Intensity Guided Depth Upsampling by Residual Interpolation

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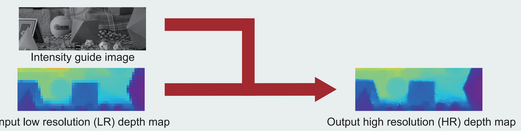
Introduction

- Existing depth acquisition systems generally have limited resolution.
- Depth upsampling procedure is a highly demanded task in many fields including computer vision and robotics.

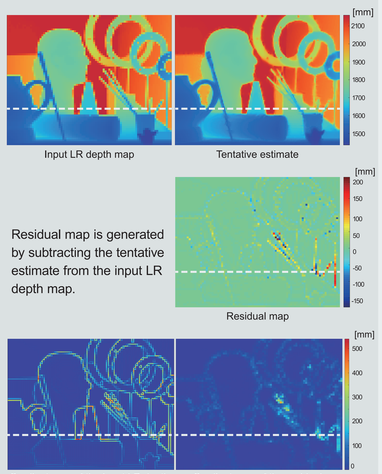


The Idea of Residual Interpolation

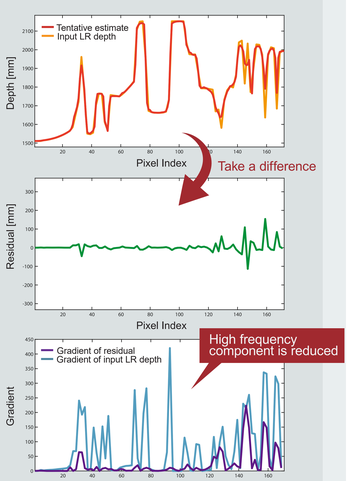
Residual Interpolation [3] is motivated from the two observations

- When an input image doesn't have high frequency component, interpolation process is performed more accurately.
- The residual map becomes smooth when there are correlations between a guide image and a depth map.

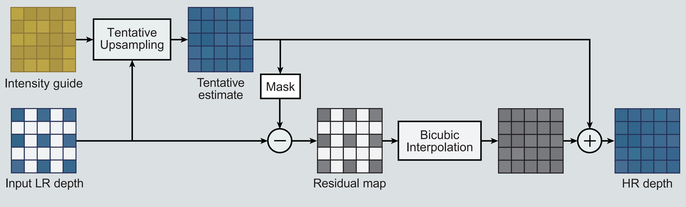
Actual examples

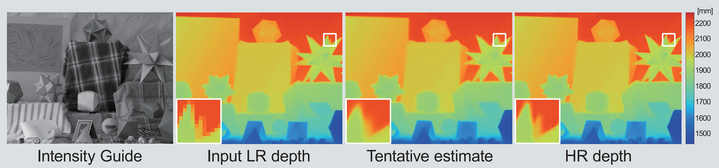


Sectional views in the dashed line



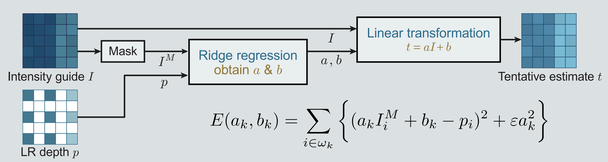
Proposed Algorithm





Tentative Upsampling

Assuming that the input LR depth p can be expressed as local linear transformation of the guide image I, the coefficients are obtained by minimizing the cost function.



$$E(a_k, b_k) = \sum_{i \in \omega_k} \left\{ (a_k I_i^M + b_k - p_i)^2 + \varepsilon a_k^2 \right\}$$

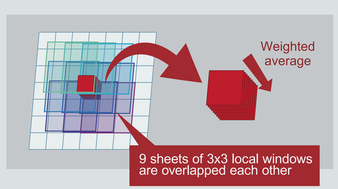
The local windows are overlapped each other. Therefore, tentative estimate is obtained as follows by taking the weighted average of overlapped coefficients.

$$t_k = \bar{a}_k I_k + \bar{b}_k$$

where

$$\bar{a}_k = \frac{\sum_{i \in \omega_k} W_i a_i}{\sum_{i \in \omega_k} W_i}, \quad \bar{b}_k = \frac{\sum_{i \in \omega_k} W_i b_i}{\sum_{i \in \omega_k} W_i}$$

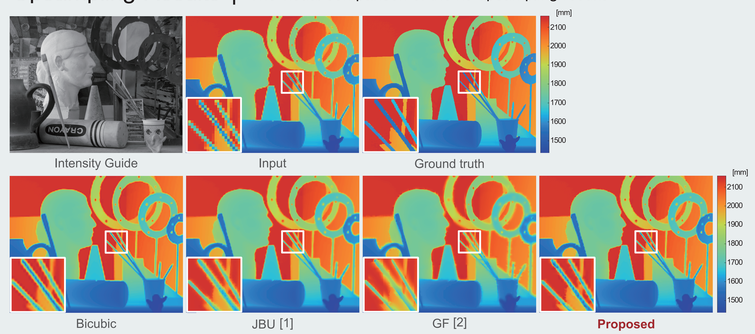
$$W_i = \frac{1}{\max\left(\frac{1}{|\omega_i|} \sum_{j \in \omega_i} (a_i I_j^M + b_i - p_j)^2, \ \delta \right)}$$



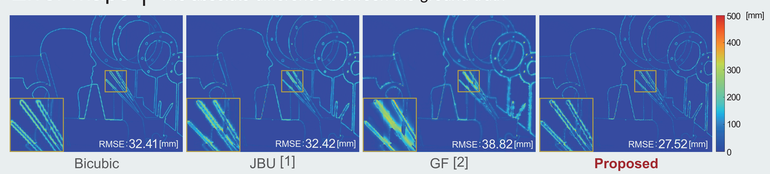
Experimental Results

The qualitative and quantitative comparison on the Middlebury dataset [4].

Upsampling Results | The visual comparison of the x8 upsampling results



Error maps | The absolute difference between the ground truth



Numerical Performance | RMSE [mm]

	Art				Books				Moebius				Average			
Algorithms	x2	x4	x8	x16	x2	x4	x8	x16	x2	x4	x8	x16	x2	x4	x8	x16
Bicubic	18.13	23.31	32.41	47.71	7.15	9.28	13.09	17.63	7.13	9.06	12.45	18.21	10.80	13.89	19.32	27.85
JBU [1]	18.22	23.66	32.42	47.07	7.23	9.58	13.05	17.81	7.55	9.99	13.74	19.69	11.00	14.41	19.73	28.19
GF [2]	19.63	26.84	38.82	55.29	7.94	11.12	15.58	22.18	8.52	11.90	16.83	24.56	12.03	16.62	23.74	34.01
Proposed	**17.02**	**20.41**	**27.52**	**40.32**	**6.89**	**8.36**	**11.45**	**15.80**	**7.06**	**8.73**	**11.76**	**16.92**	**10.32**	**12.50**	**16.91**	**24.35**

References

The MATLAB® code of our proposed method is available on the project page !
http://www.ok.ctrl.titech.ac.jp/res/DSR/RI.html

[1] J. Kopf, M. F. Cohen, D. Lischinski, and M.Uyttendaele, "Joint bilateral upsampling." ACM TOG, vol. 26, no. 3, 2007.
[2] K. He, J. Sun, and X. Tang, "Guided image filtering." In ECCV, pp. 1-14, 2010.
[3] D. Kiku, Y. Monno, M. Tanaka, and M. Okutomi, "Residual interpolation for color image demosaicking." In ICIP, pp. 2304-2308, 2013.
[4] D. Scharstein and C. Pal, "Learning conditional random fields for stereo." In CVPR. 2007.