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Enhancement of Night Time Video using Dark Channel Prior IP Accelerator

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Abstract—The enhancement of night-time video using Dark Channel Prior IP accelerator is proposed in this paper. Night time video processing is difficult due to low brightness, low contrast and high noise in the video. The above problems affect the accuracy and may results in failures of object detection in night time video. Dark Channel Prior (DCP) filter is used to improve the visibility, brightness and contrast of the video at night time. Processing speed is challenging task on real time application of DCP algorithm for night time video enhancement. Hence, DCP algorithm is implemented on FPGA (ALVEO Board) to increase the speed of video processing.

Keywords: Image enhancement, DCP, FPGA, Vitis Xilinx software

I. INTRODUCTION

Object detection in real time video is one of the prevalent applications in the field of video processing. The video captured at nighttime has a low illumination and usually suffer from a poor visibility.The variety of algorithms for object detections is available and provides good results on still images. The algorithms are required to be accelerated for object detections in real time video. DCP is one of the fastest algorithms used for hardware acceleration due to its simplicity. DCP algorithm can be implemented on hardware using general purpose microprocessor, or graphics processing unit (GPU) or on FPGA. FPGAs offer many advantages over traditional CPU/GPU acceleration, including a custom architecture capable of implementing any function that can run on a processor, resulting in better performance at lower power dissipation [1]. In this paper ALVEO board and Vitis Xilinx unified software are used for implementation. The Vitis unified software platform is a new tool that combines all aspects of Xilinx software development into one unified environment. Vitis unified software supports embedded software development flow, for XilinxSoftware Development Kit (SDK). If users are looking to move into the next generation technology then Vitis application acceleration development flow is the latest in Xilinx FPGA-based software acceleration. Here, an application acceleration flow, and use of the Vitis core development kit and Xilinx Runtime is provided [2]. The new tool provides framework as caffe tensor flow for developing an application on FPGA. In Vitis software the application program is split into host and kernel. The both software and hardware can be used as high-level programming using C++ for hardware acceleration. The high-level programming uses libraries that make the development easier. In this paper C++ language is used to develop the application program for both host and kernel. The following Fig.1 shows the architecture of Vitis unified software.

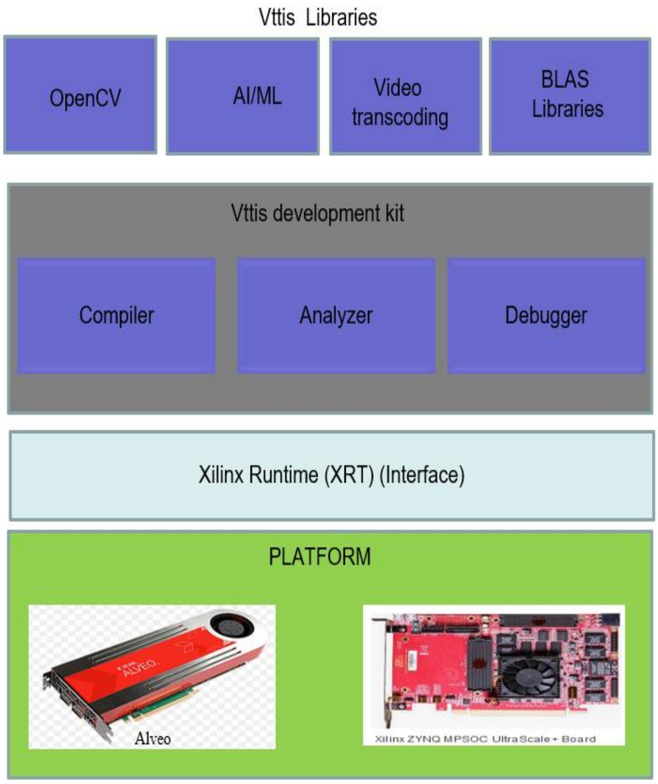

Fig. 1.Architecture of vitis unified software

The paper is organized as follow: Section II describe the related work. Section III discusses the algorithm used for enhancement of night time video, and the implementation of DCP based algorithm on FPGA. The result is discusses in section IV.Conclusion is drawn in Section V.

II. RELATED WORK

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Enhancement of dark input video improves the quality of the night time video and, a few years ago, a variety of different algorithms were used to enhance night time video [3], [4], [5], [6], [7], [8], [9] [10], [11], [12], [13], [14]. Infrared is one of the techniques used to improve the quality of dark input images or video. Infrared is a non-contact device that detects infrared energy and converts it into electronics signal and infrared systems capture only the objects with higher temperature than their surroundings [3]. While infrared cameras are expensive compare to the normal cameras. This disadvantage limits the scope of their applications and future development. We can also use the traditional image processing techniques to improve the quality of night input images or video. Histogram equalization and gamma correction are mostly used for traditional image processing, Ko et. al proposed methods for removal of noise motion adaptive temporal filtering based on the Kalman structured updating. By adaptive adjustment of RGB histograms causes the increment in Dynamic range of denoised video. Ultimately, remaining unwanted factor which is noise can be removed using Non-local means (NLM) denoising. In this method exploits color filter array (CFA) raw data for obtaining low memory consumption. The final experimental results indicate that, this method is highly promising for various real time applications to consumer digital cameras, especially CCTV and the surveillance video system [4]. Although they reported pleasing results for low lighting images and videos, they still inevitably introduce undesirable halo effects and excessive enhancement phenomenon [5]. Bhagya et al. proposed video enhancement using histogram equalization with JND model and this technique, besides being used to achieve visually pleasant enhancement effects, the over-enhancement and saturation artifacts are avoided in this method [6]. However, this method is complex, and it requires a large size of hardware. R.Peng et al. proposed a contrast stretching method which improves the quality of image by stretching the intensity range, while it stretches the lower intensity pixels to lower and higher intensity pixel to higher. As each value in input image can have several values in output image, so objects in original image may misplace their relative brightness values [7]. Choi et al. proposed single scale retinex which is one of the new emerging techniques in the enhancement field. The advantage of this method is the speed of execution. But there is also a limitation with Single retinex, as it deals with dynamic range enhancement and color interpretation, but fails in achieving both together [8]. Rahman et al. proposed multiple scale retinex to solve this problem of Single scale retinex but this method fails to produce good quality of enhancement of input videos or images, it finds input videos or images having high spectral characteristic in the single band [9]. Xuesong Jiang et al. proposed enhancement of dark input video based on DCP algorithm. This method is simple and improves the quality of night time video or images, but it's quite slower for real-time video processing of ultra-high definition video [10]. Due to the low speed of video processing on CPU, our proposed method is to develop an accelerator for DCP algorithm, to accelerate the video processing of night time, and obtain a continuous time video processing

III. PROPOSED METHOD

This paper aims to improve contrast and brightness of night time input video. An objective is to develop an accelerator for DCP algorithm on Alveo using Vitis Xilinx tool, to accelerate the speed of video processing. The Vitis tool uses languages like C++, RTL, OpenCL, C for kernel function development. In this paper C++ language is used for development of host and kernel function. The language C++ provides libraries in hardware implementation that makes the development easier. The following Fig.2 shows the flow of proposed methods.

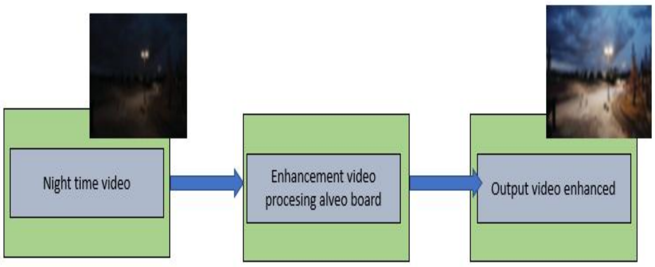

Fig. 2. Flow of proposed method

A. DCP based algorithm

In this part we are going to discuss the algorithm of DCP (Dark Channel Prior) for night time frames enhancement. Xuang et al. observed that a pixel-wise inversion of a night video is quite similar to a video captured on foggy days [10]. The night input frames are inverted into foggy days frames by inversion the pixelwise of the night time frame. of pixel-wise [Xuang]. I(x) is the input of night frame which is RGB, and $I_{inv}(x)$ is the inverse frame of the night input frame. $I_{inv}(x)$ which is also RGB. McCarteney defined the equation bellow:

$$I_{inv}(x) = J_{inv}(x) + A(1 - t(x) \quad (1)$$

Where,

$J_{inv}(x)$: Schene radiance (recovere image) at x,

A:Global atmospheric light,

t(x): medium transmission at x,

x: coordinate of the image x = (i,j)

Here the Jinv and t are unknown so we are going to find the expression of Jinv and t to recover the night input image using the haze removal algorithm based DCP .

Using the equation (1), we can express the $J_{inv}(x)$:

$$J_{inv}(x) = \frac{I_{inv}(x) - A(1-t(x)}{t(x)} \quad (2)$$

With:

$$t(x) = 1 - \omega I^{c}{}_{dark}(x) \quad (3)$$

$$I^{c}{}_{dark}(x) = min_{c\in\{r,g,b\}} \left(\frac{I^{c}{}_{inv}(x)}{A^{c}}\right) \quad (4)$$

Where:

ω: control parameter

$I^{c}{}_{dark}$: indicates a dark channel map (DCM) of inverted frames. DCM for each color channel is derived from the equation number (3), A^c for color, channel c is defined as the average of the lightest pixels per frame for the first 5 frames. Generally, all of the pixels in an object should have the same depth.

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However, some pixel in an object may have different DCM values. If we use the equation (3) and (4) directly, some detail can disappear. To solve this problem, we use the equation (5) [10]

$$I^c{}_{dark}(x) = \mu I^c{}_{dark}(x) \quad if\ \mu I^c{}_{dark}(x) < I^c{}_{dark}(x)$$
$$I^c{}_{dark}(x) = I_{smooth}(x) \quad \text{others} \qquad (5)$$

Where

$I_{smooth}(x)$: smoothed result of $I_{dark}(x)$ by median filter of $J_{inv}(x)$

μ: Constant parameter that controls the strength of constraints

Using the equations (3), (4), (5) in (2), we can get the result of $J_{inv}(x)$. Finally inversing $J_{inv}(x)$,to get the enhancement of dark input frames [10] [11].

B. Design flow of night time enhancement based DCP algorithm

The following Fig. 3 shows the design flow of night time frames enhancement using DCP based algorithm.

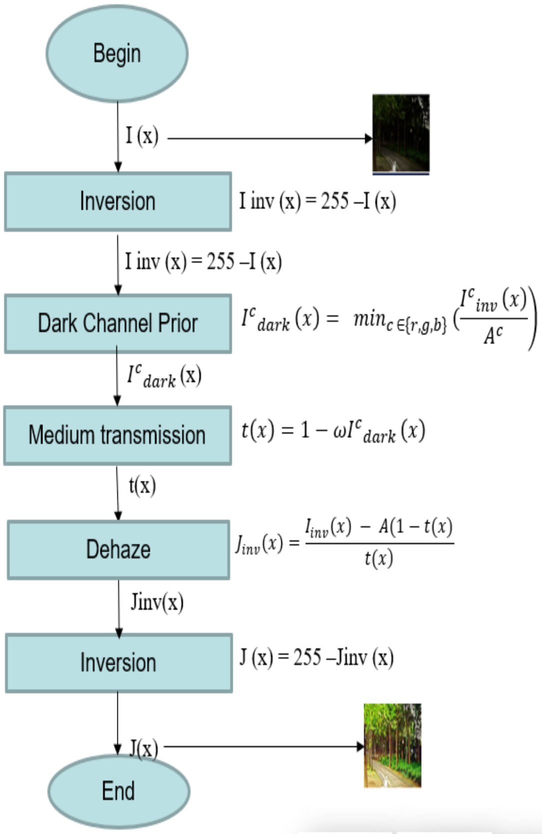

Fig .3 Design flow of night frames enhancement using DCP based algorithm

C. Implementation of DCP on FPGA

In Vitis software, the application program is split into host code and kernel function. The host and kernel are interconnected by the (Peripheral Component Interconnect Express) PCIe. Following Fig.4 shows the global architecture of Host/Kernel

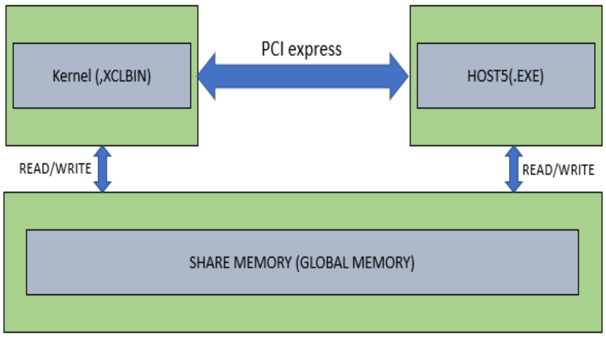

Fig .4 Global architecture of Host/Kernel

The host can read/write the data from kernel through a global memory or shared memory and vice versa for kernel. The architecture of our proposed methods is given below in Fig.5.

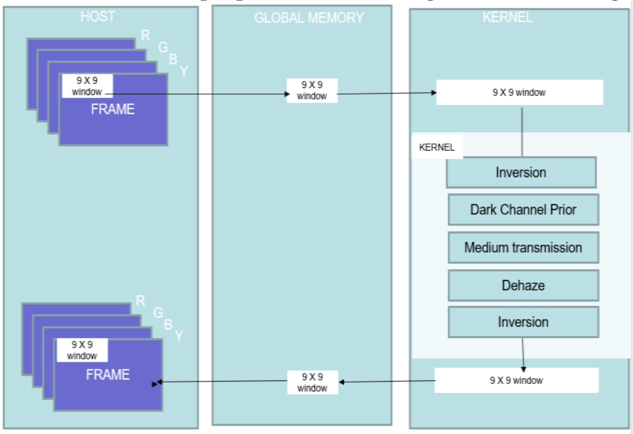

Fig .5 Design flow of DCP based algorithm implemented on Alveo

D. Performance parameter

The qualities of the images or frames from video are depending on the parameter bellow

- **Mean square error (MSE)**:

MSE measures the average of the square errors, if x(i,j) is the source images with M and N are the number of rows and columns of the source images,

And Y, the reconstructed by decoding the encoded version of x(i,j)

The mean square error is defined by the equation (6) bellow:

$$MSE = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}[x(i,j) - y(i,j)]^2}{M \times N} \qquad (6)$$

The RMSE (Root Mean Square Error): is defined as square root of MSE , the equation (7) bellow show the RMSE formula.

$$RMSE = \sqrt{\frac{1}{NM}\sum_{i=1}^{M}\sum_{j=1}^{N}[Yij - \hat{y}ij]^2} \qquad (7)$$

- **Peak Signal to Noise Ratio (PSNR)**

PSNR represent the measure of peak error, when we have a higher value of PSNR the error will be reduced. The equation (8) show the PSNR expression.

$$PSNR = 10\ log_{10}\left[\frac{255}{MSE}\right]^2 \qquad (8)$$

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IV. RESULT

The results of night time video enhanced using DCP filter are shown in Fig.6 and Table 1.

It shows thatcontrast and visibility of the input frames are improved. Our proposed methods, enhanced the quality of night time video and increased the speed of video processing, using hardware alveo U200 Xilinx platform for the implementation. Our proposed methods are faster than DCP implemented on CPU, the average running speed of our methods is 82 faster compare to the enhancement of night time video using CPU (Intel core i7 Dell precision T1700, 3.0GHZ with 16Go RAM). The implemented DCP algorithm on software can achieve the real time speed with 38 frames per second which is far away from our proposed method.Our proposed methods can be run continuosly on ultra high definition video.

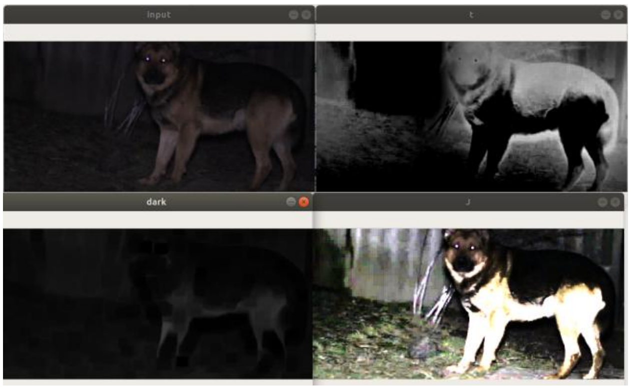

Fig .6 a) Input frame [11] b) medium transmission c) Dark channel of input frame d) output frame

Table 1. Performance parameter

Input frames [1242(W),375 (H)]	PSNR	SNR	Processing time Frames /s
Alveo-u200	48.80	11.256	3116

Fig .7 Alveo Board interconnected with Host

V. CONCLUSION

The implemented DCP based algorithm on Alveo board increased the speed of processing of night time video enhancement. The experiment result showed that our proposed method can achieve real time video processing with fast video processing compare to DCP algorithm implemented on software. The future work is to increase the Compute Unit of kernel (FPGA) to enhance the speed of processing.

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