Bacteria Foraging Optimization based color quantization

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Abstract:
Natural Swarm inspired algorithms like PSO,ACO have found their way into image processing. In this paper the same trend of swarm based algorithm BFO is used in application of image processing like image quantization and found effective and optimal results as compared to other algorithms. Color image quantization is an important process of representing true color images using a small number of colors. The objective of this research work is to design an algorithm for Image Quantization using CIE Luv color space based on Bacteria Foraging Optimization. The conducted experiments indicate that proposed algorithm generally results in a significant improvement of image quality .

Keywords: Bacteria Foraging Optimization, Luv color space, CMC distance, Swarm intelligence.

PROPOSED ALGORITHM

Bacteria Foraging Optimization is a population oriented algorithm used to search optimal solution. In this research each Pixel of the image is considered as bacteria and the color of the pixel is considered as bacteria food. The aim of the proposed algorithm is to minimize the food sources i.e. to reduce the number of colors in the image. In this research, al lthe pixels initially have some color and the purpose of this research is to optimize the number of colors in the image. All the colors in the image are evaluated as the number of pixels having that color. This evaluation defines the health status of all the colors present in the image. Depending upon the health status of the colors, all the colors in the image are divided into two categories popular colors and unpopular colors. If the health status of the color is high i.e. the color is present on too many pixels then that color is considered as popular color and all other colors whose health status is poor are considered unpopular colors. All the pixels in the image are compared with every other pixel in the image to find the most similar color to be eliminated. The fitness function is taken as CMC distance to find out the distance between two food sources i.e. colors. In this research we have considered CMC threshold value as 0.7 to further optimize the colors in the image. After
comparing the colors of all the pixels in the image if the CMC distance between two colors is found less than 0.7 then the color with which the CMC distance is found and all other colors having that color are eliminated with the other color . After this elimination process the health status of all the colors is evaluated again because after elimination the health status of colors may change. After the elimination process, the unpopular colors are compared and if the CMC distance between two unpopular colors is found less than 0.7 then those two colors are combined to produce a new color. This process of producing the new color is called as reproduction. The colors from which the new color is produced are killed. This new color is now dispersed at the pixels where the parents of new color were present.

BFO Consist of following basic principal mechanisms:-

- Chemo-taxis.
- Elimination.

- Reproduction.
- Dispersal.

A. Chemo-taxis

The motion patterns that the bacteria will generate in the presence of chemical attractants and repellents are called chemo-taxis. For E. coli, this process was simulated by two different moving ways: run or tumble. A Bacterium alternates between these two modes of operation its entire lifetime. The bacterium sometimes tumbles after a tumble or tumbles after a “run”. This alternation between the two modes will move the bacterium, and this enables it to "search" for nutrients (Chanet.al. 2009). In this research, each bacteria takes a unit step of size one in the same direction to find its nutrient i.e. each pixel takes a unit step of size one to find the most similar color. If the pixel find the most similar color after a unit walk fulfilling the fitness function i.e. CMC distance then it is called as swim where the pixel color is replaced with the color of that next pixel. If the most similar color is not found at the immediate next pixel position then the bacterium i.e. the pixel run to the next pixel positions with the unit steps, to find the most similar color. This process of swimming continued till the maximum number of similar colors is found.

B. Elimination

Elimination is performed in two steps. Primary elimination and secondary elimination.

1) *Primary Elimination:* In primary elimination if a pixel in the image found similar color following the fitness function then one of them becomes candidate pixel for the elimination.

2) *Secondary Elimination:* In secondary elimination firstly the health status is of all the colors in the image is evaluated. Then based on the health status the colors are divided into two categories surviving i.e. popular and the un-surviving i.e. unpopular colors. The un-surviving colors following the fitness function become candidate for the elimination. In this research, after comparing the colors of all the pixels in the image the elimination of colors in this step is based on the primary elimination.

C. Reproduction

All the colors in the image are evaluated as the number of pixels having that color.

$$\text{Health status} = \frac{N_i}{S}$$

Where N represents the number of pixels having i^{th} color. And S represents total number of pixels in the image. This evaluation defines the health status of all the colors present in the image. Depending upon the health status of the colors, all the colors in the image are divided into two categories surviving colors and un-surviving colors. If the health status of the color is high then that pixel is considered as surviving color and all other colors whose health status is poor are considered un-surviving colors. The unpopular colors are compared and if the Euclidean distance between two unpopular colors is found less than threshold value then those two colors are combined to produce a new color. This process of producing the new color is called as reproduction.

D. Dispersal

As explained above in the reproduction, we can add new colors to our color palette. The un-surviving colors from which the new color is produced are eliminated. Elimination in this step is performed according to the secondary elimination. This new color is now dispersed i.e. allocated to the parents of new color. In the classical BFO, the bacteria with the best positions are kept and the remaining bacteria population is killed. The bacteria with best positions are then moved to another position within the environment. In this research, the colors with poor health status are eliminated and the colors with high health status are kept. The new colors dispersed to other pixels in the image where the parents of new color were present. In the classical BFO, only the first half of population survives. In this research, instead of killing bacteria population the food sources are killed and reproduced. BFO has been implemented and validated on by applying the algorithm on images as well phantom images.

E. Proposed Algorithm

Step1.Initialize parameters

S, i, N_s, N_c, k, l, n, N_u, $\Delta E((k_{i1}, k_{i+1}))$

Where

S : Total number of pixels in the image (total number of bacteria).

i :Total colors in the image (number of food sources).

N_s: Number of swim steps ($N_s = 1$).

N_c : Number of chemo-tactic steps ($N_c = 1$).

k_i : Color of the current pixel (Current bacteria).

l : New color (new food source).

n_i :Number of pixels having same color (Number of bacteria following ith food source).

N_u : Number of pixels having unpopular color (Total number of bacteria with unpopular food source).

$\Delta E((k_{i1}, k_{i+1}))$: This is $\Delta E((k_{i1}, k_{i+1}))$i.e CMCdistance between Bacteria's current food source and nearest food source).

Food sources are divided into categories popular and unpopular depending upon how many bacteria are moving toward that particular food source. Colors in the image are divided into two categories surviving colors and un-surviving colors depending upon how many pixels have the similar color.

Step 2. Chemo-tactic step: Compute

$$\Delta \boldsymbol{E}^*_{\mathrm{CMC}} = \left((\Delta \boldsymbol{L}^*/l\boldsymbol{S_L})^2 + (\Delta \boldsymbol{C}^*/c\boldsymbol{S_C})^2 + (\Delta \boldsymbol{H}^*/\boldsymbol{S_H})^2 \right)^{\mathbf{1/2}}$$

$$\Delta C^*_{\mathrm{uv}} = ((u^*_2 - u^*_1)^2 + (v^*_2 - v^*_1)^2)^{1/2}$$

$$\Delta L = L_2 - L_1$$

$$\Delta H^* = ((\Delta E^*_{uv})^2 - (\Delta L^*)^2 - (\Delta C^*)^2)^{1/2}$$

l&c are application dependent coefficient.

Step 2. Elimination step

For $k = 1.........S$. Take a chemo-tactic step of size one for pixel k as follows:

If $\Delta E((k_{i1}, k_{i+1})) <= 0.7$

Eliminate $k_i$pixel's color and all other pixels having i^{th}color with k_{i+1}pixel's color.

Else

$k = k + 1$

END
END
Step 3. Reproduction and dispersal step

$$\text{Health status} = \frac{N_i}{S}$$

Categorize the colors in the image into two categories popular and unpopular depending upon the health status.

Substep 3.1

For $k = 1.........N_u$ Take a chemo-tactic step of size one for pixel k as follows:

If (k_i = popular)

Continue;

Else If $\Delta E((k_{i1}, k_{i+1}))$<= 0.7

$l = \frac{(k_i) + k_i + 1}{2}$...3.2

Eliminate k_{i+1} pixel's color and k_i pixel's color.

Disperse l^{th} color at the pixels were the parents of

l^{th} color were.

END

END

RESULTS AND DISCUSSIONS

Our objective is to use the proposed Bacteria Foraging Optimization algorithm for Color image quantization using Luv color model. Bacteria Foraging Optimization using Luv color model has been validated by using ΔE<= 0.7 and applying the algorithm on images as well as phantom images by varying the size of image and number of bacteria. Phantom images are also called as computer generated images. This category collects images that are scans, screen captures, photos, and/or illustrations of the Phantom and related characters and intellectual properties. The following figures show input image with original number of colors and resulting image with quantized colors.

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Figure 4.1:Original image 'Phantom1.jpg'
with10270 colors on left
and Quantized image 'Phantom1.jpg'

with 5592 colors on right.

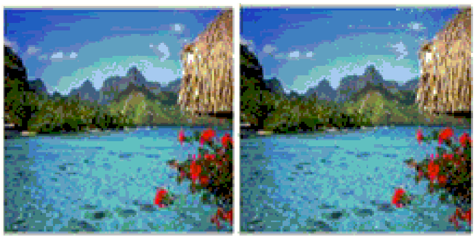

Figure 4.2: Original image ‘Scene1.bmp’
with 14608 colors on left
and Quantized image ‘Scene1.bmp’
with9823 colors on right.

Figure 4.3:Original image ‘Phantom2.jpg’
With 8024 colors on left
and Quantized image “Phantom2.jpg’
with4817 colors on right.

Figure 4.4: Original image ‘Phantom3.jpg’
with 5918 colors on left
and Quantized image ‘Phantom3.jpg’
with 3694 colors on right.

Figure 4.5: Original image ‘Flower.png’

ISSN: 2229-6913 (Print), ISSN: 2320-0332 (Online) - www.ijoes.org

with15717 colors on left
and Quantized image ‘Flower.png’
with9986 colors on right.

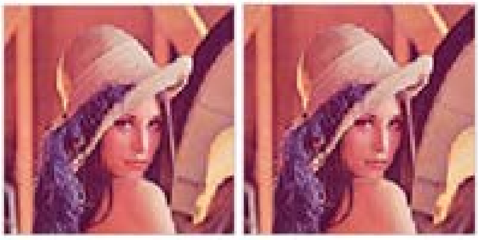

Figure 4.6:Original image ‘Lena.jpg’ with
9094 colors on left side
and Quantized image ‘Lena.jpg’
with 6189 colors right side.

The computational results which have been obtained using the proposed algorithm are shown below in a table. These results have been analyzed based on LMSE, PSNRand Average Difference.

TABLE 4.1
COMPUTATIONAL RESULT & ANALYSIS OF RESULTS BASED ON LMSE, PSNR AND AVERAGE DIFFERENCE

File Name	**Colors before Quantiza-tion**	**Colors after Quantiza-tion**	**PSNR**	**LMSE**	**Average Difference**
Phantom1.j	10270	5592	274.76	0.0528	0.0029
Scene 1	14608	9823	325.67	0.0099	0.0791
Phantom2.j	8024	4817	332.61	0.0079	0.1213
Phantom3.j	5918	3694	294.46	0.0071	0.1002
Flower	15717	9986	308.58	0.0053	0.1352
Lena.jpg	9094	6189	342.23	0.0067	0.0975

From the above results it can be observed that perceptual uniformity is there in the output image. There is no degradation in the image quality. The processed image is visually similar to the input image. The performance of proposed algorithm is evaluated based on LMSE, PSNR and Average Difference. In this research work the results which have been achieved using Bacteria Foraging Optimization for color quantization using Luv color model are compared with the other approaches. The results of the proposed algorithm are analyzed by comparing it with the existing techniques of color image quantization.

The following figures shows the processed images based on Bacteria Foraging Optimization for color quantization using Luv color model and processed images based on Bacteria Foraging Optimization for color quantization using LAB color model.

Figure 4.7: Quantized image ‘Phantom4.jpg’
with 3978 colors using BFO-CIQ LAB on left
and Quantized image ‘Phantom4.jpg’
with 3950 colors using BFO-CIQ Luv on right.

Figure 4.8: Quantized image ‘Phantom1.jpg’
with 6231 colors using BFO-CIQ LAB on left
and Quantized image ‘Phantom1.jpg’
with 6189 colors using BFO-CIQ Luv on right.

From the results shown above, the results obtained by using Bacteria foraging optimization using Luv model are comparatively better than the previous work.

V. CONCLUSIONS AND FUTURE WORK

In this paper, we have presented Bacteria Foraging Optimization algorithm for color image quantization using Luv color model. Based on the results presented in the previous chapter, I conclude that the image quantization based on Bacteria foraging optimization using Luv color model gives better results. The Luv color model eliminates the weakness of RGB color model and LAB model. The CIE Luv color space is designed to be perceptually uniform, meaning that a given change in value corresponds roughly to the same perceptual difference over any part of the space. Using such a space for quantizing color values decreases the chance that any given step in color value will be noticeable on a display or hardcopy.In this research, Bacteria Foraging Optimization has been implemented on various types of images including the phantom images. This validates the proposed algorithm and it gives optimized results when implemented on the phantom images.

A. Future Work

Further research work may focus on developing some new algorithms related to other swarm based technique like Honey bee to decrease the computational cost and time during global optimization.

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