A NOVEL ENHANCEMENT METHOD FOR COLORED ROCK ART
ARCHAEOLOGICAL IMAGES

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Abstract- Rock Art Archaeology plays important role in understanding the Culture, Religious systems, Art forms, Gender relations and Belief systems of ancient times. The biggest challenge in studying the various art forms like paintings and engravings found on rocks is that they are prone to environmental degradation and vandalism. Therefore, enhancement of images acquired from Rocks becomes a prerequisite for Archaeological studies. In this study, an enhancement method based on application of Brightness Preserving Bi-Histogram Equalization (BBHE) and De-correlation Stretch (D-Stretch) is proposed. Performance Evaluation of existing enhancement methods for Rock Art images is performed and comparison is done with proposed method both subjectively and objectively using metrics PSNR, MSE, RMSE, MAE, NK, SC, AD. Experimental results demonstrate that proposed method attains the highest performance for enhancement of Rock Art images.

Keywords- Rock art Archaeology, Enhancement, HE, BBHE, D-Stretch, PSNR, MSE, RMSE, MAE, NK, SC, AD.

I. INTRODUCTION

The main aim of image enhancement is to enrich the visual quality of an image, to make the image more appealing to humans. Over the years a growing number of techniques are used to enhance Rock Art Images. Contrast enhancement is foremost concern as it can improve image for perception. Contrast is the difference in luminance or intensity level between objects or regions in an image. Low contrast causes loss of information in some areas in the image, while good contrast makes objects or scenes depicted in an image distinguishable and visually interpretable for human and machine analysis [1].

Aborigines, used rock art to represent and communicate their understanding of the world and reflect their spiritual and religious life. Their rock engravings and cave paintings are an indispensable source of information for our understanding of prehistoric living. However, most Aboriginal cave drawings are located in unprotected environments and are subject to environmental deterioration and vandalism. The surviving examples are now usually located in remote areas, which make it difficult for many to experience. It is therefore essential that rock art be accurately recorded, for conservation and studying by historians, archaeologists, the general public and future generations of aboriginals themselves. Standard recording techniques, mainly tracing and photography, do not allow a full and realistic experience. Traditional measurement techniques, like surveying and photogrammetric, cannot capture all the details of irregular surfaces [2].

A. Need of Enhancement for Rock Art Images

II. HISTOGRAM EQUALIZATION

Histogram equalization (HE) is primarily used because of its simplicity. HE expands the histogram by extending dynamic range of gray values to fulfill overall contrast enhancement, it has an effect of stretching dynamic range [6]. The mean brightness of resulting output image instead of input mean approach to the centered gray level, which results in uniform histogram. It is not desired where mean preservation is
required. It also acts as base for many other techniques such as BBHE, MBHE, DSIHE, and RMSE. The value of the kth pixel for Channel l, as

\[ p(X_{k}) = \frac{n_{k}}{n} \]

where \( k = 0, 1, \ldots, m \) and \( n_{k} \) represents the number of times that the level \( X_{k} \) appears in the input image \( X \). Note that \( p(X_{k}) \) is associated with the histogram of the input image, plot of \( n_{k} \) vs. \( X_{k} \) is known as the histogram of \( X \).

- Cumulative Density Function is defined based on PDF as
  \[ c(x) = \sum_{k=0}^{L} p(X_{k}) \]
  Where \( X_{k} = x \), for \( k = 0, 1 \ldots L - 1 \).
- HE maps the intensity values of input image to entire dynamic range \( \{ X_{0}, X_{L-1} \} \) using CDF as a transform function.
- Transform function \( f(x) \) is defined as
  \[ f(x) = X_{0} + (X_{L-1} - X_{0}) c(x) \]
  then the output image of the histogram equalization = \( \{ Y(i,j) \} \) can be expressed as \( y = f(x) \)
- Transformation function is applied to both images \( X_{L} \) and \( X_{U} \), these images are then concatenated to have the final output image \( Y \) of BBHE method.

IV. DE-CORRELATION STRETCH

D-stretch method is very helpful for archaeologists, historians, interested scholars and others for study and documentation of rock arts. This method brings out the details from faded pictographs which are not visible to naked eyes. Obscureness in hue is enhanced to inkling superimposed images. D-stretch diagonalize correlation matrix of color channels, then contrast stretching is performed to equalize color variation. Colors are uncorrelated at this point to fill the color space. To map back the approximate original colors inverse transformation is used. A 3x3 transformation matrix is produced that is applied to the colors in image. The common color types (red, black, and white, mainly red) of pictographs cause consistency in enhancement of De-correlation Stretch. The resultant enhanced image is of false colors, i.e. colors are extreme from original [7].

- First, a grid of pixels is selected that is expected to form a representative sample of all “good” surface pixels found within the scene.
- The requester may optionally specify a rectangular subarea for statistics gathering, rather than use the entire image. This option would permit a greater diversity of color within the region of interest, at the expense of overall scene diversity.
- Using the sampled pixels, the nine sums that are needed to calculate the covariance matrix for the three channels are accumulated.
  - These sums are:
    For \( l = 1, 3; m = 1, l \) and sampling \( n \) pixels,
    \[ \sum_{k=0}^{L} P_{k,l} = \sum_{k=0}^{L} P_{k} \]
    Where \( P_{k} \) is the value of the kth pixel for Channel 1.
- The covariance and the correlation matrices are computed, using the following formulas:
  - The elements of the covariance matrix are computed as follows:
For the correlation matrix elements:

\[ \text{Corr}_{l,m} = \frac{\text{Cov}_{l,m}}{\sqrt{\text{Cov}(l,l) \cdot \text{Cov}(m,m)}} \]

- The matrix of eigenvectors described by the correlation matrix (or, optionally, of the covariance matrix) is referred to as the rotation matrix, \( R \), in subsequent steps.
- The “stretching vector” (or Normalization vector), \( s \), is formed by taking the reciprocal of the square root of each element in the eigenvalue vector, and multiplying it by the desired standard deviation for the output image channels.
- The final transformation matrix, \( T \), is composed from the rotation matrix and the stretching vector.

\[ T = R^T \cdot s \cdot R \]

Before applying transformation on image, it is applied to vector of the means of the input channels. Result is used to compute the offsets needed to reposition the output image values to the 0 to 255 dynamic range of eight bit data. For each pixel in the scene, the output pixel vector (3 valued) is computed by applying the final transformation matrix, and then the offset vector [7].

V. BPDS METHOD FOR ENHANCEMENT

A method Brightness Preserving De-correlation Stretch (BPDS) is proposed for color image enhancement of Rock Art Images based on BBHE and DS methods. These methods have not been used for Rock Art Images. Proposed procedure is presented below and flow chart is represented in figure2.

Proposed Procedure:
- Load a color image in Matlab.
- Calculate the mean of input image.
  \[ \text{Mean}=\text{round} \left( \text{mean} \left( \text{input image} (: \right) \right) \];
- Divide the image into two halves on behalf of mean value(1st half from 1st value to mean value, second half from mean+1 to end)
  \[ 1^{st \text{ part}}= \text{input image} (:, 1:\text{Mean}, :); \]
  \[ 2^{nd \text{ part}}= \text{input image} (:, 1:\text{Mean+1}: \text{end}, :); \]
- Apply De-correlation stretch on both images
  \[ Ds=\text{decorrstretch}(1^{st \text{ part}}); \]
  \[ Ds1=\text{decorrstretch}(2^{nd \text{ part}}); \]
- Concatenate the resultant images of D-stretch
  \[ \text{Output image}=\text{cat}(2Ds,DS1); \]

![Flow Chart for BPDS method](image-url)
VI. EXPERIMENTAL RESULTS

To demonstrate the efficiency of proposed algorithm, performance evaluation of proposed method BPDS and existing methods is done both subjectively and objectively. Objective performance evaluation is done using metrics like MSE, PSNR, Average Difference, SC, and NK. Graphical outputs are presented in Table1 and results of performance metrics are presented Table2.

Results for images on regular surface, irregular surface, images having multiple colors, image with single color, having high and low brightness are computed. As we can see in last row of table 1 results of BPDS, preserves the brightness as well texture details, in image 2 the texture details are more visible in lower left corner, by equalizing the color variation in D-Stretch it degrades the quality of edges, as we can see in 5th row and 2nd column of table1 the image 1 has some grass, D-Stretch results in blur effect, whereas with BPDS the blur effect is lesser as compared to D-Stretch. The objective results of BPDS outperform than other techniques as shown in table 2, the change in Structural content in BPDS is lesser than D-Stretch.

Table1: Experimental Results for Enhancement Methods
VII. CONCLUSION

In this study, a method for enhancing the details covered in rock art images is proposed, which maintains the mean brightness of input image as well as stretch the contrast of image by equalizing color variation. The proposed method is referred to as BPDS (Brightness Preserving De-correlation Stretch), which is a novel extension of BBHE and D-Stretch. The goal is to uncover the hidden details of rock art by preserving the mean brightness and equalize color variation. Experimental results of performance evaluation of proposed method and other methods demonstrate that BPDS attains highest performance for enhancement of Rock Art Images. The proposed algorithm is complex then existing ones, an effort to reduce the complexity should be made to effectively use this algorithm.

VIII. REFERENCES

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