Performance Characterization of the Alya Fluid Dynamics Simulator

Guilherme Antonio Camelo, **Lucas Mello Schnorr**
{gacamelo,schnorr}@inf.ufrgs.br

GPPD/INF/UFRGS, Porto Alegre, Brazil

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Outline

Context: Numeric Simulation and HPC

- Numeric simulation is used to understand/study a real life scenario
- High performance computers used as execution platforms
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- Problems often require high computational power
- Distributed and parallel programming techniques provide high computational power e.g OpenMPI
- OpenMPI is ideal to deal with complex physical problems such as fluid dynamic simulation.

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MPI-based framework to numerically solve physical problems

- Simulates fluid dynamic scenarios
- Open source project
- Parallel execution
- Part of the `Prace Benchmark` from BSC (Barcelona Supercomputing Center)

Motivation: Irregular Load

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Those factors usually lead to load imbalance among both resources and time as the simulation advances

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Tracing techniques are used to acquire this information

- Keeps track of information regarding the application
- Record events
- Record MPI operations

The Extrae tracing tool from BSC is used in this experiment

Goal

Characterize Performance of Alya for the case studied

- Identify irregular execution behavior regarding the resources and the time
- Understand Alya's behavior in a smaller scale plataform

Execution Environment

Execution performed on 4 nodes that are part of the Draco cluster at INF UFRGS (Draco has 8 nodes).

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Each node equipped with:

- Intel (R) Xeon (R) E5-2640 v2 CPU @ 2.00GHz processor
- 16 physical cores (32 with hyperthreading)
- 64 gigabytes of RAM
- Ubuntu 14.04.4 LTS

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Trace size 2,7 Gb.

Files generated by the tracing tool Extrae are too big.
Thus, reducing the number of timesteps was necessary.

Methodology

Execution: OpenMPI 1.10.2

- Outputs simulation result

Tracing: Extrae 3.3.0

- Creates individual traces for each processor
- Record communication and execution information
- Trace files created in `.mpits` format

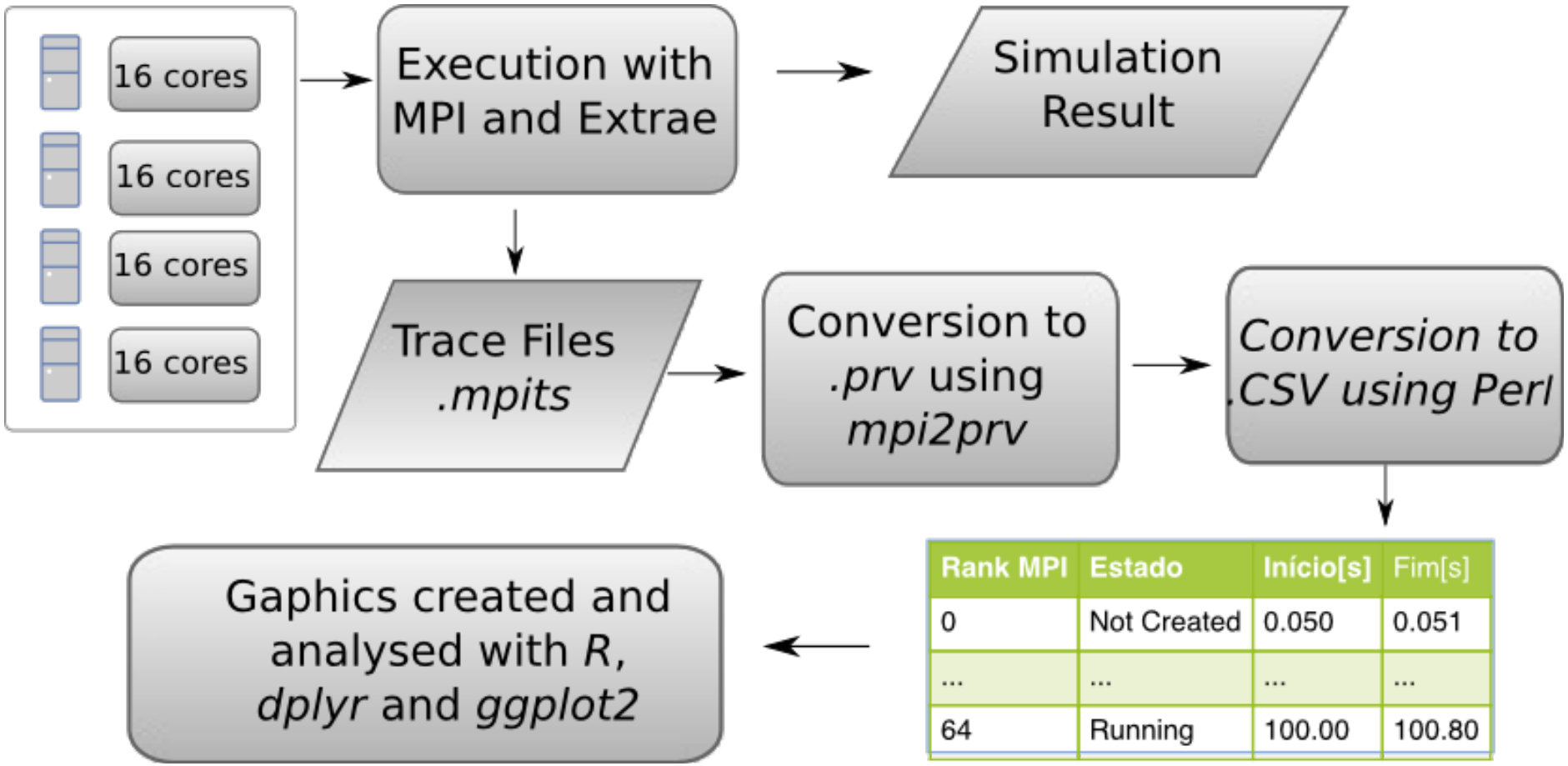
Converting:

- Trace files are converted to `.prv` format with `mpi2prv`
- `.prv` files are converted to `.CSV` (Comma-Separated Values) using a `Perl` script

Plot and Analysis:

- Using `R`, `dlyr` and `ggplot2` different graphics and analysis are made

Methodology

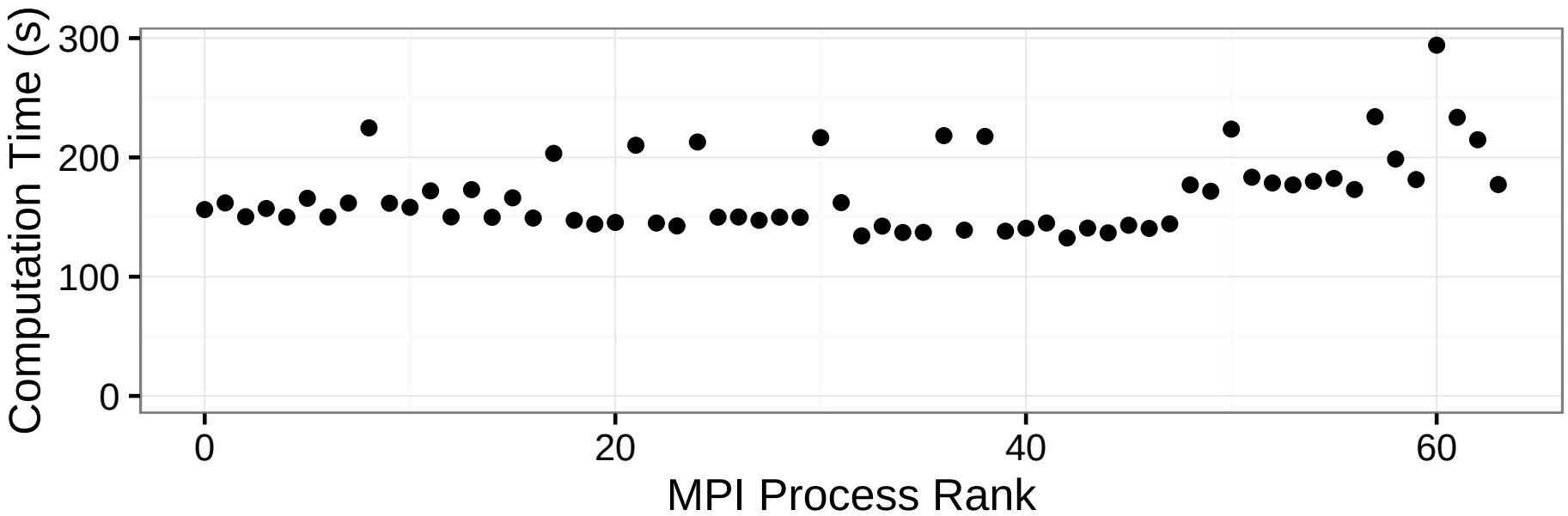


Rank MPI	Estado	Início[s]	Fim[s]
0	Not Created	0.050	0.051
...	...	...	...
64	Running	100.00	100.80

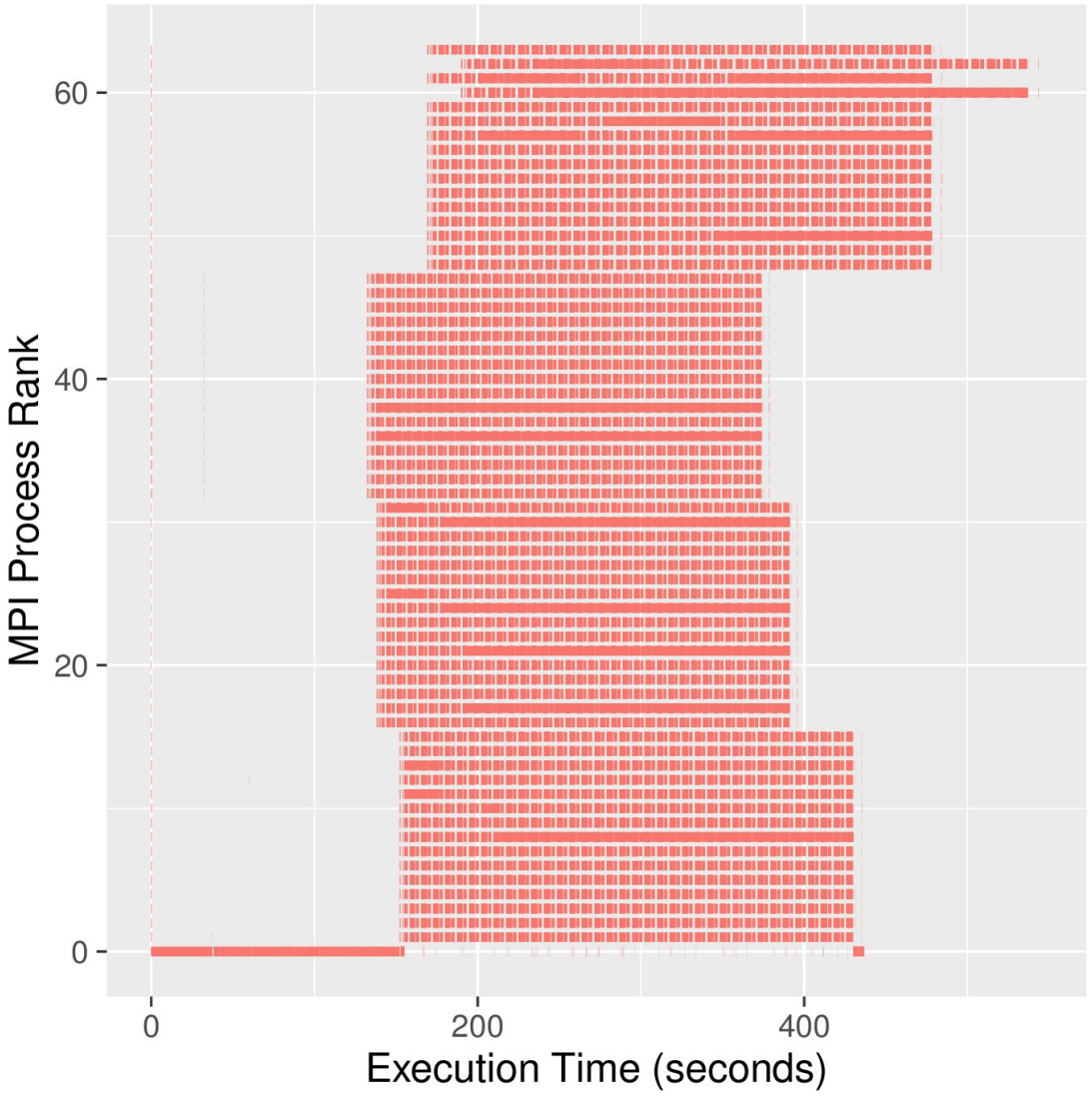
Results

All results are extracted from the same execution with 4 nodes 64 cores and 3 timesteps.

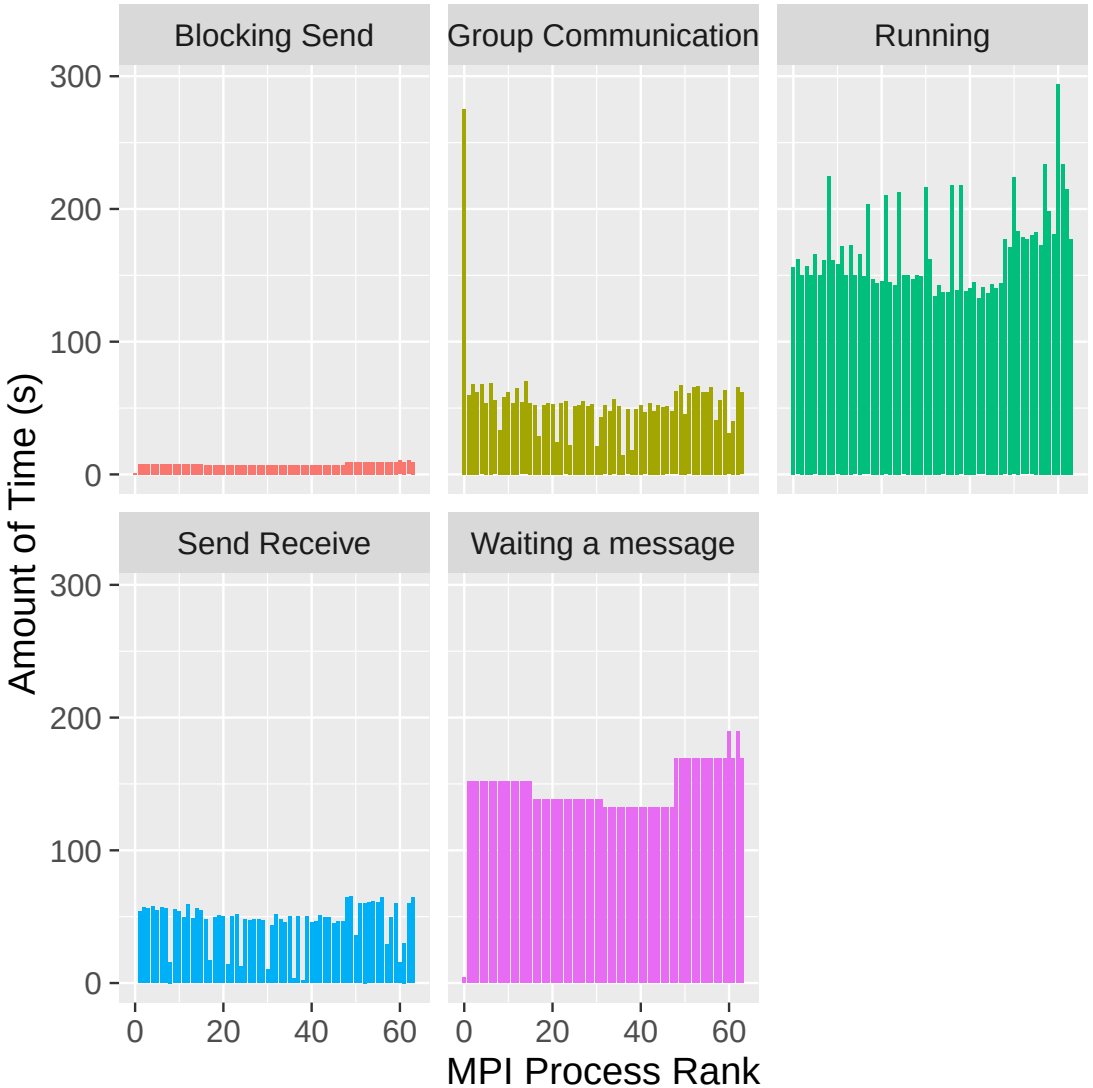
Overview of Load Imbalance



Space/Time Execution



Process Behavior by State



Percent Imbalance

The percent imbalance formula is used to calculate the load balance of applications. It characterizes the uneven distribution of work.

- L_{max} - is the value of the process with the highest load (seconds executing)
- $\overline{L}$ is the average computational load among processes

$$\lambda = (\frac{L_{max}}{\overline{L}} - 1) * 100 \quad (1)$$

The metric is calculated considering the entire execution. One global metric. Load imbalance is 75%, it indicates that if the load were better distributed we could have potential performance improvement

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- Percent imbalance metric indicates that there is a potential performance improvement. The reason for such imbalance is still being investigated.

Future Work

- Study possible change in the code to improve load balance
- Execute Similar experiment with other configurations to confirm results varying:
  - Number of nodes
  - Number of cores
  - Number of timesteps
- Mark the beginning of each iteration so balancing metrics can be applies in each phase of computation/communication
- Trace with different tracing tool that generates smaller trace files e.g. ScoreP

Thank you

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