Biomedical Assignment 3

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INTRODUCTION

This assignment is on improving segmentation accuracy by gaining the benefits of both clustering based segmentation method and graph cut based segmentation method.Here we're segmenting lession from skin using both type of clustering. Following are the steps for the same.

1 Task 1 :Histogram-based approach to assign the class label

Histogeam based clustering estimation(HBCE) is a different approach than previously proposed k-means and mean shift based segmentation algorithm. Here histogram is used to determine the number of clusters and cluster centers.Optimised clusters are determined using Intensity based histogram thresholding and frequency based thresholding.The algorithm for these are as given below,

Flow chart of HBCE algorithm is 1

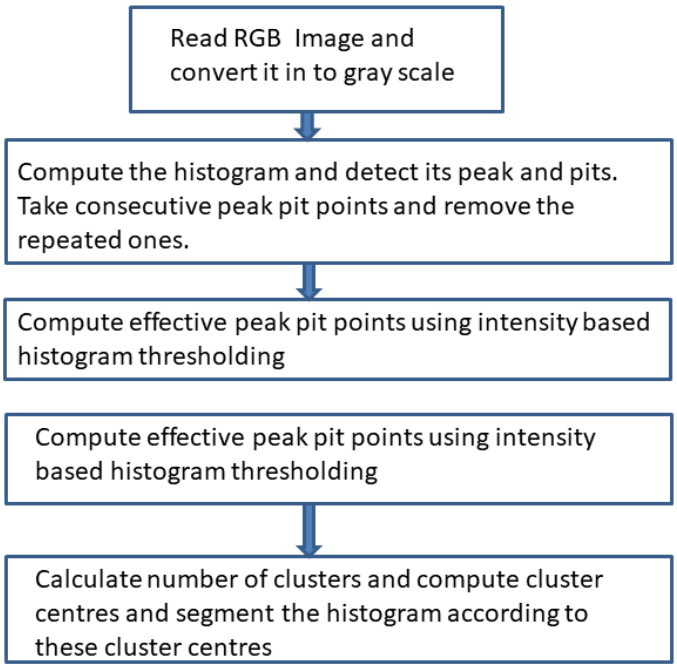


Figure 1: Flow chart for HBCE algorithm

Algorithm for HBCE algorithm-

STEP 1- First the image is converted in to gray scale and its histogram is calculated. Peaks and pits of this histogram is determined in such that they will be in alternate manner.Due to gradients in intensity in an image specially in skin where the intensity varies very gradually filtering of these peaks and pits is necessary which is as described below.

STEP 2- Intensity based Thresholding :

The histogram obtained in step 1 is filtered using intensity based thresholding which basically helps in getting intensity difference of certain distance.

1. First the vector consist of distance value for different consecutive peak and pit intensity value is obtained as,
$$LD(i) = \mid PKL(i) - PTL(i) \mid \tag{1}$$
where PKL(i) is the peak value vector and PTL(i) is the pit value vector.
2. The mean of this difference vector is calculated as $\overline{\text{LD}}$
3. Then the thresholding value of intensity can be obtained as,
$$TH_{intensity} = \overline{\text{LD}} * intensity \tag{2}$$
where $TH_{intensity}$ is the thresholding intensity value.
4. Using $Th_{intensity}$ the peak pit vector intensity of the histogram is scanned(SLD(i)).

STEP 3- Frequency based Thresholding : The intensity thresholded histogram obtained in step 1 is filtered using intensity based thresholding which basically helps in getting frequency difference of certain distance.

1. First the vector consist of diffrence value for different consecutive peak and pit height value is obtained as,
$$HD(i) = \mid hist(SLD(PKL(i))) - hist(SLD(PTL(i))) \mid \tag{3}$$
where hist(SLD(PKL(i))) is the peak of intensity thresholded peak value vector and hist(SLD(PKL(i))) is the pit of intensity thresholded pit value vector.

2. The mean of this difference height vector is calculated as $\overline{\text{HD}} Then the thresholding value of intensity can be obtained as, T$
$\overline{\text{HD}} * frequency$
(4)

3. Using $Th_{frequency}$ the peak pit vector of the histogram is scanned.

STEP 4- The intensity and frequency values can be optimised using Genetic algorithm(GA).

STEP 5- Number of cluster in an image is the size of SHD vector and centroid of each cluster is calculated and accordingly clustering based segmentation is to be done.

OBSERVATIONS:

The result of the above HBCE algorithm for segmenting lesion from skin is as shown in figures below.
In histogram plot the first histogram plot is the modified histogram with alternative peak and pit values. Second one is the intensity thresholded based histogram which removes very consecutive intensity values. The third one is the histogram plot removing consecutive frequency that is region where there is consecutive frequencies which is there in relative value.
In segmented plot the second one is the segmented output using HBCE algorithm.The thresholded intensity values are used to segment the image based on its pit peak values.The for ground region is assigned as white color.

ISIC 00009941 Image :

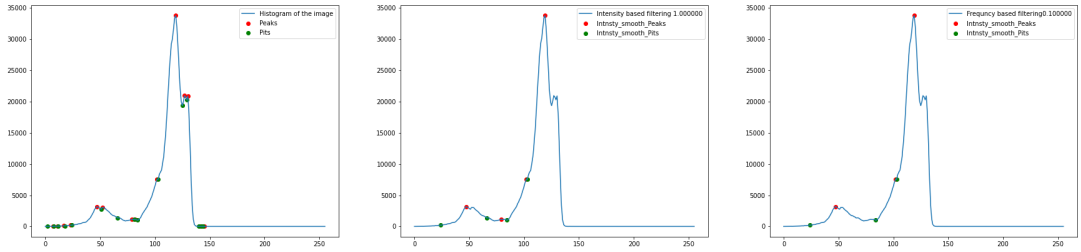


Figure 2: Histogram for HBCE algorithm
(a) Histogram of original image (b) Histogram of intensity thresholded image(c) Histogram of frequency threholded image

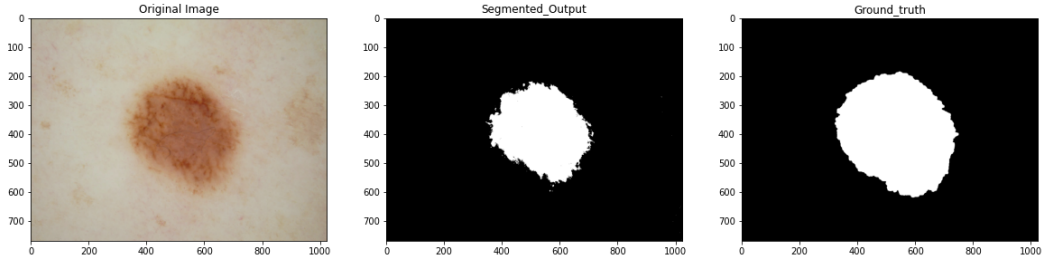


Figure 3: Segmented Output using HBCE algorithm only
(a)Original Image (b)HBCE segmented output (c)Ground truth

COMMENT:-In histogram plot the first histogram plot is the modified histogram with alternative peak and pit values. Second one is the intensity thresholded based histogram with $\beta_{intensity}$ of 1. The third one is the histogram plot removing consecutive frequency using $\beta_{frequency}$ of 0.1
In image segmentation figure, the skin lesin is slowly varying at edges so using histogram based segmentation it only segment the darker area.

ISIC 00009942 Image

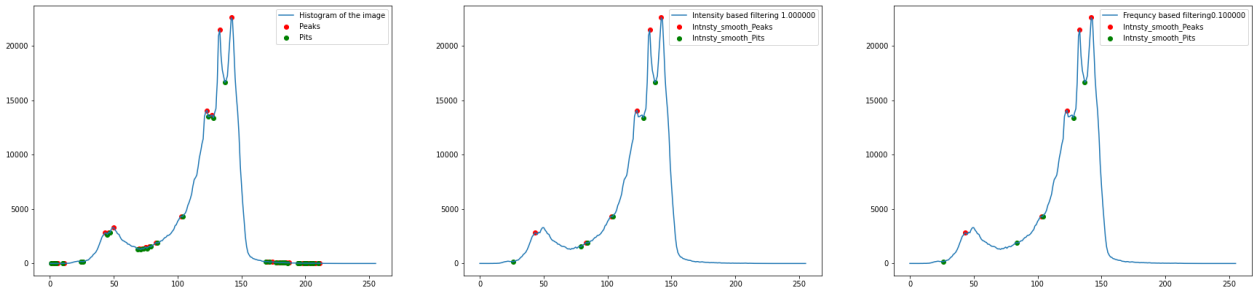


Figure 4: Histogram for HBCE algorithm
(a) Histogram of original image (b) Histogram of intensity thresholded image(c) Histogram of frequency thresholded image

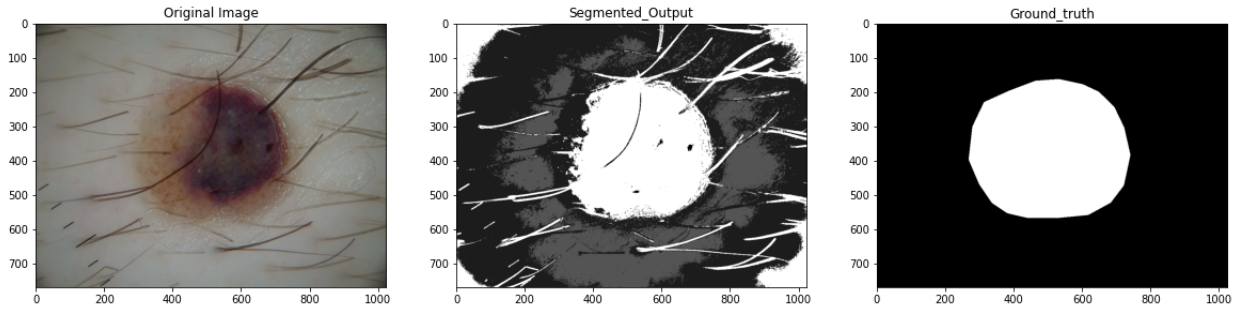


Figure 5: Segmented Output using HBCE algorithm only
(a)Original Image (b)HBCE segmented output (c)Ground truth

COMMENT:-In histogram plot4 the first histogram plot is the modified histogram with alternative peak and pit values. Second one is the intensity thresholded based histogram with $\beta_{intensity}$. The third one is the histogram plot removing consecutive frequency using $\beta_{frequency}$ of 0.1
In image segmentation figure5, the hairs as being dark color also get foreground segment as that of lesion.The corners of the image is white color as due to camera effect the corners have darker color compare to original skin.

ISIC 00009944 Image:

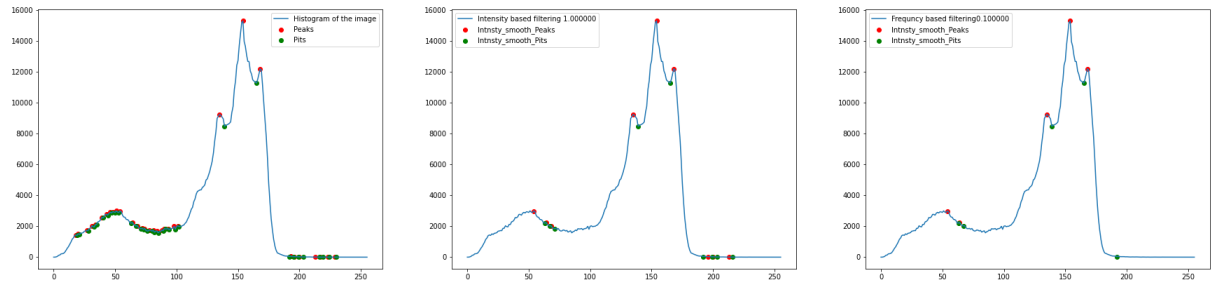


Figure 6: Histogram for HBCE algorithm
(a) Histogram of original image (b) Histogram of intensity thresholded image(c) Histogram of frequency threholded image

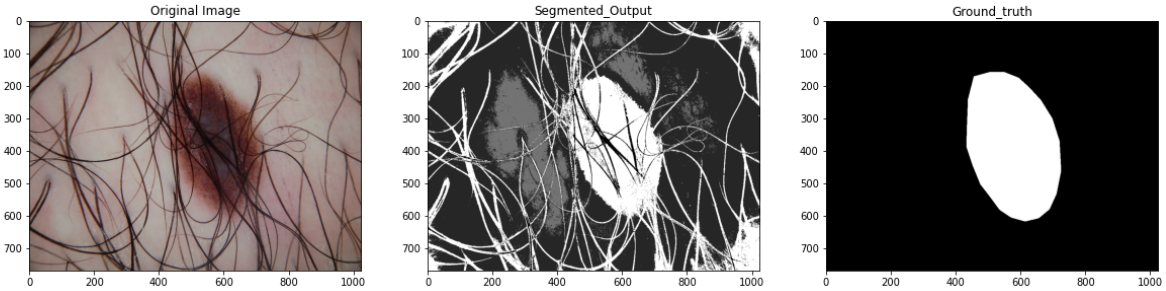


Figure 7: Segmented Output using HBCE algorithm only
(a)Original Image (b)HBCE segmented output (c)Ground truth

COMMENT:-In histogram plot6 the first histogram plot is the modified histogram with alternative peak and pit values. Second one is the intensity thresholded based histogram with $\beta_{intensity}$ of 1. The third one is the histogram plot removing consecutive frequency using $\beta_{frequency}$ of 0.1
In image segmentation figure7, the hairs as being dark color also get foreground segment as that of lesion.The corners of the image is white color as due to camera effect the corners have darker color compare to original skin.In this case hair being darker also get included in fore ground region.

ISIC 00009951 Image

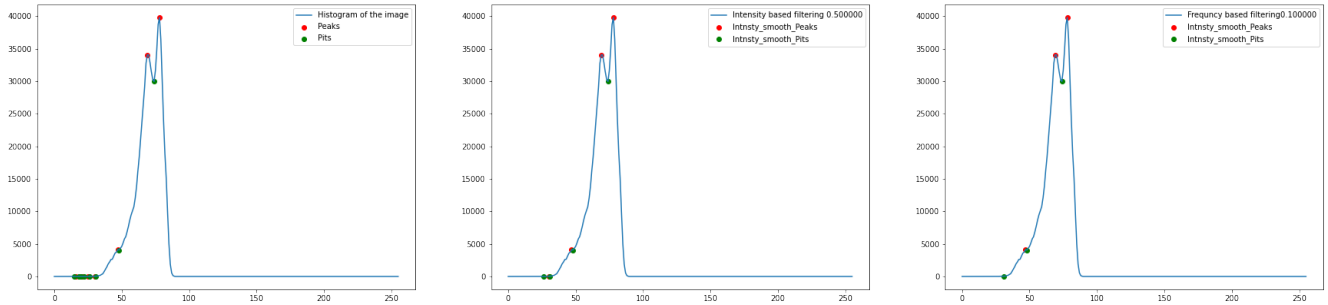


Figure 8: Histogram for HBCE algorithm
(a) Histogram of original image (b) Histogram of intensity thresholded image(c) Histogram of frequency thresholded image

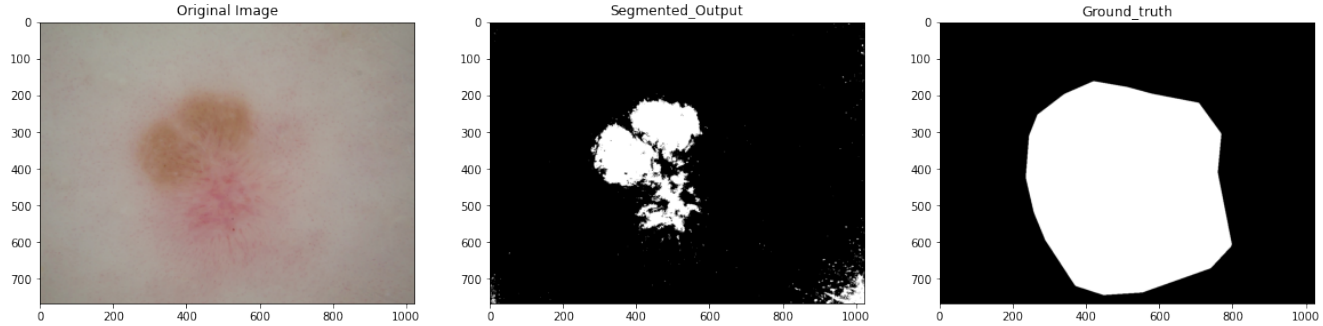


Figure 9: Segmented Output using HBCE algorithm only
(a)Original Image (b)HBCE segmented output (c)Ground truth

COMMENT:-In histogram plot 8 the first histogram plot is the modified histogram with alternative peak and pit values. Second one is the intensity thresholded based histogram with $\beta_{intensity}$ of 0.5. The third one is the histogram plot removing consecutive frequency using $\beta_{frequency}$ of 0.1
From image segmentation figure9, the lesion is of lighter color so its difficult to segment it from background skin color.In this case $\beta_{intensity}$ has been decreased as compared to previous ones so that all peak values of the histogram could remain for segmentation.

ISIC 00009968 Image

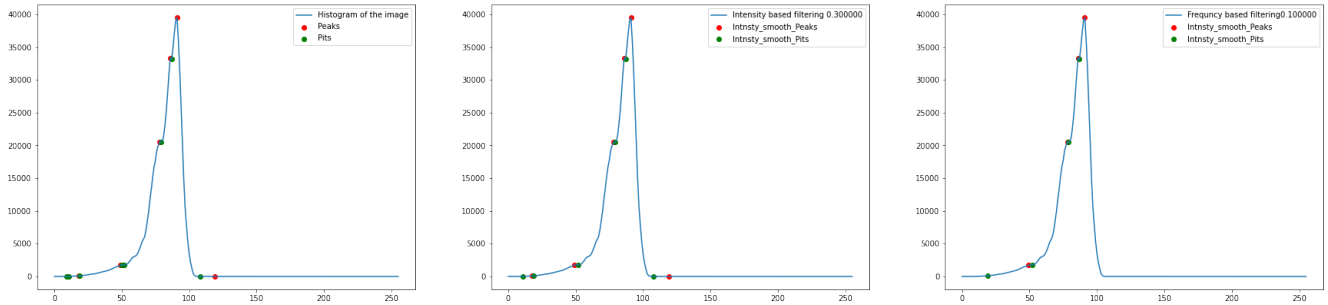


Figure 10: Histogram for HBCE algorithm
(a) Histogram of original image (b) Histogram of intensity thresholded image(c) Histogram of frequency thresholded image

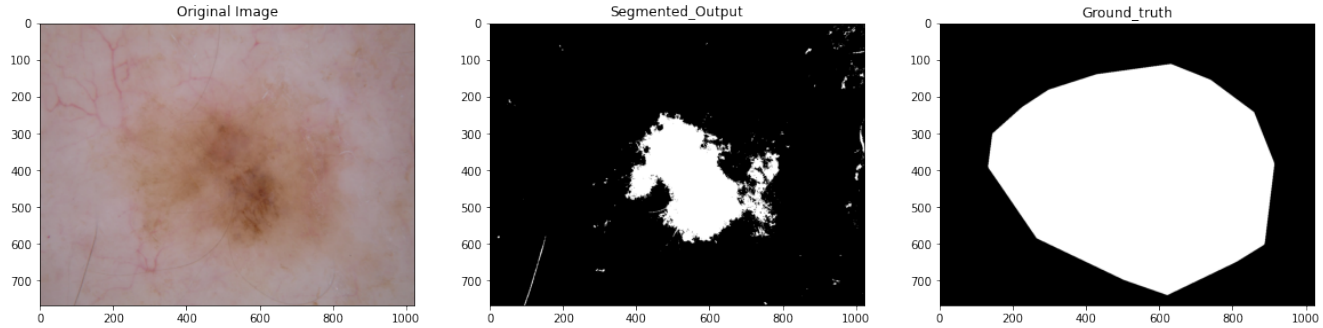


Figure 11: Segmented Output using HBCE algorithm only
(a)Original Image (b)HBCE segmented output (c)Ground truth

COMMENT:-In histogram plot10 the first histogram plot is the modified histogram with alternative peak and pit values. Second one is the intensity thresholded based histogram with $\beta_{intensity}$ of 0.3. The third one is the histogram plot removing consecutive frequency using $\beta_{frequency}$ of 0.1
From image segmentation figure11, the lesion is of lighter color and gradually fading in to skin color,so its difficult to segment it from background skin color.Even from the segmented case the whole lesion couldn't be extracted case because of its comparable color with the skin. In this case $\beta_{intensity}$ has been decreased as compared to previous ones so that all peak values of the histogram could remain for segmentation.
For the above task $\beta_{intensity}1$ and $\beta_{frequency}$ hass been taken randomly in range 0 to 2 observing the histogram plot.This can be optimised using GA algorithm to obtain $\beta_{intensity-optimal}$ and $\beta_{frequency-optimal}$

2 Task 2 :Graph cut method to optimize the delineation of the lesion from the background using minimization algorithms: alpha-expansion and alpha-beta swap

2.1 $\alpha - \beta$ Swap Method

$\alpha - \beta$ Swap method proposed by Yuri Boykov and Marie-Pierre Jolly in [1] to optimise the segmentaion done before. Here the image is divided into "object" and "background" segments using a graph cut approach. A graph is formed by connecting all pairs of neighboring image pixels (voxels) by weighted edges. Certain pixels (voxels) have to be a priori identified as object or background seeds providing necessary clues about the image content. Our objective is to find the cheapest way to cut the edges in the graph so that the object seeds are completely separated from the background seeds. If the edge cost is a decreasing function of the local intensity gradient then the minimum cost cut should produce an object/background segmentation with compact boundaries along the high intensity gradient values in the image. An efficient, globally optimal solution is possible via standard min-cut/max-flow algorithms for graphs with two terminals.The flow chart of $\alpha - \beta$ Swap method is as shown in figure12

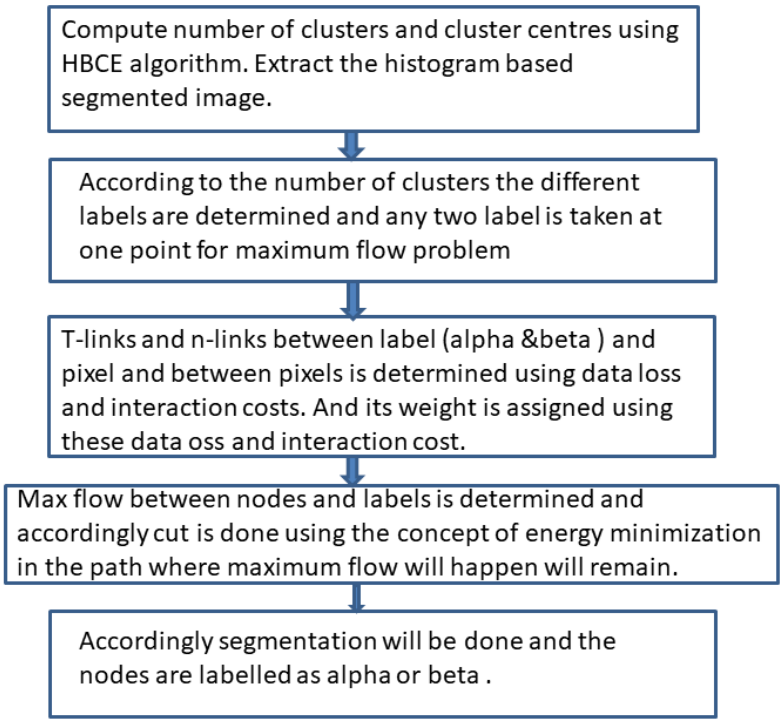


Figure 12: Flow Chart Of segmentation with alpha Bita swap Histogram Based Clustering estimation

Algorithm for $\alpha - \beta algorithm-$
STEP 1 :The image is segmented using labels determined from previous section.
STEP2 :Graph is plotted with nodes as image pixels.$n - link$ and $t - link$ edges are computed by finding out the weights between $pixel - pixel$ and $pixel - label$.The weight is calculated as a sum of data cost(D_p) and Interaction cost($V_{p,q}$).Here data cost is the likelihood of function and interaction cost represent smoothing.Here data cost is the likelihood of function and interaction cost rep-resent smoothing.Edges and its weight are determined as shown in figure 13

[1]Various edge detection techniques https://www.csd.uwo.ca/~yboykov/Papers/miccai00.pdf.

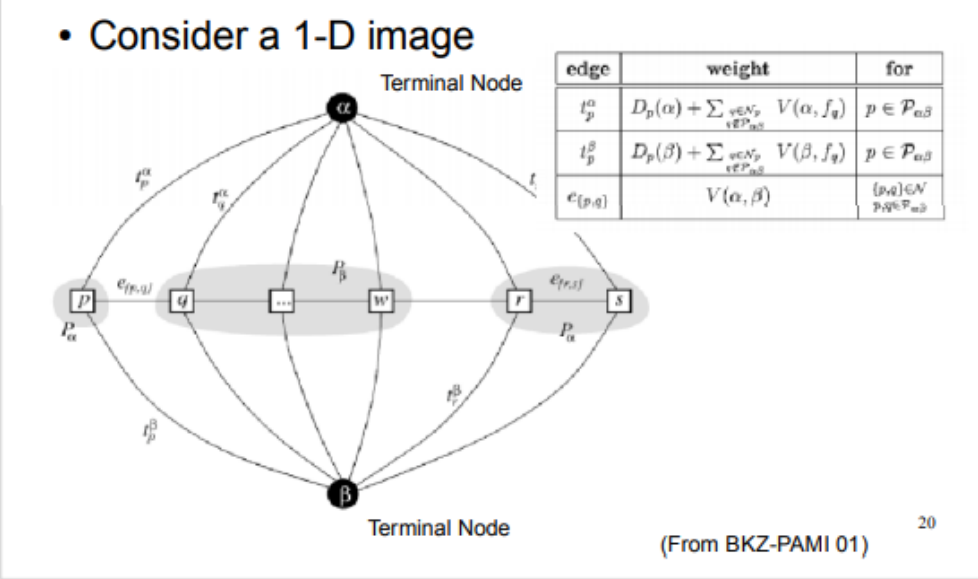


Figure 13: alpha bita swap segmentation in 1-D image.

STEP 3-Flow of each node to label is determined.

STEP 4-Cut of the graph is done using maximum low concept and the node is labeled as the one from which it get cut.This minimum cut is as shown in figure 14

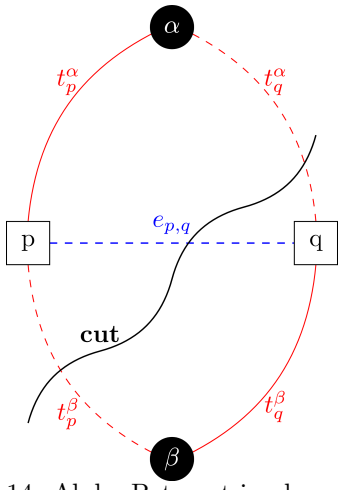


Figure 14: Alpha Beta cut implementation

$\alpha - \beta$ **Swap with morphology:** The segmented obtained above can be enhanced by smoothing boundary using morphology operation.

Observations:

ISIC 00009941 Image :

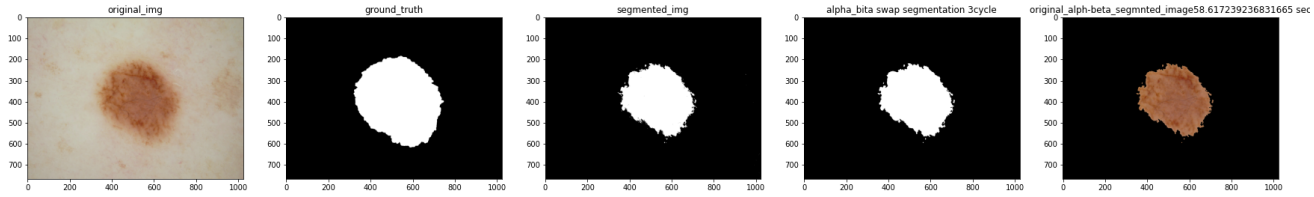


Figure 15: Segmented Output using HBCE algorithm and alpha bita segmentation
(a)Original Image (b)Ground truth (c)HBCE segmented output(d)Alpha bita segmentation output in HBCE (e)Alpha bita original skinsegmentation outputin HBCE

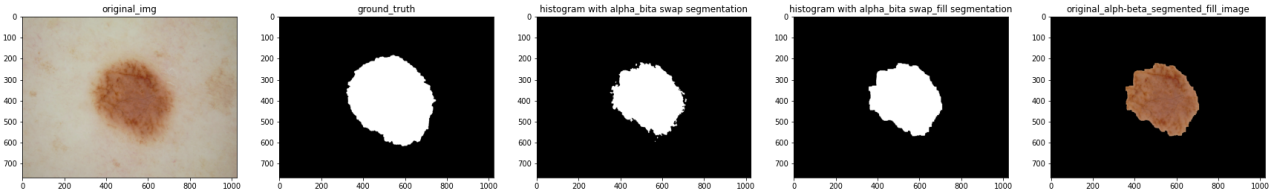


Figure 16: Segmented Output using HBCE algorithm and alpha beta segmentation
(a)Original Image (b)Ground truth (c)Alpha beta segmentation output with HBCE(d)Morphological opration on Alpha beta segmentation output with HBCE(e)Morphological Alpha beta original skinsegmentation output in HBCE

Comment-First image15 shows the implementation of alpha beta algorithm on HBCE based clustering image. This removes the noise and maintain continuity of lesion segmented area.The second image 16shows that implementation of morphological operation can improve the boundary region in segmented image.

ISIC 00009942 Image :

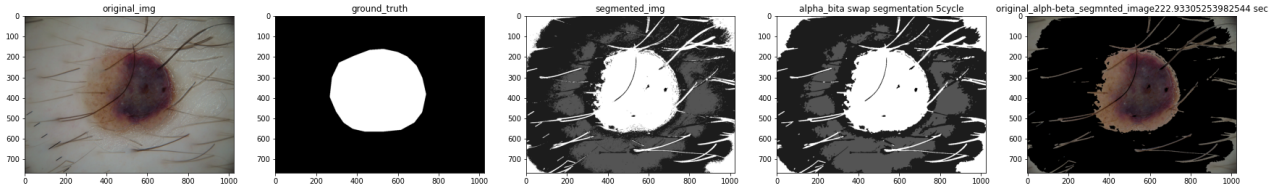


Figure 17: Segmented Output using HBCE algorithm and alpha bita segmentation
(a)Original Image (b)Ground truth (c)HBCE segmented output(d)Alpha beta segmentation output in HBCE (e)Alpha bita original skinsegmentation outputin HBCE

Comment-$\alpha - \beta$ Swap segmentation on ISIC 00009942 Image 17 shows that most of the hair being approximately same color as that of lesion is being included.The image corner being darker in color compared to skin because of camera effect also get segmented in to fore ground region.$\alpha - \beta$ Swap seg-

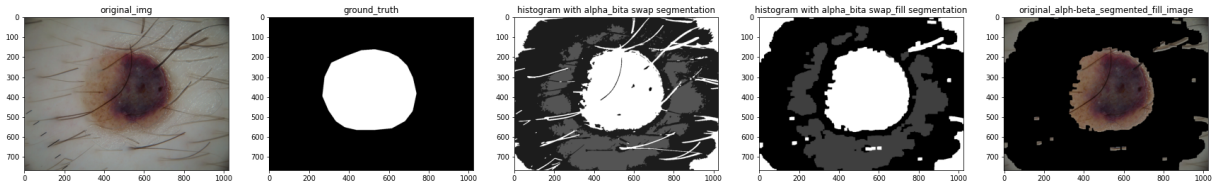


Figure 18: Segmented Output using HBCE algorithm and alpha beta segmentation
(a)Original Image (b)Ground truth (c)Alpha beta segmentation output with HBCE(d)Morphological opration on Alpha beta segmentation output with HBCE(e)Morphological Alpha beta original skinsegmentation output in HBCE

mentation 18 shows that the opening and closing operation helps in removing hair from the lesion image and lesion can be easily detected.

ISIC 00009944 Image :

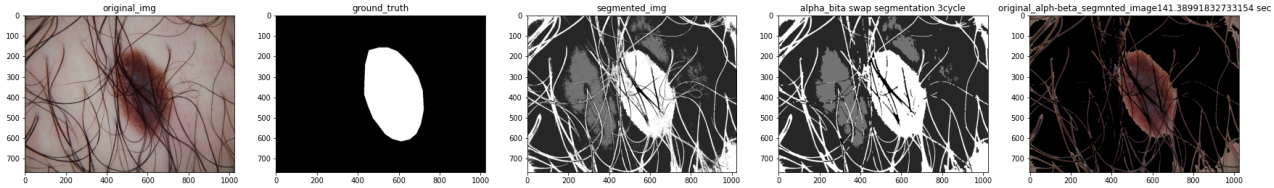


Figure 19: Segmented Output using HBCE algorithm and alpha bita segmentation
(a)Original Image (b)Ground truth (c)HBCE segmented output(d)Alpha bita segmentation output in HBCE (e)Alpha bita original skinsegmentation outputin HBCE

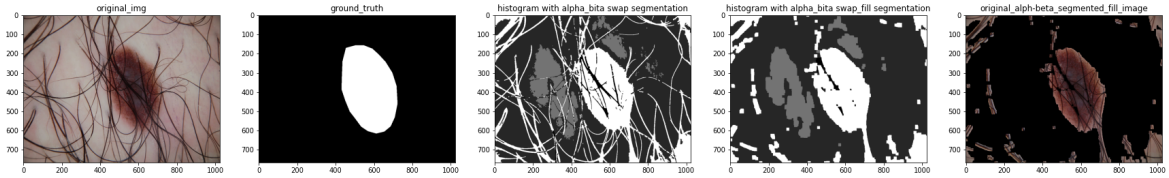


Figure 20: Segmented Output using HBCE algorithm and alpha beta segmentation
(a)Original Image (b)Ground truth (c)Alpha beta segmentation output with HBCE(d)Morphological opration on Alpha beta segmentation output with HBCE(e)Morphological Alpha beta original skinsegmentation output in HBCE

Comment-$\alpha - \beta$ Swap segmentation on ISIC 00009944 Image 19 shows that most of the hair being approximately same color as that of lesion is being included.The image corner being darker in color compared to skin because of camera effect also get segmented in to fore ground region.$\alpha - \beta$ Swap segmentation 20 shows that the opening and closing operation helps in removing hair from the lesion image and lesion can be easily detected.

ISIC 00009951 Image :

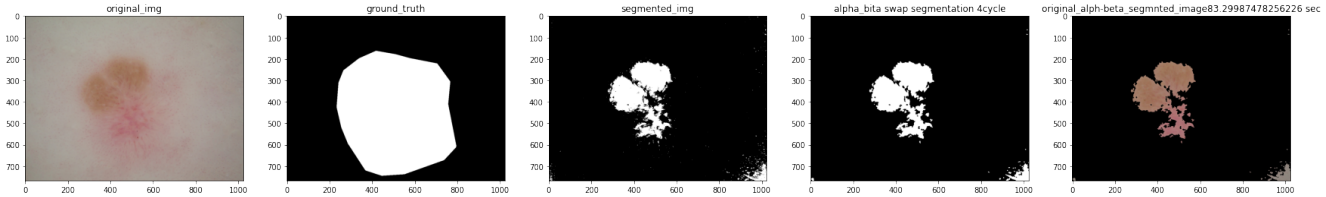


Figure 21: Segmented Output using HBCE algorithm and alpha bita segmentation
(a)Original Image (b)Ground truth (c)HBCE segmented output(d)Alpha bita segmentation output in HBCE (e)Alpha bita original skinsegmentation outputin HBCE

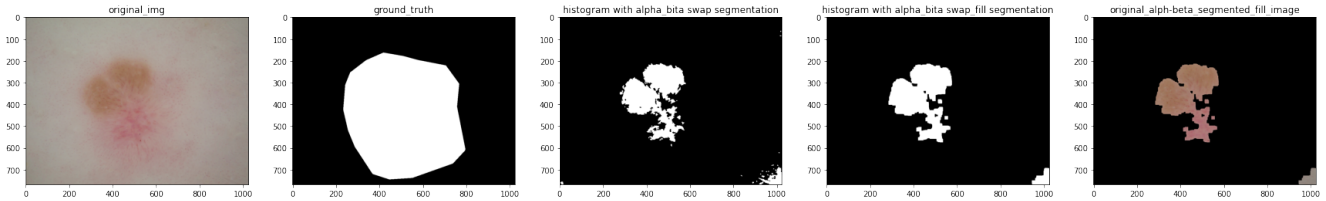


Figure 22: Segmented Output using HBCE algorithm and alpha beta segmentation
(a)Original Image (b)Ground truth (c)Alpha beta segmentation output with HBCE(d)Morphological opration on Alpha beta segmentation output with HBCE(e)Morphological Alpha beta original skinsegmentation output in HBCE

Comment-$\alpha - \beta$ Swap segmentation on ISIC 00009951 Image 21 shows that the lighter esion in skin result in similar color as that of skin and hence hard to segment it out.$\alpha - \beta$ Swap segmentation 22 shows that the opening and closing operation helps in maintaining the continuity of lesion segmented image and smoothen the boundary and hence lesion can be easily detected.

ISIC 00009968 Image :

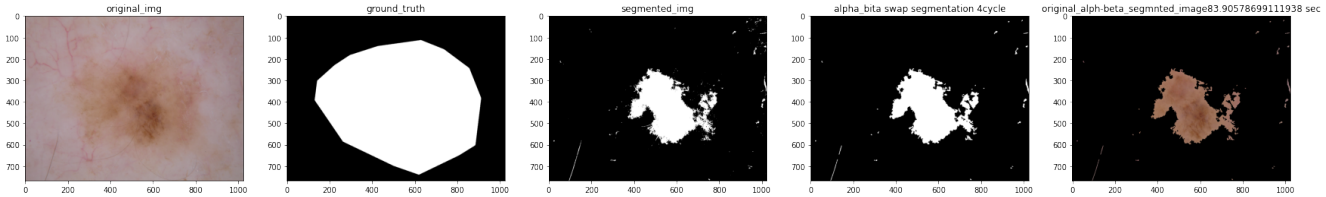


Figure 23: Segmented Output using HBCE algorithm and alpha bita segmentation
(a)Original Image (b)Ground truth (c)HBCE segmented output(d)Alpha bita segmentation output in HBCE (e)Alpha bita original skinsegmentation outputin HBCE

Comment-$\alpha - \beta$ Swap segmentation on ISIC 00009968 Image 23 shows that the lighter lesion in skin result in similar color as that of skin and hence hard to segment it out.$\alpha - \beta$ Swap segmentation 24 shows that the opening and closing operation helps in maintaining the continuity of lesion segmented image, smoothen the boundary and also removes spurious noise and hence lesion can be easily detected.

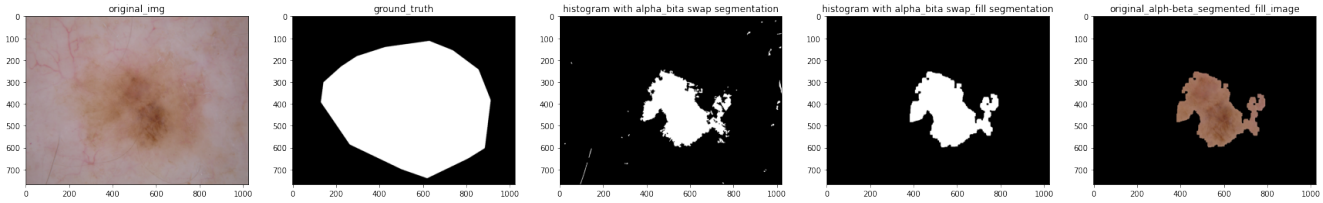


Figure 24: Segmented Output using HBCE algorithm and alpha beta segmentation with morphology. (a)Original Image (b)Ground truth (c)Alpha beta segmentation output with HBCE(d)Morphological opration on Alpha beta segmentation output with HBCE(e)Morphological Alpha beta original skinsegmentation output in HBCE

2.2 α Expansion Method

$\alpha - expansion$ method is the improvement over $\alpha - \beta$ swap Method .The main idea of the alpha-expansion algorithm is to successively segment all α and non-α pixels with graph cuts and the algorithm will change the value of α at each iteration. The algorithm will iterate through each possible label for α until it converges.

At each iteration, the α region $\mathcal{P}_\alpha$ can only expand. This changes somehow the way to set the graph weights. Also when two neighboring nodes does not currently have the same label, an intermediate node is inserted and links are weighted so they are relative to the distance to the α label.

The flow chart of $\alpha - expansion$ Swap method is as shown in figure25

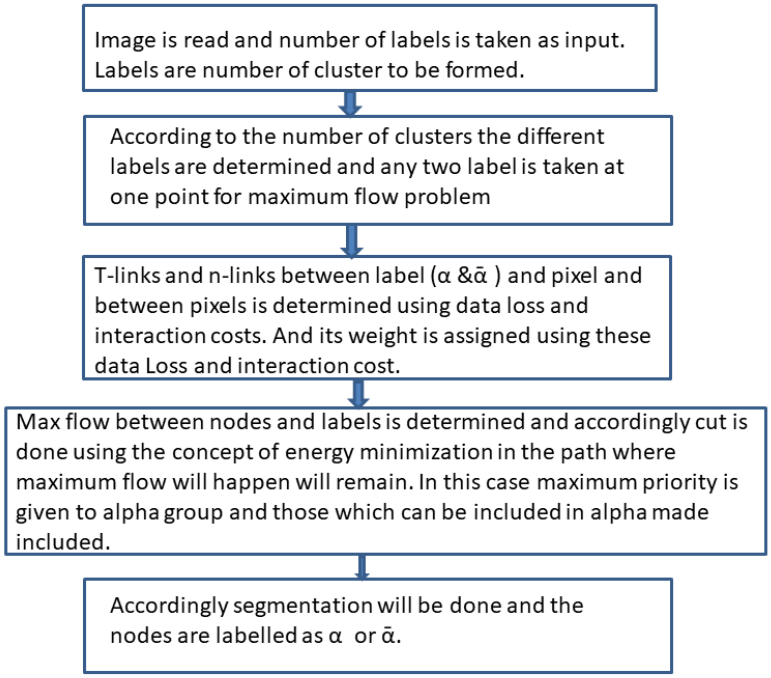


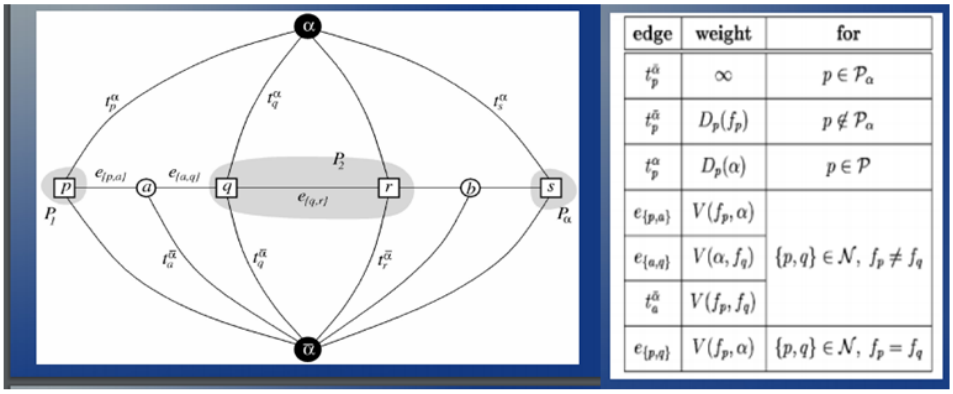
Figure 25: Flow Chart Of segmentation with alpha Bita swap Histogram Based Clustering estimation

Algorithm for α expansion segmentation-

STEP 1 :Labels is given as input along with mage to be segmented.

STEP2 :Graph is plotted with nodes as image pixels.$n - link$ and $t - link$ edges are computed by finding out the weights between $pixel - pixel$ and $pixel - label$.The weight is calculated as a sum of data

cost(D_p) and Interaction cost($V_{p,q}$).Here data cost is the likelihood of function and interaction cost represent smoothing.Edges and its weight are determined as shown in figure26



edge	weight	for
$t_p^{\bar{\alpha}}$	∞	$p \in \mathcal{P}_\alpha$
$t_p^{\bar{\alpha}}$	$D_p(f_p)$	$p \notin \mathcal{P}_\alpha$
t_p^{α}	$D_p(\alpha)$	$p \in \mathcal{P}$
$e_{\{p,a\}}$	$V(f_p, \alpha)$	$\{p,q\} \in \mathcal{N},\ f_p \neq f_q$
$e_{\{a,q\}}$	$V(\alpha, f_q)$	
$t_a^{\bar{\alpha}}$	$V(f_p, f_q)$	
$e_{\{p,q\}}$	$V(f_p, \alpha)$	$\{p,q\} \in \mathcal{N},\ f_p = f_q$

Figure 26: alpha expansion segmentation in 1-D image.

[2] STEP 3-Flow of each node to label is determined.

STEP 4-Cut of the graph is done using maximum flow (minimum energy)concept and the node is labeled as the one from which it get cut.Properties of this minimum cut is as shown in figure27

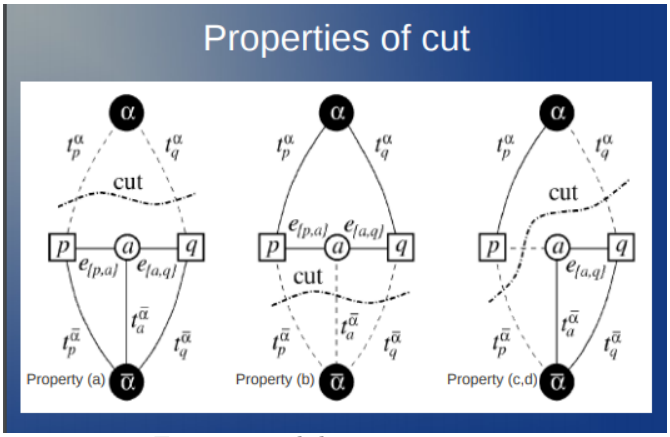


Figure 27: alpha expansion cut

[2]alpha expansion Graph cut image: https://www.cse.iitb.ac.in/~meghshyam/seminar/alpha_expansion.pdf.

Observations:

ISIC 00009941 Image :

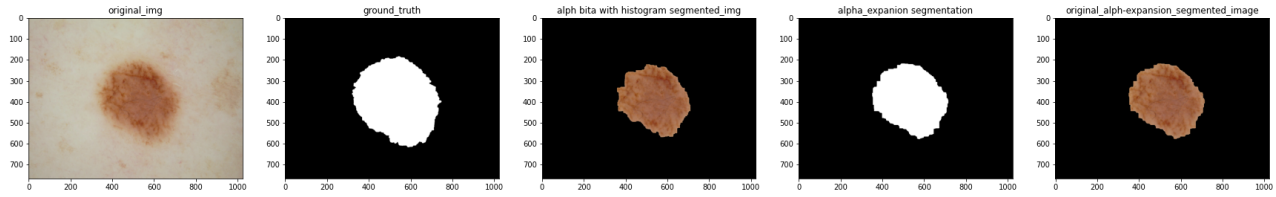


Figure 28: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-bita swap segmented output(d)Alpha expansion segmentation output (e)original skin segmentation using Alpha expansion

COMMENT: From alpha expansion method result as shown in figure28 ,its clear that alpha expansion expands the fore ground region including most of the lesion region compared to HBCE with $\alpha\beta swap$ along with morphology operation.

ISIC 00009942 Image :

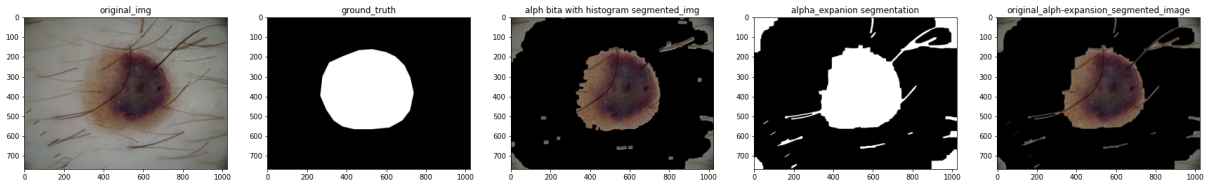


Figure 29: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE alpha-beta swap segmented output(d)Alpha expansion segmentation output (e)original skin segmentation using Alpha expansion

COMMENT:From alpha expansion method result as shown in figure 29 ,its clear that alpha expansion expands the fore ground region including most of the lesion region compared to HBCE with $\alpha - \beta swap$ along with morphology operation.But it also includes the hair outside the lesion as foreground, where as $\alpha - \beta swap$ along with morphology operation removed those.Both the methods includes the corners of image as its being darker compared to skin color selected as background.so border may be removed using masking operation.

ISIC 00009944 Image :

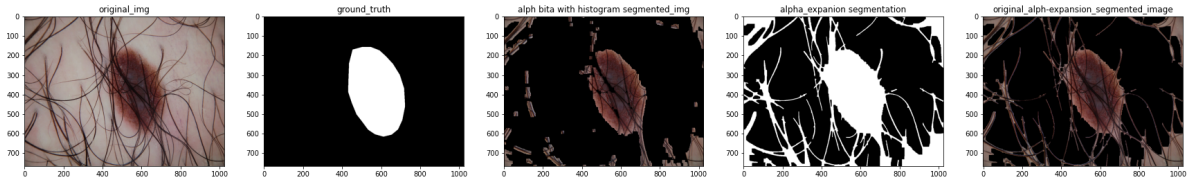


Figure 30: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-bita swap segmented output(d)Alpha expansion segmentation output (e)original skin segmentation using Alpha expansion

From alpha expansion method result as shown in figure 30, its clear that alpha expansion expands the fore ground region including most of the lesion region compared to HBCE with $\alpha\beta swap$ along with morphology operation.But it also includes the hair outside the lesion as foreground, where as $\alpha\beta swap$ along with morphology operation removed those.Both the methods includes the corners of image as its being darker compared to skin color selected as background.so border may be removed using masking operation.

ISIC 00009951 Image :

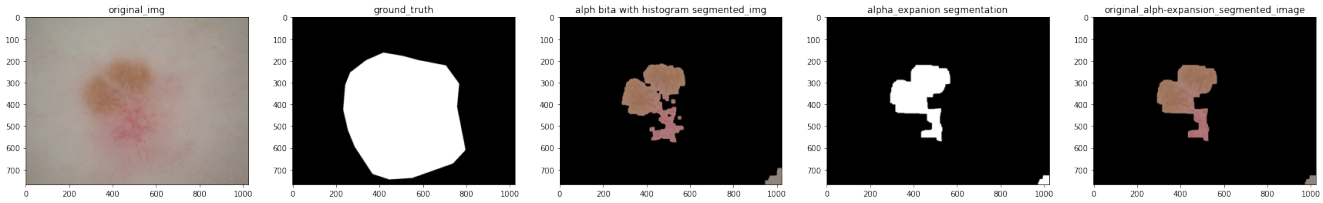


Figure 31: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-bita swap segmented output(d)Alpha expansion segmentation output (e)original skin segmentation using Alpha expansion

COMMENT:From alpha expansion method result as shown in figure 31, its clear that alpha expansion expands the fore ground region including most of the lesion region compared to HBCE with $\alpha\beta swap$ along with morphology operation.

ISIC 00009968 Image :

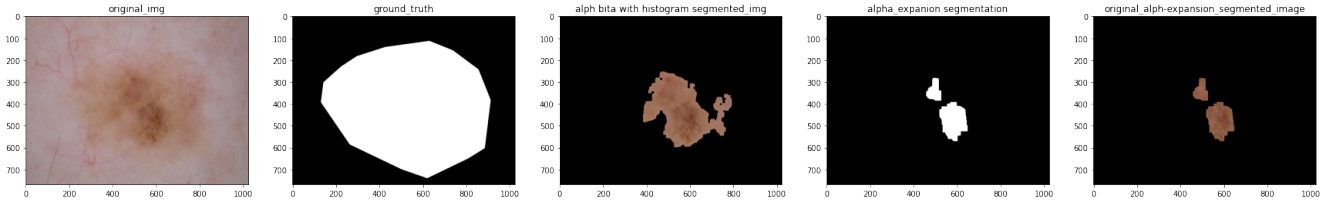


Figure 32: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-bita swap segmented output(d)Alpha expansion segmentation output (e)original skin segmentation using Alpha expansion

COMMENT:From alpha expansion method result as shown in figure 32 ,its clear that alpha expansion expands the fore ground region including most of the lesion region compared to HBCE with $\alpha - \beta swap$ along with morphology operation.Both $\alpha - \beta swap$ along with morphology operation and $\alpha - expansion$ method is unable to include lighter lesion region which has very similar color as that of the skin

3 Task 3 :Performance Analysis using metrics

Let X be the segmented image and Y be the ground truth for the following.
Dice similarity coefficient -
The Dice similarity coefficient, also known as the Sorensen–Dice index or simply Dice coefficient, is a statistical tool which measures the similarity between two sets of data.The equation for the concept is,

$$Dicesimilarity = 2 * \frac{(\mid X \mid \cap \mid Y \mid)}{(\mid X \mid + \mid Y \mid)} \tag{5}$$

Jaccard index (JAC) - The Jaccard similarity index (sometimes called the Jaccard similarity coefficient) compares members for two sets to see which members are shared and which are distinct. It's a measure of similarity for the two sets of data, with a range from $0 to 100$ percentage. The higher the percentage, the more similar the two populations.

$$JaccardindexJ(X,Y) = \frac{(\mid X \mid \cap \mid Y \mid)}{(\mid X \mid \cup \mid Y \mid)} \tag{6}$$

Accuracy - It is the percent of pixels in your image that are classified correctly.

$$Accuarcy(X,Y) = \frac{(TP + TN)}{(TP + FN + FP + TN)} \tag{7}$$

sensitivity - Sensitivity: the ability of a test to correctly identify patients with a disease.

$$Sensitivity(X,Y) = \frac{(TP)}{(TP + FN)} \tag{8}$$

Specificity - Specificity: the ability of a test to correctly identify people without the disease.The specificity between two binary datasets which denotes the fraction of correctly returned negatives. The specificity is not symmetric.

$$Specificity(X,Y) = \frac{(TN)}{(FP + TN)} \tag{9}$$

where TP is true positive= X and Y
TN is true positive= $\sim X and \sim Y$
$FPisfalsepositive = X and \sim Y$
$FNisfalsenegative = \sim X and Y$

Observations:

ISIC 00009939 Image :

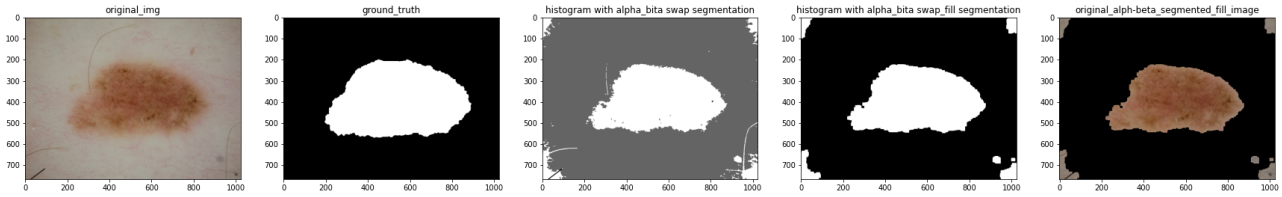


Figure 33: Segmented Output using alpha-beta segmentation method only
(a)Original Image (b)Ground truth (c)HBCE with aplpha-beta swap segmented output with morphology(d)HBCE with aplpha-beta swap segmented output with morphology (e)original skin lesion segmentation using aplpha-beta swap output with morphology

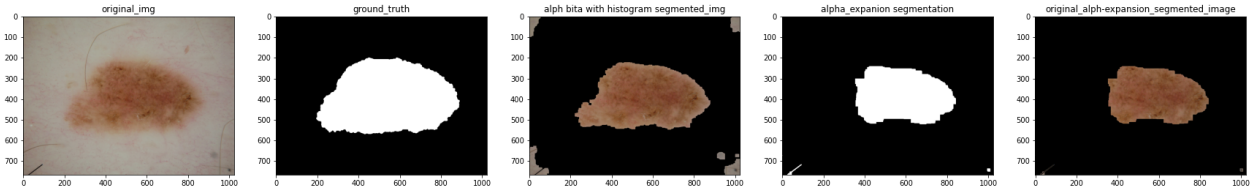


Figure 34: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-beta swap segmented output with morphology(d)Alpha expansion segmentation output (e)original skin lesion segmentation using Alpha expansion

ISIC 00009940 Image :

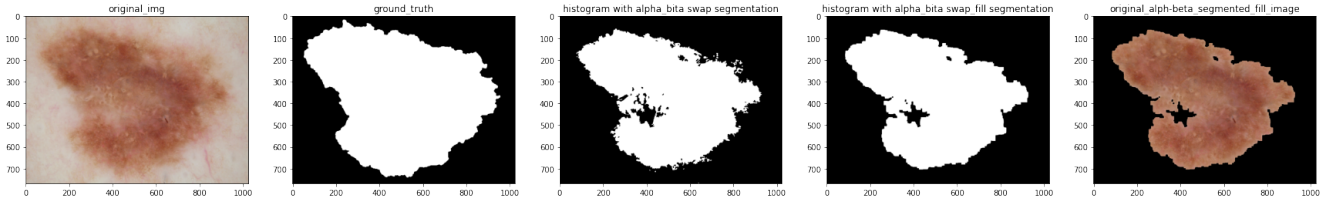


Figure 35: Segmented Output using alpha-beta segmentation method only
(a)Original Image (b)Ground truth (c)HBCE with aplpha-beta swap segmented output with morphology(d)HBCE with aplpha-beta swap segmented output with morphology (e)original skin lesion segmentation using aplpha-beta swap output with morphology

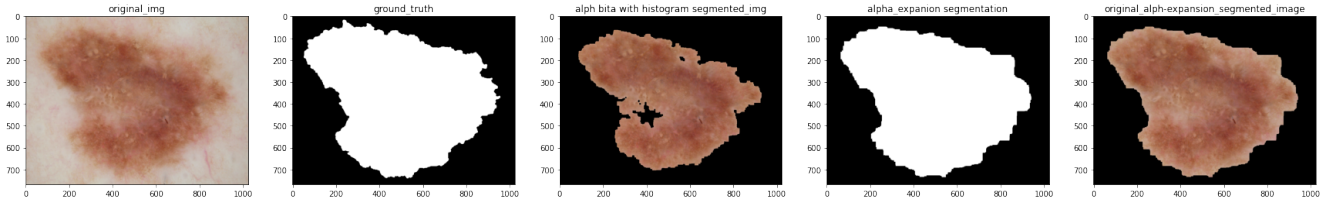


Figure 36: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-beta swap segmented output with morphology(d)Alpha expansion segmentation output (e)original skin lesion segmentation using Alpha expansion

Metric calculation for image ISIC 00009939-41

1.ISIC_0009939	Segmentation with histogram based clustering	Segmentation with alpha bita & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.914101	0.924756	0.891594
SPECIFICITY	0.958817	0.967368	0.998625
SENSITIVITY	0.775320	0.792508	0.559417
JACCARD COEFFICIENT	0.687454	0.719628	0.557039
DICE COEFFICIENT	0.814783	0.836957	0.715511

2.ISIC_0009940	Segmentation with histogram based clustering	Segmentation with alpha bita & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.875393	0.883728	0.978861
SPECIFICITY	0.999958	1.000000	0.995491
SENSITIVITY	0.760697	0.776668	0.963550
JACCARD COEFFICIENT	0.760667	0.776668	0.959566
DICE COEFFICIENT	0.864067	0.874297	0.979366

3.ISIC_0009941	Segmentation with histogram based clustering	Segmentation with alpha bita & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.939973	0.943078	0.951103
SPECIFICITY	0.999982	1.000000	1.000000
SENSITIVITY	0.632775	0.651683	0.700789
JACCARD COEFFICIENT	0.632716	0.651683	0.700789
DICE COEFFICIENT	0.775047	0.789114	0.824075

Figure 37: Table for accuracy,specificity,sensitivity,jaccard coefficient,dice coefficient for image 1-3 of given data set 27
row 1 metrics for ISIC 00009939, row 1 metrics for ISIC 00009940,row 1 metrics for ISIC 00009941

ISIC 00009947 Image :

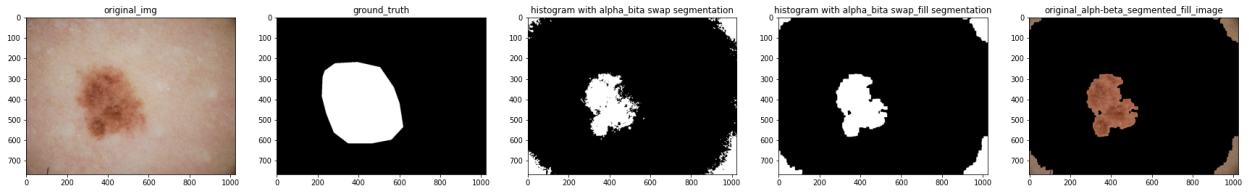


Figure 38: Segmented Output using alpha-beta segmentation method only
(a)Original Image (b)Ground truth (c)HBCE with aplpha-beta swap segmented output with morphology(d)HBCE with aplpha-beta swap segmented output with morphology (e)original skin lesion segmentation using aplpha-beta swap output with morphology

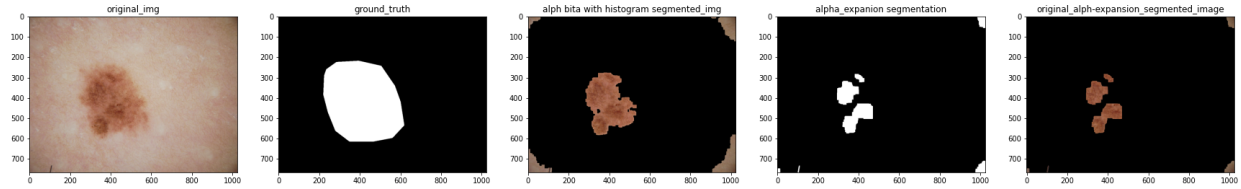


Figure 39: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-beta swap segmented output with morphology(d)Alpha expansion segmentation output (e)original skin lesion segmentation using Alpha expansion

Metric calculation for image ISIC 00009942,44,47

4.ISIC_0009942	Segmentation with histogram based clustering	Segmentation with alpha beta & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.859375	0.887557	0.903885
SPECIFICITY	0.863842	0.895083	0.918466
SENSITIVITY	0.840860	0.856359	0.843444
JACCARD COEFFICIENT	0.537504	0.596815	0.630396
DICE COEFFICIENT	0.699191	0.747507	0.773304

5.ISIC_0009944	Segmentation with histogram based clustering	Segmentation with alpha beta & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.801308	0.882989	0.797551
SPECIFICITY	0.807222	0.889955	0.781592
SENSITIVITY	0.761618	0.836248	0.904643
JACCARD COEFFICIENT	0.332060	0.481031	0.366905
DICE COEFFICIENT	0.498566	0.649589	0.536841

6.ISIC_0009947	Segmentation with histogram based clustering	Segmentation with alpha beta & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.858588	0.882989	0.797551
SPECIFICITY	0.951452	0.889955	0.781592
SENSITIVITY	0.375839	0.836248	0.904643
JACCARD COEFFICIENT	0.300102	0.481031	0.366905
DICE COEFFICIENT	0.46165	0.649589	0.536841

Figure 40: Table for accuracy,specificity,sensitivity,jaccard coefficient,dice coefficient for image 4-6 of given data set 27
row 1 metrics for ISIC 00009942, row 2 metrics for ISIC 00009944,row 3 metrics for ISIC 00009947

ISIC 00009949 Image :

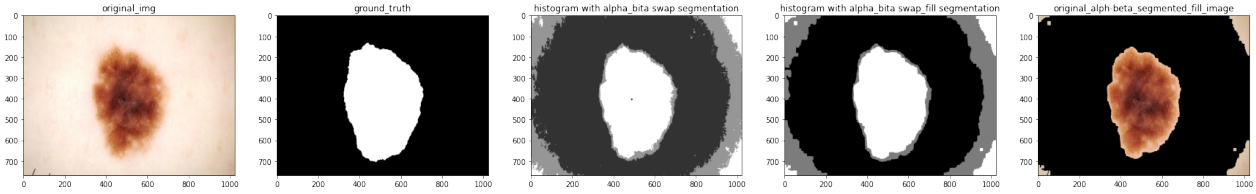


Figure 41: Segmented Output using alpha-beta segmentation method only
(a)Original Image (b)Ground truth (c)HBCE with aplpha-beta swap segmented output with morphology(d)HBCE with aplpha-beta swap segmented output with morphology (e)original skin lesion segmentation using aplpha-beta swap output with morphology

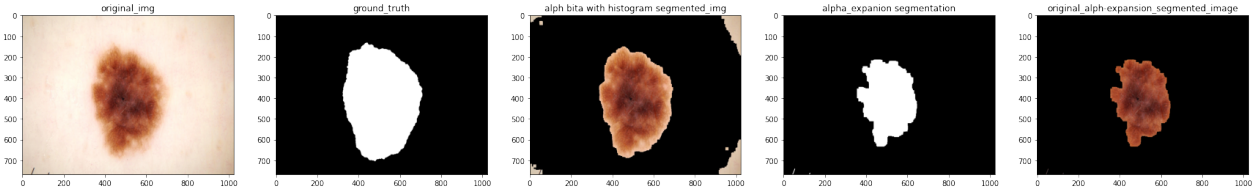


Figure 42: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-beta swap segmented output with morphology(d)Alpha expansion segmentation output (e)original skin lesion segmentation using Alpha expansion

ISIC 00009950 Image :

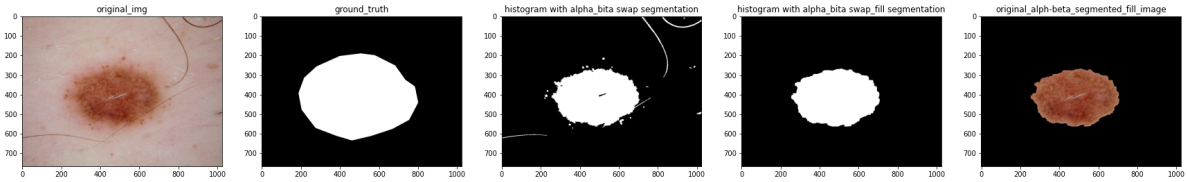


Figure 43: Segmented Output using alpha-beta segmentation method only
(a)Original Image (b)Ground truth (c)HBCE with aplpha-beta swap segmented output with morphology(d)HBCE with aplpha-beta swap segmented output with morphology (e)original skin lesion segmentation using aplpha-beta swap output with morphology

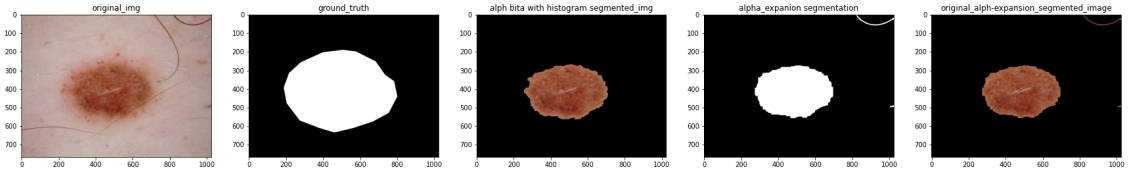


Figure 44: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-beta swap segmented output with morphology(d)Alpha expansion segmentation output (e)original skin lesion segmentation using Alpha expansion

Metric calculation for image ISIC 00009949-51

7.ISIC_0009949	Segmentation with histogram based clustering	Segmentation with alpha beta & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.936517	0.943823	0.902992
SPECIFICITY	0.958756	0.962404	0.999790
SENSITIVITY	0.848556	0.870333	0.520132
JACCARD COEFFICIENT	0.729545	0.757666	0.519699
DICE COEFFICIENT	0.843626	0.862127	0.683950

8.ISIC_0009950	Segmentation with histogram based clustering	Segmentation with alpha beta & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.863654	0.872832	0.860287
SPECIFICITY	0.991792	1.000000	0.997286
SENSITIVITY	0.487474	0.499500	0.458092
JACCARD COEFFICIENT	0.476003	0.499500	0.454471
DICE COEFFICIENT	0.644990	0.666222	0.624930

9.ISIC_0009951	Segmentation with histogram based clustering	Segmentation with alpha beta & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.734540	0.741592	0.734818
SPECIFICITY	0.989953	0.992894	0.996779
SENSITIVITY	0.207544	0.223078	0.194308
JACCARD COEFFICIENT	0.203329	0.219855	0.193026
DICE COEFFICIENT	0.337944	0.360461	0.323590

Figure 45: Table for accuracy,specificity,sensitivity,jaccard coefficient,dice coefficient for image 7-9 of given data set 27
row 1 metrics for ISIC 00009949, row 2 metrics for ISIC 00009950,row 3 metrics for ISIC 00009951

ISIC 00009953 Image :

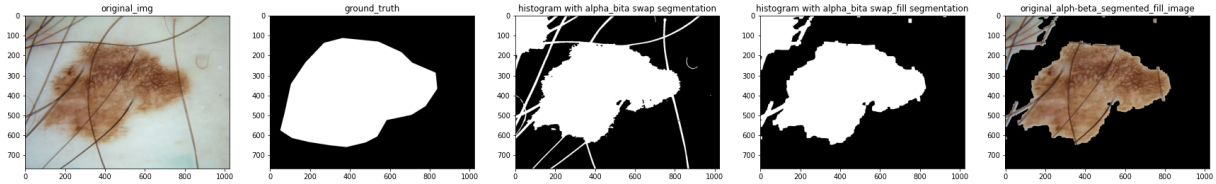


Figure 46: Segmented Output using alpha-beta segmentation method only
(a)Original Image (b)Ground truth (c)HBCE with aplpha-beta swap segmented output with morphology(d)HBCE with aplpha-beta swap segmented output with morphology (e)original skin lesion segmentation using aplpha-beta swap output with morphology

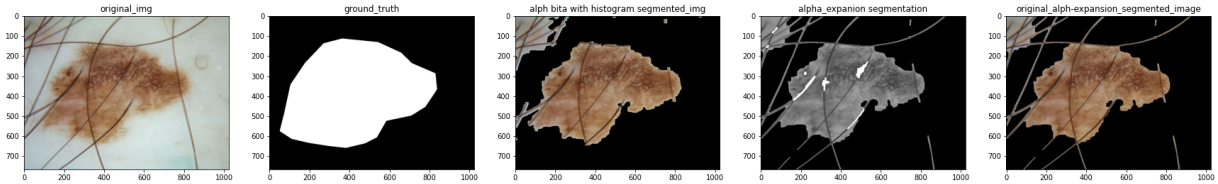


Figure 47: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-beta swap segmented output with morphology(d)Alpha expansion segmentation output (e)original skin lesion segmentation using Alpha expansion

ISIC 00009960 Image :

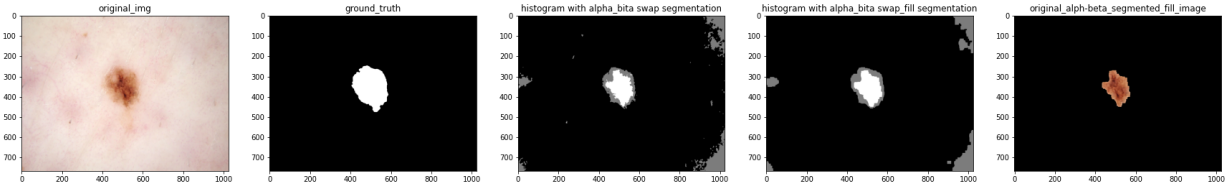


Figure 48: Segmented Output using alpha-beta segmentation method only
(a)Original Image (b)Ground truth (c)HBCE with aplpha-beta swap segmented output with morphology(d)HBCE with aplpha-beta swap segmented output with morphology (e)original skin lesion segmentation using aplpha-beta swap output with morphology

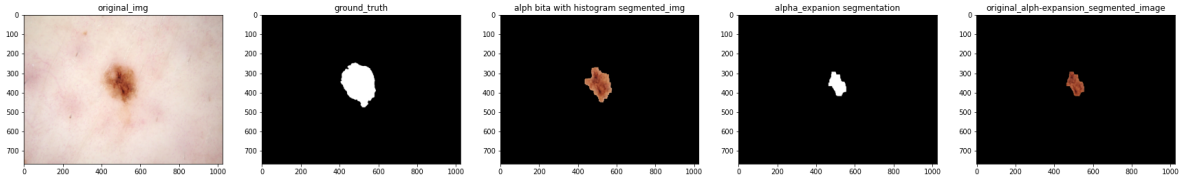


Figure 49: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-beta swap segmented output with morphology(d)Alpha expansion segmentation output (e)original skin lesion segmentation using Alpha expansion

ISIC 00009961 Image :

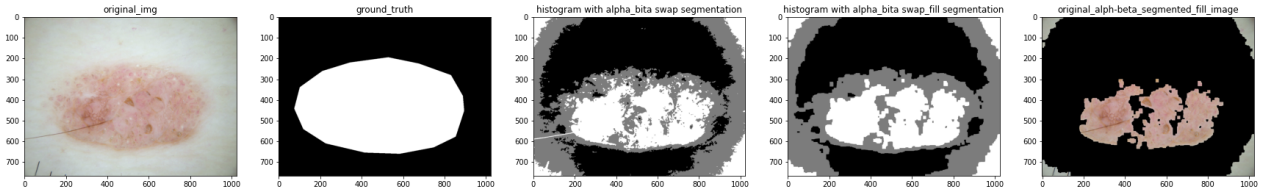


Figure 50: Segmented Output using alpha-beta segmentation method only
(a)Original Image (b)Ground truth (c)HBCE with aplpha-beta swap segmented output with morphology(d)HBCE with aplpha-beta swap segmented output with morphology (e)original skin lesion segmentation using aplpha-beta swap output with morphology

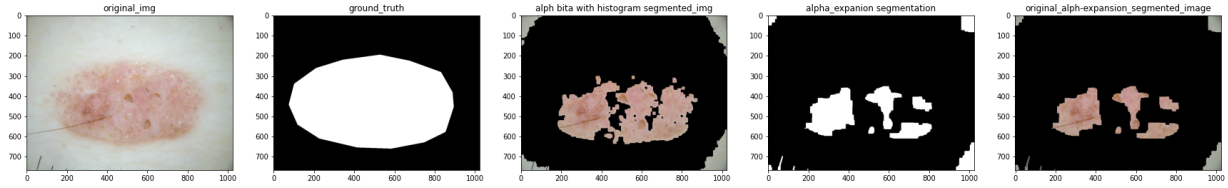


Figure 51: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-beta swap segmented output with morphology(d)Alpha expansion segmentation output (e)original skin lesion segmentation using Alpha expansion

Metric calculation for image ISIC 00009953,60,61

10.ISIC_0009953	Segmentation with histogram based clustering	Segmentation with alpha beta & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.840611	0.864995	0.841896
SPECIFICITY	0.885374	0.914303	0.910570
SENSITIVITY	0.766494	0.783355	0.72818
JACCARD COEFFICIENT	0.644225	0.686014	0.634271
DICE COEFFICIENT	0.783622	0.813771	0.776213

11.ISIC_0009960	Segmentation with histogram based clustering	Segmentation with alpha beta & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.981911	0.983362	0.973563
SPECIFICITY	0.999933	1.000000	1.000000
SENSITIVITY	0.489208	0.528485	0.250802
JACCARD COEFFICIENT	0.488310	0.528485	0.250802
DICE COEFFICIENT	0.656194	0.691515	0.401026

12.ISIC_0009961	Segmentation with histogram based clustering	Segmentation with alpha beta & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.748306	0.752964	0.688958
SPECIFICITY	0.923983	0.926400	0.967263
SENSITIVITY	0.461975	0.470285	0.235358
JACCARD COEFFICIENT	0.411047	0.419913	0.223436
DICE COEFFICIENT	0.582613	0.591463	0.365260

Figure 52: Table for accuracy,specificity,sensitivity,jaccard coefficient,dice coefficient for image 10-12 of given data set 27
row 1 metrics for ISIC 00009953, row 2 metrics for ISIC 00009960,row 3 metrics for ISIC 00009961

ISIC 00009962 Image :

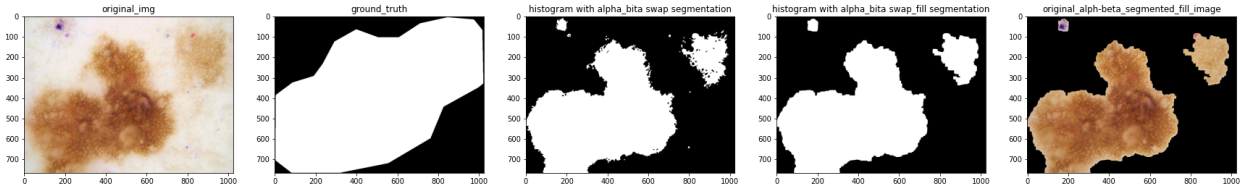


Figure 53: Segmented Output using alpha-beta segmentation method only
(a)Original Image (b)Ground truth (c)HBCE with aplpha-beta swap segmented output with morphology(d)HBCE with aplpha-beta swap segmented output with morphology (e)original skin lesion segmentation using aplpha-beta swap output with morphology

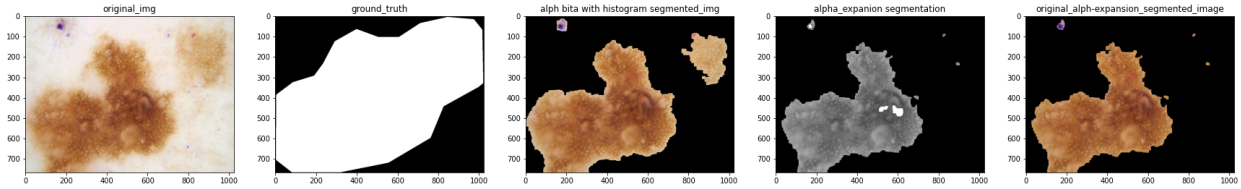


Figure 54: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-beta swap segmented output with morphology(d)Alpha expansion segmentation output (e)original skin lesion segmentation using Alpha expansion

ISIC 00009963 Image :

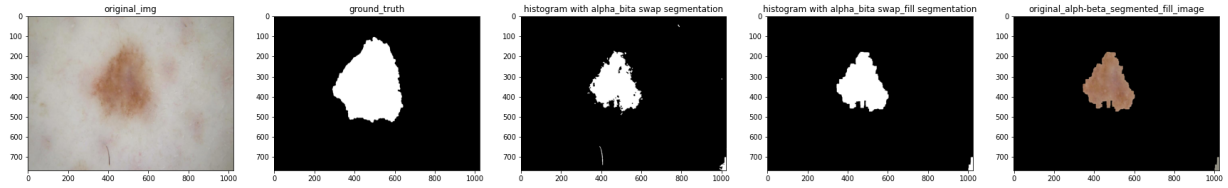


Figure 55: Segmented Output using alpha-beta segmentation method only
(a)Original Image (b)Ground truth (c)HBCE with aplpha-beta swap segmented output with morphology(d)HBCE with aplpha-beta swap segmented output with morphology (e)original skin lesion segmentation using aplpha-beta swap output with morphology

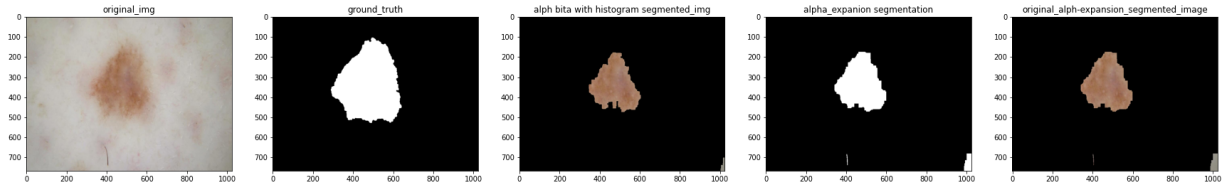


Figure 56: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-beta swap segmented output with morphology(d)Alpha expansion segmentation output (e)original skin lesion segmentation using Alpha expansion

ISIC 00009964 Image :

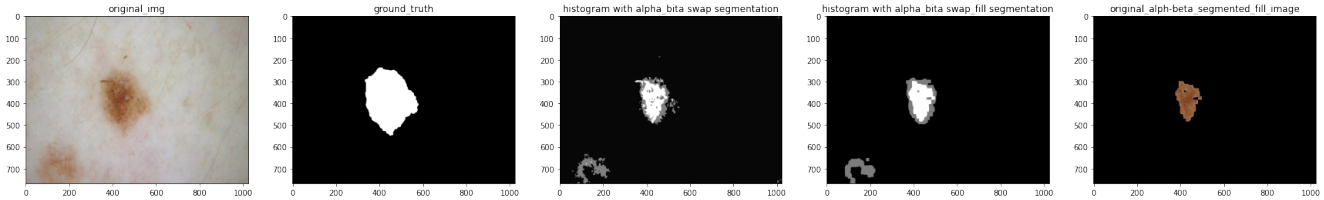


Figure 57: Segmented Output using alpha-beta segmentation method only
(a)Original Image (b)Ground truth (c)HBCE with aplpha-beta swap segmented output with morphology(d)HBCE with aplpha-beta swap segmented output with morphology (e)original skin lesion segmentation using aplpha-beta swap output with morphology

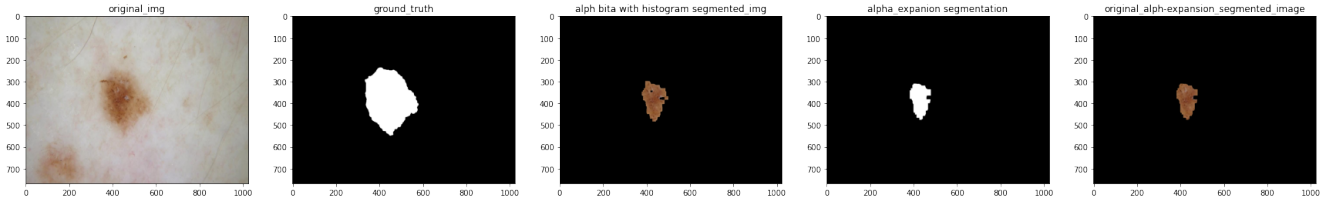


Figure 58: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-beta swap segmented output with morphology(d)Alpha expansion segmentation output (e)original skin lesion segmentation using Alpha expansion

Metric calculation for image ISIC 00009962,63,64

13.ISIC_0009962	Segmentation with histogram based clustering	Segmentation with alpha bita & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.719924	0.724958	0.326347
SPECIFICITY	0.987901	0.986165	0.998938
SENSITIVITY	0.591975	0.600241	0.005211
JACCARD COEFFICIENT	0.588575	0.596302	0.005209
DICE COEFFICIENT	0.741010	0.747105	0.010364

14.ISIC_0009963	Segmentation with histogram based clustering	Segmentation with alpha bita & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.927124	0.931043	0.932905
SPECIFICITY	0.997643	0.998475	0.995870
SENSITIVITY	0.438492	0.463799	0.496607
JACCARD COEFFICIENT	0.431445	0.458950	0.482793
DICE COEFFICIENT	0.602811	0.62915	0.651194

15.ISIC_0009964	Segmentation with histogram based clustering	Segmentation with alpha bita & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.952187	0.953214	0.950081
SPECIFICITY	0.999897	1.000000	1.000000
SENSITIVITY	0.250784	0.265398	0.216204
JACCARD COEFFICIENT	0.250404	0.265398	0.216204
DICE COEFFICIENT	0.400517	0.419470	0.355539

Figure 59: Table for accuracy,specificity,sensitivity,jaccard coefficient,dice coefficient for image 13-15 of given data set 27
row 1 metrics for ISIC 00009962, row 2 metrics for ISIC 00009963,row 3 metrics for ISIC 00009964

ISIC 00009966 Image :

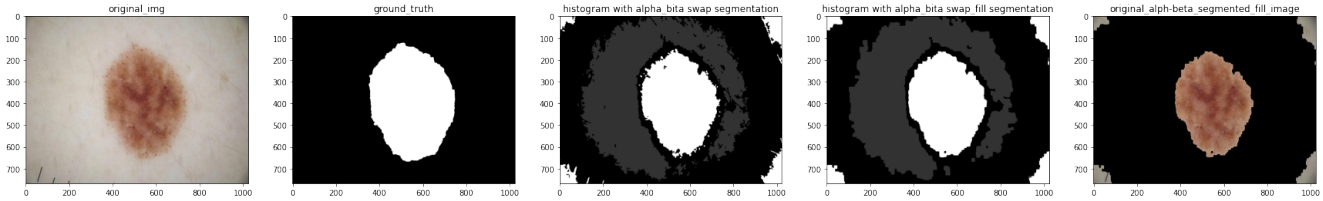


Figure 60: Segmented Output using alpha-beta segmentation method only
(a)Original Image (b)Ground truth (c)HBCE with aplpha-beta swap segmented output with morphology(d)HBCE with aplpha-beta swap segmented output with morphology (e)original skin lesion segmentation using aplpha-beta swap output with morphology

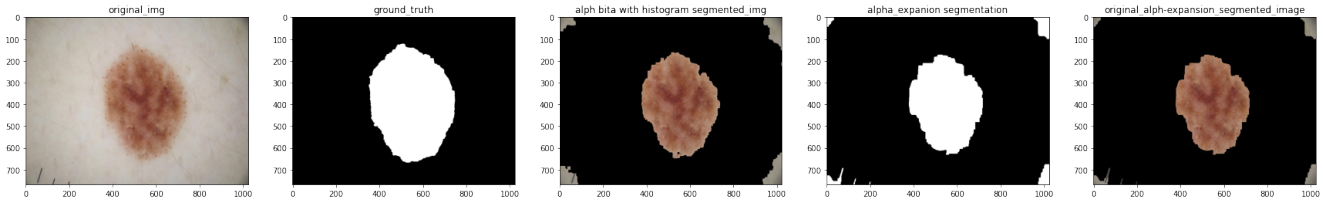


Figure 61: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-beta swap segmented output with morphology(d)Alpha expansion segmentation output (e)original skin lesion segmentation using Alpha expansion

ISIC 00009967 Image :

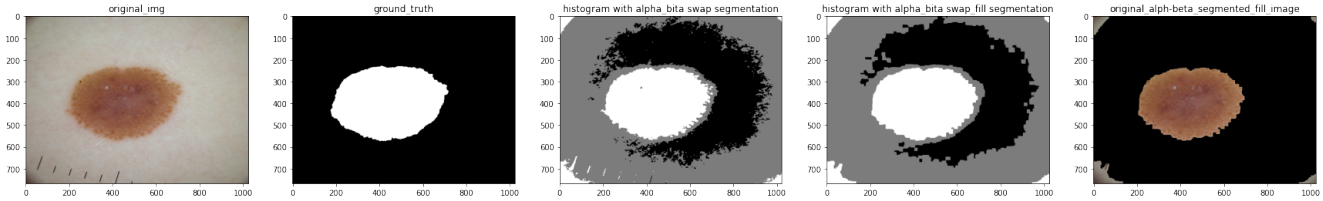


Figure 62: Segmented Output using alpha-beta segmentation method only
(a)Original Image (b)Ground truth (c)HBCE with aplpha-beta swap segmented output with morphology(d)HBCE with aplpha-beta swap segmented output with morphology (e)original skin lesion segmentation using aplpha-beta swap output with morphology

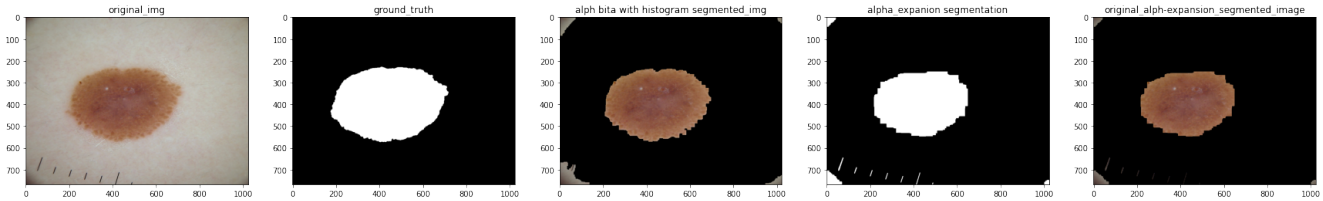


Figure 63: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-beta swap segmented output with morphology(d)Alpha expansion segmentation output (e)original skin lesion segmentation using Alpha expansion

Metric calculation for image ISIC 00009966,67,68

16.ISIC_0009966	Segmentation with histogram based clustering	Segmentation with alpha bita & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.917369	0.923192	0.853127
SPECIFICITY	0.957299	0.959778	0.998117
SENSITIVITY	0.757596	0.776802	0.272980
JACCARD COEFFICIENT	0.647043	0.669115	0.270938
DICE COEFFICIENT	0.785703	0.801760	0.426359

17.ISIC_0009967	Segmentation with histogram based clustering	Segmentation with alpha bita & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.960280	0.963886	0.945970
SPECIFICITY	0.979191	0.979271	0.991215
SENSITIVITY	0.871993	0.892060	0.734739
JACCARD COEFFICIENT	0.794781	0.813349	0.705792
DICE COEFFICIENT	0.885658	0.897068	0.827524

18.ISIC_0009968	Segmentation with histogram based clustering	Segmentation with alpha bita & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.640436	0.647065	0.579613
SPECIFICITY	0.994518	1.000000	1.000000
SENSITIVITY	0.203208	0.211256	0.06051
JACCARD COEFFICIENT	0.201842	0.211256	0.060512
DICE COEFFICIENT	0.335888	0.348821	0.114118

Figure 64: Table for accuracy,specificity,sensitivity,jaccard coefficient,dice coefficient for image 16-18 of given data set 27
row 1 metrics for ISIC 00009966, row 2 metrics for ISIC 00009967,row 3 metrics for ISIC 00009968

ISIC 00009969 Image :

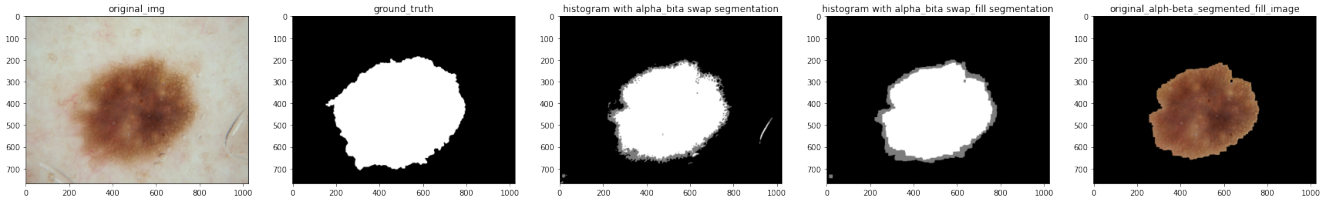


Figure 65: Segmented Output using alpha-beta segmentation method only
(a)Original Image (b)Ground truth (c)HBCE with aplpha-beta swap segmented output with morphology(d)HBCE with aplpha-beta swap segmented output with morphology (e)original skin lesion segmentation using aplpha-beta swap output with morphology

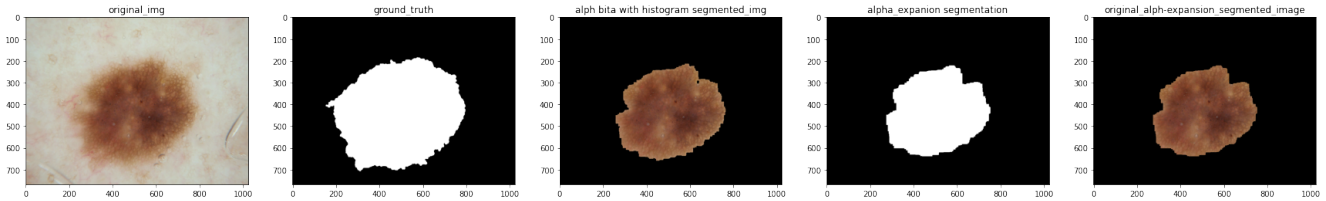


Figure 66: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-beta swap segmented output with morphology(d)Alpha expansion segmentation output (e)original skin lesion segmentation using Alpha expansion

ISIC 00009971 Image :

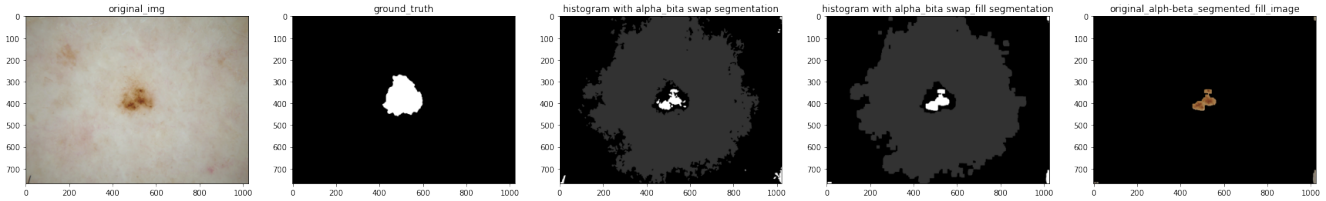


Figure 67: Segmented Output using alpha-beta segmentation method only
(a)Original Image (b)Ground truth (c)HBCE with aplpha-beta swap segmented output with morphology(d)HBCE with aplpha-beta swap segmented output with morphology (e)original skin lesion segmentation using aplpha-beta swap output with morphology

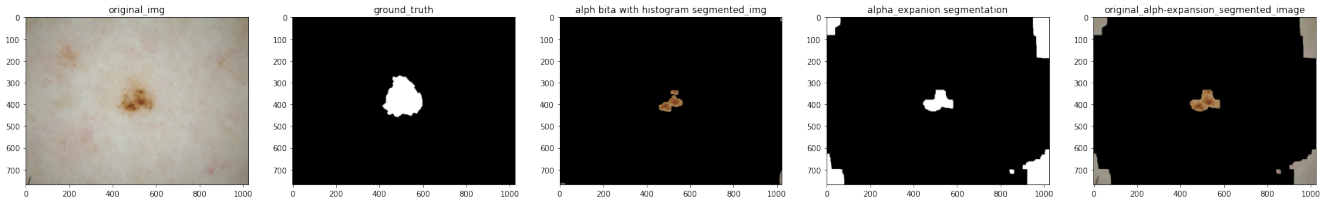


Figure 68: Segmented Output using alpha-expansion method only
(a)Original Image (b)Ground truth (c)HBCE aplpha-beta swap segmented output with morphology(d)Alpha expansion segmentation output (e)original skin lesion segmentation using Alpha expansion

Metric calculation for image ISIC 00009969,71

19.ISIC_0009969	Segmentation with histogram based clustering	Segmentation with alpha beta & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.908337	0.909087	0.888349
SPECIFICITY	0.999408	1.000000	1.000000
SENSITIVITY	0.690742	0.691871	0.621585
JACCARD COEFFICIENT	0.689767	0.691871	0.621585
DICE COEFFICIENT	0.816405	0.817877	0.766638

20.ISIC_0009971	Segmentation with histogram based clustering	Segmentation with alpha beta & hist based clustering	Segmentation with alpha expansion
ACCURACY	0.973493	0.975185	0.933337
SPECIFICITY	0.997176	0.998583	0.951211
SENSITIVITY	0.202160	0.213130	0.351176
JACCARD COEFFICIENT	0.185130	0.203729	0.135640
DICE COEFFICIENT	0.312422	0.338497	0.238879

Figure 69: Table for accuracy,specificity,sensitivity,jaccard coefficient,dice coefficient for image 19-20 of given data set 27
rrow 1 metrics for ISIC 00009969,row 2 metrics for ISIC 00009971

Comment: From above figures and metrics calculated tables ,we can interprete that segmentation with alpha beta along with histogram based clustering gives more accurate result in every aspect compared to the segmentation with only histogram method.Segmentation with alpha beta along with histogram based clustering gives better result in most of the cases compared to segmentation with only alpha expansion expect some exceptional case like $ISIC_0009942, ISIC_0009940$etc. So we may conclude that combining clustering based segmentation along with graph cut based segmentation yields better result.