EUROGRAPHICS 2017
V. Ostromoukov and M. Zwicker
(Guest Editors)

Volume 36 (2017), Number 2
STAR – State of The Art Report

EG STARs

Abstract

The ABSTRACT is to be in fully-justified italicized text, between two horizontal lines, in one-column format, below the author and affiliation information. Use the word "Abstract" as the title, in 9-point Times, boldface type, left-aligned to the text, initially capitalized. The abstract is to be in 9-point, single-spaced type. The abstract may be up to 3 inches (7.62 cm) long.
Leave one blank line after the abstract, then add the subject categories according to the ACM Classification Index (see http://www.acm.org/class/1998/).

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Picture/Image Generation—Line and curve generation

1. Introduction

2. Visibility Histograms and Visibility-Driven Transfer Functions

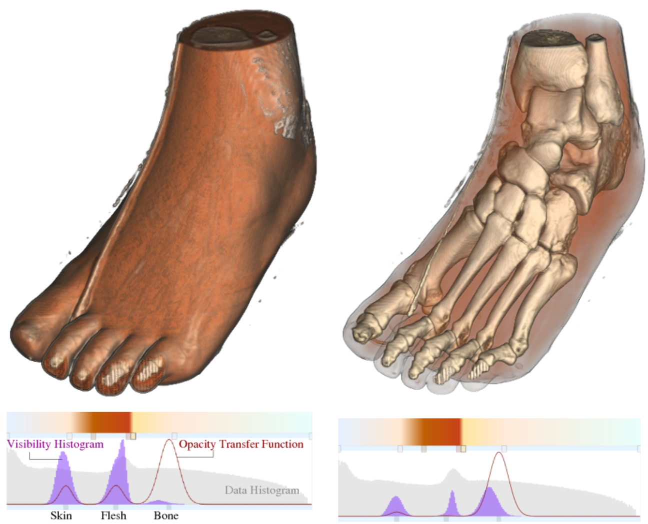
Visibility has been studied in measuring viewpoint quality [BS05] and enhancing ghost and cutaway views [VKG04] in volume visualization.

In traditional transfer function design, the visibility of structures revealed in volume rendering is a consequence of adjusting transfer function parameters, rather than a design parameter [PB13]. Correa and Ma [CM09] introduced visibility histograms to guide transfer function design for both manual and automatic adjustment. Visibility histograms (Figure 1), which summarize the distribution of visibility of voxels from a given viewpoint, are powerful feedback mechanisms of volume visualization [Ems08]. Visibility histograms encode the information required to measure the efficacy of transfer functions and are advantageous in guiding and automating the manipulation of transfer functions.

Wang et al. [WZC*11] extended the previous work on visibility histograms and proposed a feature visibility metric, in order to measure the influence of each feature to the volume rendered image. As shown in Figure 2, their approach allows the user to directly specify the desired visibility for the features of interest, and subsequently the opacity transfer function is optimized using an active set algorithm [Pol69].

Ruiz et al. [RBB*11] proposed an information-theoretic framework which obtains opacity transfer functions by minimizing the Kullback-Leibler divergence between the observed visibility distribution and a target distribution provided by the user. Later, Bramon et al. [BRB*13] extended this approach to visualize multimodal volume data.

Cai et al. [CTN*13] described a method to derive opacity transfer functions by minimizing the Jensen-Shannon divergence between the observed visibility distribution and a user-defined target distribution. The target distribution can be defined using Gaussian function weighting.

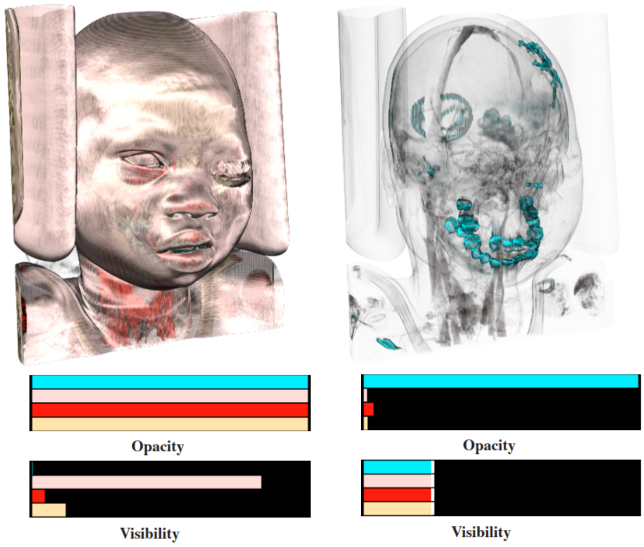


(a) A user-defined opacity transfer function and the initial visibility histogram

(b) Here the visibility histogram has been modified to match the user-defined opacity transfer function.

Figure 1: Visibility histograms [CM09]

In addition, various methods were proposed regarding the use of visibility for enhancing different aspects of volume visualization. Marchesin et al. [MDM10] introduced a volume rendering technique that manipulates the voxel opacity values in a view-dependent way, in order to enhance visibility of internal structures in the volume data set. Bronstad et al. [BATK12] described lo-



(a) Feature opacities are equal (b) Feature visibilities are equal

Figure 2: Opacities and feature visibilities of 4 features highlighted in different colors [WZC*11]

cal opacity transfer functions with feature detection along the ray profile implemented on the GPU. In their approach, visibility histograms are employed to access the performance of the feature detection algorithm.

Jung et al. [JKF12] presented a dual-modal visualization method, which uses visibility metrics to provide visual feedback regarding the occlusion caused by the volume data in one modal on the other modal. Jung et al. [JKE*13] extended visibility histograms to multimodal volume visualization. They demonstrated the use of visibility histograms together with region of interest segmentation was effective in visualizing PET-CT volume data sets.

Instead of computing the visibility of all voxels, Zheng et al. [ZCM13] employed local visibility histograms to ensure both the features of interest and contextual information are visible in multimodal volume visualization. Schlegel and Pajarola [SP13] proposed a visibility-difference entropy metric. They presented an automated approach using this metric for generating a set of transfer function candidates with high ratings and are strongly distinct in what they reveal.

Qin et al. [QYH15] presented the voxel visibility model as a quality metric for transfer function design. The voxel visibility model is a mapping function from data attributes of voxels to their visibility attributes. Instead of specifying transfer functions, this approach allows users to directly adjust the visibility of each voxel, and then the corresponding opacity transfer functions can be obtained by minimizing the distance between the desired voxel visibility distriubtion and the actual voxel visibility distribution.

2.1. Visibility-Based Sketching and Picking

The visibility of a sample refers to the alpha contribution of a sample to the final image, taking into account also the degree to which it is occluded by other samples in the view.

Guo et al. [GMY11] proposed a sketch-based manipulation technique for volume visualization based on clustering of depth, visibility, alpha and intensity. Subsequently, they described another sketch-based technique to specify local transfer functions for topology regions using contour trees [GY13].

Wiebel et al. [WVFH12] found that the user usually perceives features at a screen position with the highest visibility along the ray and they exploited this information in their volume picking technique. Based on the WYSIWYP technique, Stoppel et al. [SHW14] presented an algorithm called surfseek for selecting surfaces on the most visible features in direct volume rendering. The algorithm detects feature boundary points using WYSIWYP and then constructs a weighted graph and computes its minimal cut, from which it reconstructs the desired surface.

2.2. Conclusions

References

[BATK12] Bronstad E., Asen J., Torp H., Kiss G.: Visibility driven visualization of 3d cardiac ultrasound data on the GPU. In *Ultrasonics Symposium (IUS), 2012 IEEE International* (Oct. 2012), pp. 2651–2654. 1

[BRB*13] Bramon R., Ruiz M., Bardera A., Boada I., Feixas M., Sbert M.: Information theory-based automatic multimodal transfer function design. *IEEE Journal of Biomedical and Health Informatics 17*, 4 (2013), 870–880. 1

[BS05] Bordoloi U., Shen H.-W.: View selection for volume rendering. In *IEEE Visualization* (2005), pp. 487–494. 1

[CM09] Correa C. D., Ma K. L.: Visibility-driven transfer functions. In *IEEE Pacific Visualization Symposium* (April 2009), pp. 177–184. 1

[CTN*13] Cai L., Tay W.-L., Nguyen B. P., Chui C.-K., Ong S.-H.: Automatic transfer function design for medical visualization using visibility distributions and projective color mapping. *Computerized Medical Imaging and Graphics 37*, 7 (Oct. 2013), 450–458. 1

[Ems08] Emsenhuber G.: *Visibility Histograms in Direct Volume Rendering*. Master's Thesis, Institute of Computer Graphics and Algorithms, Vienna University of Technology, Nov. 2008. 1

[GMY11] Guo H., Mao N., Yuan X.: WYSIWYG (What You See is What You Get) Volume Visualization. *IEEE Transactions on Visualization and Computer Graphics 17*, 12 (2011), 2106–2114. 2

[GY13] Guo H., Yuan X.: Local WYSIWYG volume visualization. In *Visualization Symposium (PacificVis), 2013 IEEE Pacific* (Feb. 2013), pp. 65–72. 2

[JKE*13] Jung Y., Kim J., Eberl S., Fulham M., Feng D. D.: Visibility-driven PET-CT visualisation with region of interest (ROI) segmentation. *The Visual Computer 29*, 6-8 (June 2013), 805–815. 2

[JKF12] Jung Y., Kim J., Feng D.: Dual-modal visibility metrics for interactive PET-CT visualization. In *2012 Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)* (Aug. 2012), pp. 2696–2699. 2

[MDM10] Marchesin S., Dischler J.-M., Mongenet C.: Per-Pixel Opacity Modulation for Feature Enhancement in Volume Rendering. *IEEE Transactions on Visualization and Computer Graphics 16*, 4 (July 2010), 560–570. 1

[PB13] PREIM B., BOTHA C. P.: *Visual Computing for Medicine, Second Edition: Theory, Algorithms, and Applications*, 2nd ed. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 2013. 1

[Pol69] POLYAK B. T.: The conjugate gradient method in extremal problems. *USSR Computational Mathematics and Mathematical Physics 9*, 4 (1969), 94–112. 1

[QYH15] QIN H., YE B., HE R.: The voxel visibility model: An efficient framework for transfer function design. *Computerized Medical Imaging and Graphics 40* (Mar. 2015), 138–146. 2

[RBB*11] RUIZ M., BARDERA A., BOADA I., VIOLA I., FEIXAS M., SBERT M.: Automatic transfer functions based on informational divergence. *IEEE Transactions on Visualization and Computer Graphics 17*, 12 (2011), 1932–1941. 1

[SHW14] STOPPEL S., HEGE H.-C., WIEBEL A.: Visibility-Driven Depth Determination of Surface Patches in Direct Volume Rendering. In *EuroVis - Short Papers* (2014), Elmqvist N., Hlawitschka M., Kennedy J., (Eds.), The Eurographics Association. 2

[SP13] SCHLEGEL P., PAJAROLA R.: Visibility-difference entropy for automatic transfer function generation. vol. 8654, pp. 865406–865406–15. 2

[VKG04] VIOLA I., KANITSAR A., GROLLER M. E.: Importance-Driven Volume Rendering. In *Proceedings of the conference on Visualization '04* (Washington, DC, USA, 2004), VIS '04, IEEE Computer Society, pp. 139–146. 1

[WVFH12] WIEBEL A., VOS F., FOERSTER D., HEGE H.-C.: WYSIWYP: What You See Is What You Pick. *IEEE Transactions on Visualization and Computer Graphics 18*, 12 (2012), 2236–2244. 2

[WZC*11] WANG Y., ZHANG J., CHEN W., ZHANG H., CHI X.: Efficient opacity specification based on feature visibilities in direct volume rendering. *Computer Graphics Forum 30*, 7 (2011), 2117–2126. 1, 2

[ZCM13] ZHENG L., CORREA C., MA K.-L.: Visibility guided multimodal volume visualization. In *2013 IEEE International Conference on Bioinformatics and Biomedicine (BIBM)* (Dec. 2013), pp. 297–304. 2