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TESLA™ CASE STUDY

Petaquake

Easing the Pain of Earthquake Prediction

Background

As evidenced by Japan's deadly 2011 tragedy, earthquakes can hit without warning, even in areas without a history of seismic activity. In order to effectively study earthquakes, incredibly precise simulations are needed that take into account a number of factors, including known fault data, regional risk, geological terrain, and the anticipated type of rupture. With this data, predictions can be made on how different areas will be affected.

Challenge

Current physics-based ground motion prediction uses earthquake rupture dynamic models. These models require an enormous amount of memory and processing power that is available only from high-performance supercomputers, which are limited in availability and location.

"These predictions are difficult to make because the medium, through which the oscillation generated by the earthquake propagates, is very complex," said Lapo Boschi, Ph.D. and senior research scientist in the Seismology and Geodynamics Group at the Institute of Geophysics in Zurich.

Solution

The Petaquake project is a joint research collaboration between seismologists (ETH Zurich) and computer scientists/mathematicians (University of Basel), aimed at further developing methods to refine images of the interior of the Earth. Their core mission is to reduce the guesswork about future earthquakes and improve the chances of early detection and warnings.

By defining a numerical grid and how heavy, flexible or brittle the soil is in each grid location, seismologists can create a three dimensional model of the Earth's crust in a specific region, and calculate precisely how each segment in the area will oscillate during an earthquake. Using the ultra-high processing capabilities of GPUs, Petaquake can track the waves generated by earthquakes to map the earth's interior 3D structure.

"The concept is analogous to that of medical tomography, but instead of electromagnetic radiations (x-rays) we use elastic ones (seismic waves)," said Tarje Nissen-Meyers, Ph.D. and Senior Research Scientist in the Seismology and Geodynamics Group at the Institute of Geophysics in Zurich. "It is useful to know what's underneath a city, so that necessary precautions can be taken when building." This information also enables the ability to model early warnings that predict potentially dangerous interruptions to high-risk businesses, such as hospitals and power plants.

Impact

Improving 3D geological structures, which is essential to any earthquake assessment, requires solving a wave propagation system upon hundreds of millions of grid points with hundreds to thousands of such simulations on large computers. These simulations, which run orders of magnitude faster on GPUs compared with CPUs, can assess the results of hypothetical earthquakes in a fully statistical manner. Earthquake early warning takes advantage of the fact that the most severe damage is not caused by the first arriving wave of an earthquake, but by subsequent waves. This will lead to much-improved understanding of the unique qualities of certain geographical locations, enabling city officials to plan appropriately by reinforcing building codes and identifying potentially dangerous interruptions to high-risk business.

It is expected that Petaquake codes run on GPUs will speed up large-scale computations by a factor of 10-40 times. In the past, projects of longer than two years have been beyond the reach of most graduate-student, postdoctoral or funding time frames. However, with high-performance GPUs, a study that would have taken two years can now be done in a month, a time scale which makes computational research feasible and affordable.

GPUs also allow faster assessment of quake damage immediately after a seismic event. “With GPUs, we are able to assess the shaking in 15 minutes rather than 5 hours,” continued Nissen-Meyers. The hours after an earthquake are critical to understanding the scope of the damage in order for rescue teams to organize their best efforts.

While Petaquake does not yet have the capability to predict future earthquakes, it is capable of tackling realistic seismic wave propagation to assess the effect of potential future earthquakes on ground movement and hazard assessment. In addition, Petaquake is able to focus on the overall impact of seismic movement on a particular continent.

Currently, Europe is being studied to better understand the tectonics dominated by the collision between the African and Eurasian plates, and define the cause of major seismicity in Italy and Greece.