Stereo Correspondence with Occlusions using Graph Cuts

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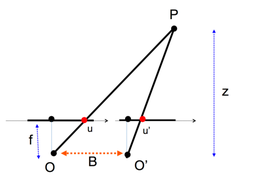
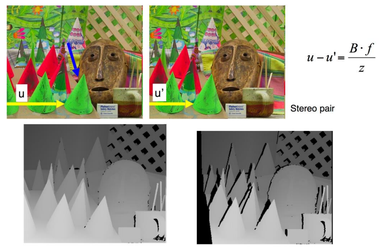
Motivation

Given two stereo images of a scene, it is possible to recover a 3D understanding of the scene. This process is useful in applications like robotics, where depth sensors may be expensive but a pair of cameras is relatively cheap.

In order to construct depth maps from stereo images, we need to first solve the stereo correspondence problem. This project used a graph cut based algorithm[1] and performed evaluation against baseline using normalized cross correlation (NCC). We used a stereo image dataset from Middlebury College to benchmark performance[2].



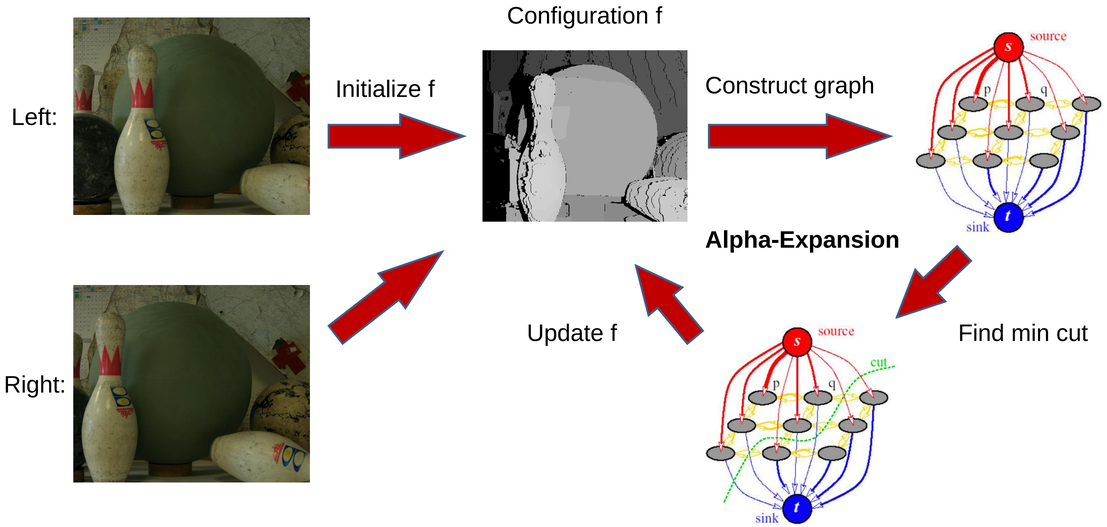
$$u - u' = \frac{B \cdot f}{z} = \text{disparity}$$



$$u - u' = \frac{B \cdot f}{z}$$

Source:[3]

Graph Cut algorithm



Objective: Minimize the following energy function within alpha-expansion of f

$$E(f) = E_{data}(f) + E_{occ}(f) + E_{smooth}(f)$$

Solution: Reduce to finding a min-cut on a constructed graph with disparity alpha

Future Work

1. Explore other approaches such as dynamic programming[4] to solve the correspondence problem that could get applied in mobile/embedded environments.
2. Investigate performance optimizations such as LogCut[5], which only has logarithmic complexity with respect to the number of disparity labels.

Reference

[1] V. Kolmogorov and R. Zabih. Computing visual correspondence with occlusions using graph cuts. In ICCV, volume II, pages 508–515, 2001.

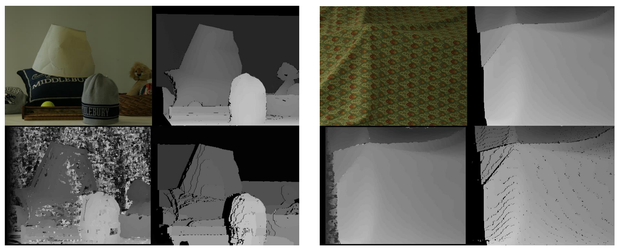
[2] Scharstein, D., Hirschmüller, H., Kitajima, Y., Krathwohl, G., Nešić, N., Wang, X., & Westling, P. (n.d.). HighResolution Stereo Datasets with SubpixelAccurate Ground Truth. Lecture Notes in Computer Science Pattern Recognition, 3142.

[3] http://cvgl.stanford.edu/teaching/cs231a_winter1415/lecture/lecture6_affine_SFM.pdf

[4] I. J. Cox, S. L. Hingorani, S. B. Rao, and B. M. Maggs. A maximum likelihood stereo algorithm. CVIU, 63(3):542–567, 1996.

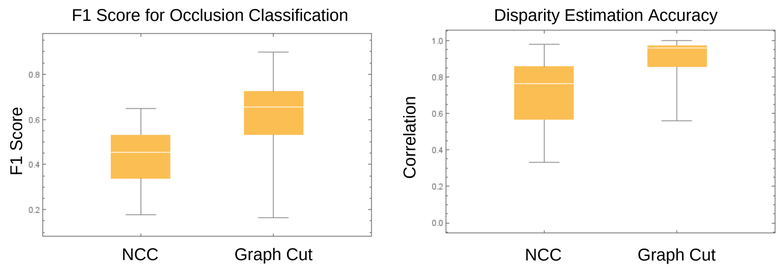
[5]Lempitsky V, Rother C, Blake A (2007) Logcut—efficient graph cut optimization for Markov random fields. In: ICCV

Experimental Results



Top: (a) Original image (b) True disparity
Bottom: (c) NCC disparity (d) Graph cuts disparity

In the left image, we observe noisy results from NCC on low contrast surfaces. However, in the right image, both algorithms perform quite well on highly textured surface.



The graph cut based algorithm outperformed the NCC algorithm on a wide variety of metrics, but at the cost of a significantly longer runtime.

Algorithm	Runtime (s)	Bias (px)	RMSE (px)	Correlation	R^2	F_1
NCC	21	1.89	10.6	0.76	0.48	0.45
Graph Cut	339	-0.02	3.8	0.96	0.92	0.65