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Implementation of Deblurring Images Using Blind Deconvolution Technique

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Abstract: ***In Imaging science, Image processing is any form of signal processing for which the input is an image and the output may be either an image or set of characteristics or parameters related to the image. Sometimes,the images may be corrupted. Such degradations may be either due to motion blur, noise or camera misfocus. So, a classical research area called Image Restoration came into existence. This refers to the operation of taking a corrupted image and estimating a clean original image by removing distortions. Some of the methods involved are usage of Inverse filters, Weinerfilters, Iterative filters and Blind Deconvolution. The technique being implemented here is Blind Deconvolution. The algorithm involved in this technique is Evolutionary algorithm. This research area is applied for medical images. New applications include HD/3D displays,mobile and portable devices which are promoting research area in this aspect.***

Keywords: Image Restoration, blur ,deblur, Convolution, DeConvolution, Point spread function(PSF), Blind deconvolution

1. Introduction

1.1 What Is Image Processing?

Image processing is a method which includes some operations to be performed in order to convert an image to get an enhanced image or to extract some useful information from it.The input is an image like a photograph or video frame whereas the output may be an image or characteristics related to the image.
The following example describes the role of image processing:

Figure 1: Basic model of Image Processing

1.2 Need for Image Processing

Image processing is often viewed as arbitrarily manipulating an image to achieve an aesthetic standard or to support a preferred reality. However, Image Processing is more accurately defined as a means of translation between the human visual system and digital imaging devices. The human visual system does not perceive the world in the same manner as digital detectors, with display devices imposing additional noise and bandwidth restrictions. Salient differences between the human and digital detectors will be shown, along with some basic processing steps for achieving translation.Various methods include fundamental techniques of digital image processing are:

1.**Image Representation and Modelling**: Image Representation includes describing an image in various forms like numbers which are used to declare its contents using position and size of geometric forms and shapes like lines,curvesetc.,co-ordinate system used to place elements in relation to each other called as user space, bit map images which indicates how a given pattern of bits in a pixel maps to a specific color. Image Modelling refers to the methods which rely on a set of two-dimensional images of a scene to generate a three-dimensional model

2.**Image Enhancement**: Image Enhancement is the process of adjusting the digital images so that the results are more suitable for further analysis.

3.**Imagerestoration**:The purpose of Image Restoration is to 'compensate for' or 'undo' defects which degrade the image.

4.**Image Analysis**: Image Analysis involves processing an image into fundamental components in order to extract statistical data which includes tasks like finding shapes, detecting edges and measuring region and image properties of an object.

5.**Image Reconstruction**: Image Reconstruction techniques are used to create 2D and 3D images from sets of 1D projections.

6.**Image Data Compression**: The objective of Image Compression is to reduce irrelevance and redundancy of the image data in order to be able to store or transmit data in an efficient form. Application of Image Processing include various areaslike: Astronomy, Biology Agriculture, Medicine, Meteorology Entertainment Law Enforcement, Industrial Inspection.

1.3 What Is Image Restoration?

Sometimes the imperfections in imaging and capturing process results in degradation of recorded image.Such degradations may be of:Noise,Geometricdegradations,Illumination,Color,imperfections,Blur
So a classical research area called Image Restoration came into existence. This refers to the process of taking a corrupted image and estimating the clean original image.

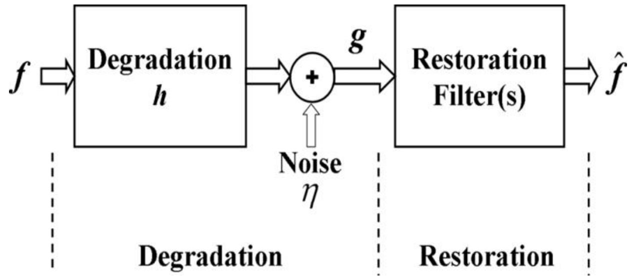


Figure 2: Image Degradation-Image Restoration.

2. Related work

Convolution: Convolution is a mathematical operation on two functions f and g producing a third function that is typically a modified version of one of the two original functions, giving the area overlap between the two functions as a function of the amount that one of the original functions is translated. It has applications that include probability, statistics, computer vision,image and signal processing,electrical engineering and differential equations.

The convolution of f and g is written f ∗ g, using an asterisk or star. It is defined as the integral of the product of the two functions after one is reversed and shifted.Assuch, it is a particular kind of integral transform:

$$(f * g)(t) \stackrel{\text{def}}{=} \int_{-\infty}^{\infty} f(\tau)\, g(t-\tau)\, d\tau$$
$$= \int_{-\infty}^{\infty} f(t-\tau)\, g(\tau)\, d\tau.$$

Where f(t) ,g(t) are two functions and f(-r) and g(-r) are the slided functions which are shifted by an amount r.

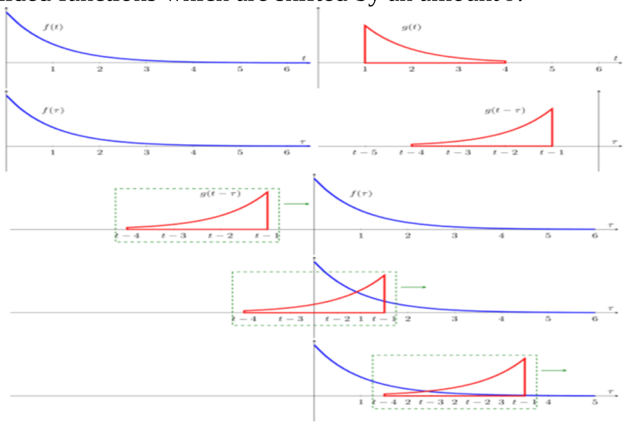


Figure 3: Basic operation of Convolution

In terms of Image Processing,it is an operation where each output pixel is the weighted sum of neighbouring input pixels.The matrix of pixels is called convolution kernel or a filter.Forexample,let us suppose the image as:

A =

17	24	1	8	15
23	5	7	4	16
4	6	13	20	22
10	12	19	21	3
11	18	25	2	9

Let the convolution kernel be:

H =

8	1	6
3	5	7
4	9	2

Steps to perform convolution:
1.Rotate the convolution kernel 180 degrees about its center element. 2.Slide the center element of the kernel so that it lies on the top of required output pixel of A.3.Multiply each weight of the rotated convolution kernel with the input pixel of A which is lying underneath.4.Find the sum of the individual products from the previous step.Find the sum of the individual products from the previous step.5.The resulting sum will replace the input pixel of A corresponding to the center of the rotated kernel when it is slided.Let u find the (3,2) element: Then rotated kernel will be:

2	9	4
7	5	3
6	1	8

H'=
(3,2) element=(23*2)+(5*9)+(7*4)+(4*7)+(6*5)+(13*3)+(10*6)+(12*1)+(19*8) =452

Similarly all the output pixels are calculated.Some of the convolution kernels are:

Sharpen filter:

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

Edge detection:

$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

Horizontal edge detection:

$$\begin{bmatrix} 1 & 0 & -1 \\ 0 & 0 & 0 \\ -1 & 0 & 1 \end{bmatrix}$$

Vertical edge detection:

$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

3. 2D Convolution

Conv2(A,B) computes two dimensional convolution of matrices A and B.If one of these matrices describes a two dimensional finite impulse response filter,the other matrix is filtered in two dimensions.The size of C in each dimension is equal to the sum of the corresponding dimensions of the input matrices minus one.That is ,if the size of A is [ma,na] and size of B is [mb,nb],then the size of C is [ma+mb-1,na+nb-1].C=conv2(hcol,hrow,A) convolves A first with the vector hcol along the rows and then with the vector hrow along the columns.Ifhcol is a column vector and hrow is a row vector,thiscase is the same as C=conv2(hcol*hrow,A).C=conv2(...,'shape') returns a subsection of the two dimensional convolution, as specified by the 'shape' parameter:

Full - Returns the full two-dimensional convolution. This is the default parameter.

Same – Returns the central part of the convolution of the same size as A.

Valid – Returns only those parts of the convolution that are computed without the zero padded edges.
For example, here first the convolution of A is computed using the default 'full' shape and then convolution using 'same' shape is computed.

```
>> A=rand(3);
>> B=rand(4);
>> C=conv2(A,B)

C =

0.7861  1.2768  1.4581  1.0007  0.2876  0.0099
1.0024  1.8458  3.0844  2.5151  1.5196  0.2560
1.0561  1.9824  3.5790  3.9432  2.9708  0.7587
1.6790  2.0772  3.0052  3.7511  2.7593  1.5129
0.9902  1.1000  2.4492  1.6082  1.7976  1.2655
0.1215  0.1469  1.0409  0.5540  0.6941  0.6499

>> D=conv2(A,B,'same')

D =

3.5790   3.9432   2.9708
3.0052   3.7511   2.7593
2.4492   1.6082   1.7976
```

4. Deconvolution

This is an algorithm-based process used to reverse the effects of convolution on recorded data.The concept of deconvolution is widely used in the techniques of signal processing and image processing. Because these techniques are in turn widely used in many scientific and engineering disciplines, deconvolution finds many applications.In general, the object of deconvolution is to find the solution of a convolution equation of the form:
$f * g = h$ Usually, h is some recorded signal, and f is some signal that we wish to recover, but has been convolved with some other signal g before we recorded it. The function g might represent the transfer function of an instrument or a driving force that was applied to a physical system.

The input is the corrupted natural image and one of the many existing deconvolution techniques is used to retrieve the true image. But this restored image is the estimation of the true image and hence the convergence of deconvolution techniques should provide the approximate and closest estimate of the true image. The blind image deconvolution on similar concept estimate the true image but there are almost no or partial information about the cause of degradation function. The partial information can be in the form of some finite support or non negativity of the image, coined as physical properties of the image. Similarly, this partial information can also be in the form of any statistical data such as entropy or probability distribution function of the signal. The different optimality criteria along with this partial information form the strong ground in image estimation.

4. 1 Point Spread Function:

This is the function which describes the response of an imaging system to a point source or point object. The degradation producing ill-effect of blur is termed as the point spread function, PSF. Any type of blur is characterized by the PSF. The electromagnetic radiation or other imaging waves propagated from a point source or point object is known as the PSF.
The degree of spreading(blurring) of the point object is a measure for the quality of an imaging system.
g(n1,n2) = d(n1,n2) * f(n1,n2) + w(n1,n2)
where, g(n1,n2) is the degraded imaged(n1,n2) is the original imagef(n1,n2) is the point spread functionw(n1,n2) is the noise.

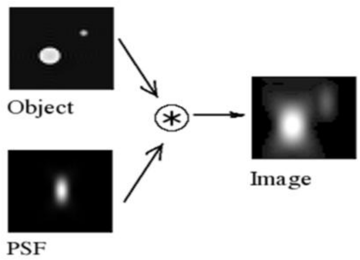


Figure 4: Image formation with a Point Spread function

4.2 Classification of Restoration Algorithms Based on PSF

Based on the PSF , the restoration algorithms are classified into two types.
1.Non-blind deconvolution.
2.Blind deconvolution.

4.3 Non Blind Deconvolution:

It refers to the deconvolution with explicit knowledge of the impulse response function used in the convolution. That is, the point spread function is known in advance in this technique.

4.4 Blind Deconvolution:

It refers to the deconvolution without explicit knowledge of the impulse response function used in the convolution. Blind deconvolution is a deconvolution technique that permits recovery of the target scene from a single or set of "blurred" images in the presence of a poorly determined or unknown point spread function (PSF). Blind deconvolution can be performed iteratively, whereby each iteration improves the estimation of the PSF and the scene. Blind deconvolution techniques have always been a challenging and critical problem. But, since the techniques are more useful for the practical scenario compared to classical ones, the methods cannot be ignored. Different blind image deconvolution techniques assume various parameters to solve the problem. The literature review on different techniques reveal that some strong underlying concept has to be used as a key to crack the problem. Though the convergence is not well-defined as well as not sure. This motivates to search for the parameters responsible for degradation. The parameter once estimated is used to reverse the ill-effect.

5. Proposed Methodology

5.1 Architecture

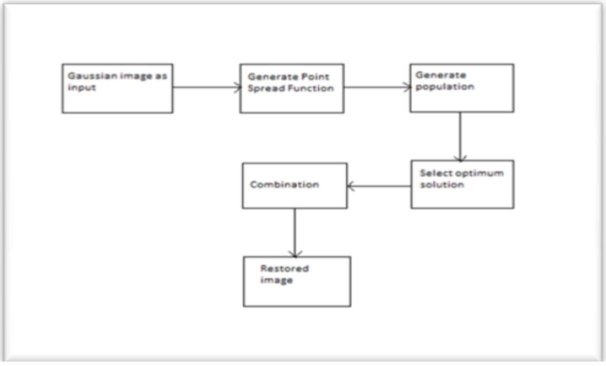


Figure 5: Architecture

5.2 Blind Deconvolution Using Evolutionary Algorithm:

The recent development and the growing popularity of genetic algorithm in various fields, motivated the researchers to utilize the same in the field of Image Processing also. The evolutionary algorithm is the generic name for the genetic algorithm. The evolutionary algorithm, in artificial intelligence, is a subset of evolutionary computation. It is generic population based meta heuristic optimization algorithm. An EA utilizes the concept of biological evolution. Evolutionary algorithms are search techniques based on the concept of natural selection and survival of the fittest in the natural world. It is an algorithm used in Blind Deconvolution technique. Evolutionary algorithm involves a search from a set of possible solutions known as "population". Each iteration ends with a set of possible and feasible solutions based on some "fitness" criteria. The solutions with high fitness are then recombined with other solutions by interchanging parts of solution with one another. These solutions are then mutated generating new solution optimal to the given problem.

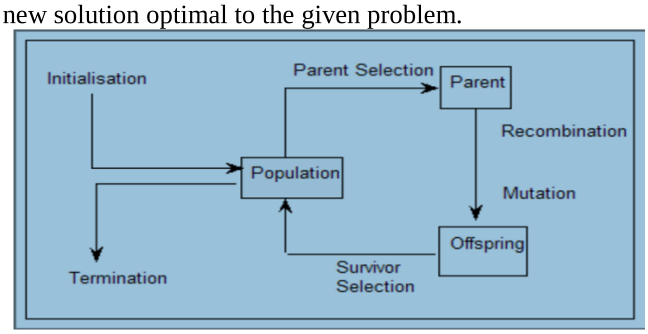


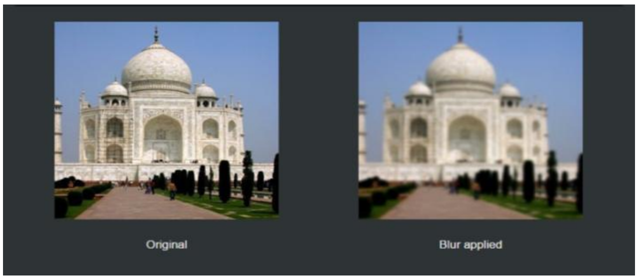
Figure 6: Overview of Evolutionary Algorithm

5.3 Applications Of Evolutionary Algorithm

Evolutionary algorithm is considered as global optimization technique.The most important factor about EA is its robust performance in "noisy" functions where there is multiple local optima. EA can find global optimal solutions discarding the local minima. There exists wide variety of application domains of EA for finding optimization problems such as wire routing, scheduling, travelling salesperson, image processing, engineering design, parameter fitting, knapsack problem, game playing and transportation problem. EA are well suited for wide range of combinatorial and continuous problems, but the different variations are tailored depending upon specific applications. The concept of EA has been utilized in the field of image processing. Different image processing area such as edge detection, segmentation, shape detection, feature selection, clustering, classification, object recognition use EA to get the optimal solution.

5.4 Gaussian Blur

The image degradation due to atmospheric condition is modeled by the Gaussian effect.It is the result of blurring an image by a Gaussian function.The Gaussian blur is a type of image blurring filter that uses normal distribution for calculating the transformation to apply to each pixel in the image.The visual effect of this blurring is a smooth blur resembling that of viewing the image through the translucent screen.



5.5 Assumptions:

The model is given below. So, an ideal noiseless scenario is assumed.

As a matter of convenience, the model is again re-written below:-
c(x, y) = i(x, y) * d(x, y)
wherei(x,y)=original image
d(x,y)=blur function
c(x,y)=degraded image

The algorithm proceeds based on following main identity:-
i(x,y) = i(x,y) * δ(x, y)
where δ is finite with all its elements zero except the central one ,given as one.

$$\delta = \begin{pmatrix} \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & 0 & 0 & 0 & \cdots \\ \cdots & 0 & 1 & 0 & \cdots \\ \cdots & 0 & 0 & 0 & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \end{pmatrix}$$

where δ is finite square matrix with all its element zero but the central element is one.

The PSF is supposed to composed of two matrices given as,dL(x,y) + dH(x,y) = δ(x, y)
where L and H denotes for low and high, respectively. Hence can be rewritten as,
i(x,y) = i(x,y) *dL(x,y) + i(x,y) * dH(x,y)
Now, if the observed blurred image, c, is given by c(x,y) = i(x,y) *dL(x,y) then an iterative approach is derived based upon the following two equations:

i'(x,y) = c(x,y) + i˜(x,y) *dH(x,y)
c(x,y) =i(x,y) *dL(x,y)
where ˜i(x,y) and i'(x,y) denote the consecutive iterative estimations of the true image i(x,y) at generation k and k+1, respectively. At every iteration, the PSF, dL(x, y) is randomly generated and dH(x, y) is obtained.

5.6 Algorithm For PSF Generation:

1. Find the PSF size n*n where n should be odd number.2. Randomly generate (n+1)/2 values in the range (0,1).3.Sort the values generated in the ascending order.4.Produce a vector d, of n elements, by flipping the values left to right provided the middle element is untouched.
 Create d=d1*d1t. Normalise the d.

5.7 Evolutionary Algorithm:

5.7.1 Algorithm Components:

EA have number of operators, components and procedures that must be specified clearly in order to define particular EA. Also, the initialisation and termination condition must also be well specified. The different components of EA are:- Definition of Individuals Fitness ,Function Population, Recombination, Mutation Survivor ,Selection Mechanism. Unlike other traditional optimization techniques, EA involve a search from set of possible solutions known as "population". Each iteration ends with a set of possible and feasible solutions, discarding the poor solutions based on some "fitness" criteria. The solutions with high fitness are then recombined with other solutions by interchanging parts of the solution with one another. These solutions are then again "mutated" generating new solution optimal to the given problem.

5.7.2 Algorithm Steps

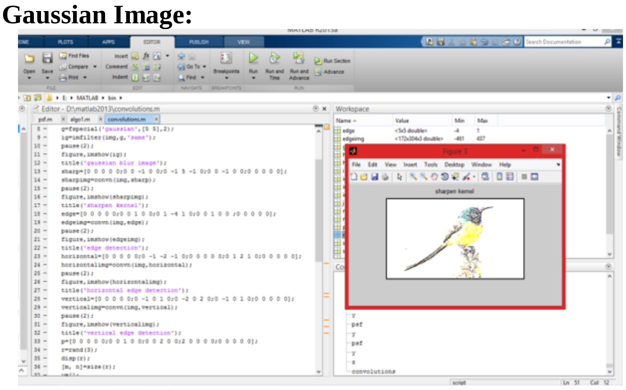
The major steps involved in this Evolutionary Algorithm are:-

- **Mutation:** A set of random PSFs is generated in every generation. These PSFs are then used along with all individual images, obtained from the previous generation.
- **Selection:** The individuals in each generation individually undergo a selection procedure called feature vectors. Those individuals which have ῤ value greater than the corresponding expectation value for the generation are excluded.
- **Clustering:** There exist only few individuals at each generation. The survivors are used in the next k + 1th generation.
- **Final Image Reconstruction:** There is set of possible estimated image obtained from each generation at the end. The best image is sort out by adopting fusion method pseudo-wigner distribution.

6. Experimental Results:

Convolution: Original Image:

Gaussian Image:



7. Conclusion

We have studied what exactly convolution is and the importance of deconvolution in deblurring an image in order to remove the noise. We have studied the role of PSF in Image Restoration techniques and how SNR best acted as fitness function. The image obtained is different from the blurred image which is proved by the signal-to- noise ratio.

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