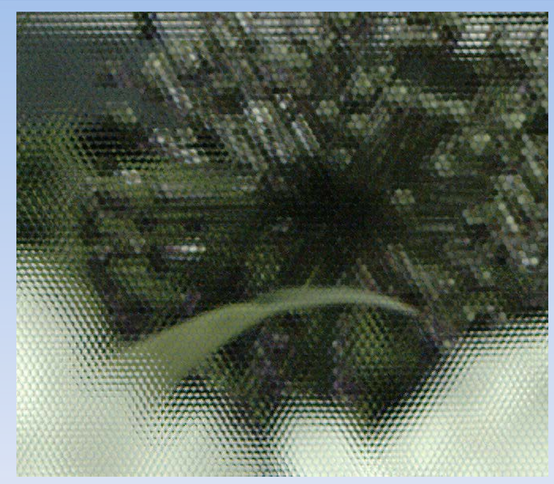
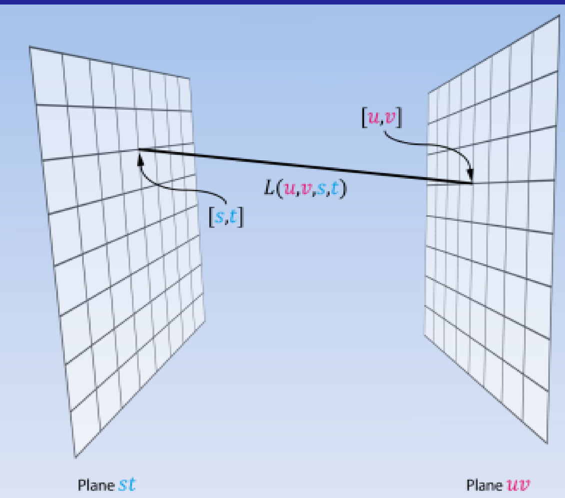
Line Assisted Light Field Triangulation and Stereo Matching

Zhan Yu[1], Xinqing Guo[1], Haibin Ling[2], Andrew Lumsdaine[3], Jingyi Yu[1],
University of Delaware[1], Temple University, Indiana University[3]

4D Light Field

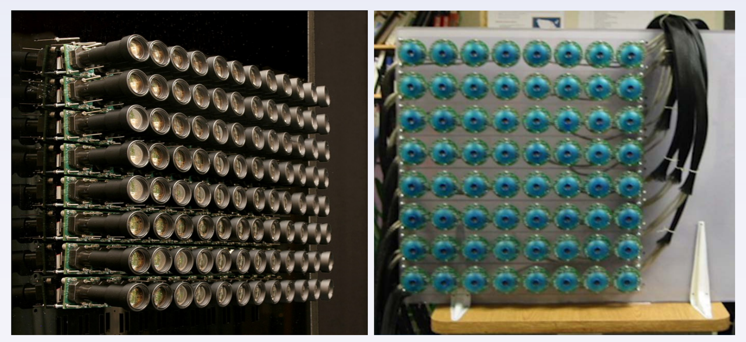


Light Field Image



Light Field Parameterization (2PP)

Light Field Acquisition Devices



Camera Arrays

Lytro, Raytrix, Pelican Cameras

Ray Geometric Structure in a Light Field

➢ *Ray [s,t,u,v] Passing Through a 3D Point [x,y,z]:*

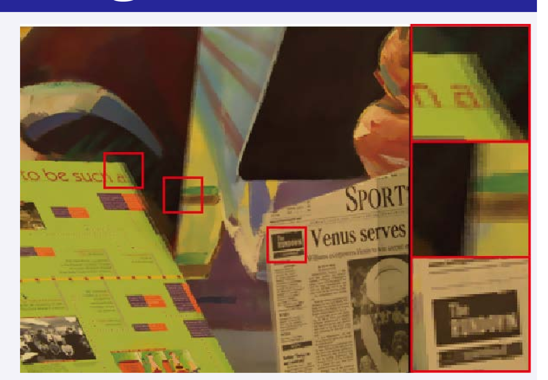
$$\lambda[s,t,1]+(1-\lambda)[u,v,0]=[x,y,z] \Rightarrow \begin{cases} zs+(1-z)u=x \\ zt+(1-z)v=y \end{cases}$$

➢ *Ray [s,t,u,v] Passing Through a 3D Line [x,y,z]+ [d_x,d_y,0]:*

$$(d_y-d_yz)s+(d_xz-d_x)+d_yzu-d_xzv+d_xy-d_yx=0$$

➢ *Largely Linear → Can Be Triangulated*

Light Field Super-resolution via Triangulation



➢ *Triangulation:*
- *Use scattered sample rays*
- *A natural intepolant for filling in the missing data*
- *Brute-force Delaunay Triangulation (strong aliasing)*

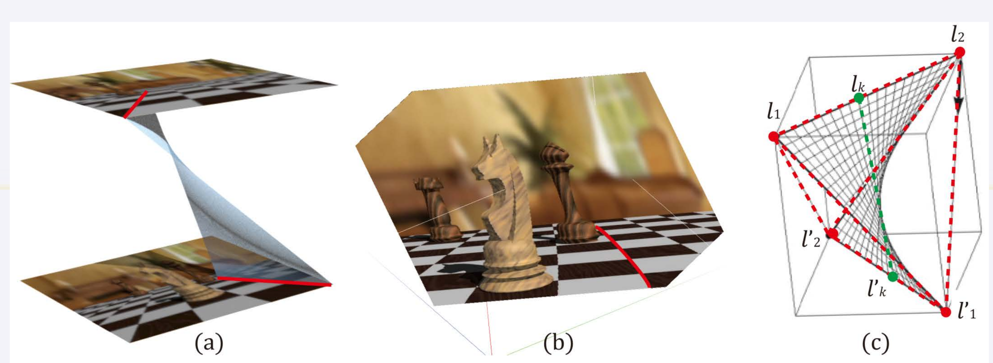
➢ *Edge Constrained Delaunay Triangulation*
- *Aliasing Near Edges*

Causes: Bilinear Ray Structure of 3D Lines

➢ *Lines [s_0, t_0, u_0, v_0]not parallel to the 2PP satisfy the bilinear constraint:*

$$\begin{cases} \lambda_1 s+(1-\lambda_1)u=\lambda_2 s_0+(1-\lambda_2)u_0 \\ \lambda_1 t+(1-\lambda_1)v=\lambda_2 t_0+(1-\lambda_2)v_0 \end{cases}$$

$$\Rightarrow \frac{s-s_0}{u-u_0}=\frac{t-t_0}{v-v_0}$$

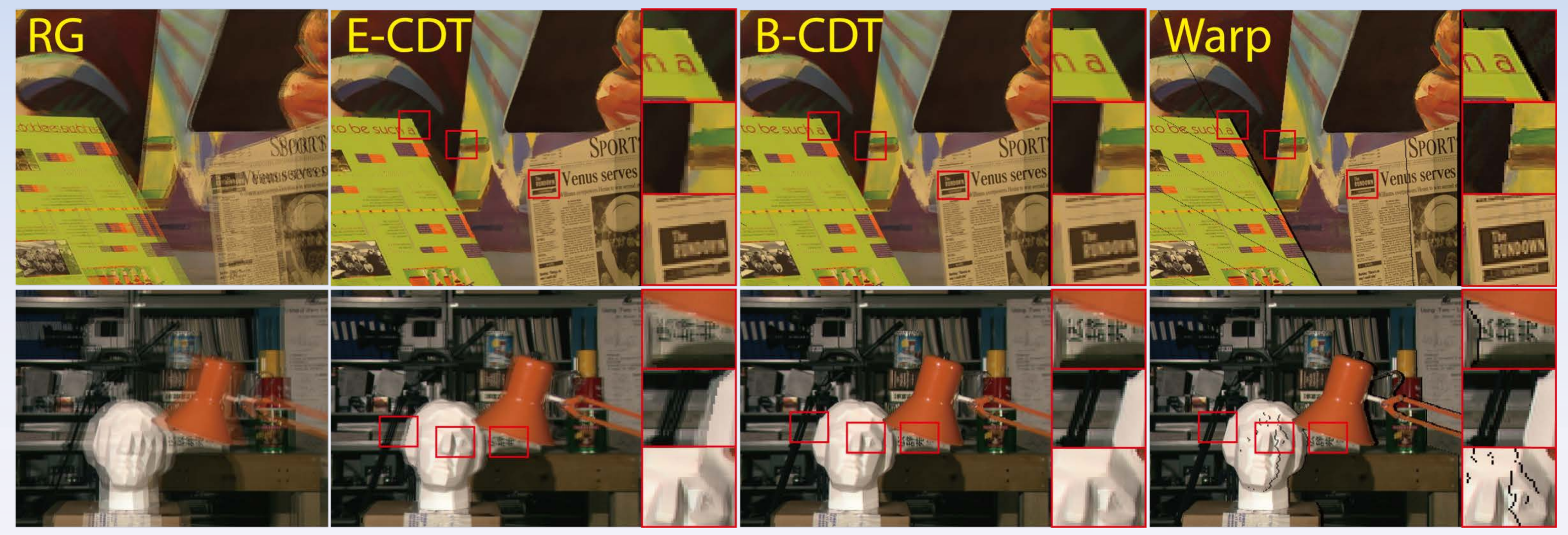


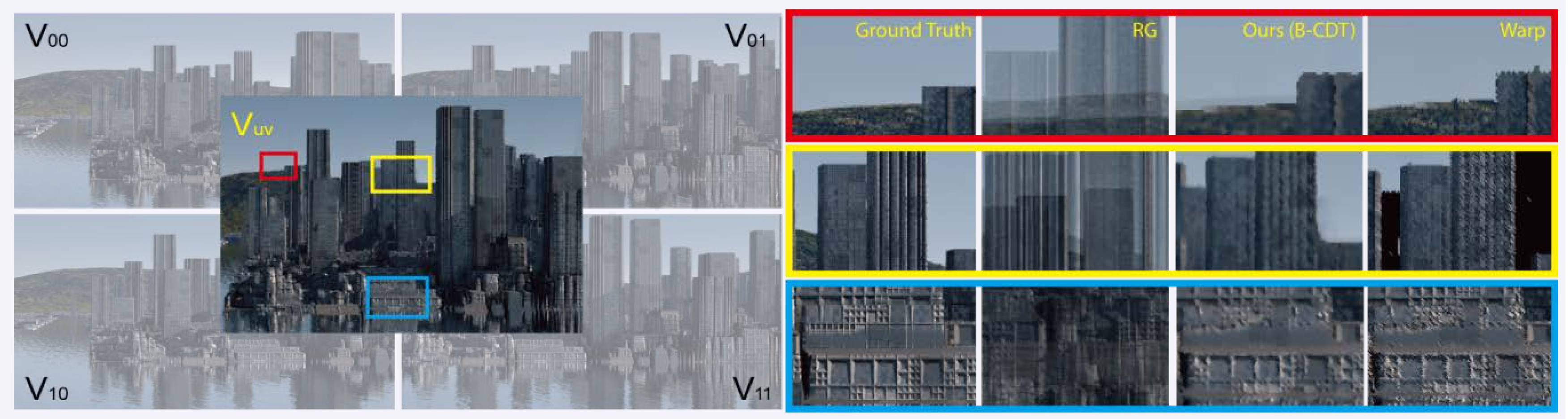
➢ *Tetrahedralizing a bilinear surface introduces volume, i.e., bleeding*

Bilinear Constrained Delaunay Triangulation (B-CDT)

➢ *Detect 3D lines in the LF*
➢ *Subdivide the corresponding bilinear surfaces into slim patches*
➢ *Triangulate each patch*
➢ *Add patch edges as additional constraints in CDT*

Light Field Triangulation Results





How to Obtain Depth at Feature Points?

➢ *Our Approach: Stereo Matching with 3D Line Constraints*
➢ *Traditional Multi-View Graph Cut (MVGC) Minimizes:*

$$E=E_{data}(p,q)+E_{smooth}(p,q)+E_{occ}(p,q)$$

Linearity of Disparity along a Line

➢ *Proof linearity of disparity along a line segment by bilinear constraints in the ray space:*

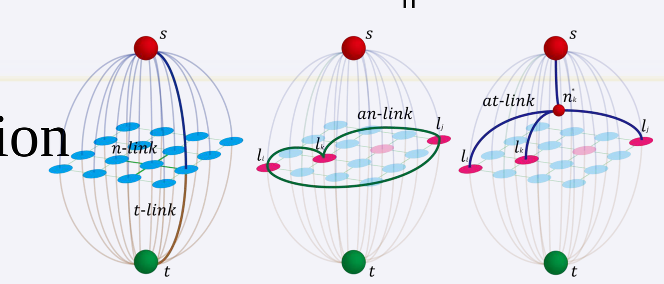
$$\frac{s+\Delta s-s_0}{u+\Delta u-u_0}=\frac{s-s_0}{u-u_0}=\frac{t-t_0}{v-v_0} \Rightarrow d=\frac{\Delta s}{\Delta u}=\frac{t-t_0}{v-v_0}$$

Line Assisted Graph Cut (LAGC)

➢ *Energy term for lines:*

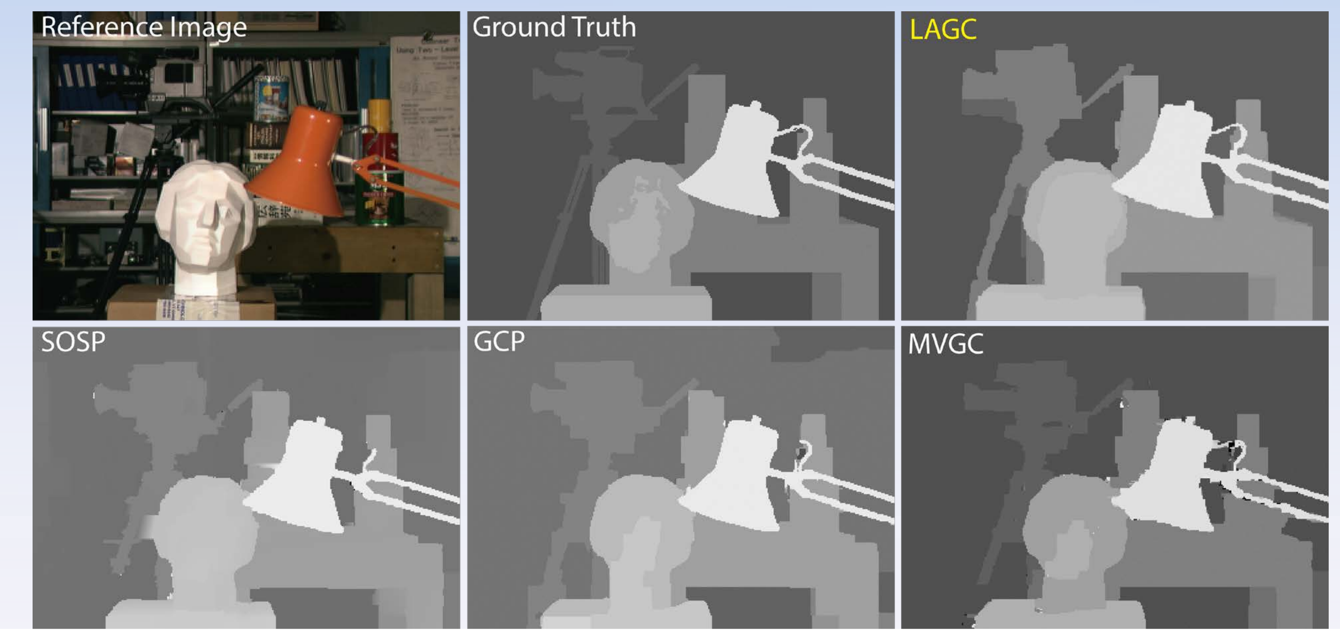
$$E_{line}(x,y,z)=\sum_{y\in[x,z]}\left\|\lambda L(x)-L(y)+(1-\lambda)L(z)\right\|$$

➢ Non-submodular
➢ Solution: Use QPBO instead of α-expansion



Experimental Results

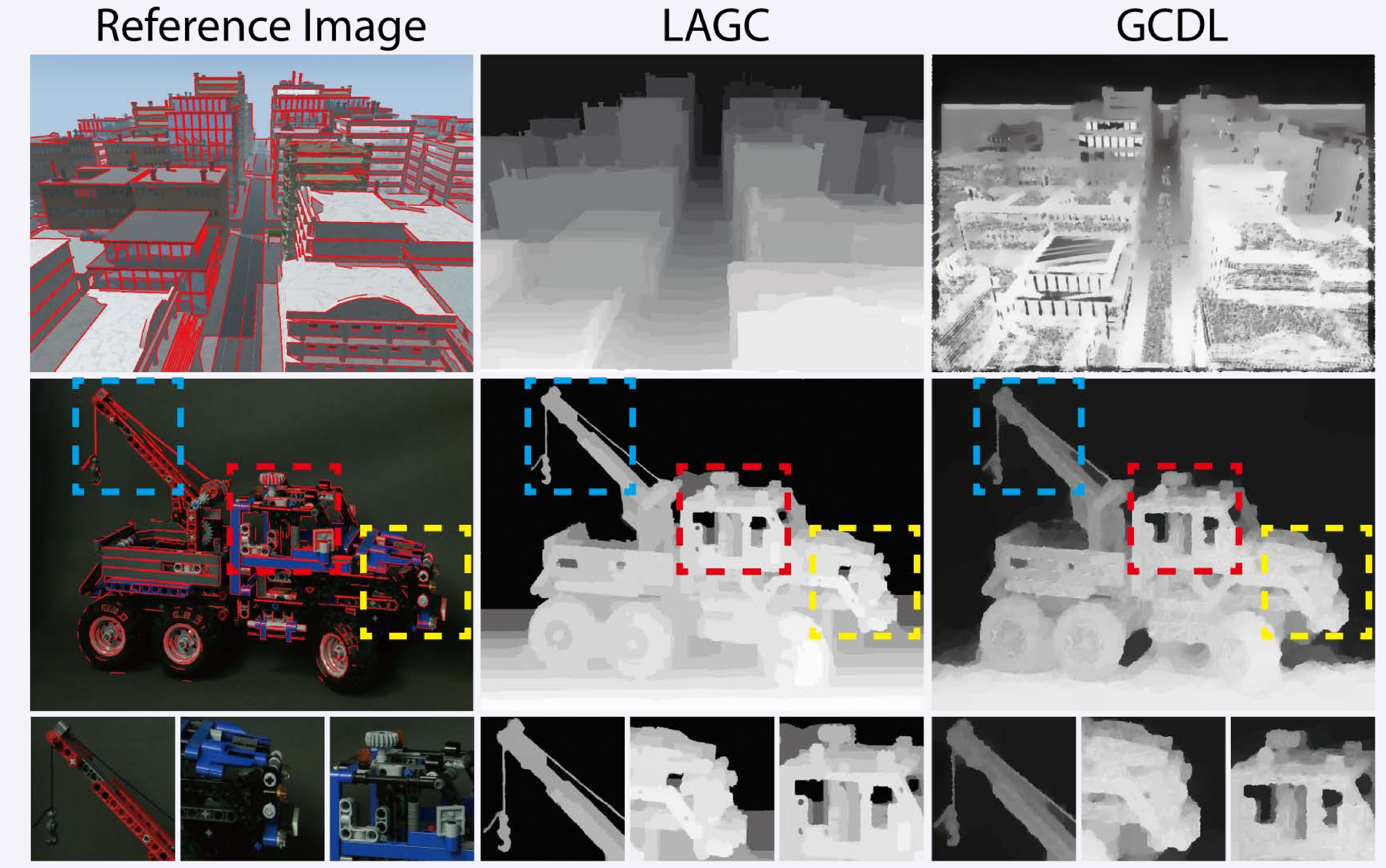
➢ *Tsukuba Dataset:*
- *SOSP: Second Order Smoothness Prior* [*Woodford et al. 08*]
- *GCP: Ground Control Points* (*Middlebury Rank 1*) [*Shi et al. 12*]
- *GCDL: Global Consistent Depth Labeling* [*Wanner and Goldlücke 12*]



Algorithm	non-occlusion	all	discontinuity
LAGC	1.00_{13}	1.41_{14}	5.39_{14}
MVGC	1.27_{35}	1.99_{50}	6.48_{38}
SOSP	2.91_{103}	3.56_{92}	7.33_{57}
GCP	1.03_{14}	1.29_{5}	5.60_{16}

Table 1. Stereo matching using LAGC (ours), MVGC, SOSP, and GCP on Tsukuba. We show both the percentage of bad pixels and the algorithm's ranking (in subscripts)

➢ *Real Light Field Dataset:*



Acknowledgments

This project was supported by the National Science Foundation under grants IIS-RI-1016395 and IIS-RI-121856.