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# Foggy Image Detection and Filtration Methods: Review

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***Abstract:*** **Image de-fogging in brightness defined to image calculated in a deprived climate like as fog, rain and ocean and pollutants or dust particles. To alter the fog and some other pollutants from the image, various methods are customized, some mainly utilized methods are DCP, Detection, and Classification of foggy images. Haze is an arrangement of dual components, air-light and DA (Direct Attenuation), low image quality and generates various issues in VS (Video Surveillance), Navigation and Target Tracking, etc. So, its removes from an image, several de-fogging approaches have been discussed in this paper. Image De-fogging can attain utilizing several and single image haze removal techniques. The famous methods are discussed in this paper used for image de-fogging in DCP, Depth-map for accurate estimation, Guided Filter, and Transmission methods. These techniques still efficient in removing haze from images have very high time complexity. The guided filter is a new region preservative filter with region enhancement and smoothing. The previous result was a local linear transformation of the Guided Image. It defines a review of the classification and detection technique of a hazy image. This method mitigates the limitations of filtration and DCP and at the same time preserves the image quality. At that time, described the existing image de-fogging methods containing image restoration, contrast improvement, and fusion-based image de-fogging methods.**

***Indexed Terms-*** **Image Defogging, Atmospheric Light, Depth-Map, Classification and detection foggy image methods.**

## I. INTRODUCTION

Image fogging is a normal scenario on the ocean and land. In a foggy climate or weather, there are various atmospheric atoms of vital size. They are not absorbed and scatter the RL (reflected light) of view, then also scatter a few AI (Atmospheric Light) to the digital camera. Accordingly[1], the image acquired by the digital camera is despoiled and normally has less image contrast and minimum visibility. Owing to the deprivation of the image, the obstacles and targets of the image are complex to detect. It is not good for automated VP (Video Processing), like Recognition, Target Tracking, and Feature Extraction of objects. The main issues are aimed at vehicle coincidences in the road, ocean, and air, etc. Thus, it is vital to develop an image de-fogging method to enhance the environment flexibility of the VS (Visual System). Computer technology has developed the image, de-fogging methods have achieved much attention and are worldwide functional in the army and civil areas like as RS (Remote Sensing), TD (Target Detection), and TS (Traffic Surveillance). The image de-fogging method is used to improve the image perceptibility of the Vehicle Visual System (VVS), which can efficiently avoid vehicle coincidences. The outside views, author [2] analyzed the visual appearances of various climate situations like fog, cloud, and rain, etc., and then developed a PHY imaging MODEL that depends on the atmospheric spreading scenarios for image de-fogging. After studying the existing research, the de-fogging methods have no-clear regions, in this review paper, we use image de-fogging to mention two methods that can eliminate haze from the image. Bad visibility situations like a foggy climate, its compliance to search runways and dangers fog VS of a flight or airplane. Most of the existing de-fogging methods eliminate the fog from land images. Various defogging methods describe with single-image have robust expectations empirically and substantially. The formation of a picture comes foggy climate situations could be complete as a three-dimensional structure of view, which is built from original profusion data like as a text, geographical data, depth, and texture, etc. Through, a de-fogged image for a geo-registered depth-map can be related as GT (Growth truth), it fetches high complexity at the same time.

The paper is summarized as follows. In this section 2 the descriptions of general organization and arithmetic derivations in the de-foggy image with the depth map. Section 3 and 4 show the related work with various filtration methods, detection, and classification of foggy images. In section 5 defines the various defogging method with learning models, Bayesian models, and intensity transformation. Lastly, section 5 concluded the paper and given our scope of further work.

## II. GENERAL STRUCTURE AND ARITHMATIC DERIVATIONS

Recent image enhancement and restoration stages are not all that cooperative to reduce the effect of dulling from dark images. The earlier, darkness reduces the optical information and then reduces the accurate information investigation. An effect of darkness additions with the separation, which types the image, de-fogging a various problem.

### *A. The Depth Map for Accurate Estimation*

This section, find accurate depth-maps and AL for a natural view, restoring, the implement de-fogging process as defined in figure 3 has two-major steps for the procedure. It is directed by Multi-level Estimation (MLE), everywhere a Multi-level estimation is fixed. Later that the main phase is established, a normal PHY model depends on image recovery is developed to get a foggy image.

Estimating the depth steps is based are three phases or levels: An initial fusion procedure depends on the DCP is working to build an uneven Depth-Map. The second Phase is foreground detection with a multi-level Model. The guided filter is working on the 3rd phase to last region refinement, the precise depth map is an estimation and eventually.

It is defined as 2 inputs that have various dimensions of the area for the DCP method as the i/p in the 1st phase.

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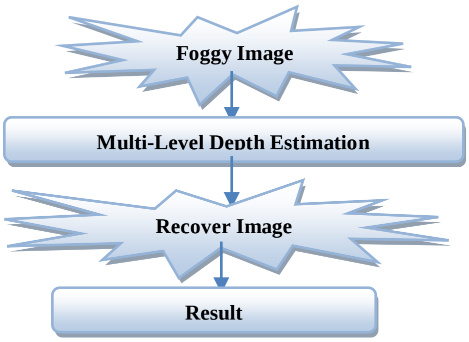
The 1 is the maximum, and another is minimized. To extract features of DCP, the uneven approximation of depth map in the view may create block effect and refining result. The facts of minor data are also misplaced when the area is growing [3]. The de-fogging technique process is shown in figure 1.

**Fig 1. De-fogging Technique Process**




The various phases in-depth map is shown in figure 2. Fuse two DCP images in an easy path. Two images are assumed equivalent weights to explain into 1 depth-map, which is stated as the prospect of i/p to subsequent phases. The uneven depth map is rebuilt to the prospect used by the multi-level method. It is an un-directed adjacent node and the graph is associated to define the complexity of the actual view. It is related Hidden Layer (HL) with the thick phase of haze and reflection layers with the uneven depth map and the classical is delivered to Cost Function (CF) as defined as follow:

$$E(ff) = \sum_{p\varepsilon P} D_p\ ff_p + \sum_{\{p,q\}\in N} Vp,q\ (ff_p, ff_q) \quad \text{(i)}$$

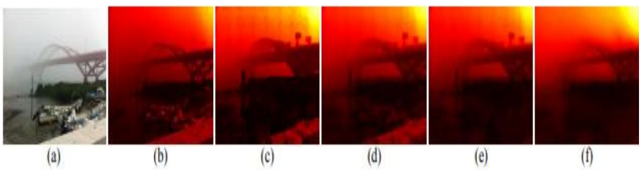



**Fig. 2. Various phases in depth map (a) Original Image (b) small area with DCP and (c) Depth map from huge area using DCP (d) Consequences from Multi-level process (MLP), which resources un-even, rewarded and precise DMs correspondingly.**

Figure 2.illuminates the procedure of multilevel distance approximation. Fig 2(a) it's a river site scene, which has the thick hazy protected with the connection and it is incomplete Whiterock edges in front of the picture. Fig 2(b) it's a picture processed by a minor area using DCP, Fig 2(c) General, DCP Fig 2(d) depth map created from the multi-level model defined in fig 2(e) successful compensated and fig 4(f) final correct depth-map[4].

## III. REVIEW CRITERIA

Weidong Zhang et al., (2019) [5] described resolving the issue of image de-gradation in defogging climate, single image de-fogging technique based on MSRCR (MultiScale-Retinex with color restoration) of Multi-Channel Convolution (MC) was implemented. The complete de-fogging procedure mainly consists of four sections: (i) Component Extraction (ii) Filtration Process (iii) Reconstruction and (iv) White-Balance Operation. In the initial phase, the Multistage Gaussian Kernels was engaged to fetch accurate characteristics to an approximation of the brightness feature set. Subsequently, a color restoration technique was developed to improve the global image contrast, feature data, and RGB (color) re-constructed of the picture. In the second phase, an image smooth boundaries of both brightness were measured, composed by utilizing Guided Filter (GF), therefore an improved picture contents the smooth boundaries and interference in the improved image was optimized. An improved picture by a Multi-Scale color re-sortation and the processed image by second GF were combined with line weight near rebuild the last output image in the 3rd phase. In the end, to remove the effect of image brightness on the color of the de-fogging picture, the output picture was calculated by White Balance (WB).

Major problems: (i) Time Complexity (ii) Less Accurate (iii) High Error Rate and (iv) Noisy Data.

The simulation result calculated that the suggested technique can out-perform state-of-the-art technique together QUANTITATIVE and QUALITATIVE evaluations.

### Guided Filter (GF)

It was a new region preservative filter with region enhancement and smoothing. The result was a local linear transformation of the Guided Image (GI). **K. He, J. Sun, et al., 2013 [6]** defined the description and comprehensive explanation procedure of the GF, which was expressed as;

$$q = guide\_filt\ (Pp, i\ , Rr, \varepsilon) \quad \text{(ii)}$$

Where eq (ii) Pp is the actual image of the guided filter, i guide image, Rr is a window size of filter and $\varepsilon > 0$, is the Regularization Co-efficient(RC) and q is filtered picture.

### Multi-Channel Convolution

Various CK (convolution kernels) can attain dissimilar characteristic mapping of the I/p image in Convolutional Neural Network (W. Ren. et al.,2016 [7], B. Cai, X et al., 2016 [8]). These characteristic maps were an illustration of Feature Information (FI). Moreover, the algorithm difficulty increases as CK increases. Therefore, MC was required to control the number of CK by weighing_count of the FI and the interval difficulty of the method. An approximation of image brightness mechanisms in Retinex is Convolution Operation (RO) on the I/p picture by Gaussian kernels (GKs) of various rules. These pictures are gained by convolution of the i/p picture by GK of various rules such as (FMs) Feature Maps in Convolution Neural Network. Though, the MultiScaleRetinex Channel restoration technique used GK methods with 3 different scales to convolution RGB color channels. The main idea of various Kernal Convolutions was described in the MultiScaleRetinex Channel restoration technique by considering the ability of various CK to fetch accurate characteristics of the convolution neural network.

Mathematical Formula is based on estimation of the illumination components was described as follows:

$$l_I^N\left(gFi(xx, yy)\right) = S\left(gFi(xx, yy)\right) * gNn(x, yy) \quad \text{(iii)}$$

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Where eq (iii), g(xx,yy) = $\frac{1}{2\pi\sigma^2}$exp( $\frac{xx^2+yy^2}{2\sigma^2}$) is a GK (Gaussian Kernel) method, Nn is the no. of filter RSs (Radius scales) of the Gaussian Filter (GF) and $\iint g(xx,yy)dxxdyy = 1$, they custom 6 scales in real uses (Nn = 6).

**Multi-Scale Retinex Channel Re-storation (MSRCR)**

The main idea of Retinex (Y. F. Wang et al.,2016[9]), is that light of intensity was not a Decisive Factor (DF) in the color of an object, while it was considered by the capability of an article to reproduce the bright of short, Short-Wave and Medium). It means the reproduction of feature of the article is conserved, and the impact of the radiance of light on the real picture was detached. Giving to the RT (Retinex Theory), the main knowledge of a picture is described as defined:

$$S(xx,yy) = l(xx,yy) * r(xx,yy) \qquad \text{(iv)}$$

Where eq(iv), S(xx,yy) is an input image considered in real-world or created by other imaging equipments and l(xx,yy) was a brightness module and r(xx,yy) was a reproduced input picture.

**Secondary-GF (Guided Filter)**

Initial GF only proceeds into an explanation of the smooth image limit on the brightness module. The consequence of the output de-fogged picture conserves the interference of the real picture and improves the approximation exception of the brightness constituent. Though, the secondary GF proceeds into account both the smooth limits of the brightness component. Secondary-GF RED, GREEN and BLUE channel was expressed as follows:

$$rr^2gf = guid_{filt}(Rmsrcr, Rmsrcr, R, \varepsilon) \qquad \text{(v)}$$

$$gg^2gf = guid_{filt}(Gmsrcr, Gmsrcr, R, \varepsilon) \qquad \text{(vi)}$$

$$bb^2gf = guid_{filt}(Bmsrcr, Bmsrcr, R, \varepsilon) \qquad (vii)$$

Where eq(v),(vi) and (vii) defines R = 32, $\varepsilon$ = 0.01 and they were considered by a huge number of experiments.

Sebastián Salazar-Colores et al., 2019 [10] discussed the outside pictures can be violated owing to the atoms in the mid-air that scatter light and absorb. The de-gradation creates image difference reduction, blur, and noise in image pixels, consequencing in less visibility.These constraints the proficiency of CVS (Computer-Vision System) like Surveillance, PR (Pattern recognition), and Target Tracking. This paper studied and proposed a rapid and operative technique, concluded alteration in the calculation of the Dark Channe (DC) which expressively mitigates the artifacts produced in the reconstruct pictures defined when expending the normal Dark Channel (DC). Investigational consequences, the technique create improved consequences than some state-of-the-art techniques in organized effective and reconstruct values. The processing time in examinations defines that technique was acceptable for pictures with high-resolution (HR) and real-time Video Processing (VP).

Shuai Shao et al., 2019 [11] offered that a Single Remote Sensing Image De-hazing (SRSID) was an ill-posture issue, that was the main stimulating task. To enhance the image reflection of a particular haze RSMI (Remote Sensing Multi-Spectral Image), they implemented a new and current method based on a knowledge structure. The LR (Linear Regression) prototype with the valuable characteristics of fog was recognized. The Gradient Descent (GD) approach was developed to the knowledge structure. Then a haze picture correct transmission-map was attained by knowledge of the coefficients of the direct structure. They planned a further efficient approach to approximation the AL (Atmospheric Light), which can re-strain the effect of highpoint fields on the Atmospheric Light (AL) gaining. All performances and graphs were associated with the outdated fog elimination approaches, the investigation outcomes validate that the projected method can attain improved visual-effect and color reliability. The scatter models for sunny climate and hazy climate are shown in figure 3.

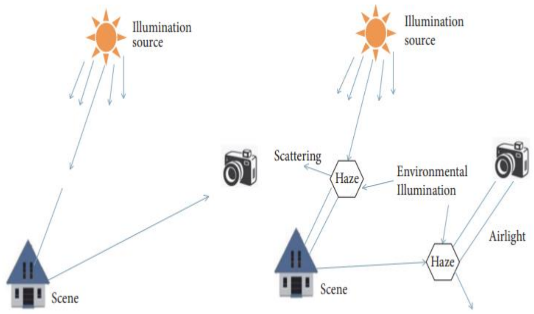


**Fig 3. Scatter Model for various climate situations such as (i) Sunny (ii) Hazy climate.**

***A. PHY Hazy Image De-gradation Model***

Liu, et al., 2020[12] and Nayer [13] et al.,2002 have described and defined by the distinctive scatter structure, as shown in fig 1. Then, the scatter structure is a worldwide referenced by advanced investigators. They separate the effect of the light reproduced by the atmospheric into dual sections:-

(i) Straight Reduction and
(ii) Covering Bright.

The development of a hazy picture can be elaborated as;

$$I(xx) = j(xx)t(xx) + A\big(1 - t(xx)\big) \qquad (viii)$$

Where eq (viii) xx defines the position of image pixel, I (xx) is the detected foggy picture, j(xx) is the view glow, A is the worldwide Atmospheric Light (AL) normally supposed to be continuous, and t(xx) is the average broadcast, which defines the light of broadcasting i.e. not scattered and fetch's to the digital camera.

Average Broadcast can be defined as;

$$t(xx) = e^{\beta d(xx)} \qquad \text{(ix)}$$

Where eq (ix) and (x) shows d (xx) is the view deapth and$\beta$ is the Scattering Co-efficient (SC) of the air. The main objective of de-hazing is to estimate the (xx), they can attain the original view j(xx) because they have an approximation of A and t(xx) by;

$$j(xx) = \frac{I(xx)-A}{t(xx)} + \text{A} \qquad \text{(x)}$$

***B. Approximation of Atmospheric Light***

Maximum of haze, remove methods are depending the image pixels connected with single-image to attain an approx. of AI. If the phase of RS image attainment is below the situation of foggy climate, they normally disregard the effect of sunlight. He [14] used the max. value of haze image pixels as an approximation of Al, though the max-values of brightness constituent might relate to the high pointed entity areas.

In K. He, et al., 2011 [15] defined the upper 0.1 percent image pixels in DC are occupied as the AL. While this approach was strong, only an attractive single-point into explanation may reason that the value of every color channel is the too great principal color point. It conducts incline to attain an acceptable outcome, once the high-light fields occur in the picture.

K. He et al., 2011 [15] proposed approach that can mitigate the effect of high-light fields on the AL acquisition. Initially, it's needed to revenue the maximum color channel map of the de-graded Remote Sensing Image (RSI).

Minimum Colour Channel Map is defined as;

$$M(xx) = min_{C\varepsilon(R,G,B)}(I_c(\mathrm{xx})) \qquad \text{(xi)}$$

The score of individual edge is attained:

$$Score_i = M_i - \delta\hat{}2_i \text{ , i = 1, 2, 3} \qquad \text{(xii)}$$

Where eq (xi) and (xii) i is the index of each edge, $Score_i$ is the score of region I, Mi defines the mean value of edge i and $\delta\hat{}2_i$ presents VAR in the edge of i.

Before, taking the edge with the Higher Score as the Candidate Iterative Region (CIR), and it's separated into 4 small edge sections. This development starts to repeat until the scope of the Candidate Region (CR) is minimum than the pre-set threshold size. The medium of each color channel in the previous CR is chosen as the outcome of A.

## IV. DETECTION AND CLASSIFICATION METHODS OF FOGGY DIGITAL IMAGES

Surveyed previous ID (Image Defogging) methods are developed into the picture irrespective of the presence or absence of haze. Then, for real-time uses, it is required to see climate, the image developed in the recent atmosphere requirements to be managed by de-fogging approach. The main idea is as described: Image Visibility of re-stored attained by the de-fogging approach may be worse than the real picture if no judgment is created. The custom of the de-fogging method is time-complexity, which isn't sufficient for original TD (Target Detection), recognition, and tracking. Present, twice approaches which can reviewer climate the recent view is foggy or not.

(i) A fog detection approach that relates the invisible view field of the image as the foggy field[16].

(ii) Classification method.

### *A. Foggy Areas Detected in DI (Digital Images)*

Normally, twice approaches can find the foggy fields of the digital image. The initial approach depends on the Semi-Inverse image, and the 2nd approach depends on the metero-logical visibility distance.

**(i) Semi-inverse digital image to detect foggy area**

The 1st developed a foggy field detection method that depends on the "SEMI-INVERSE (SI)' digital image [16]. In this method image, Ss is attained by choosing the maximum of the real image pixel data and its reverse image pixel data which is calculated as:

$$Ss^c\,(xx) = \max[i^c\,(xx), 1 - i^c\,(xx)], \qquad \text{(xiii)}$$

Where eq(xiii) c signifies one of the RGB color frequencies, i is the real picture, and $1 - i^c\,(xx)$ defines the reverse image of the real image.

After that, re-normalizing the reverse image, [17] it detected the haze areas in the H* channel of the LCH color-space, and related the image pixels which have a huge difference (D) between the SI image and real image as noise-free image pixels, and related the left pixels as foggy pixels. The haze region detection approach depends on the fact that the intensity-value is pixels in the FA (foggy area) of the image that is normally much higher than those image pixels in the noise-free field. In this sky/ foggy region of a digital image, pixels normally have a high intensity in every color channel (R, G, B) that is (xx) > 0.5.

**(ii) Meteorological visibility distance(mvd)**

The CIE (International Commission on Illumination) is defined as the MVD of an image and its consideration method. The MVD of an image is world widely practiced in the area of FID (Foggy image Detection) of the VVS (Vehicle Visual System) [18]. The day time foggy area detection approach via evaluating the MVD. 1st utilized the CDF (Canny Deriche Filter) to fetch the image regions to high-point the regions of road-ways. But, the area developing method was achieved to search the road-surface layer. 3rd, it developed 4 situations to attain the target region. At the last, the VD of the of the image was attained by evaluating the consider bandwidth. They [19,20] utilized a horizontal line (HL) to define the VD. For the VCS, the edge above the HL normally has low-contrast and can be related as the FA of an image via estimating the VD (Visibility Distance).

MVD is dividing into the foggy image into 2 areas:

(i) Visible Area and

(ii) Invisible Area

### *B. Classification of Foggy Images*

This algorithm requires developing an image Lib. which contains huge amounts of noise free images/ foggy images. It fetches some characteristics which have huge difference among the 2 kinds of images, and then utilizes an efficient classifier to train characteristics and achieve the classification HyperPlane. At the last, a QI (query image) can be classified as a foggy image/ noise free image. The process of FIC is defined in Figure 4.

In this method, the characteristic is the greatest importance and straight control Classification Accuracy (CA) rate. No characteristic accurately classify the FI and noise free image. They pointed [21] out that for IV (Image Visibility), the intensity of DC and IC (Image Contrast) can be used as the characteristic for the classification of FI and CI (Clear Images). The Support Vector Machine (SVM) to classify the FI (Foggy Image) [22]. While, their approach can achieve good classification performance analysis, it is hard to instantaneously achieve a real image and FI of the similar view in real-time applications. FIC (Foggy Image Classification) approach by utilizing the Global features (GFs), in terms if the Power Spectrum (PS) of the Fourier Transform (FT) and the Support Vector Machine for the VVS on highways [23].

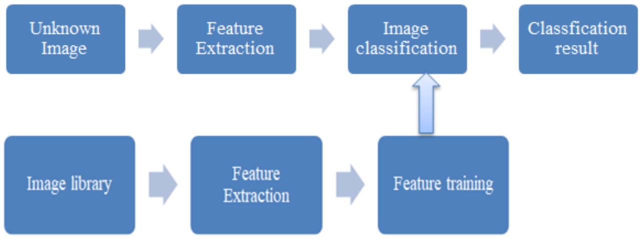


**Fig 4. Foggy image Classification**

## V. VARIOUS DEFOGGING METHODS

In this section, elaborates the various various defogging methods and Table 1 details the benefits and limitations of few typical images defogging methods.

**Table I. Some Various Image de-fogging methods**

| Methods | Benefits | Limitations | Uses |
|---|---|---|---|
| Fattal [24] | Clear visibility under im-homogeneous [thin fog]. | In-effective SNR | Single-color FI (Foggy Image) |
| Tan et al.,[25] | Better quality image contrast | Colour Noise | Gray-Foggy Image |
| He et al., [26,27] | Approx. natural clear image | Failure to recover the image with huge sky area | Outdoor image with foggy (thin) |
| Bayesian Defogging [28] | High-level visibility of an image | High cost | Single Color FI (Thin) |
| Intensity transforms | High image contrast | Edge interference Boost interference | Single color and gray image fog (same depth) |

### *A. Restoration Method (fattal et al., [24])*

The author defined a technique to approximation the transmission and AL depend on the supposition that surface shading and image transmission are nearby un-correlated. They represented a re-defined PHY MODEL via 2-decomposition phases. The author first de-composed un-defined noise free picture J to the produce of SAC (Surface-Albedo-Coefficient) R in 2-components.

(i) Similar to the AL ($A_\infty$) and extra RC (Resisual Component) R'.

(ii)ICA method and GMRFM (Gauss-Markov Random Field Model) were utilized to evaluate image transmission.

### *B. Automated Defogging Method [25]*

It is created with a single image, giving to twice simple comments:

(i) To perfect or improved image normally have high image contrast than FI and

(ii) Airlight modifies smoothly in small LA (local area)[26].

Firstly, utilized the White Balance (WB) process to alter the I/p picture in white color. But, the Markov Random Field (MRF) was utilized to structure the sunlight structure. This model is created in the air-light can be assessed via huge local image contrast of the re-stored picture. It can spontaneously improve the image perceptibility of FI and doesn't require any user interference.

### *C. Re-storation Improved algorithm [27]*

This method was used to resolve the existing issues, they proposed a new method depend on single-image, which has shown to be an efficient approach to recover outside images. The huge amount of noise-free outside images and searched that in most fields of a noise-free outside image there is a color channel of image pixels with the lowest-value of 0 is known as Dark Channel prior (DCP) Theory.

## VI. CONCLUSION

In this paper, a detailed overview of related, Dark Channel Prior, Depth-map Estimation, Image Improvement, and Image Restoration techniques had been described. While single-image de-fogging methods have achieved improvement in earlier years, several issues are faced which is required to be identified. The main problems are expressed as;

(i) Time Complexity
(ii) Noise Increases and
(iii) Lack of accuracy rate and image quality rate.
(iv) The difficulty level of approach is increased due to the overview of MCC (Multi-Channel Convolution) and GF (Guided Filter).
(v) Because the colours if the haze and the sky is same and it is complex to resolve haze effectively in the sky fields.

It describes the most successful de-fogging methods: the dark channel prioritized based image de-fogging method. It defined the major four phases of DCP method such as (i) AL estimation (ii) Transmission-map estimation (iii) Image re-finement and (iv) image re-storation. The DCP depends on the measurements of the outside pictures. Developing the prior into the foggy image model, Single-Image Fog removal becomes easier and more efficient. Various papers are analyzed by the researchers to the enhancement of images of roadside views and videos.

## REFERENCES

[1]. Parihar, A. S., Gupta, Y. K., Singodia, Y., Singh, V., & Singh, K,"A comparative study of image dehazing algorithms", In 2020 5th International Conference on Communication and Electronics Systems (ICCES) pp. 766-771, June, 2020.

[2]. Wang, W., Li, Z., Wu, S., & Zeng, L, "Hazy image decolorization with color contrast restoration" IEEE Transactions on Image Processing, pp. 1776-1787, 2019.

[3]. Kponou, E. A., Wang, Z., & Li, L., "A comprehensive study on fast image dehazing techniques". *International Journal of Computer Science and Mobile Computing*, *2*(9), 146-152, 2013.

[4]. Wang, Y. K., Fan, C. T., & Chang, C. W, "Accurate depth estimation for image defogging using Markov Random Field" In *International Conference on Graphic and Image Processing* Vol. 8768, p. 87681Q, 2013

[5]. .Zhang, W., Dong, L., Pan, X., Zhou, J., Qin, L., & Xu, W, “Single Image Defogging Based on Multi-Channel Convolutional MSRCR”, *IEEE Access*, vol. *7*, pp. 72492-72504, 2019.

[6]. K. He, J. Sun, and X. Tang, “Guided image filtering,” *IEEE Trans. Pattern Anal. Mach. Intell*., vol. 35, no. 6, pp. 1397-1409, Jun. 2013.

[7]. W. Ren, S. Liu, H. Zhang, J. Pan, and X. Gao, “Single Image Dehazing via Multi-scale Convolutional Neural Networks,” in *Proc. Eur. Conf. Comput. Vis.*, pp 154–169, 2016.

[8]. B. Cai, X. Xu, K. Jia, C. Qing, and D. Tao. “Dehazenet: An end-to-end system for single image haze removal”. *IEEE Trans. Image Process.*, vol. 25, no. 11, pp. 5187-5198, 2016.

[9]. Y. F. Wang, H. Y. Wang, C. Yin, and M. Dai, “Biologically inspired image enhancement based on Retinex,” *Neurocomputing*, vol. 177, no. 177, pp. 373-384, Feb. 2016.

[10]. Salazar-Colores, S., Ramos-Arreguín, J. M., Pedraza-Ortega, J. C.,& Rodríguez-Reséndiz, J,“Efficient single image dehazing by modifying the dark channel prior”, *EURASIP Journal on Image and Video Processing*, 2016.

[11]. Shao, S., Guo, Y., Zhang, Z., & Yuan, H. “Single Remote Sensing Multispectral Image Dehazing Based on a Learning Framework”, *Mathematical Problems in Engineering*, *2019*.

[12]. Liu, Z., He, Y., Wang, C., & Song, R., “Analysis of the influence of foggy weather environment on the detection effect of machine vision obstacles”, Sensors, vol. 2, pp. 349, 2020.

[13]. S. G. Narasimhan and S. K. Nayar, “Vision and the atmosphere,” International Journal of Computer Vision, vol. 48, no. 3, pp. 233– 254, 2002.

[14]. R. T. Tan, “Visibility in bad weather from a single image,” in Proceedings of the 26th IEEE Conference on Computer Vision and Pattern Recognition (CVPR ’08), pp. 1–8, Anchorage, Alaska, USA, June 2008.

[15]. K. He, J. Sun, and X. Tang, “Single image haze removal using dark channel prior,” IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 33, no. 12, pp. 2341–2353, 2011.

[16]. Xu, Y., Wen, J., Fei, L., & Zhang, Z. (2015). “Review of video and image defogging algorithms and related studies on image restoration and enhancement”, *Ieee Access*, *4*, 165-188.

[17]. C. O. Ancuti, C. Ancuti, C. Hermans, and P. Bekaert, "A fast semi-inverse approach to detect and remove the haze from a single image," Lecture Notes Comput. Sci. vol. 6493: Springer Berlin Heidelberg, pp. 501-514, 2011

[18]. CIE, "International Lighting Vocabulary," Central Bureau ofthe Commission Internationale de l'Eclairage, Kegelgasse, 1989.

[19]. N. Hautière, R. Labayrade, C. Boussard, J.-P. Tarel, and D. Aubert, "Perception through scattering media for autonomous vehicles," Autonomous Robots Research Advances. Nova Science Publishers, Inc, pp. 223-267, 2008.

[20]. N. Hautiére, J.-P. Tarel, J. Lavenant, and D. Aubert, "Automatic fog detection and estimation of visibility distance through use of an onboard camera," Mach. Vis. Appl., vol. 17, no. 1, pp. 8-20, Apr. 2006.

[21]. G. Li, J. Wu, and Z. Lei, "Research progress of image haze grade evaluation and dehazing technology," Lasernal, vol. 35, no. 9, pp. 1-6, Sept. 2014. [in Chinese].

[22]. Y. Zhang, G. Sun, Q. Ren, and D. Zhao, "Foggy Images Classification Based On Features Extraction and SVM," in Proc. Int. Conf. Software Eng. Comput. Sci., pp. 142-145, 2013.

[23]. M. Pavlic, H. Belzner, G. Rigoll, and S. Ilic, "Image based fog detection in vehicles," in Proc. IEEE Conf. Intelligent Vehicles Symp, pp. 1132-1137, 2012.

[24]. R. Fattal, ‘‘Single image dehazing,’’ ACM Trans. Graph., vol. 27, no. 3, pp. 72:1–72:10, Aug. 2008.

[25]. R. T. Tan, ‘‘Visibility in bad weather from a single image,’’ in Proc. IEEE Conf. Comput. Vis. Pattern Recognit., pp. 1–8, 2008.

[26]. K. He, J. Sun, and X. Tang, ‘‘Single image haze removal using dark channel prior,’’ IEEE Trans. Pattern Anal. Mach. Intell., vol. 33, no. 12, pp. 2341–2353, Dec. 2011.

[27]. K. He, J. Sun, and X. Tang, ‘‘Guided image filtering,’’ IEEE Trans. Pattern Anal. Mach. Intell., vol. 35, no. 6, pp. 1397–1409, Jun. 2013.

[28]. Zhang, L., Zhu, A., Shen, Y., Zhao, S., & Zhang, H, “ Revisit Retinex Theory: Towards a Lightness-Aware Restorer for Underexposed Images,”. Mathematical Problems In Engineering, pp. 1-11, 2020

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