MUST: Compiler-aided MPI correctness checking with TypeART

TECHNISCHE UNIVERSITÄT DARMSTADT

RWTH AACHEN UNIVERSITY

FOSDEM'23 HPC, Big Data, and Data Science Devroom
Sunday, 5th February 2023, Brussels, Belgium

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MUST
https://itc.rwth-aachen.de/must

TypeART
https://github.com/tudasc/typeart

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How many errors in this example?

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```c
#include <mpi.h>
#include <stdio.h>
int main (int argc, char** argv) {
  int rank, size, buf[8];

  MPI_Comm_rank (MPI_COMM_WORLD, &rank);
  MPI_Comm_size (MPI_COMM_WORLD, &size);

  MPI_Datatype type;
  MPI_Type_contiguous (2, MPI_INTEGER, &type);

  MPI_Recv (buf, 2, MPI_INT, size - rank, 123, MPI_COMM_WORLD, MPI_STATUS_IGNORE);
  MPI_Send (buf, 2, type, size - rank, 123, MPI_COMM_WORLD);

  printf ("Hello, I am rank %d of %d.\n", rank, size);
  return 0;
}
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No MPI_Init before first MPI call

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No MPI_Init before first MPI call
Fortran type in C
Recv-Recv deadlock
Rank 0: src=size (out of range)
Type not committed
Type not free'd before end
Send 4 int, Recv 2 int: trunc.
No MPI_Finalize before end

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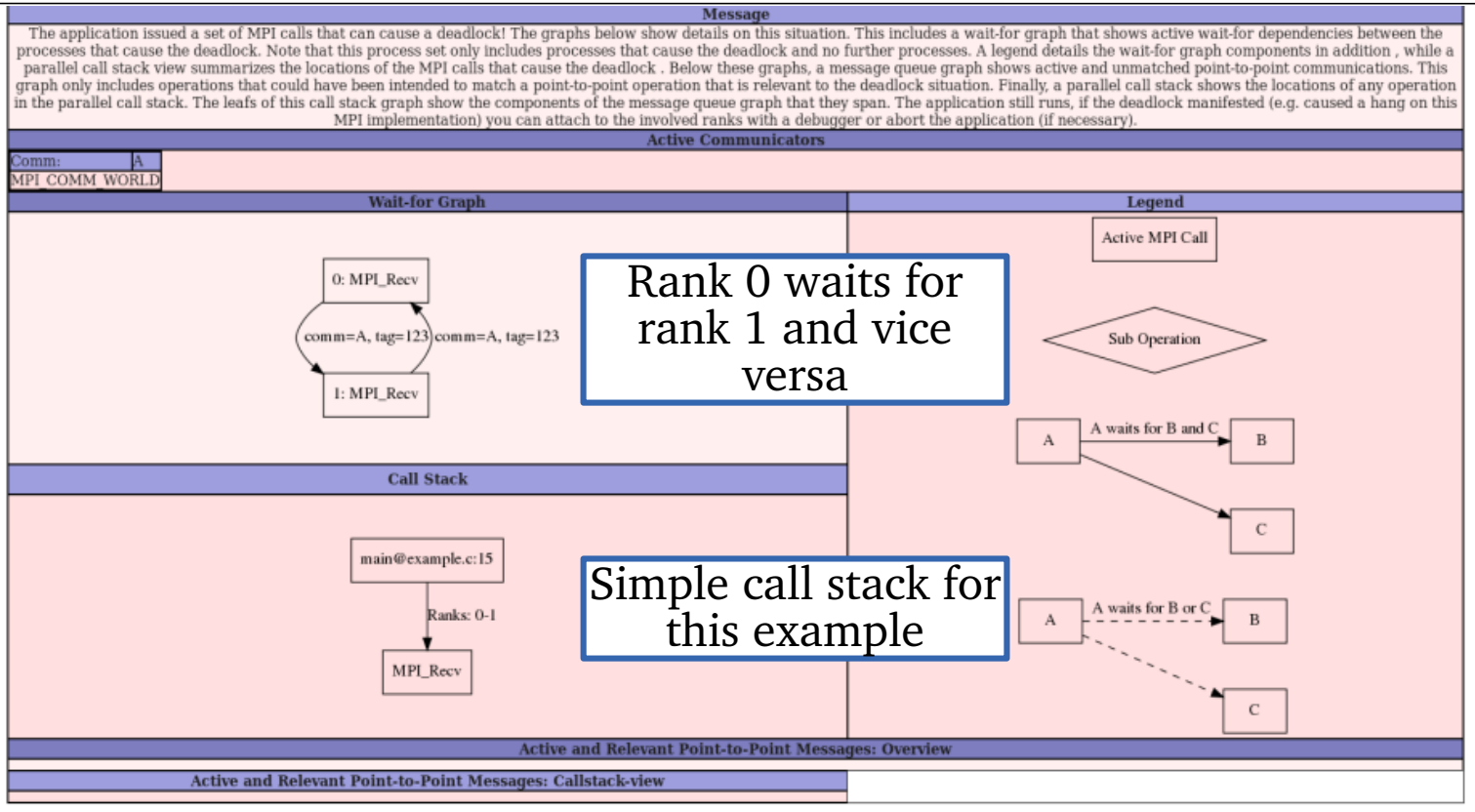
MUST report of deadlock



MUST: Agent-based distributed analsysis

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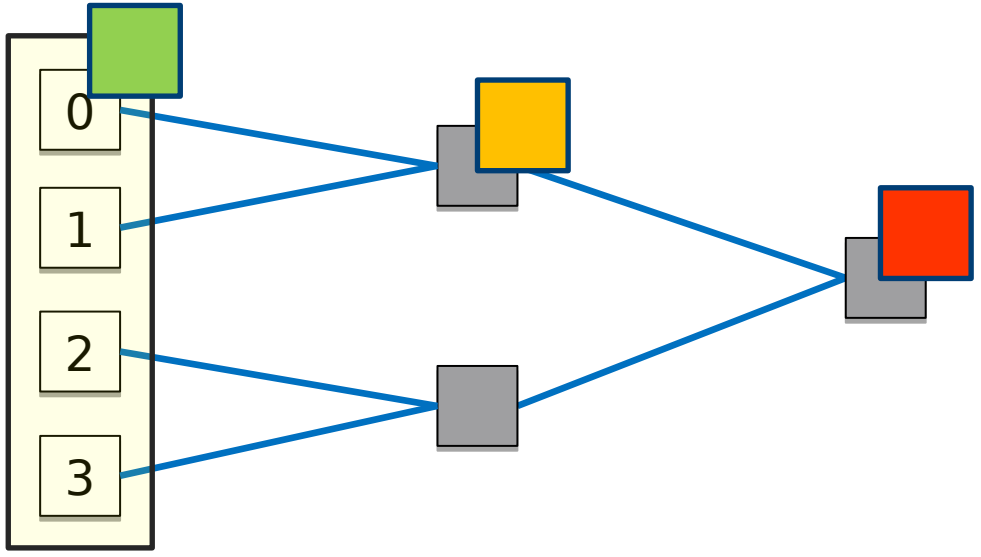
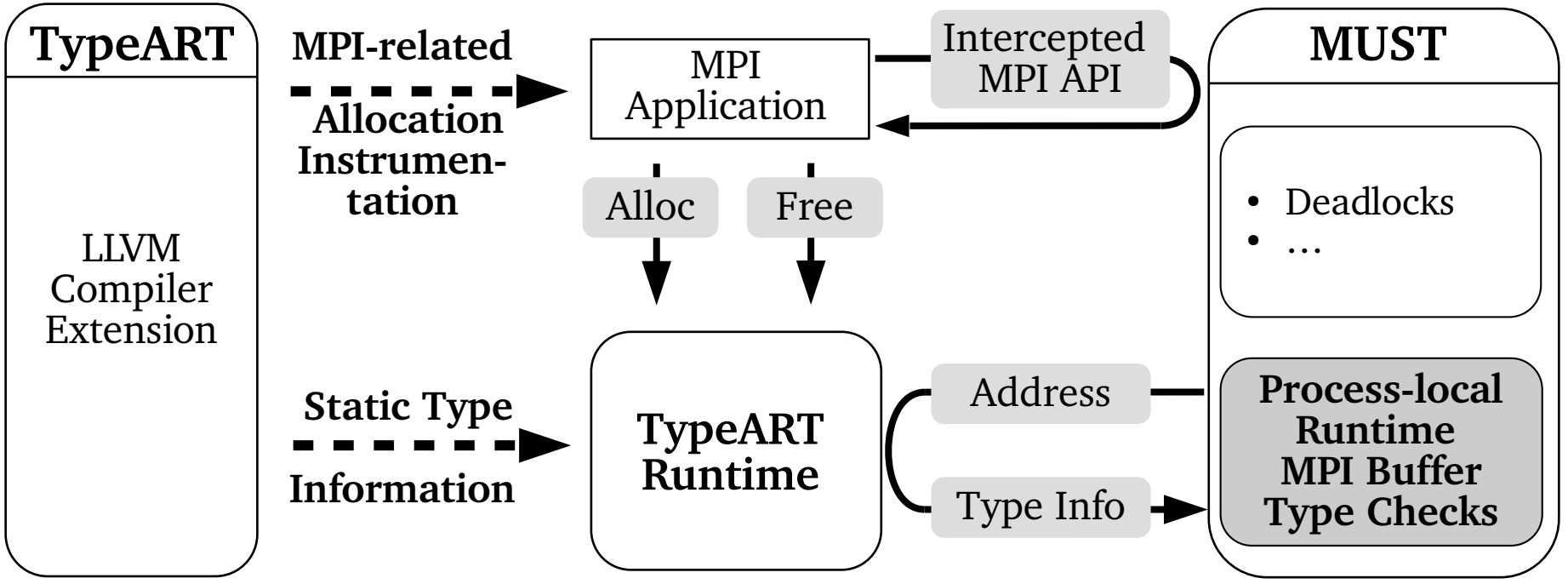


- Local analysis (e.g., TypeART MPI buffer type correctness)
- Distributed analysis for scalability (e.g., matching MPI send-recv types)
- Centralized analysis for global knowledge (e.g., global deadlocks)
- MUST specific communication (hidden from application)

MUST and TypeART



MUST and TypeART usage

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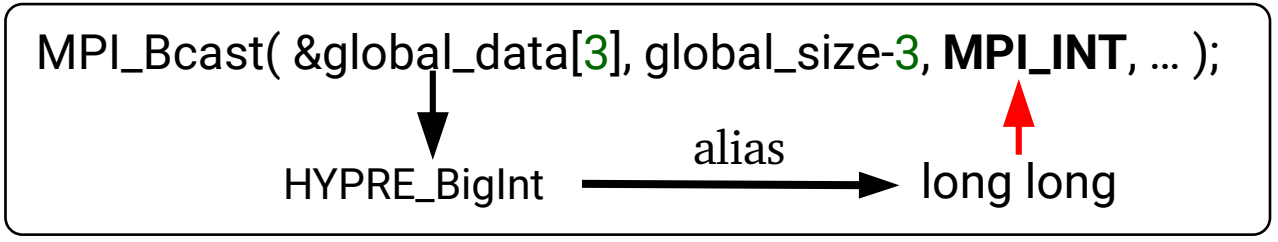
1) Compile and link with TypeART wrapper (optional, if full MPI type checking wanted)
   - mpicc → typeart-mpicc
2) Replace “mpiexec” with “mustrun”
   - e.g., mustrun -np 4 --must:typeart my-app.exe
3) Inspect “MUST_Output.html” in run directory

- The mustrun script will use an extra process for non-local checks (invisible to application)
  - “mustrun −np 4 …” will issue a “mpirun −np 5 …”
- Make sure to allocate the extra task in batch jobs

Examples

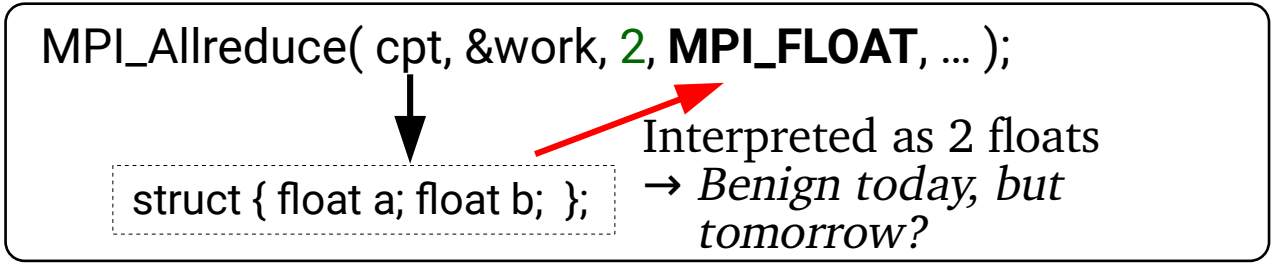
AMG2013, a CORAL performance and parallel scaling benchmark [Coral'20]

- In parcsr_mv/par_csr_matrix.c:1236, reported by [DKL LLVM'15]:



104.milc, a SPEC MPI benchmark [SpecMPI'07]

- In com_mpi.c:480



Brief evaluation

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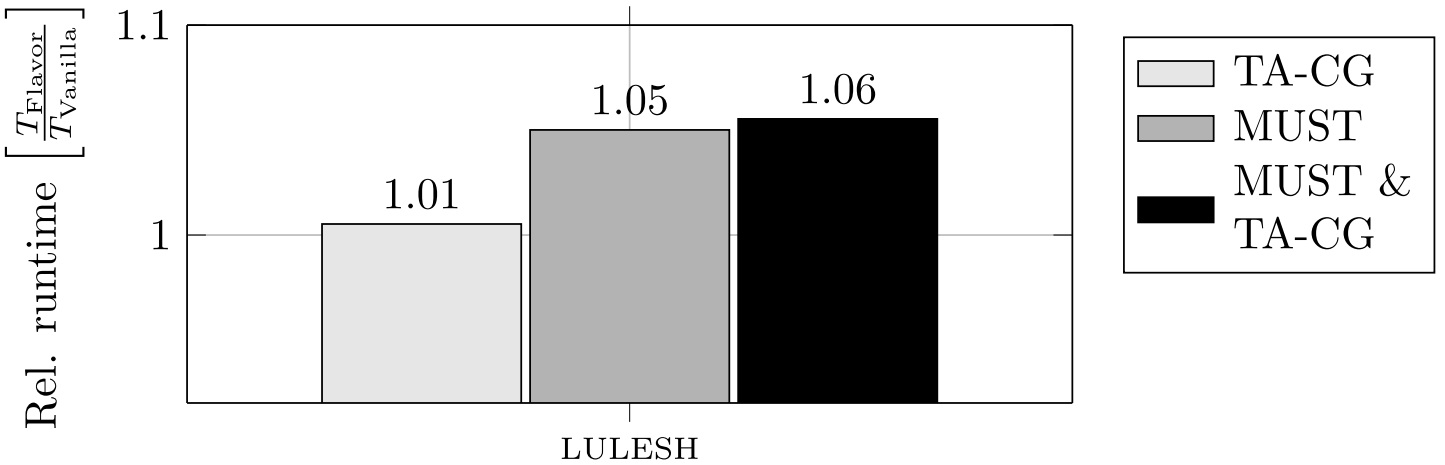
Runtime/memory impact depends on number of tracked allocations

- Runtime overhead for LULESH run, checking MPI communication with MUST (see **[2]**)



- Memory overhead **< 1.1**

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Conclusion

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"Dynamic MPI correctness checking"

TypeART

https://github.com/tudasc/typeart

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"C/C++ type and memory allocation tracking"

References

[1] A. Hück, J. Protze, J.-P. Lehr, C. Terboven, C. Bischof, M. S. Müller. **"Towards compiler-aided correctness checking of adjoint MPI applications"** In 4th International Workshop on Software Correctness for HPC Applications (Correctness). IEEE/ACM, 2020, pp. 40–48. DOI: **10.1109/Correctness51934.2020.00010**

[DKL LLVM'15] A. Droste, M. Kuhn, and T. Ludwig, **"MPI-Checker: Static Analysis for MPI"**, In: Proceedings of the Second Workshop on the LLVM Compiler Infrastructure in HPC, LLVM '15. New York, NY, USA: ACM, 2015, pp. 3:1–3:10.

[Coral'20] **"CORAL benchmark codes"**, Last accessed Feb 2020. [Online]. Available: https://asc.llnl.gov/CORAL-benchmarks/

[SpecMPI'07] M. S. Müller, et al, **"SPEC MPI2007 — an application benchmark suite for parallel systems using MPI"**, Concurrency and Computation: Practice and Experience, vol. 22, no. 2, pp. 191–205, 2009.