Window-based Stereo Matching Algorithm Using a Weighted Average of Costs Aggregated with Window Size Reduction

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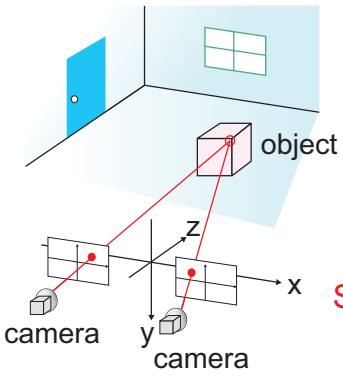
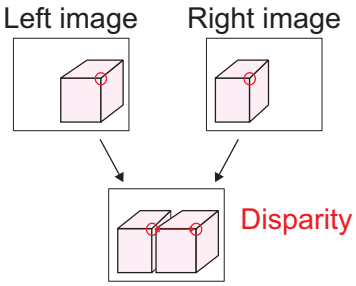
Introduction

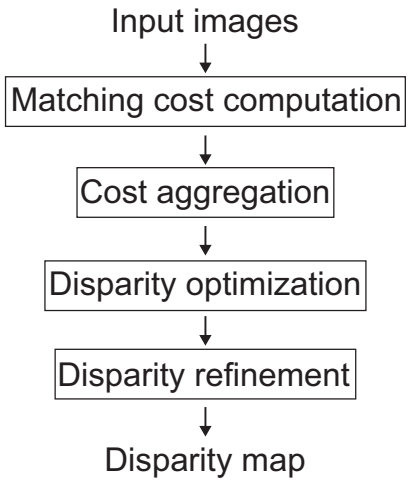




Stereoscopic System

It produces a dense disparity map by using a pair of left and right images of a stereo camera system.

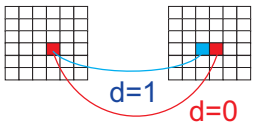
Window-based algorithm



Detail of window-based algorithm

Matching cost computation

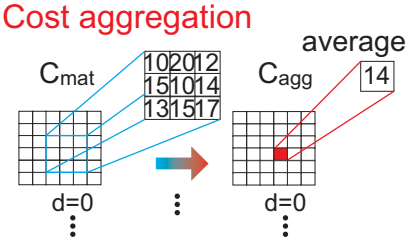
reference & matching images



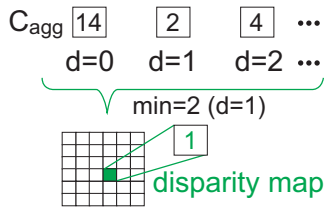
I:intensity

$$C_{mat}(x,y,d) = |I_r(x,y) - I_m(x+d,y)|$$

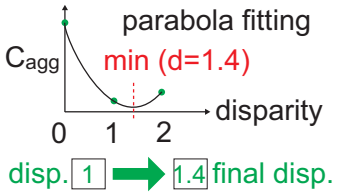
Cost aggregation



Disparity optimization

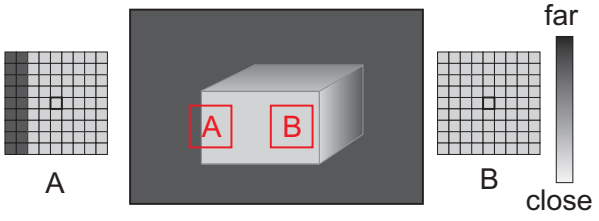


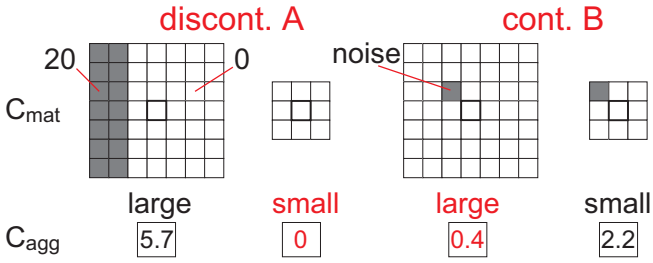
Disparity refinement



Issue of the algorithm

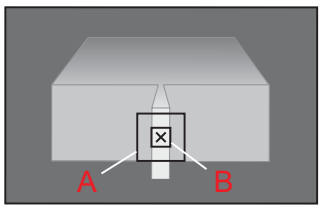
A trade-off between accuracies of the disparity map in disparity discontinuity region A and continuity region B due to the window size dependence



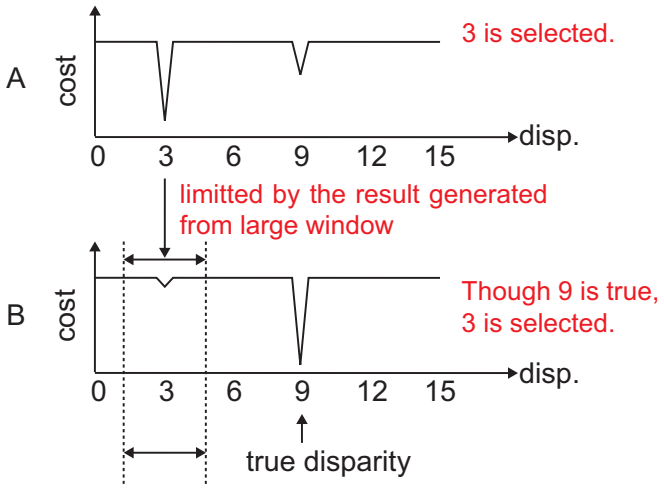


Coarse-to-fine algorithm

This algorithm solves the issue by using multiple costs aggregated by various window sizes. However, the algorithm is difficult to find a true disparity of small object differed vastly from a disparity of background.

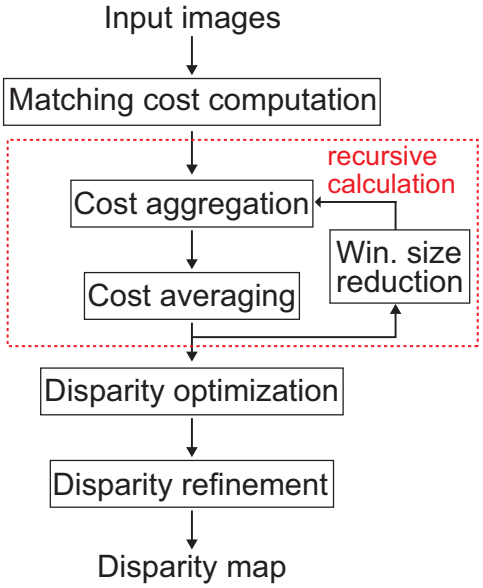


A : large window in the first iteration
B : small window in the next iteration



candidates for the best disparity

Proposed algorithm

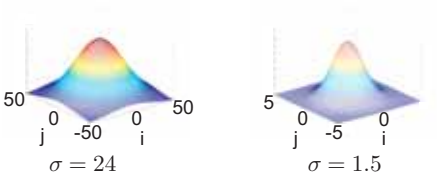


Cost aggregation

Gaussian filter

$G(i,j) = \frac{1}{2\pi\sigma^2} exp\left(-\frac{i^2+j^2}{2\sigma^2}\right)$ σ : win. size

$$C_{agg}(x,y,d) = \sum_{i,j} G(i,j) C_{mat}(x+i, y+j, d)$$



The Gaussian filter has a better performance than the box filter in the disparity discontinuity region because a weight of the Gaussian filter is the largest at a given pixel position.

Cost averaging

$C_{agg}[n]$:aggregated costs in n-th iteration

C[n]:averaged costs in n-th iteration

$$C[n] = \begin{cases} C_{agg}[n] & (n=1) \\ \frac{w_1 \cdot C[n-1] + w_2 \cdot C_{agg}[n]}{w_1 + w_2} & (n \geq 2) \end{cases}$$

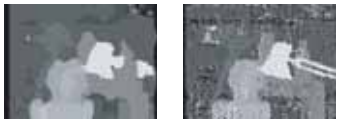
In the first iteration, matching costs are aggregated by the largest window. The averaged costs are renewed by the previous averaged costs and the present aggregated costs with window size reduction.

Disparity optimization

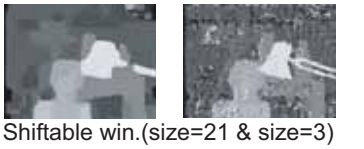
The averaged costs, C[N] have every characteristic of aggregated costs using various window sizes.
Therefore, the proposed algorithm can address the trade-off.

Simulation

reference image true disparity map

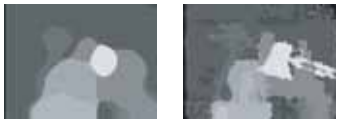


Box filter (size=15 & size=3)



Shiftable win.(size=21 & size=3)

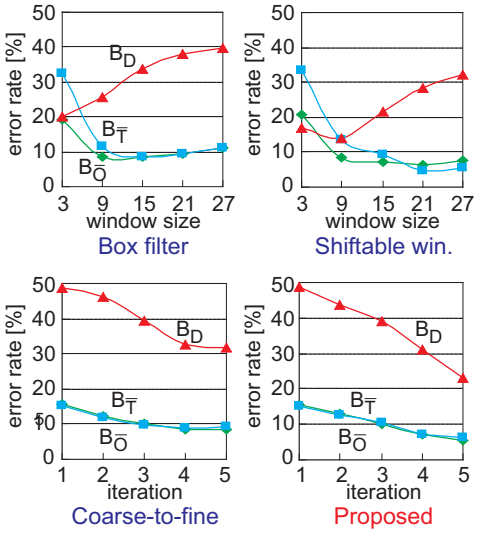
Coarse-to-fine (N=1 & N=5)



Proposed (N=1 & N=5)

condition

$w_1 = w_2 = 1$, $N = 5$, $\sigma = 24, 12, 6, 3, 1.5$



$B_{\bar{O}}$: error rate in the nonoccluded region

$B_{\bar{T}}$: error rate in the textureless region

B_D : error rate in the disparity discontinuity region

Conclusion

We proposed a new window-based stereo matching algorithm, which computes the disparity map using a weighted average of costs aggregated by various window sizes from large to small. We have designed C++ programs to evaluate the performance compared with the conventional algorithms. The proposed algorithm decreases error rates of the disparity map in both disparity continuity and discontinuity regions. In addition, the algorithm generates a better disparity map than the coarse-to-fine algorithm.