A HYBRID CUCKOO SEARCH TO ENHANCE LOW RESOLUTION IMAGES

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INTRODUCTION

Enhancement of low resolution images has been a persistent problem in the field of image processing that has seen a steady rise of many soft-computing oriented approaches oriented towards solving it [1] [2] [3] [4] [5]. The end aim of all such image enhancement techniques is related to freeing the image of noise, increasing the pixels through interpolation and sharpening its intensity. This enhancement may be performed in the image domain itself or in a transform domain [6] [7] [8].

Certain state-of-art techniques such as Cycle Spinning (CS) and WZP (Wavelet Zero Padding) have been widely used in resolution enhancement of images. A noticeable improvement over these methods was obtained by using Discrete Wavelet Transform (DWT) and interpolation techniques for dividing an image into different high frequency sub-bands and combining them again along with the initial low resolution image using IDWT. This method delivered a higher clarity for resolution enhancement than current known techniques and was initially advocated in the field of satellite images, requiring high resolution images [9] [10] [11]. Another method based on the same principle was the Forward Dual tree complex wavelet transform (DT-CWT) which was applied to obtain an estimate of wavelet coefficients by decomposing the image followed by the inverse DT-CWT which was used to construct a HR image from the given LR image [12].

Resolution enhancement schemes might suffer the loss of high frequency contents resulting in blurring. A DWT RE scheme used to lower the effects of such blurring is a dual-tree complex wavelet transform (DT-CWT) which decomposes the image into different frequency subbands and applies nonlocal means (NLM) on it, which caters to the different artifacts generated by DT-CWT [13].

Another major consideration is the interpolation of the input image which deals with increasing the pixels in the image. The three main types of interpolation are nearest neighbor, bilinear and bicubic with the latter one being the most efficient. A novel method of interpolation for the enhancement of images revolves around the idea of edge-directed interpolation by estimating the local covariance coefficients from a low-resolution image and then using these to transform the image into a higher resolution. A hybrid scheme of bilinear interpolation and covariance-based adaptive interpolation has been applied for the resolution enhancement of grayscale images and demosaicking of color CCD samples. [14] [15] [16].

In this paper, a hybrid approach for enhancing low resolution and low intensity images by using discrete wavelet transform for isolating high frequency components and an adaptive weighted cuckoo search for obtaining optimal solutions, is proposed. An automatic updated weight depending on maximum generation and pixel range of the image is attached to give the solution in less time. The visual results and post-process analysis of image quality parameters and comparison with the histogram equalized images demonstrate the effectiveness of the proposed method.

ABSTRACT

In this paper, a hybrid approach for enhancing low resolution and low intensity images by using discrete wavelet transform for isolating high frequency components and an adaptive weighted cuckoo search for obtaining optimal solutions, is proposed. An automatic updated weight depending on maximum generation and pixel range of the image is attached to give the solution in less time. The visual results and post-process analysis of image quality parameters and comparison with the histogram equalized images demonstrate the effectiveness of the proposed method.
searches which are primarily avoided using a method called 'diversification and intensification' and the efficient use of stochastic optimization and random walks until we obtain a near optimal solution.

**IMPLEMENTATION**

*Flowchart of our proposed technique*

**Step 1: Image input**
A low resolution RGB image has been taken as the test sample.

**Step 2: Wavelet Transform**
2D discrete wavelet transform and bior 3.7 is applied on one instance of the grayscale-transformed image for the purpose of dividing it into four different frequency components. The components in ascending order of frequency are Low Low (LL), Low High (LH), High Low (HL) and High High (HH). The LL component, containing the least amount of information is discarded summarily while each of the other components are interpolated and kept aside for further processing.

**Step 3: Interpolation**
Bicubic interpolation has been applied to high frequency subband images to obtain a high frequency intermediate stage with a higher resolution containing more pixel information. The resulting products are depicted below:

**Step 5: Low pass filtering**
Another instance of the initial input image is passed through a low pass filter.

**Step 6: Interpolation of the high frequency image**
Interpolation is performed on the high frequency image.
Das/A Hybrid Cuckoo Search to Enhance Low resolution images

**Step 8: Input image interpolation:**

Bicubic interpolation, a popular method of interpolation [9][14], has been performed on one instance of the given input image to increase the image pixels in it. This also inadvertently causes smoothening of the image pixels. It may be noted that, in all cases the interpolated image is twice the input image.

![Figure 12: Interpolated input image](image)

**Step 9: Adding interpolated high frequency sub band images in the intermediate stage**

The generated interpolated high frequency image is summed up with each of the three interpolated high frequency sub band images (interpolated LH, HL, HH) of wavelet domain to preserve edge information and for sharper and clearer images. LH1, HL1, and HH1 depicted below denote these estimated images.

![Figure 13: LH1 component](image)

![Figure 14: HL1 component](image)

![Figure 15: HH1 component](image)

**Step 10: Inverse wavelet transform**

Here inverse discrete wavelet transform (IDWT) is applied on estimated high frequency images (LH1, HL1, HH1). A larger sized, edge preserved image with higher resolution is obtained at this intermediate stage.

**Step 11: Enhancement using cuckoo search via Lévy flight**

_Cuckoo Search_ is one of the most efficient and rigid metaheuristic algorithm for solving computational problems.

Cuckoo search and Lévy flight

_1) Cuckoo search_

It is a relatively new nature inspired development (2009) in the field of computer science [17] [18] pioneered by Yang and Deb based on the brood parasitic behavior of certain species of the cuckoo bird. It is a robust algorithm providing an efficient trade-off between diversification/intensification and hence proving to be an ideal approach for obtaining an optimal solution. Diversification deals with the thorough end-to-end coverage of the search space while intensification is concerned with the intensive search of the given portions of the search space for better quality solution. [19]. The aforementioned parasitic behavior among cuckoo birds refers to the aggressive and highly successful reproduction strategy of certain species of cuckoo birds based on an evolutionary predisposition to lay their eggs in the nests of other birds. [17] This behavior aided in the propagation of their species. This natural observation is applied in the computational field by treating the host bird eggs as the initial solutions and the cuckoo eggs as the alternative solutions with the aim of reaching a near-optimal solution by successful iterations involving the replacement of weaker solutions with better ones.

_ii) Lévy flight_

It can be expressed by the formula

\[ SN = \sum X_i = X_1 + X_2 + \ldots + X_N \]

Where \( X_N \) is a random step size drawn from a random distribution and \( SN \) is the sum of each of these consecutive random steps.

Lévy flight is a random walk whose step size is determined from the Lévy distribution. It is capable of exploring large amount of search space. Lévy flight is also found in nature as certain species of birds and insects exhibit this type of motion while gathering food [20][21][22][23][24]. Even physical phenomena such as diffusion of gas molecules have been seen to follow Lévy flight behavior under the right conditions.

Cuckoo search was performed via Lévy flight. Among the different algorithms in Lévy flight which includes Rejection algorithm and McCulloch’s, we use Mantegna’s algorithm. It produces random numbers according to a symmetric Lévy stable distribution

\[ K = \text{random (size(input image))} \]

So, \( K \) is a matrix of normally distributed numbers with the same size as that of the input image.

Here, \( \sigma (\alpha) = \left[ \Gamma(1+\alpha) \sin(\pi \alpha/2) / \Gamma((1+\alpha)/2) \alpha^{2(\alpha-1)/2} \right]^{1/\alpha} \)

where, \( \Gamma \) is the gamma function.

The algorithm is,

\[ v = x / \left| y \right|^{1/\alpha} \]

Here \( x \) and \( y \) are stochastically distributed variables.

\[ v = K \cdot \sigma (\alpha) / \left| K \right|^{1/\alpha} \]

The resulting distribution has the same behavior of Lévy distribution for large values of the random variables. [24]

_iii) Adaptive Weighted cuckoo search_
With the assistance of the three idealized rules of cuckoo search [17][18][19][20] the following five basic assumptions about the image under process, are made:

1) Each pixel in the image is considered as a nest and its intensity values are eggs or solutions.
2) A cuckoo bird lays one egg at a time, and dumps it in one of the host bird’s nests, at random.
3) The high quality eggs (solutions) are passed on over the generations. Here the pixel with intensity value greater than some fitness threshold is passed to the next generation.
4) The number of available host nests (pixels) is fixed. If the host discovers the cuckoo egg (which has a probability ranging from 0 to 1), it can either throw the egg away or abandon its nest. This probability was determined by the fitness value of each pixel. If the fitness of the egg or solution (intensity value of that pixel) is less than some fitness value then it is replaced by some randomly generated solution.
5) A parameter “w” is signifying the weight reduces the time complexity of the algorithm reducing the total number of iterations or the maximum generation. As a result, the algorithm converges towards the solution rapidly. “w” depends on both the maximum generation and the pixel range of the image.

It can be represented as:

\[ w = \alpha_1 + (\alpha_2 \times (\text{maxgen} - t) / (\text{maxgen})^2) + \alpha_3 / \sqrt{\text{maxmin}} \]

where maxgen = maximum generation
maxmin = pixel ranges.
t = current iteration
\( \alpha_i \) = constant values.

6) As shown in the post-process analysis in table 1, the algorithm is called adaptive weighted because it can modify its weight to enhance all types of low intensity images like medium-low or very low.

iv) Pseudocode for Lévy flight:

From [15] we adopted the following algorithm for Lévy flight for application on the image:

1) \( \beta = 1.5 \)
2) \( \sigma = \frac{\Gamma(1 + \beta) \sin(\pi \beta / 2)}{\Gamma(1 + \beta / 2) \beta 2^{\beta - 1} / 2} \)
3) \( s = \text{input image} \)
4) \( g = \text{randn(size}(s)) \)
5) \( k = g^* \sigma \)
6) \( y = g \)
7) \( \text{step} = u / |\text{abs}(y)| \times (1 / \beta) \)
8) \( \text{stepsize} = \bar{Y} \times \text{step} [ \text{here, } \bar{Y} \text{ depends upon the typical length scale}.] \)

A random walk is a mathematical method of representing a series of consecutive random steps. It has far flung applications in the fields of computer science, physics, statistics, economics and engineering. [22]

v) The flow of control of cuckoo search via Lévy flight technique:

vi) Pseudocode

1. Start with a random population of n host nests or pixels with the intensity of each pixel being its solution. Consider this to be the initial solution.
2. Get a random cuckoo solution denoted by (i) by Lévy flight technique.
3. Evaluate its quality or fitness value (Fi).
The function is evaluated as: xi(t+1) = wi xi(t) + \alpha . Lévy (\lambda) where \alpha is a weight factor. Note that the fitness value of every pixel is proportional to the intensity of the corresponding pixel.
4. Choose a nest with another solution among n randomly and say this solution is j.
5. Compare the two fitness values.
6. If the fitness value of the cuckoo egg is greater than that of the random nest, then replace the host egg (solution) with the cuckoo egg, otherwise do nothing.
7. Post each iteration, a fraction of the worst nests which do not contribute better solutions are abandoned and the ones yielding the best solutions are carried over to the next generation.
8. Processes 1-7 is repeated until the amount of iterations needed reaches the optimal maximum generation criteria.

vii) Parameter Selection

In the above procedure, the parameters were selected as follows:
1) Maximum generation when fixed at 10 was found to give the best result. Thus, we fixed maxgen as 10.
2) The weight, w, is taken as inversely proportional to maxgen.
3) \( \alpha_1, \alpha_2 \) are of order 1 while the order of \( \alpha_3 \in (0,1) \).
4) Beta is taken as 1.5 as it yielded the best results in accordance with [24]
5) Parameter \( \bar{Y} \) which is associated with steps size in Lévy flight belongs to the range (0,1).

RESULTS

i) High resolution image using Cuckoo Search via Lévy flight

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Figure 17: Hybrid Cuckoo modified image

ii) Comparison:
The Low resolution input image:

Figures 18: Input image

Figure 19: Final result.

FURTHER RESULTS AND POST-PROCESSING ANALYSIS:

i) Histogram comparison:
Image histograms of the input image and the resultant image are compared.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Input image</th>
<th>Hybrid cuckoo modified image</th>
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The proposed hybrid image enhancement technique has been tested on the following image set. The visual and analytical results of the testing are provided below. The efficiency of cuckoo search in enhancing images is well illustrated in the following result table:

ii) The visual results is provided in the following table.

Image quality parameter comparison.
Root mean square errors (RMSE), normalized cross correlation (NCC) and normalized absolute error (NAE) are the image quality parameters considered. RMSE and NCC are concerned with the deviation between the original image and the output image and NAE depicts the mismatch between the two images.

Mathematically, these are expressed as:

\[
\text{RMSE} = \sqrt{\frac{\sum (\sum e^2)}{MN}}
\]

\[
\text{NCC} = \frac{\Sigma (\Sigma (\text{origIm}^\times \text{outIm}))/\Sigma (\Sigma (\text{origIm} \times \text{origIm}))}{\Sigma (\Sigma (\text{origIm}^\times \text{origIm}))/\Sigma (\Sigma (\text{origIm}))}
\]

\[
\text{NAE} = \frac{\Sigma (\Sigma (\text{absolute}(e)))/\Sigma (\Sigma (\text{origIm}))}{\Sigma (\Sigma (\text{absolute}(e)))/\Sigma (\Sigma (\text{origIm}))}
\]

Where, \(e\) = pixelwise difference of the two images.
\(M, N\) is the dimensions of the original image.
\(\text{origIm}\) = intensity values of pixels of original image
\(\text{outIm}\) = intensity values of pixels of output image.

The original image and the output image is of the same size.

Image quality parameters for cuckoo search image:

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Reference image</th>
<th>RMSE</th>
<th>NCC</th>
<th>NAE</th>
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Table 1: Visual Results

iv)
The modified hybrid weighted cuckoo search method has been shown to possess a distinct and definite advantage over histogram equalization. The results in case of all the three parameters for the weighted cuckoo search method are considerably better than that of histogram equalization.

CONCLUSION
Enhancement of low resolution images has been a subject of numerous researches in recent years. This paper introduces a novel hybrid approach for enhancing low resolution images using a combination of discrete wavelet transform and cuckoo search via Lévy flight. Discrete wavelet transform selects high frequency subbands from this image and then interpolates them to preserve and augment pixel information. Pixels of these interpolated images are treated as solutions and these solutions are optimized by cuckoo search via Lévy flight to yield the final high resolution image. The quantitative results validate and complement the visual superiority of the proposed approach over the normal methods.

REFERENCES


[4] Liangpei Zhang a, Hongyan Zhang a, Huanfeng Shen b, Pingxiang Li a "A super-resolution reconstruction algorithm for surveillance image”. The State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing, Wuhan University, Wuhan, Hubei, China b School of Resource and Environmental Science, Wuhan University, Wuhan, Hubei, China


[6] Junzhong Huang, Li Ma, Tieniu Tan, Yunhong Wang, "Learning Based Resolution Enhancement of Iris Images” National Laboratory of Pattern Recognition, Institute of Automation, Chinese Academy of Sciences, P.O. Box 2728, Beijing, 100080, P.R. China


[8] Haidawati Nasir a, b, n, Vladimir Stankovic’ a, Stephen Marshall b, “Signular value decomposition based fusion for super-resolution image reconstruction” Department of Electronic and Electrical Engineering, University of Strathclyde Royal College Building, G11XW Gloucester, United Kingdom b Universiti Kuala Lumpur Malaysian Institute of Information Technology, Malaysia


[23] Xin-She. “Nature inspired metaheuristic algorithm”. Published by luniverpress.
