MAQAO
Performance Analysis and Optimization Tool

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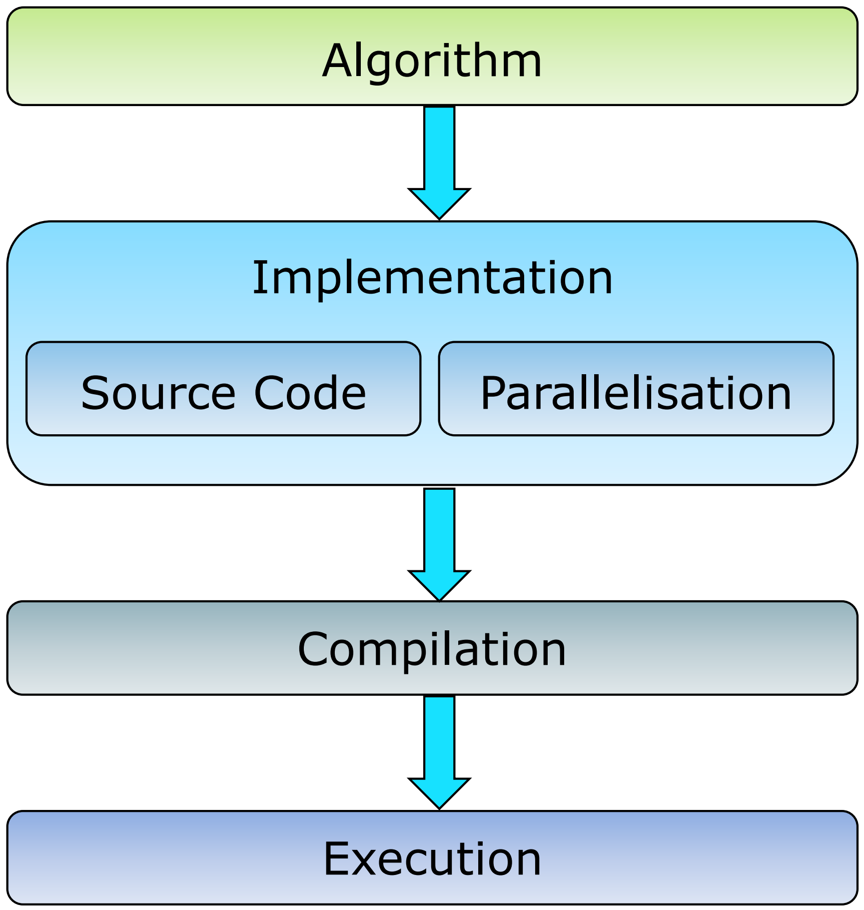
Performance analysis and optimisation

How much of an application can be optimized?
- What would the effort/gain ratio be?

Where is the application spending most execution time and resources?

Why is the application spending time there?
- Algorithm, implementation, runtime or hardware?
- Data access or computation?

How to improve the application?
- At which step(s) of the workflow or dev process?
- What additional information is needed?

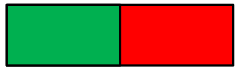


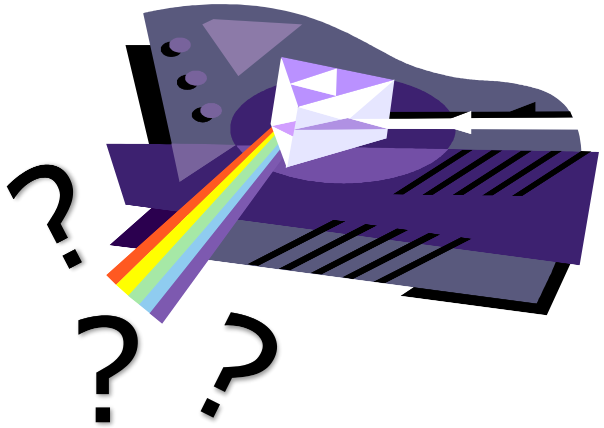
A multifaceted problem

Pinpointing the performance bottlenecks

Identifying the dominant category of issues
- Algorithms, implementation, parallelism, …

Making the **best use** of the machine features
- Complex multicore and manycore CPUs
- Complex memory organization

Finding the **most rewarding** issues to be fixed
- **40%** total time, expected **10%** speedup
  - ➔ TOTAL IMPACT: **4%** speedup 
- **20%** total time, expected **50%** speedup
  - ➔ TOTAL IMPACT: **10%** speedup 



➔ **Need for dedicated and complementary tools**

Motivating example

Code of a loop representing ~10% walltime

6) Variable number of iterations

2) Non-unit stride accesses

```
do j = ni + nvalue1, nato

   nj1 = ndim3d*j + nc ; nj2 = nj1 + nvalue1 ; nj3 = nj2 + nvalue1
   u1 = x11 – x(nj1) ; u2 = x12 – x(nj2) ; u3 = x13 – x(nj3)
   rtest2 = u1*u1 + u2*u2 + u3*u3 ; cnij = eci*qEold(j)
   rij = demi*(rvwi + rvwalc1(j))
   drtest2 = cnij/(rtest2 + rij) ; drtest = sqrt(drtest2)
   Eq = qq1*qq(j)*drtest
   ntj = nti + ntype(j)
   Ed = ceps(ntj)*drtest2*drtest2*drtest2
   Eqc = Eqc + Eq ; Ephob = Ephob + Ed
   gE = (c6*Ed + Eq)*drtest2 ; virt = virt + gE*rtest2
   u1g = u1*gE ; u2g = u2*gE ; u3g = u3*gE
   g1c = g1c –u1g ; g2c = g2c – u2g ; g3c = g3c –u3g
   gr(nj1, thread_num) = gr(nj1, thread_num) + u1g
   gr(nj2, thread_num) = gr(nj2, thread_num) + u2g
   gr(nj3, thread_num) = gr(nj3, thread_num) + u3g

end do
```

1) High number of statements

4) DIV/SQRT

3) Indirect accesses

5) Reductions

2) Non-unit stride accesses

Source code and associated issues:

1) High number of statements
2) Non-unit stride accesses
3) Indirect accesses
4) DIV/SQRT
5) Reductions
6) Variable number of iterations

MAQAO: Modular Assembly Quality Analyzer and Optimizer

Objectives:

- Characterizing performance of HPC applications
- Focusing on performance at the **core level**
- **Guiding users** through the optimization process
- Estimating return on investment (**R.O.I.**)

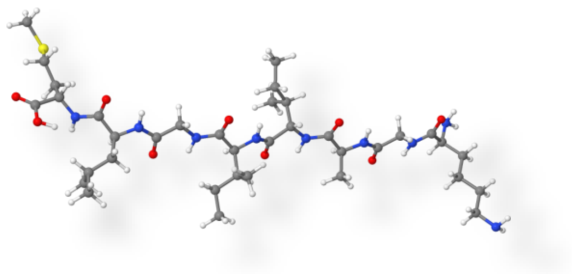
Characteristics:

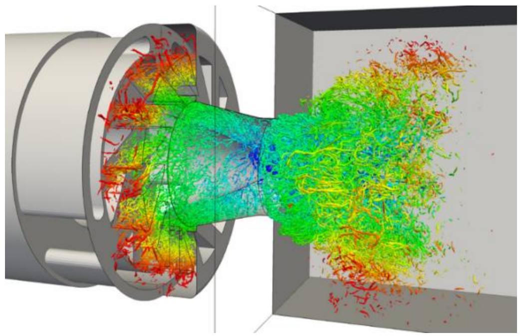
- **Modular tool** offering complementary views
- Support for **Intel x86-64** and **Xeon Phi**
  - ARM on-going development
- LGPL3 Open Source software
- Developed at UVSQ since 2004
- Binary release available as a **static executable**

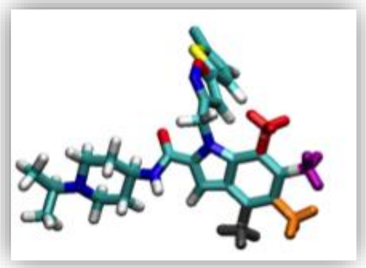
Success stories

MAQAO is used for optimizing industrial and academic HPC applications:

- QMC=CHEM (IRSAMC)
  - Quantum chemistry
  - Speedup: **> 3x**
    - Optimization: moved invocations of functions with identical parameters out of the loop body
- Yales2 (CORIA)
  - Computational fluid dynamics
  - Speedup: **up to 2.8x**
    - Optimization: removing double structure indirections
- Polaris (CEA)
  - Molecular dynamics
  - Speedup: **1.5x – 1.7x**
    - Optimization: enforcing loop vectorization through compiler directives
- AVBP (CERFACS)
  - Computational fluid dynamics
  - Speedup: **1.08x – 1.17x**
    - Replaced divisions by reciprocal multiplications
    - Complete unrolling of loops with a small number of iterations







Partnerships

MAQAO is funded by UVSQ, Intel and CEA (French department of energy) through Exascale Computing Research (ECR) and the French Ministry of Industry's various FUI/ITEA projects (H4H, COLOC, PerfCloud, ELCI, etc...)

Provides core binary analysis and instrumentation capabilities and features for other tools:

- TAU performance tools with MADRAS patcher through MIL (MAQAO Instrumentation Language)
- ATOS bullxprof with MADRAS through MIL
- Intel Advisor
- INRIA Bordeaux HWLOC

PeXL ISV also contributes to MAQAO:

- Commercial performance optimization expertise
- Training and software development
- www.pexl.eu

MAQAO team and collaborators

MAQAO Team

- William Jalby, Prof.
- Cédric Valensi, Ph.D.
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Collaborators

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Past Collaborators or Team Members

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- Julien Jaeger, Ph.D.
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- Tipp Moseley, Ph.D.
- Jean-Christophe Beyler, Ph.D.
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- Jean-Baptiste Le Reste, M.Sc.Eng.
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- José Noudohouenou, Ph.D.
- Aleksandre Vardoshvili, M.Sc.Eng.
- Romain Pillot, Eng
- Youenn Lebras, Ph.D.

Analysis at binary level

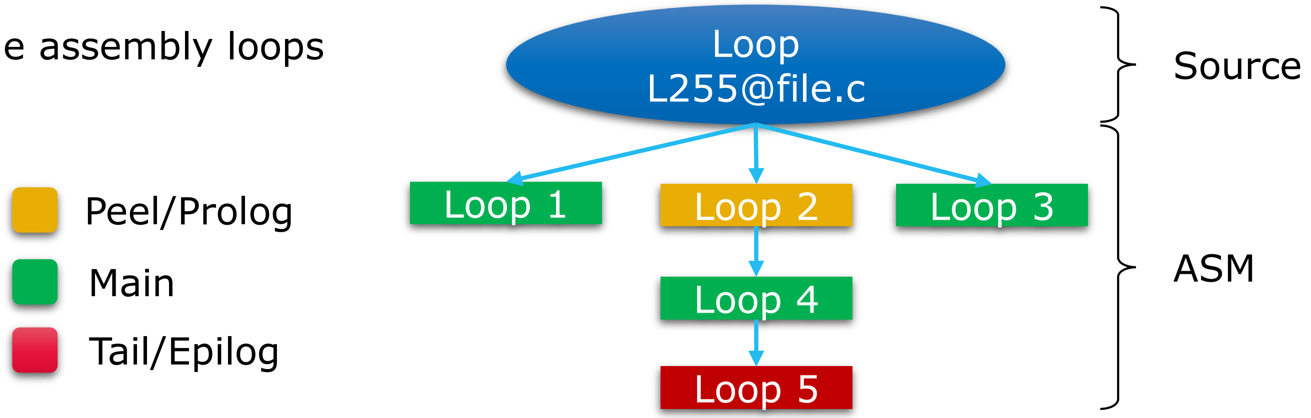
Advantages of binary analysis:

- Compiler optimizations increase the distance between the executed code and the source code
- Source code instrumentation may prevent the compiler from applying certain transformations

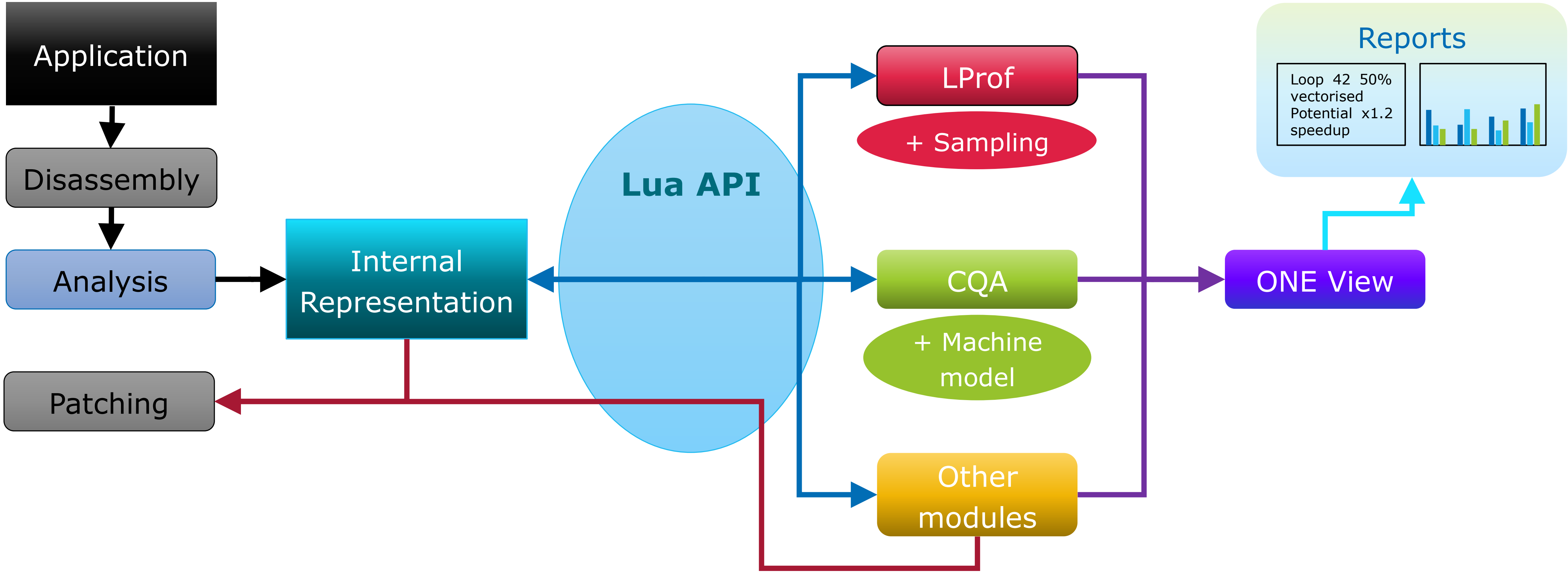
Evaluate the “real” executed code: **What You Analyse Is What You Run**

Main steps:

- Construct high level structures (CFG, DDG, SSA, …)
- Relate the analyses to source code
  - A single source loop can be compiled as multiple assembly loops
  - Affecting unique identifiers to loops

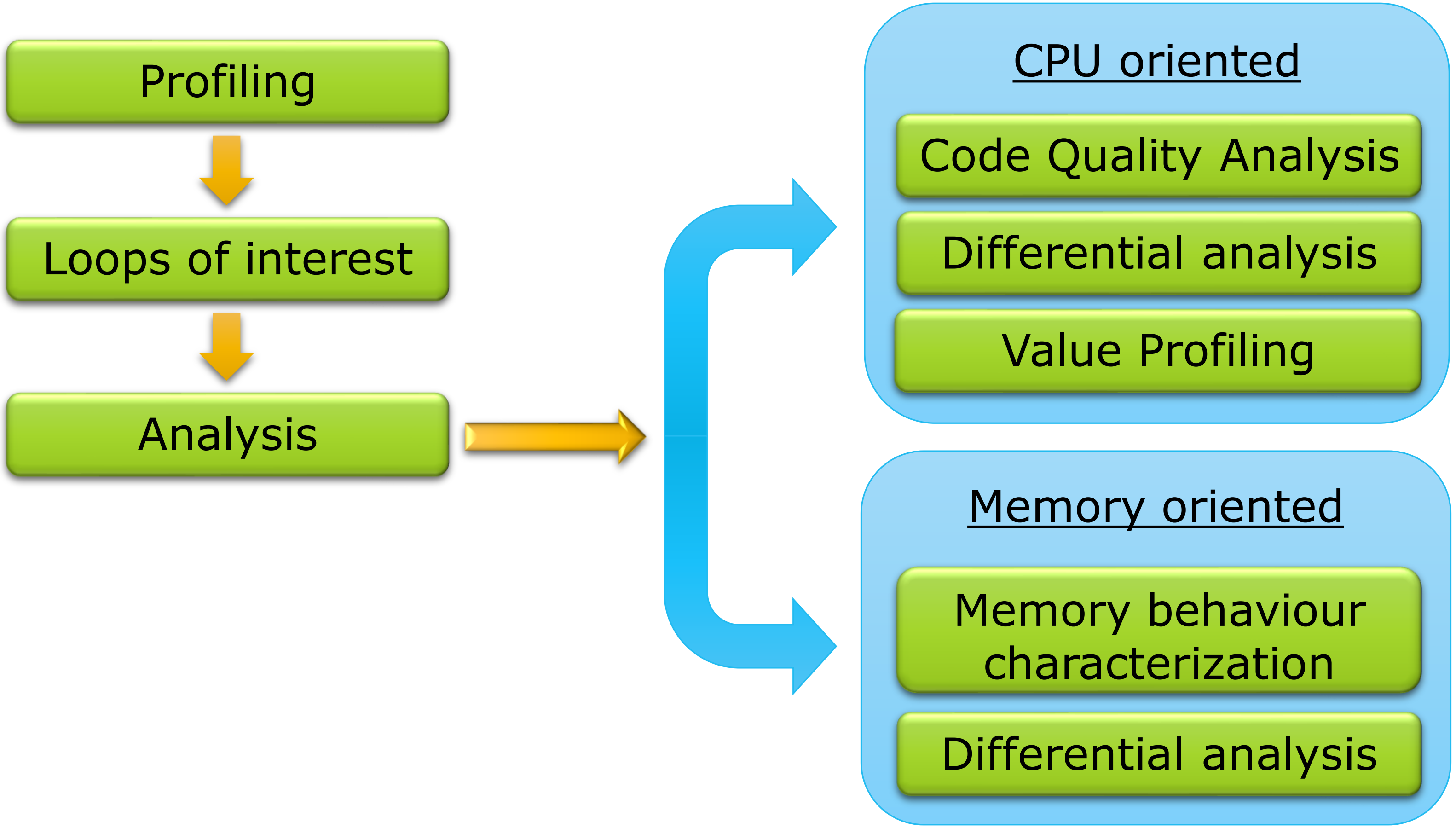


MAQAO Main structure



MAQAO Methodology

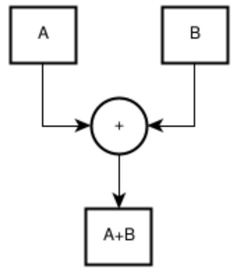
Decision tree



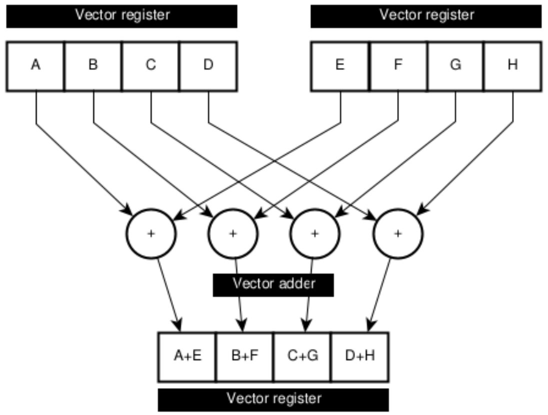
SIMD, Memory and Compiler optimizations

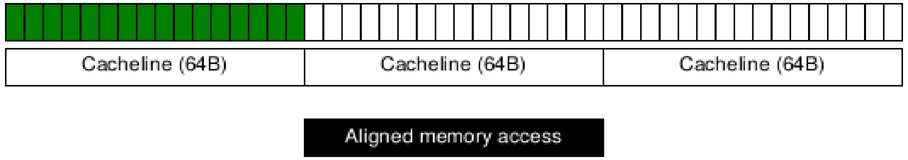
- **SIMD/Vectorization/Data Parallelism**
  - Scalar pattern: a[i] = b[i] + c[i]
  - Vector pattern: a(i, i + 8) = b(i, i + 8) + c(i, i + 8)
  - Benefits : increases memory bandwidth and **IPC**
  - Example implementations :
    - ARM : Neon, SVE
    - x86 : SSE, AVX, AVX512
- **Memory**
  - Computations are, in general, faster than memory accesses
  - Alignment/Contiguity of memory (x86) : **posix_memalign**, **aligned_alloc**, ...
  - Caches: L1, L2, L3, …
- **Compiler optimizations**
  - Programming languages: C, C++, Fortran, …
  - Target micro-architectures : Haswell, Skylake, Rome, ...
  - Loop unrolling
    - Reduce branches
    - Fill the pipeline (more instructions per iteration)
    - Increases memory bandwidth and **IPC**

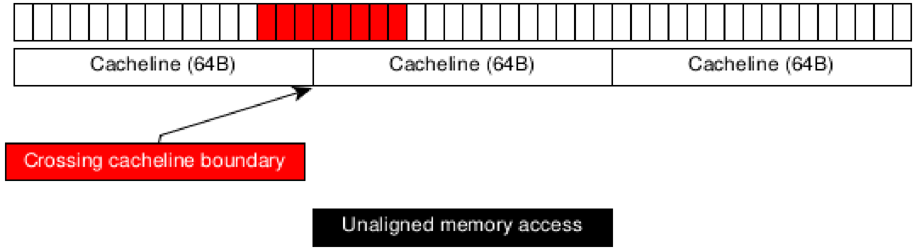
Scalar addition



Vector addition







MAQAO LProf: Lightweight Profiler

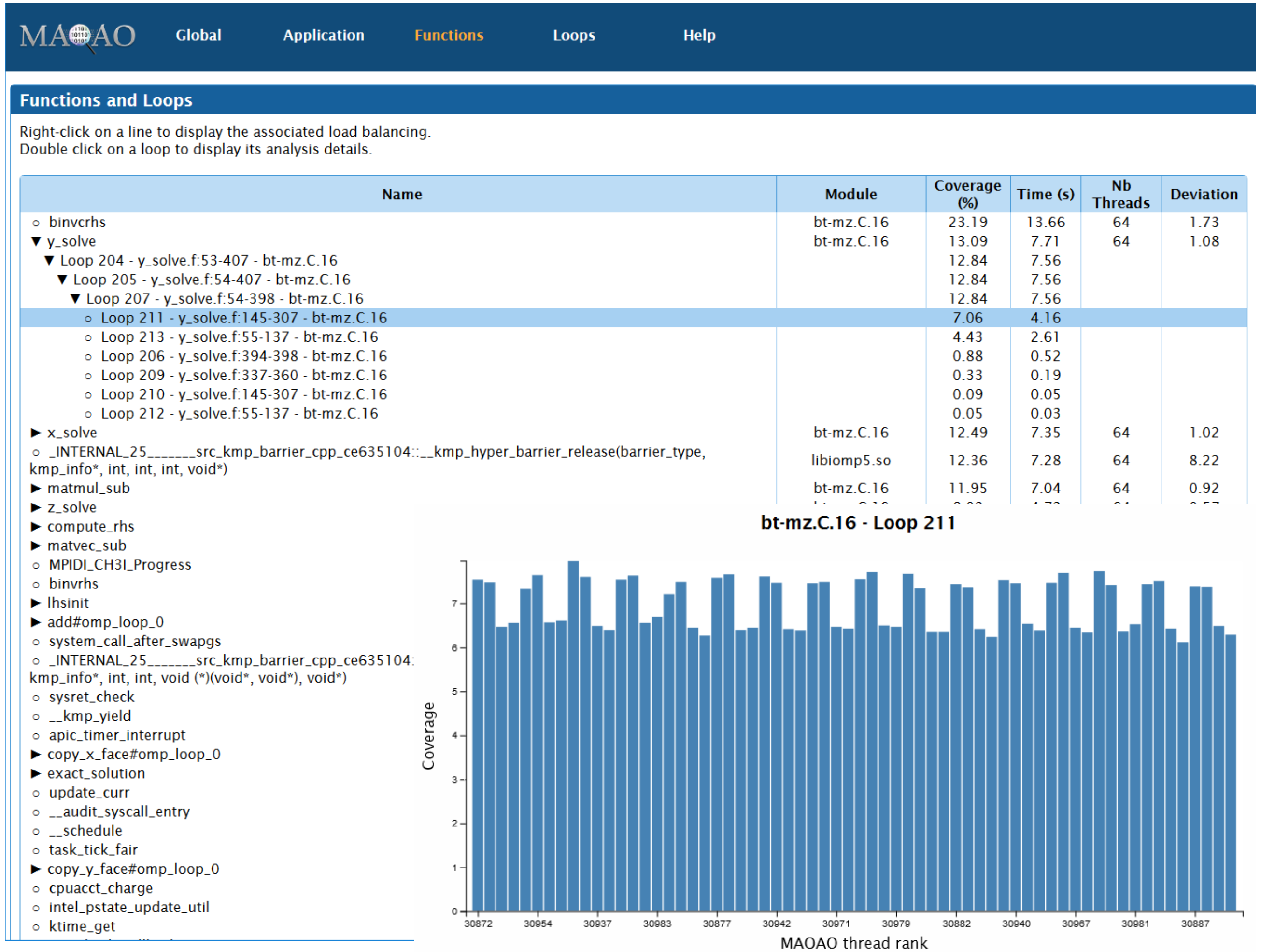
Goal: Lightweight localization of application hotspots

Features:

- **Sampling** based
- Access to hardware counters
- Analysis at function and loop granularity

Strengths:

- **Non intrusive**: No recompilation necessary
- **Low overhead**
- Agnostic with regard to parallel runtime

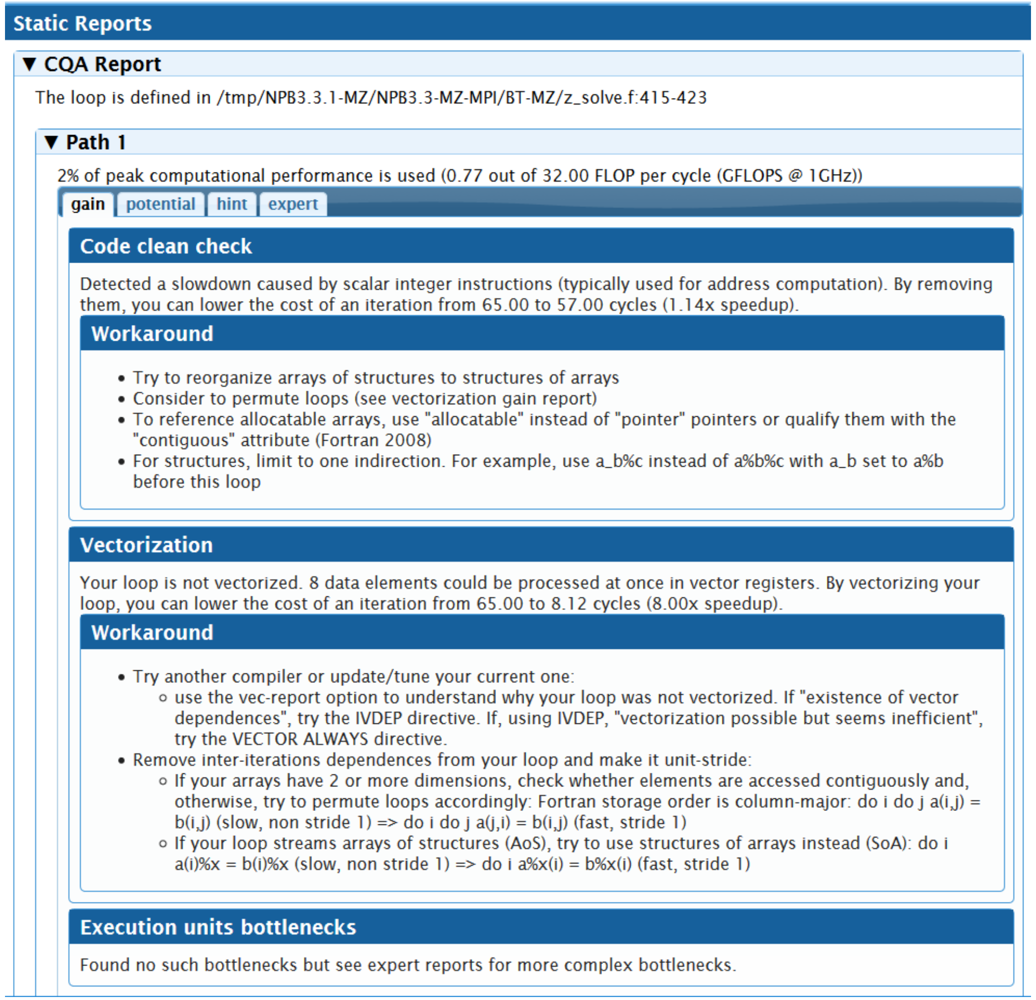


MAQAO CQA: Code Quality Analyzer

Goal: **Assist developers** in improving code performance

Features:

- Static analysis: **no execution** of the application
- Allows **cross-analysis** of/on multiple architectures
- Compiler generated code **quality evaluation**
- Proposes **hints and workarounds** to improve quality/performance
- **Loops centric**
  - In HPC, loops cover most of the processing time
- Targets **compute-bound** codes



MAQAO CQA: Main Concepts

Applications exploit at best 5 to 10% of the peak performance.

Main elements of analysis:
- Peak performance
- Execution pipeline
- Resources/Functional units

Key performance levers for core level efficiency:
- Vectorization
- Avoiding high latency instructions if possible (DIV/SQRT)
- Guiding the compiler code optimization
- Reorganizing memory and data structures layout

Same instruction – Same cost

Process up to 8X data

MAQAO CQA: Guiding the compiler and hints

Compilers can be driven using flags, pragmas, and keywords:

- Ensuring full use of architecture capabilities (e.g. using flag -xHost on AVX capable machines)
- Forcing optimizations (unrolling, vectorization, alignment, …)
- Bypassing conservative behaviour when possible (e.g. 1/X precision)

Hints for implementation changes:

- Improve data access patterns
  - Memory alignment
  - Loop interchange
  - Changing loop strides
  - Reshaping arrays of structures
- Avoid instructions with high latency (SQRT, DIV, GATHER, SCATTER, …)

Application to Motivating Example

Issues identified by CQA

6) Variable number of iterations

2) Non-unit stride accesses

```
do j = ni + nvalue1, nato
  nj1 = ndim3d*j + nc ; nj2 = nj1 + nvalue1 ; nj3 = nj2 + nvalue1
  u1 = x11 – x(nj1) ; u2 = x12 – x(nj2) ; u3 = x13 – x(nj3)
  rtest2 = u1*u1 + u2*u2 + u3*u3 ; cnij = eci*qEold(j)
  rij = demi*(rvwi + rvwalc1(j))
  drtest2 = cnij/(rtest2 + rij) ; drtest = sqrt(drtest2)
  Eq = qq1*qq(j)*drtest
  ntj = nti + ntype(j)
  Ed = ceps(ntj)*drtest2*drtest2*drtest2
  Eqc = Eqc + Eq ; Ephob = Ephob + Ed
  gE = (c6*Ed + Eq)*drtest2 ; virt = virt + gE*rtest2
  u1g = u1*gE ; u2g = u2*gE ; u3g = u3*gE
  g1c = g1c –u1g ; g2c = g2c – u2g ; g3c = g3c –u3g
  gr(nj1, thread_num) = gr(nj1, thread_num) + u1g
  gr(nj2, thread_num) = gr(nj2, thread_num) + u2g
  gr(nj3, thread_num) = gr(nj3, thread_num) + u3g
end do
```

4) DIV/SQRT

3) Indirect accesses

5) Reductions

2) Non-unit stride accesses

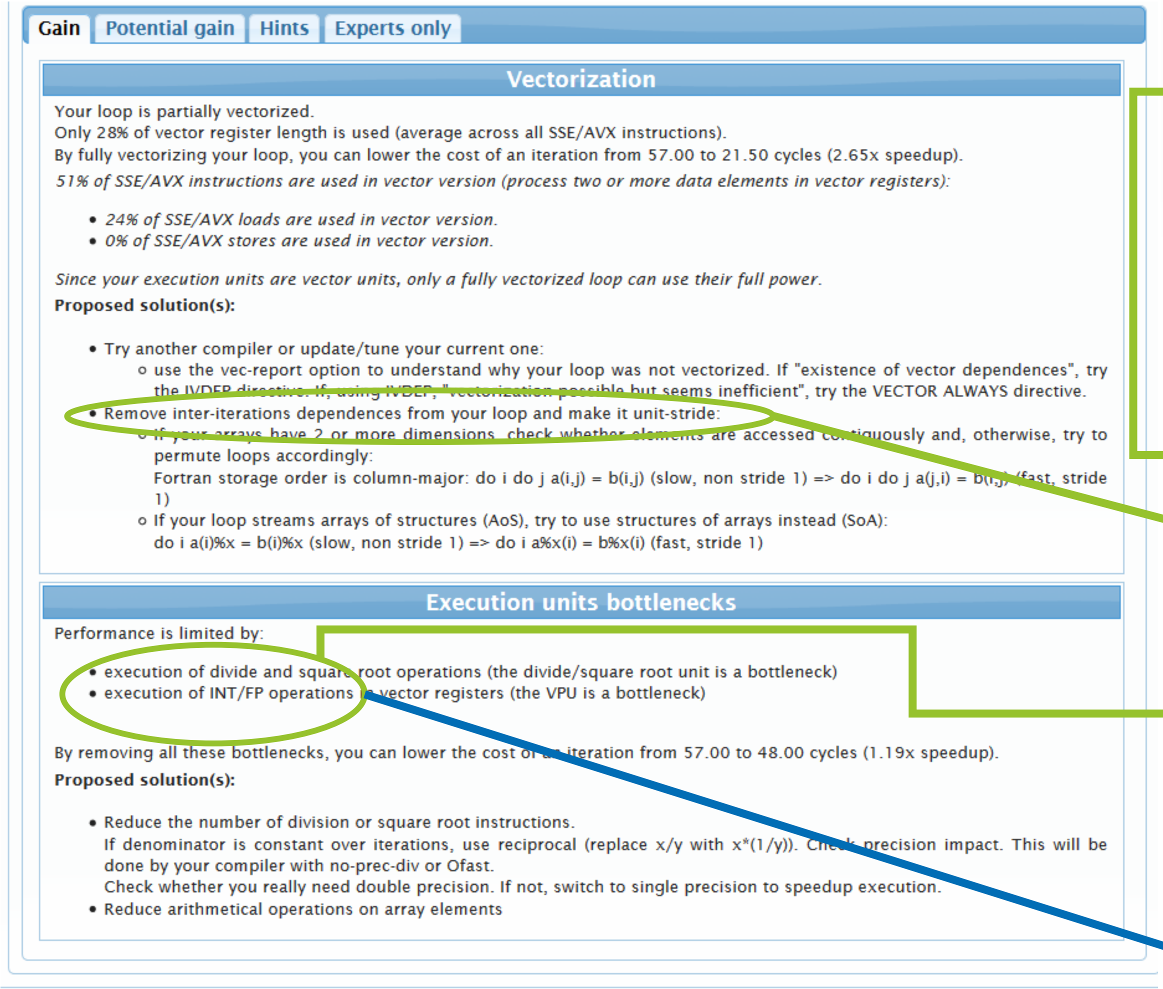
1) High number of statements

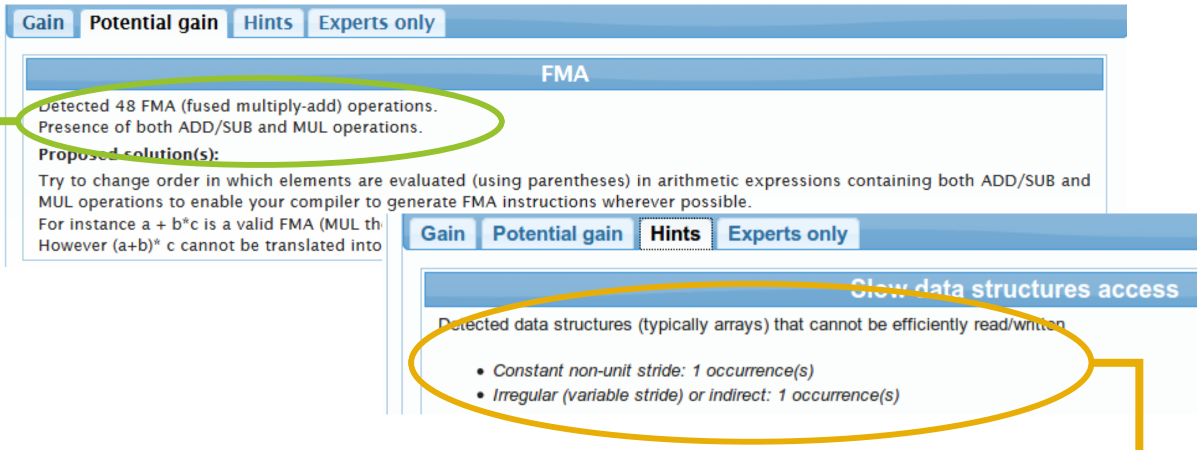
7) Vector vs scalar

CQA can detect and provide hints to resolve most of the identified issues:

1) High number of statements
2) Non-unit stride accesses
3) Indirect accesses
4) DIV/SQRT
5) Reductions
6) Variable number of iterations
7) Vector vs scalar

Application to Motivating Example





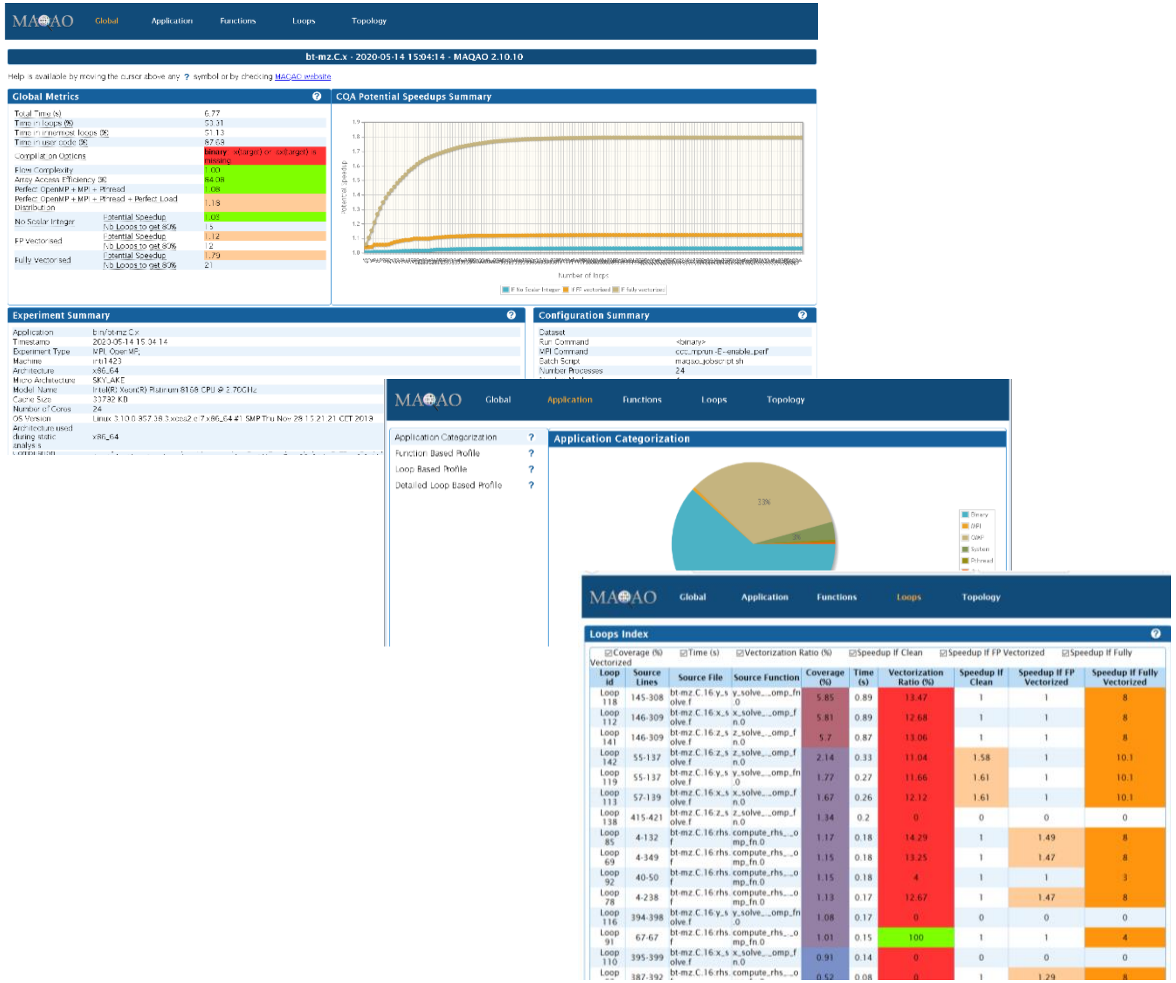
1) High number of statements
2) Non-unit stride accesses
3) Indirect accesses
4) DIV/SQRT
5) Reductions
6) Variable number of iterations
7) Vector vs scalar

MAQAO ONE View: Performance View Aggregator

Automating the whole analysis process
- Invoke multiple MAQAO modules
- Generate **aggregated performance views**
- Generate a report in HTML format

Main steps:
- Invokes LProf to **identify hotspots**
- Invokes CQA on **hotspots**

Available results:
- **Speedup** predictions
- Global **code quality** metrics
- **Hints** for improving performance
- Parallel **efficiency** analysis



Analysing an application with MAQAO

ONE View execution

- Provide all parameters necessary for executing the application
  - Parameters can be passed on the command line or as a configuration file
  - Parameters include binary name, MPI commands, dataset directory, …

```
$ maqao oneview --create-report=one --binary=bt-mz.C.16 --mpi_command="mpirun -n 16"
```

```
$ maqao oneview --create-report=one --config=my_config.lua"
```

- Analyses can be tweaked if necessary
  - Report level **one** corresponds to lightweight profiling (**LProf**) and code quality analysis (**CQA**)
- ONE View can reuse an existing experiment directory to perform further analyses
- Results available in HTML format by default
  - XLS spreadsheets and textual output generation are also available

Online help is available:

```
$ maqao oneview --help
```

Analysing an application with MAQAO

MAQAO modules can be invoked separately for advanced analyses

- LProf
  - Profiling

```
$ maqao lprof xp=exp_dir --mpi-command="mpirun -n 16 -ppn 4" ppn=4 -- ./bt-mz.C.16
```

  - Display functions profile

```
$ maqao lprof xp=exp_dir -df
```

  - Displaying the results from a ONE View run

```
$ maqao lprof xp=oneview_xp_dir/tools/lprof_npsu -df
```

- CQA

```
$ maqao cqa loop=42 bt-mz.C.16
```

Online help is available:

```
$ maqao lprof --help
```

```
$ maqao cqa --help
```

More on MAQAO

MAQAO website: www.maqao.org

- Documentation: www.maqao.org/documentation.html
  - Tutorials for ONE View, LProf and CQA
  - Lua API documentation
- Latest release: http://www.maqao.org/downloads.html
  - Binary releases (2-3 per year)
  - Source code
- Publications around MAQAO: http://www.maqao.org/publications.html

Navigating ONE View Reports

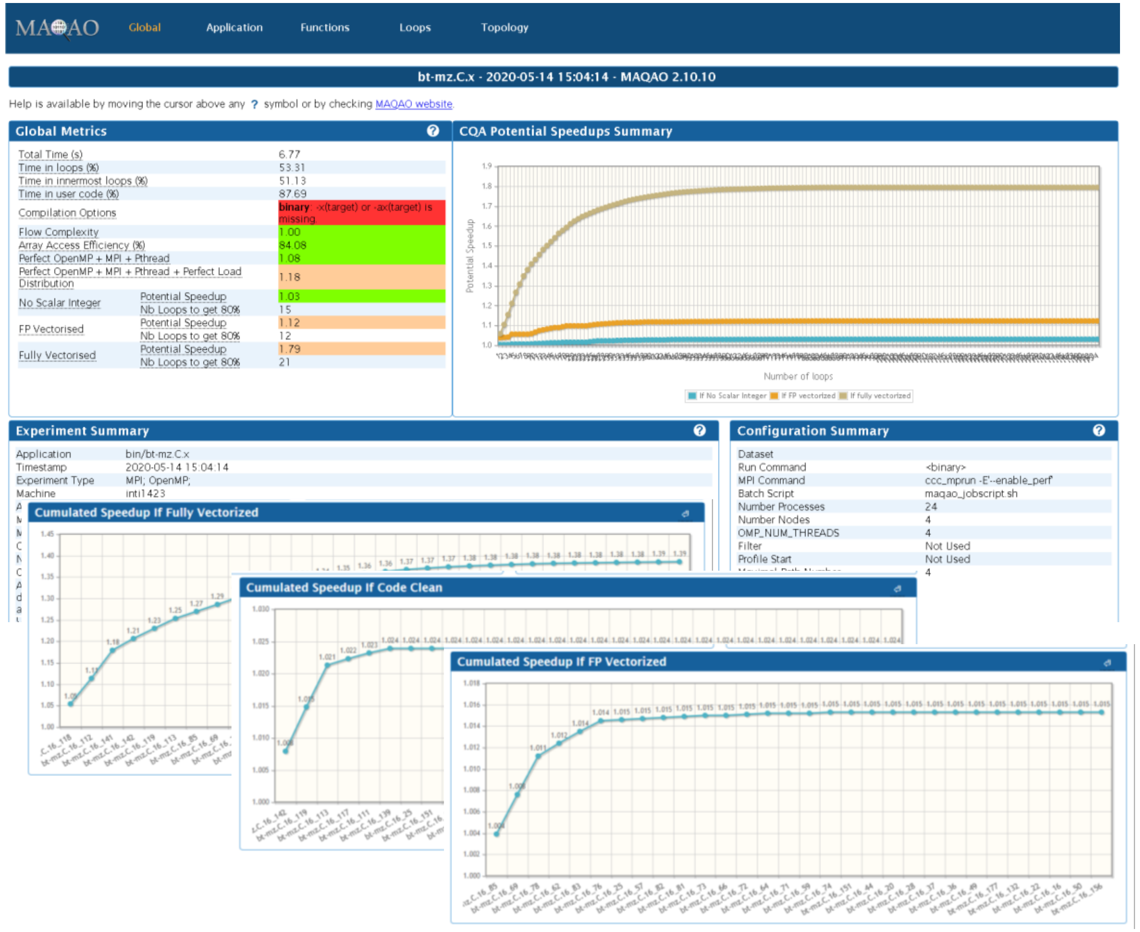
Global summary

Experiment summary

- Machine characteristics and configuration

Global metrics

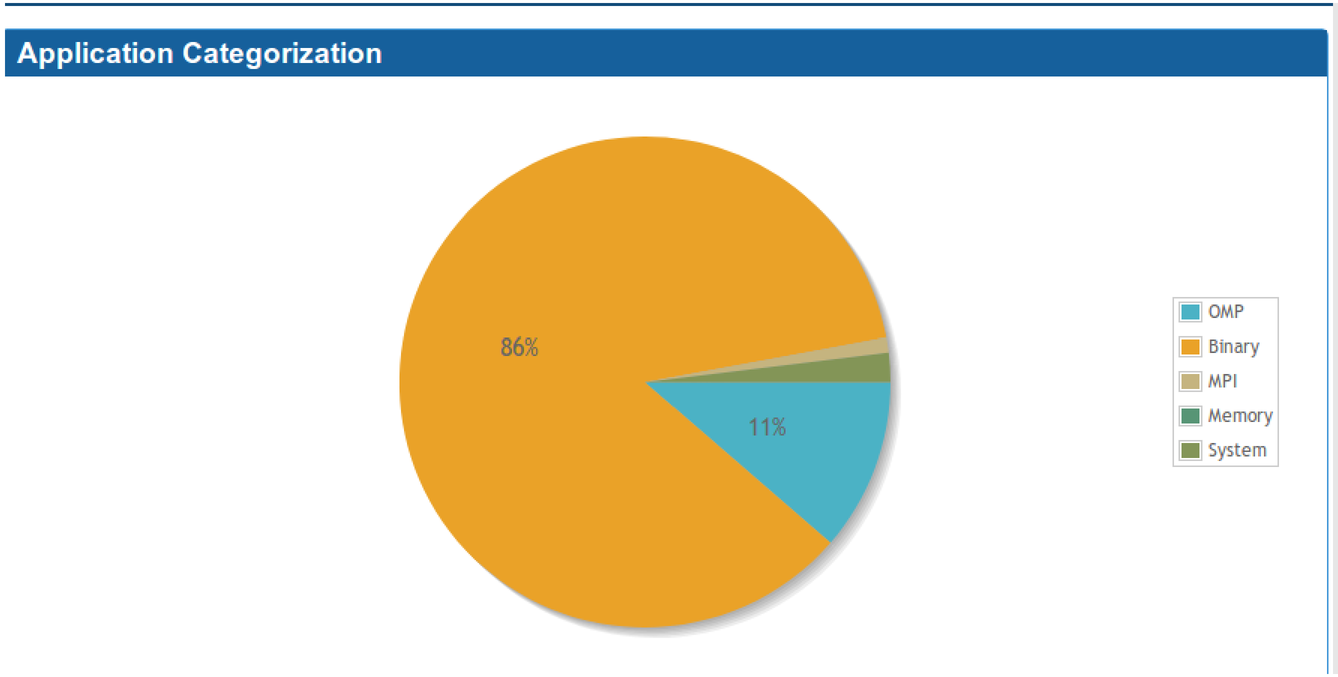
- General quality metrics derived from MAQAO analyses
- Global speedup predictions
  - Speedup prediction depending on the number of vectorised loops
  - Ordered speedups to identify the loops to optimise first



Time Categorisation

Identifying at a glance where time is spent

- Application
  - Main executable
- Parallelization
  - Threads
  - OpenMP
  - MPI
- System libraries
  - I/O operations
  - String operations
  - Memory management functions
- External libraries
  - Specialised libraries such as libm / libmkl
  - Application code in external libraries

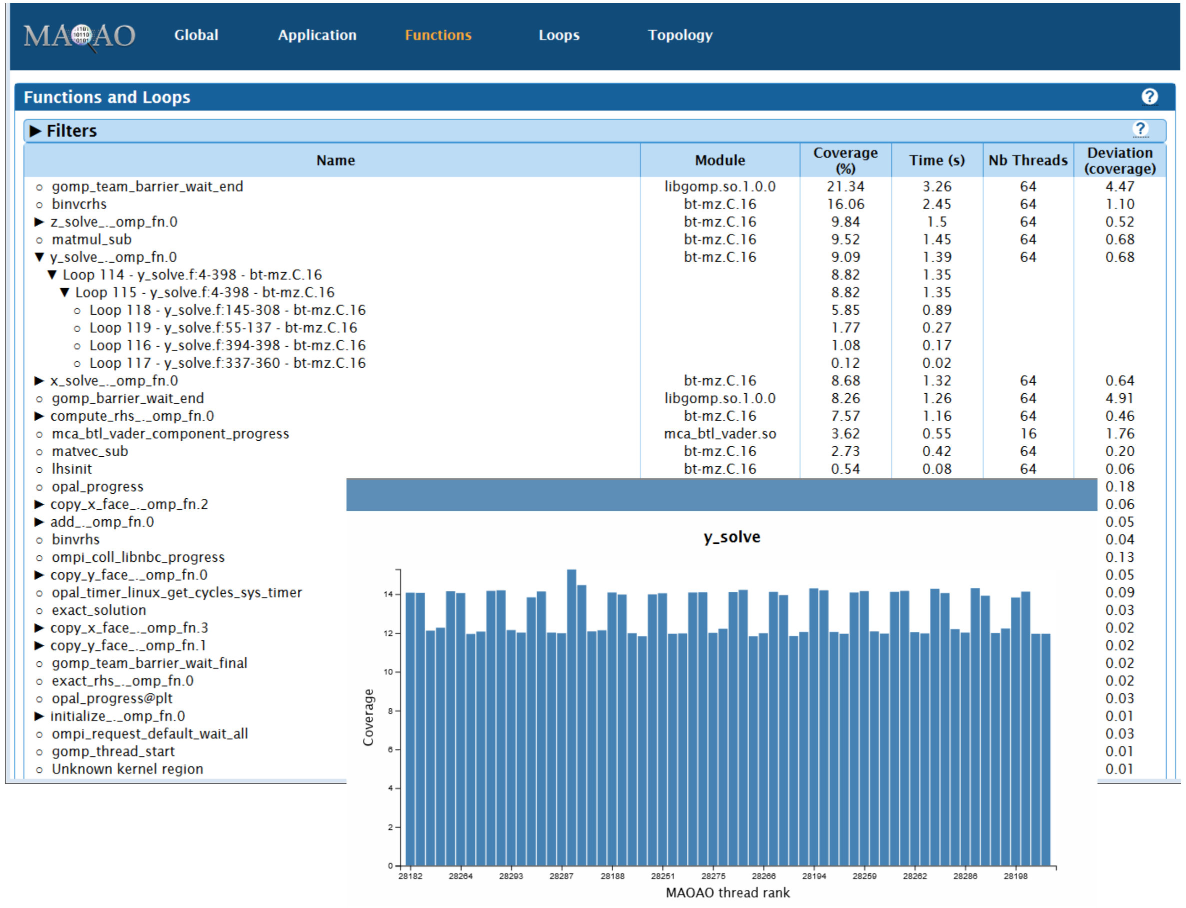


Functions Profiling

Identifying hotspots

- Exclusive coverage
- Load balancing across threads
- Loops nests by functions

- ▼ matmul_sub
  - ○ Loop 230 - solve_subs.f:71-175 - bt-mz.C.16
  - ○ Loop 231 - solve_subs.f:71-175 - bt-mz.C.16 — Single
- ▼ z_solve
  - ▼ Loop 232 - z_solve.f:53-423 - bt-mz.C.16 — Outermost
    - ▼ Loop 233 - z_solve.f:54-423 - bt-mz.C.16 — Inbetween
      - ▼ Loop 236 - z_solve.f:54-423 - bt-mz.C.16 — Inbetween
        - ○ Loop 239 - z_solve.f:146-308 - bt-mz.C.16 — Innermost
        - ○ Loop 235 - z_solve.f:55-137 - bt-mz.C.16
        - ○ Loop 234 - z_solve.f:415-423 - bt-mz.C.16

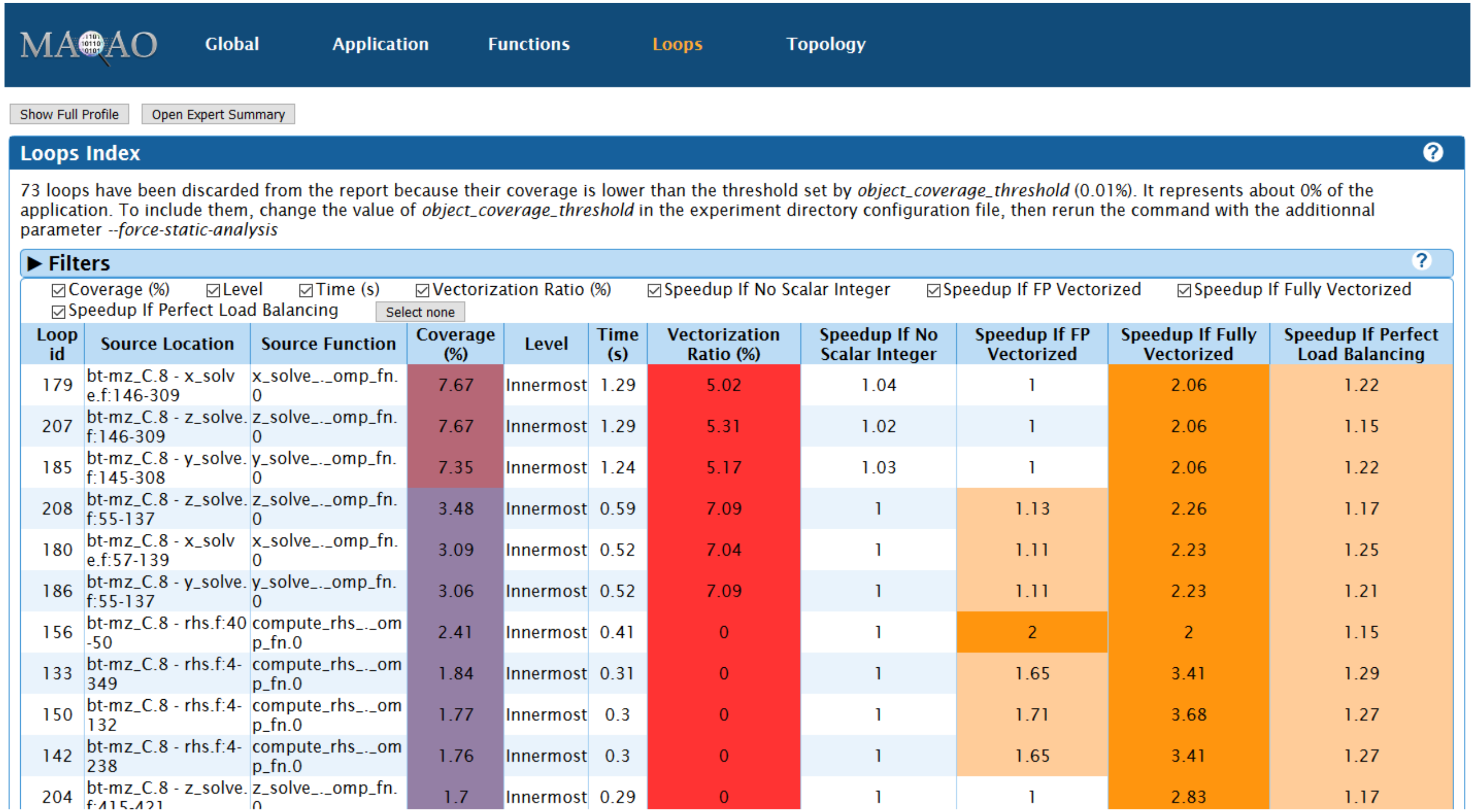


Name	Module	Coverage (%)	Time (s)	Nb Threads	Deviation (coverage)
○ gomp_team_barrier_wait_end	libgomp.so.1.0.0	21.34	3.26	64	4.47
○ binvcrhs	bt-mz.C.16	16.06	2.45	64	1.10
▶ z_solve_._omp_fn.0	bt-mz.C.16	9.84	1.5	64	0.52
○ matmul_sub	bt-mz.C.16	9.52	1.45	64	0.68
▼ y_solve_._omp_fn.0	bt-mz.C.16	9.09	1.39	64	0.68
▼ Loop 114 - y_solve.f:4-398 - bt-mz.C.16		8.82	1.35		
▼ Loop 115 - y_solve.f:4-398 - bt-mz.C.16		8.82	1.35		
○ Loop 118 - y_solve.f:145-308 - bt-mz.C.16		5.85	0.89		
○ Loop 119 - y_solve.f:55-137 - bt-mz.C.16		1.77	0.27		
○ Loop 116 - y_solve.f:394-398 - bt-mz.C.16		1.08	0.17		
○ Loop 117 - y_solve.f:337-360 - bt-mz.C.16		0.12	0.02		
▶ x_solve_._omp_fn.0	bt-mz.C.16	8.68	1.32	64	0.64
○ gomp_barrier_wait_end	libgomp.so.1.0.0	8.26	1.26	64	4.91
▶ compute_rhs_._omp_fn.0	bt-mz.C.16	7.57	1.16	64	0.46
○ mca_btl_vader_component_progress	mca_btl_vader.so	3.62	0.55	16	1.76
○ matvec_sub	bt-mz.C.16	2.73	0.42	64	0.20
○ lhsinit	bt-mz.C.16	0.54	0.08	64	0.06
○ opal_progress					0.18
▶ copy_x_face_._omp_fn.2					0.06
▶ add_._omp_fn.0					0.05
○ binvrhs					0.04
○ ompi_coll_libnbc_progress					0.13
▶ copy_y_face_._omp_fn.0					0.05
○ opal_timer_linux_get_cycles_sys_timer					0.09
○ exact_solution					0.03
▶ copy_x_face_._omp_fn.3					0.02
▶ copy_y_face_._omp_fn.1					0.02
○ gomp_team_barrier_wait_final					0.02
○ exact_rhs_._omp_fn.0					0.02
○ opal_progress@plt					0.03
▶ initialize_._omp_fn.0					0.01
○ ompi_request_default_wait_all					0.03
○ gomp_thread_start					0.01
○ Unknown kernel region					0.01

Loops Profiling Summary

Identifying loop hotspots

- Vectorisation information
- Potential speedup by optimisation
  - No scalar integer: Removing address computations
  - FP Vectorised: Vectorising floating-point computations
  - Fully Vectorised: Vectorising floating-point computations and memory accesses
  - Perfect Load Balancing: Optimal balance across all threads

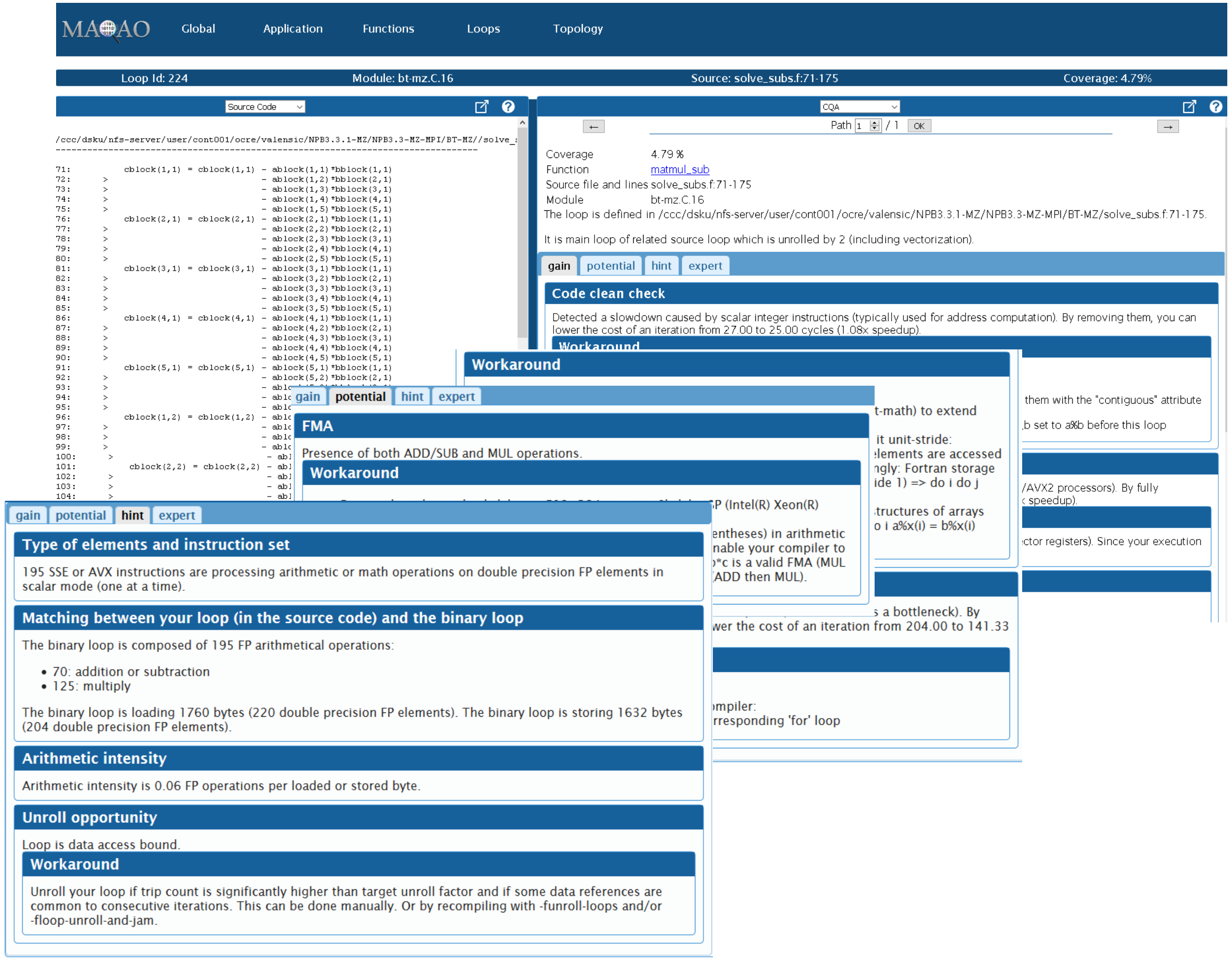


Loop id	Source Location	Source Function	Coverage (%)	Level	Time (s)	Vectorization Ratio (%)	Speedup If No Scalar Integer	Speedup If FP Vectorized	Speedup If Fully Vectorized	Speedup If Perfect Load Balancing
179	bt-mz_C.8 - x_solve.f:146-309	x_solve_._omp_fn.0	7.67	Innermost	1.29	5.02	1.04	1	2.06	1.22
207	bt-mz_C.8 - z_solve.f:146-309	z_solve_._omp_fn.0	7.67	Innermost	1.29	5.31	1.02	1	2.06	1.15
185	bt-mz_C.8 - y_solve.f:145-308	y_solve_._omp_fn.0	7.35	Innermost	1.24	5.17	1.03	1	2.06	1.22
208	bt-mz_C.8 - z_solve.f:55-137	z_solve_._omp_fn.0	3.48	Innermost	0.59	7.09	1	1.13	2.26	1.17
180	bt-mz_C.8 - x_solve.f:57-139	x_solve_._omp_fn.0	3.09	Innermost	0.52	7.04	1	1.11	2.23	1.25
186	bt-mz_C.8 - y_solve.f:55-137	y_solve_._omp_fn.0	3.06	Innermost	0.52	7.09	1	1.11	2.23	1.21
156	bt-mz_C.8 - rhs.f:40-50	compute_rhs_._omp_fn.0	2.41	Innermost	0.41	0	1	2	2	1.15
133	bt-mz_C.8 - rhs.f:4-349	compute_rhs_._omp_fn.0	1.84	Innermost	0.31	0	1	1.65	3.41	1.29
150	bt-mz_C.8 - rhs.f:4-132	compute_rhs_._omp_fn.0	1.77	Innermost	0.3	0	1	1.71	3.68	1.27
142	bt-mz_C.8 - rhs.f:4-238	compute_rhs_._omp_fn.0	1.76	Innermost	0.3	0	1	1.65	3.41	1.27
204	bt-mz_C.8 - z_solve.f:415-421	z_solve_._omp_fn.0	1.7	Innermost	0.29	0	1	1	2.83	1.17

Loop Analysis Reports

High level reports

- Reference to the source code
- Bottleneck description
- Hints for improving performance
- Reports categorized by probability that applying hints will yield predicted gain
  - Gain: Good probability
  - Potential gain: Average probability
  - Hints: Lower probability



Loop Analysis Reports – Expert View

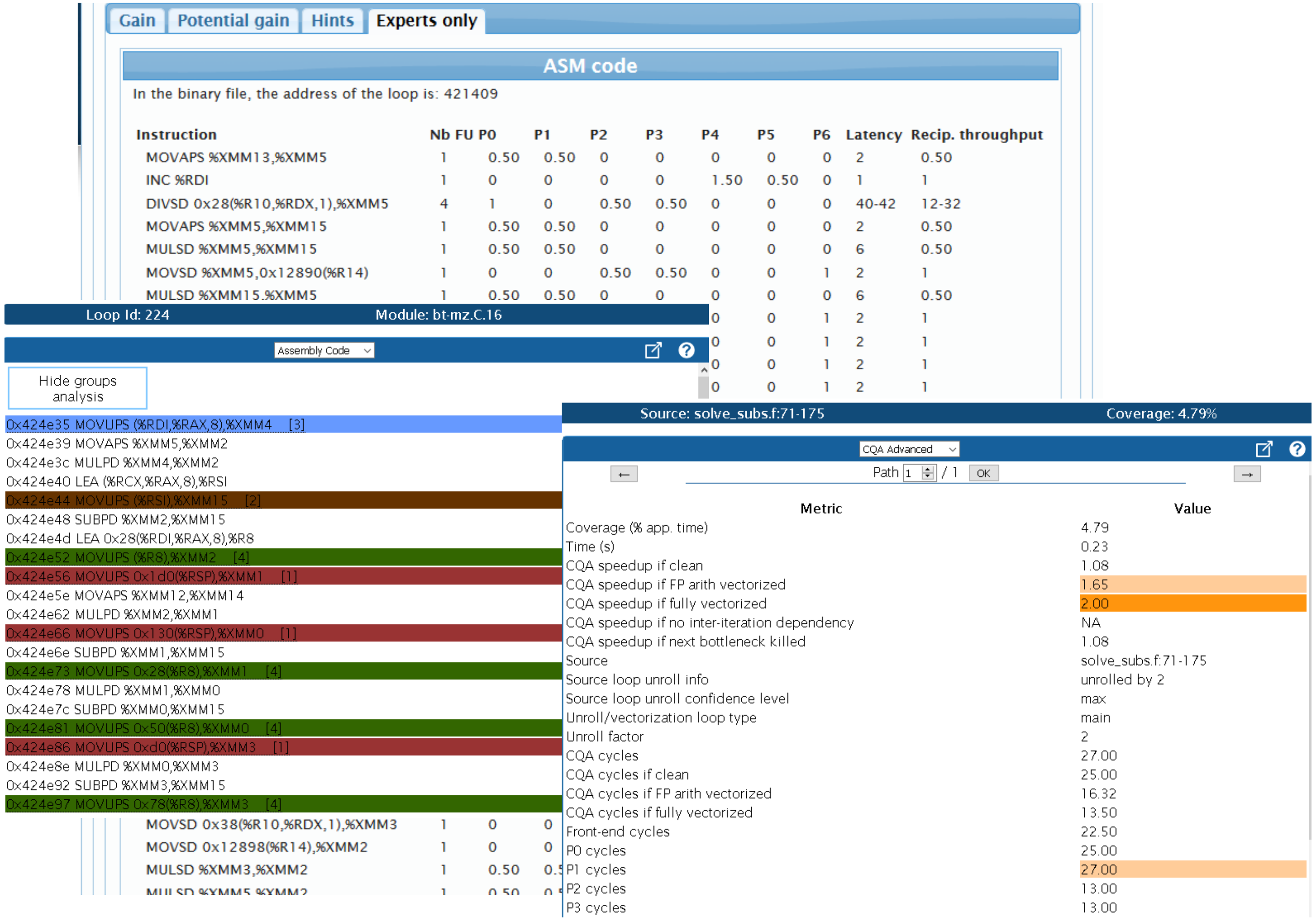
Low level reports for performance experts

- Assembly-level
- Instructions cycles costs
- Instructions dispatch predictions
- Memory access analysis

Assembly code

- Highlights groups of instructions accessing the same memory addresses

CQA internal metrics



MAQAO ONE View Thread/Process View

Software Topology
- List of nodes
- Processes by node
- Thread by process

View by thread
- Function profile at the thread or process level

MAQAO Global Application Functions Loops Topology

Software Topology

ID	Processes	Threads	Time(s)
▼ Node c251-109.wrangler.tacc.utexas.edu	8	32	5.34
▼ Process 145897		4	5.34
○ Thread 145897			5.34
○ Thread 145933			5.32
○ Thread 145952			5.32
○ Thread 145969			5.3
▶ Process 145899		4	5.34
▶ Process 145901		4	5.34
▶ Process 145903		4	5.34
▶ Process 145898		4	5.34
▶ Process 145900		4	5.34
▶ Process 145895		4	5.34
▶ Process 145896		4	5.34
▶ Node c251-110.wrangler.tacc.utexas.edu	8	32	5.36
○ AVERAGE			5.36

MAQAO Global

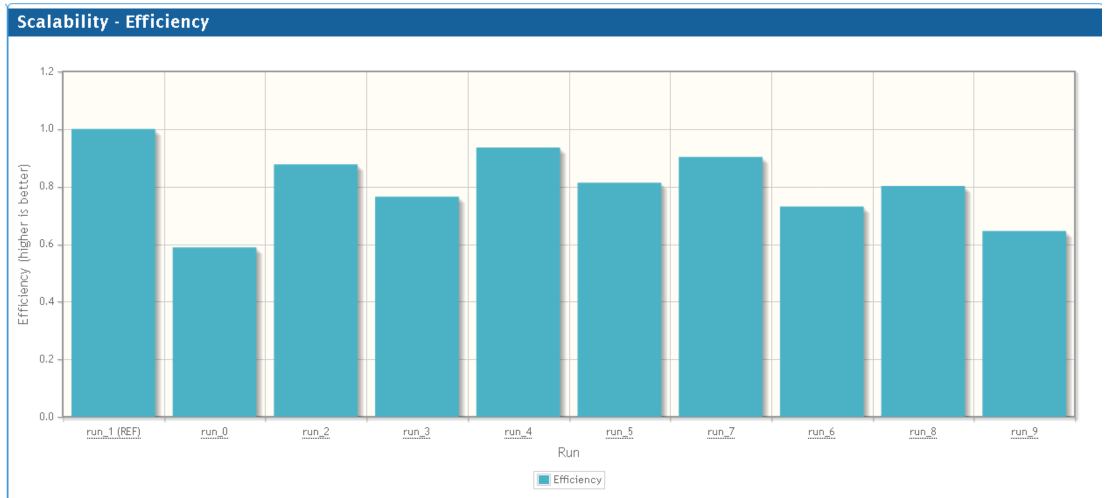
Profiling node c251-109.wrangler.tacc.utexas.edu - process 145897 - thread 145897

Name	Module	Coverage (%)	Time (s)
○ binvcrhs	bt-mz_B.16	24.34	1.3
○ _INTERNAL_25_______src_kmp_barrier_cpp_fa608613::__kmp_hyper_barrier_gather(barrier_type, kmp_info*, int, int, void (*)(void*, void*), void*)	libiomp5.so	17.6	0.94
▶ matmul_sub	bt-mz_B.16	12.73	0.68
▶ y_solve	bt-mz_B.16	7.87	0.42
▶ compute_rhs	bt-mz_B.16	7.49	0.4
▶ x_solve	bt-mz_B.16	7.12	0.38
▶ z_solve	bt-mz_B.16	6.74	0.36

MAQAO ONE View Scalability Reports

Goal: Provide a view of the application scalability

- Profiles with different numbers of threads/processes
- Displays efficiency metrics for application



▼ **Detailed Efficiency**

Run	Number of observed threads	Efficiency (ideal is 1)
run_1 (REF)	2	1
run_0	96	0.59
run_2	3	0.88
run_3	5	0.77
run_4	8	0.94
run_5	9	0.81
run_7	9	0.9
run_6	16	0.73
run_8	16	0.8
run_9	32	0.65

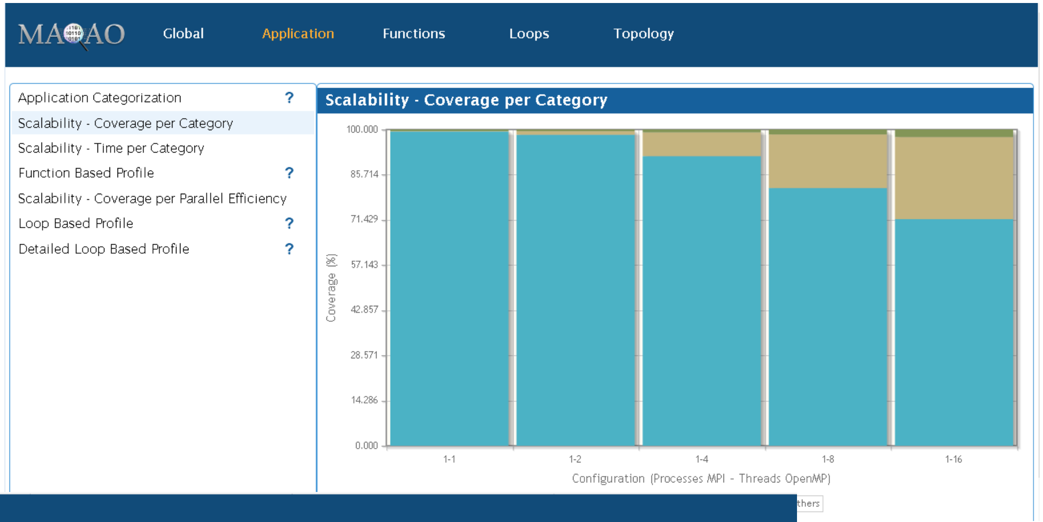
MAQAO ONE View Scalability Reports – Application View

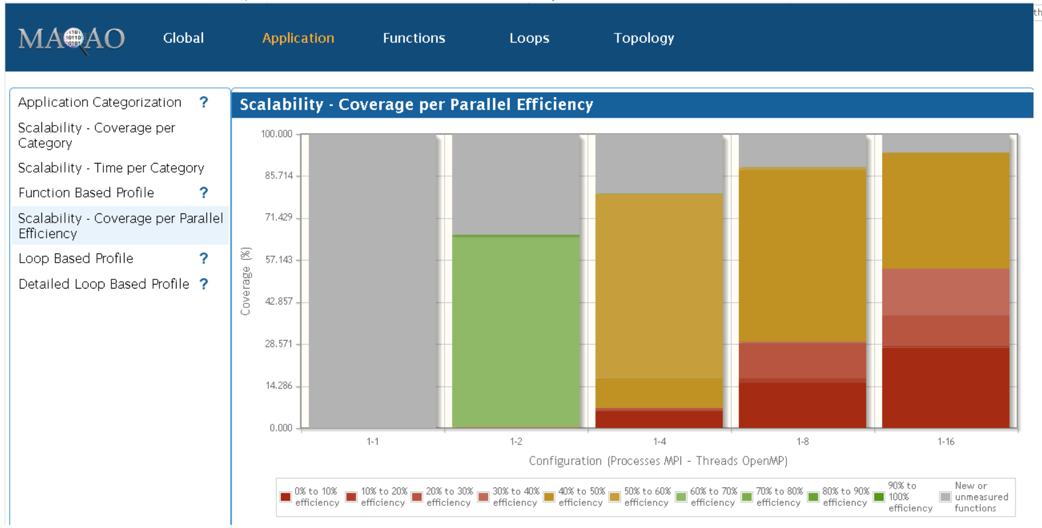
Coverage per category

- Comparison of categories for each run

Coverage per parallel efficiency

- $Efficiency = \frac{T_{sequential}}{T_{parallel} * N_{threads}}$
  - Distinguishing functions only represented in parallel or sequential
- Displays efficiency by coverage

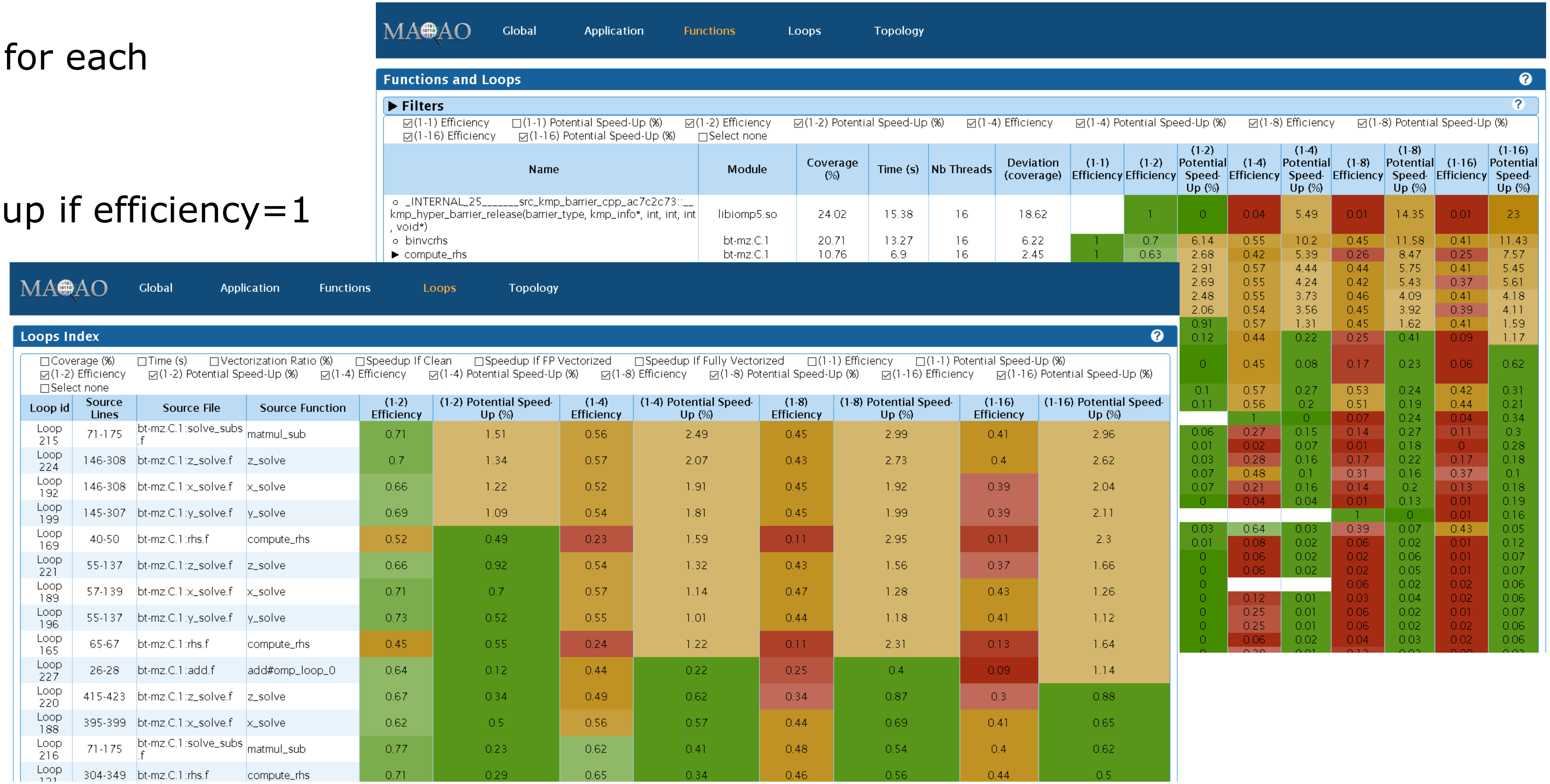




MAQAO ONE View Scalability Reports – Functions and Loops Views

Displays metrics for each function/loop

- Efficiency
- Potential speedup if efficiency=1



Name	Module	Coverage (%)	Time (s)	Nb Threads	Deviation (coverage)	(1-1) Efficiency	(1-2) Efficiency	(1-2) Potential Speed-Up (%)	(1-4) Efficiency	(1-4) Potential Speed-Up (%)	(1-8) Efficiency	(1-8) Potential Speed-Up (%)	(1-16) Efficiency	(1-16) Potential Speed-Up (%)
○ __INTERNAL_25_______src_kmp_barrier_cpp_ac7c2c73::__kmp_hyper_barrier_release(barrier_type, kmp_info*, int, int, int, void*)	libiomp5.so	24.02	15.38	16	18.62		1	0	0.04	5.49	0.01	14.35	0.01	23
○ binvcrhs	bt-mz.C.1	20.71	13.27	16	6.22	1	0.7	6.14	0.55	10.2	0.45	11.58	0.41	11.43
▶ compute_rhs	bt-mz.C.1	10.76	6.9	16	2.45	1	0.63	2.68	0.42	5.39	0.26	8.47	0.25	7.57
								2.91	0.57	4.44	0.44	5.75	0.41	5.45
								2.69	0.55	4.24	0.42	5.43	0.37	5.61
								2.48	0.55	3.73	0.46	4.09	0.41	4.18
								2.06	0.54	3.56	0.45	3.92	0.39	4.11
								0.91	0.57	1.31	0.45	1.62	0.41	1.59
								0.12	0.44	0.22	0.25	0.41	0.09	1.17
								0	0.45	0.08	0.17	0.23	0.06	0.62
								0.1	0.57	0.27	0.53	0.24	0.42	0.31
								0.11	0.56	0.2	0.51	0.19	0.44	0.21
									1	0	0.07	0.24	0.04	0.34
								0.06	0.27	0.15	0.14	0.27	0.11	0.3
								0.01	0.02	0.07	0.01	0.18	0	0.28
								0.03	0.28	0.16	0.17	0.22	0.17	0.18
								0.07	0.48	0.1	0.31	0.16	0.37	0.1
								0.07	0.21	0.16	0.14	0.2	0.13	0.18
								0	0.04	0.04	0.01	0.13	0.01	0.19
											1	0	0.01	0.16
								0.03	0.64	0.03	0.39	0.07	0.43	0.05
								0.01	0.08	0.02	0.06	0.02	0.01	0.12
								0	0.06	0.02	0.02	0.06	0.01	0.07
								0	0.06	0.02	0.02	0.05	0.01	0.07
								0			0.06	0.02	0.02	0.06
								0	0.12	0.01	0.03	0.04	0.02	0.06
								0	0.25	0.01	0.06	0.02	0.01	0.07
								0	0.25	0.01	0.06	0.02	0.02	0.06
								0	0.06	0.02	0.04	0.03	0.02	0.06

Loop id	Source Lines	Source File	Source Function	(1-2) Efficiency	(1-2) Potential Speed-Up (%)	(1-4) Efficiency	(1-4) Potential Speed-Up (%)	(1-8) Efficiency	(1-8) Potential Speed-Up (%)	(1-16) Efficiency	(1-16) Potential Speed-Up (%)
Loop 215	71-175	bt-mz.C.1:solve_subs.f	matmul_sub	0.71	1.51	0.56	2.49	0.45	2.99	0.41	2.96
Loop 224	146-308	bt-mz.C.1:z_solve.f	z_solve	0.7	1.34	0.57	2.07	0.43	2.73	0.4	2.62
Loop 192	146-308	bt-mz.C.1:x_solve.f	x_solve	0.66	1.22	0.52	1.91	0.45	1.92	0.39	2.04
Loop 199	145-307	bt-mz.C.1:y_solve.f	y_solve	0.69	1.09	0.54	1.81	0.45	1.99	0.39	2.11
Loop 169	40-50	bt-mz.C.1:rhs.f	compute_rhs	0.52	0.49	0.23	1.59	0.11	2.95	0.11	2.3
Loop 221	55-137	bt-mz.C.1:z_solve.f	z_solve	0.66	0.92	0.54	1.32	0.43	1.56	0.37	1.66
Loop 189	57-139	bt-mz.C.1:x_solve.f	x_solve	0.71	0.7	0.57	1.14	0.47	1.28	0.43	1.26
Loop 196	55-137	bt-mz.C.1:y_solve.f	y_solve	0.73	0.52	0.55	1.01	0.44	1.18	0.41	1.12
Loop 165	65-67	bt-mz.C.1:rhs.f	compute_rhs	0.45	0.55	0.24	1.22	0.11	2.31	0.13	1.64
Loop 227	26-28	bt-mz.C.1:add.f	add#omp_loop_0	0.64	0.12	0.44	0.22	0.25	0.4	0.09	1.14
Loop 220	415-423	bt-mz.C.1:z_solve.f	z_solve	0.67	0.34	0.49	0.62	0.34	0.87	0.3	0.88
Loop 188	395-399	bt-mz.C.1:x_solve.f	x_solve	0.62	0.5	0.56	0.57	0.44	0.69	0.41	0.65
Loop 216	71-175	bt-mz.C.1:solve_subs.f	matmul_sub	0.77	0.23	0.62	0.41	0.48	0.54	0.4	0.62
Loop [illegible]	304-349	bt-mz.C.1:rhs.f	compute_rhs	0.71	0.29	0.65	0.34	0.46	0.56	0.44	0.5

Thank you for your attention !

Questions ?