Stereo Correspondence

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Assumption : For both the SSD and graph cut algorithm Images have been pre rectified to make use of the epipolar constraint.

Simple Sum Squared Difference

Description : It's a very basic method which compares the pixels within a window in both the images along the epipolar line. Window around pixel p and q are compared using Sum of Squared Differences(SSD)

Implementation

Both the images are converted to grayscale, Window(m*m size) around each $pixel_L$ (X,Y_L)in the left image is compared with a window of similar size around $pixel_R$ (X,Y_r) along the epipolar line in the right image. The windows are compared using SSD as shown below.

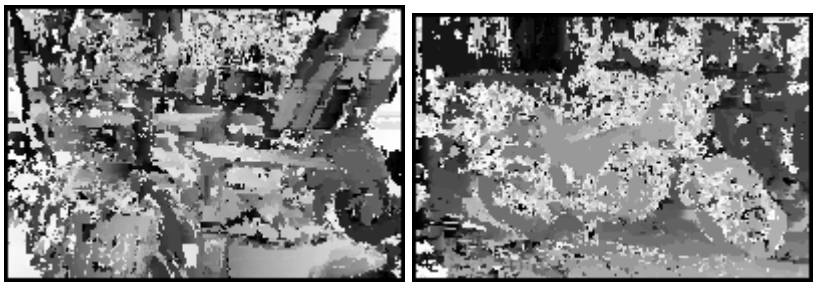
$$S_{tx}(r,\ c) = \sum_{j=0}^{tplRows-1} \sum_{i=0}^{tplCols-1} \left[t(j,\ i) - x\left(r + j - \frac{tplRows}{2},\ c + i - \frac{tplCols}{2}\right) \right]^2$$

Pixels corresponding to minimal SSD is considered to be a match and disparity map for that pixel is set to the $abs(Y_L - Y_r)$
SSD is calculated around a window to minimize false correspondence.

Tunable Parameters and effect

Size of the windows over which SSD is calculated for my implementation , I used 5*5
Smaller Window size provides better precision but is very sensitive to noise.
Larger Window size is robust to noise but reduced precision

Results



Adirondack Motorcycle

Analysis

1. Since SSD doesn't handle occlusion it assigns a corresponding pixel in the right image for all pixels in the left image as a result some value disparity set may be wrong , which we can see in the form white patches at places where there are occlusion.
2. At areas where the surface is uniform SSD may match against a wrong pixel which may be before the actual pixel at those spots we can observe black patches.
3. SSD doesn't take into account disparity constraint among the neighboring pixels, in graph cut method there is a penalty if the disparity values fluctuate too much in the neighbouring pixel

Energy minimization using Graph cut

Description : This approach is based on paper by V. Kolmogorov and R. Zabih[3]. It treats stereo correspondence as an energy minimization problem.

Each configuration *f* under which correspondence among pixels in both the images can be established has an associated energy term , using graph cut max flow , this algorithm tries to finds the configuration *f,* which has the minimum energy term.

Energy term has four terms and each term promotes a desired property of the configuration

$$E_{(f)} = E_{data(f)} + E_{occlusion(f)} + E_{smoothness(f)} + E_{uniqueness(f)}$$

$E_{data(f)}$ = measures how well matched pixels fit , better the matches in terms of grayscale intensity smaller the data term

$E_{occlusion(f)}$ = measure the number number of pixels which have not been assigned(occluded pixels) , fewer the occluded pixel smaller would be this term

$E_{smoothness}$ = this term tries to leverage the fact that neighbouring pixels has similar disparity value , hence penalizes high disparity jumps among neighbouring pixel.

$E_{uniqueness(f)}$ = this term penalizes non unique correspondence a pixel in the left image corresponds to multiple pixels in the right images

Implementation

Graph Construction:
For each disparity value(alpha) we construct a graph , initial disparity map is set to occluded because there are no active assignment

Adding Nodes in the graph :

For each pixel in the left image there are two cases

Pixel is occluded: that means there is no active assignment for the pixel, if pixel + alpha exists in the right image an inactive assignment node is created.

Pixel is not occluded: this means that there is a unique assignment for this pixel. If the disparity for this pixel is equal to alpha , that means there is an active assignment and new node is constructed

Adding Edges to the graph

Energy term for data , occlusion, smoothness acts as weights for edges between terminal and non terminal nodes

Energy term for smoothness and uniqueness appear in the edges between non terminal nodes

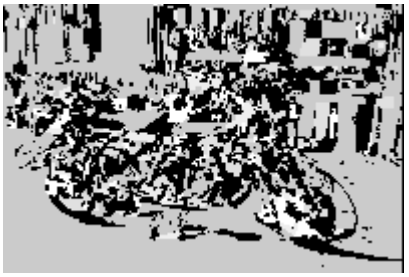
Once the graph is constructed max flow algorithm is launched to get the cut of the minimal cost of the graph by maximizing the flow

Updating the disparity Map

For each pixel in the left image if active and inactive assignment is VAR_ALPHA then disparity for that pixel is set to alpha

Results:

Adirondack



Motorcycle

Results

1. The results don't look great because a large number of pixels were tagged occluded, since i initialized the disparity set to occluded but were not assigned any active assignments

References

1. http://dev.ipol.im/~morel/Soutenances%20stages%20licence%202010/4_soutenance%28L%E9ger%2CPumir%2CTan%29%20version%20finale.pdf

2. http://www.academicjournals.org/app/webroot/article/article1380810673_Marghany%20et%20al.pdf

3. Kolmogorov and Zabih's Graph Cuts Stereo Matching Algorithm

4. https://github.com/pmonasse/disparity-with-graph-cuts