How OPS (Optimizing Parallelizing System) May be Useful for Clang

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Optimizing parallelizing system (OPS)

OPS at a glance

- High-level internal representation: “Reprise”;
- Frontend (Clang based);
- Analysis:
  - Dependencies graph, Alias analysis, Computations graph, ...
- Transformations:
  - Recurrent loops parallelizing, Loop unrolling, Loop fusion, Loop nesting, Loop interchange ...

OPS at a glance (end)

- GUI for testing purposes;
- Data visualization:
  - Dependencies graph, ...
- Backends:
  - MPI, OpenMP, CUDA, VHDL, Clang, ...

Generating high-level code

- Automatic parallelization:
  - CUDA
  - OpenMP
  - MPI
  - VHDL
- Optimizing memory usage: tiling.

Clang + OPS integration

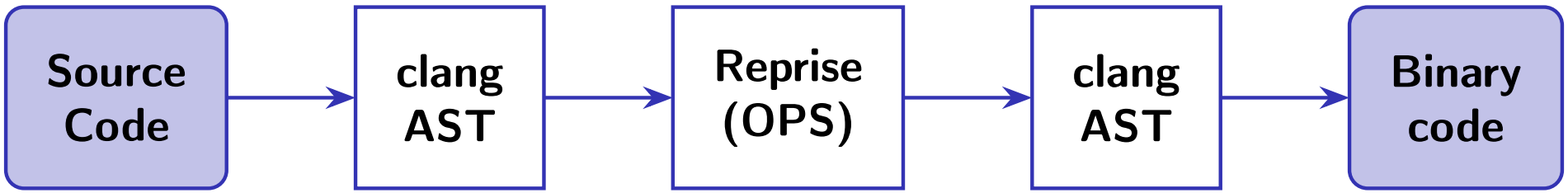


Figure 1: injecting OPS inside Clang

Low-level IR vs. High-level IR

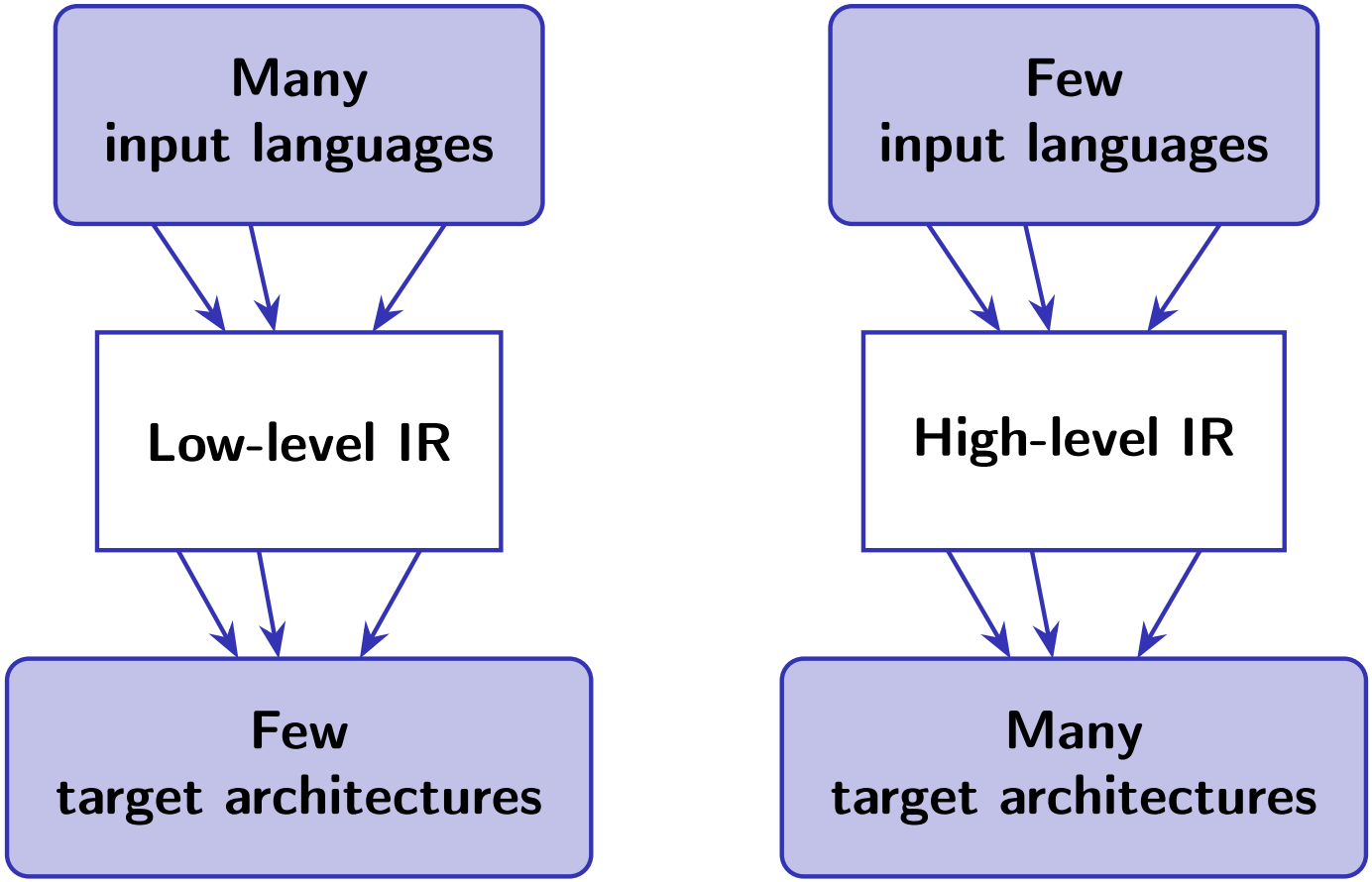


Figure 2: comparison of low-level and high-level internal representations

Advantages of using OPS

- Code generation for accelerators
  - GPU
  - FPGA
- Block data placement
  - shared memory
  - distributed memory
- Parallel programming visual aid: dependency visualization in terms of original source code.
- Dialog compilation

Block array placement

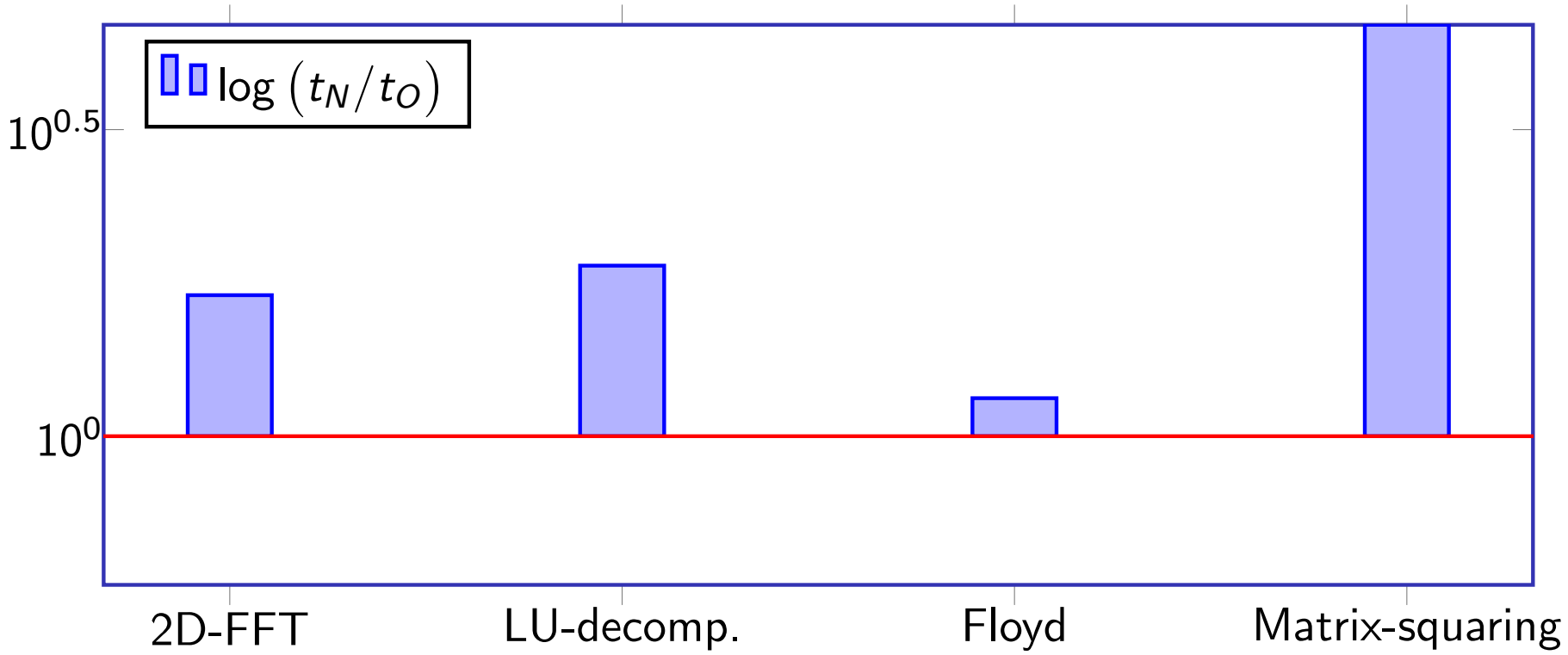


Figure 3: running times for algorithms with and without block placement in shared memory

Block affine array placement in distributed memory

Result

Automatically generated MPI code + block affine data placement.

Table 1: solving 3D Dirichlet problem for Poisson equation with iterative Jacobi algorithm

	Running time, s			
Size	1 node	2 nodes	4 nodes	8 nodes
$128 \times 128 \times 128$	38.25	19.74	10.9	5.97
$256 \times 256 \times 256$	310.19	165.64	87.11	48.64
$384 \times 384 \times 384$	1078	697.95	356.9	190.12
$512 \times 512 \times 512$	2786.47	1432.2	776.14	418.38

Graphics accelerator

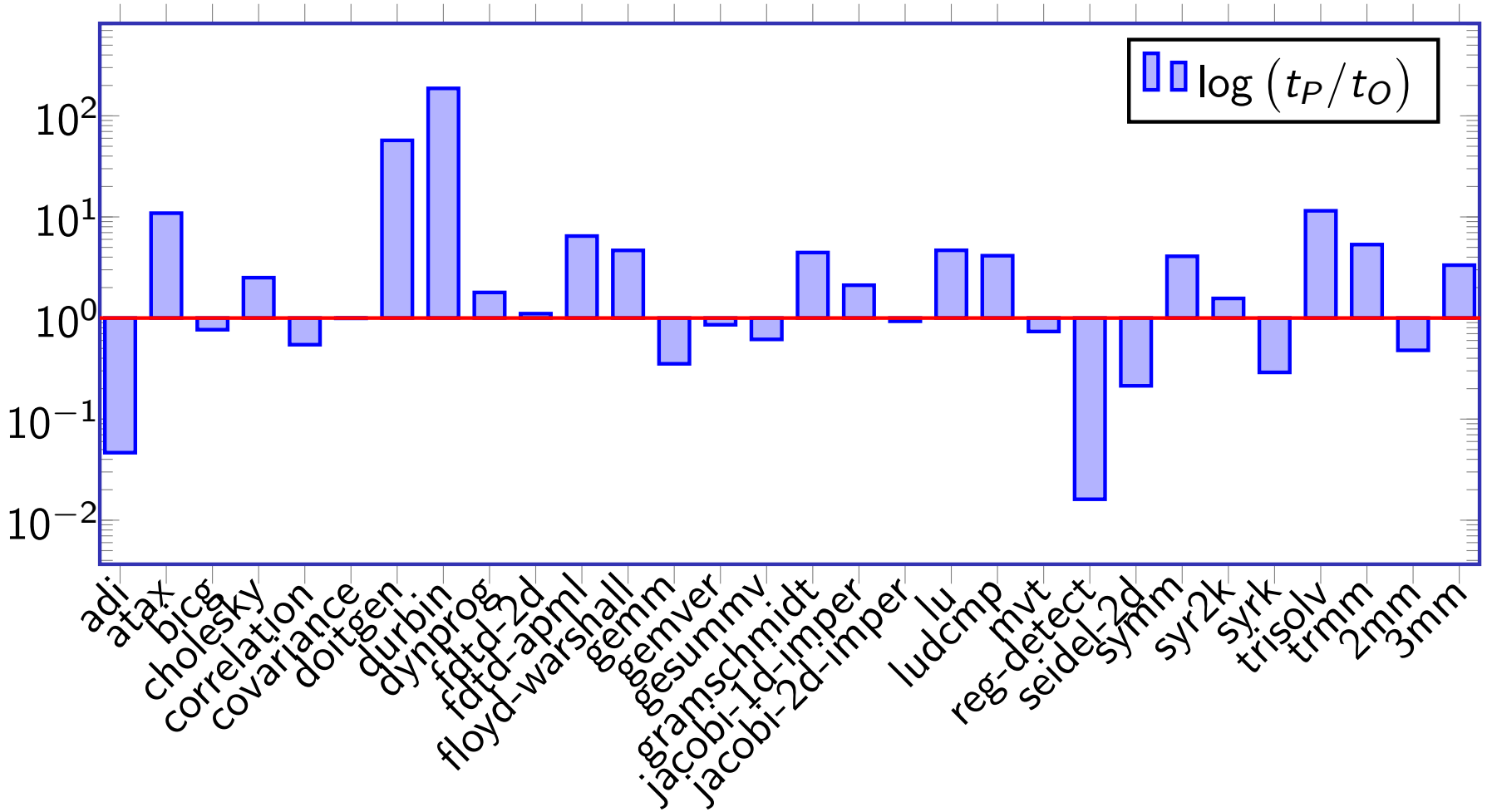
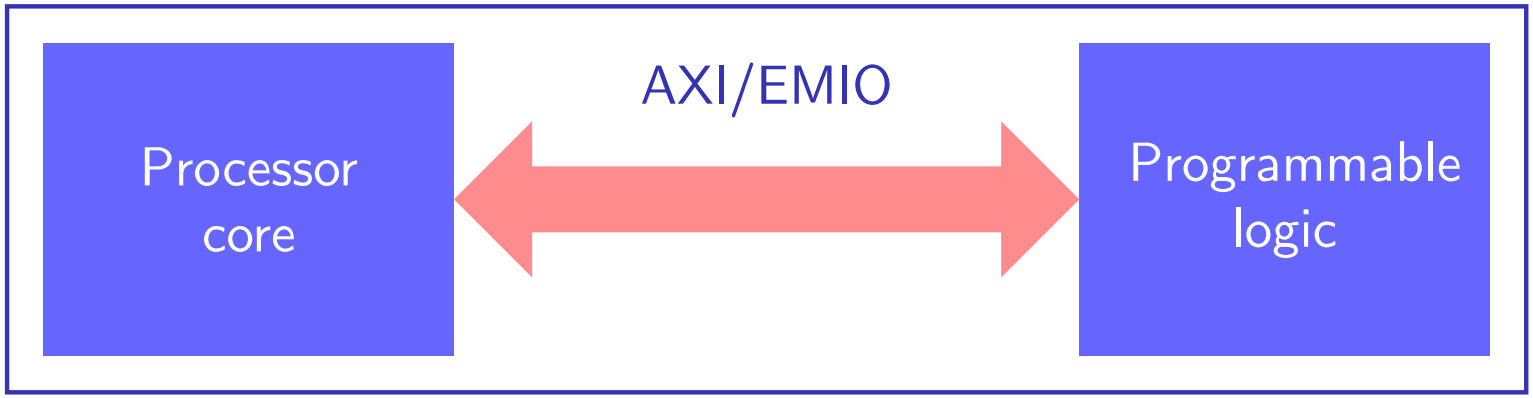
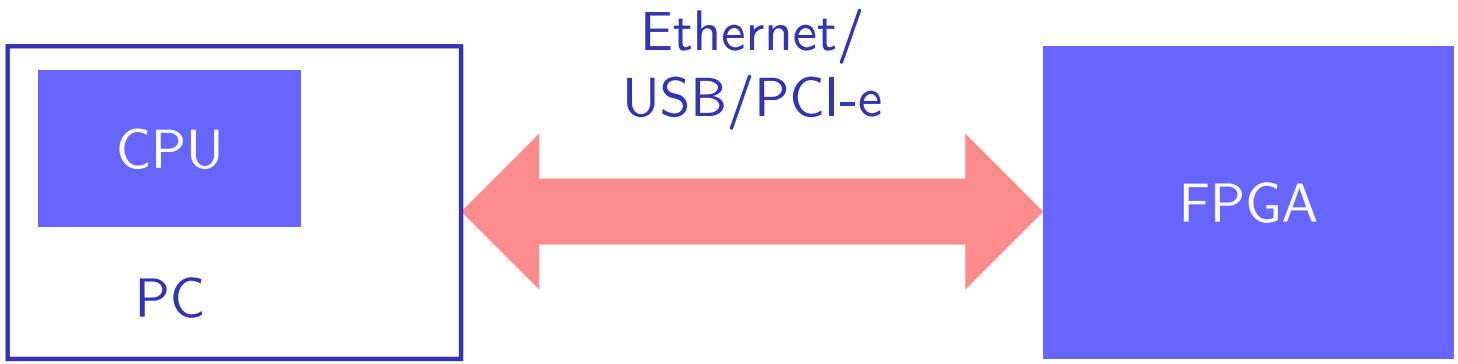


Figure 4: comparison of OPS-based solution with PPCG (`http://ppcg.gforge.inria.fr/`)

FPGA accelerator



a) on one core



b) on separate cores

Figure 5: the hybrid compute systems with FPGA/CPU

Dependency visualization

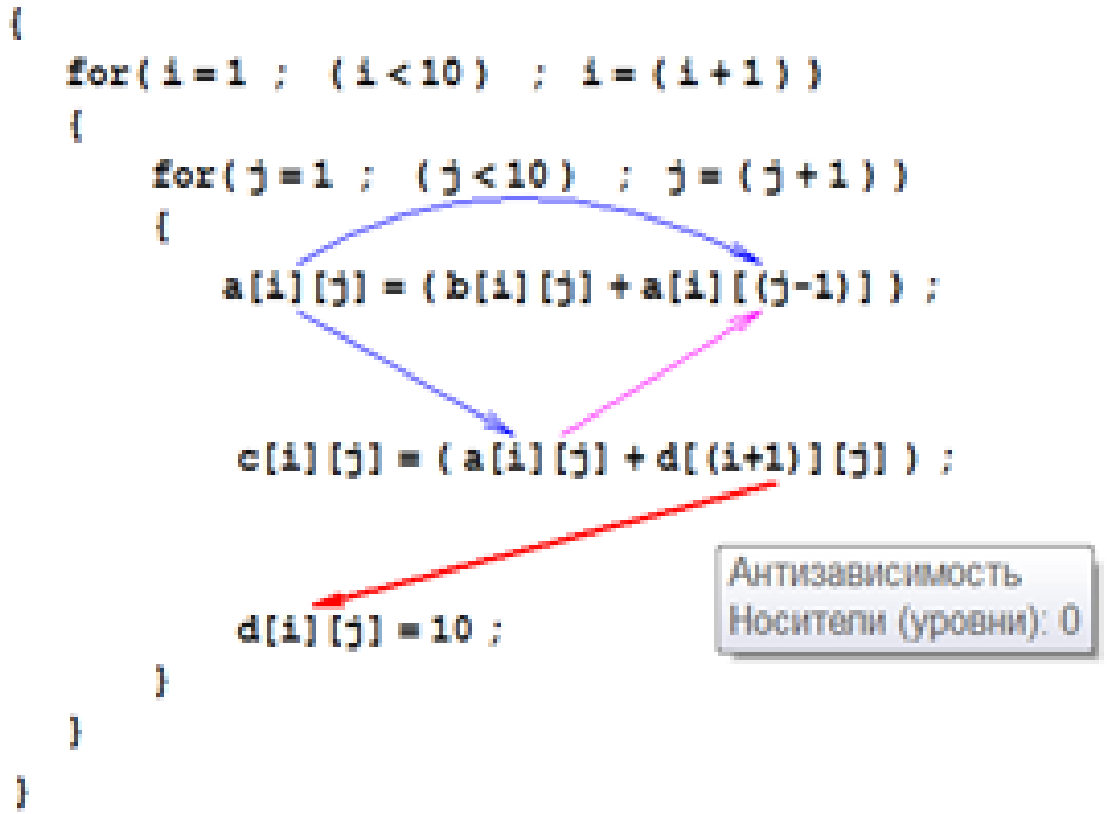
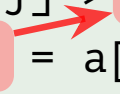


Figure 6: parallel programmer's training simulator output

Dependency refinement in dialog

Example (Floyd algorithm)

```
for (k = 0;  k < n; ++ k)
  for (i = 0; i < n; ++ i)
    for (j = 0; j < n; ++ j)
      if (a[i][j] > a[i][k] + a[k][j])
        a[i][j] = a[i][k] + a[k][j];
```



- Neither loop can be automatically parallelized due to data dependency.
- Actually, the dependency is not realized if `a[i][i] >= 0`.
- The dialog compiler may ask the question to the programmer.

OpenOPS

OpenOPS source code	`https://github.com/OpsGroup/open-ops`
OPS website	`http://www.ops.rsu.ru/`
Web auto-parallelizer	`http://ops.opsgroup.ru/en/`