Application resilience

Problems and objectives
- Most powerful supercomputers: more than one failure per day
- Resilience: ability to produce correct result in spite of faults
- Extensive experimental campaigns are too expensive
- How to choose a resilience protocol? How to tune it?

Methods
- Probabilistic analyses
  - Exact derivations
  - First-order approximations
- Discrete-event simulations
- Applied to various protocols/techniques:
  - Fault prediction
  - Silent error detection
  - Checkpointing, replication, migration, error correction

Lower bound

\[ \text{A} \text{\ø} \text{A} \text{\ø} \text{N} \text{\ø} \text{A} \text{\ø} \text{m} \text{\ø} \text{N} \text{\ø} \text{A} \text{\ø} \text{N} \text{\ø} \text{A} \text{\ø} \text{N} \]

No online algorithm \( A \) is < \( \frac{p}{m/k} \) - competitive for any \( m, k \).

Proof (where \( \phi = \frac{p}{m/k} = 3 \)):

Graph with

\[ \begin{array}{cccccccc}
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
\end{array} \]

Theorem

Solvers for sparse linear algebra and related optimization problems

Direct solvers for sparse linear systems
- Target performance and numerical robustness
- Limit resource consumption (e.g., memory)
- Exploit low-rank representations to reduce complexity

Combinatorial scientific computing
- Design, analysis, and implementation of combinatorial algorithms to enable scientific computing
  - Matchings and partitioning in graphs and hypergraphs
  - High performance computing with matrices and tensors

The MUMPS solver

- Solve systems of linear equations \( AX = B \) (A sparse)
- Owners: CERFACS, CNRS, ENS Lyon, INPT, Inria, Univ. Bordeaux
- Software platform to experiment and transfer research
- CeCILL-C license, used worldwide, included within many open-source and commercial packages
- Many features, addresses a wide range of problems: symmetric, unsymmetric, indefinite, multiple (sparse) right-hand sides, Schur, ...

Multi-criteria scheduling strategies

Mix user-oriented objectives (time-to-solution, throughput) with platform-oriented constraints (energy, memory)

Energy-aware algorithms
- Energy consumption of fault-tolerance protocols
- Use of Dynamic Voltage and Frequency Scaling (DVFS)
- Powering cores below nominal voltages

Memory-aware algorithms
- Minimize memory or I/O when processing task graphs
- Memory minimizing traversals for trees and SP-graphs
- Limit memory-peak usage of parallel execution
- Allow for efficient runtime schedulers

Hybrid CPU-GPU scheduling
- Task or task-graph scheduling
- Low-cost scheduling algorithms
- Online scheduling with guarantees

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