9th International River Engineering Conference
Shahid Chamran University, 22-24 Jan 2013, Ahwaz

Seepage Simulation in Porous Media on GPU vs. CPU

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Abstract

Graphics processor units (GPU) which are originally designed for graphics and video games rendering have recently used as massive parallel computing device for general purpose computations.. This paper compares performance of GPUs against CPUs for numerically solving Laplace Partial Differential Equations (PDEs) governing on seepage in porous media. The equations are discretized with finite volume method. Results demonstrate that modern GPUs can be effective computational devices in order to reduce the execution time of numerical methods. CUDA is used as software development kit (SDK) to employ NVIDIA graphic cards for general-purpose tasks and the main program is coded in MATLAB.

KEYWORDS: CUDA, GPU, Seepage, Computational effort, execution time, CFD.

1. Introduction

Numerical methods are the most demanded tools in engineering and science to deal with complex equations such as partial differential equations (PDE); however since they are iterative methods, they are always time consuming processes. The parallel nature of grid problems provides an opportunity to reduce the execution time of these methods. There are two main options: (1) using high-performance computing (HPC) on supercomputers consisting of thousands of CPU cores, or (2) using the novel computing architectures such as Graphics Processing Units (GPUs) (Crespo et al. 2011). This paper focuses on the second approach. GPUs are designed to render millions of pixels several times per second to run video games. Thus they are designed to have multi-threading capabilities and are suitable for general purpose calculations in addition to their main tasks. General purpose calculation on GPUs is called GPGPU.

Early in 2007, NVIDIA, the manufacturer of GeForce GPUs, introduced CUDA as a software development kit (SDK) that allows NVIDIA graphic cards to be programmed for general-purpose tasks. Soon after introduction of CUDA, the use of GPUs for CFD applications increased rapidly. The earliest implementations of CFD on GPU are done before the advent of CUDA. Amada et al. 2003, Scheidegger et al. 2005, Kolb & Cuntz 2005, and Harada et al. 2007 employed GPU without using CUDA to solve CFD problems. After introduction of CUDA, Elsen et al. 2008, Brandvik & Pullan 2008 and 2009, and Cohen & Molemaker 2009