AsHES’15 Keynote Speaker

The Numerical Reproducibility Fair Trade:
Facing the Concurrency Challenges at the Extreme Scale

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Abstract: Trends in execution concurrency on accelerated platforms make a compelling case for developing methods that can automatically and efficiently model and mitigate numerical irreproducibility beyond petascale and into exascale. High-performance accelerated computers at the extreme scale exhibit an enormous level of concurrency—a factor of 10,000 greater than on traditional platforms—that is moving computer simulations from bulk-synchronous executions to nondeterministic multithreading calculations and asynchronous I/O. As concurrency levels in simulations increase, the impact of rounding errors on numerical reproducibility is also exacerbated, ultimately affecting the ability of scientific simulations to reproduce program executions and numerical results. Under these circumstances, irreproducible results may not be trusted by a scientific community expecting reproducible behaviors; and any attempt to pursue reproducibility may come at a cost in performance that is too high.

In this talk we discuss the impact of rounding errors on result reproducibility when concurrent executions burst and workflow determinism vanishes on cutting-edge accelerated platforms. We unveil the power of mathematical methods to model rounding errors in scientific applications and discuss how these methods can mitigate error drifting on new generations of accelerators. Specifically, we focus on floating-point error accumulations for global summations for which any reduction order is too expensive or even impossible to enforce at the extreme scale from run to run. We model summations as reduction trees and identify those parameters that can be used to estimate the reduction's sensitivity to variability in a reduction tree. We assess the impact of these parameters on the ability of different reduction methods based on compensated summation (e.g., composite-precision summation) and “distillation” algorithms (e.g., prerounding) to mitigate errors. Our results illustrate the pressing need for intelligent runtime selection of reduction operators that ensure a given degree of reproducibility.