Which C compiler and BLAS/LAPACK library should I use – `gretl`'s numerical efficiency in different configurations[1]

Marcin Błażejowski

University WSB Merito in Toruń, Poland

Gretl Conference 2023

[1] This research is a part of Oracle for Research grant (agreement No. v040119) entitled: "Which C compiler and which BLAS/LAPACK library? – gretl numerical efficiency in different configurations".

Workplan

1. Environment
   - Hardware
   - Libraries
   - Compilers
2. Compilation
   - `CFLAGS` in use
   - `LAPACK_LIBS` in use
3. Simulation scenarios
   - `dgemm` efficiency (pure BLAS Level 3)
   - LAPACK/BLAS efficiency
   - Real econometrics efficiency
4. Results
   - `dgemm` efficiency (pure BLAS Level 3)
   - LAPACK/BLAS efficiency
   - Real econometrics efficiency
   - Overall performance

6 core paravirtualized machines available in Orace Cloud and run under `Canonical-Ubuntu-22.04-2023.02.15-0`:

AMD	**Intel**
EPYC 7J13 64-Core Processor	Xeon Gold 6354 CPU @ 3.00GHz
VM.Standard.E4.Flex	VM.Optimized3.Flex

Terminology

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  - abbreviation: **aocl** (as AOCL-BLIS with AOCL-libFLAME)

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  - package used: `intel-oneapi-mkl-2023.1.0`
  - abbreviation: **mkl**

Kernels used

Values reported by `$sysinfo["blascore"]`

library	AMD	Intel
OpenBLAS	Zen	SkylakeX
BLIS	zen3	haswell
AOCL-BLIS	zen3	—
oneMKL	—	AVX-512

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  - version: Ubuntu Clang 15.0.7
  - package used: `1:15.0.7-0ubuntu0.22.04.1`

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  - version: Ubuntu Clang 15.0.7
  - package used: `1:15.0.7-0ubuntu0.22.04.1`
  - abbreviation: **llvm**

Provided by CPU vendor

- AMD Optimizing C/C++ and Fortran Compilers (AOCC)

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  - based on LLVM Mirror.Version.14.0.6
  - version: AMD Clang 14.0.6 (CLANG: AOCC_4.0.0-Build#434 2022_10_28)
  - package used: `aocc-compiler-4.0.0`
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  - package used: `aocc-compiler-4.0.0`
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  - package used: `aocc-compiler-4.0.0`
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- Intel oneAPI DPC++/C++ Compiler
  - based upon LLVM 16.0.0git
  - version: Intel oneAPI DPC++/C++ Compiler 2023.1.0 (2023.1.0.20230320)
  - package used: `intel-oneapi-dpcpp-cpp-2023.1.0`

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  - package used: `intel-oneapi-dpcpp-cpp-2023.1.0`
  - abbreviation: **icx**

We use `gretl` version 2023a compiled with the following flags:

`-march=native -mtune=native -O3`.

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In case of compilers provided by CPU vendor we also use:

	aocl	mkl	oblas	bflame
aocc	-ffast-math	—		
icx	—	-fp-model=precise		

aocl

We always use: `-l:libflame.so.4.0 -lblis-mt`.

aocl

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In case of different compilers we also use:

gcc	`-lm -ldl`
llvm	`-fopenmp=libomp`
aocc	`-fopenmp=libomp -lalm`

mkl

We always use:
`-L/opt/intel/oneapi/mkl/2023.1.0/lib/intel64 -lmkl_intel_lp64 -lmkl_intel_thread -lmkl_core -liomp5 -lpthread -lm -ldl`.

oblas

We always use: `-lopenblas`.

bflame

We always use: `-lflame -lblis -ldl`.

gretl's packages in use

In simulations we use:

1. **matrix_perf** (ver. 1.11) by Allin Cottrell
2. **DCC** (ver. 0.1) by Riccardo "Jack" Lucchetti, Giulio Palomba and Luca Pedini
3. **StrucTiSM** (ver. 0.7) by Riccardo "Jack" Lucchetti and Sven Schreiber
4. **BMA** (ver. 3.1) by Marcin Błażejowski and Jacek Kwiatkowski

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- We have scenarios for smaller and bigger cases which is controlled via different `mnk` values.

dgemm test

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- The packages was slightly modified to return results as **`bundle`** of bundles of matrixes.

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- We use the following build-in functions: `mols`, `qrdecomp`, `cholesky`, `inv`, `invpd`, `eigen`, `det`, `psdroot`, `svd`

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  - non-square: 5000×40 $(m = k = 5000, n = 40)$
  - square: 500×500 $(m = n = k = 500)$
- Dimensions for bigger cases:

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  - non-square: 5000×40 ($m = k = 5000, n = 40$)
  - square: 500×500 ($m = n = k = 500$)
- Dimensions for bigger cases:
  - non-square: 5000×200 ($m = k = 5000, n = 200$)
  - square: 1500×1500 ($m = n = k = 1500$)

gretl's packages test

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- Dimensions for smaller cases:
  - DCC: 528×3 $(m = k = 528, n = 3)$
  - StrucTiSM: 731×4 $(m = k = 731, n = 4)$
  - BMA: 72×14 $(m = k = 72, n = 14)$
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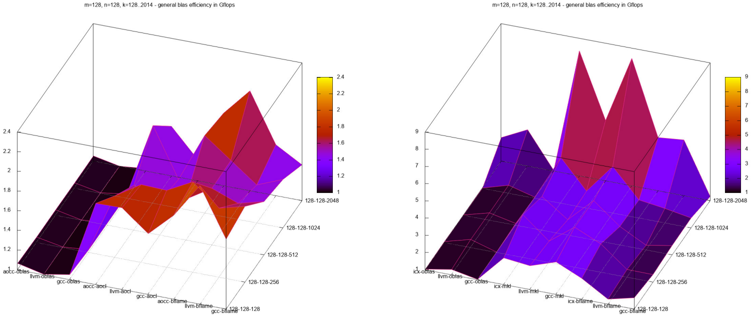
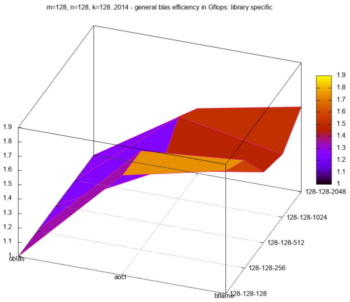
- Dimensions for bigger cases:
  - DCC: 528×4 ($m = k = 528, n = 4$)
  - StrucTiSM: 731×8 ($m = k = 731, n = 8$)
  - BMA: 72×41 ($m = k = 72, n = 41$)



(a) AMD (b) Intel

Figure: Results of `matrix_perf_1_1` experiment: overall setup: $m = 128, n = 128, k = 128 \dots 2014$



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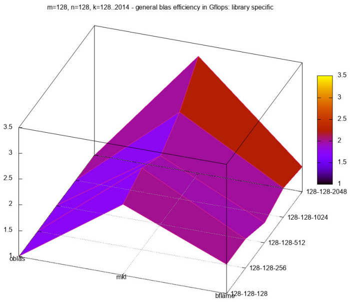

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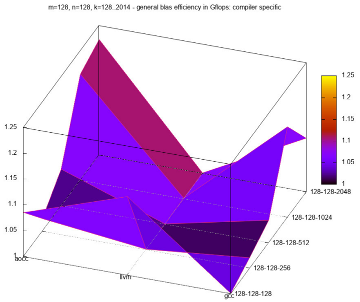

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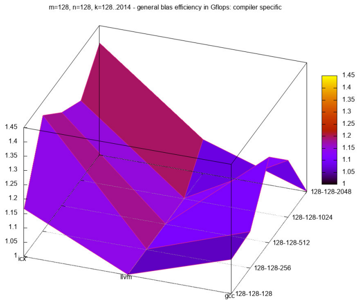

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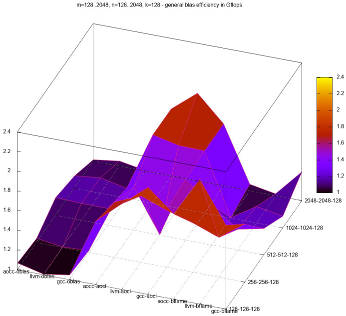

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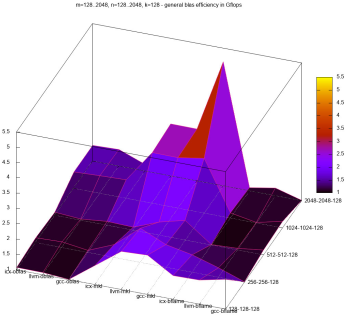
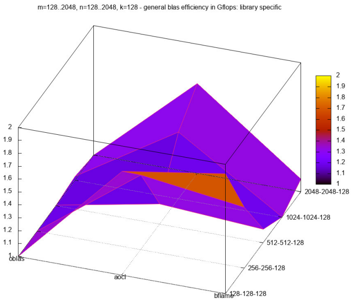


(b) Intel

Figure: Results of `matrix_perf_1_2` experiment: overall setup: $m = 128 \dots 2048, n = 128 \dots 2048, k = 128$



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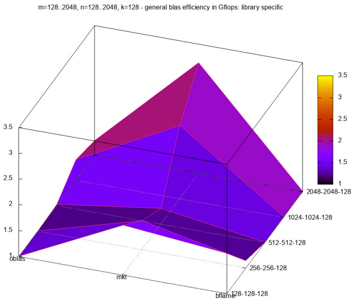

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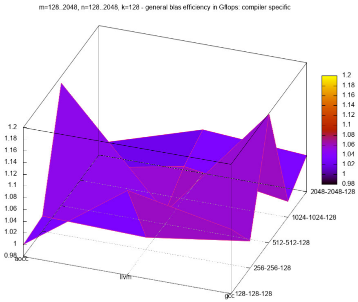

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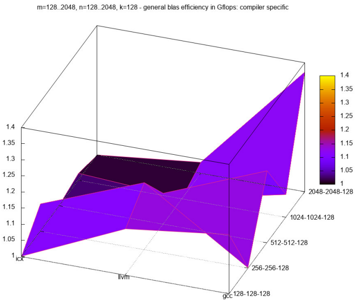
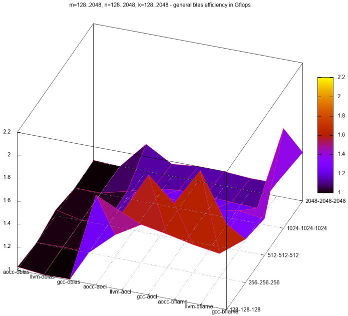


(b) Intel

Figure: Results of `matrix_perf_1_2` experiment: compiler specific setup: $m = 128 \dots 2048, n = 128 \dots 2048, k = 128$



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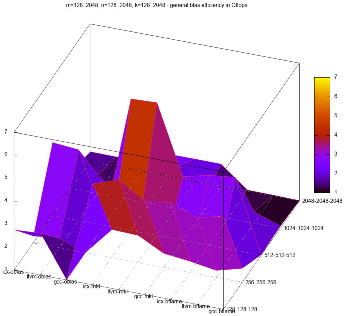

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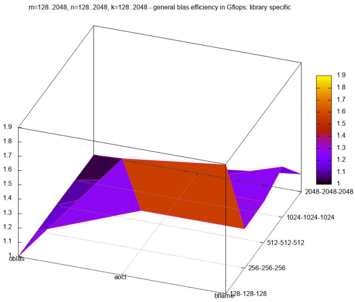
Figure: Results of `matrix_perf_1_3` experiment: overall setup: $m = 128 \ldots 2048, n = 128 \ldots 2048, k = 128 \ldots 2048$



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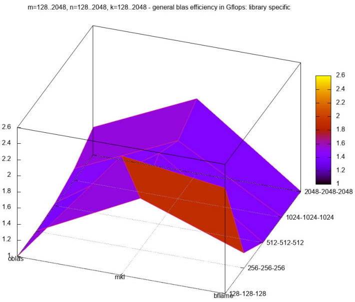

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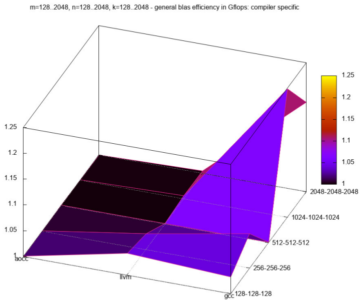
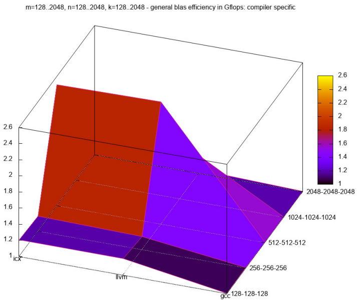
Figure: Results of `matrix_perf_1_3` experiment: library specific setup: $m = 128 \ldots 2048, n = 128 \ldots 2048, k = 128 \ldots 2048$

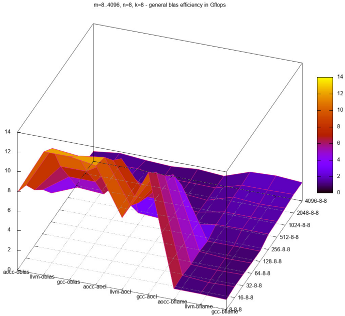


(a) AMD

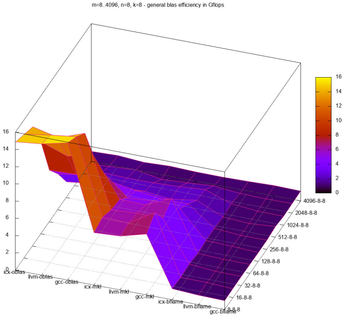


(b) Intel

Figure: Results of `matrix_perf_1_3` experiment: compiler specific setup: $m = 128 \dots 2048, n = 128 \dots 2048, k = 128 \dots 2048$

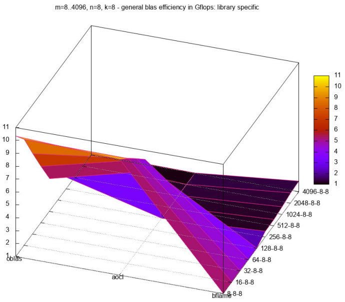


(a) AMD

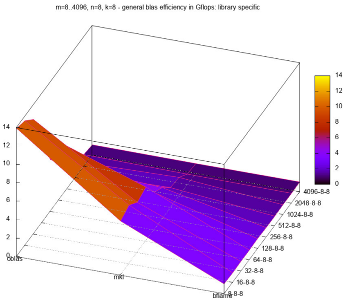


(b) Intel

Figure: Results of `matrix_perf_2_1` experiment: overall setup: $m = 8 \dots 4096, n = 8, k = 8$

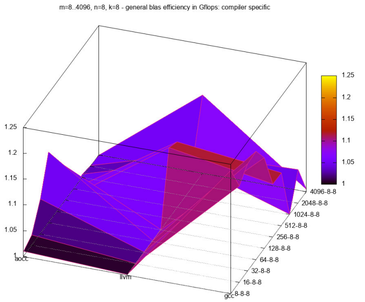


(a) AMD



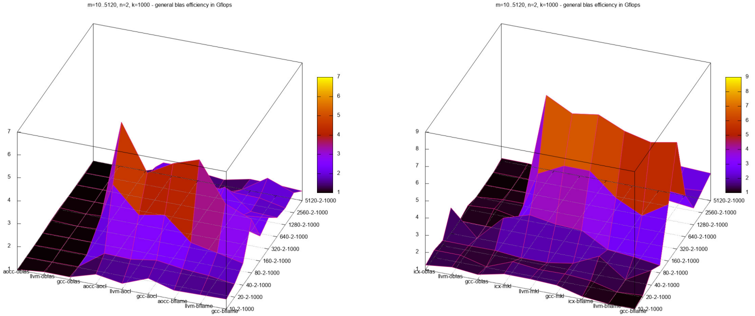
(b) Intel

Figure: Results of `matrix_perf_2_1` experiment: library specific setup: $m = 8 \dots 4096, n = 8, k = 8$



(a) AMD (b) Intel

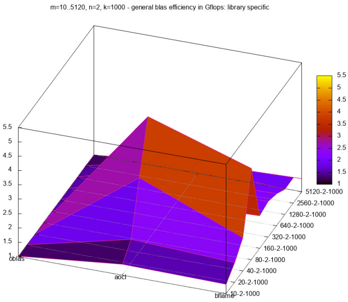
Figure: Results of `matrix_perf_2_1` experiment: compiler specific setup: $m = 8 \dots 4096, n = 8, k = 8$



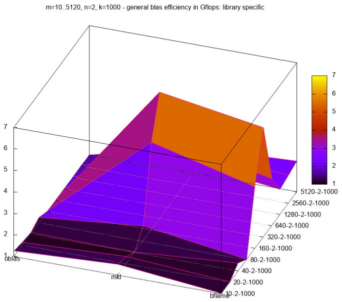
(a) AMD

(b) Intel

Figure: Results of `matrix_perf_2_2` experiment: overall setup: $m = 10 \ldots 5120, n = 2, k = 1000$

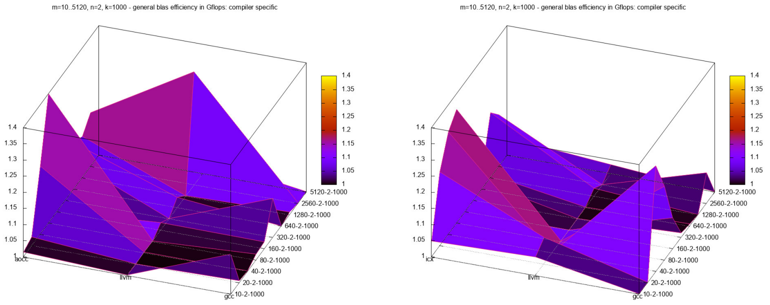


(a) AMD



(b) Intel

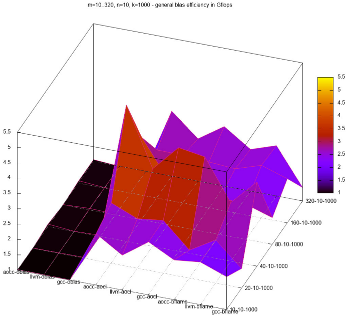
Figure: Results of `matrix_perf_2_2` experiment: library specific setup: $m = 10 \ldots 5120, n = 2, k = 1000$



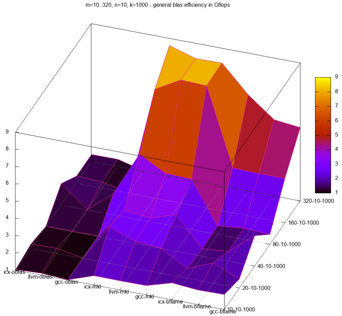
(a) AMD

(b) Intel

Figure: Results of `matrix_perf_2_2` experiment: compiler specific setup: $m = 10 \dots 5120, n = 2, k = 1000$

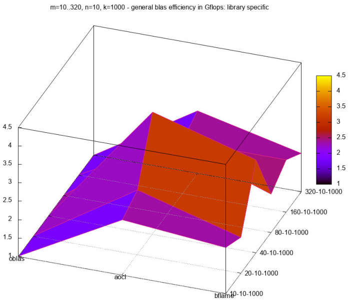


(a) AMD

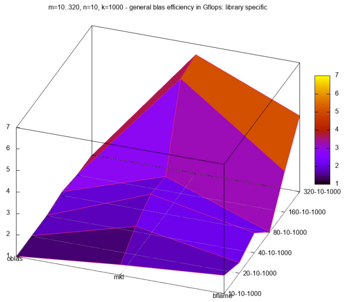


(b) Intel

Figure: Results of `matrix_perf_2_3` experiment: overall setup: $m = 10 \ldots 320, n = 10, k = 1000$

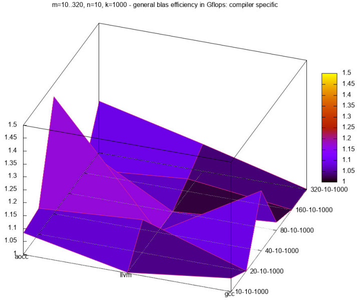


(a) AMD

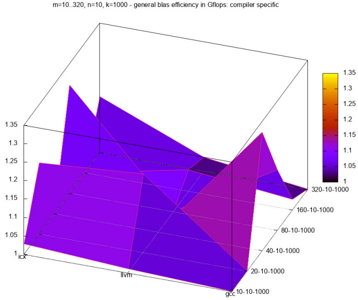


(b) Intel

Figure: Results of `matrix_perf_2_3` experiment: library specific setup: $m = 10 \dots 320, n = 10, k = 1000$

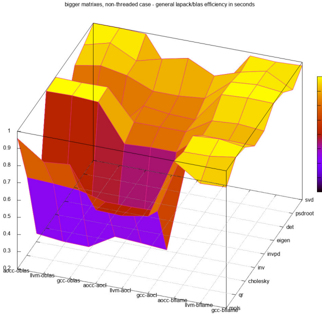


(a) AMD

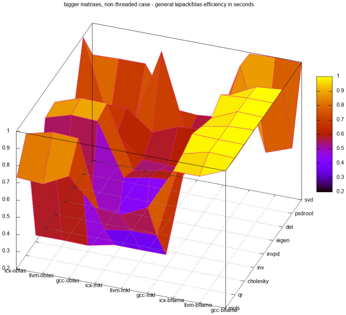


(b) Intel

Figure: Results of `matrix_perf_2_3` experiment: compiler specific setup: $m = 10 \ldots 320, n = 10, k = 1000$

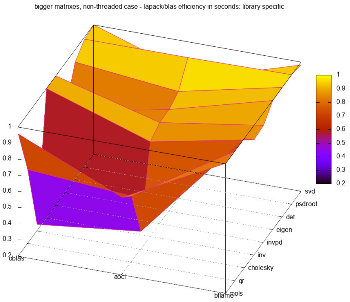


(a) AMD

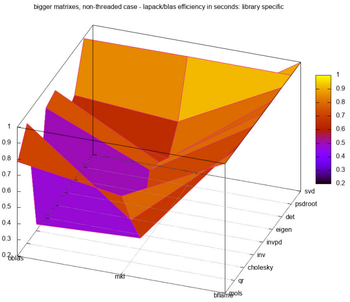


(b) Intel

Figure: Results of `algebra_perf_0_1` experiment: overall setup: $m = 5000, n = 40$ or $m = n = 500$ (non-threaded)



(a) AMD



(b) Intel

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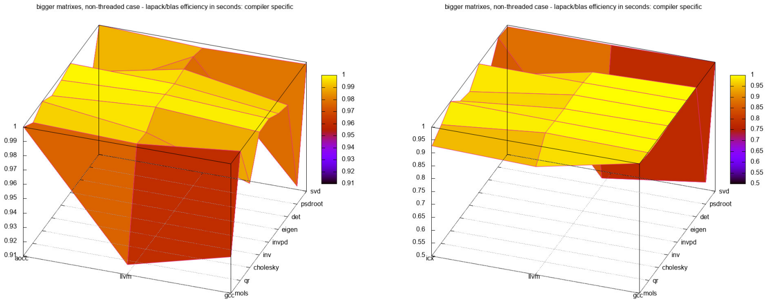

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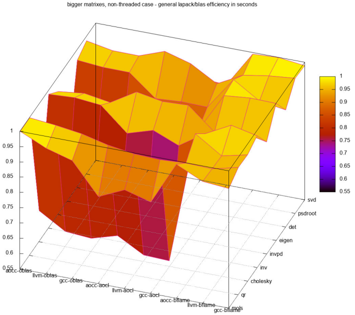
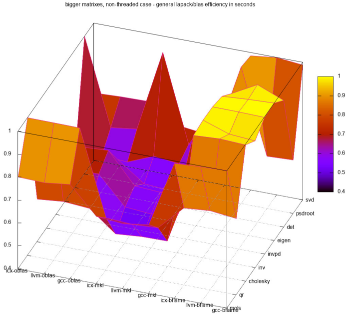
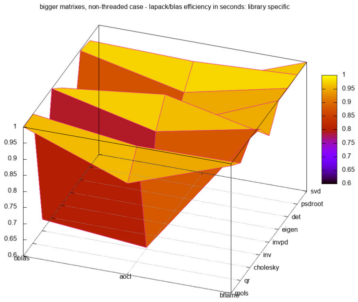


(a) AMD

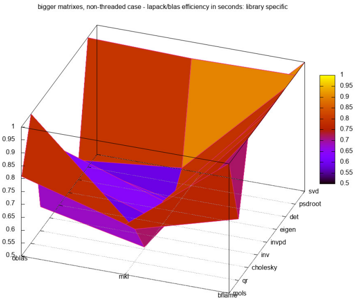


(b) Intel

Figure: Results of `algebra_perf_0_2` experiment: overall setup: $m = 5000, n = 200$ or $m = n = 1500$ (non-threaded)



(a) AMD



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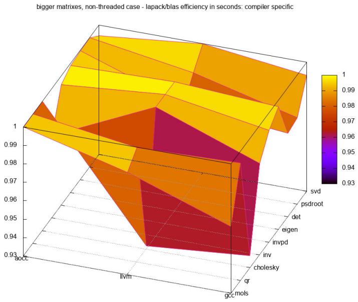
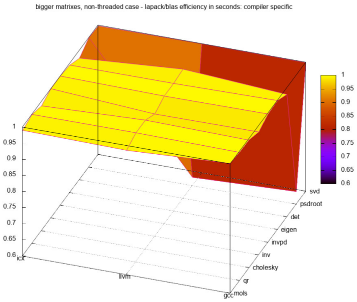


(a) AMD



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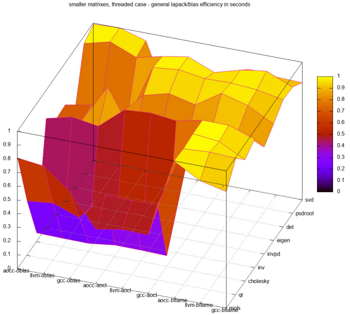

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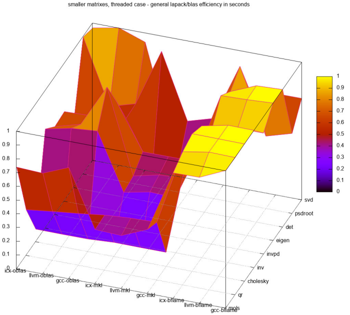

(b) Intel

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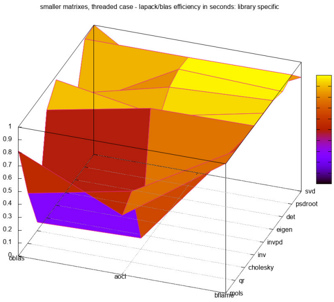
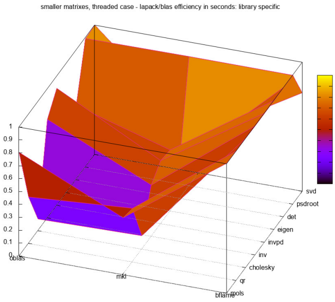


(a) AMD



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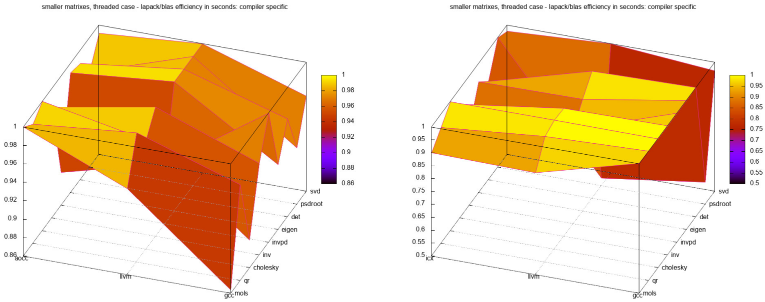

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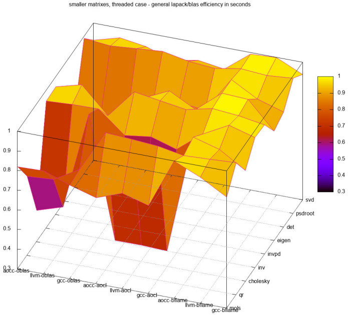

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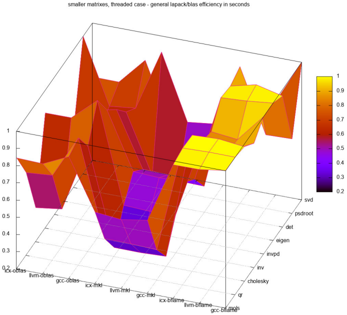

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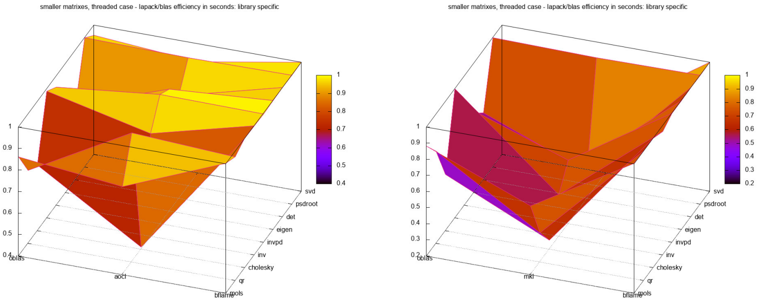

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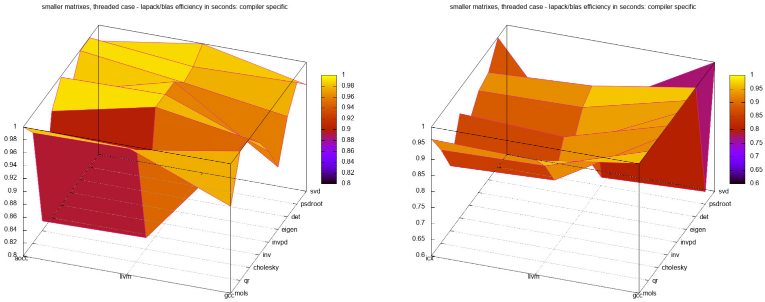

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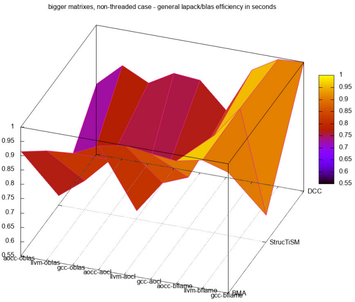

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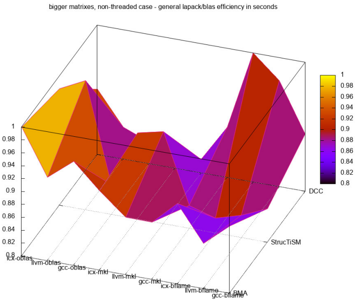
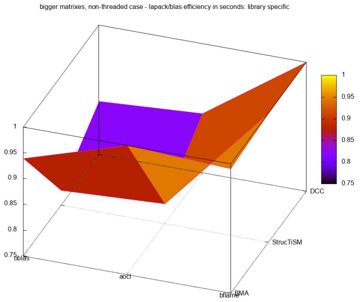


(b) Intel

Figure: Results for selected packages experiment: overall setup: smaller cases (non-threaded)



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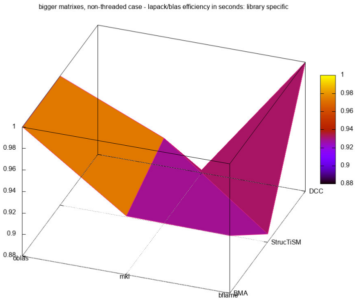

(b) Intel

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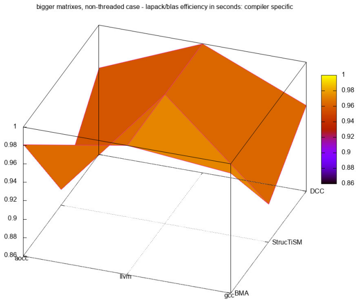

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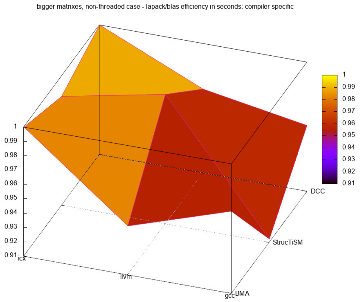
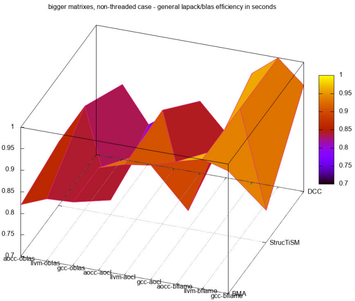


(b) Intel

Figure: Results for selected packages experiment: compiler specific setup: smaller cases (non-threaded)



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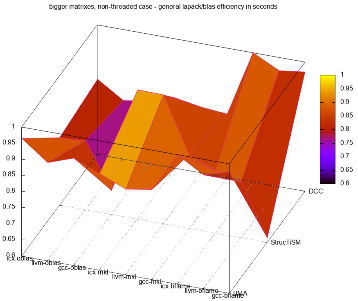

(b) Intel

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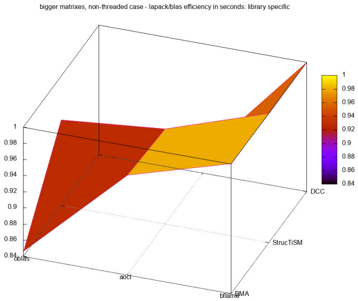
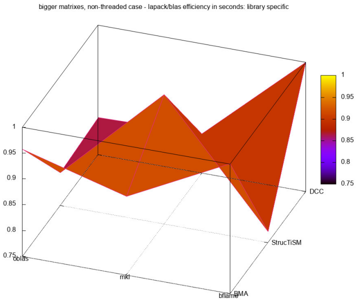
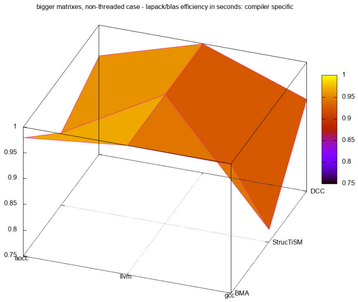


(a) AMD



(b) Intel

Figure: Results for selected packages experiment: library specific setup: bigger cases (non-threaded)



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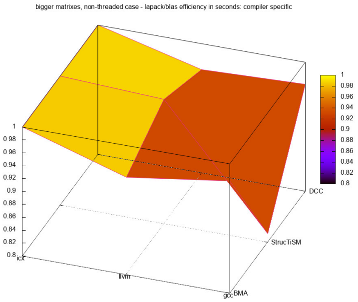

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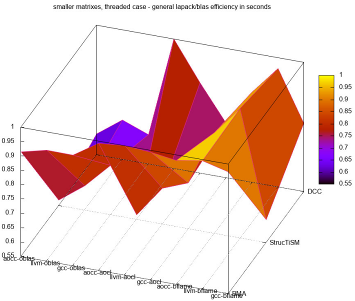

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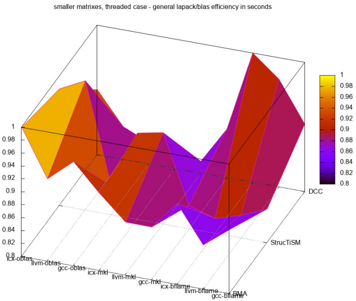
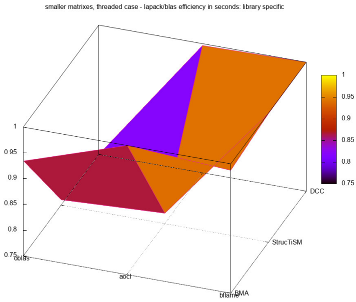
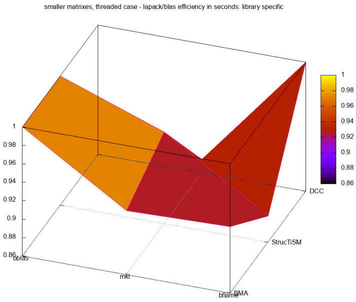


(b) Intel

Figure: Results for selected packages experiment: overall setup: smaller cases (threaded)

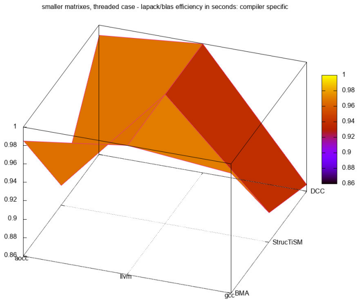


(a) AMD



(b) Intel

Figure: Results for selected packages experiment: library specific setup: smaller cases (threaded)



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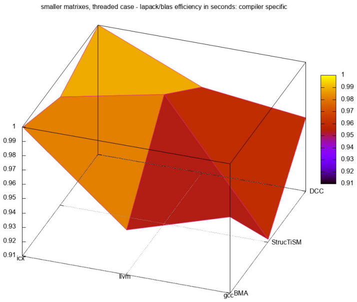
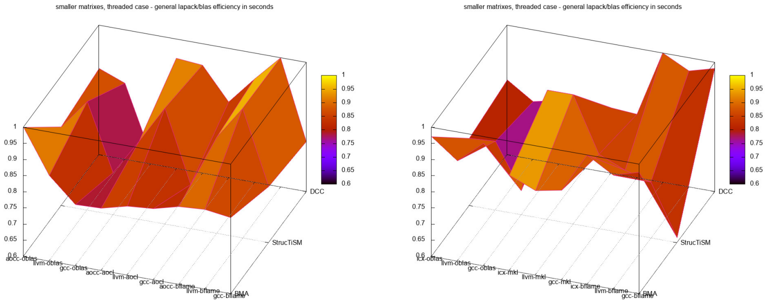


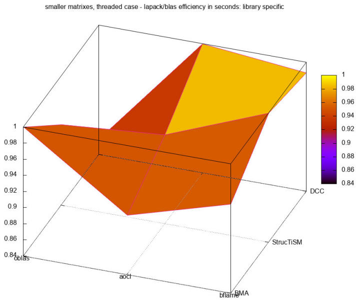
(b) Intel

Figure: Results for selected packages experiment: compiler specific setup: smaller cases (threaded)



(a) AMD (b) Intel

Figure: Results for selected packages experiment: overall setup: bigger cases (threaded)



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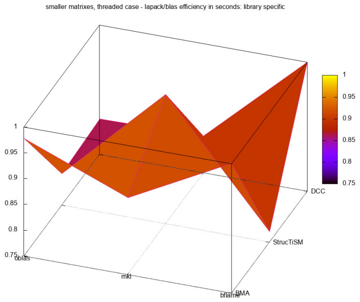
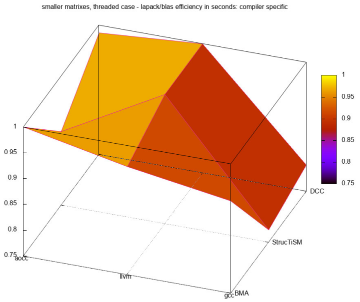


(b) Intel

Figure: Results for selected packages experiment: library specific setup: bigger cases (threaded)



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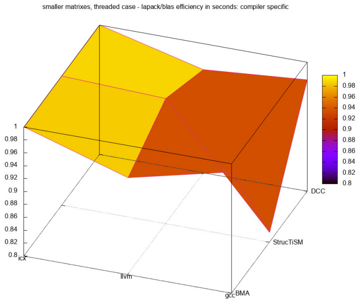

(b) Intel

Figure: Results for selected packages experiment: compiler specific setup: bigger cases (threaded)

To calculate overall performance (across all three scenarios) we use *Min-Max Feature Scaling*:

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$$x^{'} = \frac{x - x_{min}}{x_{max} - x_{min}}$$

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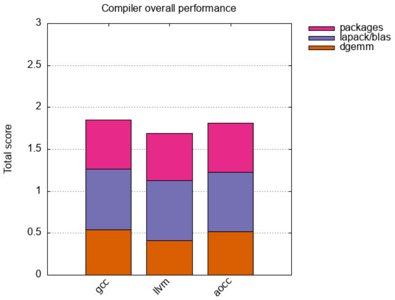
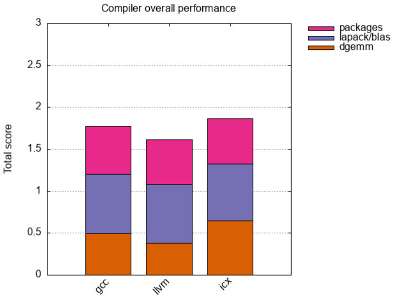
- for results in seconds:

$$x' = \frac{x_{max} - x}{x_{max} - x_{min}}$$

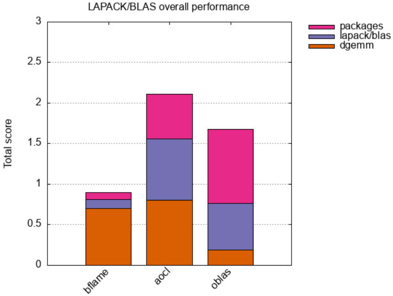


(a) AMD

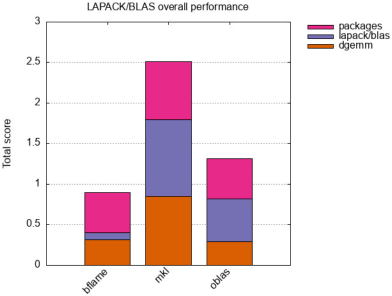


(b) Intel

Figure: Overall score based on three experiments: compiler specific



(a) AMD



(b) Intel

Figure: Overall score based on three experiments: library specific

The end