DBSCAN 을 이용한 4 차원 Light Field 에서의 깊이영상 복원

윌리엄, 박인규
인하대학교 정보통신공학과
{williem.pao@gmail.com, pik@inha.ac.kr}

Abstract

Light field depth estimation is an essential part of many light field applications. Numerous algorithms have been developed using various light field characteristics. However, their methods fail when addressing with scene with occlusion. To remedy this problem, we present a light field depth estimation method which is more robust to occlusion. A novel data cost based on density measure of a cluster generated by density-based spatial clustering of applications with noise (DBSCAN) algorithm is introduced. Experimental results confirm that the proposed data cost is robust and achieves high quality depth maps. The proposed method outperforms the state-of-the-art light field depth estimation methods in qualitative and quantitative evaluation.

1. Introduction

4D light field camera has become a potential technology in image acquisition due to its rich information captured at once. It does not capture the accumulated intensity of a pixel but the separate intensity for each light direction. Commercial light field cameras, such as Lytro and Raytrix, trigger the consumer and researcher interests on light field because of its practicability compared to conventional light field camera arrays. A light field image allows wider application to be explored than a conventional 2D image.

Depth estimation from a light field image has become a challenging and active problem for the last few years. Many researchers utilize various characteristics of light field (*i.e.* epipolar plane image, angular patch, focal stack) to develop the algorithms. However, the state-of-the-art techniques [2, 3] mostly fail on occlusion because it breaks the photo consistency assumption.

In this paper, we introduce a novel data cost based on our observation on light field angular patch. First, we utilize a DBSCAN clustering algorithm [1] to find the largest cluster in RGB space. Then, we introduce a novel density metric of a cluster and utilize the density measure as the data cost. The proposed data cost is robust on occlusion.

2. Proposed Method

2.1 Light Field Images

We observe new characteristics from light field image which are useful for designing the data costs. To measure the data costs for each depth candidate, we need to generate the angular patch for each pixel and the refocus image. Thus, each pixel in light field $L(x,y,u,v)$ is remapped to sheared light field image $L_\alpha(x,y,u,v)$ based on the depth label candidate α as follows:

$$L_\alpha(x,y,u,v) = L(x+\nabla_x(u,\alpha), y+\nabla_y(u,\alpha), u, v) \quad (1)$$

$$\nabla_x(u,\alpha) = (u-u_c)\alpha k \quad ; \quad \nabla_y(v,\alpha) = (v-v_c)\alpha k \quad (2)$$

where (x,y) and (u,v) are the spatial and angular coordinates, respectively. The center pinhole image position is denoted as (u_c,v_c). ∇_x and ∇_y are the shift value in direction x and y with k is the unit disparity label. The shift value increases as much as the distance between light field subaperture image and center pinhole image increases. We can generate an angular patch for each pixel (x,y) by extracting the pixels in the angular images from the sheared light field.

2.2 Angular Patch Analysis

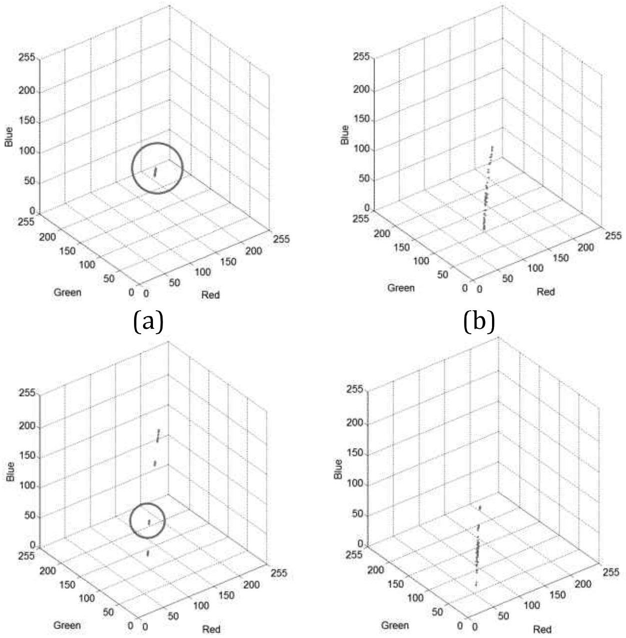
Conventional correspondence data costs are designed to measure the similarity between pixels in angular patch. However, most of them do not consider the occlusion when they model the data cost. When an occluder affects the angular patch, the photo consistency assumption is not satisfied in all pixels of the angular patch. However, there are still dominant pixels which satisfy the assumption.

Figure 1 shows the angular patches of two pixel position with two different disparity candidates. The first two angular patches are generated from a non-occluded pixel, while the last two patches are from the occluded pixel. It is noticed that the photo consistency of all or most pixels is maintained if the disparity is true even though there is occlusion effect.

We observe that the photo consistency is denoted as a cluster in RGB space, as shown in Figure 2. When there exists occlusion, there are several clusters in the RGB space. However, it is noticed that there exists the largest cluster that represents the photo consistency of a dominant pixel color.

(a) (b) (c) (d)

Figure 1. Angular patch. (a & b) Non-occluded pixel (p = 349,467); (c & d) Occluded pixel (p = 383,475); (a & c) Ground truth depth; (b & d) Non ground truth depth.



(a) (b) (c) (d)

Figure 2. RGB plot of each angular patch in Figure 1. Red circle denotes the largest cluster in the RGB space.

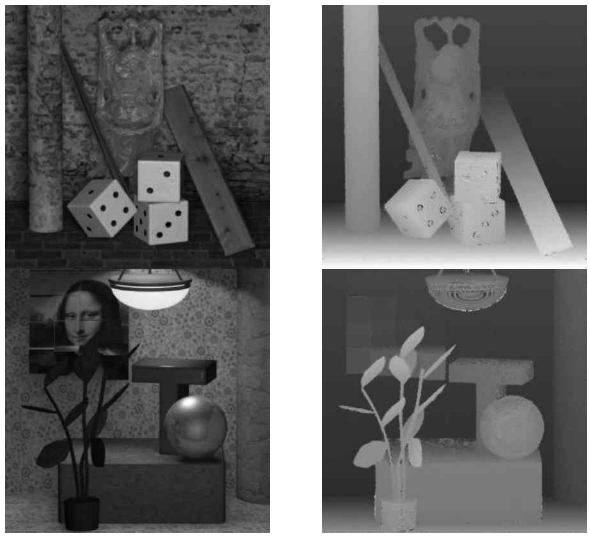
2.3 Data Cost based on DBSCAN

Based on the angular patch analysis, we develop a novel data cost for the robust light field depth estimation. To find the largest cluster in RGB space, we utilize a DBSCAN clustering algorithm. We refer to [1] for the detail of the clustering algorithm. The clustering algorithm is robust on noise which is suitable for separating between the cluster of the dominant pixels and the cluster of the noise/occlusion pixels. The example of selected largest cluster is shown in Figure 2.

After we found the largest cluster, we measure the density of the cluster $E(x,y,\alpha)$ as defined in:

$$E(x,y,\alpha)=\frac{D(x,y,\alpha)}{M(x,y,\alpha)} \quad (3)$$

where $D(x,y,\alpha)$ is the maximum distance between cluster member inside the largest cluster. $M(x,y,\alpha)$ is the number of cluster member of the largest cluster. The smaller the maximum distance and the larger the number of cluster member, the more dense the largest cluster. After computing each cost for every pixels and disparity candidates, we perform winner-takes-all (WTA) algorithm to compute the depth map.



(a) (b)

Figure 3. Disparity maps results. (a) Input image; (b) Disparity map.

3. Experimental Results

To evaluate the quality of depth map, we utilize Buddha and Mona dataset from [4]. Figure 3 shows the visual comparison of disparity results of the proposed method for each dataset and it is clearly shown that the proposed algorithm obtains accurate disparity maps, especially in occlusion region area. Note that the result can be improved by utilizing global optimization method.

4. Conclusion

In this paper, we proposed a novel data cost for light field depth estimation that is robust on occlusion. An analysis of angular patch was described and we observed that state-of-the-art clustering algorithm can be used to design the data cost. It was shown that the proposed work obtains accurate depth map. The future work is to develop a data cost that is robust on occlusion and less sensitive to noise.

References

[1] M. Ester et al., “A density based algorithm for discovering clusters in large spatial database with noise,” Proc. Second International Conference on Knowledge Discovery and Data Mining, pp. 226-231, 1980.

[2] H. G. Jeon et al., “Accurate depth map estimation from a lenslet light field camera,” Proc. IEEE CVPR, pp. 1547-1555, 2015.

[3] M. Tao et al., “Depth from shading, defocus, and correspondence using light-field angular coherence,” In Proc. IEEE CVPR, pp. 1940-1948, 2015.

[4] S. Wanner et al., “Datasets and benchmarks for densely sampled 4D light fields,” Proc. International Workshop on Vision, Modelling and Visualization, 2013.