Adaptive bilateral filtering for range images

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Abstract

We propose an improvement for range images of the standard bilateral filter consisting in adapting it locally to the distribution of the range noise at each pixel.

Introduction

In recent years, real-time, high resolution 3D range cameras have become widely affordable. For example, the structured-light Microsoft Kinect is able to deliver 640x480 pixels depth maps at 30 fps and the time-of-flight PMD[vision] CamCube up to 200x200 pixels at 30 fps. The noise affecting the range values provided by such cameras is not identically distributed across the images and depends on several factors such as the depth and the materials composing the scene.

Previous works

To the best of our knowledge, previous methods for filtering noise out of range images either target a single type of range cameras [2], or do not adapt to local noise as in the case of the standard bilateral filter [1].

Estimating the uncertainty

To adapt the filter to the local range noise level, we use an uncertainty measure at each pixel $\boldsymbol{x}$: we choose the standard deviation $\sigma_{cam}(D(\boldsymbol{x}))$ of the depth $D(\boldsymbol{x})$. One finds in the literature two expressions for σ_{cam} .

1. For a time-of-flight camera, Frank [3] gives:

$$\sigma_{ToF}(D(\boldsymbol{x}))=\kappa_{ToF}\frac{1}{A(\boldsymbol{x})}$$

where A is the amplitude image given by time-of-flight cameras and κ_{ToF} a proportionality constant.

2. For the Microsoft Kinect, Khoshelham [4] gives:

$$\sigma_{kinect}(D(\boldsymbol{x}))=\kappa_{kinect}D(\boldsymbol{x})^2 .$$

Adaptive bilateral filter

The output of the standard bilateral filter at pixel $\boldsymbol{x}$ is

$$\hat{D}(\boldsymbol{x})=\frac{\sum_{y\in N_x} D(\boldsymbol{y})f_s(\boldsymbol{x},\boldsymbol{y})f_r(D(\boldsymbol{x}),D(\boldsymbol{y}))}{\sum_{y\in N_x} f_s(\boldsymbol{x},\boldsymbol{y})f_r(D(\boldsymbol{x}),D(\boldsymbol{y}))}$$

where f_s and f_r are Gaussian functions with standard deviations σ_s and σ_r respectively and $N_{\boldsymbol{x}}$ a set of pixels in the neighborhood of $\boldsymbol{x}$.

Our innovation consists in adapting the function f_r to include the standard deviation of the pixel as follows:

$$f_r(D(\boldsymbol{x}),D(\boldsymbol{y}))=e^{-\frac{(D(\boldsymbol{x})-D(\boldsymbol{y}))^2}{2(\sigma_r*\sigma_{cam}(D(\boldsymbol{x})))^2}}$$

Our method has the same parameters as the standard bilateral filter: the standard deviations σ_s and σ_r .

Conclusion

In contrast to other filters, our new adaptive bilateral filter preserves the edges in a range image while removing noise.

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Figure 1: (a) Microsoft Kinect and (b) PMD[vision] CamCube cameras.

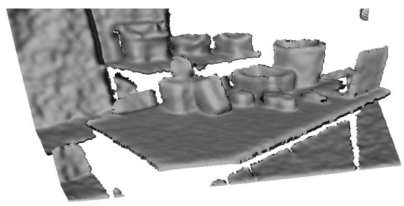

Figure 2: Range image captured by the Microsoft Kinect, filtered with our algorithm and displayed in 3D using MeshLab.

References

1. C. Tomasi et al. International Conference on Computer Vision, 1998, page 839-846
2. M. Frank et al. Optical Engineering, Vol. 8, No. 7 (2009)
3. M. Frank et al. Optical Engineering, Vol. 8, No. 1 (2009)
4. K. Khoshelham, ISPRS Workshop on Laser Scanning, XXXVIII-5/W12 (2011)