Transfer Function Optimization Based on a Combined Model of Visibility and Saliency

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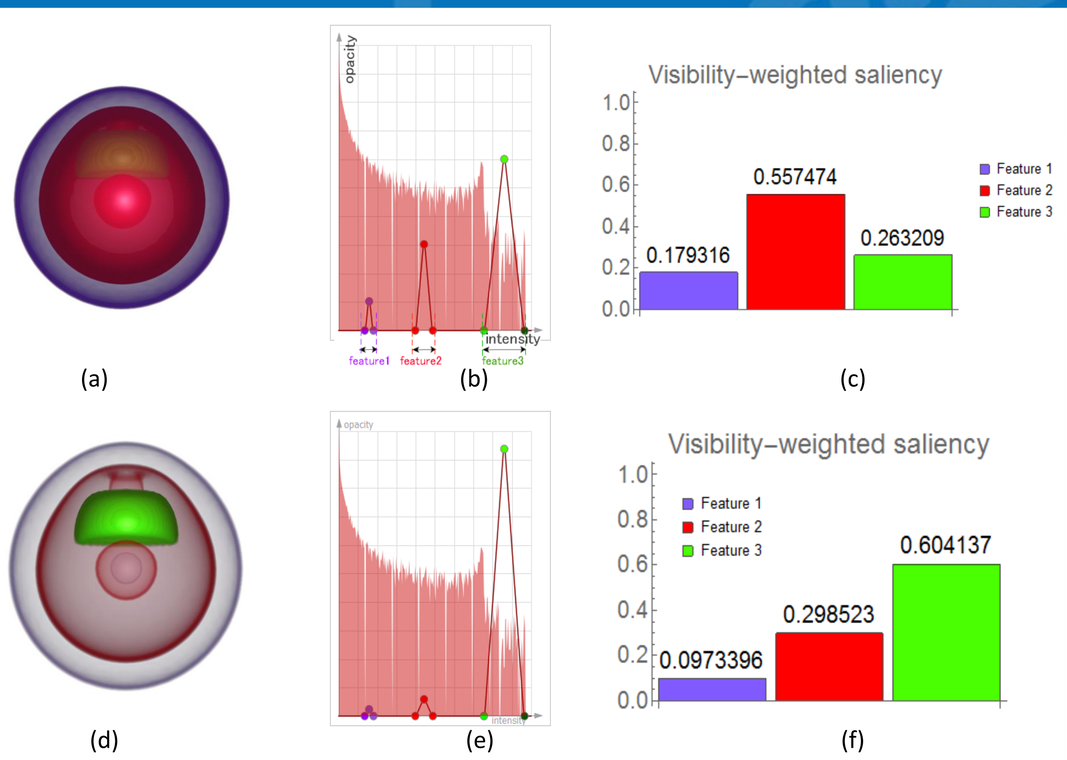
Introduction

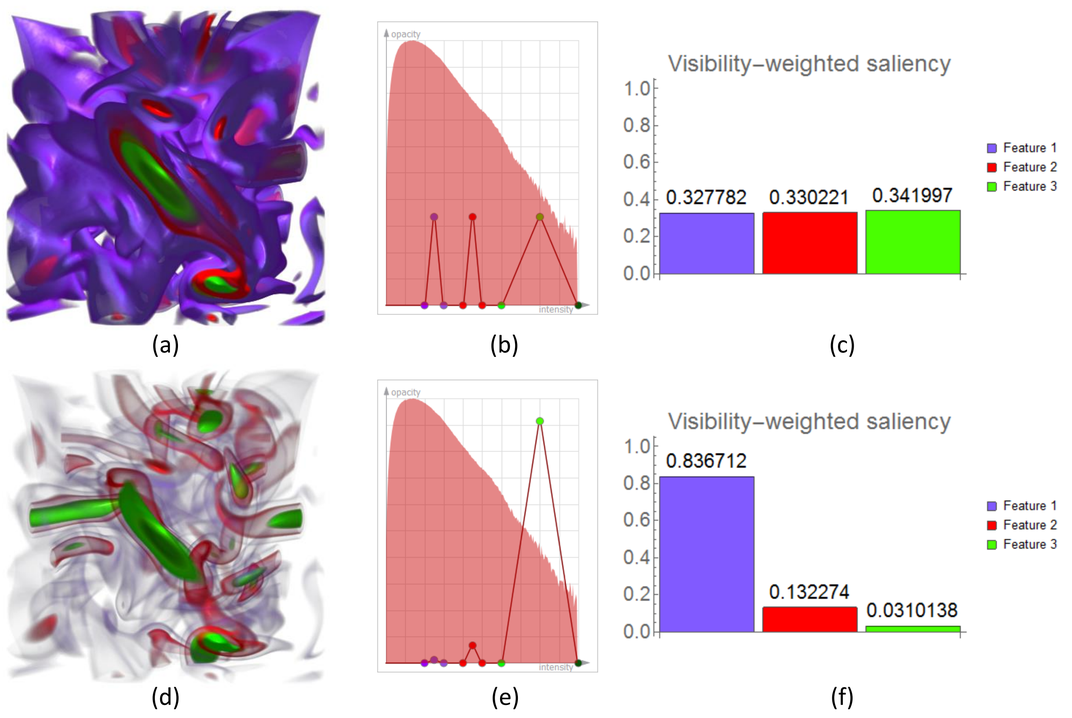
- We addresses the challenge of obtaining **clear visualizations of features of interest in volume visualization**.
- We automatically optimize the conspicuity of features to match a *simple-to-specify* target distribution reducing the need for the user to tweak unintuitive visualization parameters.
- We take into account both visibility and saliency of features in the definition of conspicuity as required by the user.



(a) Nucleon data set; (b) Transfer function with 3 features with opacities set by the user in the ratio 0.1 : 0.3 : 0.6 (c) VWS graph indicates the red feature is prominent despite lower opacity; (d) After opacity towards relative visibility distribution of 0.1 : 0.3 : 0.6, the green feature is particularly emphasized; (e) The optimized transfer function. (f) VWS graph after optimization.

Approach

- We define **conspicuity** to describe the opacity of a feature combined with the degree to which it is occluded by other features, and enhanced this in order to support visualization tasks.
- Users typically have a general idea of how conspicuous certain features should be for a given task and then accordingly adjust parameters such as opacity values in the transfer function.
- However the relationship between the opacity of voxels and the conspicuity of features in the final image is not linear, necessitating a trial-and-error process with the user having only indirect control through a set of complex unintuitive parameters.
- To address this need, we propose an iterative approach that automatically refines the opacity transfer function to achieve any given conspicuity distribution specified by the user.
- We employ an improved model of visibility that takes into account issues of saliency as well as occlusion and transparency.



Visualization, transfer function and VWS of Vortex: (a) feature dominates even though opacities are set to equal; (b) after optimization details in internal green and red features are more recognizable.

Background: Visibility weighted saliency metric

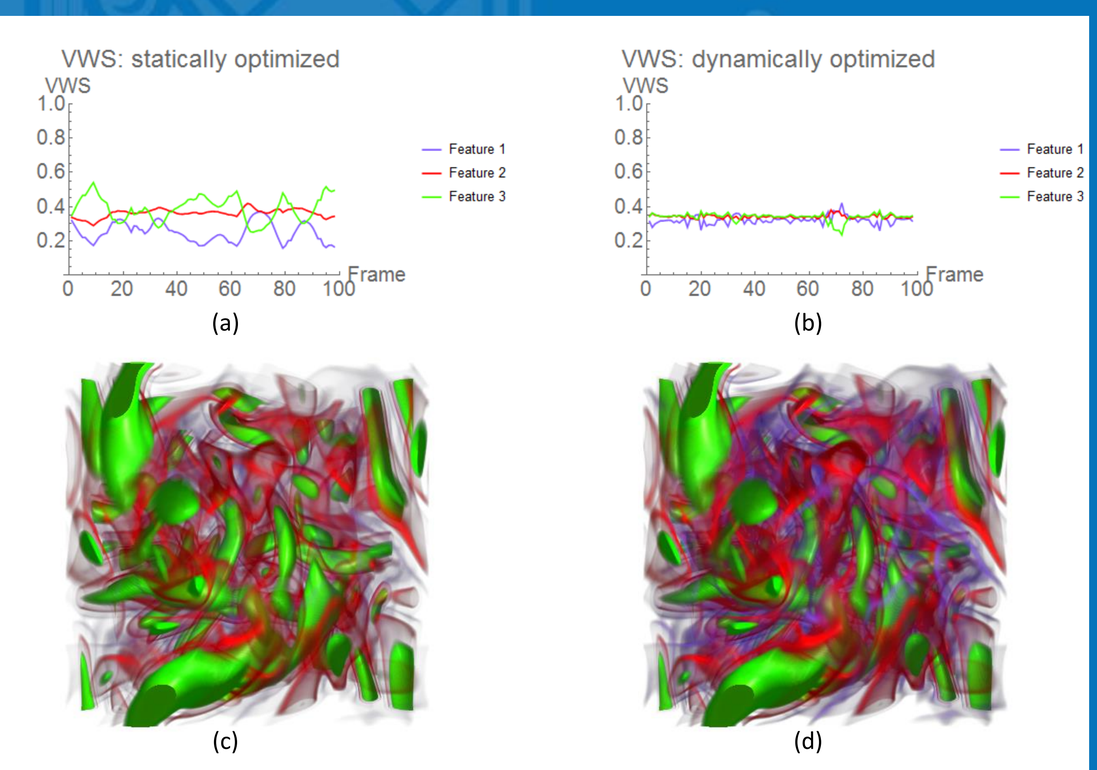
- Visibility-weighted saliency (VWS) [1] simultaneously indicates the perceptual saliency and visibility of features in volume rendered images.
- VWS is defined based on two components:
  - **I. The Saliency field** [2] is essentially a difference of Gaussian in 3D indicating the center-surround effect in a local neighborhood of voxels with respect to appearance attributes such as brightness and saturation
  - **II. The Visibility field** is computed from the opacity contribution of voxels to the final rendered image, and indicates viewpoint-dependent occlusions of the voxels [3] [4].

VWS-based Optimization of Transfer Functions

- We exploit the visibility-weighted saliency metric to automatically adjust the relative conspicuity of features based on a user's specification of their relative importance.
- A gradient descent with an inexact line search strategy is employed for iterative optimization, minimizing the following Objective Function:

$$F = \sqrt{\frac{\sum_{i=1}^{n}(W_i - t_i)^2}{n}}$$

where W_i is the visibility weighted saliency and t_i is a the user-defined importance of feature i, and n is the number of features.



(a) VWS plot of the Vortex simulation after a single optimization based on the first timestep; (b) Dynamically optimized for each time step; (c) Rendering of timestep 80 with the single optimization; (d) Timestep 80 with dynamic optimization.

Main contributions

- **A novel transfer function optimization approach using the visibility-weighted saliency metric**
- **Our automated technique optimizes the clarity of features in visualizations of 3D volume datasets.**
- **The approach achieve user-specified target distributions of feature conspicuity by adjusting the opacity transfer function iteratively.**
- **The automated approach is demonstrated to be useful in particular for optimizing the visualization of time-varying volume datasets.**

References

[1] S. Luo and J. Dingliana, "Visibility-Weighted Saliency for Volume Visualization," in Computer Graphics and Visual Computing (CGVC), London, UK, 2015.

[2] Y. Kim and A. Varshney, "Saliency-guided Enhancement for Volume Visualization," IEEE Transactions on Visualization and Computer Graphics, vol. 12, no. 5, pp. 925–932, Sep. 2006.

[3] G. Emsenhuber, "Visibility Histograms in Direct Volume Rendering," Master's Thesis, Institute of Computer Graphics and Algorithms, Vienna University of Technology, Favoritenstrasse 9-11/186, A-1040 Vienna, Austria, 2008.

[4] C. D. Correa and K.-L. Ma, "Visibility Histograms and Visibility-Driven Transfer Functions," IEEE Transactions on Visualization and Computer Graphics, vol. 17, no. 2, pp. 192–204, Feb. 2011.

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This research has been conducted with the financial support of Science Foundation Ireland (SFI) under Grant Number 13/IA/1895.

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