Remote Visualization of Large Scale Fast Dynamic Simulations in a HPC Context

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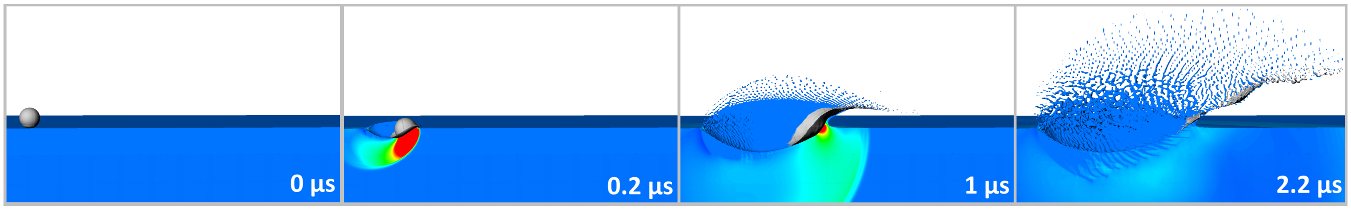

Figure 1: 15 degrees oblique impact of a steel projectile around 4km/s in a graphite sample

ABSTRACT

This paper details the conception of a remote and powerful visualization tool intended to be directly used by physicists in order to better understand the physical phenomena in the field of fast dynamics simulations. The goal is to explore large dataset composed of billions of cells distributed in thousands of domains on a supercomputer. The solution uses the visualization tool VisIt [1] adapted with specific developments based on the knowledge of both the simulation code and the supercomputer architecture used to run the simulations.

Keywords Visualization systems and tools, Fast dynamics.

1 INTRODUCTION

CEA is running numerical simulations in order to guarantee the performances of a complex system. In such a process many physics need to be studied such as mechanics, aerodynamics, electromagnetism etc. In this project we focus on the understanding of specific physical phenomena happening during debris shielding against hypervelocity impact (HVI). The numericians and the physicists who lead this study face several challenges on analyzing the large amount of data generated in a HPC context. In order to ease the understanding of the physical phenomena, this paper details a user-friendly software environment adapted to the exploration of such data but generic enough to be extended to other fields. Based on the knowledge of the simulation code and the architecture where the computations are done, this solution provides a production analysis tool integrating the access to the remote data, the handling of the large amount of distributed solution files, the speed-up of a parallel visualization tool and the easy off-screen movie generation.

2 FAST DYNAMIC SIMULATION CODES

Debris shielding against HVI is a major concern for many applications such as spacecraft technology and high-power laser facilities. Indeed, meteoroids can impact satellites at several kilometers per second, possibly damaging or destroying some vital equipment. Moreover, ejecta created by HVI may remain in orbit and collide with other man-made space structures. Similarly, the various instruments of the Laser MégaJoule (LMJ) experiment chamber can be hit by a variety of shrapnel and debris originating from the target assembly. Due to their low density and high mechanical properties, composite materials are now more and more being used in the aerospace industry. Amongst other materials, carbon is of particular interest since it is widely used as elementary component in composite materials.

Our study [4] relies on HVI experiments and uses numerical simulations of crater formation in EDM3, a commercial grade of polycrystalline graphite approximately 20% porous and macroscopically isotropic. The visualization of the simulations is used to compare our results with experimental observations. The experiments consisted in impacts of a 0.5-mm-diameter steel sphere around 4 km/s in a 30-mm-diameter, 15-mm-thickness graphite target. The projectile is launched by MICA, a two-stage light-gas gun located at CEA CESTA. Post-mortem tomographies and Scanning Electron Microscope (SEM) observations helped us to adjust an isotropic damage model for porous and brittle materials in the Eulerian component of the HESIONE hydrocode developed at CEA. This hydrocode deals with multi-material flows in explicit mode on Cartesian 2D or 3D grid using the BBC numerical scheme [3].

For the normal impacts, 2D-axisymmetric numerical simulations of MICA shots were performed. For oblique impacts 3D simulations are needed. Then to obtain a good representation of the damaged area, the cell size used for computations was 12.5 x 12.5 x 12.5 μm. It ensures both a good convergence level and a reasonable computation time. It yields to 3D computations with 350 millions of cells as shown on figure 1 or 2 billions of cells for another study illustrated figure 3.2.

3 VISUALIZATION STRATEGY

In order to provide a user-friendly dedicated analysis tool, the scientific visualization software VisIt is adapted. The main challenges are to setup a remote and distributed environment and to be able to understand the simulation files.

3.1 VisIt configuration in a HPC environnement

The simulation code is run on the TERA-100 supercomputer from CEA. The exploitation site is located hundreds of kilometers away from the production site with standard graphical workstations. VisIt has been compiled and deployed for the specific use on TERA-100. It uses a specific MPI version to be able to run in parallel setting to compute fast visualizations. The connection has been configured in a host profile integrating the secure protocols such as SSH needed to communicate through the dedicated network. This configuration allows the user to interactively choose the number of processors

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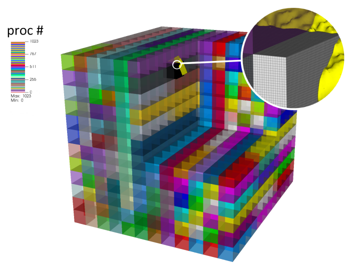
to use for computation on several partitions such as parallel, large (nodes with more than 512Go of memory) or hybrid (nodes with GPU). Then, the user can browse and load its remote solution files with a specific database plugin without downloading them on the local site.

3.2 Database plugin for large distributed data

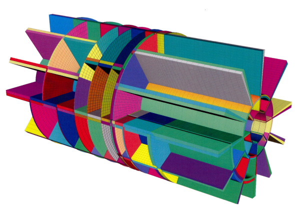
The HESIONE Eulerian code give post processing data which contains the geometry description (a 3D fixed Cartesian grid), and for each cell, the volume of material present in it and the different thermodynamics quantities. Because of the eulerian description, some cells are mixed (they contain different materials) in the interfaces between materials. The environment introduces in this paper first extracts thousands of data files from archives. Each file of several Gigabytes corresponds to the computation of one processor for a sub-domain of the original grid. Using the development tools of VisIt, a specific database plugin has been implemented taking advantages of the automatic code generation. The input file is interpreted as a Single Timestep Multi Domain (STMD). Using the metadata of only one data file in the *PopulateMeshMetaData* method of the reader, VisIt is initialized without any further computation and transfer operation. Then, the parallel capability of VisIt is used through the loading of the sub-domain files distributed on each compute engine running on every nodes of the TERA-100 partition chosen previously. Figure 3.2 shows a parallel visualization of a 2-billion cells dataset where the 2048 sub-domains of the simulation shown as blocks are colored by the distribution on the 1024 processors used to explore the dataset using $1024 * 2GB \sim 2TB$ of memory.



3.3 Optimization of the visualizations with extra data

3.3.1 Ghost zones

In order to help the interpolation needed by the visualization algorithms amongst blocks, ghost zones can be added. These extra cells, duplicated from the cells in the neighboring domain, enable smooth interpolation and are used to remove cracks in isosurfaces at the boundaries of the blocks. This extra information has to be provided by the simulation code by transferring the neighboring block connectivity to the visualization algorithms (using the *avtCurvilinearDomainBoundaries* for example). The information needed describe the orientation of each block and the zone of neighboring interval. On some data, complex inter-blocks connectivity can be addressed such as T-intersections with this method.

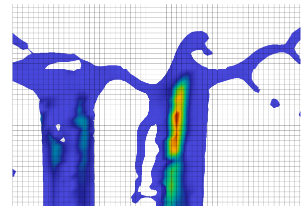


3.3.2 Data and spatial extents

A simple but efficient way of speed-up computation of the visualizations is to use extent information for each block. The loading of a sub-block returns to a global structure, the data and spatial extents of its own block. Thus the visualization algorithms traversing the whole data only load the blocks needed based on the comparison of respectively the min-max values of the coordinates of a block (spatial extents) and the scalar field (data extents).

3.3.3 Material Interface reconstruction

Material Interface reconstruction is a key feature in analyzing Eulerian simulation code data. VisIt implements several visualization algorithms such as the *Equi-Z* method [2]. The feature is enabled by providing to the database reader the precise description of the composition of each cell. The structure used in the *AuxilaryData* method is based on several link arrays describing the material of pure cells, the fraction of presence of each material in every mixed cells and the empty cells. The implementation has to convert the data given from the input file to the VisIt datastructure.



4 Results

We use the simulations to analyze the effects of the impact such as crater volume, fragments velocities and ejected fragmented volume. In addition of the crater depth and diameter, we can compare the crater shape with the experiment thanks to the visualization. We can also observe the deformation of the projectile and compare its penetration depth with experimental data. Visualizing pressure waves propagation and interaction (figure 1) with the material surface allows the understanding of the damage process in the graphite. This interpretation can be complemented by visualizing the damage variable (also shown on figure 2) around the crater and its retroaction on the pressure waves propagation. The access and initialization of the 1024 compute engines on TERA takes about 45 seconds. Then the 2048 data files are loaded in about 30 seconds. The computation of the visualization takes less than 5 seconds depending of the algorithms used.

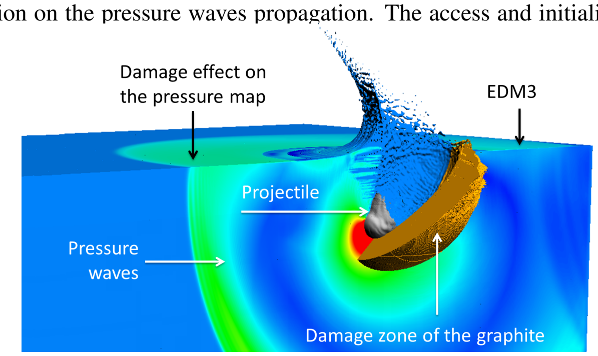


Figure 2: Visualization of the pressure and the damage of a graphite sample with the 45 degrees oblique impact of a steel projectile around 4km/s

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