A Stochastic Cost Function for Stereo Vision

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The goal of this paper is to present a novel stochastic cost function for binocular stereo vision that delivers statistics about the most probable disparities on the pixel level. We drive these statistics by many independent stochastic processes so that robustness to outliers can be achieved. Each of these stochastic processes may be understood as an individual who is requested to deliver his opinion about the depth. Finally, the idea is to fuse all these individual measurements into one global disparity map. In this paper, we use random walks for this.

Figure 1: Examples for random walks.

Random walks, like the ones shown in Fig. 1, randomly traverse the image where at each step of the walk, an adjacent pixel location is chosen based on color similarity. In this sense, a random walk can be viewed as a local segmentation which is assumed to be robust along discontinuities. The set of pixels which is covered by the random walk is used to infer information about the disparity. In this paper, we demonstrate that random walks are useful for gathering important statistics about disparities. One strong property of our method is that our cost function is statistically motivated and we show that our proposed statistical consistency is a powerful and very useful confidence measure with which occlusions may be filtered out effectively.

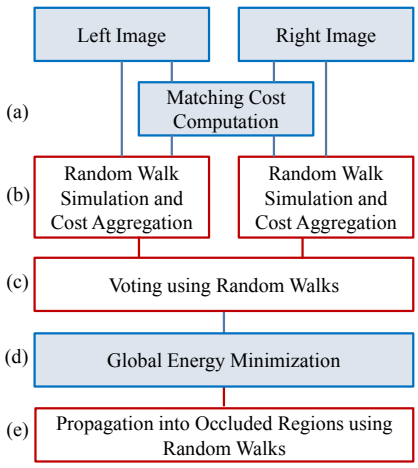

Figure 2: The processing steps of our method.

In Fig. 2 we depict the processing steps of our method: (a) the computation of pixel-wise matching costs. (b) In our cost aggregation stage, we simulate random walks for every pixel of the image. The costs are then summed for all pixels of a random walk. Since random walks rarely cross large image gradients, this can be understood as a pre-segmentation step to increase robustness at discontinuities. We also explicitly consider slanted surfaces by evaluating different surface orientations and by simulating random walks in both left and right images, we address occluded regions. (c) Once we computed a cost function for every random walk, we introduce a novel voting technique that fuses information of all random walks into one global voting space. The collected votes contain statistical information about the likelihood of every disparity at every pixel location and also reveal inconsistencies in places where matching is ambiguous. (d) The votes may be used in a global optimization or for direct disparity selection. (e) After this step, random walks may be used to propagate reliable matches into inconsistent regions.

In our paper, we provide a statistical consistency measure that serves as a confidence for every disparity value. The idea is that the confidence is high if many random walks confirm to the same disparity. Given that $\mathcal{V}(\mathbf{x},d)$ is the number of votes for disparity d at pixel $\mathbf{x}$, the *consistency* is defined as: $\frac{\mathcal{V}(\mathbf{x},\hat{d})}{1+\sum_i \mathcal{V}(\mathbf{x},i)}$, where $\hat{d}$ is the disparity with most votes at pixel $\mathbf{x}$. We analyze the reliability of this confidence value, also by discussing its ROC curve, which we present as an example in Fig. 3. Finally, we show disparity maps of challenging stereo images and we compare to other related methods.

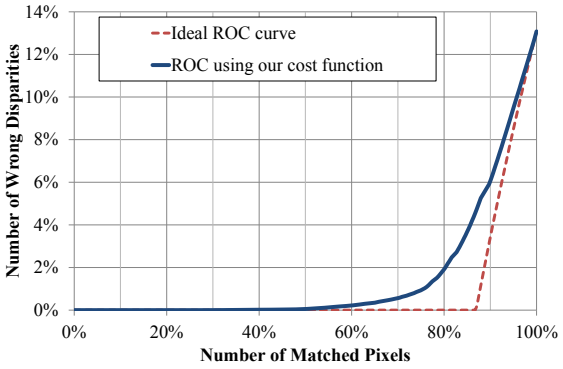

Figure 3: The ROC curve of our method.

To summarize, this paper proposes a novel stochastic cost function based on random walks which enables statistical reasoning on the discovered depth measurements. In particular, we introduce (1) a cost aggregation technique based on random walks which is orientation- and occlusion-robust, (2) a novel voting technique based on random walks to obtain statistical information about the disparity likelihood and (3) a strong novel statistical consistency measure. In our experiments we show impressive results on challenging stereo images. Given the obtained results we believe that our cost function together with the confidence is useful for other stereo methods and is valuable in practical applications.