Visualizing results in the SALOME platform for large numerical simulations: an integration of ParaView

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ABSTRACT

SALOME is an Open Source numerical simulation platform that allows the complete realization of a numerical study. Indeed, the user can easily plug his core numerical code in the platform, define the problem geometry, mesh it, define the boundary conditions, run the solver on a supercomputer, visualize the result and analyze the data; all these actions are performed in an integrated and coherent environment. SALOME can deal with large numerical simulations, like the ones found in multi-physics and/or parametric studies. In this context, ParaView has been integrated into the platform to benefit from its capacity to visualize large models. In this abstract we give an overview of the capabilities of SALOME/ParaView.

Keywords: Large simulations visualization, numerical simulation, ParaView, SALOME.

1 INTRODUCTION

Over the last decade, the improvements in computer hardware and software have brought significant changes in the capabilities of simulation software. New computer power made possible the emergence of simulations that are more realistic (complex 3D geometries being treated instead of 2D ones), more complex (multi-physics and multi-scales being taken into account) and more meaningful (with propagation of uncertainties). As a consequence, the data size produced by simulations keeps on increasing.

Since 2001, CEA (French Alternative Energies and Atomic Energy Commission) and EDF (Electricity of France) have developed a software platform named SALOME [1], [2], that provides tools for building complex and integrated applications in the context of numerical simulations. The end user only needs to plug the interfaces of its numerical solver (for example a FEM solver for mechanical stress computations), and will automatically benefit from all the tools provided by the platform to feed his code. Some of the core tools are: CAD modules, meshing of CAD models, definition of input/output files, and visualization.

The platform has been built using a collaborative development approach and is therefore available under the LGPL license (http://www.salome-platform.org). SALOME provides modules and services that can be combined to create integrated applications that make the scientific codes easier to use and well interfaced with their environment. SALOME is being actively developed with the support of EURIWARE/Open Cascade and benefits from more than 10 years of development effort.

SALOME is used in research and industrial studies by CEA and EDF in the fields of nuclear reactor physics, structural mechanics, thermo-hydraulics, nuclear fuel physics, material science, geology and waste management simulation, electromagnetism and radioprotection.

The Open Source software ParaView (developed by Kitware) has been recently integrated in the SALOME platform. It represents the main visualization tool of the platform and it was specifically chosen for its capabilities to manage large volumes of data.

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2 SALOME PLATFORM OVERVIEW

SALOME is divided in two main parts: a kernel and a set of standard modules. The platform uses two languages, Python and C++, and all kernel and module functionalities have to be exported into Python. Thus the platform can be used through scripts, through the GUI or through a combination of both. This allows SALOME to be used by users with different levels of expertise or in different situations (batch mode, interactive mode).

2.1 User interface

The platform provides an environment which covers a complete study, starting from a CAD component to define the geometry up to the visualization of the results, coupling different codes through a common data exchange model and a supervision/coupling tool. Two different modes of interaction with SALOME components are systematically provided:

- A graphical interface coupled with 3D graphic interaction (Qt4, VTK),
- A text interface based on the Python language.

Both modes provide the same set of functionalities and SALOME offers easy shortcuts from one mode to the other.

2.2 Component embedding and solver integration

As a platform for numerical simulation, SALOME has a modular architecture that can be extended with additional commands or modules developed either in Python or in C++. It is possible to integrate codes ranging from legacy ones to state-of-the-art ones (written in Python, C++, C or Fortran). Furthermore, component wrapper generators are available in order to facilitate the integration process.

2.3 Workflow supervision

With the supervisor of the platform, a user can define and control the execution of complex interconnected scientific applications on computer networks and clusters. They may be run either interactively or in batch mode. An example of workflow is shown in figure 1. This means that SALOME provides a basic streaming mechanism that streams the simulation results to the other parts of the workflow as they are produced (on-the-fly processing). However the connection of this streaming mechanism with the visualization module is still under development.

2.4 Mesh and field management

The platform relies on an internal data model (the MED format, [4]) that describes meshes and fields that are stored as sequences of HDF5 structures. Distributed meshes are also taken into account, thus facilitating parallel computations. Moreover, interpolations are also handled in order to manage different meshes which are adapted to each simulation. This proves especially helpful when dealing with coupled simulations in which two different codes relies on two different spatial discretizations.

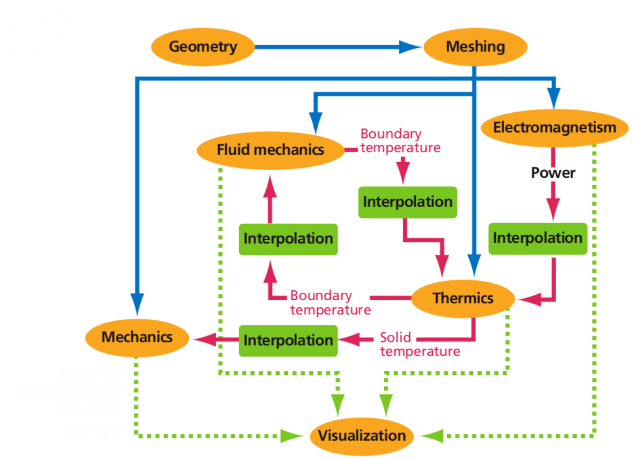

Figure 1: Diagram illustrating a complex multi-physics simulation performed on SALOME.

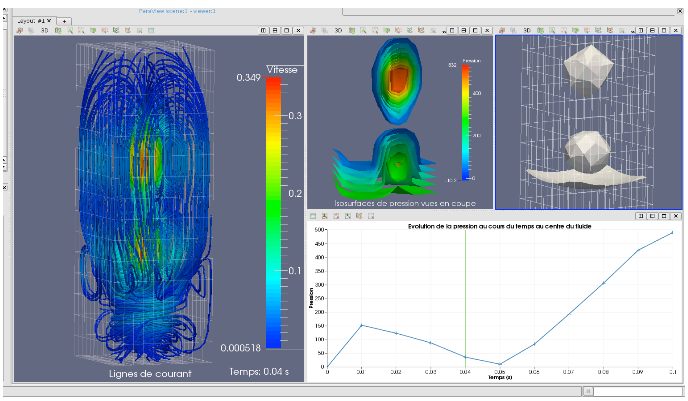

Figure 2: Post-processing of a diphasic simulation (two air bubbles in a liquid with a magnetic agitator). The pressure streamlines (left) and the pressure iso-surfaces (right) are shown.

3 Large simulations in SALOME/ParaView

There is an increasing need for multidisciplinary parametric simulations in various research and engineering domains. Fluid-structure interaction and thermal coupling are two examples. The software strategy in many simulation contexts (at least at CEA and EDF) is to develop numerical solvers dedicated to their own domain, and then to execute multi-domains simulation by coupling the existing dedicated solvers.

The SALOME platform provides a set of services to create a simulation workflow that connects different computation units and then to execute the workflow on a distributed network of computers and/or HPC resources. In figure 1 we can see an example of workflow that could be managed by the platform. Numerical simulations of this kind produce an increasingly larger volume of data to be analyzed and visualized. We believe this represents a general trend in the world of physical simulation and having an integrated environment for managing this workflow, where large volumes of data are involved, is a real advantage.

Furthermore, a new trend appears in this context: parametric studies. When a parametric study is conducted, the simulation (or coupled simulations, like in figure 1, is ran N times with one or several varying parameters, then some kind of statistical study is performed. Consequently, the already large amount of data produced in a single simulation is multiplied by N. Indeed, parametric studies are becoming increasingly popular. SALOME has already developed some software infrastructure to perform them, such as OpenTurns [3] and the *Parametric* module.

4 Integration of ParaView

ParaView visualization capabilities have been integrated in the SALOME application in the form of a dedicated module. The capabilities of ParaView with respect to large data sets and its naturally efficient integration in a parallel/cluster-type environment guided this choice. For example, ParaView can be used in a client/server mode where a server is deployed in a visualization cluster. The integration consists in:

- A reader for the simulation results based on the MED format, [4], i.e. the standard exchange format of simulation data in the platform;
- Additional ParaView filters to deal with specific visualizations for the SALOME users;
- The architecture of ParaView was modified in 2012 by Kitware to better fit the integration. From this time on, ParaView servers accept multi-client connections and also a unique client can connect to several servers. Ultimately this will allow more complex uses of the module (e.g. visualizing the results of a Python script as it runs).

Figure 2 shows an example of use of ParaView inside the Salome platform: a front tracking computation realized with the CFD code *Trio_U* at CEA. A drop of fluid in free fall hits the free surface of another rotating fluid. The figure exhibits both the streamlines (left) and the pressure iso-surfaces (right).

Concerning large models, EDF R&D currently deploys visualization servers (parallel *pvservers* of ParaView) for SALOME on the graphic sub-cluster of its Ivanhoe corporate supercomputer (number 66 in the top 500 list in 2011). In 2013, a study was successfully performed on how to use in-situ visualization techniques: Catalyst (the co-processing library of ParaView) was integrated in the Computational Fluid Mechanics solver *Code_Saturne*, [5], usually coupled to the SALOME platform. Using the platform to also provide in-situ visualization techniques is an on-going project. This will allow the management of even larger amounts of data.

5 Conclusion

This abstract briefly presents the visualization capabilities of the SALOME platform for numerical simulations. The visualization module of this platform mainly consists in an integration of ParaView. As a result, the platform can not only deal with large volumes of data at simulation time but also when complex post-processing and/or visualization is needed.

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