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FPGA Implementation of Video Dehazing using Dark Channel Priori Algorithm

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Abstract: The images captured by the camera are dependent on the illumination and reflectance components. The quality of images is degraded by the atmospheric parameters such as poor illumination intensity, rain, haze and fog. The images affected by fog and haze generally lose edge and color information. The image restoration techniques such as dehazing help in retrieving the edge information, but at the cost of color information. The image enhancement such as image dehazing using a dark channel priori algorithm is performed on the image to improve the information content in the image. In this paper, we propose a method of FPGA implementation of video dehazing using a dark channel priori algorithm. The proposed architecture is implemented using VHDL in Cyclone III FPGA with an operating frequency of 108 Hz. The results of the dark channel priori method are verified with the MATLAB simulation results.

Keywords: Dark Channel Priori algorithm, dehazing, FPGA, Hardware Implementation, Image enhancement, image restoration.

I. INTRODUCTION

An image is formed due to the illumination of the light source and reflectance component from the object. Outdoor images are degraded by haze which is the water droplets and dust particles present in the atmosphere. The reflectance component from the scene varies due to the absorption and reflectance by these atmospheric particles. The image thus formed gets degraded and losses color and contrast information as shown in Figure 1. The original image is degraded by the haze which is not an additive in nature, and it is spatially varying. Hence, image restoration techniques such as dehazing needs to be performed on the degraded image to restore the original quality. This restortion demands, prior information about the scene.

Haze removal improves the scene visibility and corrects the color variations. Dehazing is a challenging task in which the depth of the haze should be estimated before it is being processed. The depth of the haze cannot be predicted accurately from a single hazy image [3]. The dehazed output from a single hazy image depends on the prior assumptions. The problem can be nullified by using Polarization method. In the polarization based method, the effect of haze can be eliminated with the help of two or more images taken with different degrees of polarization [1, 2, 8]. Tan et al. concluded from their experiments that, the contrast of the hazy free image is better compared to the hazy input image [4].

He proposed that the hazy free output image can be obtained by increasing the contrast of the hazy input image. In this paper, the haziness of the image is removed from the input hazy image by using the dark channel prior algorithm, which is dependent on the statistics of the hazy free outdoor images. The intensity of the dark pixel is around zero, but it varies due to atmospheric particles in a hazy image [7]. The effect of atmospheric light of each color is calculated from these dark pixels. The depth of the haze can be estimated by examining the dark pixel in the hazy image. The architecture of the dark channel priori method was explained in this paper for real time applications. Fattal et al. proposed a new method of dehazing based on the independent component analysis under the assumption of surface shading and transmission is uncorrelated. The method fails for heavy haze images [5].

The rest of the paper is organized as follows. Section II deals with the degradation model. Section III deals with the Dark Channel Priori Algorithm, and section IV deals with the FPGA implementation. Section V deals with Implementation Results followed by conclusions in Section VI.

Figure 1: Hazy input image

II. DEGRADATION MODEL

The mathematical model of a hazy image is shown in eq 1.

$$I(x,y) = J(x,y) * t(x,y) + A\big(1 - t(x,y)\big) \qquad (1)$$

where I(x, y) is the observed hazy output image, J(x, y) is the original haze free image, A is the global atmospheric light Parameter, and t(x, y) is the transmission coefficient that defines the portion of the light reaching the camera after a part of light scattered by the atmospheric particles.

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The transmission coefficient is shown in eq. 2 for the homogeneous medium.

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

The first term on the right hand side of the eq.(1) is called direct attenuation, which defines the decay of scene irradiance in the medium and it is multiplicative in nature [9]. The second term on the right hand side of the eq.(1) is called airlight parameter, which results due to scattering of light. The airlight parameter leads to the shift of scene colors and it is additive in nature [10]. β and d in the above eq.(2) are the scattering coefficient of atmosphere and scene depth respectively. In a clear weather conditions, scattering coefficients tends to zero and hence the output image will be a haze free image. As the value of coefficient of scattering increases, the t(x, y) decreases. Hence it has less impact on the scattering and more impact on the decay of scene irradiance. The major objective of dehazing is to recover J from I [11].

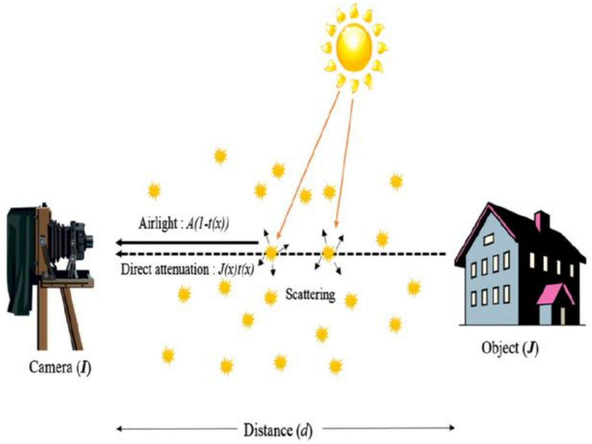


Figure 2: Formation of a Hazy image [6]

III. DARK CHANNEL PRIOR ALGORITHM

The dark pixels whose intensity value approaches zero within a patch for the individual channel are calculated as shown in eq.(3). J^c is the luminous intensity of the three color channels within the patch. The minimum value of the patch is considered almost equal to zero. But the dark channel values in the hazy image have the values far above zero.

$$J^{Dark}(x) = \min_{y\,\epsilon\Omega(x)}\left(\min_{c\epsilon\{r,g,b\}} J^c(y)\right) \qquad (3)$$

The hazy image shown in eq.(1) is normalized with respect to the airlight parameter. The result of the normalized hazy image is shown in eq.(4). The dark channel values from the eq.(4) can be calculated as shown in eq.(5).

$$\frac{I(x)}{A} = t(x)\frac{J(x)}{A} + (1 - t(x)) \qquad (4)$$

$$\min_{y\,\epsilon\Omega(x)}\left(\min_{c}\left(\frac{I(y)}{A}\right)\right) = t(x)\min_{y\,\epsilon\Omega(x)}\left(\min_{c}\left(\frac{J(y)}{A}\right)\right) + (1 - t(x)) \qquad (5)$$

The value of the atmospheric light parameter needs to be estimated in advance to obtain the transmission map. The dehazed image can be obtained once the transmission map is estimated using the eq.(6). The transmission map coefficient of the patch is obtained using the maximum value of the lower bound of the transmission map and the value of the transmission map in the patch.

$$J(x) = \frac{I(x) - A}{\max(t(x), t_0)} + A \qquad (6)$$

IV. FPGA Implementation

The hardware architecture of the FPGA implementation of video dehazing using DCP algorithm is shown in Figure 3.

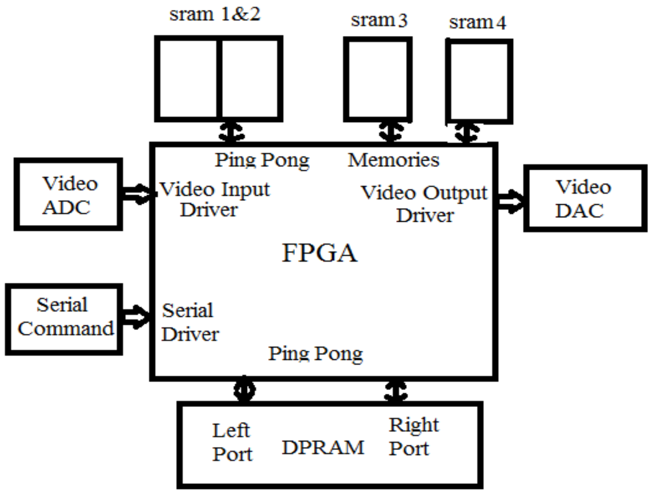


Figure 3: Hardware architecture of the DCP algorithm

The input video taken is a sequence of 15 frames per second. The input data from the camera was digitized using the ADC. The processed output from the FPGA was displayed on the screen using DAC. The ADC is configured for 15 frames per second. The outputs of ADC were stored in a SRAM 1 and SRAM2. The outputs of SRAM3 and SRAM 4 were sent to the DAC. The size of the each SRAM is 512 KB in the design to incorporate an image of size 720 X 576 X 3. The input video was stored in Static Ram 1 and 2 in a ping pong fashion. The odd frames were stored in SRAM 1 and the even frames were stored in SRAM 2. While the data was being stored in even SRAM, the image data in the odd SRAM was dehazed and vice versa.

The Dual Port RAM (DPRAM) provided on the bottom of the figure 3 is used for storing the intermediate outputs in a ping pong fashion. The SRAM 3 and SRAM 4 are used for storing the processed output in a ping pong fashion. The size of the DPRAM is 2MB in the design. The serial command is used for providing the serial commands to the FPGA such as frame rate, the initial value of the airlight parameter and scattering coefficient. The calculated airlight parameter can be overwritten with the manual airlight parameter through the serial commands. The user has the flexibility to change the quality of the dehazed output image with the help of serial commands.

The flowchart for the video dehazing is shown in figure 4. The video input from the camera was stored in SRAM1 and SRAM2 in a ping pong style. The patch size is chosen as 15 X 15 pixels for this implementation.

The minimum of the RGB channel was obtained and stored as a dark pixel for reference by using three separate comparators for each channel.

The value of the atmospheric light was estimated from the top 15% of the brightest pixels in the dark channel.

The images were normalized with the atmospheric light values. The transmission map values were calculated based on the dark value of the patch and atmospheric light parameters. The transmission map values were processed by the fast guided filter. The hazy image was dehazed based on the transmission map and was stored in the output SRAM. The output image contains the edge details and preserves the overall characteristics of the input image.

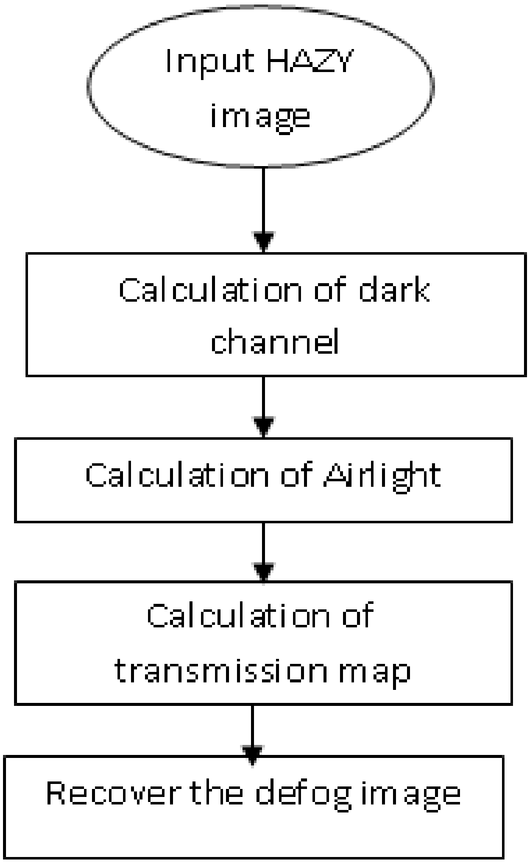


Figure 4: Flowchart of the DCP algorithm for image dehazing

V. IMPLEMENTATION RESULTS

The input color image has resolution of 720 X 576 X 3. The Figure 5 (a) and 6 (a) show the hazy input images and the Figure 5 (b) and 6 (b) show the hazy free output images. The proposed design on the cyclone III FPGA operates at a frequency of 108 MHz. The delay for each frame is around 39.155 msec. The obtained results are compared with the MATLAB. MATLAB requires 4 sec to process a single image of specified resolution on the PC. The compilation report for the proposed algorithm on the EP3C120F780I7 FPGA board is shown in Table 1. In addition to these resources, the algorithm requires the 4 external SRAM, One DPRAM, ADC, DAC and RS 232 for the serial command interface.

Table . I : Compilation report

S.No	Resources	Utilization
1	Number of slices	30,045 / 119,088 (25 %)
2	Block RAM	590,003 / 3,981,312 (15%)
3	DSP Blocks	70 / 576 (12 %)
4	Number of flip flops	15,075 / 119,088 (13 %)
5	Frequency	108 MHz

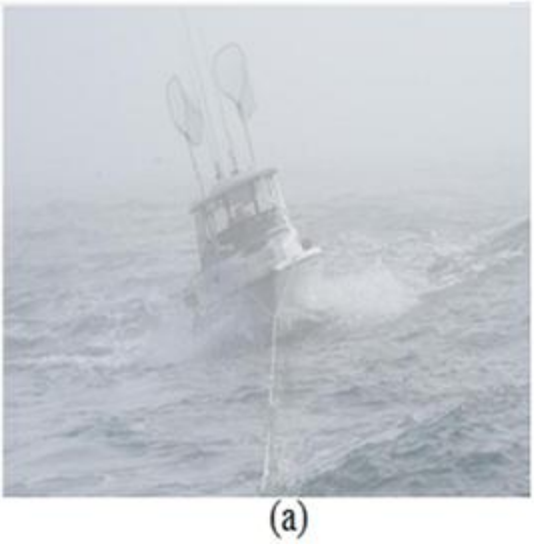


Figure 5: (a) Hazy image

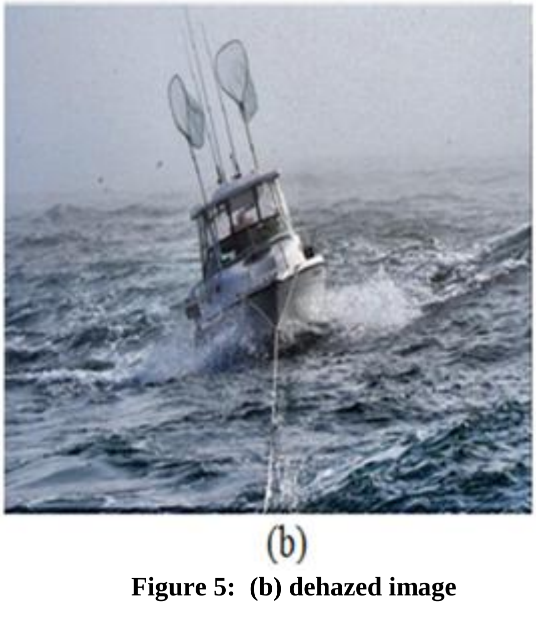
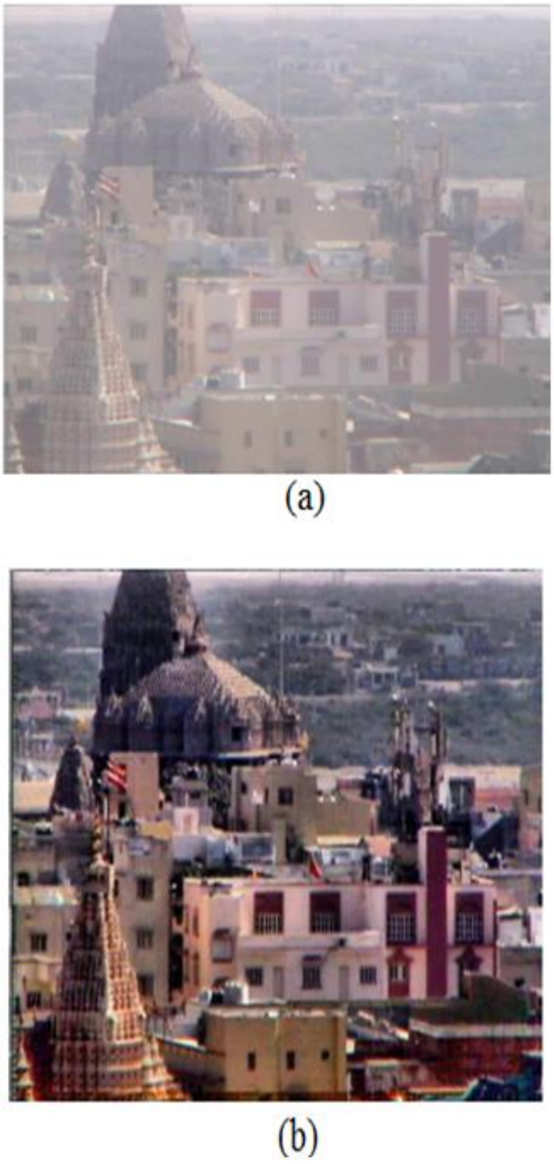


Figure 5: (b) dehazed image


(a)

(b)

Figure 6: (a) Hazy image (b) dehazed image

VI . CONCLUSIONS

Dehazing the image and video using the dark channel priori method has been implemented on the cyclone III FPGA. Though the algorithm has significant computational complexity, the architecture is designed in such a way that it reduces the memory requirements and computational complexity. The algorithm is applied on a real time video with a frame rate of 15 frames per second. The proposed design operates at a frequency of 108MHz. The proposed architecture has been implemented on a real time hardware which makes the system reliable in outdoor visual system for dehazing. it has a wide practical value.

REFERENCES

1. Y.Y. Schechner, S.G. Narasimhan, and S.K. Nayar, "Instant Dehazing of Images Using Polarization," Proc. IEEE Conf. Computer Vision and Pattern Recognition, vol. 1, pp. 325-332, 2001.
2. S.G. Narasimhan and S.K. Nayar, "Contrast Restoration of Weather Degraded Images," IEEE Trans. Pattern Analysis and Machine Intelligence, vol. 25, no. 6 pp. 713-724, June 2003.
3. R. Fattal, "Single Image Dehazing," Proc. ACM SIGGRAPH, Vol 08, pages 1– 9, 2008.
4. R. Tan, "Visibility in Bad Weather from a Single Image," Proc. IEEE Conf. Computer Vision and Pattern Recognition, June 2008.
5. J. P. Oakley and B. L. Satherley, "Improving image quality in poor visibility conditions using a physical model for contrast degradation," IEEE Transaction on Image Processing. Vol 7, pages: 167–179, 1998.
6. S. Lee, S. Yun, J. Nam, C.Won and S. Jung.,"A Review on dark channel prior based image dehazing algorithms". In EURASIP Journal on image and video Processing,2016.
7. K. He, J. Sun and X. Tang, "Guided Image Filtering", IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 35, Issue 6, 2013, pp. 1397-1409.
8. YY Schechnner, SG Narasimhan, SK Nayar, "Polarization-based vision through haze", Appl. Optics, Vol 42, No. 3, pages: 511–525, 2003.
9. LU, J., AND JR., D. M. H. "Contrast enhancement via multiscale gradient transformation", IEEE International Conference on Image Processing, Pages: 482–486, 1994.
10. Hyvrinen, A., AND OJA, E.,"Independent component analysis: Algorithms and applications",Neural Networks,Volume 13, Pages: 411– 430, 2000.
11. Oakley, J. P., AND BU, H., "Correction of simple contrast loss in color images", IEEE Transactions on Image Processing,Vol 16, Pages: 511–522, 2007.

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