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EXTENDED RESULTS: ACO BASED MIX-CLAHE FOR UNDERWATER HAZE REMOVAL

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Abstract— **The probabilistic Ant Colony Optimization (ACO) approach is presented to solve the problem of designing an optimal route for hard combinatorial problems. The analysis presented in this paper focuses on haze removal for underwater images which have poor visibility due to presence of haze. It is found that most of the existing researchers have neglected many issues i.e. no technique is accurate for different kind of circumstances. The existing methods have neglected the use of ant colony optimization to reduce the noise and uneven illuminate problem. The main objective of this paper is to evaluate the performance of Ant colony optimization based haze removal over the available MIX-CLAHE (Contrast Limited Adaptive Histogram Equalization) technique. The experiment has clearly showed the effectiveness of the proposed technique over the available methods.**

Index terms- **CLAHE, MIX-CLAHE, Haze, ACO.**

I. INTRODUCTION

In underwater image capturing, the presence of haze is the well-known source of distortion. The underwater images are very important as they provide critical pieces of information regarding underwater mines, shipwrecks, coral reefs, pipelines, ocean engineering, sea life and navigation details. The possible causes of haze effect may be presence of sand, minerals, plankton in ocean, river and lakes which absorb and scatter some part of the light on the way coming back to camera after reflection from object. Haze removal is considered a tough task because fog depends upon the unknown scene depth information. Haze effect is the event of distance between camera and object. Hence removal of haze requires the estimation of air light map or depth map.

The haze removal techniques are categorized into two sub categories: image enhancement and image restoration. The former doesn't explain the core reason of image degradation by haze. The contrast of haze image can be enhanced by this technique but some of the image information is lost. In contrast, image restoration firstly studies the physical procedure for imaging in foggy weather. After observing that degradation style of fog, image will undoubtedly be established. At last, the degradation process is inverted to generate the haze free image without the degradation. So, the quality of degraded image might be improved. The paper addresses MIX-CLAHE (Contrast limited adaptive histogram equalization) which combines two outputs of CLAHE applied onto two color models of RGB and HSV with the primary goal of reducing significant noise introduced by CLAHE in order to ease a subsequent process of underwater images. MIX-CLAHE improves local contrast of an image more than standard histogram equalization does by bringing out more details but still has tendency to amplify noise. This paper proposes new method which integrates MIX- CLAHE and ACO technique. The main goal is to reduce the noise and uneven illuminate problem.

II. ACO IMPLEMENTATION

Ant Colony Optimization (ACO) is a meta-heuristic for solving hard combinatorial optimization problems. The inspiring supply of ACO could be the pheromone trail laying and following behavior of real ants, which use pheromones as a communication medium. In analogy to the biological example, ACO is based on indirect communication inside a colony of simple agents, called (artificial) ants, mediated by (artificial) pheromone trails. The pheromone trails in ACO serve as distributed, numerical information, that the ants use to probabilistically construct methods to the issue being solved and that the ants adapt during the algorithm's execution to reflect their search experience.

The (artificial) ants in ACO implement a randomized construction heuristic making probabilistic decisions as a function of artificial pheromone trails and possibly available heuristic information on the basis of the input data of the issue to be solved. As a result, ACO could be interpreted as an extension of traditional construction heuristics, which are plentiful for several combinatorial optimization problems. Yet, an important difference with construction heuristics could be the adaptation of the pheromone trails during algorithm execution to consider the cumulated search experience.

Table 1**:** List of various parameters used in ACO implementation:

Nature	Description(Computer Science)
Natural Habitat	Graph (nodes and edges)
Nest and food	Nodes in the graph: start and destination
Ants	Agents, our artificial ants
Visibility function	The reciprocal of distance, η
Pheromones(Attractiveness)	Artificial pheromones ,τ
τ_0	Pheromone initial value
σ_e	Heuristic value of the edge e
τ_{ij}	Pheromone value of the arc Connecting points i and j
α	Weight parameter of the pheromone information
β	Weight parameter of the heuristic information
ρ	Percentage of pheromone that remains after evaporation
n	Number of ants used in algorithm
C	Ants in colony
q	Number of iterations
NC	Independent runs of algorithm
p_e	Choose edge e according to probability
Rand_pixels	Randomly generated pixels
Iimage_pixelsort	Best sorted image pixels
Global_best	Global pheromone update value
Ones(m,n)	Predefined Ones of trail value
td	Pheromone distance value
pk	Delta pheromone value

Since, there are no pre-defined connections between nodes, the implementation starts with generating the connections between the nodes. The generation of the next edge of the current point for ant follows Equation 1 in which it choose next edge probabilistically according to the attractiveness and visibility.

Distance(i,j)= sqrt $((x(i)- x(j)^2 +(y(i)- y(j)^2))$ (1)

x, y location co-ordinates such that is Euclidean distance between location i, j

$$pe= \frac{(\tau_e).(\sigma_e)}{\sum available\ edges\ e^{\tau}(e')|(\sigma^{(e')}} \quad (2)$$

where τ_e is the current pheromone trace in the arc *e*; $\sigma_e$is the heuristic value of the arc *e* To avoid the repetition of a location in the route, each ant stores the location of the visited nodes in a temporal memory Each ant maintains a tabu list of infeasible transitions for that iteration and Update attractiveness of an edge according to the number of ants that pass through. The pheromone update process is done in two phases; first, each ant updates its own local path, and later a global process updates the arcs of the best route, according to Equation 3 and Equation 4, respectively. Then we have to update local pheromone value

$\tau_{ij}(t) = (1\text{-}p)\ \tau_{ij}(t)\ )p.\ \tau_0$ (3)

τ_{ij} Describes the amount of pheromone on edge $[i, j]$ at time t. ρ Describes pheromone decay $0< \rho <1$; and $\tau_0$is the initial value of pheromone on all edges. Experimentally, the optimal value for ρ has been found to be 0.1 and good formulation for τ_0 has been found to be:

$$\tau_0 = \frac{1}{(n.L_{nn})}$$

Where n is the number of nodes in the graph; and L_{nn} is the length of the tour found by a nearest neighbour heuristic.

$$\tau_{ij}(t) \leftarrow (1\text{-}p)\ \tau_{ij}(t) + p.\ \Delta\ \tau_{ij}(t) \quad (4)$$

Where $\tau_{ij}(t)$ is the amount of pheromones on the edge (i,j) at time t; ρ is a parameter governing pheromone decay such that $0< \rho <1$; and $\cdot\Delta\tau_{ij}(t) = 1/L^+$ where L^+ is the length of the current best tour. The pseudo code of our implementation is presented in three parts. Algorithm 1 shows the random pixel generation and Algorithm 2 shows generation of pheromone matrix and Algorithm 3 find the best path (route) procedure performed by each ant.

ALGORITHM 1: RANDOM PIXEL GENERATION

```
for  i=1:n
  for j=1:n
distance(i,j)=sqrt(
(x(i)-
x(j))^2+(y(i)-
y(j))^2);%distance
    end
  end
for i=1:n
distance(i,i)=0.01;
%
```

ALGORITHM 2**:** generation of pheromone matrix

```
for i=1:100
    if
limage_pixelsc(i)
<=130%     30
      for
k=1:n-1

t(rand_pixels(i,k
),rand_pixels(i,k
+1))=t(rand_pixel
s(i,k),rand_pixel
s(i,k+1))+10;%
30
```

ALGORITHM 3: find the best path (route)

```
for k=1:m
 for step=1:n-1
   ta=t^a;
 tb=distance.^(-b);
  td=ta.*tb;
dd=path(k,step);
  if dd<=30
   dd=30;
    end

pd=tabu(k,:).*td(dd,:);
 pk=pd/sum(pd);
   rk=rand;
   spk=0;
```

III. Experimental Setup:

Below are the steps for the proposed algorithm

Phase 1: Select the input image. Any digital image is represented as an array of size M*N pixels

Phase 2: First of all, apply MIX-CLAHE technique on the input image. This technique was invented to reduce undesired artifacts as well as brightness in an image. MIX-CLAHE technique mixes the results of CLAHE-RGB and CLAHE-HSV. The main aim of this technique was to enhance the contrast of an image and give natural look to underwater images. This method first normalizes the result of CLAHE-RGB.

$$\{r_{c1}, g_{c1}, b_{c1}\} = \left[\frac{R_c}{(R_c+G_c+B_c)}, \frac{G_c}{(R_c+G_c+B_c)}, \frac{B_c}{(R_c+G_c+B_c)}\right] \quad (5)$$

Then the result of CLAHE-HSV is converted to RGB color model by finding chroma

$$C = V * S \quad (6)$$

$$H' = \frac{H}{60^0} \quad (7)$$

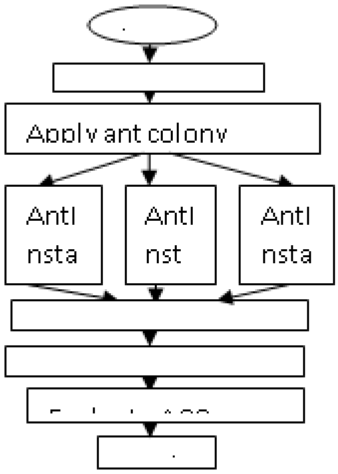


Figure 2. Flow Chart of Ant colony optimization based Mixed-CLAHE technique

Then, by using C and , X is determined as follows:

$$X = C(1 - |(H' \bmod 2) - 1|) \quad (8)$$

The conversion from HSV to RGB which is denoted by

$$\{r_{c1}, g_{c1}, b_{c2}\} = \begin{cases} (0,0,0), \text{ if } H \text{ is undef} \\ (C, X, 0), \text{ if } 0 \le H' < 1 \\ (X, C, 0), \text{ if } 1 \le H' < 2 \\ (0, C, X), \text{ if } 2 \le H' < 3 \\ (0, X, C), \text{ if } 3 \le H' < 4 \\ (X, 0, C), \text{ if } 4 \le H' < 5 \\ (C, 0, X), \text{ if } 5 \le H' < 6 \end{cases} \quad (9)$$

Finally, both conversions' from eq.5 and eq.9 are integrated using Euclidean norm:

$$RGB_n = \sqrt{r_{c1}^2 + r_{c2}^2} + \sqrt{g_{c1}^2 + g_{c2}^2} + \sqrt{b_{c1}^2 + b_{c2}^2} \quad (10)$$

Phase 3: In this phase whole working of ACO algorithm will be performed as discussed earlier.

Phase4: At the end we have to merge pheromone value and then evaluate ACO based MIX-CLAHE factor.

$$\frac{\sqrt{r_{c1}^2 + r_{c2}^2} + \sqrt{g_{c1}^2 + g_{c2}^2} + \sqrt{b_{c1}^2 + b_{c2}^2}}{((fsh * fsv) + 255)} \quad (11)$$

In above equation we have is the value of pheromone on horizontal side and is the value of pheromone on vertical side.

Phase 5: Then the final image is obtained.

VI. Performance Evaluation

The algorithm is applied using various performance indices peak signal to noise ratio (PSNR), Mean squared error (MSE), Root Mean Square Error (RMSE) and Normalized Cross Correlation (NCC),Bit Error Rate (BER), Normalized Absolute Error (NAE).

In order to implement the algorithm, design and implementation has been done in MATLAB using image processing toolbox. The developed approach is compared against a well-known image dehazing technique. We are comparing proposed approach using some performance metrics. Result shows that our approach gives better results than the existing technique Table 2 is showing the quantized analysis of the mean square error. As mean square error needs to be reduced therefore the algorithm is showing the better results than the available methods as mean square error is less in every case. The mean Square error is reduced in each case. The method is tested on the number of images and in each case shows the better results than the existing method. For example in given table it is clearly shown that the 4, 7, 9 images have very much less MSE values so this technique work efficiently.

TABLE 2: MSE EVALUATION

Images	HSV-CLAHE	RGB-CLAHE	MIX-CLAHE	Proposed results
1	14309.70	1195.483	991.6318	823.4952
2	16005.32	832.2210	832.5355	817.2272
3	13060.62	1648.870	1762.560	1071.750
4	**22374.29**	**1389.822**	**696.1084**	**612.1575**
5	**28652.12**	**1700.179**	**1546.954**	**1088.406**
6	7278.215	3063.898	4309.123	4068.933
7	**5621.792**	**2644.050**	**519.6979**	**303.2442**
8	25560.98	485.3160	1729.360	1677.561
9	**7621.892**	**5944.350**	**577.6879**	**383.2842**
10	12207.08	1330.753	1467.562	1349.558

Table 3 is showing the comparative analysis of the root mean square error. Table has clearly shown that is less in our case therefore the algorithm has shown significant results over the available algorithm. The highlighted rows clearly had shown the better results of proposed techniques.

TABLE 3: RMSE EVALUATION

Images	HSV-CLAHE	RGB-CLAHE	MIX-CLAHE	Proposed results
1	**119.6232**	**34.5758**	**31.4902**	**28.6966**
2	126.5122	28.8482	28.8537	28.5872
3	**114.2831**	**40.6063**	**41.9829**	**32.7376**
4	149.5804	37.2804	26.3839	24.7418
5	169.2694	41.2332	39.3313	32.9910
6	85.3125	55.3525	65.6439	63.7882
7	**74.9786**	**51.4203**	**22.7969**	**17.4139**
8	159.8780	22.0299	41.5856	40.9580
9	115.9648	29.5158	3.5814	3.1788
10	110.4857	36.4795	38.3088	36.7363

Table 4 is showing the comparative analysis of the Peak Signal to Noise Ratio (PSNR). As PSNR need to be maximized; so the main goal is to increase the PSNR as much as possible. Table 3 has clearly shown that the PSNR is maximum in the case of the algorithm; therefore algorithm is providing better results than the available methods. The method is tested on the number of images and in each case shows the better results than the existing method.

TABLE 4: PSNR EVALUATION

Images	HSV-CLAHE	RGB-CLAHE	MIX-CLAHE	Proposed results
1	6.5745	17.3554	18.1673	18.9742
2	**6.0882**	**18.9284**	**18.9268**	**19.0074**
3	**6.9712**	**15.9589**	**15.6694**	**17.8299**
4	**4.6333**	**16.7012**	**19.7040**	**20.2622**
5	3.5592	15.8259	16.2360	17.7629
6	9.5106	13.2681	11.7869	12.0360
7	**10.6321**	**13.9081**	**20.9733**	**23.3129**
8	4.0550	21.2706	15.7519	15.8840
9	6.8443	18.7297	37.0497	38.0855
10	7.2647	16.8898	16.4648	16.8289

Table 5 is showing the quantized analysis of Bit Error Rate. As Bit Error Rate need to be reduced therefore the algorithm is showing the better results than the available methods as Bit Error Rate is less in every case. The Bit Error Rate is reduced in each case. The method is tested on the number of images and in each case shows the better results than the existing method.

TABLE 5: BER EVALUATION

Images	HSV-CLAHE	RGB-CLAHE	Mix-CLAHE	proposed Methods
1	0.1849	0.0619	0.0400	0.0364
2	0.2466	0.0466	0.0631	0.0619
3	0.1593	0.0600	0.0499	0.0490
4	0.2159	0.0599	0.0511	0.0488
5	0.1051	0.0754	0.0848	0.0837
6	0.0981	0.0691	0.0767	0.0738
7	0.1784	0.0551	0.0371	0.0360
8	0.1643	0.0586	0.0617	0.0614
9	0.1409	0.0553	0.0481	0.0470
10	0.1434	0.0627	0.0638	0.0620

Table 6 is showing the comparative analysis of the Normalized Cross-Correlation. Table has clearly shown the results of NCC, therefore the proposed algorithm has shown significant results over the available algorithm.

TABLE 6: NCC EVALUATION

Images	HSV-CLAHE	RGB-CLAHE	Mix-CLAHE	proposed Methods
1	0.0042	0.9716	0.9566	0.9587
2	0.0053	0.9920	0.8299	0.8161
3	0.0037	0.9145	0.8583	0.8646
4	0.0034	0.9343	0.9428	0.9524
5	0.0073	0.4819	0.2760	0.2879
6	0.0046	0.5275	0.3021	0.3386
7	0.0037	0.9861	0.9303	0.9366
8	0.0058	0.8961	0.7632	0.7649
9	0.0050	0.9718	0.9670	0.9802
10	0.0051	0.8307	0.7077	0.7238

Table 7 is showing the comparative analysis of the Normalized Absolute Error (NAE). As NAE need to be minimized; so the main goal is to de crease the NAE as much as possible. Table 5.3 has clearly shown that the NAE is minimum in the case of the algorithm; therefore algorithm is providing better results than the available methods. The method is tested on the number of images and in each case shows the better results than the existing method.

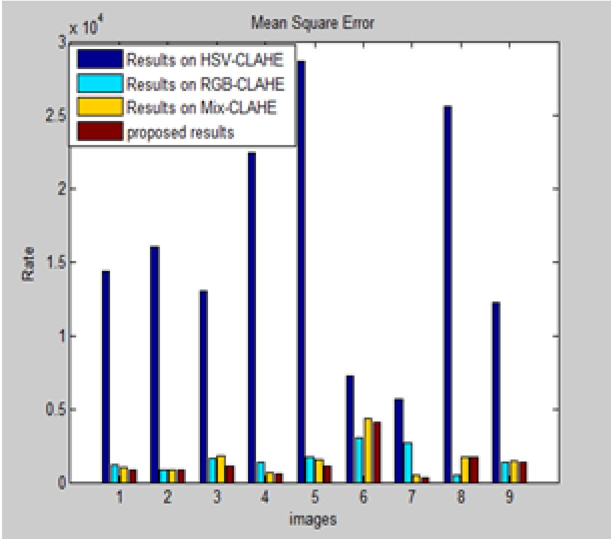
TABLE 7: NAE EVALUATION

Images	HSV-CLAHE	RGB-CLAHE	Mix-CLAHE	proposed Methods
1	0.9961	0.2417	0.0900	0.0674
2	0.9949	0.0911	0.2331	0.2255
3	0.9969	0.2493	0.2053	0.1962
4	0.9971	0.2122	0.1667	0.1506
5	0.9932	0.5562	0.7030	0.6908
6	0.9959	0.5146	0.6665	0.6314
7	0.9966	0.1902	0.0836	0.0760
8	0.9945	0.1879	0.2794	0.2768
9	0.9955	0.2422	0.1797	0.1662
10	0.9952	0.2858	0.3144	0.2981

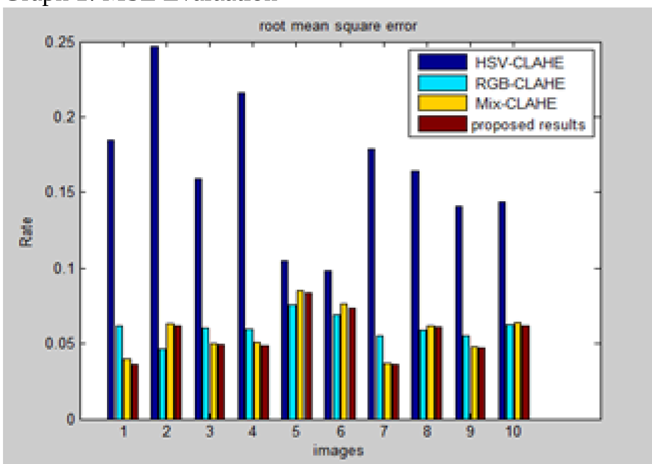
IV. COMPARATIVE ANALYSIS:

The algorithm has shown the various comparative analysis graphs on different performance parameters, which reflects the improvement in analysis outcomes and better results from previous technique. Graph 1 has shown the quantized analysis of the mean square error of different images. It is very clear from the graph that there is decrease in MSE value of images with the use of method over existing method. This decrease represents improvement in the objective quality of the image.

Graph 2 has shown the quantized analysis of the Root mean squared Error of different images. It is very clear from the plot that there is decrease in RMSE value of images with the use of method over existing method. This decrease represents improvement in the objective quality of the image

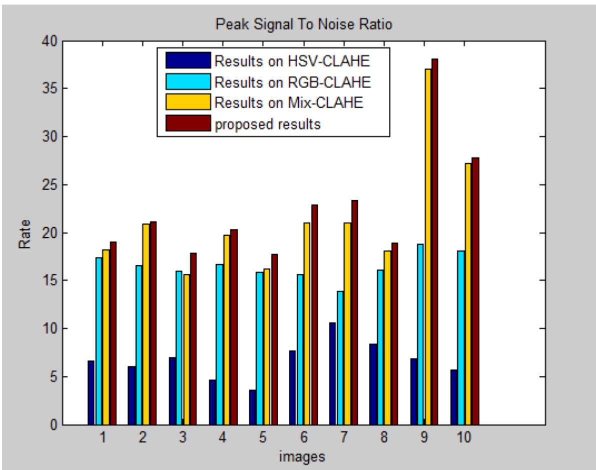


Graph 1: MSE Evaluation



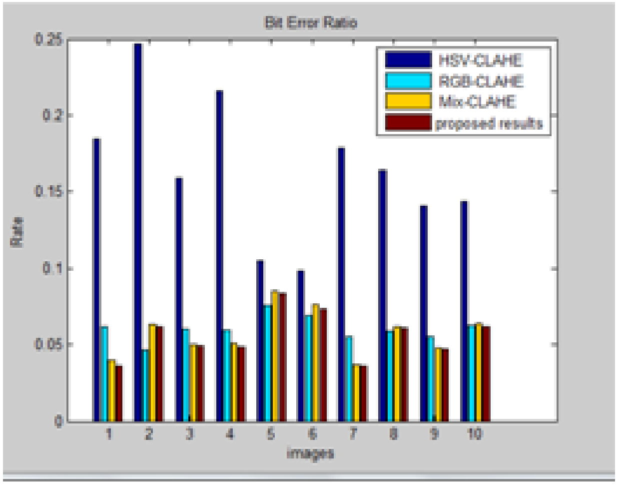
Graph 2: RMSE Evaluation

Graph 3 has shown the quantized analysis of the peak signal to noise ratio of different. It is very clear from the plot that there is increase in PSNR value of images with the use of method over existing methods. This increase represents improvement in the objective quality of the image.



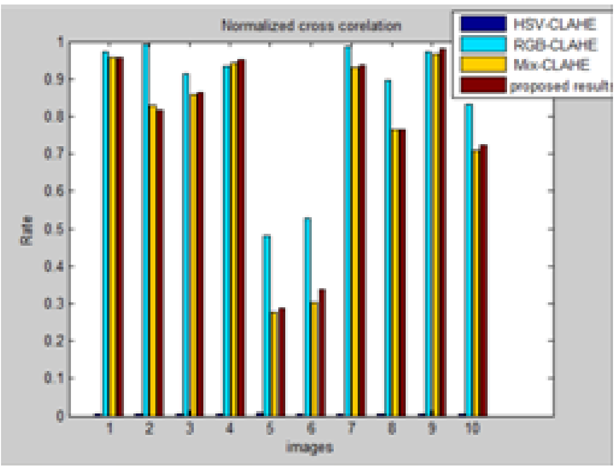
Graph 3: PSNR Evaluation

Graph 4 has shown the quantized analysis of the Bit Error Rate of different images. It is very clear from the graph that there is decrease in BER value of images with the use of method over existing method. This decrease represents improvement in the objective quality of the image.



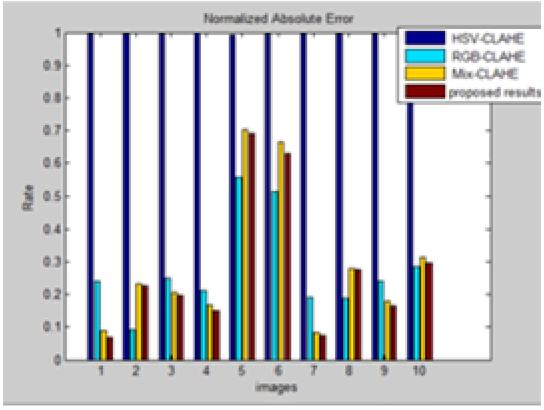
Graph 4: BER Evaluation

Graph 5 has shown the quantized analysis of the Normalized Cross-Correlation of different images. It is very clear from the plot that there is increase in NCC value of images with the use of method over existing method. This increase represents improvement in the objective quality of the image



Graph 5: NCC Evaluation

Graph 6 has shown the quantized analysis of the Normalized Absolute error of different images.. It is very clear from the plot that there is decrease in NAE value of images with the use of method over existing methods. This decrease represents improvement in the objective quality of the image.



Graph 6: NAE Evaluation

V. Conclusion and Future Work

This paper has proposed a new technique which basically used for underwater haze removal. The review analysis shows that underwater images are suffering from low contrast and low visibility. This paper has offered a new technique ACO based MIX-CLAHE which is integrated technique of MIX-CLAHE and ANT colony optimization. The proposed technique has been designed and implemented in MATLAB using image processing tool. The experimental results indicates that proposed technique offers better results as compare to available methods. In near future we use more quality metrics to judge the potency of the proposed technique. Also the Ant colony suffers from slow converges speed therefore in future we will try to reduce it using other evolutionary optimization based techniques.

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