Depth of Field Rendering Algorithms for VR

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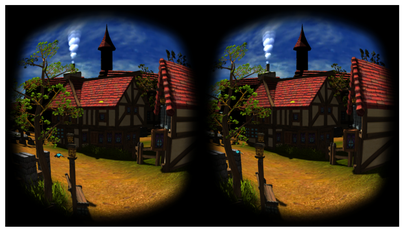
Motivation

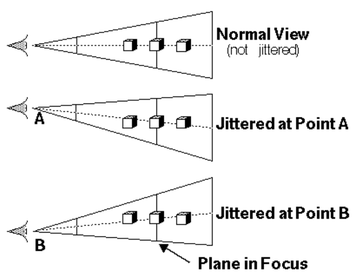
•Visual experience in VR is very different from natural viewing conditions (entire scene is in focus)
•DoF rendering has shown to be an effective depth cue [1]
• Has been shown to reduce the fusion time of images in stereoscopic displays [2]
• Natural blurring is associated with reduced levels of visual fatigue [3]
• Latency is critical in VR applications

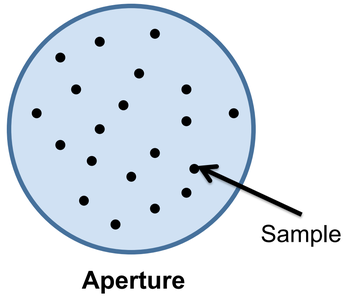
vs



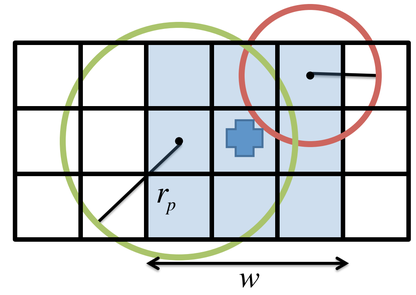
Overview of Algorithms

Ray Tracing (Reference)





Non-linear Filter [4]



r_p = circle of confusion

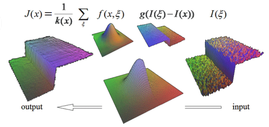
w = filter width

Bilateral Filtering

$$I^{filtered}(x) = \frac{1}{W_p}\sum_{x_i \in \Omega} I(x_i) f_d(\|d(x_i) - d(x)\|) \cdot g_s(\|x_i - x\|)$$

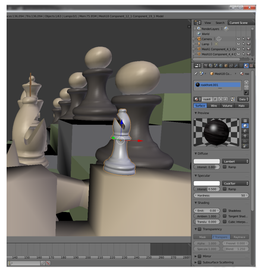
$$W_p = \sum_{x_i \in \Omega} f_d(\|d(x_i) - d(x)\|) \cdot g_s(\|x_i - x\|)$$

Adaptive Recursive Filtering [5]



$$I_i^{'}(p) = (1 - \alpha(p, pl)) \bullet I_i(p) + \alpha(p, pl) \bullet I_i^{'}(pl)$$

DoF Rendering Pipeline



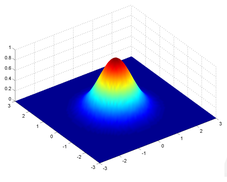
Render to FrameBuffer

RGB Image

Depth Map

Estimate Focal Plane

Apply Blur



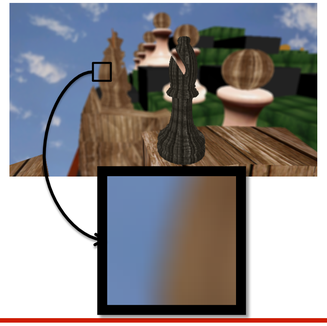
Experimental Results

	Non-Linear	Bilateral	Recursive
PSNR (dB)	30.4325	27.7492	35.59
Time* (ms)	0.5**	0.0605	0.081937

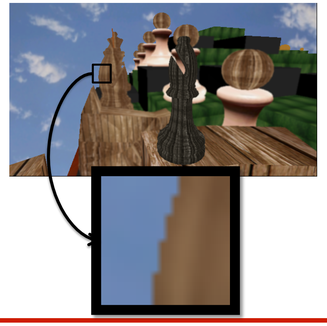
* Computed by computing per pixel time in Matlab

** Corresponds to 7.67 ms in OpenGL on GPU

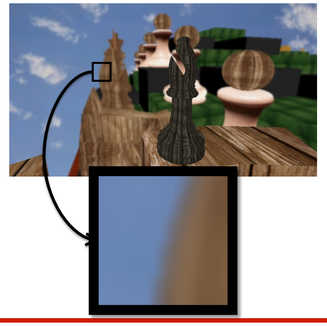
Non-linear



Bilateral



Recursive



Related Work

•[1] Michael Mauderer, Simone Conte, Miguel A. Nacenta, and Dhanraj Vishwanath. 2014. Depth perception with gaze-contingent depth of field. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.*
• [2] Maiello, G., Chessa, M., Solari, F., Bex, P.J. (July 2014). Simulated disparity and peripheral blur interact during binocular fusion. *Journal of Vision*, 14(8):13.
•[3] Hoffman, D.M., Girshick, A.R., Akeley, K. & Banks, M.S. (2008). Vergence-accomodation conflicts hinder visual performance and cause visual fatigue. *Journal of Vision,* 8(3):33.
•[4] Zhou, T., Chen, J., Pullen, M. (2007). Accurate Depth of Field Simulation in Real Time. *Computer Graphics Forum*, 26(1), pp 15-23.
• [5] Shibiao Xu, Xing Mei, Weiming Dong, Xun Sun, Xukun Shen, and Xiaopeng Zhang. 2014. Depth of field rendering via adaptive recursive filtering. In *SIGGRAPH Asia 2014 Technical Briefs* (SA '14). ACM, New York, NY, USA, , Article 16 , 4 pages.