SCALABLE NUMERICAL METHOD FOR BIPHASIC FLOWS IN HETEROGENEOUS POROUS MEDIA IN HIGH-PERFORMANCE COMPUTATIONAL ENVIRONMENTS

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INTRODUCTION

This poster describes the "Scalable Numerical Method for Biphasic Flows in Heterogeneous Porous Media in High-performance Computational Environments" based on the high-performance numerical methodology firstly proposed by **Correa and Borges [2013]** and higher-order related numerical methods. The project, which aims to develop a mature approach for modeling biphasic flows in porous media, can leverage HPC machines. Researches undertaken by the project collaborators founded the project. In this system, an elliptical subsystem determines the velocity field. Additionally, a non-linear hyperbolic equation represents the transport of the flowing phases (saturation equation). The model applies a locally conservative finite element method for the mixing speed. Additionally, the model employs a high-order non-oscillatory finite volume method, based on central schemes, for the non-linear hyperbolic equation that governs phase saturation. In the mathematical model, for $\Omega \subset \mathbb{R}^3$ a connected domain, open and limited, and I is an time interval. We consider the scalar conservation law $\phi\frac{\partial s}{\partial t}+\nabla\cdot\mathbf{f}=0$ in $\Omega\times I$, where $\phi : \Omega \Rightarrow (0, \phi^{max}]$ is the storage coefficient, $s : \Omega\times I \rightarrow Im\{s\} = [s^{min}, s^{max}]$ is the scalar function, and the vector function $\mathbf{f} : Im\{s\} \rightarrow \mathbb{R}^3$ is the flow of the conserved quantity s. Particularly, for the tests we consider

$$\mathbf{f} = s\mathbf{v} = \left\{ \begin{array}{c} s \\ 0 \\ 0 \end{array} \right\}.$$

For more information on initial and boundary conditions see **[Correa, M. R.; Borges, M. R. 2013]**

Flowchart of the simulator under development

The flowchart in **Figure** 1 begins with a configuration of the processes (Point 1). The next step is to read the information from the three-dimensional reservoir mesh (Point 2). Then the number of iterations of the simulation is calculated.

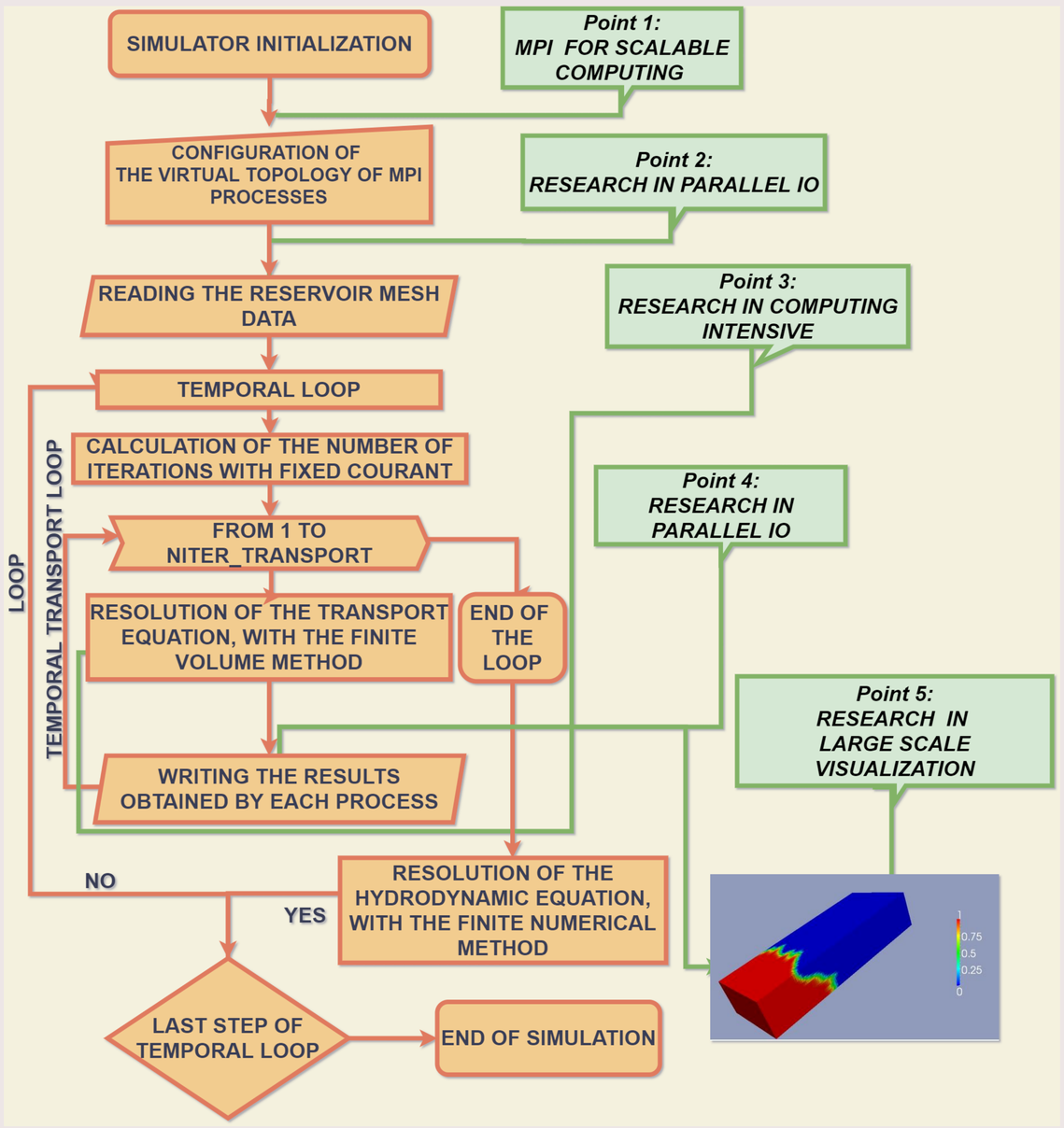

Figure 1: *Simulator flowchart*.

Afterward, we calculate the number of iterations to solve the partial differential equation of fluid flow using the finite volume numerical method and a fixed Courant number (Point 3). Thus, the approach records the results registered in files at each iteration (Points 4 and 5). Finished this step, we solve the partial differential equation of the hydrodynamics using the finite element method.

SDUMONT SUPERCOMPUTER

Santos Dumont (SDumont) is the largest supercomputer in Latin America dedicated to scientific research. SDumont is a 5,1 Petaflops Supercomputer with 36,472 computing cores distributed in 1,134 computing nodes.Performance evaluation on 20 nodes Intel(R) Xeon(R) Cascade Lake Gold 6252 CPU @ 2.10GHz 384Gb RAM.

Figure 2: *Santos Dumont Supercomputer*.

PERFORMANCE EVALUATION

Figure 3 shows several tests performed on the Cascade Lake architecture of the SDumont Supercomputer. Due to the I/O bottleneck, we turned off the I/O operations for the experiment below.

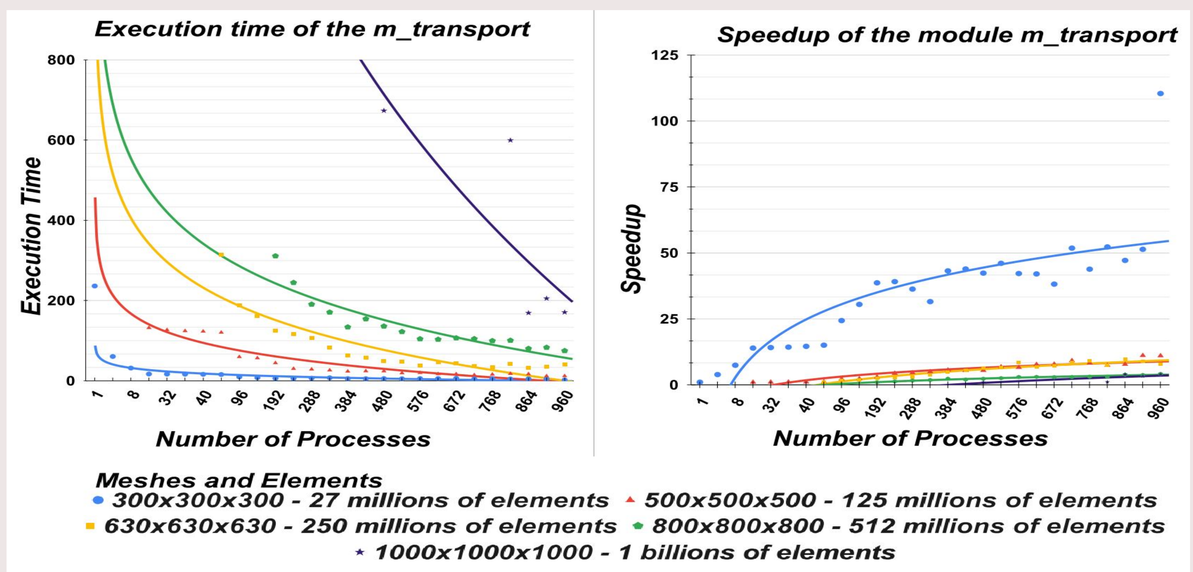

Figure 3: *Speedup with an execution of 960 processes using 20 computational nodes of SDumont's Cascade Lake architecture*

The plot shows the execution time (at left) and speedup (at right). Furthermore, the results show that the speedup decreases as the mesh size increases. We performed profile tests. As expected, the results show that the time consumption of the MPI message exchange functions increases as the mesh size also increases. We are working to decrease these bottlenecks. The main goal is to decrease MPI bottlenecks (flowchart point 1) by implementing MPI for scalable computing. We also aim to reduce the bottleneck by implementing efficient parallel I/O (flowchart points 2 and 4). Additionally, we aim to implement large-scale visualization (flowchart point 5). Finally, we also need to develop SDumont nodes code optimizations to resolve flow chart point 4 bottlenecks.

Bibliography

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