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

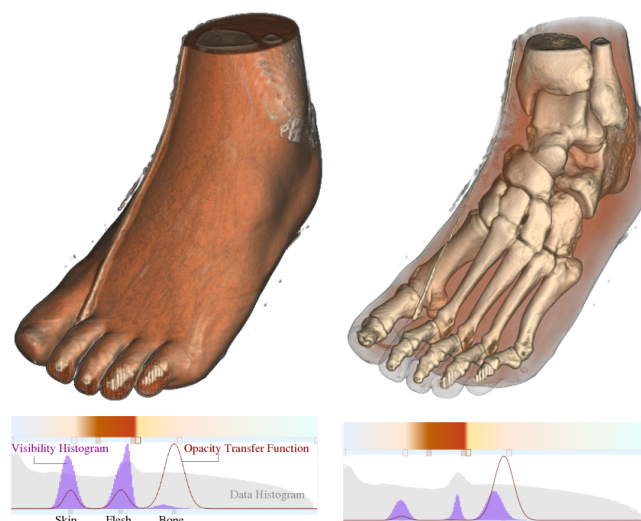## 2. Visibility Histograms and Visibility-Driven Transfer Functions

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 be-

(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]

tween the observed visibility distribution and a user-defined target distribution. The target distribution can be defined using Gaussian function weighting.

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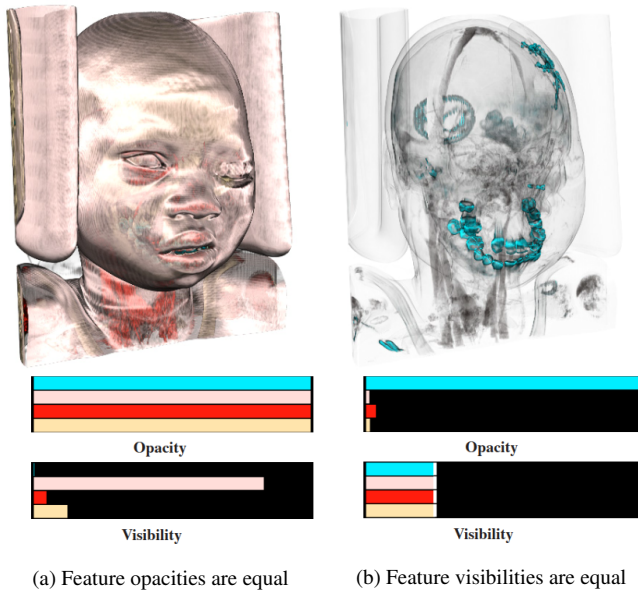
(a) Feature opacities are equal   (b) Feature visibilities are equal

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 Volume Picking

[WVFH12] [GMY11] [GY13] [LPC*16]

2.2. Conclusions

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