HAZE REFINEMENT STRATEGIES

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Abstract— Haze is mainly caused due to weather changes that affects the atmosphere resulting in unclear images mainly taken in open - air . This paper presents two methods for regaining the image clarity: - Single Image Haze Removal using Multi Level Fusion and Single Image Haze Removal using Dark Channel that improve the visual quality of images. In this paper, we implement and examine the effect of above mentioned techniques based on objective and subjective image quality parameters (like Peak Signal To Noise Ratio, Normalized Absolute Error And Maximum Difference etc) to measure the quality of enhanced color images. A comparative analysis between the two is also being carried out. The first method presents a new single image strategy for the improvement of the visibility of unclear images that are affected by atmospheric changes. Image fusion merges two images. The image retains useful regions using three maps: luminance, chromaticity, and saliency. Since using weight maps additional errors may occur, so to minimize those errors the maps then undergo Laplacian and Gaussian pyramid representations and shows effectiveness and the power of a fusion-based strategy of dehazing centered on single degraded image. In second method, a simple but powerful prior, color attenuation prior, for haze removal from a single input hazy image. By creating a linear model for modeling the scene depth of the hazy image under this novel prior and learning the parameters of the model by using a supervised learning method. Experimental results leads to highly effective algorithm. Both the methods compared are suitable for real – time applications but differs in execution time and other performance parameters used for comparison.

Keywords—Weight maps, Pyramidal refinement, Fusion, Dark channel, Transmission estimate, Peak Signal To Noise Ratio, Normalized Absolute Error And Maximum Difference.

INTRODUCTION

The goal of haze removal algorithms is to enhance and recover details of scene from haze image. The quality of photograph in our daily life is easily undermined by the aerosols suspended in the medium, such as dust, mist, or fumes. This has an effect on the image in which contrasts are reduced and color of the image gets low causing image less visible affecting the entire clarity of the scene. There are many circumstances that accurate haze removal algorithms are needed. In computer vision, most automatic systems for surveillance, intelligent vehicles, object recognition, etc., assume that the input images have clear visibility. However, this is not always true in bad weather. Therefore, these applications will fail in the conditions. In consumer photography, the presence of fog will be an annoyance to the images for it reduced the contrast significantly. In this paper, novel algorithms that is able to enhance hazy image based on a single image. **SIHRMLF(Single Image Haze Removal using Multi Level Fusion)** is built on the fusion principle that has shown utility in several applications such as multispectral video enhancement, underwater image enhancement and intelligent transport system. The image fusion combines different inputs and finally gives a enhanced image. **SIHRDC(Single Image Haze Removal using Dark Channel) is based on patches of pixels is also useful for day today real time applications.** In most of the algorithms , that was previously implemented usage of multiple images , polarized filters , etc were used to bring out the clarity of the images. Here the methods discussed uses only a single image which was captured in not so suitable weather conditions **. The** both methods uses only a image to clear fog , smoke , smog and other obscurities present in the captured image to enhance the visibility. This scene degrading factors are due atmospheric changes. The main advantage of the proposed algorithms compared with other is less intricate. The speeds of the algorithms are also comparatively faster than previous related works. This methods can be included in real-time applications such as vehicle detection in surveillance cameras, scene or object detection for providing support in enhancing the vision of scene. The main concentration of our paper mainly centered on a comparatative review on both the methods using PSNR, MSE, NAE (Peak Signal To Noise Ratio, Normalized Absolute Error And Maximum Difference) etc to measure the similarity, quality of the obtained image with the original one .

RELATED WORKS

H. S. Narasimhan, S. Nayar (1999) proposed a technique based on using multiple images[1]. The paper proposes a Narrow Spectral Band (Monochrome) Weather model, and is evaluated on the basis that with distance, contrast of a scene degrades .Multiple images are taken at different distance and weather conditions of the same scene and only standard contrast enhancement techniques can handle a scene at a fixed distance from the sensor. The entire analysis is computed for single narrow spectral band(monochrome) images. The main drawback was in restoring the contrast of degraded images due to atmospheric changes .Contrast restoration was same for all the different images of the same scene taken in different weather conditions which requires time and may become more complex in some cases. The method sometimes might get limited due to extreme bad weather conditions.

E. Robby T. Tan (2008) implemented polarized filter approach[2]. By using different degrees of polarization(DOP) of the same scene , two or more images are derived . A polarizing filter that can be adjusted to different degree is attached to the camera.The main limitation of the method is it cannot work effectively for dynamic scenes. For dynamic scenes the changes are more faster with respect to the filter rotation , therefore it will be difficult to find higher and and lower level degree of polarization. This increases the complexity and reduces the application in which the method can be introduced. Also multiple scattering of light can affect the effective working of the polarizing filter.

D. Raanan. Fattal (2008) et al.conjoined a method of smaze removal using RGB channels. For this a model based on Radiative Transport Equation is observed carefully and from that a model is formulated for images captured by the camera. Mathematically the color channels are put together using the coefficient of transmission. By light scattering principle of physics from the light source to the eye of the observer determines the coefficient of transmission without scattering. This is given by a graphical representation by showing that the signal to noise ratio is below the expected level and needs shading comparing to noise present in images. This is implemented without using multiple images , polarization filters etc.This also need not require much complex assumption but the method also depends heavily on the amount of haze present and the sensors used[3].

G. L. Kratz and K. Nishino(2009) put forward the method of factorizing scene albedo and depth of haze image[4]. Here the image is modeled using a probabilistic formulation called Factoial Markov Random Field with the single image, independent layers of clear day of the image and scene depth. These methods mostly give the true color of the hazed image and restore the image color through a algorithm i.e canonoical Expectation Maximization algorithm. Either the scene albedo or depth has to be known to compute the algorithm , this is also the main constrain for the proposed method. So It is important to make assumptions for adding additional constraints and is limited in that way.

Erik Matlin and Peyman Milanfar(2011) proposes dual procedures to recover scene radiance[5]. The procedure begins on the assumption that all images has noise or errors because of measurement errors. The first procedure acts as a pre-processsing step which includes removing noise and hazy portions of the image separately. The second procedure is to remove noise and haze simultaneously is continous till the said condition is acheived . This procedure confronts problem of separating haze and noise simultaneously because noise level has to be accurately known to provide good results. Thus the effectiveness depends on the inexact levels of denoising.

Codruta Orniana Ancuti and Cosmin Ancuti (2013) introduced the concept of single image dehazing by multi-scale fusion. In this proposed method decomposition image into different detailed levels are done pyramidal decomposition and finally combined by fusion.This strategy merges the minute details from the inputs derived from the single input haze image using fusion technique. To derive the very small details of the inputs, at first, unavoidable features of the original image are extracted using weighted maps. The maps extracts features of light , color and object structure. The extracted features may contain certain errors which are again filtered using pyramidal refinement strategy. For deriving inputs the method uses shades of grey color constancy algorithm for white balance which is quite complex. Eventhough this method using fusion is one among the first to be implemented for dehazing. The method vary in many ways than the previously mentioned methods and much simple concept and less complex for real-time applications[6].

BASIC WORKING PROCEDURE

SIHRMLF

The first method proposed i.e the SIHRMLF comprises of an input deriving section in which two inputs from the original single degraded image is derived using contrast enhancement and white balancing procedures and separately decomposed to multiple levels using laplacian pyramid both the derived images will undergo feature extraction separately using three weight maps for luminance, chrominance and saliency features[6]. These maps are normalized and are undergone multi-scale decomposition using Gaussian pyramid. finally fusion of these pyramid levels of Laplacian and Gaussian takes place which will give the expected output. The working procedure is shown in figure1 in a step by step manner.

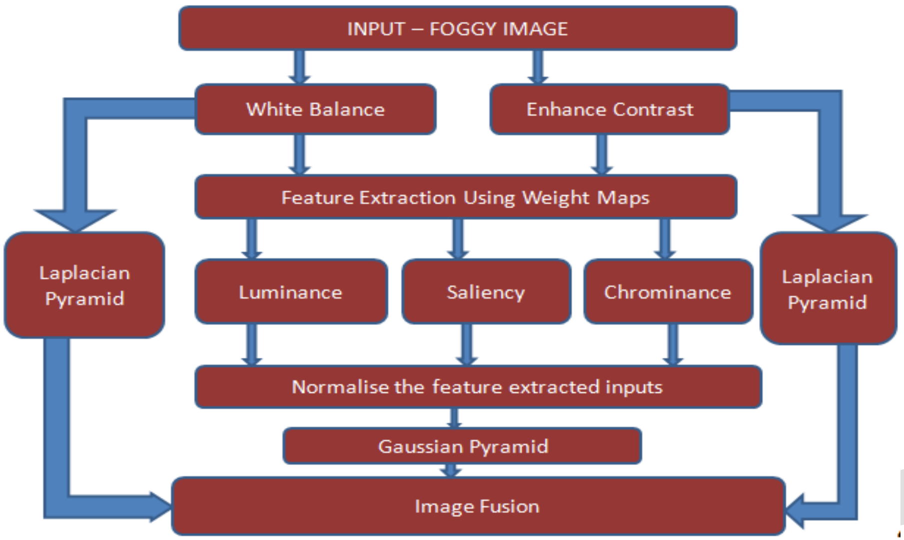

Figure 1: SIHRMSF Block Diagram

Single image haze removal using fusion method works completely by per-pixel strategy. Fusion aims in combining the most essential features which gives the information captured in the haze image and completely converts it to a haze free output image. But to completely extract the important features without any additional errors from the original haze image, certain feature extracting process and different levels of filtering process are required. For that , at first, two inputs has to be derived. The derived inputs are from the original haze image, one is by enhancing the color and other by white balancing. Here the input image which is affected by haze is given as ***H.*** The first step is to apply white balancing in the image. White balancing simply is to adjust colors to give image a more natural look. The light sources such as sun , light bulbs , flashlights and so on depends on different color temperatures. Indoor lighting and outdoor lighting have different color temperatures. Sometimes white things are not exactly white in nature light for example a white object or white car may not seem pure white in photos slightly yellowish or orange in certain photos since different light sources emit different color variations called color temperatures. Humans receive information directly from and immediately change the color temperature. So while capturing images certain errors in adjusting the color temperature, since it only approximate it from the ambient light during outdoor photography. Color temperature of light during day time in outdoors is about 5000K. Our method has taken the concept of conjoined by Ormania [6],[3]. So in the previous implementation the white balancing is done by shades of grey color constancy algorithm which is much more complex to formulate. It is based on modeling the image based on Lambertian surface for formulating the intensity of the image by using its radiance, wavelength and reflectance of the surface. We have introduced a much simpler process by calculating the simple mean of the pixels for different color channels i.e. for R,G,B. The mean of pixels of each color channels is computed separately and again the mean of the three means are taken and normalized . this normalized value is then multiplied to all the three channels separately and combined to extract the RGB input from $\boldsymbol{H}$, $\boldsymbol{H_1(x)}$ imply one of the calculated input.

Contrast Enhancement [6]enhances the dissimilarity in brightness consistently in overall images dynamic range between the scenery and the elements present in the scene. Here the course is to first determine the luminance value **L**, using the R,G,B channel, compute the mean of luminance value denoted as $\tilde{\boldsymbol{H}}$, this then differenced from the whole input image. It raise visualness of image but certain areas get effected at the same time this is corrected in the next step. For gamma a default value given in [6],[7],[11] is set , since it so far gives a good approximate second input, which is given mathematically as,

$$\boldsymbol{H_2(x) = \alpha(H(x) - \tilde{H})}$$

Luminance given by weighted sum of RGB components,

$$\boldsymbol{L = 0.299 * R + O.587 * G + 0.114 * B}$$

Weight maps harmonize the beneficence of both inputs in the feature extraction . It also assure the allocation of higher values to regions having appropriate and conservative features that is unavoidable in the final output. Mainly three features are ensured in this method which very vital to regain the image structure[8]. Of which the first to be ensured is luminance feature , by using effortless per-pixel techniques , here the mean value of the image is taken as the luminance **L**, and minuses from the RGB components and is multiplied by 1/3rd fraction following its square root which is , ***i*** is the no: of inputs[6],[17],

$$M_L^i = \sqrt{1/3[(R^i - L^i)^2 + (G^i - L^i)^2 + (B^i - L^i)^2]}$$

Second map is the Chrominance map which wholly depends on the saturation value of the image. Here for computational smoothness and to set the ultimate saturation range to one HIS model is preferred. Since in HIS the R,G,B amount in RGB components is constraint to the [0,1] range called normalization. The difference of saturation **S,** and top saturation range $\mathbf{S_{max}}$ is calculated dividing by standard deviation, and exponentiated giving[6],

$$M_C^i(x) = exp\left(-\frac{\left(S^i(x) - S_{max}^i\right)^2}{2\sigma^2}\right)$$

Thirdly salient map is advised to correctly estimate whether any objective elements of the image, which could be any object person, or building etc regarding to the adjacent regions [19]. The left hand side of the equation given below indicates the salient map and the right hand side gives the corresponding average pixel value of two inputs differenced from a out focused image of the input image. With cut off frequency as Π/2.75 as $\mathbf{w_{hc}}$, the H_i^{whc} filters noise of that frequency from input image. Given by[6],[5],

$$M_S^i = \left\| H_i^{whc}(x) - H_k^{\mu} \right\|$$

Maps assure the features remain intact in the final output. More detailed information about the inputs and the normalized features are collected by pyramidal refinement. Here Laplacian and Gaussian Pyramid is utilized to fragmentize the descendant inputs from the initial input and finely draw out all the details available in each level and induce it in the final output by fusion without losing any of the input structure. Refinement makes better result by small changes. Pyramidal arrangement is done by convolution of a weighting function and an image. Here the two inputs undergo Laplacian formation and weight maps are normalized for Gaussian refinement. We use same type of pyramid formation for both i.e. the effect of convolution of image is same as low pass filtering, so the variant levels denote the filtered variations of the input image. Both spatial density and resolution of the image get reduced in a set of images which is in effect low pass filtered form series structure in pyramid arrangement. To attain Gaussian distribution the weighting function set as 0.4 (default) since it denotes the shape of the function. Laplacian Pyramid is formed from the Gaussian algorithm as a set of error images between two levels of Gaussian pyramids i.e [6].

$$L_i = G_i - G_{i+1}$$

Here ***i*** denotes the level of refinement. This will look as band pass filtered variations of input image[9]. This way all the image structure is regained and retained by fusion by simply applying summation of both the refined inputs at different levels. At the end of the procedure all the levels are summed up to reconstruct the output clear image for which fusion is formulated as[6],

$$F(x) = \sum_i (M^i(x) * H_i(x))$$

G and ***L*** denotes Gaussian and Laplacian formation and ***l*** denotes different levels, 5-7 levels of is set as preferred for different images[20] , ***F*** denotes the fused output[6],

$$F_l(x) = \sum_i (G_l\{M^i(x)\} L_l\{H_i(x)\})$$

SIHRDC

The second method SIHRDC formulates an image model using Radiative Transport Equation[3],[18]. In SIHRDC uses dark channels that make use of dark pixels and by using atmospheric light assumption, the transmission map is computed[10] for the single input image. Finally the scene radiance is recovered from the image model which gives the dehazed image. The basic working algorithms of the method is formulated as a block diagram and is derived as shown:

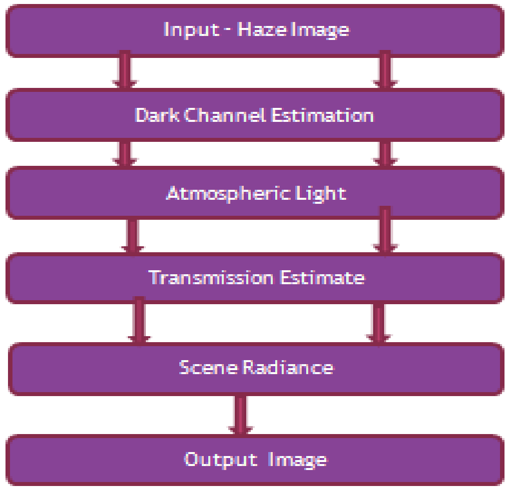

Figure 2: SIHRDC Block Diagram

Haze Removal Using Single Image Dark Channel is patch based procedure. This method is adaptation from [3]. Here radiative transport equation is modified to model an image to the mathematical form. Here H is the input image, D gives scene radiance, A denotes atmospheric light, and T denotes transmission. The past assumption of this model comes from physics[14] based on scattering of light. Atmospheric scattering occurs and increases as the distance between light source and object or eye of the observer [3],[2]. Image equation [3] is,

$$\boldsymbol{H(x) = D(x)T(x) + A(1 - T(x))}$$

Transmission is given by the equation, where β is the scattering coefficient,

$$\boldsymbol{T(x) = e^{-\beta d(x)}}$$

In certain regions except the sky regions a few pixels might be dark in intensity in any one of the color channels. Otherwise, there will be such a patch whose lower intensity is very low valued. Then algebraically for an image ***H***, the dark channel ***D*** is given by [3],

$$\boldsymbol{D^{dark}(x) = \min_{c\epsilon\{r,g,b\}}\left(\min_{y\epsilon\emptyset(x)}\left(D^c(y)\right)\right)}$$

where $\boldsymbol{D^c}$ is a color channel of ***D*** and ***ϕ(x)*** is the local patch focussed at ***x***. ***c*** denotes the RGB channel, and ***y*** belongs to local patch. Patch size of 15×15 is formulated to calculate the darkest pixel in the RGB channel , the images are also resized for calculation convienence. As mentioned above assuming that the regions excluding sky region have a very low valued intensities and limited to zero . Factors contributing very low value for dark channels are shadows of object or people , color deficiency of any color in the RGB channel can cause dark channel and also by objects which are dark. In outdoor photography all these elements are very common which will definitely give the opportunity to seek dark channels[3],[12] . In haze region the transmission is reduced , so the dark channels are a reflection of the amount of thickness in which the haze is present, applying reduction operation using min in both RHS and LHS of the image mode[3],

$$\underset{y\epsilon\emptyset(x)}{\mathrm{MIN}}\left(H^c(y)\right) = \tilde{T}(x) \min_{y\varepsilon\phi(x)}\left(D^c(y) + (1 - \tilde{T}(x)A^c)\right)$$

Assuming for regions other than sky,

$$\mathbf{D^{dark}(x) = \min_{c}\left(\min_{y\epsilon\emptyset(x)}\left(D^c(y)\right)\right) = 0}$$

The atmospheric light **A** is computed from those haze pixels in which passing of light is almost incapable. For atmospheric light estimation, the highest 0.1 percentage pixels which are bright are considered and from this the maximum bright of the input image is put under assumption as atmospheric light. Note that , considering the image as a whole this may not be the brightest. Putting into account the image model equation of the smazed image, the local patch , H^c is the image in different color channels separately, from the above equations , it is concluded that the transmission estimate $\widetilde{T}$(x) is given by,

$$\widetilde{T}(x) = 1 - \min_{c}(\min_{y \epsilon \emptyset(x)}(\frac{H^c(y)}{A^c}))$$

Min operation[2],[3] is applied to both the equation for evaluating the color channels separately, but in certain conditions the image may seem very superficial or seem to be made too perfectly. So to avoid unwanted perfection , i.e. to give the output a natural feeling by retaining its natural colors a additional parameter ω is induced to the second term or the difference term of the derived formula and transmission is reformulated as,

$$\widetilde{T}(x) = 1 - \omega \min_{c}(\min_{y \epsilon \emptyset(x)}(\frac{H^c(y)}{A^c}))$$

The final step is to produce scene radiance from the image equation [16]. Since recouping the radiance directly might not be a good choice because it will be easily affected by noise. So a limited quantity of haze is allowed and transmission is constrained to the minimum bound given as T_0,

$$D(x) = \frac{H(x) - A}{max(T(x), T_{0)})} + A$$

PERFORM ANCE COMPARISON

PSNR, Peak Signal to Noise Ratio is computed by deriving the Mean Square Error i.e., where R and C denotes rows and columns [6],[3],

$$MSE = \frac{1}{RC}\sum_{X=1}^{M}\sum_{Y=1}^{N}(H_i(X,Y) - H_O(X,Y))$$

$$PSNR = 10 * log\ 10(\frac{256^2}{mse})$$

NAE , Normalized Absolute Error is given by,

$$NAE = \Big(sum\big(sum\big(abs(error\ image)\big)\big)\Big) / \Big(sum\big(sum(orginal\ image)\big)\Big)$$

Error image is obtained by subtracting output image from the original image. MD, maximum difference is said to be,

$$MD = max(max(error\ image))$$

RESULTS AND DISCUSSIONS

The method implemented in SIHRMLF is operated on each and every pixel of the inputs extracted from the original input. Thereby it is indicated as per-pixel strategy. The SIHRDC method uses strategy on patches of group of pixel from the single input. Both the methods are quite simple to put into practice and can be easily implemented in real time applications. The outdoor images are mainly used in implementing the so called methods. Both the methods give comparatively very good results than the results obtained by previously proposed methods [13],[15]16]. Here, comparison of the results using the outputs of two methods is obtained by certain quality measurements. An example of a haze image will be any outdoor image that is covered with fog , smoke, mist, dust, smaze, etc , here such an image is under consideration as the input. The image is showing a bridge amidst of green trees . It is captured in an outdoor environment, so atmospheric color cast, shadows of objects such as trees etc would be present. So these small artifacts have to be filtered.

Figure 3.a: Input Image   Figure 3.b: SIHRMLF   Figure 3.c: SIHRDC

Figure:3. Results of both methods SIHRMLF and SIHRDC with bridge image and corresponding final outputs as a,b,c

The figure shows image taken as input and its corresponding outputs of the two methods . Here in the output image, comparing with the input image the upper portion of the bridge is very clearly visible though the downward portion is still has some of the fog to be removed . In white balance section, the regions having white colour gets more white avoiding the atmospheric color, here it is the mist region. The contrast enhancement increases clarity on the unclear regions covered by haze .But during this stage other regions may tend to get darker which can be rectified in feature extraction process . By different levels of pyramidal filtering the image information can be regained and thus in the output, more clear image obtained by retaining its structure . The results of second procedure includes only one input and no need of other derived inputs. It recovers the darkest channel, transmission estimate and scene radiance from the obtained image model as described earlier in this paper. The scene radiance is the one which recovers the image haze-free. This shows much better results as shown above. Similarly examples of two other images are also taken into account for performance measure of the two method.

Figure 4.a: Input Image   Figure 4.b: SIHRMLF   Figure 4.c: SIHRDC

Figure:4. Results of both methods SIHRMLF and SIHRDC with the another image and corresponding final outputs .

The performance of the two methods are done by using PSNR, NAE, MD which is Peak Signal To Noise Ratio, Normalized Absolute Error And Maximum Difference. The basic concept of all these parameters is to measure the difference between input image and the final output image. This gives the amount of similarity or error difference between the input and output image. The tabular column shown below gives the corresponding parameter values for three different images are shown of which first two images are figure 3 and figure 4.

INPUT	**PSNR**		**NAE**		**MD**	
METHODS	SIHRMLF	SIHRDC	SIHRMLF	SIHRDC	SIHRMLF	SIHRDC
FIGURE 3	54.88	54.84	0.4737	0.5495	0.8373	0.6237
FIGURE 4	63.10	59.73	0.2574	0.4345	0.6287	0.5212
IMAGE 3	58.74	56.26	0.4195	0.6918	0.9879	0.6409

Figure 5: Tabular Representation of PSNR ,NAE and MD values on RGB channels.

For all the three images, PSNR,NAE,MD values ranges very closely between both methods . The PSNR of first method has shown significant increase compared to the other method. SIHRMLF is comparatively very appropriate and yields good PSNR though the SIHRDC gives good output but has certain small disturbances and also loss in image naturality is due to color variations compared to the actual image, first one is much better performance. Normalized Absolute Error should be minimum value, so as the tabular comparison shown the method that includes fusion give more similarity than the other method in terms of recollecting the image information without loss . Here the maximum difference should be greater comparing to the input image since the output image obtained will be better in terms of image clarity. So the fusion method is much more appropriate in terms of image structure similarity and image information regaining where as SIHRDC method also gives better performance in removing the fog or haze but has a few amount of noise which can have further scope of modification by undergoing any normal filtering methods.

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CONCLUSION

Haze refinement techniques have a significant amount of importance in day today real time applications. So for the increasing need of efficient refinement strategy, this paper study is very relevant since the paper basically compare the performance including PSNR, NAE, MD of Single Image Haze Removal using Multi Level Fusion and Single Image Haze Removal using Dark Channel which are highly applicable because of its less complex features used in every step. Each step included in either of the methods are simple image processing steps which can be easily understood.. Both the implementation has been made suitable for images of resolution 500×500 . First one is pixel based and second is patch based (having patch size of about 15×15).This is can be easily done in almost all versions of Matlab.

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