How can we reduce the effect of noise on 3D Gaussian Splats?

T.G. Meijer[1]

[1] Bsc. Computer Science & Engineering, TU Delft - t.g.meijer@student.tudelft.nl

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1 Background

Multi-view image recognition is crucial for developing autonomous navigation and robotics by enabling 3D model creation from multiple 2D images. This technology helps machines better understand and interact with their environment. However, real-world challenges like motion blur and lighting change impact the accuracy of these models, which results in noise in the point clouds. So how can we reduce the effect of **motion blur** and **varying lighting conditions** in 3D Gaussian splatting? The repository can be found on GitHub[4].

2 Methodology

With the help of Blender [1] we will construct 3 sets of images: normal, noised and denoised. We then construct 3D Gaussian splats from these sets, and evaluate them.

Figure: Original cube, blurred cube and deblurred cube using DeblurGAN. [3]

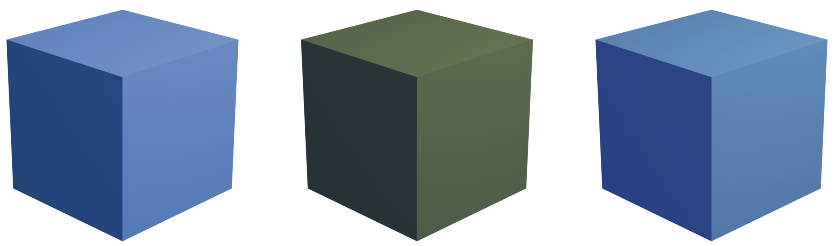

Figure: Original cube, colored cube and recolored cube using the Color Matcher algorithm [2]

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3 Evaluation methods

- **Peak Signal-to-Noise Ratio (PSNR)** is used to measure the quality of the reconstructed image compared to the original.
- **Delta E (CIE76)** is used to measure the color difference between the original and recolored images in the LAB color space.
- The **Structural Similarity Index (SSIM)** measures the similarity between two images.
- The **Cumulative Distribution Function (CDF)** is used to analyse the distribution of distances between the points in the point clouds.

4 Results and Discussion

Regarding motion blur, with a visual comparison we can see the improvements of using DeblurGAN, but it is difficult to statistically compare 3D point clouds. We can try using a CDF, and if the curve is closer to the upper-left corner it indicates better performance.

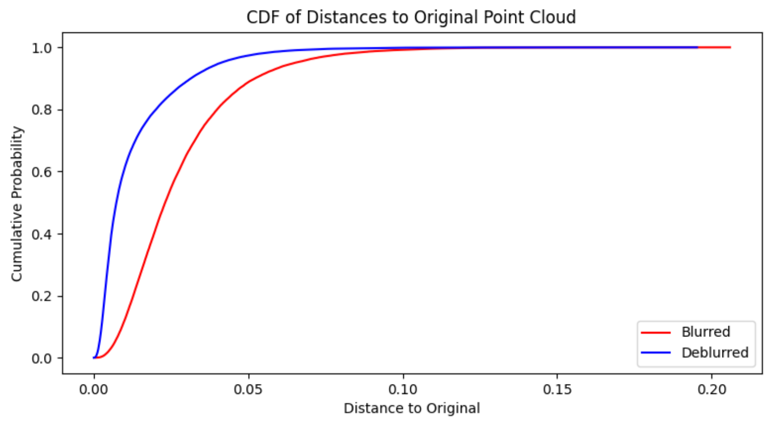

Figure: CDF of comparison between blurred and deblurred v.s. original point cloud.

Regarding varying lighting conditions, in the following table the results of the algorithms are displayed. The relatively low ΔE value, together with the high SSIM and PSNR indicates that both methods have a positive impact.

Method	ΔE	SSIM	PSNR
Cube with strong yellow light	27.24	0.94	15.49 dB
Numpy mean algorithm	4.03	0.99	33.66 dB
color matcher algorithm	7.04	0.89	28.31 dB

Table: Quantitative comparison of recoloring methods, which indicate that both methods result in an improved recoloring of the image.

5 Conclusion

With these findings, advancements have been made in optimizing Gaussian Splatting for multi-view image recognition. The integration of advanced de-noise methods and color consistency techniques make Gaussian Splatting a more effective tool in diverse environmental and motion conditions.

Motion Blur: The application of advanced deblurring techniques, particularly Deblur-GAN, slightly improves the clarity of motion-blurred images. this methods demonstrate substantial potential in approximating the original details, thereby enhancing the accuracy of 3D reconstructions.
Lighting variation: The Numpy Mean Method and Colormatcher demonstrate notable improvements in maintaining color fidelity across varied lighting conditions. These techniques are crucial for ensuring reliable feature matching and high-quality 3D models.

6 Limitations

- Despite the effectiveness of the deblurring techniques evaluated, motion blur cannot be fully reconstructed.
- Recolor methods are not always perfect and can sometimes introduce artifacts or fail to achieve exact color consistency.

References

[1] B. O. Community. *Blender - a 3D modelling and rendering package*. Blender Foundation. Stichting Blender Foundation, Amsterdam, 2018.

[2] C. Hahne and A. Aggoun. "PlenoptiCam v1.0: A Light-Field Imaging Framework". In: *IEEE Transactions on Image Processing* 30 (2021), pp. 6757–6771. DOI: 10.1109/TIP.2021.3095671.

[3] O. Kupyn, V. Budzan, M. Mykhailych, D. Mishkin, and J. Matas. "DeblurGAN: Blind Motion Deblurring Using Conditional Adversarial Networks". In: *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*. June 2018.

[4] T. Meijer. *How can we reduce the effect of noise on 3D Gaussian Splats?* Version 1.0.0. June 2024.