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FRANCE 2030
PROGRAMME DE RECHERCHE
NUMÉRIQUE POUR L'EXASCALE

Compilation and Automatic Code Optimization

Work Package 2

Philippe Clauss

September 24, 2025

University of Strasbourg & Inria Camus

WP2 Goals

- Make advanced code optimizations available to the HPC community
  automatic parallelization, *loop transformations*, *polyhedral optimizations*, ...
- Using static or runtime optimization techniques
  additional compilation passes, *just-in-time analysis & optimization*, ...
- Implement automatic code optimizations in mainstream HPC programming tools
  Clang-LLVM, *Kokkos*, ...
- User-transparent code optimizations yielding:
  - better computing resource usage
  - better time performance
  - less energy consumption

WP2 Members

- WP2 leaders: Philippe Clauss (Inria Camus) & Thierry Gautier (Grenoble)
- Other permanent researcher: Christophe Alias (Inria Cash)
- PhD Students:
  - Ugo Battiston (WP1+WP2, since October 2023)
  - Raphaël Colin (since October 2023)
  - Alec Sadler (since October 2023)
- Engineers:
  - Erwan Auer (since January 2024)
  - Pierre-Etienne Polet (since March 2024)

Running PhDs

- Ugo Battiston (WP1+WP2, since October 2023)
  Connecting Kokkos with the polyhedral model
  Advisors: Philippe Clauss & Marc Pérache (CEA, WP1)

- Raphaël Colin (since October 2023)
  Context-adapted multi-versioning of computation kernels
  Advisors: Philippe Clauss & Thierry Gautier

- Alec Sadler (since October 2023)
  Automatic Specialization of Polyhedral Programs on Sparse Structures
  Advisor: Christophe Alias

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Connecting Kokkos with the Polyhedral Model

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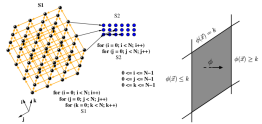
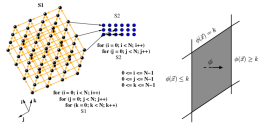


kokkos

- Kokkos:
  - a production level solution for writing modern C++ applications **in a hardware agnostic way** (CPU, GPU)
  - increasingly used by the HPC community (and by people involved in NumPEx)

Connecting Kokkos with the polyhedral model



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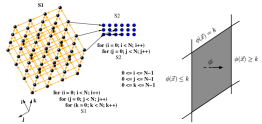

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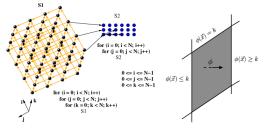

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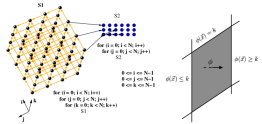

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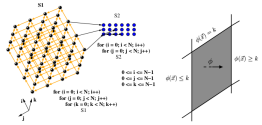
  - The kind of parallel code kernels that may be written with Kokkos are too restricted
    ⇒ *Only rectangular loop iteration domains, e.g. no triangular domains*
    ⇒ *Only one loop nest per kernel, no kernel made of several loop nests*
    ⇒ *missed optimization opportunities (e.g. loop fusion)*

Connecting Kokkos with the polyhedral model



kokkos

- Our solution
  - Make advanced fully-automatic code optimizations available to Kokkos
  - Enable users to write a wider range of kernels
- Opportunities
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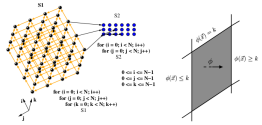
  - Existing code optimizers may be connected/adapted to Kokkos: LLVM-Polly, Pluto, ...
- First WP2 deliverable at the end of October

Connecting Kokkos with the polyhedral model



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Context-Adapted Multi-Versioning of Computation Kernels

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  - **Performance portability is a fake!**

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  - Different optimizing code transformations per context are required

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- Our solution
  - Seeking the best performing code versions for observed actual contexts, on-the-fly
    - By testing different optimizing transformations
    - By simulating real execution samples
    - On separated nodes/cores
  - While the main code is running
  - Branching the main code on a better performing version
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Conclusion

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- Next main steps:
  - Consolidate and generalize our results
  - Make our software implementations the most robust and reliable
  - Target GPU codes
- Longer term:
  - Many more useful automatic code optimizations should be made available to the HPC community
- WP2 staff
  - 1 PhD to be hired in 2025/2026 (task 2.1)
  - Erwan Auer's engineer contract extended by 2 years (starting Jan. 2026)

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