
	150	'264.772	'42.428	'86,19	'13,81	
	170	'277.429	'29.771	'90,31	'9,69	
	190	'282.217	'24.983	'91,87	'8,13	
15 - People	110	'73.721	'586.279	'11,17	'88,83	'660.000
	130	'85.698	'574.302	'12,98	'87,02	
	150	'101.680	'558.320	'15,41	'84,59	
	170	'126.040	'533.960	'19,10	'80,90	
	190	'153.666	'506.334	'23,28	'76,72	
16 - Pizza	110	'196.404	'283.596	'40,92	'59,08	'480.000
	130	'222.623	'257.377	'46,38	'53,62	
	150	'244.289	'235.711	'50,89	'49,11	
	170	'274.659	'205.341	'57,22	'42,78	
	190	'318.453	'161.547	'66,34	'33,66	
17 - Rubic	110	'70.430	'409.570	'14,67	'85,33	'480.000
	130	'76.497	'403.503	'15,94	'84,06	
	150	'117.084	'362.916	'24,39	'75,61	
	170	'230.900	'249.100	'48,10	'51,90	
	190	'328.416	'151.584	'68,42	'31,58	
18 – Shark Archipelago	110	'50.334	'15.202	'76,80	'23,20	'65.536
	130	'52.730	'12.806	'80,46	'19,54	
	150	'54.982	'10.554	'83,90	'16,10	
	170	'57.213	'8323	'87,30	'12.70	
	190	'59.058	'6478	'90,12	'9.88	
19 - Skyscraper	110	'734.320	'314.768	'70,00	'30,00	'1.049.088
	130	'786.771	'262.317	'75,00	'25,00	
	150	'837.675	'211.413	'79,85	'20,15	
	170	'878.203	'170.885	'83,71	'16,29	
	190	'914.578	'134.510	'87,18	'12,82	
20 – Social Media	110	'335.914	'713.174	'32,02	'67,98	'1.049.088
	130	'338.631	'710.457	'32,28	'67,72	
	150	'341.574	'707.514	'32,56	'67,44	
	170	'350.764	'698.324	'33,44	'66,56	
	190	'371.058	'678.030	'35,37	'64,63	

Table 5.15: Table of Manual Threshold (Camouflage image 1-10)

Camouflage image	Threshold	Frequency (pixels)		Percentage (%)		Total Pixels
		Black	White	Black (Background)	White (Object)	
1 – Frog	110	24.592	40.944	37,52	62,48	65.536
	130	36.372	29.164	55,5	44,5	
	150	47.796	17.740	72,93	27,07	
	170	55.199	10.337	84,23	15,77	
	190	59.316	6.220	90,51	9,49	
2 - Iguana	110	87.532	72.468	54,71	45,29	160.000
	130	109.456	50.544	68,41	31,59	
	150	130.388	29.612	81,49	18,51	
	170	144.265	15.735	90,17	9,83	
	190	152.904	7.096	95,57	4,43	
3 - Stingray	110	74.466	246.534	23,20	76,80	321.000
	130	143.266	177.734	44,63	55,37	
	150	231.473	89.527	72,11	27,89	
	170	283.999	37.001	88,47	11,53	
	190	305.121	15.879	95,05	4,95	
4 - Snake	110	104.119	203.081	33,89	66,11	307.200
	130	134.531	172.669	43,79	56,21	
	150	169.172	138.028	55,07	44,93	
	170	209.989	97.211	68,36	31,64	
	190	251.923	55.277	82,01	17,99	
5 – Leopard	110	23.980	283220	7,81	92,19	307.200
	130	43.167	264.033	14,05	85,95	
	150	74.676	232.524	24.31	75,69	
	170	124.180	183.020	40,42	59,58	
	190	187.152	120.048	60,92	39,08	
6 – Owl	110	169.820	137.380	55,28	44,72	307.200
	130	201.805	105.395	65,69	34,31	
	150	228.728	78.472	74,46	25,54	
	170	251.404	55.796	81,84	18,16	
	190	271.247	35.953	88,30	11,70	
7 - Cat	110	333.795	350.845	48,75	51,25	684.640
	130	410.861	273.779	60,01	39,99	
	150	509.282	175.358	74,39	25,61	
	170	592.184	92.456	86,50	13,50	
	190	653.145	31.495	95,40	4,60	
8 – Chameleon	110	145.834	126.270	53,59	46,41	272.104
	130	189.966	82.138	69,81	30,19	
	150	219.248	52.856	80,58	19,42	
	170	238.210	33.894	87,54	12,46	
	190	249.643	22.461	91,75	8,25	
9 – Leafbug	110	465.812	14.188	97,04	2,96	480.000
	130	476.419	3.581	99,25	0,75	
	150	479.978	22	100	0	
	170	480.000	0	100	0	
	190	480.000	0	100	0	
10 – Chameleon	110	415.091	64.909	86,48	13,52	480.000
	130	436.752	43.248	90,99	9,01	
	150	452.322	27.678	94,23	5,77	
	170	463.008	16.992	96,46	3,54	
	190	470.121	9.879	97,94	2,06	

Table 5.16: Table of Manual Threshold (Camouflage image 11-20)

Camouflage image	Threshold	Frequency (pixels)		Percentage (%)		Total Pixels
		Black	White	Black (Background)	White (Object)	
11 – Tiger	110	338.285	448.147	43,02	56,98	786.432
	130	455.629	330.803	57,94	42,06	
	150	563.644	222.788	71,67	28,33	
	170	661.388	125.044	84,10	15,90	
	190	738.686	47.746	93,93	6,07	
12 – Ladybug	110	393.639	392.793	50,05	49,95	786.432
	130	551.835	234.597	70,17	29,83	
	150	698.480	87.952	88,82	11,18	
	170	767.801	18.631	97,63	2,37	
	190	778.826	7.606	99,03	0,97	
13 – Lizard	110	206.205	580.227	26,22	73,78	786.432
	130	272.280	514.152	34,62	65,38	
	150	360.664	425.768	45,86	54,14	
	170	465.051	321.381	59,13	40,87	
	190	567.484	218.948	72,16	27,84	
14 – Lizard	110	452.765	468.835	49,13	50,87	921.600
	130	516.507	405.093	56,04	43,96	
	150	576.974	344.626	62,61	37,39	
	170	643.770	643.770	69,85	30,15	
	190	716.881	204.719	77,79	22,21	
15 – Leafbug	110	326.154	595.446	35,39	64,61	921.600
	130	405.867	515.733	44,04	55,96	
	150	499.817	421.783	54,23	45,77	
	170	613.757	307.843	66,60	33,40	
	190	742.447	179.153	80,56	19,44	
16 – Snake	110	343.615	81.185	80,89	19,11	424.800
	130	364.658	60.142	85,84	14,16	
	150	383.346	41.454	90,24	9,76	
	170	397.783	27.017	93,64	6,36	
	190	411.070	13.730	96,77	3,23	
17 – Fish	110	253.767	188.601	57,37	42,63	442.368
	130	286.754	155.614	64,82	35,18	
	150	321.523	120.845	72,68	27,32	
	170	356.113	86.255	80,50	19,50	
	190	387.730	54.638	87,65	12,35	
18 – Chameleon	110	644.325	404.763	61,42	38,58	1.049.088
	130	733.943	315.145	69,96	30,04	
	150	810.348	238.740	77,24	22,76	
	170	883.032	166.056	84,17	15,83	
	190	944.920	104.168	90,07	9,93	
19 – Turtle	110	752.346	296.742	71,71	28,29	1.049.088
	130	839.170	209.918	79,99	20,01	
	150	904.068	145.020	86,18	13,82	
	170	953.097	95.991	90,85	9,15	
	190	989.970	59.118	94,36	5,64	
20 – Raccoon	110	666.127	382.961	63,50	36,50	1.049.088
	130	819.246	229.842	78,09	21,91	
	150	924.171	124.917	88,09	11,91	
	170	986.477	62.611	94,03	5,97	
	190	1.025.235	23.853	97,73	2,27	

Based on data rows of highest threshold (T = 190) and lowest threshold (T = 110) which applied on all image samples, the average percentage in data

difference of background and data difference of object are calculated with these formula:

$$Bg_{change} = \frac{\sum(Bgp_{T2} - Bgp_{T1})}{N} \qquad Obj_{change} = \frac{\sum(Objp_{T1} - Objp_{T2})}{N}$$

Information:

Bg_{pT2} = Background percentage of highest threshold

Bg_{pT1} = Background percentage of lowest threshold

Obj_{pT1} = Object percentage of lowest threshold

Obj_{pT2} = Object percentage of highest threshold

N = Total of tested images

The purpose of this calculation is to obtain the average of background change and average of object change. The results are same between average of change in background and object: 22,76% in discrete images and 37,53% in camouflage images. Therefore, based on those results proven that discrete images have better segmentation result than camouflage images because of smaller average of change in background and object.