How can we accelerate traditional models for a real time setting?

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Introduction

- models for physical, financial, biological, and technical problems
- mostly based on Partial Differential Equations
- used for prediction, optimisation, combination with measurements
- coupled problems
- complex physics
  - more advanced simulation methods
  - more unknown coefficients/parameters

Discretization methods (classical)

- Finite Difference Method
- Finite Element Method
- Finite Volume Method
- Boundary Element Method
- Panel Method

Discretization methods (new developments)

- Discontinuous Galerkin
- Spectral Methods
- Particle methods (SPH, MPM, Meshfree)
- Isogeometric Analysis (CAD $\Leftrightarrow$ CAA)
- Space-time Discretization
- High order time integration methods
- Implicit methods
- Monolithic $\Leftrightarrow$ segregated
- local grid refinement

Solver methods

- Direct (parallel) methods
- Iterative solution methods
  - Krylov methods
  - preconditioners
  - multi grid method
  - domain decomposition method
- multi-level methods (model order reduction)
- accelerators (Deflation, Coarse Grid Correction)
- combined methods, standard building blocks
- operator based preconditioners

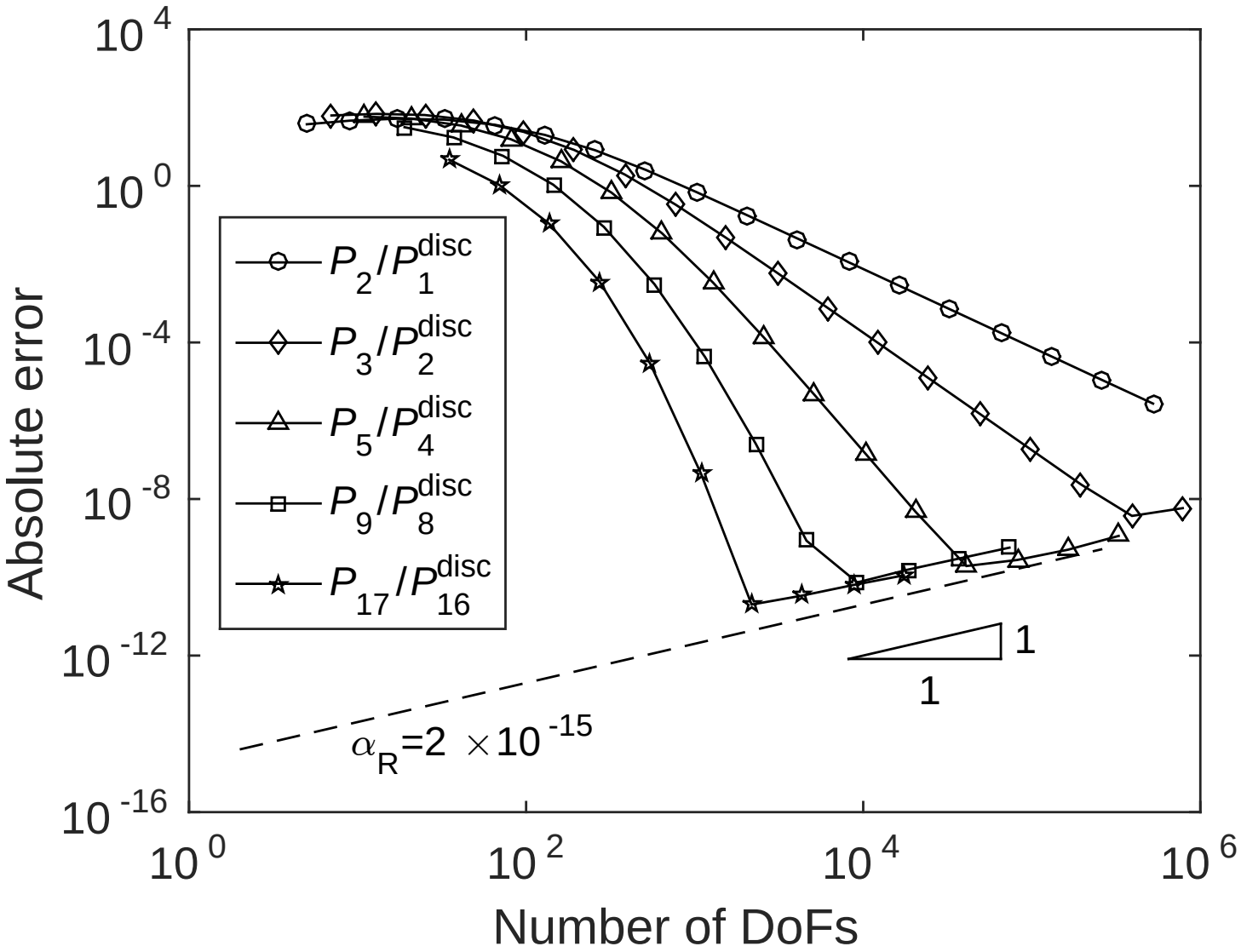
High performance computing

- multi core
- multi node
- MPI / OpenMP
- GPU (OpenCL, CUDA, OpenACC)
- FPGA (hardware and software optimisation)
- memory access slower than flops
- operations per memory access (roofline model)

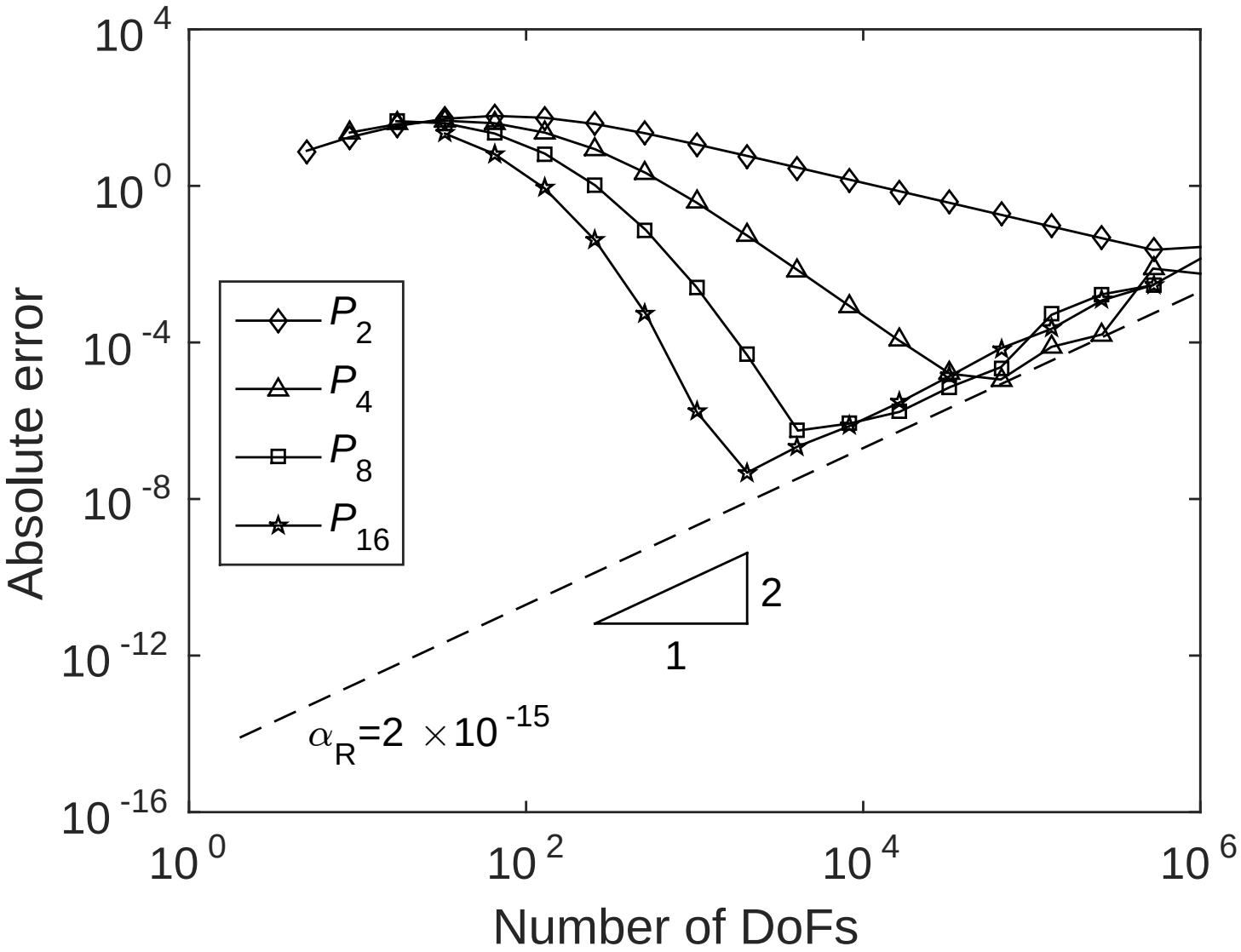
Software developments

- nothing wrong with Fortran
- Linux
- mix of languages
- C++, C, Python, Julia
- Matlab $\Rightarrow$ Python
- Open source
- Reliable, reproducible, ...
- containers (Docker, Singularity)
- Machine Learning / Tensor flow machines

Accuracy FEM



Accuracy Mixed FEM



Move to new software

The Singular Value Decomposition: Anatomy of Optimising an Algorithm for Extreme Scale
Jack Dongarra, Mark Gates, Azzam Haidar, Jakub Kurzak, Piotr Luszczek, Stanimire Tomov, and Ichitaro Yamazaki
SIAM Rev., 60(4), 808-865i, 2018

We show that algorithmic and implementation improvements have increased the speed of the SVD by several orders of magnitude, while using up to 40 times less energy.

Read More: https://epubs.siam.org/doi/10.1137/17M1117732

Conclusions

- Numerical methods are developing fast.
- Keep up to date!