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Object Removal using A New Exemplar-Based Image Inpainting Algorithm and Seam Carving

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Abstract*: *This paper proposed a new object removal techniques based on exemplar-based technique and seam carving. Exemplar- based inpainting technique has been a point of attraction due to its moderate computational task an its performance. Moreover in this paper object removal technique for image based on discontinuous by seam carving has been introduced. Image inpainting is an approach fro restoring the damage part of an image in reference to the information from the undamaged part to make the restored image continuous, natural and to look complete. In this method patches are used to fill the target region in the image. Both texture synthesis and structure propagation are used simultaneously. Here robust exemplar method has been used avoiding dropping effect by using robust priority function. We have also used seam-carving for object removal. The PSNR values of the proposed model have been calculated and is also compared with the previous techniques' results.

Keywords : exemplar-based , seam carving , PSNR ,dropping effect , priority function

I. INTRODUCTION

Digital image inpainting includes certain complex algorithms which endures the user to guess the damaged part of degraded image. It is done by utilizing the rest of the data of that image, such that image obtained output is plausible. In other words image inpainting is the filling in missing regions in any destructed image. Image inpainting can also remove unwanted objects from images for specific purposes (Enhancing, editing, forgery etc). It can also be applied to super resolution, red eye correction and compression. Now a days several methods of image inpainting came into picture. *Bertalimo et al* demonstrated a new inpainting method in which the target region is filled with textural synthesis, it fills the selected region pixel by pixel [1]. Besides number of algorithms addressing the image filling issue for the task of image inpainting have been reported where overlaid text, speckles and scratches are removed [2-5].

Another method introduced by A. Criminisi, which is Exemplar-Based image inpainting removes large objects from the image, it also fills the target region with an approach based on mask or set of pixels [6]. Similarly robust Exemplar based inpainting uses region wise segmentation, it defines the robust priority function which helps in avoiding the dropping effect (rapid decrease in confidence value) by using image segmentation and determining the size of adaptive patch and thus reduce the search region [7]. This method results more accurate results with less error. Moreover the other image inpainting algorithms are Partial Differential Equation (PDE), Hybrid inpainting Exemplar and search based image inpainting ,semi automatic image inpainting etc. [8-13].

Shai Avidan developed an algorithm for content aware image re-sizing commonly known as Seam Carving [14-17]. It works by establishing a number of paths that are less important in an image. It removes seams(part of less important) to reduce image size. It can also extend the image size by inserting similar seams. Seam carving allows manual defining of areas in which pixels may not be modified. It also defines features and ability to remove the whole object from the image [18-20]. The basic purpose of the seam carving is image re-targeting. This is the problem of image display without distortion of media with various size. Using document standards which support dynamic changes in page layout and text but not images. Basically a seam is an optimal 8_connected path of pixels on a single image both horizontally or vertically. Optimally is defined here by image energy function. It also used for image content enhancement in object removal.

In this paper object removal from an image has been done by following : a) Criminisi method. b) further modification has been introduced by adding canny edge detector. This method adopted in this paper can be widely used for text inpainting and scratches and other distorted images. Further c) seam carving has also been implemented. At the end a comparison between the previous three method has been performed taking PSNR as a point of difference.

II. MATHEMATICAL ANALYSIS OF THE ALGORITHMS USED

Both texture synthesis and inpainting techniques are the combined advantages of Criminisi inpainting algorithm. As demonstrated in Fig(1) (a, b, c) as per Criminisi algorithm literature the damaged portion in the image that needs to be filled is termed as target region and in indicated by (Ω),

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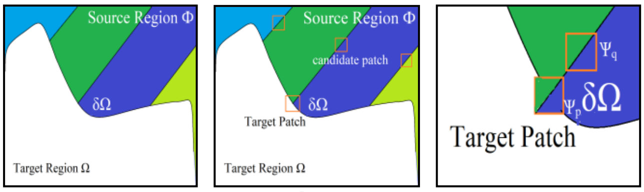
the rest part of the image I is known as source region which further can be explained as (Φ=I - Ω). The "fill-front" denoted by ($\delta\Omega$) is the border line between source region and target region. Basically Criminisi algorithm is an iterative algorithm, such that at each iteration a patch centered at (p ϵ Ω) on the fill front with superiority is carefully chosen to be filled in a right way, such patch is termed as target patch. Similarly to obtain similar patch to the target patch , the source region is searched patch by patch. It can easily comprehended from **Fig .1**(b),(c) that the candidate source patch will lay exactly either on that edge or edges with same color of the edge if the target patch is along one of the image edges.



(a) (b) (c)

Fig .1 a) the original image. b) the target patch Ψ_p and the candidate patch Ψq. C) target patch filling with most similar patch from the source region

By default patch size used in Criminisi model is of (9x9). this patch by patch completion reduces the execution time of the algorithm. It further increases the accuracy of image structure propagation as well. Removal of the unfavorable object and reconstruction of the image by Criminisi model occur by three steps. Initially the priority function assigns all the priority values to each target patch. Here a patch with highest priority is chosen to be completed.

$$P(p) = C(p)D(p) \quad (1)$$

Where C(p) is the confidence ,P(p) patch priority and D(p) is the data. Again data term and confidence term can be re-calculated as

$$C(p) = \sum_{q \in \psi_p \cap (1-\Omega)} C(p) / |\psi_p| \quad (2)$$

$$D(p) = \nabla I_p^{\perp} . n_p / |\psi_p| \quad (3)$$

Where patch area is presented by $|\Psi_p|$ and the normalized factor (α=255) in grayscale image. Orthonormal vector at point(p) is (n_p). orthogonality is denoted by ($\perp$).
Reconsidering the following expression of C(p):

$$C(p) = \begin{cases} 0 & \forall p \in \Omega \\ 1 & \forall p \in (1-\Omega) \end{cases} \quad (4)$$

In the very next step this algorithm works on image texture and structure propagation. Once each pixel on the fill-front is assigned a priority value, the patch with the highest priority is selected ($\Psi_{p^\wedge}$). after that source region is searched to find out most similar source patch to $\Psi_{p^\wedge}$.

$$\psi_{\hat{q}} = \arg \min_{\psi_q \in \phi} d(\psi_{\hat{p}}, \psi_q) \quad (5)$$

Where d($\Psi_{p^\wedge}$,Ψ_q) is the sum of square differences. Then the information related to the source patch pixels gets copied into the corresponding pixels of target patch. As a result image texture and structure are propagated patch by patch into the target region. Lastly in the third step new fill-front is differentiated over thus the confidence values gets updated.

$$C(p) = C(\hat{p}) \quad \forall p \in \psi_{\hat{p}} \cap \Omega \quad (6)$$

Seam carving: object removal includes removing strangers from the photographic portrait and logo from images. Seam carving is an effective approach for image editing, it supports content aware re-sizing by continuously removing or adding seams as designed by energy function in order to change the aspect ratio of the image. Mainly seam carving algorithm for object removal can be implemented using two steps. In the first step the direction in which carving of the image will be done(vertical or horizontal) is decided and the second step is the method of energy computation is determined. Gradient magnitude is a good performance energy function depending on its consistent :

$$e_1(I) = \left|\frac{\partial I}{\partial x}\right| + \left|\frac{\partial I}{\partial y}\right| \quad (7)$$

III. PROPOSED MODEL

1-Exemplar-based method for object removal :

Originally this method is meant to perform the inpainting task by propagating the texture information of the source region through the missing region(Ω)and filling its patches completely. After determining the missing area contains the object to be removed ,an initialization process is done by setting the confidence values as per equation(4). The next step in Criminsi algorithm is to compute all the boundary pixels priorities. Finally literately doing the same process with the target region patches and searching for the maximum priority to fill the whole region. After each iteration the target region boundary is updated so this area becomes smaller. Finding best matches within the missing region was done by using sum of squared distance (SSD) and searching for its minimum value between patches from the unknown region and known patches from the source region. And then copying the pixels data from best matched patch to the unknown pixel point P in the target patch. And finally updating the confidence value for all the unknown region pixels by making each pixel maintaining new color value and confidence value.

Actually Criminisi has combined the PDE and texture synthesis methods to fill the occluded area by choosing a similar patch from the source region. Criminsi algorithm is known as best_fill first algorithm where the priority of a patch tends to achive the balance of propagating linear structures with filling in composite textures. Many modifications have been done to Criminisi algorithm.

Criminisi method can be summarized in three main steps:

A) Patch priorities computation.

B) Diffusing source region information(texture and structure) into the missing region.

C) Iterately update the confidence value.

Our new modification method has been done to show its effectiveness in both object removal and image restoration of damaged paintings and photographs and text inpainting. The flow chart of this algorithm is shown in Fig .4:

I. Once the image is acquired , a mask image is accomplished where the object that we want to remove is located behind.

II. We make a combination of the original image and the mask image to remove the desired object. So there will be unfilled pixels(black region) which we ant to fill it depending on the background propagation.

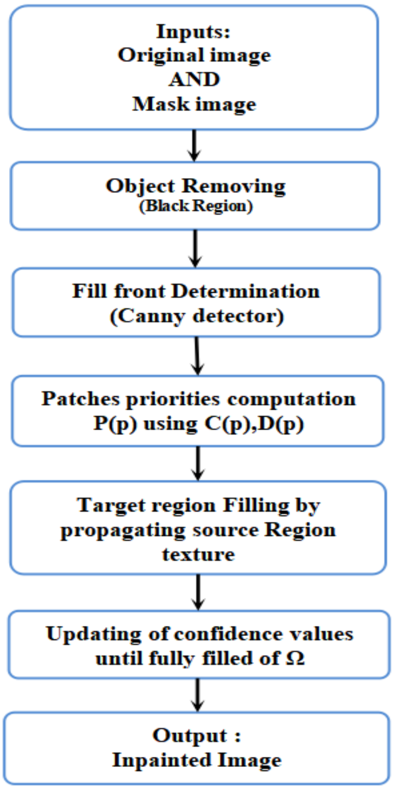


Fig .4 flow chart of proposed model for image inpainting

III. Finding the fill front (target borders):

Fill front can be found by using any edge detection algorithm like "Laplacian based edge detection" or "canny". we used canny edge detector which has the major steps in finding the magnitude of gradient. These steps are shown in TABLE .1.

IV. Find the priority of the pixels that belongs to the fill front using confidence and data terms. Once the fill front is found each pixel on the fill front is given a priority value that is the order in which they are to be filled. To calculate the priority value at each pixel we follow equations (1) ,(2) , (3). For each pixel on the fill front we extract a 9x9(default size of the patch) and calculate the priority of the pixel p (P(p)) by calculating both confidence of the pixel and data term of the pixel form the formula given above. Where 'I' in the data term represents the isophotes at that pixel and 'n' represents the normal at the pixel. The alpha value for a gray scale image is 255.

V.Filling the target region pixels from the similar patches from the source region:

Once the priorities are calculated we take the highest priority pixel and extract a (9x9) patch around the pixel and look for similar patches in the source region (Φ) and fill the unfilled pixels using the similar patches found (equation (5)).

VI. Finally update the confidence values for all the pixels that have been filled (equation (6)). The process completion is done by repeating last three steps until the whole target region is filled, where each of its pixel has a new color and confidence values.

- Canny edge detector steps:

1. Applying Gaussian filter on candidate image.
2. Finding intensity gradients of the image g(m,n) by using any gradient operator(Roberts,sobel,etc) $M(m,n)=\sqrt{g_m^2(m,n)+g_n^2(m,n)}$
and $\theta(m,n)=\tan^{-1}[g_n(m,n)/g_m(m,n)]$
3. Magnitude thresholding

$$M_T=\begin{cases} M(m,n) & When M(m,n)>T \\ 0 & Otherewise \end{cases}$$

Where T is the chosen threshold value that keeping all the edges elements and suppresses most of the noise.

4. Edge tracking by hysteresis.

TABLE .1 canny edge detector algorithm

Seam Carving for object removal:

Usually Seam carving is a method that mostly used for image re_sizing(for example enlarging and compressing). to make this method applicable for object removal some modifications in image energy matrix is done in order to make seams pass through the object that we want to remove. Re_weighting the area of energy matrix that contain the object is the solution for this purpose.

In this method objects are removed either vertically or horizontally. The basic step is the image's energy calculation depending on which are histogram of gradients and gradient magnitude, then seams removing in the desired dimensions is done.

Implementation of Seam carving algorithm for object removal:

Basically as mentioned above the main two aspects of this algorithm are :the direction of which to carve the image (vertical or horizontal) ,and the method of energy computation (for example :Gradient magnitude or histogram of gradients). the image energy is high negatively weighted where the pixels of the target object in order to ensure that seams is crossing the wanted object to be removed with priority. **Fig .5** show the flow chart of this algorithm.

The procedure can be explained as follows:

I. After the original image is acquired,there are two ways to remove the object : either a binary mask image which determine the target object is provided, or the mask image can be a specific part of the original image where this part contain the target object.

II. The next step is to calculate the energy map which means sum of gradient in each channel.

III. Manipulating the energy map: after we calculate the energy map of the input image, we set the energy of each pixel that belongs to the target object to a negative value.

Thus seams will be more attracted to the target region which is containing the target object.

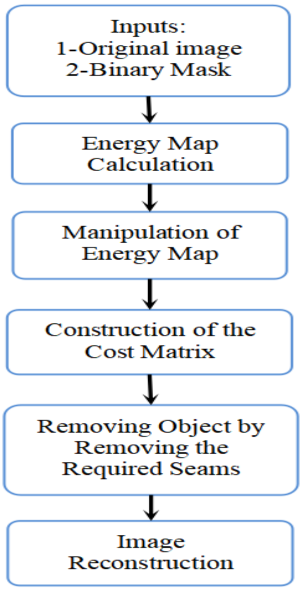


Fig . 5 Seam carving flow chart for object removal

IV. Build the cost matrix: we calculate the cost matrix where the cost of pixels in the first row is same as the cost of the energy function value at respective positions. For all other pixels the cost of the pixel is the sum of the energy function value at that pixel added to the minimum of energy function value of three nearest top neighbors:

$$C(i,j) = E(i,j) \quad ; \quad \text{where i=1}$$

$$C(i,j) = E(i,j) + \min(\ C(i-1,j-1), C(i-1,j\_, C(i-1,j+1))$$

;for all i≠1

V. Finding all the seams needed to remove the target object and its seams:

After finding the cost matrix, a minimum energy seam is found from bottom to top using dynamic programming. First minimum value in the bottom row of the cost matrix is found and is tracked up to the top edge and all the co-ordinates of the seam are recorded. Find all the seams until the target object is completely removed. Out of the low energy seams we find the seams which are the reason for disappearance of the object. By recording all the x-coordinates and y-coordinates of those seams. We remove those seams from the original Image.

VI. Reconstructing the image by adding the number of removed seams:

After removing the target object seams the image size is changed , Thus by adding low energy seams we restore the original image size.

IV. RESULT AND DISCUSSION

For implementation purposes MATLAB R2017 has been used as our software tool. With a core i5 CPU 2.7GHZ and RAM of 8GB ,Intel® HD graphics with 4GB memory. We proposed a new modified Exemplar-based image inpainting algorithm for object removal and image restoration. Depending on the size of patch and size of the mask applied the time of processing is varied. Our results has been compared with Criminisi algorithm [6] for object removal and Seam carving [14] for object removal. With the help of image inpainting we tried to reconstruct the damaged image with the best technique. Our proposed method has shown better results in many cases especially fro the images that contains more texture.

Experimental results of our proposed model are demonstrated in **Fig .6** and in **Fig .7** there are the results of Criminisi model. **Fig .9** shows the results of Seam carving model. For the implementation of the algorithm, we used a 9x9 patch size and normalized cross correlation to obtain similar patch from the source region. Instead of filling it pixel wise, we tried to fill the unfilled pixels 'fill front wise', and the results regarding to the PSNR values TABLE .2 were little bit better than Criminisi method and the implementation is faster. In this paper four images were presented for object removal and are given in the order (Pacific_coast , Bob Dylan book , Beach_ball ,Lake).

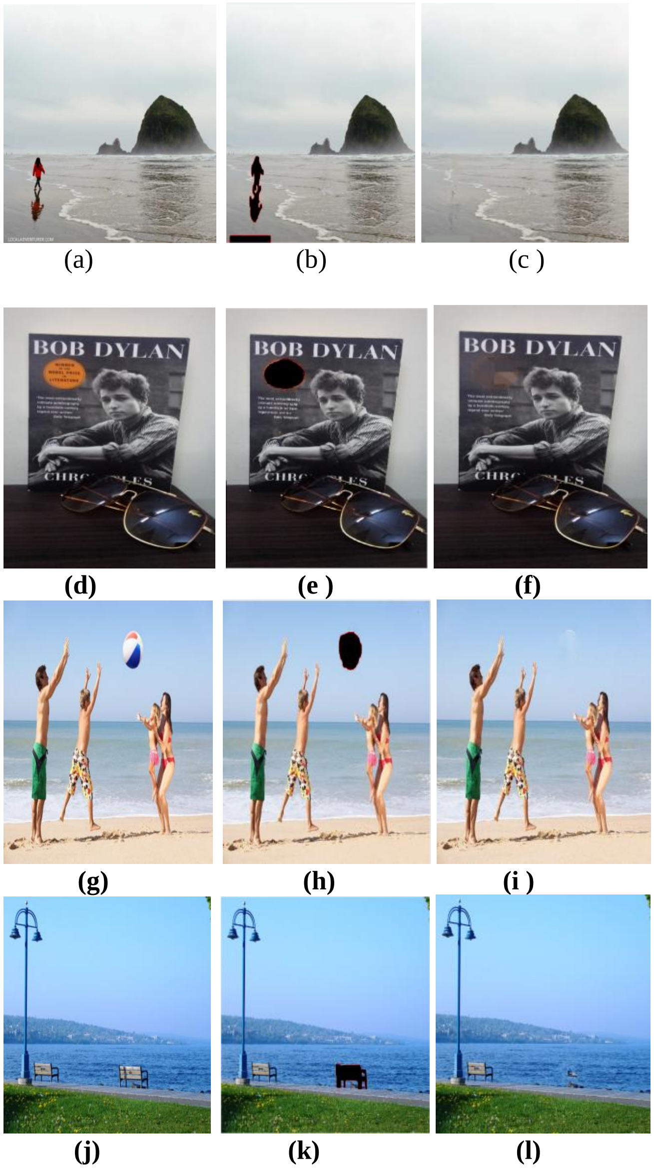
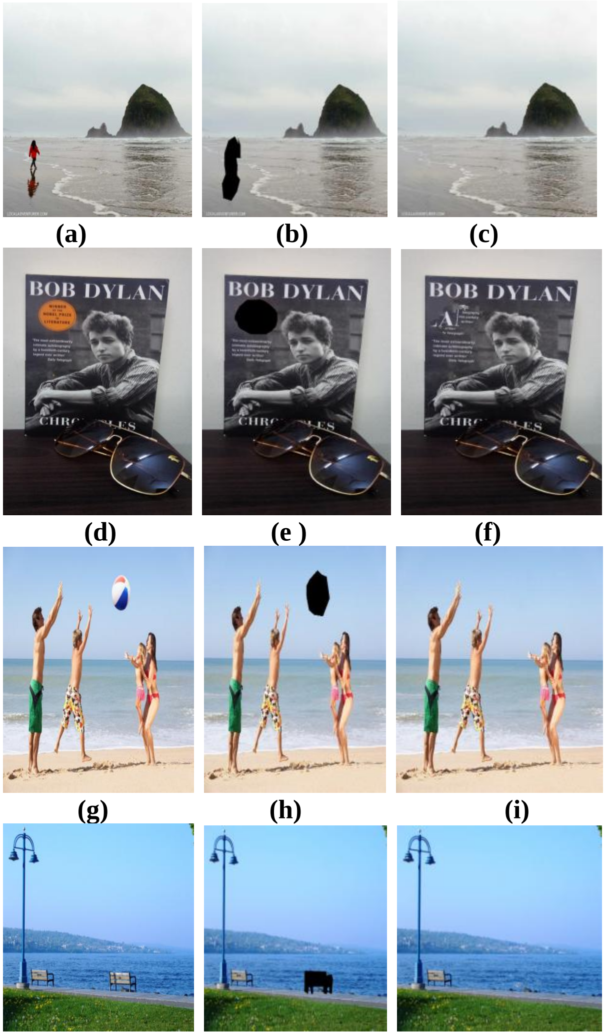


Fig. 6 our proposed model of exemplar-based for object removal (a), (d), (g), (i) are the original images. (b),(e),(h),(k) are the masked images with a red contour(canny edge detector) surrounding the target object to be removed.(c), (f), (i),(l): are the result images of our model.



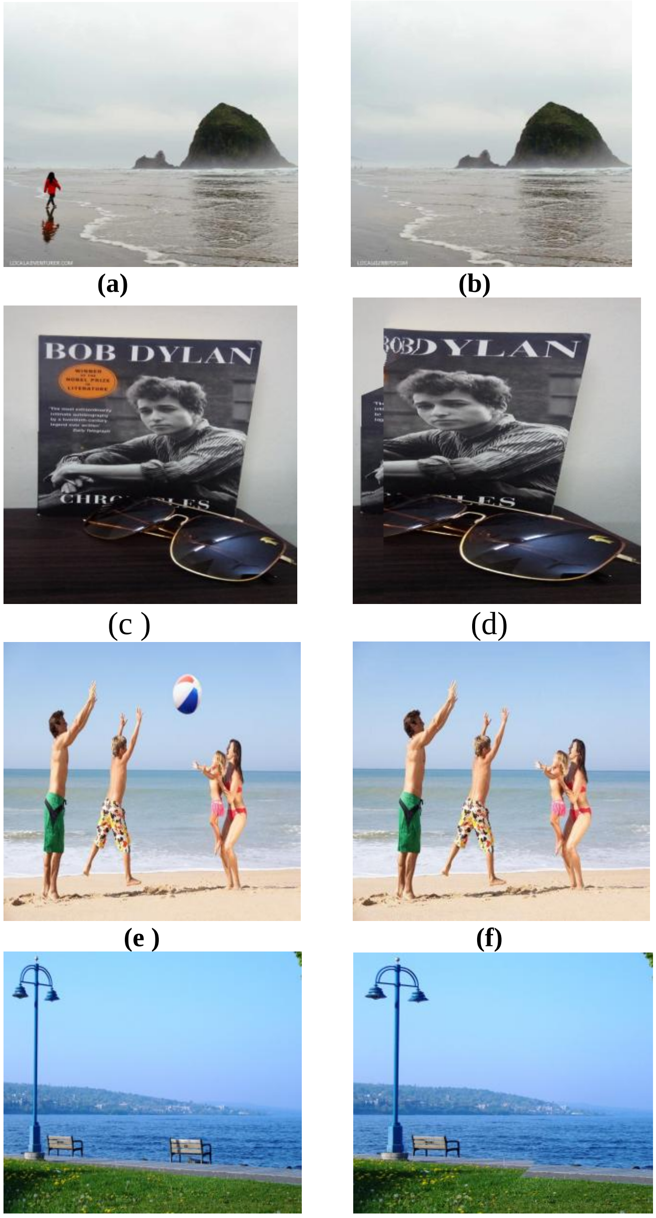
(a) (b) (c)
(d) (e) (f)
(g) (h) (i)
(j) (k) (l)

Fig . 7 Criminisi model results. (a) , (d), (g), (j) original images. (b), (e), (h), (k) exemplar (mask) images. (c), (f), (i), (l) Criminisi results .

Exemplar -Based method basically needs more calculation time. Criminisi provides a good advantage which is that mask image can be selected by the user. But in some cases where a lot of textural information surrounding the target region this method is not accurate. Fig .8 shows zoomed results of Bob dylan book photo in our modified model and Criminisi mode. It is clear that our method is more accurate and has better results.

Fig . 8 the zoomed left image is Criminisi model result ,and the right image is the zoomed result of our model

Seam carving algorithm results were given in the Fig .9



(a) (b)
(c) (d)
(e) (f)
(g) (h)

Fig .9 Seam carving for object removal results : (a),(c),(e),(g) original images , (b),(d),(f),(h) are the results respectively.

From the figures of seam carving results we can Conclude that this technique is applicable for object removal even though this method is widely used for image re-sizing. The basic concept of this model is the mask used for object is being removed by removing target seams and then again inserting low energy seams to retrieve the original image size. In Fig .9 [(b), (d), (f), (h)] it is clear that this method work properly when the unwanted object is separate from other objects, because when more textural information is there then more important pixels is to be removed.

In order to measure the quality of our proposed model Peak Signal to Noise Ratio (PSNR) is used to evaluate the results of the discussed models. PSNR is given as:

$$PSNR = 10 \times \log_{10}\left(\frac{255 \times 255}{MSE}\right) \qquad (8)$$

Where MSE is the Mean Squared Error and it is given by

$$MSE = \frac{1}{m \times n} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i,j) - K(i,j)]^2 \quad (9)$$

I(i,j) is our original image with size of (m ×n). K(i,j) is our result image (reconstructed image).

TABLE .2 PSNR values for propse discussed models

Image Name	proposed		Criminisi		Seam Carving	
	PSNR	MSE	PSNR	MSE	PSNR	MSE
Pacific-coast	33.10	31.78	33.07	32.04	32.76	34.41
Bob Dylan	37.80	10.77	34.51	24.42	31.17	49.58
Beach-ball	35.47	18.44	35.54	18.14	33.81	27.00
Lake	35.95	16.50	35.31	19.11	31.15	49.84

As per TABLE .2 results we conclude that our model is more accurate depending on PSNR values. Moreover it needs less time than Criminisi model due to smoothed edge of fill-front by canny. The low value of PSNR of Seam-carving model is due to the low energy inserted seam which makes the image energy less.

V. CONCLUSION

A Modified exemplar-based algorithm for abject removal and region filling has been proposed. Further object removal has been performed using seam carving method. Thus a novel approach for the removal of scratches and text from a damaged image has been introduced. The PSNR values of the proposed model have been calculated and is also compared with the previous techniques' results.

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