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Hardware Architecture for Stitching Images with Haze Removal Function

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***Abstract*:** *Clear and wide-angle images are essential to detect and trace objects for applications such as CCTV and unmanned vehicles. Fog, haze, and rain causes problem in getting clear image and lowers the detection rate of objects. To remove haze, we use median dark channel prior which can reduce the complexity of hardware. Image stitching stitches a number of images from multiple cameras into single wide-angle image like a panorama view. It is more efficient for surveillance to use single wide-angle image than multiple images. Stitched image is generated by several steps, feature point extraction, matching, and brightness correction. For real-time application, software implementation is not feasible due to its large complexity and long computation. Therefore, we exploit parallel processing architecture of hardware to implement haze removal and stitching. FPGA implementation shows that the performance is 30fps at 1280x720 resolution which is suitable for real-time applications.*

Keywords: *image stitching, haze removal, real-time image hardware, dark channel prior*

1. Introduction

Recently, image processing and computer vision is widely used for medical appliance, security, augmented reality, vehicle, and satellite image. Especially, due to growing up concerns about security, security system is required to become smart, fast, and accurate. Conventional security system such as CCTV(closed circuit television) simply stores image to recording media. One can find clue after something happens if he does not inspect monitors all the time. On the contrary, recently-developed smart CCTV can detect the movement of object, trace the object, and alarms if something unexpected happen.

Smart CCTV obtains image from cameras and then process the image. The performance of the CCTV largely depends on the quality of image from cameras. Especially when there is fog, haze, rain or sandy dust, the quality of image degrades so that the smart CCTV cannot operate normally. To get the clear image, large amount of studies have been done to improve the image quality. Fig. 1 illustrates (a) image with haze and (b) image after haze removal.

Image stitching stiches a number of images from multiple cameras into single wide-angle image like a panorama view. If the overlapped area of two images is more than 30%, the two images can be stitched. Image stitching can be applied to CCTV so that wider range of area can be inspected on single scene. Fig 2 illustrates the example of image stitching.

In this paper, we proposes hardware architecture to improve the quality of images sent from couple of cameras and then stitches the images into single image.

(a) Image with haze (b) Image after haze removal

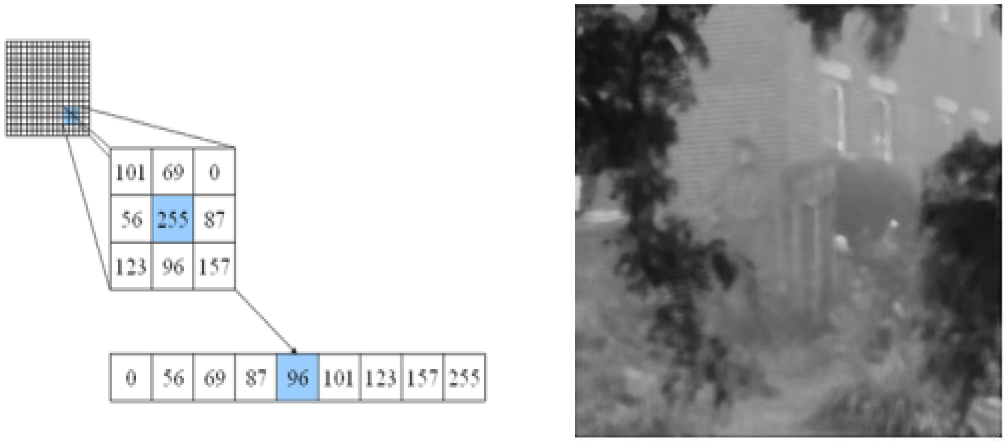
Fig. 1: Example images of haze removal

Fig. 2: Example images of image stitching

2. Haze Removal

The methods of improving the quality of image are divided into two categories, local and global methods. Global algorithm takes similar effect on all the pixels of image. Histogram equalization[1], for example, uses global processing method which distribute the brightness of image evenly. Retinex[2] algorithm and Dark channel prior[3]-[5] based on local processing method divide images into several blocks and process each block sequentially. Global processing method has the advantage that it is typically faster than local method, but the quality of result is limited. Local processing method can make good quality of image, but accompanies heavy computation and requires the reduction of blocking artifacts. In this paper, we use median dark channel prior as a local processing method to enhance the quality of image in real-time.

Dark channel assumes that one of RGB values of single pixel in certain block is almost zero if there is no sky in the image. Dark channel is set of pixel which has least value in certain block. Similarly, median dark channel is defined as the set of pixel which has middle value in certain block. Fig. 3 (a) show the detection of middle value in the certain block and Fig. 3 (b) show the example of median dark channel



(a) Extraction of median dark channel (b) Example of median dark channel extracted

Fig. 3: Median value extraction and example

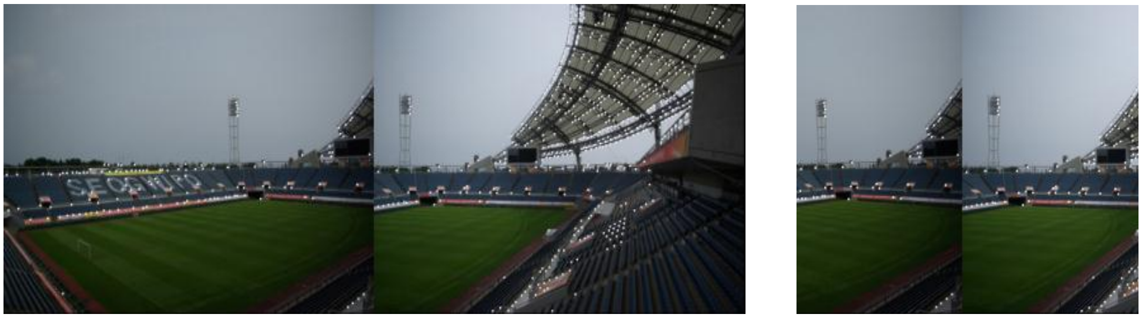
To extract the air light, we find the maximum value among R, G, and B for a pixel. Then each maximum values for a pixel are compared to decide the highest value. After estimating air light, the transmission map can be calculated. Fig 4 shows the example of transmission map. Using the transmission map, image without for can be obtained.

(a) Original image (b) Transmission map

Fig. 4: Transmission map example

3. Image Stitching

To stitch images, the first step is find feature points. Many algorithms[6] are proposed for detecting feature points but we select SIFT (scale-invariant feature transform) algorithm[7] because it is conveniently applied to hardware with its parallel processing architecture. After finding feature points, the same corresponding feature points are extracted from the overlapped part of two images. Fig. 4 (a) illustrates two images and (b) the overlapped area.

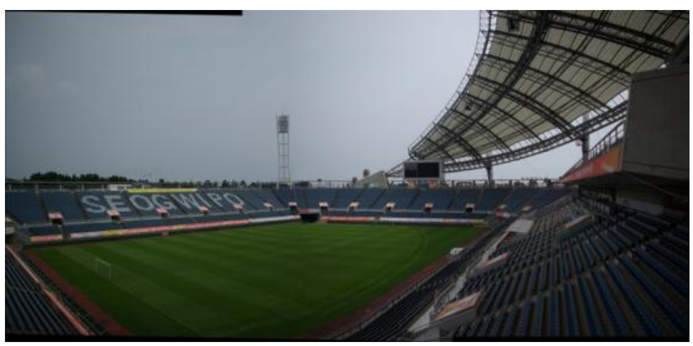


(a) Two images from two cameras (b) Overlapped part

Fig. 5: Feature points detected from overlapped part

The two images can be merged using four corresponding feature points which lead to 8 linear functions and 8 parameters. Fig. 6 (a) shows the merged images. However, there may be the difference in brightness between two images. Therefore, brightness correction[8] should be done by calculating the weight of brightness. Fig. 6 (b) shows the final stitched image.

(a) Merged image



(b) Stitched image after brightness correction

Fig. 6: Image merging and brightness correction

4. Implementation

The haze removal algorithm and image stitching algorithm are programmed in MATLAB and OpenCV to validate feasibility. During simulation with software, we could determine the suitable parameters in regard to performance, complexity, and speed.

Fig. 7 shows the block diagram of our implementation. Two images from CCTV are sent to the haze removal block and the resultant dehazed images are sent to the image stitching block to obtain single wide-angle image. We used Verilog HDL to implement on FPGA board.

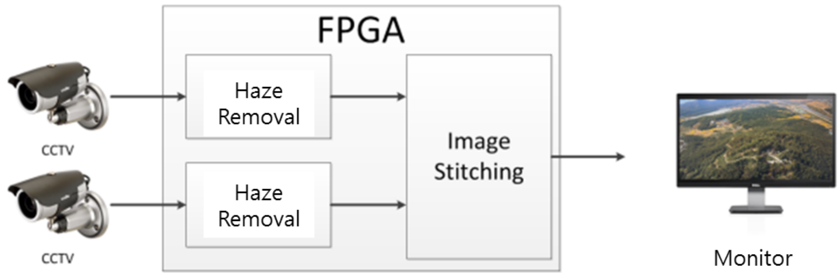


Fig. 7: Block diagram

5. Conclusion

In this paper, we implemented the haze removal and image stitching hardware. We exploit parallel processing of hardware to meet real-time requirements. FPGA implementation shows that the performance is 30fps at UHD resolution. The design can be applied to unmanned vehicle, medical appliances, and other computer vision devices.

6. Acknowledgement

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