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Simultaneous active camera array focus plane estimation and occluded moving object imaging ☆

Tao Yang [a,*], Yanning Zhang [a], Rui Yu [b], Xiaoqiang Zhang [a], Ting Chen [a], Lingyan Ran [a], Zhengxi Song [a], Wenguang Ma [a]

[a] ShaanXi Provincial Key Laboratory of Speech and Image Information Processing, School of Computer Science, Northwestern Polytechnical University, Xi'an, China
[b] Department of Computer Science, University College London, London, UK

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ABSTRACT

Automatically focusing and seeing occluded moving object in cluttered and complex scene is a significant challenging task for many computer vision applications. In this paper, we present a novel synthetic aperture imaging approach to solve this problem. The unique characteristics of this work include the following: (1) To the best of our knowledge, this work is the first to simultaneously solve camera array auto focusing and occluded moving object imaging problem. (2) A unified framework is designed to achieve seamless interaction between the focusing and imaging modules. (3) In the focusing module, a local and global constraint-based optimization algorithm is presented to dynamically estimate the focus plane of the moving object. (4) In the imaging module, a novel visibility analysis based active synthetic aperture imaging approach is proposed to remove the occluder and significantly improve the quality of occluded object imaging. An active camera array system has been set up and evaluated in challenging indoor and outdoor scenes. Extensive experimental results with qualitative and quantitative analyses demonstrate the superiority of the proposed approach compared with state-of-the-art approaches.

1. Introduction

Occluded moving object imaging is a challenging problem in the field of computer vision and pattern recognition. It plays an important role especially in surveillance, remote sensing and underwater filming. Since high level understanding of a scene relies heavily on accurate low level imaging of objects, developing a high performance occluded moving object imaging system has become a subject of great scientific and commercial interests.

Although many algorithms and systems have been developed in the literature, to the best of our knowledge few works have been done in occluded moving object imaging possibly due to several challenges: (1) Visibility varies significantly over frames, ranging from occlusion-free to complete occlusion due to complex interaction among objects and surroundings. (2) The out of focus problem caused by the movements of the camera and the object adds huge uncertainty to the automatic focus plane estimation.

1.1. Our approach

To address the problems above, we present a novel active synthetic aperture imaging approach in this paper. Fig. 1 displays our camera array system and examples of auto-focusing and occluded object imaging results. Please note that the reason why the synthetic aperture images look dark is that image wrapping will then change the size of the image and the region where there is no mapping will be dark (Fig. 1, bottom row).

Our first contribution is a unified framework with two interactive modules (see Fig. 2), which can estimate the focus plane and see object even under occlusion and depth variations. Our second contribution is an active camera array auto focusing approach, which estimates the best focus plane through global optimization of spatial and temporal feature correspondences. Our third contribution is improvement of occluded object imaging quality based on visibility analysis.

To evaluate our method, we construct an active camera array system as the main acquisition device. Our motivation to develop an active camera array mainly comes from two parts: (1) Although the camera array has been well studied in the literatures, most of the existing systems are static and lack the pan tilt ability to monitor a large area and auto focusing on certain object. (2) Another motivation is straightforward, inspired by the traditional active pan-tilt-zoom camera, we

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* Corresponding author. Tel.: +86 15002919079.
E-mail addresses: yangtaonwpu@163.com, tyang@nwpu.edu.cn (T. Yang).

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0262-8856/

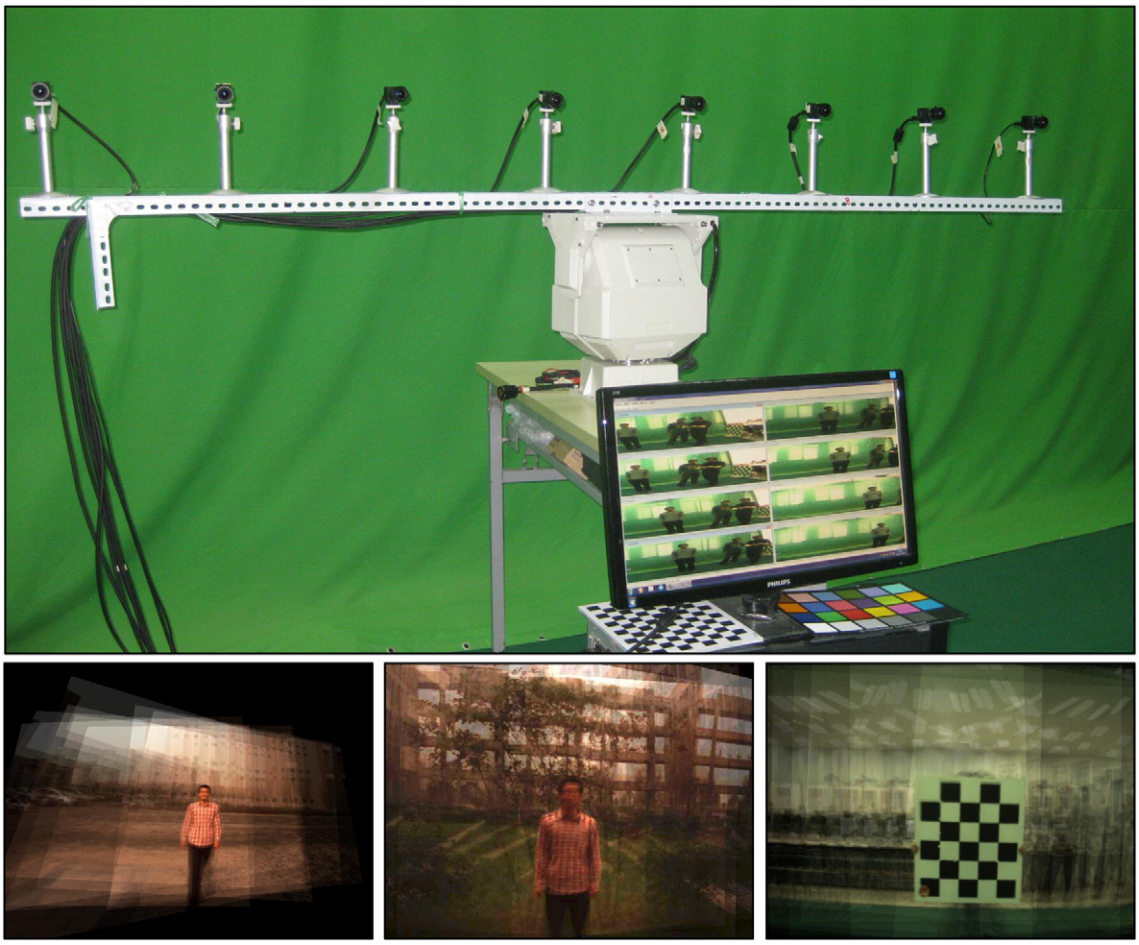

Fig. 1. The top image shows our active camera array system and the bottom row gives examples of our auto-focusing and occluded moving object imaging results.

want to design a more powerful pan-tilt-focus camera array. In our camera array system, the synchronous data acquisition, storage and processing are completely managed by a single workstation. A set of video sequences with various occlusions have been captured in challenging indoor and outdoor scenes. We test the proposed approach on these sequences and observe promising auto focusing and imaging results in comparison with several state-of-the-art approaches.

1.2. Related work

Multi-view approach or system is a natural solution for occluded object imaging because of its ability of decreasing the occluded regions and recovering 3D space information [1–8]. Among the existing multiple camera techniques, recently the camera array [9–17] proves to be a powerful way to see objects through occlusion. The camera array technique is firstly made famous by the 1999 movie The Matrix, in which a 1D camera array is used to create an impression of orbiting around a scene that has been frozen in time. The pioneer work of synthetic aperture imaging is proposed by Levoy et al. [9–12]. They set up a two dimensional Stanford light field camera array which consists of 128 FireWire cameras, and align multiple cameras to a focus plane to approximate a camera with a very large aperture. The constructed synthetic aperture image has very limited depth of field, so that objects off the plane of focus would disappear due to significant blur. The MIT

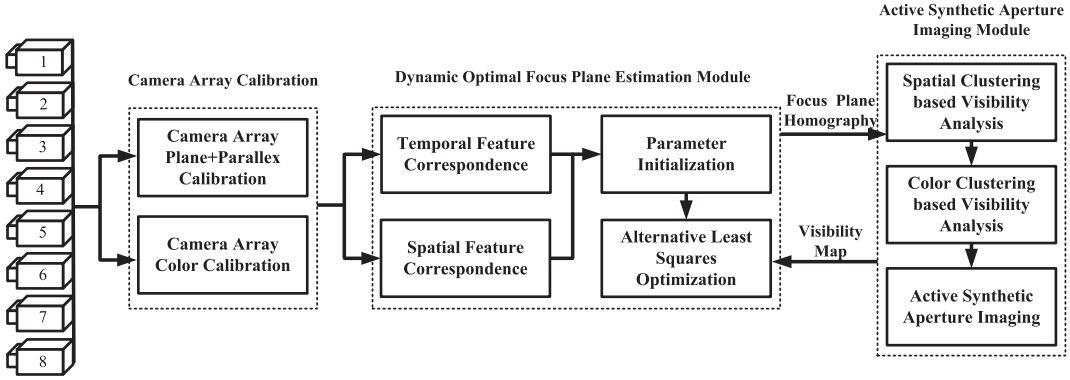

Fig. 2. Framework of our active synthetic aperture imaging algorithm.