CHAPTER IV

EXPERIMENTAL RESULTS

This section illustrates the training set and test images, the explanation of the depth order error measurement in this dissertation, the experiments of cross validation in 125 depth-of-field images and the comparison of the region of image depth ordering results of our proposed method and the test image with ground truth of the other work.

4.1 The Training and Testing Images

The training and testing images in this work were downloaded from the public website in the internet (http://www.thaiphoto.com/gallery/index.php, http://www.photostock.com, and http://freestockphotos.com) and some images are photos taken by the researcher. All of the images are shown in *Appendix II*. In this dissertation, we categorized the images into 5 groups from 125 images. The amount of images in each groups is equal to 25 images and the condition for selecting the images is the position of in-focus regions. It have 3 kinds of in-focus region's position, appearing in foreground, middleground and background and the proportion of the in-focus position in each group is 10-10-5 images, respectively.

The generalize of the learning and testing processes starting at we selected the 100 images (4 of 5 groups) to be inputs for the neural networks and feed to the networks and using 25 images (1 of 5 groups) to be a cross validating images. After learning process, we tested the networks with the images from the group that have never trained before, then, the error measurement is the next process. We applied the 5-fold cross validation process to measuring the performance of the neural networks in this work.

4.1.1 Applying Cross Validation

We applied the cross validation to the training image sets in order to measure the performance of region depth ordering in each network. We obtained the performance of foreground, middleground and background neural network by measuring the error that measuring from the error measurement equation between the region image depth ordering result image and the groundtruth images. The applied the cross validate by picked one group from five groups of

the image to be a 5-fold cross validating image set and using another four groups of image to be a training images. Then, repeated the collecting process with the image group that not redundant to another image group to be a test images. The 5-fold cross validation can be illustrated in Algorithm 4:

Algorithm 4: 5-fold Cross Validation

1. Dividing the 125 test images into 5 groups (25 images/group) by considering the position of in-focus regions in each image and labeling each group by the index *1 to 5*. The proportion of in-focus region's position in each group is 10-10-5 (foreground - middleground - background).
2. *For* $i = 1$ *to* 5
3. Define image group(i) to be a validating image set and the other groups to be a training image set.
4. Train the three neural network with the three region images of the training image set.
5. Stop learning as soon as the desired error met.
6. Test the learned network with the cross validation set(i), then, measure the error of the region image depth ordering image with the ground truth image.
7. Save the error of the cross validation set(i).
8. *End for.*

The error measurement will appear in the depth's order error measurement section .

4.2 Depth Order Error Measurement

In this section, the error measurement of depth's order from the experimental results on the in-focus regions are compared with the in-focus regions in the groundtruth. The error metric used is the ratio between the depth order extracted regions and the groundtruth regions.

$$Error(\%) = \sum_{q=1}^{Q} \frac{|Q - ((gt_q = 0 \,\&\, ext_q = 0) + (gt_q = 1 \,\&\, ext_q = 1))|}{Q} * 100 \qquad (4.1)$$

where q is the index number that running from 1 to Q, Q is the number of blocks in the test images that is equal to 400, gt and ext are the groundtruth regions and depth order extracted regions. In the error measurement, groundtruth region image are the region of foreground, middleground, and background of the validation images that we use for training and validating. In the programming step, we check the errors by making an error metric size 20-by-20 that equal to the number of block in test image. *Error Checking Algorithm* was used for the error check.

Error Checking Algorithm

1. *For* q = 1 to Q
2. *If* the standard deviation of gt_q and $ext_q > 0$ *then* error metric == 1
3. *Else* temporary array == 0
4. *End if*
5. *End for*

In this work, there are two kinds of false regions in depth's ordering extraction, the false positive and the false negative extracted regions. The false positive region is defined as the total number of positions that their groundtruth are equal to 0 but the extracted result

are equal to 1. On the other hand, the false negative regions is defined as the total number of positions that their groundtruth are equal to 1 and the extracted results are equal to 0. The false-positive and the false-negative equations can be expressed as follows:

$$\begin{aligned} False-positiveerror(\%) &= \left(\frac{gt=0 \ \& \ ext=1}{Total\ Number\ of\ Blocks}\right) * 100 \\ False-negativeerror(\%) &= \left(\frac{gt=1 \ \& \ ext=0}{Total\ Number\ of\ Blocks}\right) * 100 \end{aligned} \tag{4.2}$$

4.3 Cross Validation Results

The cross validation results was reported in the 5 tables, each of tables including to 25 test images that reported the percentage error and the average error of the region image depth ordering results in each network. The Tables A.1 - A.5 in *Appendix I* are shows the error of the cross validation images group 1 to group 5. The error shown in Tables A.1 - A.5 are compared with the regions depth ordering image and the regions groundtruth. Figure C.1 - C.5 in *Appendix III* are shows the regions depth ordering in 5 groups of validating images and Figure D.1 - D.5 in *Appendix IV* are shows the regions of groudtruth images. All of the validation images are shows in Figure B.1 to B.5 in *Appendix II.*

The false positive and the false negative from the cross validation results are shows in Table A.6 to A.10 in Appendix I. Each of table including to the false-positive of foreground regions(pF), the false-negative of foreground regions(nF), the false-potitive of middleground regions(pM), the false-negative of middleground regions(nM), the false-positive of background regions(pB) and the false-negative of background regions(nB). The table was reported the false-positive, and the false-negative in each regions and its average values.
Table 4.1 shows the comparison of average error in 5 validation of test's image group and Table 4.2 shows the comparison of the false-positive and the false-negative in foreground, middleground and background regions.

The average of percentage error of foreground, middleground, and background

	Foreground	Middleground	Background
Cross Validation % Error	10.74	17.52	8.86

Table 4.1: The comparison of average error of depth's ordering in foreground, middleground and background regions from the cross validation process.

regions from the cross validation process can be shows in Table 4.3.
Table 4.4 shows the average value of the false-positive and the false-negative in foreground, middleground, and background region image.

From Table 4.3, the minimum percentage error of foreground region in all validation images is equal to 8.70% and middleground is equal to 12.33%, the minimum percentage error in background regions are have the same value 5.75 % from the three validation image groups 2, 4, and 5.

From Table 4.4, the summarized of minimum percentage false rate are shows below here.

	pF	nF	pM	nM	pB	nB
Cross Validation % False Average Error	2.25	1.25	7.00	5.25	3.00	7.00
Average False	4.83	6.86	11.15	7.36	4.58	9.25

Table 4.2: The average error of the false-positive of foreground(pF), false-negative of foreground(nF), false-positive of middleground(pM), false-negative of middleground(nM), false-positive of background(pB), and false-negative of background(nB) regions from the cross validation process.

Cross Validation Image	Foreground Region	Middleground Region	Background Region
Group 1	11.07	19.08	15.79
Group 2	8.70	20.16	5.75
Group 3	8.87	17.16	11.29
Group 4	8.77	18.87	5.75
Group 5	16.25	12.33	5.75

Table 4.3: The average error of cross validation results in foreground, middleground and background regions.

- The minimum percentage false-positive of foreground region is equal to 2.63% from the validation images group 4.
- The minimum percentage false-negative of foreground region is equal to 6.41% from the validation images group 2.
- The minimum percentage false-positive of middleground region is equal to 9.24% from the validation images group 1.
- The minimum percentage false-negative of middleground region is equal to 3.09% from the validation images group 5.
- The minimum percentage false-positive of background region is equal to 1.25% from the validation images group 5.
- The minimum percentage false-negative of background region is equal to 7.9% from the validation images group 1.

In oder to analyze the percentage error of foreground, middleground, and background regions that have the percentage error less than 5 % and grather than 5%, we had considered the data in Table A.1 to A.5 of Appendix I. The data in all table shows the percentage error of foeground, middleground, and background regions and can be summarized the number of validation image in every groups that have greater than and less than 5% of error in Table 4.5 to Table 4.7.

We had concentrated in validation image that give the error less than 5% and greater 5 % in all foreground, middleground, and background validating. The main reason is neural network give the best and poor performance of learning and testing, respectively. The average is the selected function, by compute the average value of wavelet coefficients in all three regions of interested image. We obtain three values from three regions. These three values are considered again by taking standard deviation over them in order to explain the behavior of data distribution. Finally, the behavior of data distribution can be shown in the

Cross Validation Image	pF	nF	pM	nM	pB	nB
Cross Validation Image Group 1	5.55	6.48	9.24	2.25	1.00	9.75
Cross Validation Image Group 2	3.25	6.41	11.3	4.00	2.50	1.50
Cross Validation Image Group 3	2.71	7.16	10.88	1.50	0.25	3.75
Cross Validation Image Group 4	2.63	7.24	14.10	6.00	0.50	11.00
Cross Validation Image Group 5	10.1	7.05	10.24	6.00	4.75	9.00

Table 4.4: The false-positive of foreground(pF), the false-negative of foreground(nF), the false-positive of middleground(pM), the false-negative of middleground(nM), the false-positive of background(pB), and the false-negative of background(nB) in all cross validation image groups.

Number of Cross Validation Image groups	Less than 5%	Grather than 5%
Cross Validation Image Group 1	14	11
Cross Validation Image Group 2	11	14
Cross Validation Image Group 3	10	15
Cross Validation Image Group 4	8	17
Cross Validation Image Group 5	16	9

Table 4.5: The cross validation error results of foreground region.

Fig. 4.1, Fig. 4.2, and Fig. 4.3.

4.4 Comparison to the related work method

Our works can be comparing to the approach of Saxena et al.[9] from the Stanford University on the same constraint that the imaging system is unknown and based on the machine learning approach. Our work is based on the machine learning of the texture information of three difference regions in an images and our work products are the regions image that ordering by the logical depth. The Saxena approach is based on capturing the depth and relationship between depths using an Markov Random Fields(MRFs) that is the stochastic machine. They are generate the relative depth map to be an outputs and we can applied the depth map of Sexana approach into three regions (foreground, middleground and background) by using the threshold values of the depth map to separate the depth's region in a depth map. The test image and the approach can be downloaded at their websited (http://ai.stanford.edu/ asaxena/learningdepth/data.html).

It have two parts of procedure of the comparison method.

1. Testing the Standforrd test images with our region image depth ordering method.
2. Measuring the percentage error of the ordering results image with the Standford groundtruth images.

Because our constraint of the training and testing images are DOF type image but

Number of Cross Validation Image groups	Less than 5%	Grather than 5%
Cross Validation Image Group 1	5	20
Cross Validation Image Group 2	1	24
Cross Validation Image Group 3	1	24
Cross Validation Image Group 4	2	23
Cross Validation Image Group 5	5	20

Table 4.6: The cross validation error results of middleground region.

Number of Cross Validation Image groups	Less than 5%	Greater than 5%
Cross Validation Image Group 1	5	20
Cross Validation Image Group 2	5	20
Cross Validation Image Group 3	6	19
Cross Validation Image Group 4	3	22
Cross Validation Image Group 5	5	20

Table 4.7: The cross validation error results of background region.

the Stanford test images are have a little of DOF type image, so, we selected the image that contains the region of in-focus and blurred from the Standford University websited. Figure. 4.4 and Fig.4.5 are twelve test images its groundtruth images from the Standford data test.

Table 4.8 and Table 4.9 shows the percentage error and the false-positive and the false-negative errors in foreground, middleground, and background regions of twelve Standford's test images.

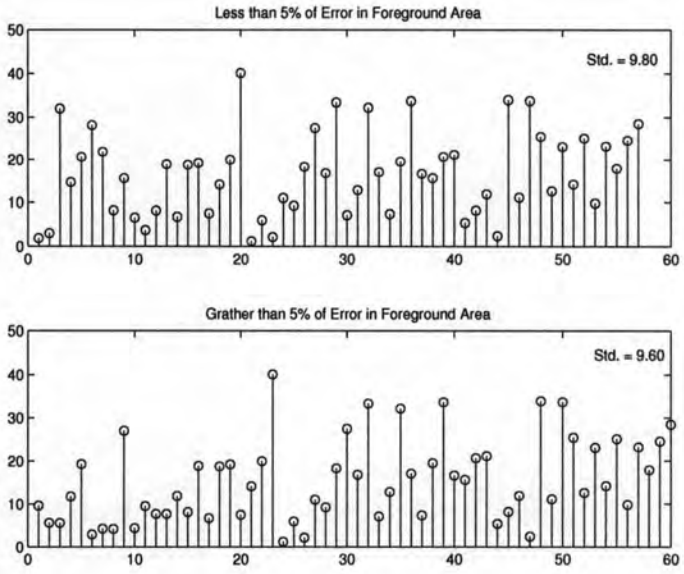


Figure 4.1: The data distribution of percentage error in foreground region. The upper graph shows the less than 5% of image group and the lower shows greater than 5% of image group.

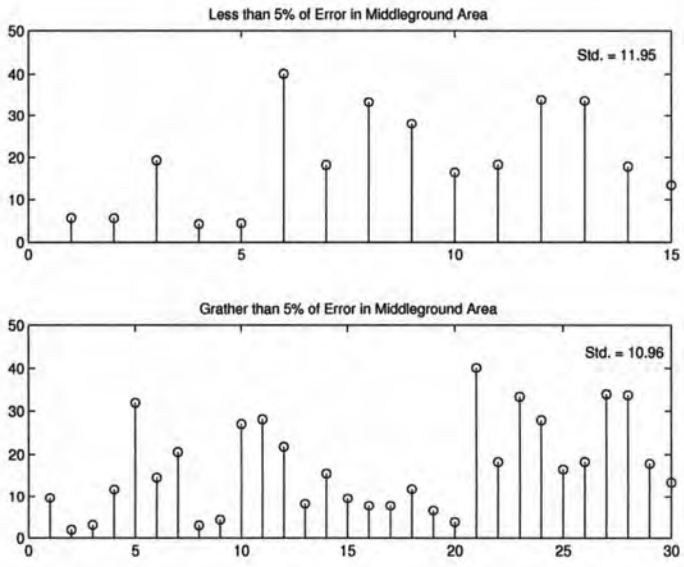


Figure 4.2: The data distribution of percentage error in middleground region. The upper graph shows the less than 5% of image group and the lower shows greater than 5% of image group.

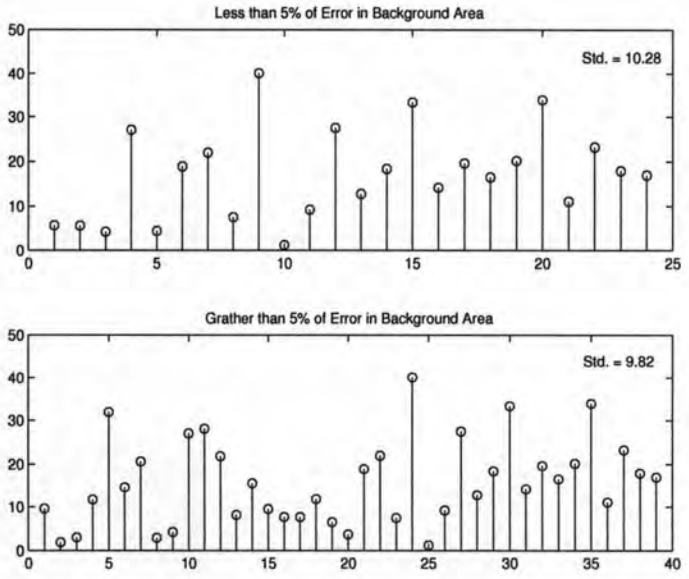


Figure 4.3: The data distribution of percentage error in background region. The upper graph shows the less than 5% of image group and the lower shows greater than 5% of image group.

% Error	Foreground	Middleground	Background
Test Image 1	28.50	15.75	4.00
Test Image 2	3.75	5.75	2.75
Test Image 3	15.75	54.75	40.75
Test Image 4	19.50	20.00	5.00
Test Image 5	20.75	15.75	2.75
Test Image 6	19.50	26.25	5.00
Test Image 7	35.50	22.00	1.25
Test Image 8	13.50	12.25	2.50
Test Image 9	12.75	17.75	6.00
Test Image 10	16.25	15.75	2.00
Test Image 11	9.50	13.00	3.50
Test Image 12	18.25	19.75	3.50
Avarage Error	10.06	12.43	5.75

Table 4.8: The error and its average of the test images from Standford University test image.

Test image 1.

Test image 2.

Test image 3.

Test image 4.

Test image 5.

Test image 6.

Test image 7.

Test image 8.

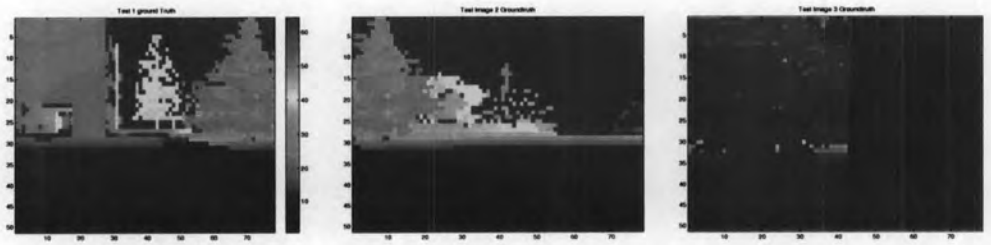
Test image 9.

Test image 10.

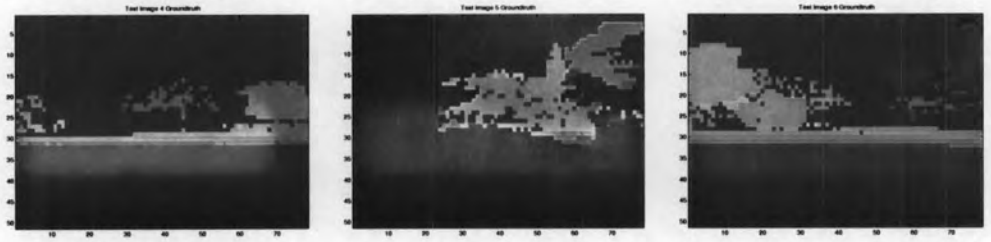
Test image 11.

Test image 12.

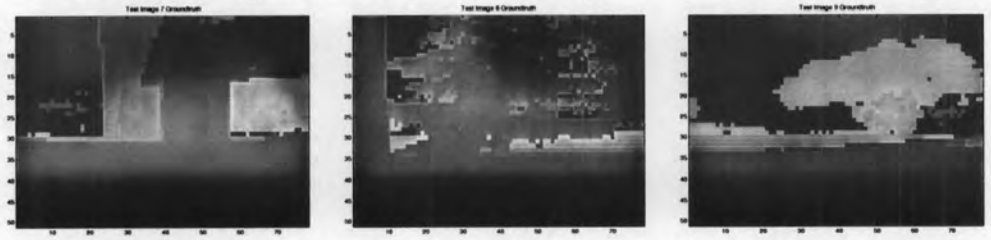
Figure 4.4: The twelve test images from Stanford University.



Groundtruth image 1. Groundtruth image 2. Groundtruth image 3.



Groundtruth image 4. Groundtruth image 5. Groundtruth image 6.



Groundtruth image 7. Groundtruth image 8. Groundtruth image 9.

Groundtruth image 10. Groundtruth image 11. Groundtruth image 12.

Figure 4.5: The twelve groundtruth images from Stanford University.

% Error	pF	nF	pM	nM	pB	nB
Test Image 1	0.25	47.25	49.00	1.75	2.50	2.50
Test Image 2	0.25	4.50	5.25	1.50	3.00	0.75
Test Image 3	16.00	0.75	39.50	16.25	0.25	41.50
Test Image 4	0.25	20.25	20.75	0.25	0.50	5.50
Test Image 5	21.25	0.50	1.00	15.75	0.25	3.50
Test Image 6	0.25	20.25	20.25	7.00	5.50	0.50
Test Image 7	0.25	56.25	59.25	1.75	2.00	0.25
Test Image 8	4.50	10.00	8.25	5.00	1.75	1.75
Test Image 9	0.25	13.50	18.50	0.25	0.25	6.75
Test Image 10	0.25	17.00	16.50	0.25	0.25	2.75
Test Image 11	0.25	10.25	11.00	3.00	3.00	1.50
Test Image 12	0.25	19.00	19.75	1.00	0.75	3.75
Average False	1.76	8.78	10.76	2.15	0.81	2.84

Table 4.9: The error and its average of the false positive and the false negative in foreground, middleground and background regions classification of Standford University test image.