The ExaHyPE story & Profiling for ExaHyPE
Part I

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Introduction

Topics not covered by this presentation

- Numerics deep dive (ADER-DG, Limiting, etc.)
- Performance analysis case studies and scaling graphs
- Demo session ;-(

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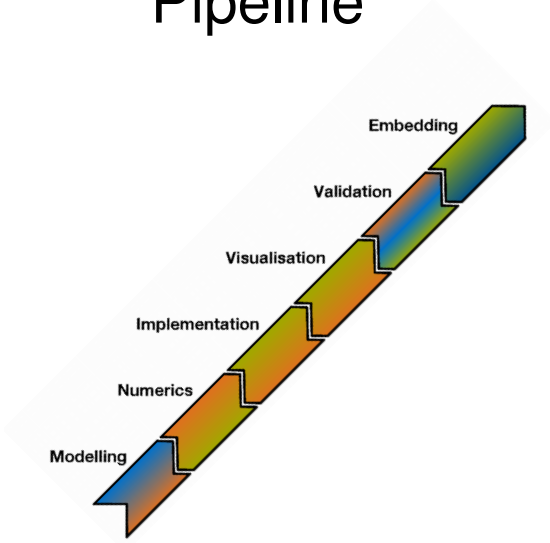
Topics covered by this presentation

- Context and motivation behind the project
- Overview on key objectives of ExaHyPE
- Summary on techniques employed by the framework
- Current state and next steps on the agenda
- Profiling infrastructure for ExaHyPE

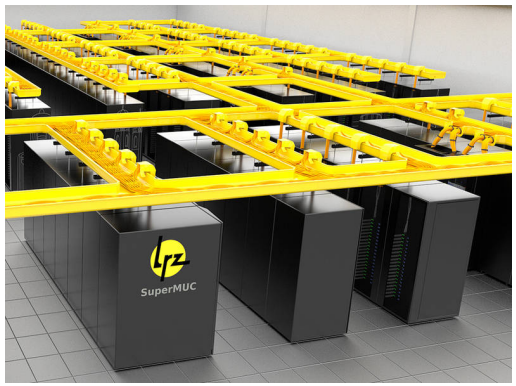
Context & Motivation

Important aspects in the context of Scientific Computing

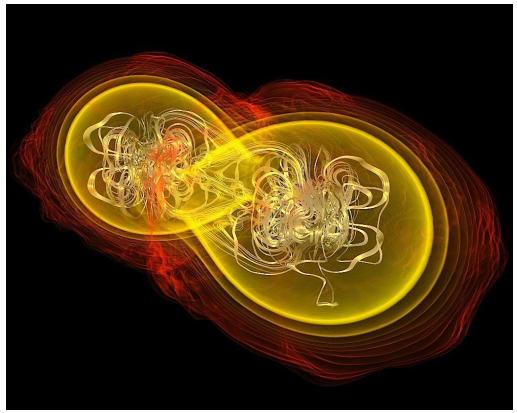
Simulation Pipeline



Exascale computing



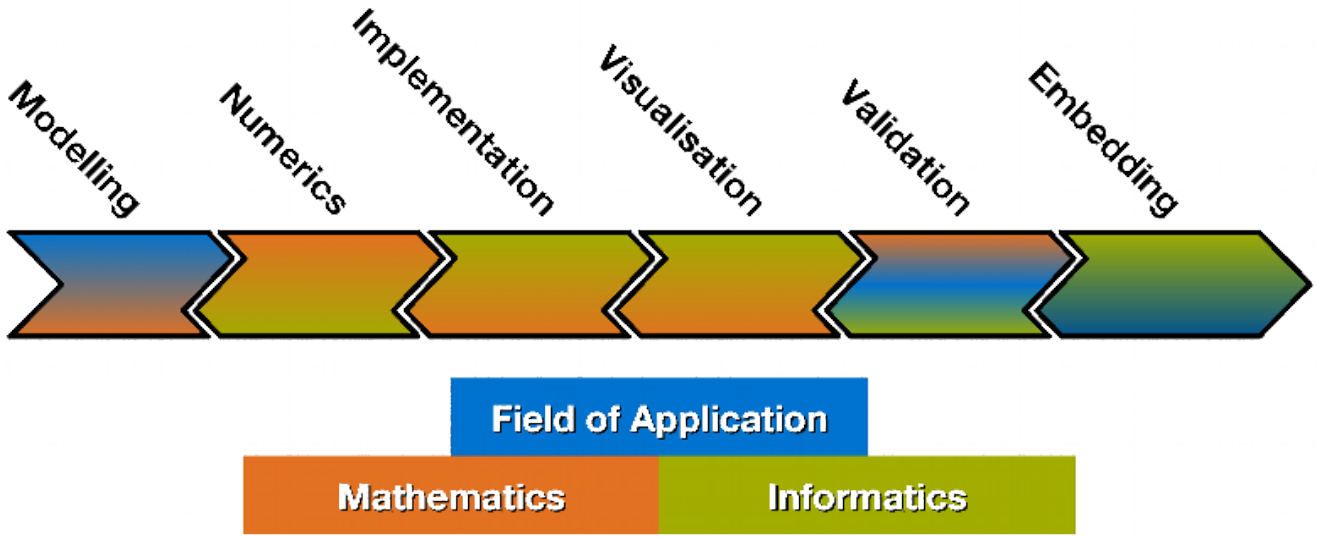
Hyperbolic PDEs



Simulation Pipeline

Observations from practice

- All steps are repeated over and over again!
- Nobody can be an expert in everything!
- Why not focus on what you are best in and consider the other problems solved?



The Simulation Pipeline

via Hans-Joachim Bungartz: Modeling and Simulation (IN2010)

Exascale Computing

Major challenges

- Energy consumption
- Multi-level parallelism on hybrid architectures
- Fault tolerance and resilience
- Memory and bandwidth as bottleneck
- ...

Exascale Computing

Sunway TaihuLight, Wuxi, China, 2016
125 PFlop/s, 15.3 MW, 237M USD

An exascale system, Europe, 2020?

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148 SuperMUCs don’t fit on a slide. . .

Hyperbolic PDEs

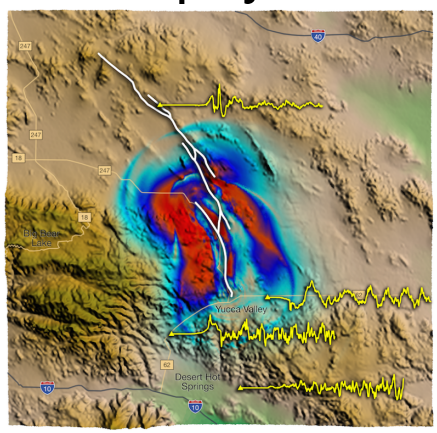
General form

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

where $v \in \{1, 2, \ldots, V\}$ and $\boldsymbol{F} = [\boldsymbol{f}_1, \boldsymbol{f}_2, \ldots, \boldsymbol{f}_D]$ and $\frac{\partial [\boldsymbol{f}_d]_i}{\partial x_j}$ has real eigenvalues for all $d \in \{1, 2, \ldots, D\}$.

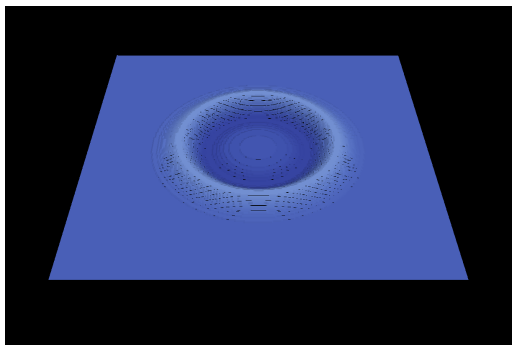
Areas of application

Geophysics



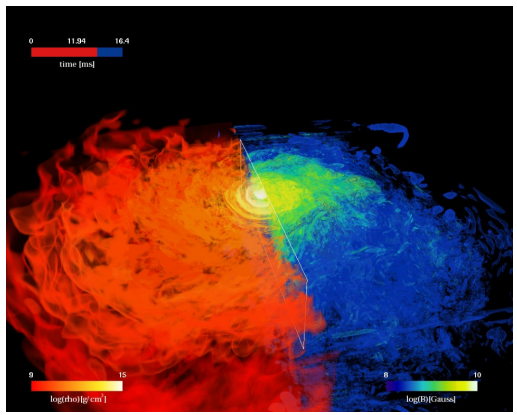
Simulation of ground shaking of the 1992 Landers Earthquake

Gas dynamics



Simulated pressure wave in a compressible gas

Astrophysics



Simulation of the merger of two magnetized neutron stars

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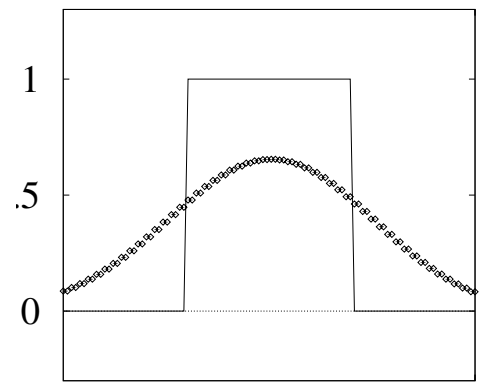
Challenges

- Long-term accuracy
- Stability at shocks
- Time step restrictions
  (e.g. for stiff source terms)
- Arithmetic density and data locality



Example Linear Advection
(via Eleuterio F. Toro:
Riemann solvers and numerical
methods for fluid dynamics)

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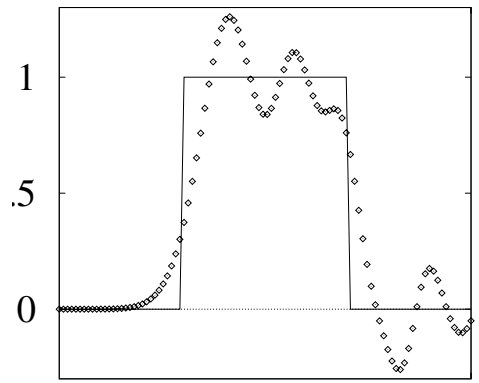

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The ExaHyPE project

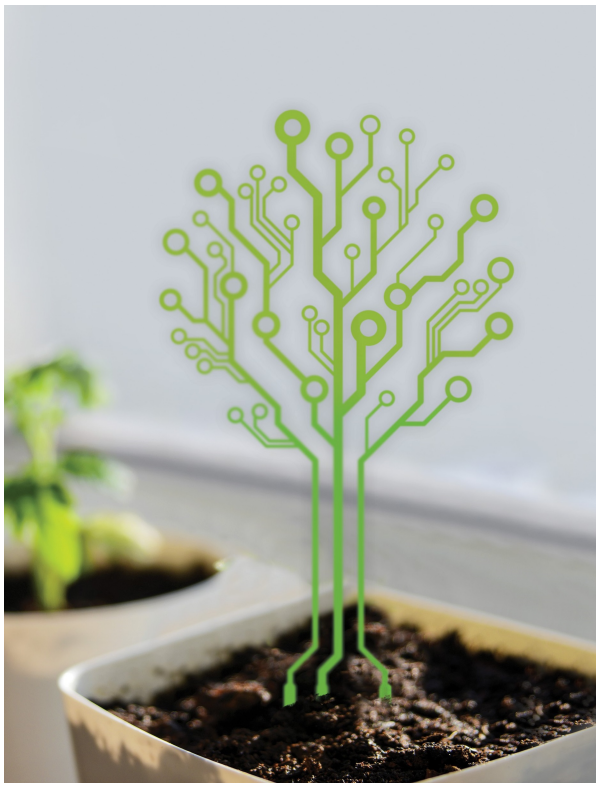
Vision

- 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
  - Correspondence with Europe's 2020 exascale strategy

The ExaHyPE 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



The ExaHyPE project

Benefit

- Simulation of risk scenarios
- Fundamental scientific findings
- Open-source

The ExaHyPE project

Approach

- bla

Exahype: Applications

Exahype: As a user

Exahype: Consortium

Exahype: Profiling motivation

Exahype: Profiling arch

Exahype: Profiling next steps