Fusion of Median and Bilateral Filtering for Range Image Upsampling

Project ID: 2

Github: https://github.com/Digital-Image-Processing-IIITH/dip-project-paka

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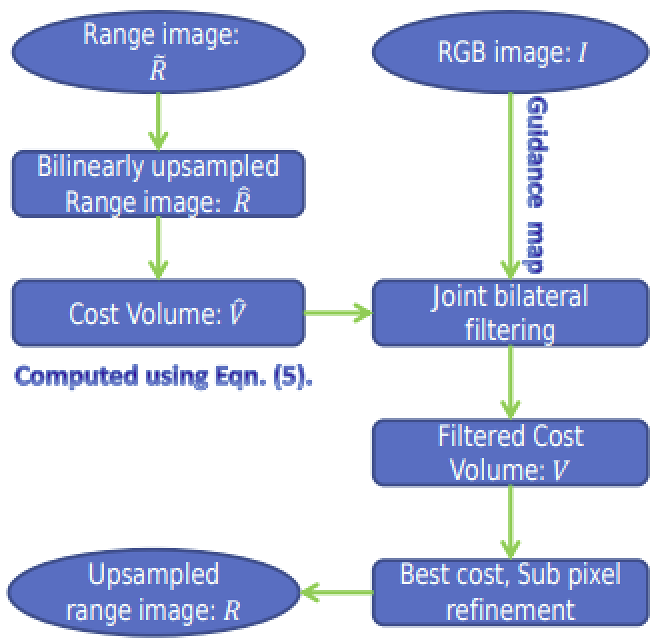
Main Goals

- Enhance the spatial resolution of depth images that have been upsampled from a lower resolution, using a high resolution RGB image as a guide.
- Perform this in a fashion that is less computationally expensive.

Problem Definition and Approach

Problem - Formulate an upsampling method to enhance the spatial resolution of depth images, given a low-resolution depth image from an active depth sensor and a potentially high-resolution color image from a passive RGB camera.

Approach - The paper aims to optimise an existing method which generates a cost volume for the upsampled method and applies a joint bilateral filter to each slice of the cost volume, where the eventual formulation simplifies as an adaptive cost aggregation problem where the support weights are calculated using a bilateral filter kernel.



The computation cost of this method is quite high as the main computation resides in the use of joint bilateral filtering. Let the number of depth hypotheses used to create the cost volume V^ be L, then L joint bilateral filtering processes will be required.

So, A hierarchical approach has been suggested to reduce the computational complexity. We start from the lowest resolution (the resolution of the original depth image R˜), and hierarchically estimate the depth values for the mis-sampled pixels by the following equation -

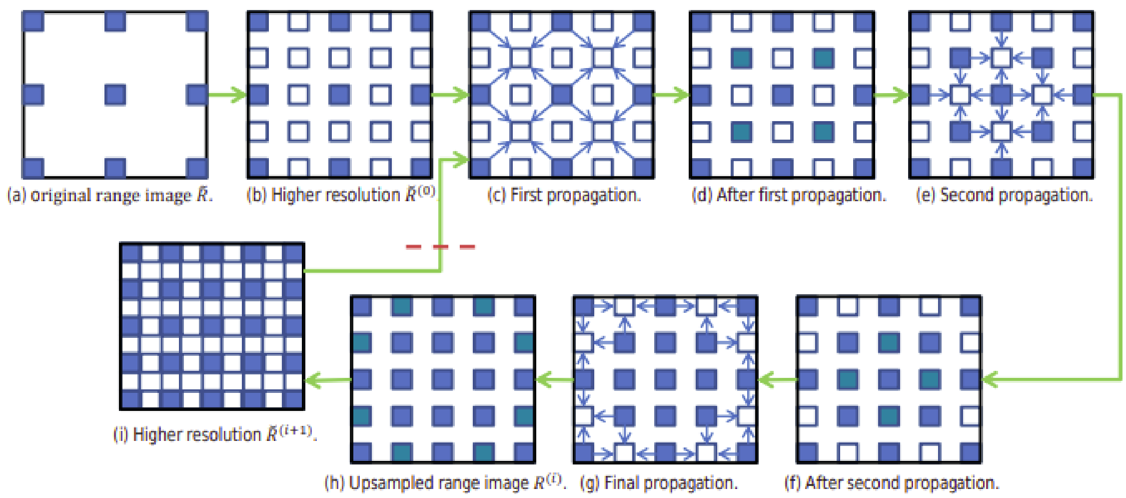
$$R_{\mathbf{x}}^{(0)} = \arg\min_{d \in \vec{d}_{\mathbf{x}}} \sum_{\mathbf{y} \in N(\mathbf{x})} \lambda(\mathbf{y}) f_S(\mathbf{x}, \mathbf{y})$$

$$f_R(I_{\mathbf{x}}^{(0)}, I_{\mathbf{y}}^{(0)}) \min\left(\eta \mathcal{L}, |d - \check{R}_{\mathbf{y}}^{(0)}|\right),$$

$$\lambda(\mathbf{y}) = \begin{cases} 1 & \text{if } \mathbf{y} \in \mathcal{B}, \\ 0 & \text{else.} \end{cases}$$

Considering all the mis-sampled pixels as the white squares, for every white pixel x which has four blue neighbours, we estimate its depth value by the above equation where dx denote a vector comprising of the four depth values of the four blue neighbors and B denote the collection of all pixels with depth values (blue squares).

Below is a picturesque representation of the same -



The above image shows one hypothesis. This process is repeated multiple times to increase the accuracy of the output image.

Dataset

The authors of the paper used the Middlebury datasets (https://vision.middlebury.edu/stereo/data/scenes2006/) to test their algorithm. Hence we too shall use this set for experimentation and verification.

Experimentation and Expected Results

- Our ground truth shall be depth images from the Middlebury set.
- These images shall be downsampled to obtain our input depth images.
- The input high resolution RGB image serves as a guide image.

- The hierarchical method of upsampling is then applied to our depth image, with one iteration of working up to the resolution of the RGB image serving as one depth hypothesis.
- A claim made in the paper is that after 5 depth hypotheses, the reduction in percentage of missampled pixels is very small and exponentially decreases. We shall test and verify this claim.
- We shall also test whether differences in parameters for the bilateral filter affect our output, and whether there exist global values that work for all images.

Project Milestones and Timeline

9th November,2021	Project Proposal Submitted
17th November,2021	Coding Phase Completed
24th November,2021	Debugging, Experimentation
27th November,2021	Analysis, Report Generation
29th November,2021	Code Freeze
1st December, 2021	Final Submission