

A Generic Profiling Infrastructure for the Hyperbolic PDE Solver Engine ExaHyPE

Part II

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The project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 671698 (ExaHyPE).



Introduction

What this presentation is not about:

- ▶ **Numerics** deep dive into ADER-DG, Limiting, etc.
(first ~ 30 pages of the thesis)
- ▶ No beautiful **pictures**, convergence **plots**, application **examples**, ...
- ▶ **Demo session** ;-(

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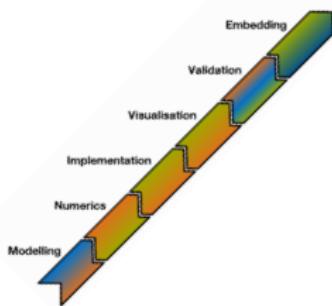
What this presentation is about:

- ▶ Review: **Context** and **motivation** behind the project
- ▶ Theory on **hardware performance monitoring** (HPM)
- ▶ A **generic profiling infrastructure** for ExaHyPE
- ▶ Preliminary **profiling results** and two **case studies** focusing on metrics-driven performance engineering

Context & Motivation

Important aspects in the context of Scientific Computing:

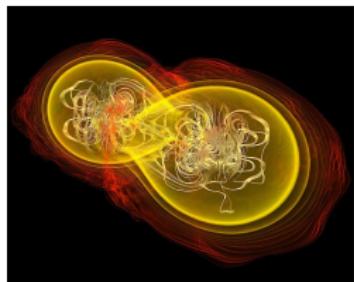
Simulation Pipeline



Exascale Computing



Hyperbolic Balance Laws



ExaHyPE: The Project

Vision:

- ▶ Three pillars of scientific progress:
Theory, Experiment and **Simulation**
- ▶ Programming (exascale) supercomputers is a key challenge
- ▶ The ExaHyPE project seeks to address the **software aspect** of supercomputer development
 - ▶ Development of new mathematical and algorithmic approaches
 - ▶ Initial focus on applications in geo- and astrophysics
 - ▶ In correspondence with Europe's **2020 exascale strategy**
- ▶ Goal: Become **the engine** for large HCL simulations!

ExaHyPE: The Project

Objectives:

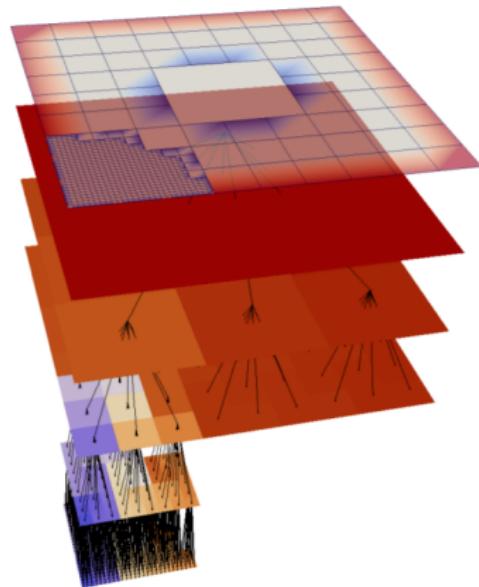
- ▶ **Energy efficiency** on tomorrow's supercomputing hardware
- ▶ Scalable algorithms through well-balanced **dynamic adaptivity**
- ▶ **Compute-bound** simulations in spite of slow memory and networks
- ▶ Extreme parallelism on **unreliable hardware**



ExaHyPE: The Project

Approach:

- ▶ High-order space-time Discontinuous Galerkin method (**ADER-DG**) with a-posteriori FVM based subcell limiting
- ▶ Dynamically adaptive Cartesian grids (**AMR**), space filling curves and dynamic load balancing (**Peano**)
- ▶ Hardware specific optimization of dominant compute kernels (**libxsmm**)



Adaptive grids in Peano
(via Tobias Weinzierl, 2014)

ExaHyPE: Applications

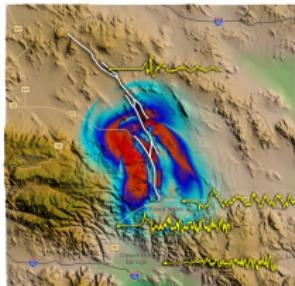
Hyperbolic Balance Laws:

$$\frac{\partial}{\partial t} [\mathbf{u}]_v + \frac{\partial}{\partial x_d} [\mathbf{F}(\mathbf{u})]_{vd} = [\mathbf{s}(\mathbf{u})]_v$$

Initial focus:

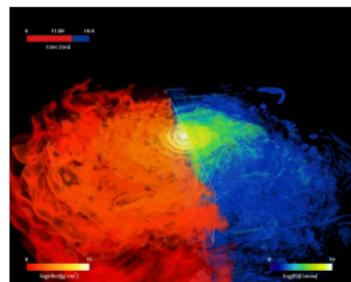


Geophysics



Simulation of ground shaking of
the 1992 Landers Earthquake

Astrophysics



Simulation of the merger of two
magnetized neutron stars

Profiling for ExaHyPE: Motivation

You can't optimize for what you don't measure!

Profiling provides metrics to

- ▶ obtain a **baseline**,
- ▶ **guide** and **track progress** of optimization efforts,
- ▶ **compare** current status to other state of the art solutions.



We don't need a third one
of these on campus!



Profiling and Energy-Aware ...



On the Importance?



x86 in contemporary HPC

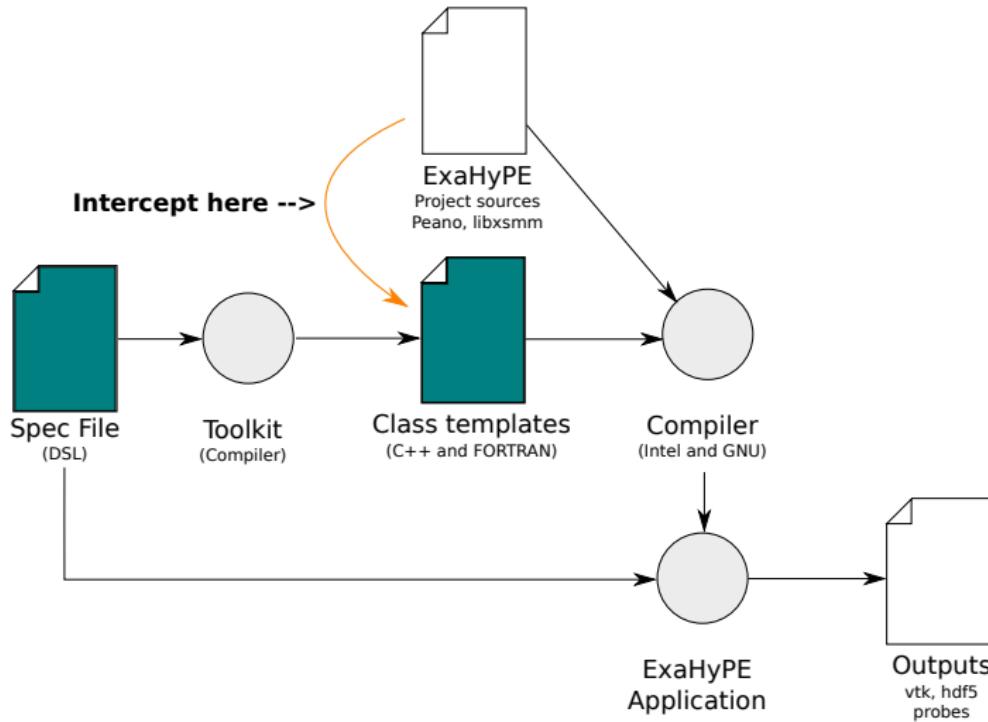


HPM in x86

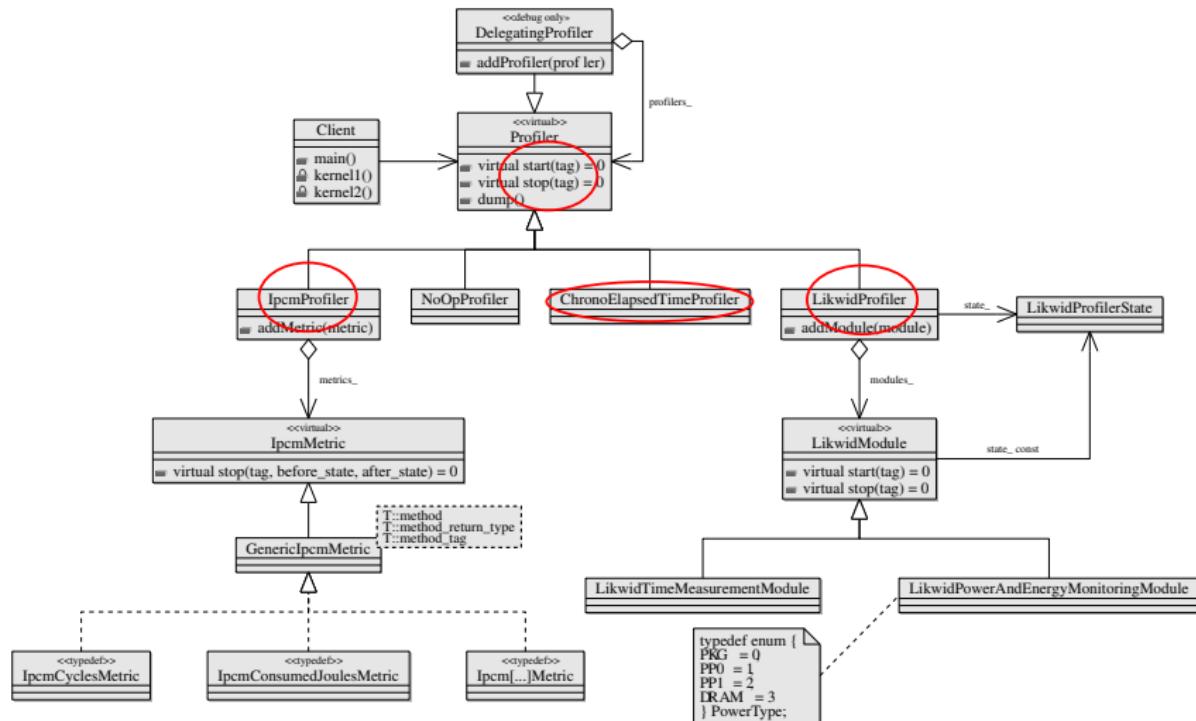


Energy Monitoring in x86

Profiling for ExaHyPE: Architecture



Profiling for ExaHyPE: Architecture





Implementations

Profiling for ExaHyPE: Metrics

What we can measure at the moment:

- ▶ Kernel call counts
- ▶ Cycles and wall clock time
- ▶ RAM reads/writes
- ▶ **Flop/s** (estimate)
- ▶ **Energy consumption** (Core, RAM, package; estimate)
- ▶ Cache hits/misses/ratio (I, L2, L3)
- ▶ **Cycles lost** due to cache misses (L2, L3)
- ▶ Instructions retired
- ▶ Branch prediction ratio
- ▶ ...

Overheads



Complete Simulation



Kernel-by-kernel breakdown



The seventh order itch



Finding the juiciest fruits

Conclusion

Key aspects:

1. Exascale Computing is about both hardware and **software**
2. ExaHyPE as an **answer to future challenges** in Scientific Computing
3. **Frameworks** are necessary to manage the increasing complexity in HPC
4. Profiling is important: **Measure, then optimize!**

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