Direct Multifield Volume Ray Casting of Fiber Surfaces

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IEEE TVCG (Proc. IEEE Visualization 2016), doi:10.1109/TVCG.2016.2599040

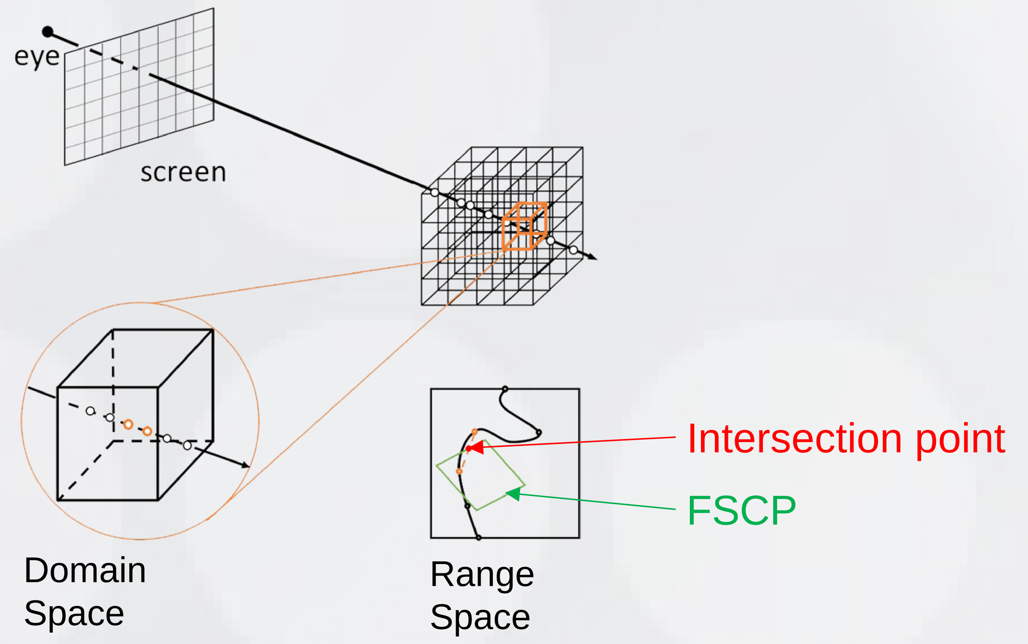
Top right: histogram and three fiber surface control polygons (FSCPs), specified by red, blue green, and purple. Center: Corresponding fiber surfaces, comparing residence time and oxygen across both data range and spatial domain in a simulation of coal combustion in GE-Alstom's 15 MWth Boiler Simulation Facility (BSF) rendering 16 fps at 10241024 on an NVIDIA Geforce GT 650M mobile GPU.

Abstract

Multifield data are common in visualization. However, reducing these data to comprehensible geometry is a challenging problem. Fiber surfaces, an analogy of isosurfaces to bivariate volume data, are a promising new mechanism for understanding multifield volumes. In this work, we explore direct ray casting of fiber surfaces from volume data without any explicit geometry extraction. We sample directly along rays in domain space, and perform geometric tests in range space where fibers are defined, using a signed distance field derived from the control polygons. Our method requires little preprocess, and enables real-time exploration of data, dynamic modification and pixel-exact rendering of fiber surfaces, and support for higher-order interpolation in domain space. We demonstrate this approach on several bivariate datasets, including analysis of multi-field combustion data.

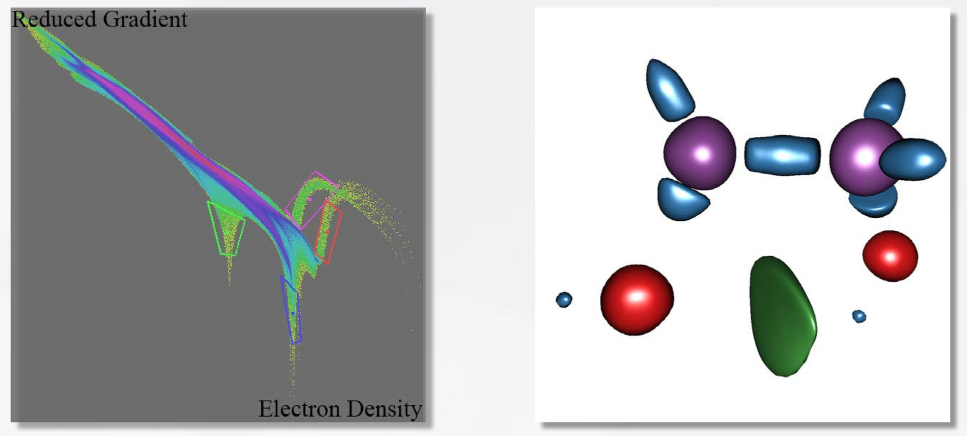
Ray-FSCP Intersection

Sample along the ray within voxel, finding the intersection point in range space



Interactive FSCP Editor

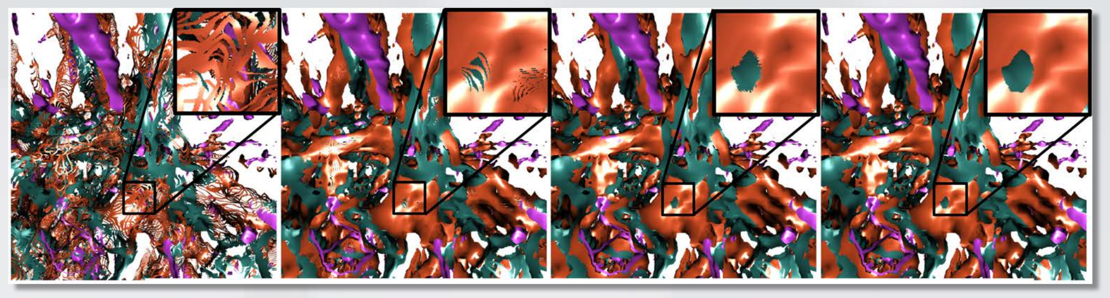
FSCP editor allows users to drag FSCP vertices and drag the entire polygon to explore data interactively



Our FSCP editor classifying the Ethane-Diol dataset.

Robustness

Though our method cannot guarantee never missing fibers, the artifacts will become less and converge, when segment size is small.



0.4 0.1 0.25 0.625

Higher-order filtering

A major benefit of our approach is that it operates independently of the choice of interpolation filter.

Higher-order interpolation of the Homo-Lumo dataset. Left: rendering image with B-spline filter .Right: without B-spline filter.

Use Case: Coal boiler combustion in Uintah

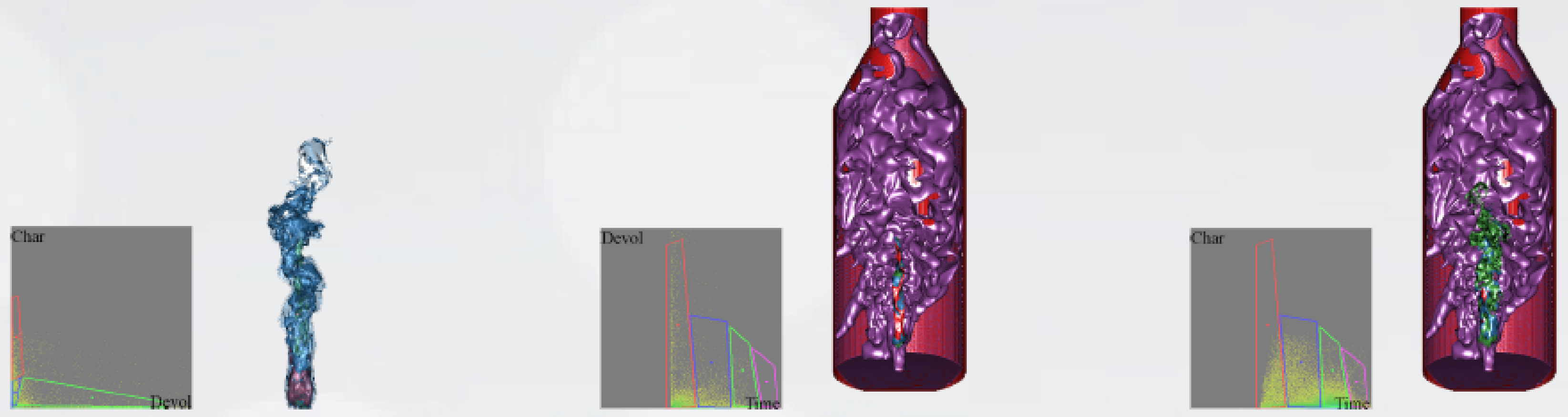


Fig. 8. Devolatilization (η_1) vs char oxidation (η_2) rates (kg/m^3/s). From left to right: η_1 vs η_2, residence time vs η_1, and residence time vs η_2. Fiber surfaces show that devolatilization dominates close to the inlet, whereas char oxidation spreads out towards the center of the furnace.

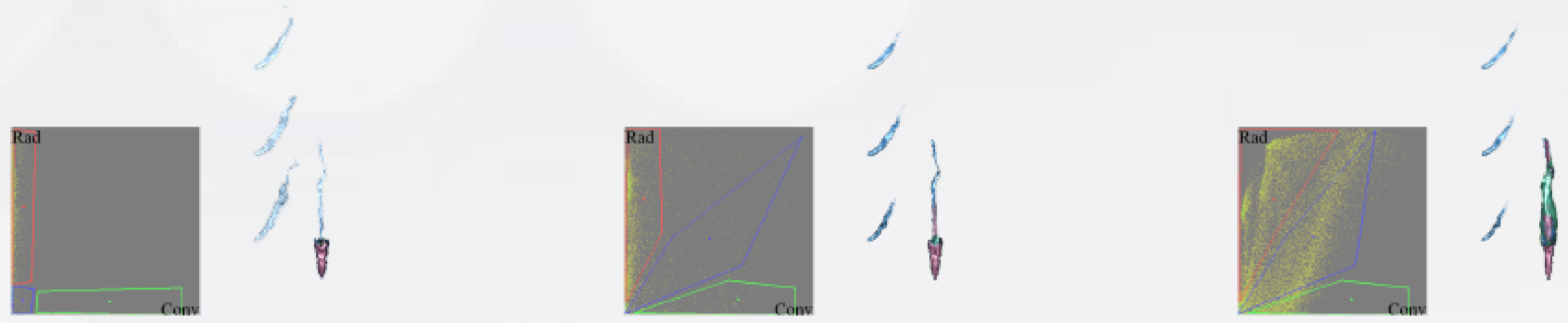


Fig. 9. Radiative and convective heat transfer rates in the OFC combustion dataset, for various sized coal particles (15 μm, 50 μm, 150 μm, from left to right). The 2D histogram shows the heat transfer mechanism for both small and large particles are dominated by radiation; for larger particles convection tends to become more significant.

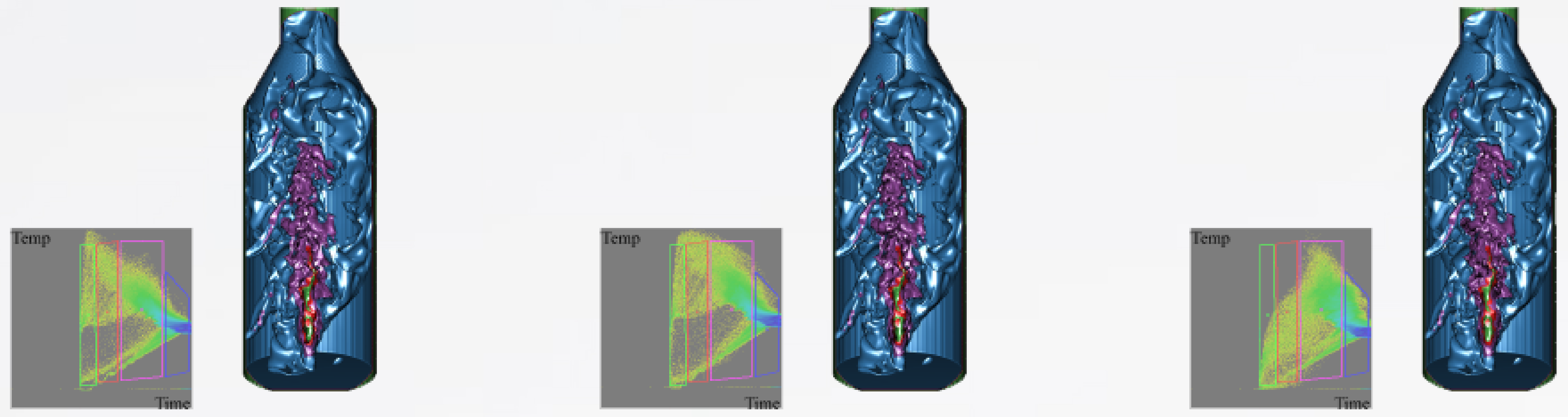


Fig. 10. Residence time vs. temperature of various sized coal particles, from left to right 15 μm, 50 μm, and 150 μm. While the 2D histogram shows that larger particles take a longer time to heat up, the fiber surfaces show that the overall geometry of the temperature field inside the chamber is similar for all particle sizes, except for a very small region close to the inlet.

Acknowledgments:

This work is supported in part by NSF: CGV: Award:1314896, NSF CISE ACI-0904631, DOE/Codesign P01180734, DOE/SciDAC DESC0007446, CCMSC DE-NA0002375, and PIPER: ER26142 DE- SC0010498. Additional support comes from the Intel Parallel Com- puting Centers program, the Argonne Leadership Computing Facility, and EPSRC Grant EP/J013072/1. Kui Wu was supported by NSF grant #1538593. This material is also based upon work supported by the De- partment of Energy, National Nuclear Security Administration, under Award Number(s) DE-NA0002375.We thank Joe Insley, Mike Papka and Julius Jellinek at ANL for the Enzo and HOMO-LUMO datasets, and Julien Tierny at the Sorbonne for the ethane diol data.