Computer Vision

Stereo Matching

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1. Disparity Computation

1.1 Implementation

After rectifying two images, a stereo matching method using winner-takes-all rule is implemented. Within disparity range, each offset, d is used to shift one image and then the SSD is computed for this image pair. Then perform a convolution using average filter with determined window size on computed image difference. Comparing the current result with the previous result (using previous offsets), the one with smaller difference is considered as 'winner' and the corresponding offset is considered as 'disparity'.

1.2 Result and Discussion

As shown in Figure 1, results of winner-takes-all method with different window size(3x3, 5x5, 7x7, 20x20) are plotted. When window size is small, the disparity map looks not smooth as there are many depth continuities. When using a larger window size like 20x20, disparity map looks more smooth. Generally, the differences of disparity with different window size are very obvious.

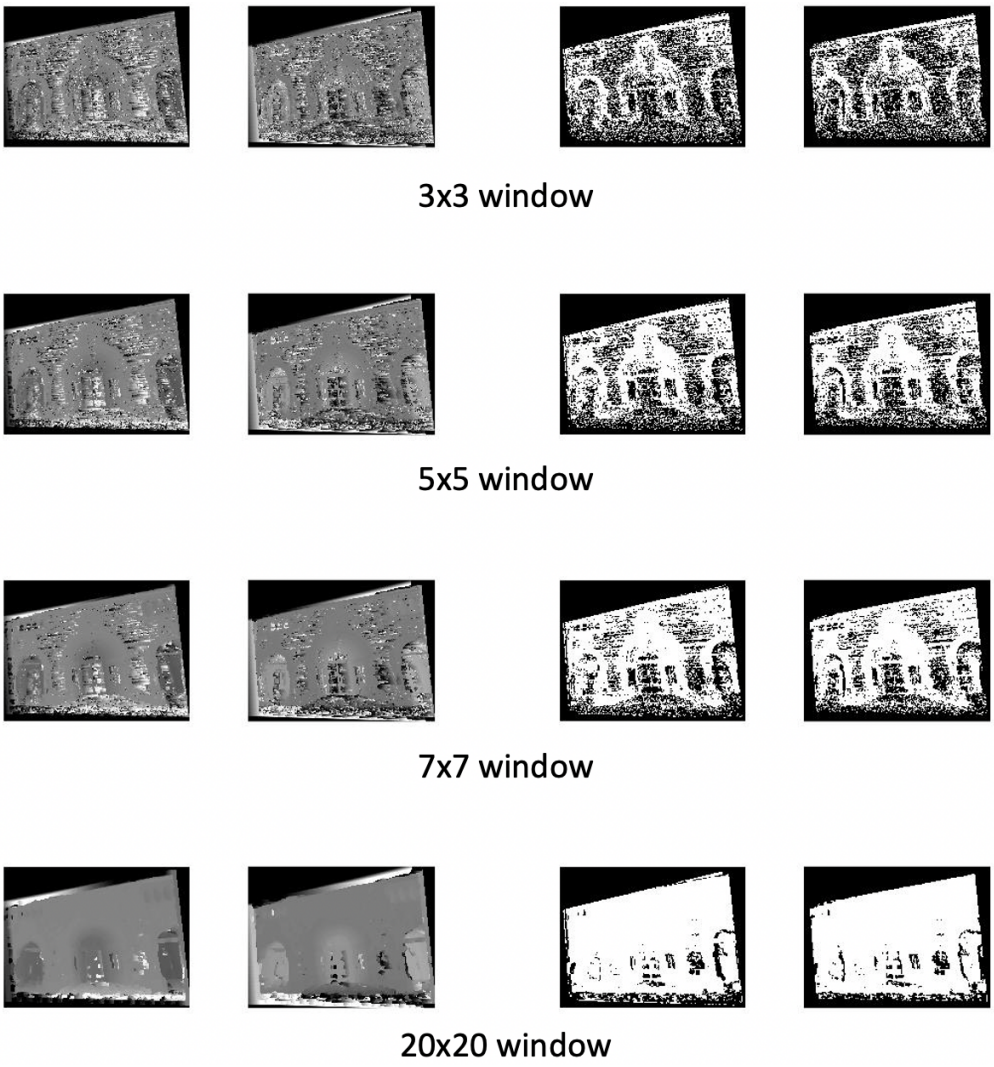

Figure 1: Result of winner-takes-all

2. Graph-Cut

2.1 Implementation

If treat disparity computation as graph labelling problem, Graph-cut can be used here. Graph-cut method will try to minimize an energy function: $E(f) = E_{cost}(f) + E_{smooth}(f)$ so both data cost and smoothness will be considered. The assumption is that nearby pixels should have similar disparity. In my implementation, the computation process for cost term is: for each possible offset, shift one image and compute SSD as image difference. Then use average filter for convolution. The result of cost is stored in a matrix with size MxNxL, MxN is the image size and L is the label size (disparity range).

The smoothness term is initialized as a square matrix (LxL) filled with ones, except for diagonal elements, which are zero.

2.2 Result and Discussion

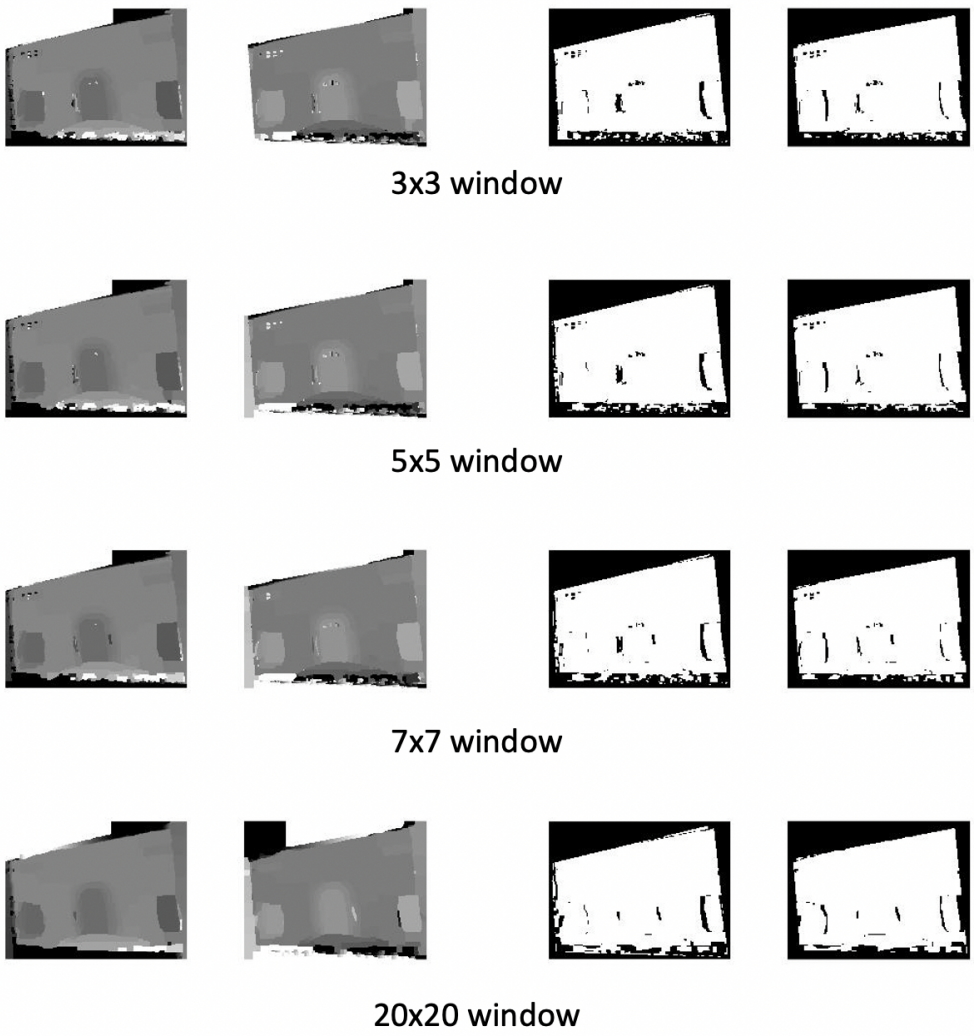

Figure 2: Result of Graph-cut

As shown in Figure 2, results of Graph-cut method with different window size (3x3, 5x5, 7x7, 20x20) are plotted. Comparing to the results of winner-takes-all, the differences between disparity maps with different window size are much smaller. Even with a small window size, 3x3, Graph-cut can produce smooth results. This can be explained by the inclusion of smoothness term in Graph-cut computation. When window size increases, the disparity map becomes more smooth but the change is small.

The results of Graph-cut are generally better than those of winner-takes-all. However, considering the running time, winner-takes-all method can take an advantage.

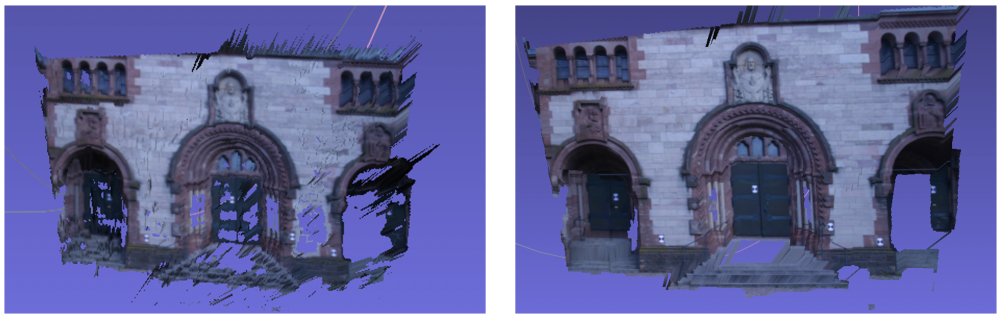

Figure 3: Comparison of 3D model of winner-takes-all and Graph-cut

Using resulted disparity map and camera parameters, dense point clouds are reconstructed. As shown in Figure 3, the 3D model from results of winner-takes-all and Graph-cut are generated. (left one is winner-takes-all and right one is Graph-cut) The window size used here is 20x20. The 3D model of Graph-cute is more complete and more smooth than that of winner-takes-all while the 3D model of winner-takes-all has many holes and strange outlier points. Thus, the reconstruction from Graph-cut is better.

3. Automatic Disparity Range

3.1 Implementation

With $getClickedPoints.m$, all points with marker on the images are manually selected. Then the absolute differences between image coordinates in two images are computed and the ceil integer of the largest absolute value is treated as the maximum offset. Besides, a buffer offset is defined for disparity range: $disparity\ range = -(buffer + max\ offset) : (buffer + max\ offset)$. Here the buffer value is defined as $\frac{max\ offset}{3}$. The resulted disparity range is from -19 to 19, which is about half of the fixed range used before, from -40 to 40.

3.2 Result and Discussion

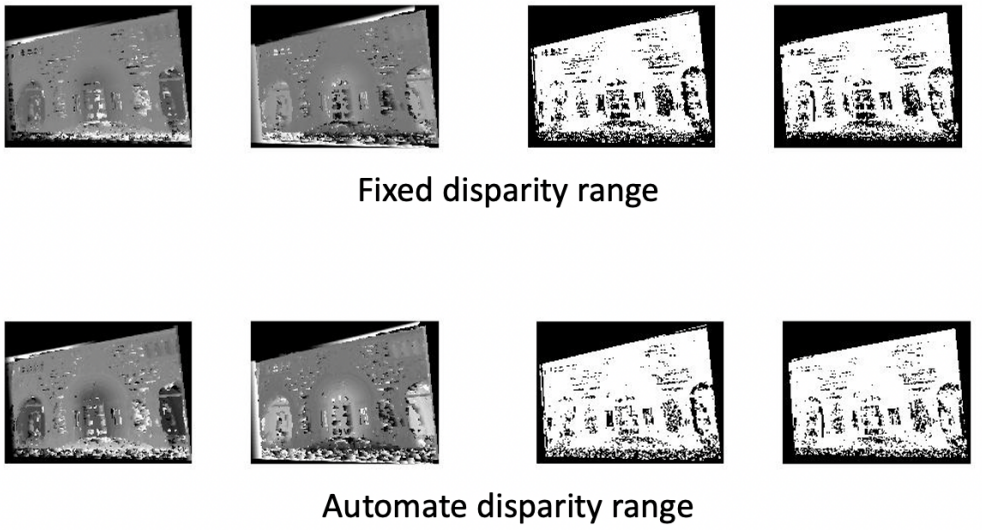

Figure 4: Comparison of fixed and automate disparity range (winner-takes-all)

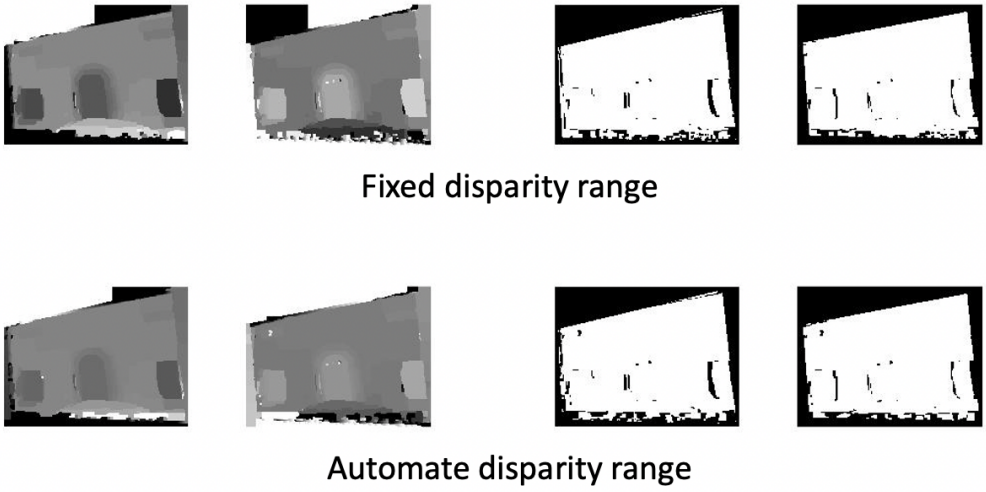

Figure 5: Comparison of fixed and automate disparity range (Graph-cut)

As shown in Figure 4 and Figure 5, results of winner-takes-all and Graph-cut with fixed disparity range (-40:40) and generated disparity range (-19:19) are plotted. Although the generated range from point correspondence is just half of fixed range, the results look very similar, which means using generated range is reliable and more efficient.