High-dynamic-range Imaging for Depth Maps

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Motivation

- High-dynamic-range (HDR) imaging is based on the idea of cherry picking 2D images from different settings.
- This idea is also compelling for depth maps. I propose a method to merge depth maps from different settings (i.e. frequencies) into a depth map adopting the technique from HDR imaging.

Related Work

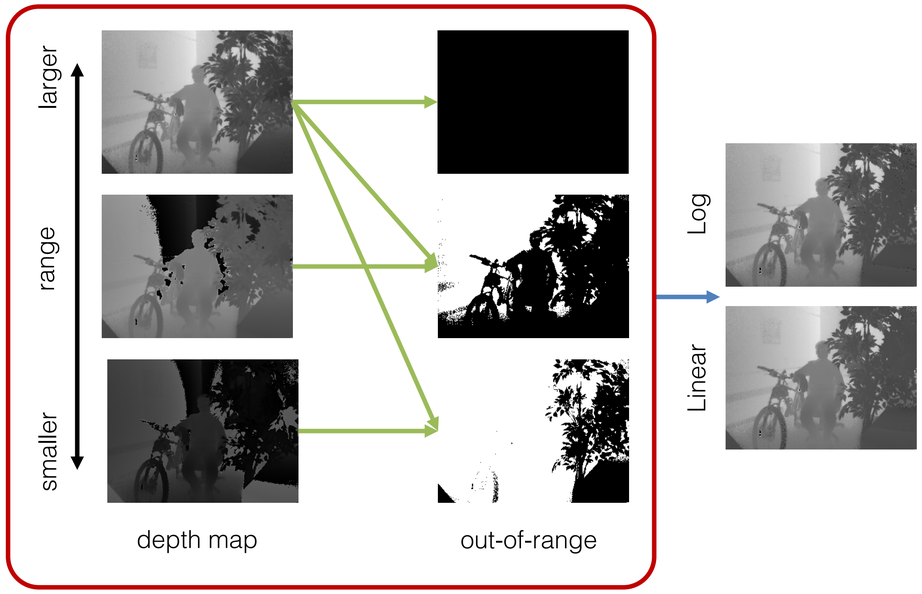
This work can be considered as a "phase unwrapping" [1] algorithm, which is an attempt to overcome the nature of time-of-flight depth cameras since when they are based on sinusoidal signals, their result gets limited to the signals' wavelength. The optimization technique comes from [2]. While [2] is based on a log-scale model, our method also utilizes a linear model, which is based on the nature of time-of-flight sensors.

References

[1] O. Choi, S. Lee, and H. Lim. "Interframe consistent multifrequency phase unwrapping for time-of-flight cameras," in Optical Engineering 52 (5).

[2] P. E. Debevec and J. Malik. "Recovering high dynamic range radiance maps from photographs," in Proc. SIGGRAPH 2007, San Diego, California, August, 2007.

New Technique



- Out-of-range Detection: Using the depth map with the largest range, to detect pixels out of range.
- Merge: The optimization technique used for HDR imaging, ignoring pixels out-of-range.

Merge formulas for each models

Log: $\hat{X} = argmin_X \sum_i w_i \left(\log(D_i) - \log\left(\frac{X}{r_i}\right)\right)^2 = \exp\left(\frac{\sum_i w_i(\log(D_i) + \log(r_i))}{\sum_i w_i}\right)$

Linear: $\hat{X} = argmin_X \sum_i w_i \left(D_i - \frac{X}{r_i}\right)^2 = \frac{\sum_i \frac{w_i D_i}{r_i}}{\sum_i \frac{w_i}{r_i^2}}$

$w_i = \exp\left(-4\frac{(D_i - 0.5)^2}{0.5^2}\right)$, when in range, $w_i = 0$ when out of range.

D_i: normalized depth in range i, r_i: max distance of range i

Experimental Results

In region 1, compared to the baseline method—the default method of OPT8241 from Texas instruments—the proposed method is more robust. Also, in region 2, it contains more details.