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COMPARING PARALLEL TECHNOLOGIES BASED ON *GPU* AND *CPU* IN NUMERICALLY SOLVING SINGLE PHASE FLOW PROBLEMS

Dany S. Dominguez[1]*, Esbel T. V. Orellana[1], Bruno P. Santos[2] and Susana M. Iglesias[1]

[1]Pós-graduação em Modelagem Computacional, Universidade Estadual de Santa Cruz, Rodovia Jorge Amado km 16, CEP 45662-900, Ilhéus-Bahia, dsdominguez@gmail.com, evalero@uesc.br, smiglesias@uesc.br

[2]Departamento de Ciências Exatas e Tecnológicas, Universidade Estadual de Santa Cruz, Rodovia Jorge Amado km 16, CEP 45662-900, Ilhéus-Bahia, bruno.ps@live.com

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The solution of single phase flow through porous media is of special interest in several fields of science and engineering, such as primary exploration of hydrocarbon reservoirs [1], groundwater aquifer simulation and heat transfer in pebble bed gas cooled nuclear reactors among other disciplines. All those problems present high computational cost and generally are solved using parallel processing techniques. The first of these techniques used to solve this type of problems was based in Central Processing Unit (CPU) using Message Passing Interface (MPI) and Open Multi Processing (OpenMP) models. In the last years the use of Graphics Processing Unit (GPU) and Compute Unified Architecture (CUDA) platform has settled as the main technique for solving large scientific problems [1,2].

This work presents a numerical solution for a single phase flow in a porous medium problem using GPU-CUDA technology. The efficiency of this approach is compared with previous results that used MPI and OpenMP to solve the same problem. The mathematical modeling of the problem is using a mixed Poisson equation, in two-dimensional Cartesian geometry with zero-flux boundary conditions:

$$\vec{q}(x,y) = -k(x,y)\vec{\nabla}p(x,y) \tag{1a}$$

$$\nabla\vec{q}(x,y) = f(x,y) \tag{1b}$$

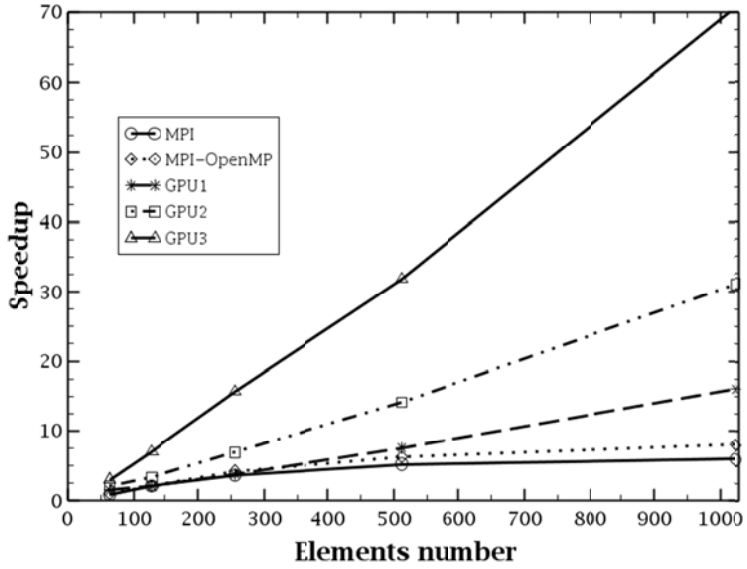
$$\vec{q}(x,y)\bullet\vec{n}_{\Gamma} = 0 \tag{1c}$$

where $\vec{q}$ is the speed, k is the permeability coefficient, p is the pressure, f is the source function, and $\vec{n}$ the normal vector at the boundary Γ.

To obtain a unique solution of the equation system in (1), is imposed a normalization condition in the distribution of pressure field. The equations (1) are discretized using Raviart-Thomas finite elements and then are solved using the conventional domain decomposition method [3]. Were implemented four codes for the problem solution (i) a sequential code (ii) an MPI code, (iii) a hybrid code (combining MPI-OpenMP) and (iv) a CPU-CUDA code. The major difficulty in the code parallelization was the speed dependencies of the neighbor elements in the pressure calculation. Were made performance tests for different mesh in CPU and GPU architectures. A summary of the main characteristics of the hardware used in each architecture, is presented in the following Table.

Parallel machine	**CPU Cluster**		**GPU – Workstation**
Nodes/Cores Number	8/2		¼
Processor	Core 2 Duo E6550		Core™ i7-2600
RAM/Cache Memory	2GB/4MB		8GB/8MB
GPU Cards	**1**	**2**	**3**
Name	GeForce GT 520	GeForce 9800GT	GeForce GTX 560 Ti
GPU Cores	48	112	384
GPU Memory	1024 MB	512 MB	1024 MB
GPU Clock	810 MHz	600 MHz	822 MHz

For meshes of 64, 128, 256, 512 and 1024 elements in each spatial direction were executed numerical experiments. The speedup values for each parallel implementation were calculated. The results are shown in the next Figure.



In this graphic, we can observe that the CPU-based implementations reaches a relatively low speedup. The speedup order is approximately the number of nodes available in the parallel machine. Even using domestic GPUs this implementation reaches high speedups (between 16 and 70, for mesh with 1024 elements). The results show the great potential and low cost of the parallel techniques based on GPU-CUDA to obtain a numerical solution of the single phase flow in porous mediums.

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