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The HPCToolkit

Introduction to Rosa Course
Scientific Computing Group

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HPCToolkit: Motivation

- HPCToolkit's measurement tools collect performance data on each process and thread of an MPI program
  - Can be used with MPI or hybrid programs (MPI with OpenMP or pthreads)
- Supports C, C++ and Fortran
- The *hpcviewer* tool aids analysis of the application performance data

HPCToolkit: Motivation

- HPCToolkit can provide ***accurate fine-grain*** measurements of production applications running at scale, through
  - *low measurement overhead*
  - *call path profiling*
  - mapping between *fully optimised object code* and *associated source code*

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HPCToolkit: Motivation

- Requirement: low measurement overhead
  - ***Avoid* instrumentation**
    - Tools such as *Tau* use source code instrumentation to insert profiling code into the source before compilation
      - Instrumentation can interfere with compiler optimisations such as inlining and loop transformations
      - Source instrumentation is not useful when using libraries
    - Binary instrumentors such as *gprof* may prevent full optimisation of code

HPCToolkit: Motivation

- Requirement: low measurement overhead
  - Instead of instrumentation use ***statistical sampling***
    - Sample events triggered by periodic interrupts from an interval timer or from the overflow of hardware performance counters
    - One can sample metrics that reflect work (e.g. floating point operations performed), resource consumption (e.g. cycles, memory bus transactions) or inefficiency (e.g. stalls)

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HPCToolkit: Motivation

- Call path profiling
  - Important to associate the costs incurred by a procedure with the context in which it is called
  - Particularly important for codes based on application frameworks and libraries

HPCToolkit: Motivation

- Recovering static program structure
  - Since measurements are made with reference to executables, it is necessary to map measurements back to program source code
  - HPCToolkit constructs this mapping using binary analysis
    - Can thus accurately attribute performance metrics to calling contexts, procedures, loops, and inlined instances of procedures

HPCToolkit: How to use on Rosa

- Load the hpct module
  - **module load hpct**
- Compile code with debugging support
  - *for PGI*: **-gopt**; *for PathScale*: **-g1**; *for GNU*: **-g**
    - Remember to add optimisation flags (eg. –O3) *after* –g to make sure compiler optimisation is not reduced
- Link your application using hpclink
  - **hpclink ftn –o code.exe code.o code1.o …**
  - **hpclink cc –o code.exe code.o code1.o …**

HPCToolkit: How to use on Rosa

- In your PBS batch job script set the CSPROF_OPT_EVENT environment variable according to which events you wish to monitor, e.g.
  - **export CSPROF_OPT_EVENT="PAPI_TOT_CYC@4000000 PAPI_L2_TCM@400000"**
    - This would sample your executable every 4 million cycles and every 400k level 2 cache misses
  - Note: use "papi_avail" program to see which hardware counters are available on the XT5

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HPCToolkit: How to use on Rosa

- Launch code with **aprun** as normal
  - You will get a directory called hpctoolkit-<exe>-measurements-<pbs_jobid>
    - This will contain files with suffix .hpcrun (one for each MPI task) and logfiles (.log)
- Do a one-time binary analysis of your code using the hpcstruct command (interactively)
  - **hpcstruct <exe>**
    - This generates a file called <exe>.hpcstruct
    - May take some minutes!

HPCToolkit: How to use on Rosa

- Finally, invoke “hpcprof” to join the information from the run to the information from “hpcstruct”
  - **hpcprof –S <exe>.hpcstruct –I <path-to-source> hpctoolkit-<exe>-measurements-<pbs_jobid>/*.hpcrun**
    - This produces a directory hpctoolkit-<exe>-database, which can be shipped elsewhere if you wish to analyse the results on another machine

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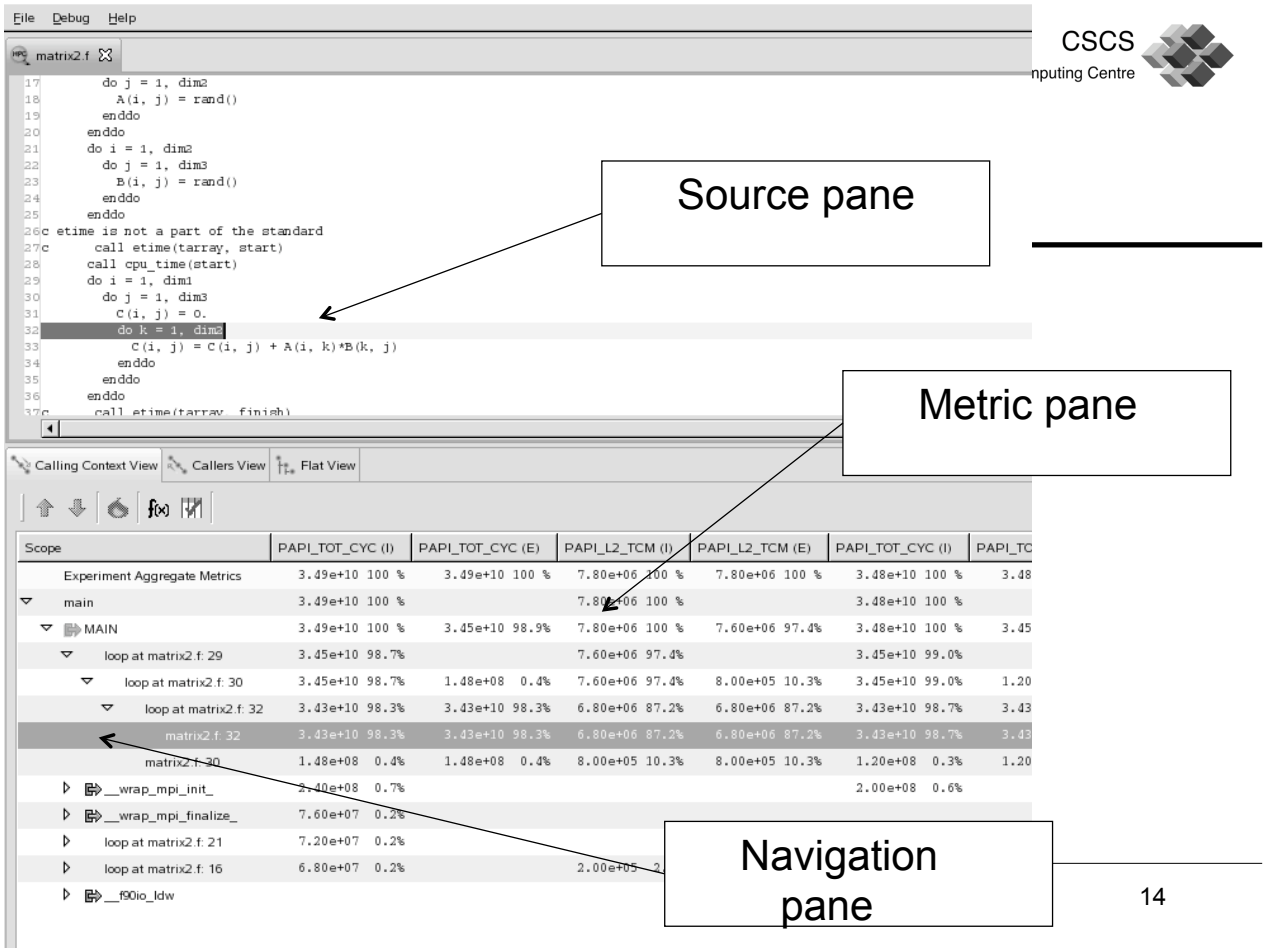
HPCToolkit: How to use on Rosa

- Java-based viewer “hpcviewer” provides a top-down visualisation of the experiment database
  - **module load hpct**
  - **hpcviewer hpctoolkit-<exe>-database**
- Viewer can also be installed and launched on your workstation
- Help can be found in a help pane
- Documentation on how to use the viewer at http://hpctoolkit.org/documentation.html

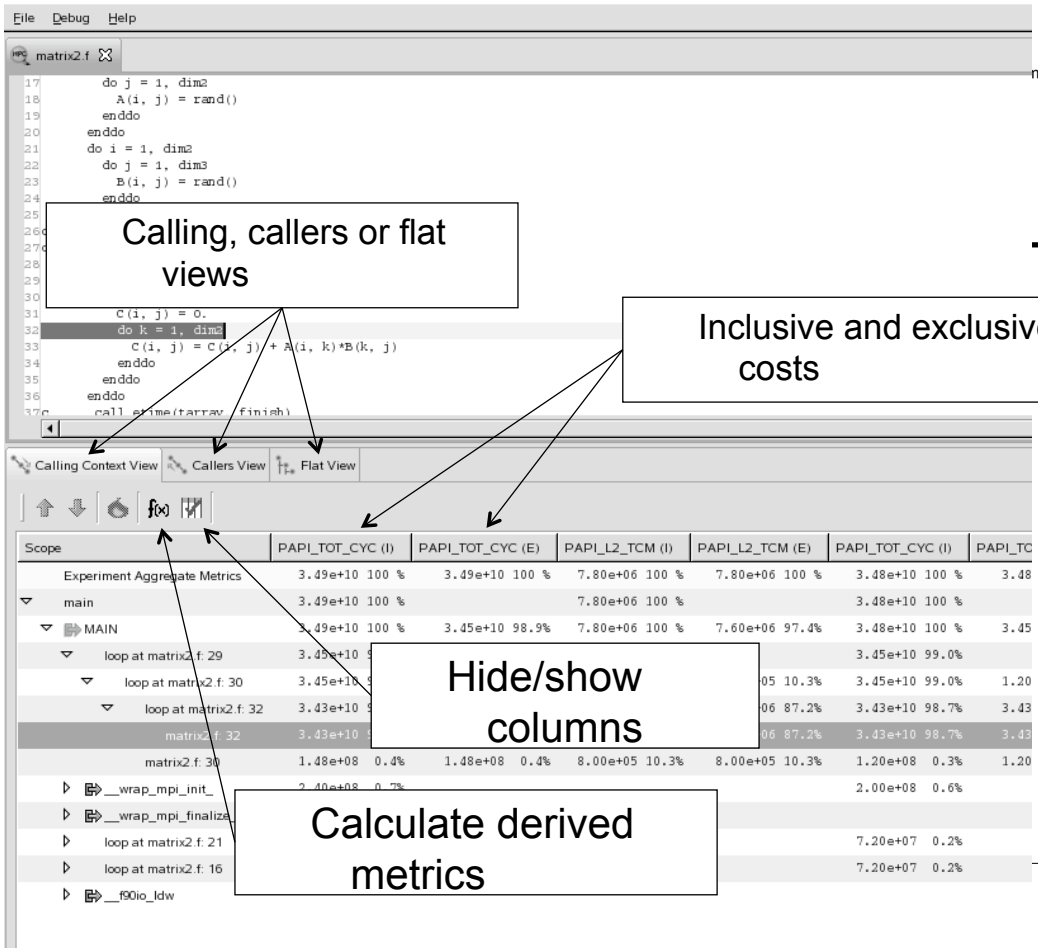
HPCToolkit: hpcviewer

- Browser window divided in three panes
  - Source pane
    - Select an entity in the navigation pane and the source pane will load appropriate file and highlight corresponding line
  - Navigation pane
    - Hierarchical tree-based structure used to organise performance data. Display depends on whether a context, callers, or flat view is being shown
  - Metric pane
    - Displays performance metrics



HPCToolkit: hpcviewer

- Supports three main views of performance data
  - Calling context view
    - Can see costs incurred by calls to a procedure in a particular calling context (call path)
  - Callers view
    - Bottom-up view enables you to look upward along call paths. Useful for understanding performance of procedures that are used in multiple contexts
  - Flat view
    - Costs incurred by a procedure in any calling context are aggregated together



HPCToolkit: How to analyse

- Values of individual metrics are of limited use by themselves
  - e.g. number of cache misses for a loop or routine is of little value in isolation – only useful when compared to the number of instructions executed or the number of cache accesses
  - hpcviewer can be used to calculate derived metrics via spreadsheet-like formulae (e.g. *cycles/instruction* from PAPI_TOT_CYC/PAPI_TOT_INS for a particular scope)

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HPCToolkit: How to analyse

- Derived metrics can be used to pinpoint and quantify inefficiencies
- Scalability bottlenecks can be pinpointed by differential analysis of two profiles run using different numbers of processes
- See *Effective Strategies for Analysis Program Performance with HPCToolkit* for more details
- http://hpctoolkit.org