Postdoctoral researcher position

High performance volume rendering for interactive visualisation of large-scale simulation

Hosting institute: University of Strasbourg, ICube lab, IGG team (Computer Graphics and Geometry), Strasbourg, France

Collaborators:
Jean-Michel Dischler, Professor (dischler@unistra.fr)
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Dates and grant:
The postdoc is expected to start on 1st October 2025 at the latest for a duration of 12 months
Salary will vary depending on the candidate experience.

Keywords: ray-tracing volume rendering, high performance/in-situ visualization, large-scale simulation data

Desired skills:

- Rendering
- Visualisation
- Volume data
- GPU programming
- HPC programming

Context and motivations:

This postdoc is part of the LUM-Vis ANR project (ANR-21-CE46-0005).

Access to increasingly powerful computing machines allows scientists to simulate increasingly complex phenomenon. However, large-scale numerical simulations produce data that are complex in terms of their size and their geometric, topological and physical characteristics. Specifically, such simulations can generate multi-variate volume meshes of large spatial dimension at each time step. Moreover, these meshes can be unstructured, high order, heterogeneous, with non-convex cells, non-planar faces etc.

On the other hand, modern visualisation methods are essential for several stages of numerical simulations: design, validation... Efficient **visualisation of volume data** is possible today with the **ray-tracing algorithm on GPU** [1,2] offering good performance for a good rendering quality. However, **interactive and in-situ visualisation** algorithms need to adapt to the complexity of data from large-scale numerical simulations. The memory of GPUs is still too limited and their parallel SIMD architecture is not adapted to complex unstructured data. Moreover, the in-situ visualisation approaches proposed in the scientific literature are not adapted to HPC environments with storage capacities in RAM lower than the data set of a whole simulation.

In this context, it is necessary to focus on the **evolution of interactive and in-situ visualisation algorithms** so that they are able to provide an abstraction of the complexity and size of the input data.

Project goals:

The objective of this project is to address the scientific challenges outlined above, at the intersection of rendering and HPC for scientific visualisation in the application domain of numerical simulation.

From a state of the art that covers i) visualization of unstructured volume grids, ii) visualization of large volume data and iii) in-situ visualization, the identified objective is the following:

- To explore the possibilities of interactive visualization of large volumes [7] of dynamic data in an **HPC environment**, based on the combination of **out-of-core rendering methods** [3, 4] and **in-situ methods** [5, 6]. It will be necessary to consider the evolution in time of the data to be visualised, both in terms of topological and geometrical changes and in the scalar/vector field(s). This objective will also cover aspects of parallel and distributed rendering.

Work environment:

This project will take place at the Laboratory of Engineering, Computer Science and Imaging (ICube) of the University of Strasbourg. The candidate will be integrated into the Geometric and Graphic Informatics team (IGG). Moreover, with the support of the partners involved in the LUM-Vis project, we will have the advantage during this thesis to have access to:
- **real data** from numerical simulations from the Advanced Mathematics Laboratory of Strasbourg (IRMA) and the French Atomic Energy Commission (CEA), as well as direct support from the researchers in charge of developing these simulations.
- resources for large-scale tests via the **computing** (ROMEO) **and visualization** (CENTRE IMAGE) **platforms** of the simulation centre of the University of Reims Champagne-Ardenne.

References:

[1] N. Morrical, I. Wald, W. Usher, et V. Pascucci, « Accelerating Unstructured Mesh Point Location With RT Cores », IEEE Trans. Visual. Comput. Graphics, vol. 28, no 8, p. 2852-2866, août 2022, doi: 10.1109/TVCG.2020.3042930.

[2] N. Morrical, W. Usher, I. Wald, et V. Pascucci, « Efficient Space Skipping and Adaptive Sampling of Unstructured Volumes Using Hardware Accelerated Ray Tracing », *arXiv:1908.01906 [cs]*, août 2019

[3] J. Sarton, N. Courilleau, Y. Remion, et L. Lucas, « Interactive Visualization and On-Demand Processing of Large Volume Data: A Fully GPU-Based Out-of-Core Approach », *IEEE Transactions on Visualization and Computer Graphics*, vol. 26, n° 10, p. 3008-3021, oct. 2020, doi: 10.1109/TVCG.2019.2912752.

[4] J. Sarton, Y. Remion, et L. Lucas, « Distributed Out-of-Core Approach for In-Situ Volume Rendering of Massive Dataset », in *High Performance Computing*, Cham, 2019, p. 623-633. doi: 10.1007/978-3-030-34356-9_47.

[5] J. Kress *et al.*, « Comparing the Efficiency of In Situ Visualization Paradigms at Scale », in *High Performance Computing*, Cham, 2019, p. 99-117. doi: 10.1007/978-3-030-20656-7_6.

[6] H. Childs *et al.*, « A terminology for in situ visualization and analysis systems », *The International Journal of High Performance Computing Applications*, p. 1094342020935991, août 2020, doi: 10.1177/1094342020935991.

[7] J. Sarton, S. Zellmann, S. Demirci, U. Güdükbay, W. Alexandre-Barff, L. Lucas, J-M. Dischler, S. Wesner, et I. Wald. « State-of-the-Art in Large-Scale Volume Visualization Beyond Structured Data»,Computer Graphics Forum (Vol. 42, No. 3, pp. 491-515). https://doi.org/10.1111/cgf.14857.