Volume Ray Casting quality estimation in terms of Peak Signal-to-Noise Ratio

N. Gavrilov and V. Turlapov

Lobachevsky State University of Nizhni Novgorod, Russia

Abstract

In spite of a large number of techniques aimed for improvement of Direct Volume Rendering (DVR) quality and performance proposed in the literature, there is a lack of approaches for numerical quality estimation of the images obtained by visualization of medical and scientific volumetric datasets. In this paper we propose a method to estimate sampling artefacts. Using the proposed estimation method we compare different RC algorithms to expose optimal ones in quality-performance criteria.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Picture/Image Generation—Viewing Algorithms; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Raytracing

1. Introduction

Nowadays there are a lot of GPU-based approaches allowing for interactive rendering [EHK*06]. In addition to different acceleration structures to improve rendering performance by empty space skipping, there are many approaches to improve rendering quality without significant performance loss [EHMDM08], [KHW*09]. Still there is not any method proposed in the literature to estimate the quality of the output generated by RC algorithm, there are no criteria by which we could compare different quality improvement techniques. Mostly researchers simply put images of competing algorithms side by side, appointing the human visual system to be the judge [MHB*00]. In this paper we propose a noise-based method to estimate sampling artefacts of RC. In addition we propose new RC rendering techniques and compare them with the pre-integrated rendering method [EHMDM08] in terms of quality and performance.

2. Ray Casting artefacts

Methods involving uniform sampling with post-classification invariably miss thin features along the ray path, omitting the desired surface features thus casing sampling artefacts [KHW*09]. The regularity of such artefacts has a wood-like appearance, which can be converted to noise by stochastic jittering of ray starting positions or other shifting strategies [Sch05]. For big datasets (of size greater than 512^3) or transfer functions that cause superficial thin slices the optimization of RC algorithm is needed to keep an acceptable rendering quality and performance.

There is also another important type of DVR artefacts which are introduced by the interpolation method – filtering artefacts, caused by tri-linear interpolation. Unfortunately they can not be randomized like sampling artefacts, but they can be significantly reduced by using B-splines interpolation [RtHRS08].

3. Quality measurement method

As we use stochastic jittering of rays' starting positions, sampling artefacts can be captured by the image noise measurement. We can obtain a set of rendered images of the same dataset from the same viewpoint with the same TF and other visualization settings, but we can still change the jittering pattern changing the seed for random values generation. We can consider the image pixels as a set of independent random values to measure the noise of each single pixel by evaluating the dispersion of its color C (we use YPbPr color space for the calculations below). We consider dispersion of C as an error in pixel (i, j), or as a level of its sampling artefact:

$$Error(i,j) = D(I(i,j)) = M(M(C(i,j)) - C(i,j))^2 \quad (1)$$

DOI: 10.2312/conf/EG2013/posters/007-008

Here M is the average color. To measure the noise level we use PSNR (Peak Signal-to-Noise Ratio) logarithmic decibel scale which is mostly used to measure the error introduced by images compression. In the volume rendering domain PSNR is mostly utilized to measure the error of 3d dataset compression [GS04], but not for the rendering quality estimation. We consider PSNR as a quality of the rendering algorithm, it is calculated as follows:

$$PSNR = 10log_{10}\left(\frac{MAX_C^2}{MSE}\right); MSE = \frac{1}{N}\sum_{i=0}^{n-1}\sum_{j=0}^{m-1} D(C(i,j)) \quad (2)$$

MSE is the mean-square error, MAX_C is the maximal length of color vector, equal to 1 in our case, N – number of non-background pixels, n and m are image width and height. Usually N=n*m, but in DVR case there are too many background pixels with a null dispersion. To avoid the quality overstatement these pixels should be ignored.

SR: 2.2; PSNR: 20dB; SR: 6.9; PSNR: 40dB;

Figure 1: *Quality maps and corresponding overall PSNRs for UDVR with different sampling rates (SR).*

We also use PSNR to estimate quality of each single pixel in order to build the quality map of the image which shows us areas of higher and lower rendering quality. The pixels with *PSNR > 40dB* have no noticeable noise – for these pixels the mean error is less than 1%. Areas where PSNR is less than 30dB contain rather noticeable noise. Figure 1 shows quality maps for different sampling rates.

3.1. Quality-Performance dependence

When comparing different quality improvement efficiency of methods it is necessary to consider not only quality but the rendering performance as well. We change RC sampling rate, thus varying rendering quality and performance. As the result, we obtain quality-performance dependence for each rendering method. Depending on rendering conditions we have obtained a set of dependencies. There are 4 cases: use/not use local shading and tri-linear/tri-cubic filtering. Mostly these two options define the optimal RC algorithm, while other visualization conditions do not have such influence on efficiency of a method. In figure 2 we present an example of dependencies we obtained in our experiments. Each line corresponds to a rendering method. We vary sampling rate from 1 to 8 samplings per voxel.

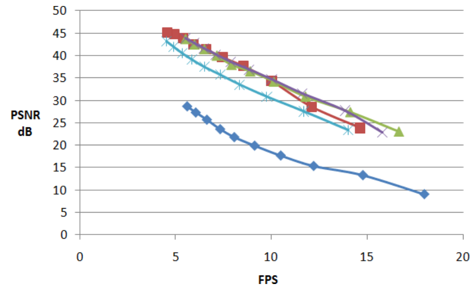

Figure 2: *Quality-Performance dependencies for different RC algorithms in case of using tri-cubic filtering and local shading. Blue and red plots represent unoptimized and preintegrated volume rendering algorithms correspondently.*

4. Conclusion

A new method for Ray Casting quality numerical estimation was proposed. By evaluating noise we calculate PSNR for each single pixel and for the whole image as well. The usage of PSNR allowed us to measure RC noise in decibel scale, and like in images compression domain, the desired quality lies in [30dB, 40dB] range.

References

[EHK*06] ENGEL K., HADWIGER M., KNISS J., REZK-SALAMA C., WEISKOPF D.: Real-time volume graphics. *Eurographics Association* (2006), 112–114. 1

[EHMDM08] EL HAJJAR J., MARCHESIN S., DISCHLER J., MONGENET C.: Second order pre-integrated volume rendering. In *Visualization Symposium, 2008. PacificVIS'08. IEEE Pacific* (2008), IEEE, pp. 9–16. 1

[GS04] GUTHE S., STRASSER W.: Advanced techniques for high-quality multi-resolution volume rendering. *Computers & Graphics 28*, 1 (2004), 51–58. 2

[Han10] HAND R.: High definition volume rendering from fovia, on the cpu.

[KHW*09] KNOLL A., HIJAZI Y., WESTERTEIGER R., SCHOTT M., HANSEN C., HAGEN H.: Volume ray casting with peak finding and differential sampling. *Visualization and Computer Graphics, IEEE Transactions on 15*, 6 (2009), 1571–1578. 1

[MHB*00] MEISSNER M., HUANG J., BARTZ D., MUELLER K., CRAWFIS R.: A practical evaluation of popular volume rendering algorithms. In *Proceedings of the 2000 IEEE symposium on Volume visualization* (2000), ACM, pp. 81–90. 1

[NIH08] NAGAYASU D., INO F., HAGIHARA K.: A decompression pipeline for accelerating out-of-core volume rendering of time-varying data. *Computers & Graphics 32*, 3 (2008), 350–362.

[RtHRS08] RUIJTERS D., TER HAAR ROMENY B., SUETENS P.: Efficient gpu-based texture interpolation using uniform b-splines. *Journal of Graphics, GPU, and Game Tools 13*, 4 (2008), 61–69. 1

[Sch05] SCHARSACH H.: Advanced gpu raycasting. *Proceedings of CESCG 5* (2005), 67–76. 1