A New Image Stitching Approach for Resolution Enhancement in Camera Arrays

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***Abstract*— The major developments in digital imaging are provided thanks to the development of a digital image sensor. Camera arrays are one of the studies in this area. The camera array is formed by combining a many image sensors having the same characteristics. High resolution and high speed imaging systems can be obtained by using camera arrays. In this paper, a new feature extraction based image stitching algorithm is presented to the camera arrays. One of the advantages of the proposed algorithm, the new high resolution single image is formed by using low resolution image sensors. In the study, camera arrays are formed in 2x4 size by utilizing a different number of image sensors having the same features. The images obtained from the camera arrays is combined with a new image stitching algorithm based on the feature extraction and matching. The performance of the proposed method was tested in real time and validated with experimental results. The results of the algorithm show that the proposed approach gives faster results than a well-known image stitching algorithm.**

Keywords—feature extraction; camera arrays; image stitching, resolution enhancement.

I. INTRODUCTION

The concept of digital imaging has made significant advances since the first day it turned out. In particular, the day to day development of CCD and CMOS image sensors is the most important reason for the progress of digital photography. The three most basic elements in digital imaging are (1) lens (2) digital image sensor and (3) microcontroller, respectively. A block diagram representing the digital imaging concept is shown in Fig. 1. The high quality of these three factors directly affects the quality of digital images to be obtained. However, choosing high quality of these factors greatly increases the price of the camera.

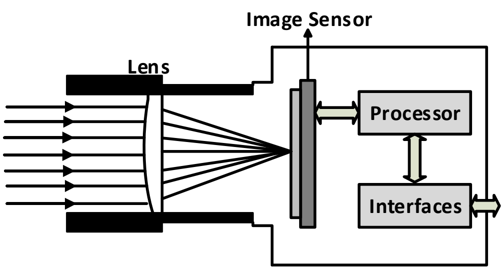


Fig. 1. Basic camera components

To support certain resolutions of the digital image sensor, end users working in this field are exposed to some restrictions. One of the technologies used to overcome these limitations is camera array. Basically camera arrays constitute high-resolution and high-speed imaging systems. Camera arrays are a system generated using a lot of the image sensors and lenses with the same characteristics. In other words, the camera arrays are large-scale virtual camera which is formed by combining the camera with low features. A block diagram illustrating the basic camera arrays is given in Fig. 2.

High speed imaging systems are frequently used in many industrial fields such as packaging, automotive and barcode reading. However, the high cost of these systems is the main drawback. These disadvantages with camera arrays are eliminated and new less costly systems can be created [1]. Because the most important benefits that have been provided by the camera array, a single system of high quality and high resolution can be obtained by utilizing low-resolution and low-cost image sensors [2-4]. There are a wide variety of image processing algorithms in the literature and users can perform a variety of these image processing algorithms on high-speed videos and high-resolution images [2-6]. One of these algorithms is image stitching algorithms [7]. Image stitching systems are basically formed by a microcontroller and software power. Generally, the microcontrollers connected to each camera transmit to the processor unit the image received as input. The images from different microcontrollers are combined to form a single image in the main processing unit. One of the studies in this field is a virtual reality project, and it is the basis for a multi - camera system [8]. A total of 51 cameras used in this study and the cameras was placed on the dome. Thus, it is intended to capture all the details of the scenario.

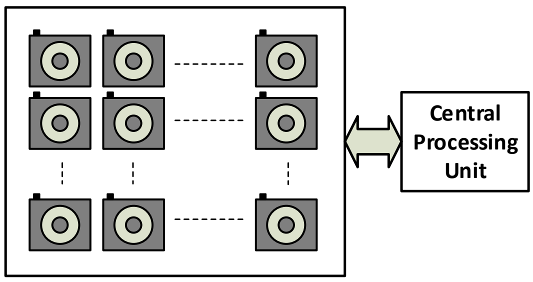


Fig. 2. Basic camera arrays

High-performance imaging system is obtained by using camera arrays [9]. The 100 video cameras are used in experimental studies for this paper imaging procedures have been performed. This study is provided to transfer the images using a MPEG-2 compression technique. A block diagram illustrating the architecture used in this paper is given in Fig. 3. Zhang and Chen [10], achieves a self-reconfigurable camera array. In the study, 48 cameras mounted on a mobile platform and estimating the depth values of the images is provided in 4-10 fps. The cameras which can move sideways are provided by using servo motors in this system. The synchronization of the camera arrays has contributed in another paper. In this study, a fully automated approach is presented for geometric, photometric and transient calibration of camera arrays [11]. Natural video matting was carried out in a study conducted using camera arrays [12]. The system computes mattes with camera arrays by creating synthetic aperture image. The figure in the foreground is separated from the background by performing various operations on the image. Network camera array is realized for a video-based rendering in another study [13]. The total of 64 cameras used in this paper and the cameras are connected to a single PC via gigabit Ethernet. Vaish et al. [14], the parallax based calibration technique examines in dense camera arrays. The students standing behind the bushes are tried to be determined with artificial synthetic aperture photography. Full metric and parallax-based calibration is compared in the experimental studies. The parallax-based calibration process has been observed that better results. Wilburn et al. [15], the high speed video is obtained by using the camera arrays. An array of 52 cameras is created for taking high speed video. The cameras are placed closely together approximate a single center of projection. 1560 fps video is provided by utilizing 52 cameras with 30 fps in this paper. The light field video camera is conducted in another study [16]. The camera arrays are utilized for video based rendering applications. The advantages of the proposed method are verified by using six cameras.

This paper presents the image stitching approach for camera arrays. The image stitching process that is a difficult problem in the camera arrays was carried out quickly and accurately with this paper. The 2x4 size of camera arrays was created to test the accuracy of the algorithm. The image frames taken from different cameras for the same scenario is provided as input to the designed algorithm. First, the random coordinates have been selected in these images. The pixel values of these coordinates have been tried to find in the second image.

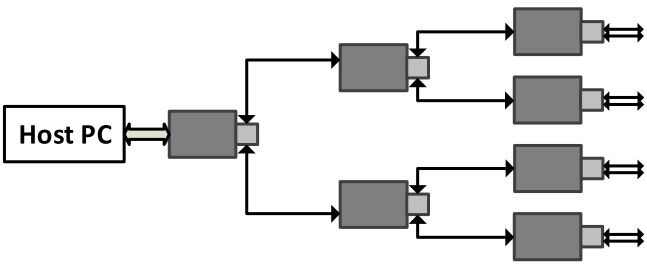


Fig. 3. Camera array architecture [2]

This process is repeated for the specified number of iterations, and the optimal match point is determined for two images. The same procedure was carried out in the other cameras and finally, the combined dual images were matched with each other. The feature extraction based image stitching algorithm that quickly and accurately processing was carried out in this study. The most important problems in the application about the camera arrays, the image frame is combined quickly. This problem has been addressed by this study and demonstrated a rapid and accurate system. In addition, studies are modeled in the MATLAB / Simulink environment and have proven the correctness of the system.

The organization of the paper is as follows. Section 2 explains the details of the image stitching approach for camera arrays. Section 3 provides experimental results of the proposed system. Conclusions are given in Section 4.

II. Proposed Approach

An image stitching process in camera arrays is a difficult problem to be overcome. In particular, high-speed video frame merges process is a process quite compelling. The reasons for this difficulty, there are multiple cameras with the same characteristics in the camera arrays and should be available to the common point of the images taken from these cameras [17, 18]. In this study, an image stitching algorithm is presented for the camera arrays. First, 2x4 size camera arrays were created in this process. The characteristics of the camera used to create the camera array are same and features of these cameras are given in Table 1.

The stitching process of images taken from different cameras is performed by using the proposed approach in the study. Basically, the feature extraction and matching, homography estimation and blending process between the two images are realized for this purpose. Firstly, the interest points between the two images are determined by using the Harris Corner Detection method and these points are marked on both images. Then, the feature matching between these images is made by utilizing correlation process. After these processes, the homography estimation is carried out via the RANSAC algorithm. Finally, the blending process is applied to the images and these images are stitched through the proposed approach. In this paper, the image resolution has tried to improve with the proposed approach and the effective results are obtained. A block diagram illustrating the proposed approach is presented in Fig. 4.

TABLE I. THE CHARACTERISTICS OF CAMERAS

Features	Device properties
	Values
Resolution	0.3 MP
Speed	30 fps
Focus	Fixed
Connection type	USB 2.0

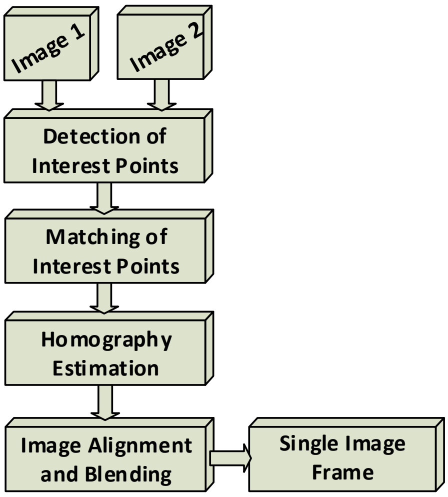


Fig. 4. The proposed approach for image stitching process

As shown in Fig. 4., the proposed approach takes two images as input parameters and gives the single image frame as output parameter. Fig. 4 is presented only for the two image frames. But, these processes are made for the camera arrays and repeat until all the images are stitched. The images obtained from the camera arrays stitches in twos by using the proposed image stitching algorithm. The process the architecture of the proposed approach is given in Fig. 5.

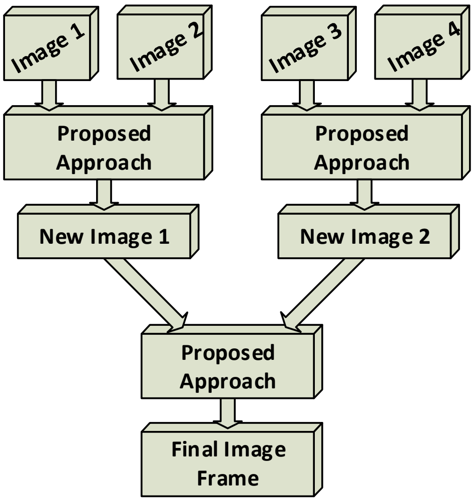


Fig. 5. The system architecture of the proposed method

Any image processing algorithm is not applied to the results obtained from the proposed method. In this paper focused on the camera arrays and the stitching process only made to images obtained from the multiple cameras for the same scenario. The proposed approach contains many new advantages for the camera arrays. The method has the following advantages.

- Image stitching process is an important problem in camera arrays and has been overcome with the proposed method.
- Slowness in the image stitching processes is largely eliminated with this paper.
- Key points on the two images are detected quickly.

III. Experimental Results

In this paper, the image stitching process is carried out for the camera arrays. The camera array is formed in a 2x4 size by using 8 cameras have the same characteristics for this operation. Images were taken at the same time the cameras and those were stitched by using a new image stitching algorithm. To evaluate the performance of the proposed approach, a real experimental setup is constituted and images are taken from the same scenario experimentally. Two computers are used to obtain images from the camera array. The second row is attached to the second computer while the first row is connected to the first computer. The experimental setup of the proposed algorithm is given in Fig. 6.

As shown in Fig. 6, the cameras in the first row is connected to the first computer and the rest of the camera is linked to the second computer. Additionally, the distance between the lenses of the cameras located in each column of the camera array is determined as 9 cm. The distance between rows in the camera arrays is 21 cm. All cameras are mounted on a fixed surface and the images are stitched through two computers used in the system. As mentioned at the beginning of this section, 8 cameras are used in the system and all of these cameras have the same characteristics. In the first phase, the images are taken from the camera has a 201x263 size and these sizes varies at each step of the proposed approach. In this way, the larger camera systems are obtained by using small scale cameras. Moreover, the high resolution images can be constituted by utilizing a lot of image sensors that have lower cost and resolution.

The example results obtained by proposed algorithm are presented in Fig. 7 for the same scenarios. The images obtained from all cameras and the stitched status of these images are given in Fig. 7. In addition, the size of the images and the running time values of the proposed approach for the example given in Fig. 7 are shown in Table 2.

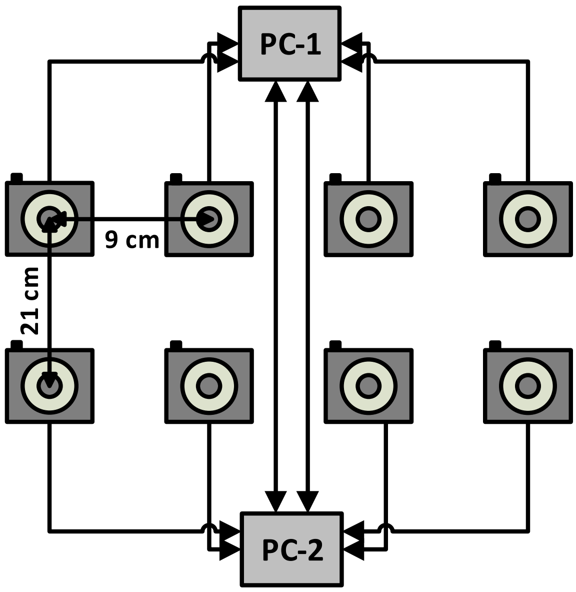
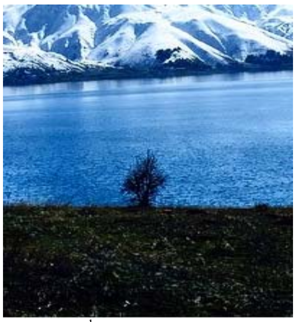


Fig. 6. The schematic diagram of the proposed method


(a) 1st camera of first row


(b) 2nd camera of first row


(c) 3rd camera of first row

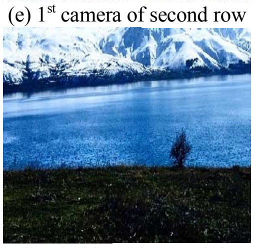

(d) 4th camera of first row

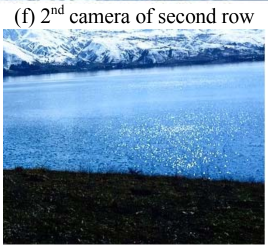

(e) 1st camera of second row


(f) 2nd camera of second row


(g) 3rd camera of second row

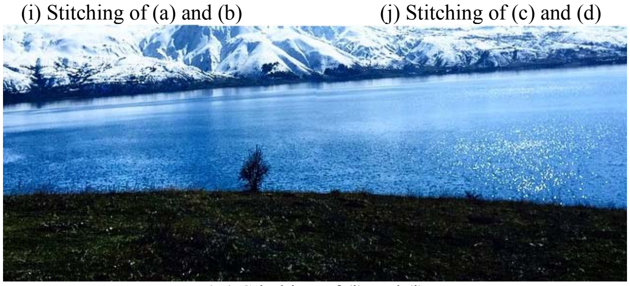

(h) 4th camera of second row


(i) Stitching of (a) and (b)


(j) Stitching of (c) and (d)


(k) Stitching of (e) and (f)


(l) Stitching of (g) and (h)


(m) Stitching of (i) and (j)

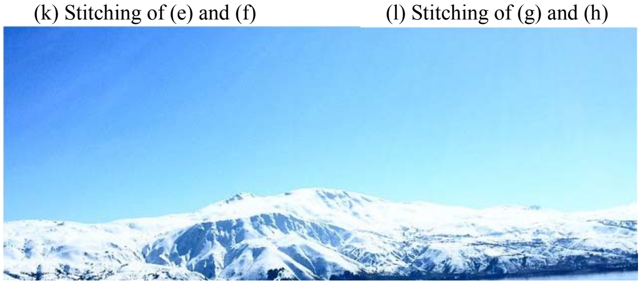

(n) Stitching of (k) and (l)

Fig. 7. An example of a 2x4 camera arrays

As shown in Table 2, the image stitching process has a very low time consumption. The first column of Table 2 shows the width size of the images given in Fig. 7. The second column illustrates height of the images and finally, third column presents the total time consumptions. As can be seen from Fig. 6, the two computers has been used in the system. The image stitching process is performed on these computers and the single image is obtained by using smaller cameras. The biggest challenge in these types of process is stitched images quickly. The values given in Table 2 is pretty good for a computer-based system. However, if a hardware-based board is utilized in the system, these values will drop lower. The single image frame obtained by using these images is given in Fig. 8. The single image frame arising by utilizing these images has 642x468 size.


Fig. 8. The output of proposed approach for given example

TABLE II. THE SIZE OF IMAGES AND CONSUMPTION TIME

Operations	**The proposed approach**		
	Size, width (p)	***Size, height (p)***	***Time (sec)***
(a), (b), (c), (d), (e), (f), (g), (h)	201	263	0.04
(i)	361	264	0.27
(j)	320	263	
(k)	361	264	0.27
(l)	321	263	
(m)	641	264	0.44
(n)	643	260	
Final Image	**642**	**468**	**0.72**
Total Time	**---**	**---**	**1.74**

IV. CONCLUSIONS

In this study, feature extraction based method has been proposed to image stitching process and the camera arrays and experimentally tested. The eight cameras are used to this process and these cameras are assembled to a fixed surface. Then, the eight different images are taken from these cameras for the same scenario. Finally, these images are stitched by using the proposed approach. The proposed method detects more accurately and rapidly the merge point of the images. Thus, higher resolution images can be obtained by using low resolution and low cost cameras. The image alignment and blending process have been applied to the single image frame. However, more accurate results will be achieved with the implementation of the different image enhancement approaches. The proposed method is suitable for higher resolution and high speed camera solutions. Future works will include the following:

- The proposed image stitched method will be implemented on a field-programmable gate array (FPGA) device.
- The larger camera arrays systems will be constitutes.
- Real-time video mosaicing method will be performed for the camera arrays.
- The larger scale camera arrays will be made in real time and high speed image processing.
- The image enhancement algorithms will be realized.

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