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On the Performance analysis of image Dehazing using fuzzy theory and Artificial Neural Networks

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Abstract: Photography in hazy environment, light attenuation and scattering caused by the water particles present in the medium, result in loss of severe image quality and loss of valuable information. In order to minimize the effect of haze and improve visual quality, this literature present a novel technique combining fuzzy theory, artificial neural networks and image fusion. Transmission map is estimated using fuzzy inference system. Then morphological operation and artificial neural network are applied to remove the halation present. Backpropagation, feedforward, cascaded-feedforward and fitnet artificial neural networks are applied on halation free transmission map for further refinement. Finally, image fusion technique is used to recover an enhanced version of all four images.

Keywords: Fuzzy inference system, artificial neural network, fusion, halation, morphological operations, backpropagation, feedforward, cascaded feedforward, fitnet.

1. INTRODUCTION

In order to get a clear picture of a scene, in outdoor environment, the effects of fog, haze, smoke, dust and many other environmental factors need to be considered, as they all effect image quality, by causing light attenuation and scattering. To reduce the climate effects on image quality many studies (He, 2011) (Ancuti, 2012) tried to minimize the effects.

Dehazing methods can broadly be categorized into two categories: Multi Image enhancement(Schechner, 2001) (Shwartz, 2006) Single image enhancement (He, 2011) (Ancuti, 2012). Multi Image enhancement techniques uses the technique of polarization of light and take multiple images of the same scene to estimate haze thickness.

Single Image enhancement technique utilizes single image to derive an enhanced version. Various techniques (He, 2011) (Ancuti, 2012) uses the concept of single image enhancement. (He, 2011), uses the concept of dark channel by calculating the minimum values in a particular mask, called dark channel prior. Dark channel prior is employed to determine the atmospheric light in order to determine transmission map. Ancuti *et al.,* (Ancuti, 2012), uses the concept of image fusionderived two inputs from the original image and then different weights are calculated and applied on each input, finally both the inputs are combined using image fusion. Since, (He, 2011) uses mask, final image result in halation. Also, (He, 2011) has high processing time and poor result for sky regions. "*Underwater image and Video enhancement by Fusion*" (Ancuti, 2012) was developed to enhance underwater images, but when applied to hazy images, worked fine, especially for sky regions.

(a) (b)

Fig 1:Our single image dehazing technique. (a) Input hazy image. (b) Image obtained through our algorithm.

Fuzzy theory (Pham, 2001) (Van De Ville, 2003) impersonate human brain and has capabilities to think like humans, while artificial neural network (Zhou, 1988) simulate human brain and has learning capabilities. Researchers uses both fuzzy theory and artificial neural networks to solve complex problems and are applied in numerous imaging techniques, i.e. image enhancement (Zhou, 1988), recognition (Kanellopoulos, 1997), segmentation (Cheng, 1996), compression (Daugman, 1988), face detection (Rowley, 1998) etc.

Many methods achieve goal of image dehazing, however the effects of halation, color cast, huge

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processing times still exist. This paper proposes a novel technique to solve problems of halation and colour cast by combining fuzzy theory, artificial neural networks and image fusion.

2. Previous And Related Work

As shown in **(Fig 2)**, in hazy environment photography, observed scene is greatly affected by the presence of water particles in air. The light reflected by the object is effected due to the absorption and scattering (Bohren, 2008) of light due to water particles present. Attenuation and object distance are directly proportional. Amount of attenuation and scattering, both depend on the amount of water particles suspended in air (Bohren, 2008). Due to light attenuation and scattering the resultant image loses its colour and appear blur.

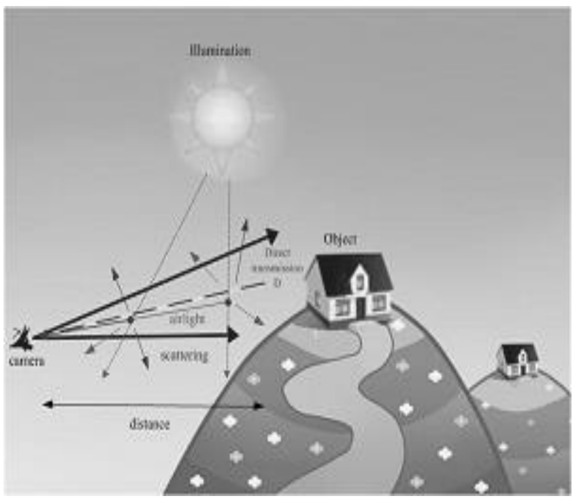


Fig 2: Haze Model

According to Fattal (dehazing, August 2008), the physical mathematical model of haze can be written as:

$$I(x) = J(x) * t(x) + A\left(1 - t(x)\right) \quad (1)$$

Where

x= (x,y) coordinates of each pixel
I= Observed Hazy Image
J= Reflected light from scene
t= Transmission map
A= Atmospheric light

Lambert-Beer's(Zaccanti, 1988) proposes that when light transmit through air, it is exponentially attenuated with respect to the transmission depth. The Lambert-Beer's law can be written as;

$$t(x) = e^{-\beta\, d(x)} \quad (2)$$

Where

d(x)=depth of scene coordinates x
β=attenuation coefficient

Majority of image dehazing models (He, 2011), (Ancuti, 2012), (dehazing, 2008) are utilizing the concept presented in equation 1. Various techniques were proposed based on transmission map estimation for haze removal. A general haze removal algorithm, based on transmission map estimation is shown in **(Fig 3)**.

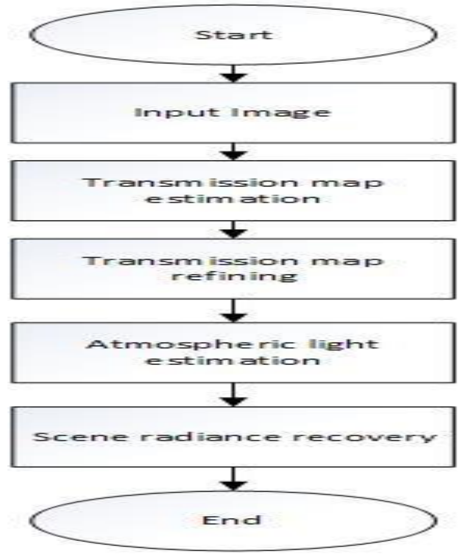


Fig 3:Flowchart of transmission map based dehazing model

3. PROPOSED METHOD

In this letter we proposes a novel image dehazing technique. This paper intends to dehaze image using white balancing, fuzzy inference system, artificial neural networks and image fusion. First, the image is white balanced using white-patch (Land, 1977) algorithm. Secondly, a mask of fixed size is applied to calculate each channel minimum value in the applied mask size. Each channel minimum value obtained through masking is further processed using fuzzy inference system for estimation of transmission map. Since, by applying mask size greater than 1x1 result in halation, morphological operation of erosion (Dougherty, 2003) is utilized to erode any halation present around edges. To further refine the transmission map, artificial neural networks (Mendoza, 2009) are used to refine the transmission map using back propagation (Hecht-Nielsen, 1989), feed forward (Hornik, 1990), cascaded feed forward (Littmann, 1992) and fitnet (Romero, 2014) techniques. Finally all four images are fused together to create a final enhanced image.

3.1 WHITE BALANCING

White balancing often referred to as colour constancy in literature is the process of eliminating the constant color casts present, so that objects which appear white in person are rendered white in the image(Patent No. U.S. Patent Application No.

10/420,097). Due to the presence of a very little color cast, modified-white patch algorithm (Banić, 2014) is applied to remove the slightly constant color cast present as shown in **(Fig. 4-5)**.

(a) (b)

Fig 4: White Balancing (a) Input hazy image. (b) Image obtained by removing the colour constancy.

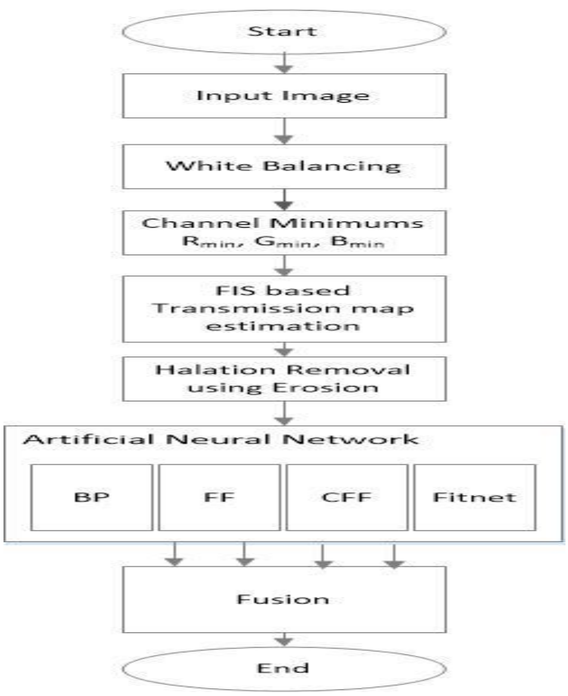


Fig. 5: Flowchart of proposed dehazing algorithm

3.2 Transmission Map Estimation Using Fuzzy Inference System.

Fuzzy Inference System (FIS) (http://www.cs.princeton.edu/courses/archive/fall07/cos436/HIDDEN/Knapp/fuzzy004.htm, n.d.) -(Jouffe, 1998) using fuzzy theory to translate inputs into output. Fuzzy system is proficient of captivating logic decisions, mimicking human brain. FIS consist of four parts; *fuzzifier*, *inference engine*, *fuzzy rules* and *defuzzification* (www.massey.ac.nz/.../Lec2012-3-159741-FuzzyLogic-v.2.pdf, n.d.).

Fuzzifier is the process of computing or converting clear meaning expressions into fuzzy expressions by using fuzzy logic algorithms.The fuzzy set described in terms of mathematical equations with values in the range of 0 to 1 are called *membership functions*.*Fuzzy rules* are conditional statement, like if then else statements, that entitle what will happen when a certain state is met or some criteria well-defined is fulfilled. *Inference engine* is the brainy tool in the FIS. It is the inference engine that syndicate with the fuzzy rules, to form if then else logic, imitating the human brain to make intellectual conclusions. Defuzzification is the procedure of generating crisp results that are easily comprehensible to human beings. Numerous defuzzification approaches are present in literature, prevalent practices are: Basic Defuzzification Distribution (BADD) (Filev, 1991), Adaptive Integration (AI) (Yasuda, 2003), Centre of Area (COA) (Patel, 2002), Extended Centre of Area (ECOA) (Runkler, 1996), Centre of Gravity (COG) (Broekhoven, 2006) and Bisector of Area (BOA) (http://www.cs.rpi.edu/courses/fall01/soft-computing/pdf/chapter4.pdf, n.d.). In this research we use the technique of Center of Area in the defuzzification step for output calculation.

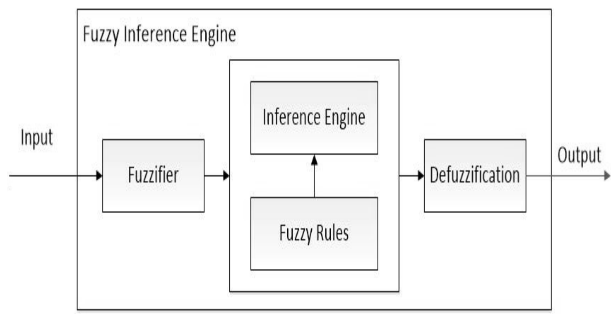


Fig. 6: Block Diagram of Fuzzy Inference System.

Light attenuation and scattering caused by the water particles varies with the intensity of haze and depth of the scene. The light attenuation and scattering can be termed as a nonlinear problem and is haze (Loisel, 1998). To solve the nonlinear problem of image dehazing, fuzzy inference system is used to estimate the transmission map.

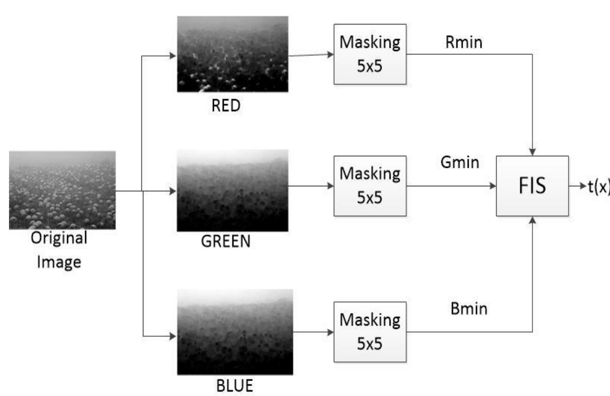


Fig. 7: FIS based transmission map estimation

First, an image is read and each color channel is stored as separate red (R), green (G) and blue (B) channel. A fixed size mask is applied on each channel separately to calculate the minimum pixel value of that particular mask, as presented in equation 3.

$$R_{min} = \min_{i \in \Omega(x)} R_i;$$
$$G_{min} = \min_{i \in \Omega(x)} G_i;$$
$$B_{min} = \min_{i \in \Omega(x)} B_i; \qquad (3)$$

Where Ω is mask size. The minimum pixel value of each channel (R_{min}, G_{min} and B_{min}) obtained through masking are treated as inputs to the FIS, as shown in **(Fig. 7)**. The FIS, degree of membership (Au, 2001) is calculated using fuzzy logic for each input and output. The fuzzy rules that are used to estimate the transmission map are presented in (**Fig. 8** and **Fig. 9)** correspondingly.

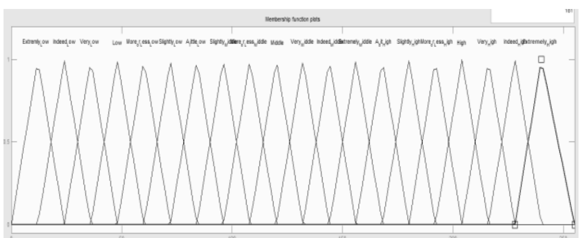


Fig8: Fuzzy input Rules

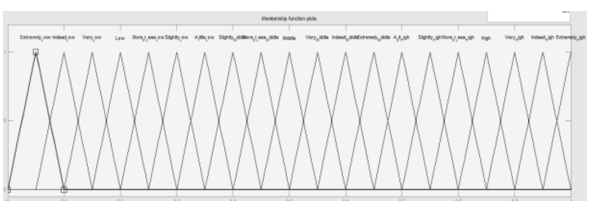
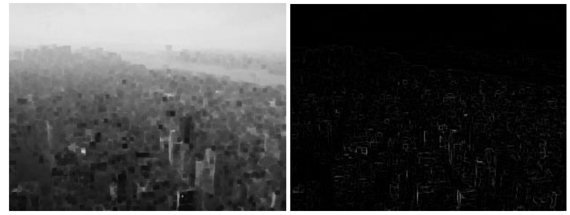


Fig. 9: Fuzzy output rule

3.3 Halation Removal Using Morphological Operation

Using mask size greater than 1x1 results in halation (He, 2011). By using mask greater than 1x1, it is assumed that neighboring pixels are exposed to the same level of transmission as its surrounding. The assumption is not true in nature. To remove the halation present around object edges, erosion of morphological operations (Dougherty, 2003) is applied to erode any halation present. The technique proved quite successful in removing the halation present as shown in **(Fig.10)**.

(a) (b)



(c) (d)

Fig.10: Transmission map refinement using erosion of morphological operations a) Original Image b) Transmission map obtained through FIS c) Eroded transmission map (d) halation in transmission map (difference of both transmission map).

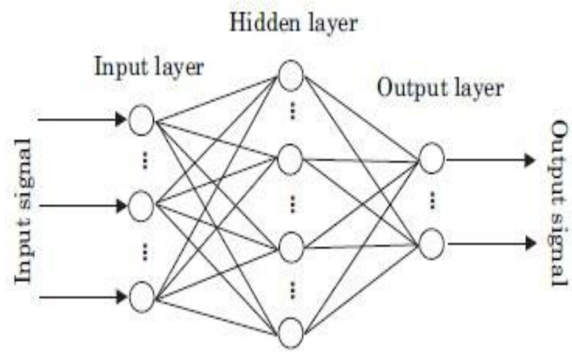


Fig 11: Artificial Neural Network

3.4 Artificial Neural Network

Artificial Neural Network, simulate human brain with learning capabilities.ANN consist of three layers: *Input layer*, *Hidden Layer*&*Output layer*as shown in (**Fig. 11)**. ANN consist of neurons and the network learn through repeated process of training by adjusting the weights of neuron. Four types of ANNs (feed forward (FF) (Hornik, 1990), back propagation (BP) (Hecht-Nielsen, 1989), cascaded feed forward (CF) (Littmann, 1992) and fit net) are utilized to refine the transmission map obtained through erosion.

Original image and halation free transmission map are used as input to all four ANNs for repeated learning of the training data. During learning, ANNs algorithms (FF, CF,BP and Fitnet) adjust the weights and bias of the neurons to minimize the error during filtered image generation. The parameters used in all four types of neural networks are shown in **(Table 1).**

Table 1: Experimental parameters

Parameters	**Values**
Size of Input Mask	5x5
Size of Erosion Mask	5x5
Neural Network Iterations	50
Number of Inputs	4
Number of hidden neurons	10
Number of outputs	1
Learning algorithm	Levenberg-Marquardt
Transmission Factor	0.15
Learning Rate	0.01

3.5 Atmospheric Light Estimation

To estimate the atmospheric light, technique of Fattal *et al.*, (dehazing, August 2008) is utilized. Atmospheric light estimation is based on equation 4, where t(x) is the transmission map and v(x) represent the atmospheric light.

$$v(x) = 1 - t(x) \quad (4)$$

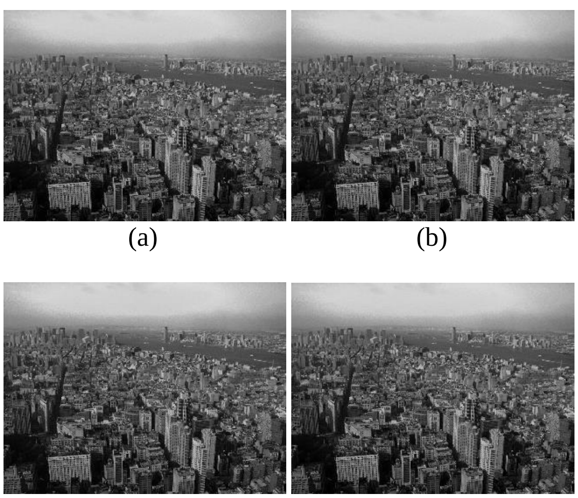
v(x)is also denoted by A.

3.6 Scene Radiance Recovery

In scene radiance recovery step, equation 1 is converted to equation 5, to get the dehazed image. Here, according to (He, 2011), we have to set a lower limit t_0, called transmission factor to estimate the scene radiance recovery. In our experiment, 0.15 is used as minimum value for the transmission factor.

$$J(x) = \frac{I(x)-A}{\max(t(x),t0)} + A \quad (5)$$

Since, we are filtering the transmission map using four types of neural network filters, four different types of scene radiances are recovered using equation 5, as presented in **(Fig. 12)**.



(a) (b) (c) (d)

Fig12: Scene Radiance recovered using (a) BP (b) FF (c) CF (d) Fitnet

3.7 Image Fusion:

Since, different ANNs produces different results with varying amount of error, all four recovered radiances are combined to create a single enhanced image using prominent features from all images using the technique of image fusion. The final enhanced version is more visibly pleasant, has less halation and haze effects, as presented in **(Fig. 13)**.

(a) (b)

Fig 13: (a) Original hazy image (b) Image obtained through fusion

4. EXPERIMENTAL RESULTS

In this experiment, we use mask size of 5x5 for both channel minimums calculations and transmission map erosion. Fuzzy rules and degree of memberships are defined according to (Fig 7- 8). Various settings used in artificial neural networks are presented in Table 1. From the experiment we obtained high quality haze free images as shown **in (Fig. 14)**.

Fig 14:Original Image (Left), Dehazed Image (right)

5. CONCLUSION

We presented a novel image dehazing algorithm by means of fuzzy inference system, morphological operation, artificial neural networks and fusion of images. Unlike the normally used crispy logic, a more advanced human logic based fuzzy inference system is used forapproximationof the transmission map, which is additionally refined by the erosion of morphological operations and neural networks. The technique proved quite successful in removing haze with varying amount of haze depth. The technique overcome the shortcomings of many image dehazing algorithms by removing the color cast and halation.

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