7. Segmentation using VQ based Clustering on Entropy images

7.1 Introduction

As we have seen in chapter 6 some US images responded well when their structure has been changed. However Type-D images of the dataset still remain a challenge task due to their complex structure. As we discussed earlier, every US breast image has different structure, texture pattern, tumor shape, fuzzy boundary. Due to this phenomenon achievement of the general algorithm is not a trivial problem. However to move near to the generality we have decided not to leave problem unsolved up to some extent. Therefore in order to cover most of the images of our dataset we thought to have some another statistical parameter for texture analysis which can change the structure of US image differently. During the literature survey we come across many first order statistical parameters such as correlation, wavelet transform, variance, and entropy [201-206].

In chapter 6, probability has been explored and used as vital statistical parameter in order to change the structure of original US images. These new images with changed structure are called as probability images. Subsequently we observed that these probability images can be used as input to calculate the entropy of the image. Therefore entropy has been selected as another statistical parameter where probability could not perform well. As we have discussed earlier the segmentation is local problem and pertain to single image and single entropy value of entire image has no significance. Therefore we used convolution of the small window over entire probability image and investigated the regional entropy. Therefore in order to change the regional statistics, entropy values are calculated over a small
kernel and inserted at the center. Eventually entropy images are generated and further used as input to the clustering algorithms to extract the region of interest. Flow of the proposed algorithm with entropy is shown in Figure 7.1. Primarily entropy images are generated using two different kernels (i.e. 3x3 and 5x5) to see the difference in the structure and usefulness in the segmentation process.

![Figure 7.1: Flow of the proposed algorithm](image)

**7.2 Segmentation on probability images**

As discussed earlier some images from dataset (i.e. particularly Type-D images) have extremely difficult structure and not responded well to the earlier implemented algorithms in segmentation process. Indeed these algorithms are able to detect the tumor but unable to produce proper demarcation. As we have discussed, **augmented KFCG 3x3** is the most suitable algorithm for segmentation of
maximum images of the dataset. Therefore we selected this algorithm to demonstrate results when it is applied directly on some original US images of the dataset. Primarily two original US images are used in this chapter to show results of the proposed algorithm. However prior to that we have also shown the results of these images obtain by earlier proposed algorithms (i.e. augmented KFCG 3x3). In this section, segmentation results of original US images, its probability images and histogram equalized probability images are shown. Results of “Image-1” and “Image-2” are shown in Figure 7.2 and Figure 7.3 respectively. According to the radiologist’s opinion these results are rated as Poor and not acceptable.

7.2.1 Segmentation results of “Image-1”

(a) Result for Original US “Image-1”

(b) Result for Probability image
Segmentation using VQ based Clustering on Entropy Images

Figure 7.2  Segmentation results for “Image-1” obtained by augmented KFCG 3x3

7.2.2 Segmentation results of “Image-2”

(a) Result for Original US “Image-2”

(b) Result for Probability image
Observation: As shown in Figure 7.2 and Figure 7.3 augmented KFCG 3x3 cannot produce proper tumor demarcation for original US images, probability images and histogram equalized probability images. For “Images-1” this algorithm is able to detect the tumor. However for original US image and histogram equalized probability images it gives over segmentation and for probability image it gives under segmentation. For “Images-2”, probability and histogram equalized probability images gives over segmentation and for original US image, it gives under segmentation. Therefore all the results are considered as Poor according to the radiologist’s opinion. Refer Appendix-A, section E.1.1 and section E.2.1.

7.3 Entropy and its Histogram Equalized Images

Entropy basically deals with the amount of uncertainty (i.e. disorder) in the random information (i.e. signal). US breast Image is nothing but the representation of enormously random values, therefore entropy is used as useful information to quantify, manipulate...
and represent the uncertainty. This concept was initially introduced by Shannon [207] in communication theory, now a day it has been extensively used in various domain and image processing is one of them [208-213]. Following equation is provided by Shannon to calculate the entropy of particular signal (i.e. data):

\[
H = - \sum_{x} P(x) \log P(x)
\]  \hspace{1cm} (7.1)

Where, \( H \) is the entropy, \( P(x) \) is the probability of \( x \) and \( x \) is any random value. Usually entropy can be represents in terms of bits or symbols and higher the uncertainty, more number of bits required. Value provided by equation 7.1 quantifies and represents uncertainty. Most uncertain information in the US images is boundary of the tumor region and heterogeneous texture within the tumor. Therefore this equation has been used here to calculate the entropy over a small region and replaced central value by entropy to make the boundary clear and reduced the heterogeneity of texture.

Primarily in order to achieve this phenomenon, probability images are used as input to calculate the entropy images. Initially probability image is acquired from the original US image using the equation 6.1 shown in chapter 6. Since segmentation is the local problem, we proposed to calculate the entropy over small region. Therefore here two different window sizes 3x3 and 5x5 are used in order to calculate the entropy images over probability images. First entropy has been calculated over these windows to see their gray levels neighborhood relationship and replaced the center value by entropy. Entropy images calculated by using 3x3 and 5x5 windows along with their histogram equalized images shown in Figure 7.4 and Figure 7.5 respectively.
7.3.1 Entropy and histogram equalized entropy images for “Image-1”

Figure 7.4  Original US “Image-1”

Figure 7.5  Entropy image and its histogram equalized image obtained for original US “Image-1” using 3x3 window
Observation: as shown in Figure 7.5 (a1) and Figure 7.6 (a1) distribution of pixel intensities are changes and concentrated at higher end of the histogram obtained from the entropy 3x3 and entropy 5x5 images. Entropy images shown in Figure 5.5 (a) and Figure 7.6 (a) reflects the change in the structure. However boundary of the tumor is not clear and mixed with the background. On the other hand after histogram equalization of entropy images the tumor boundary is clearer than both the images (i.e. entropy and original US “Image-1”) particularly at the lower end of the tumor shown in Figure 7.5 (b) and Figure 7.6 (b). Primarily blurriness has been removed present at the lower end of the original image. This change in the intensity levels is substantial and has impact on the end segmentation results shown in section 7.4.
7.3.2 Entropy and histogram equalized entropy images for “Image-2”

![Original US “Image-2”](image_url)

**Figure 7.7** Original US “Image-2”

(a) Entropy Image (3x3 window)  
(b) Histogram Equalized entropy image

![Histograms](image_url)

**Figure 7.8** Entropy image and its histogram equalized image obtained for original US “Image-1” using 3x3 window
Figure 7.9  Entropy image and its histogram equalized image obtained for original US “Image-1” using 5x5 window

Observation: as shown in Figure 7.7 tumor structure in the original US “Image-2” is not clear and contains excessive amount of heterogeneous texture within the tumor region. However it has been changed up to certain extent in entropy 3x3 and entropy 5x5 images shown Figure 7.8 (a) and Figure 7.9 (a) respectively. Here intensities are changed and concentrated at higher end of the histogram same as earlier results, shown in Figure 7.8 (a1) and Figure 7.9 (a1). Tumor boundary becomes clearer than the original US “Image-2” in histogram equalized entropy images shown in Figure 7.8 (b1) and Figure 7.9 (b1). This change in the intensity levels is substantial and has impact on the end segmentation results shown in section 7.4.
7.4 Results and analysis

As shown in the Figure 7.1, entropy and its histogram equalized images are used as input to the clustering process. In this chapter following four codebook generation algorithms are used for clustering since they have proven their effectiveness in the segmentation.

1. Augmented KMCG 2x2
2. Augmented KFCG 2x2
3. Augmented KMCG 3x3
4. Augmented KFCG 3x3

All the segmentation results are displayed according to above shown codebook generation algorithms for entropy and histogram equalized entropy images. In all the results, three things are shown firstly selected merged cluster, secondly separated tumor after post processing and finally demarcated tumor superimposed on original image.

7.4.1 Segmentation results for “Image-1”

In this section segmentation results are shown, obtained by selected codebook generation algorithms on entropy images.

1. Results for augmented KMCG 2x2 algorithm

(a) Results for Entropy Images with 3x3 window
(i) Fourth merged cluster image
(ii) After post processing
(iii) Superimposed image

(b) Results for **Entropy Images** with **5x5** window

(i) Fourth merged cluster image
(ii) After post processing
(iii) Superimposed image

(c) Results for **Histogram equalized entropy Images** with **3x3** window

(i) Fourth merged cluster image
(ii) After post processing
(iii) Superimposed image

(d) Results for **Histogram equalized entropy Images** with **5x5** window

**Figure 7.10**  Segmentation results obtained by augmented KMCG 2x2

**Observation:** results obtained by **augmented KMCG 2x2** on entropy 3x3, entropy 5x5 and its histogram equalized images are **Moderate** as shown in Figure 7.10 (a), (b), (c) and (d). Refer **Appendix-A, sections E.1.2 to E.1.5**.
2. Results for augmented KFCG 2x2 algorithm

(a) Results for Entropy Images with 3x3 window

(b) Results for Entropy Images with 5x5 window

(c) Results for Histogram equalized entropy Images with 3x3 window
Observation: results obtained by augmented KFCG 2x2 on entropy 3x3, entropy 5x5 are Poor and not accepted by the radiologists shown in Figure 7.11 (a) and Figure 7.11 (b). However results obtained on its histogram equalized images are accepted as Moderate as shown in Figure 7.11 (c) and Figure 7.11 (d). Refer Appendix-A, sections E.1.2 to E.1.5.

3. Results for augmented KMCG 3x3 algorithm

(a) Results for Entropy Images with 3x3 window
Segmentation using VQ based Clustering on Entropy Images

Observation: results obtained by augmented KMCG 3x3 on entropy 3x3, entropy 5x5 and its histogram equalized images are accepted as Moderate as shown in Figure 7.12 (a), (b), (c) and (d). Refer Appendix-A, sections E.1.2 to E.1.5.
4. Results for augmented KFCG 3x3 algorithm

(a) Results for **Entropy Images** with 3x3 window

(b) Results for **Entropy Images** with 5x5 window

(c) Results for **Histogram equalized entropy Images** with 3x3 window
Segmentation using VQ based Clustering on Entropy Images

(i) Fourth merged cluster image  
(ii) After post processing  
(iii) Superimposed image 

(a) Results for **Histogram equalized entropy Images** with **5x5** window 

**Figure 7.13** Segmentation results obtained by augmented KFCG 3x3 

**Observation:** results obtained by **augmented KFCG 3x3** on entropy 3x3, entropy 5x5 are **Poor** and not accepted by the radiologists shown in Figure 7.13 (a) and Figure 7.13 (b). However results obtained on its histogram equalized images are accepted as **Moderate** as shown in Figure 7.13 (c) and Figure 7.13 (d). **Refer Appendix-A, sections E.1.2 to E.1.5.** 

7.4.2 Segmentation results for “Image-2”

In this section segmentation results are shown, obtained by selected codebook generation algorithms on entropy images. 

1. **Results for augmented KMCG 2x2 algorithm** 

(a) Results for **Entropy Images** with **3x3** window
Observation: results obtained by augmented KMCG 2x2 on entropy 3x3, entropy 5x5 and its histogram equalized images are considered as Poor shown in Figure 7.14 (a), (b), (c) and (d). Refer Appendix-A, sections E.2.2 to E.2.5.
2. Results for augmented KFCG 2x2 algorithm

(a) Results for **Entropy Images** with 3x3 window

(b) Results for **Entropy Images** with 5x5 window

(c) Results for **Histogram equalized entropy Images** with 3x3 window
Observation: Results obtained by augmented KFCG 2x2 on entropy 3x3 is considered as Poor shown in Figure 7.15 (a). Whereas entropy 5x5 and its histogram equalized image are considered as Moderate shown in Figure 7.15 (c) and (d). Result obtained on histogram equalized entropy 3x3 is considered as Good shown in Figure 7.15 (b). Refer Appendix-A, sections E.2.2 to E.2.5.

3. Results for augmented KMCG 3x3 algorithm

(a) Results for Entropy Images with 3x3 window
Segmentation using VQ based Clustering on Entropy Images

(b) Results for Entropy Images with 5x5 window

(c) Results for Histogram equalized entropy Images with 3x3 window

(d) Results for Histogram equalized entropy Images with 5x5 window

Figure 7.16 Segmentation results obtained by augmented KMCG 3x3

Observation: Results obtained by augmented KMCG 3x3 on entropy 3x3 is considered as Poor. Other results are accepted as Moderate shown in Figure 7.16 (b), (c) and (d). Refer Appendix-A, sections E.2.2 to E.2.5.
4. Results for augmented KFCG 3x3 algorithm

(a) Results for Entropy Images with 3x3 window

(b) Results for Entropy Images with 5x5 window

(c) Results for Histogram equalized entropy Images with 3x3 window
Segmentation using VQ based Clustering on Entropy Images

Figure 7.17 Segmentation results obtained by augmented KFCG 3x3

**Observation:** Results obtained by augmented KFCG 3x3 on entropy 3x3 is considered as Poor. Results obtained on entropy 5x5 and its histogram equalized images are accepted as Moderate shown in Figure 7.17 (b) and (d). Whereas results obtained on histogram equalized entropy 3x3 gives Good results. Refer Appendix-A, sections E.2.2 to E.2.5.

From the above results and overall observation it has been clear that only augmented KFCG 2x2 and augmented KFCG 3x3 gives Good results in case of histogram equalized entropy 3x3 images. For all other images and algorithms either it produced Moderate or Poor results. Next section summarized the overall result of proposed algorithm.

### 7.4.3 Comparison with other results

As discussed earlier augmented KFCG 3x3 gives acceptable results for both “Image-1” and “Image-2” as shown in Figure 7.18 (c) and Figure 7.19 (c) respectively. Table 7.1 summarized the overall results and helps to draw the useful conclusion.
As shown in Table 7.1 augmented KFCG 3x3 gives proper results for both the image. For “Image-1” all the codebook generation algorithms provide either Moderate or Poor results. However these algorithms produced three types of results for “Image-2”. (i.e. Good, Moderate and Poor) Amongst these algorithms augmented KFCG 3x3 has lowest time complexity along with the accurate results.
### Table 7.1 Result analysis in consultation with the radiologists

<table>
<thead>
<tr>
<th>Original US Images</th>
<th>Codebook Generation Algorithms</th>
<th>Input Images</th>
<th>Accuracy of Tumor Demarcation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Image-1</strong> (Malignant)</td>
<td>Augmented KMCG 2x2</td>
<td>Entropy 3x3</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Entropy 5x5</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Histogram EE 3x3</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Histogram EE 5x5</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Augmented KFCG 2x2</td>
<td>Entropy 3x3</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Entropy 5x5</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Histogram EE 3x3</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Histogram EE 5x5</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Augmented KMCG 3x3</td>
<td>Entropy 3x3</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Entropy 5x5</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Histogram EE 3x3</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Histogram EE 5x3 5x5</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Augmented KFCG 3x3</td>
<td>Entropy 3x3</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Entropy 5x5</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Histogram EE 3x3</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Histogram EE 5x5</td>
<td>Moderate</td>
</tr>
<tr>
<td><strong>Image-2</strong> (Malignant)</td>
<td>Augmented KMCG 2x2</td>
<td>Entropy 3x3</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Entropy 5x5</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Histogram EE 3x3</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Histogram EE 5x5</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td>Augmented KFCG 2x2</td>
<td>Entropy 3x3</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Entropy 5x5</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Histogram EE 3x3</td>
<td>Moderate</td>
</tr>
</tbody>
</table>
### 7.5 Complexity analysis

In this chapter four selected VQ based algorithms are used for clustering. We have studied and implemented these algorithms in chapter 5 along with the complexity analysis. Here we found that augmented KFCG is the fastest amongst all algorithms with complexity $6M + M(K-1)$. Therefore computational complexity remains same with the additional time required to calculate the entropy images.

### 7.6 Observation and discussion

As discussed earlier all the results are validated **unanimously** by the panel of three experts. We have considered not only accuracy but also time complexity of algorithms while finalizing the results. Following points are observed during study and experimentation.

1. Using entropy image structure of the original images are change significantly, which help to understand the nature of tumor. Two different window sizes (i.e. 3x3) are used to obtain the entropy images. We also tried the histogram equalized entropy images as input to the clustering algorithms.
2. Four selected codebook generation algorithms are used on these input images for clustering.

3. We observed that when these algorithms are applied to Type-D original images, poor segmentation results are obtained.

4. Augmented KFCG 3x3 produced acceptable results for both the image shown in this chapter.

5. Next chapter describe a novel method of region growing with vector sequencing and neighborhood using VQ based clustering to remaining images of the dataset effectively.