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GPU accelerated simulation of the elastodynamic Biot's equations

Yury Alkhimenkov, Beatriz Quintal, and Yury Podladchikov
Swiss Geocomputing Centre, University of Lausanne, Lausanne, Switzerland (yury.alkhimenkov@unil.ch)

Biot's theory describes the coupled solid-fluid interaction in a porous medium. In the earth sciences, poroelasticity is essential in many applications, for example, in hydrogeology, in seismic monitoring of CO_2 reservoirs, etc. In the present work, we solve Biot's equations for particle velocity and stress in the time domain with a finite difference approach on a staggered grid. Depending on the medium's properties, besides the elastic compressional and shear waves, one may observe the propagating slow wave or the diffusive static slow mode. In such a case, when the diffusive slow mode is present, the time-stepping should be very small in order to reach a stable simulation of Biot's equations. We present a new treatment of this problem based on the so-called pseudo-transient method. The idea is that at each time step, another pseudo iteration causes the slow mode to attenuate quickly. As a result, very fine time-stepping is unnecessary and the time-stepping is controlled by a standard Courant stability condition for the fast P-wave. Furthermore, we accelerate a finite-difference code using an NVIDIA graphics card with the CUDA programming language.