HPCTOOLKIT: tools for performance analysis of optimized parallel programs

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HPCTOOLKIT: tools for performance analysis of optimized parallel programs

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- Department of Computer Science, Rice University
- Oak Ridge National Laboratory
- Concurrency and Computation: Practice and Experience
- 2010

- Developed for their own use at Rice University.
- More papers on HPCToolkit: <u>http://hpctoolkit.org/publications.html</u>

Introduction

- HPCToolkit
 - Collecting performance measurements of fully optimized executables.
 - Analyzing application binaries to understand the structure of optimized code.
 - Correlating measurements with program structure.
 - Presenting the resulting performance data.
- Pinpoint performance and scalability bottlenecks in complex applications.

Motivation

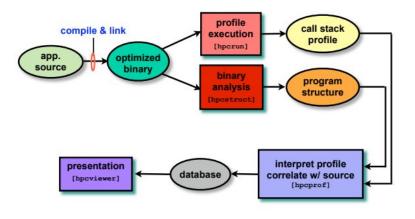
- HPC systems and applications are very complex.
- Achieving top performance is important.
- Problems with tools at that time:
 - Relying on instrumentation and compromise measurement accuracy.
 - High overhead.
 - Not fully capable of correlating measurements with the source code.
 - Using call graph structure or not fully capable of understanding full calling context of optimized code.
 - Problem focused analysis

Measurement Methodology

- Scalable measurement and analysis
- Supports C, C++, and Fortran
 - Directly works with application binaries
- Avoid code instrumentation
 - Uses statistical sampling
- Avoid blind spots
 - Source code might not be available (e.g. math and communication libraries)
 - Performs binary analysis
- Calling context tree
- Multiple metrics
- Present in a hierarchical fashion

Performance Measurement - hpcrun

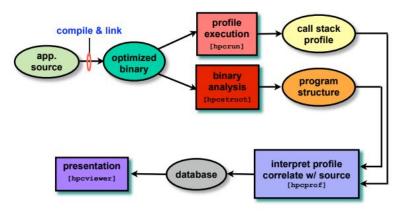
- Call path profiling and tracing
- Statistical sampling
- Coping with fully optimized binaries
 - Unwind the call stack at any point in a program's execution
- Event triggers
 - Measure different aspects of the program performance.
 - Cache misses, I/O, memory allocations, etc.
- Control over parallel applications
 - Intercepts certain process control routines using library preloading.
- Handling dynamic loading
- Generate a measurement directory



HPCToolkit workflow http://hpctoolkit.org/pubs/cpe-2010-hpctoolkit.pdf

Analysis - hpcstruct & hpcprof

- hpcstruct
 - Recover the program structure using binary analysis
 - Mapping between object code and its associated source code structure
 - Generate a .hpcstruct file
- hpcprof
 - Attribute measurements to the application's source code using the program structure file.
 - Generate a performance database directory



HPCToolkit workflow http://hpctoolkit.org/pubs/cpe-2010-hpctoolkit.pdf

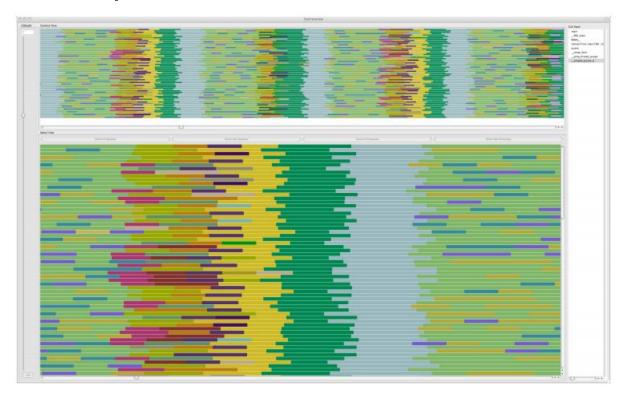
Presentation - hpcviewer

	hpcviewer: GTC scalability analysis	
main.F90 🖾 🗮 poisson.f90		
125! push electron, sub-cycling 126 do i=1,ncycle*irk 127! 1st RK step 128 CALL PUSHE(i,1) 129 coll time(t0,dt,t0wc,dtwc) 130 time(7)-time(7)+dt 131 timewc(7)-timewc(7)+dtwc 132 timewc(7)-timewc(7)+dtwc		
133 CALL SHIFTE 134 coll timer(t0,dt,t0wc,dtwc) 135 time(8)-time(8)-dt 136 timewc(8)-timewc(8)+dtwc 137 137		
138! 2nd RK step 139 CALL PUSHE(i,2) 140 call timer(t0,dt,t0wc,dtwc)		
Calling Context View 📐 Callers View 🎠 Flat View		
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Presentation - hpcviewer

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	MPI 0/32 (us) (f) 9.49=+08 100 8 3.24e+07 3.48 3.24e+07 3.48 2.40e+07 2.58 2.40e+07 2.58 2.40e+07 2.58 2.40e+07 2.58 8.36e+06 0.98 1.66e+07 1.73 6.60e+08 69.58	9.49++08 100 2.89++07 3.0 2.89++07 3.0 2.14++07 2.3 2.14++07 2.3 2.14++07 2.3 2.14++07 2.3 2.14++07 2.3 1.50++06 0.8 1.64++07 1.7 4.76++08 50.1	5.20+08 100 6.2.870+07 5.51 6.2.870+07 5.51 7.870+07 5.19 1.910+07 3.71 1.910+07 3.71 1.910+07 3.71 1.910+07 3.71 1.910+07 3.71 1.910+07 3.71 1.910+07 3.71 1.910+07 3.71 1.910+07 3.71 1.900+07 3.31 3.380+08 5.01	\$ 5.20e+08 100 \$ 2.65e+07 5.11 \$ 2.65e+07 5.11 \$ 2.65e+07 5.14 \$ 1.76e+07 3.44 \$ 1.88e+06 3.21 \$ 1.68e+07 3.24 \$ 2.45e+08 47.21	5.164+08 100 1 2.95e+07 5.77 2.95e+07 5.77 2.05e+07 3.99 2.00e+07 3.99 2.00e+07 3.99 2.00e+07 3.99 9.48e+06 1.88 1.71e+07 3.33 3.38e+08 65.55	 5.16e+08 100 % 2.73e+07 5.3% 2.73e+07 5.3% 2.73e+07 5.3% 1.85e+07 3.6% 1.85e+07 3.6% 1.85e+07 3.6% 8.80e+06 1.7% 1.69e+07 3.3% 2.46e+08 47.6% 	Percent Excess Work(# 9.13e+00 2.62e+00 2.62e+00 1.56e+00 1.56e+00 1.56e+00 1.56e+00 1.67e+00 1.63e+00 1.58e+00
	MPI 0/32 (us) (1) 9.49e+08 100 8 3.24e+07 3.48 3.24e+07 3.48 2.40e+07 2.58 2.40e+07 2.58 2.40e+07 2.58 2.40e+07 2.58 8.36e+06 0.98 1.66e+07 1.78 6.60a+08 69.55 3.00e+04 0.08	9.49++08 100 2.89++07 3.0 2.89++07 3.0 2.14++07 2.3 2.14++07 2.3 2.14++07 2.3 1.54++07 2.3 1.54++07 1.7 4.76++08 50.1 3.00++04 0.0	 5.204+08 100 1 2.870+07 5.51 2.870+07 5.51 1.910+07 3.71 1.910+07 3.71 1.910+07 3.71 3.5050+06 1.91 1.700+07 3.31 3.380+08 65.01 4.780+06 0.91 	\$ 5.20++08 100 \$ 2.65++07 5.11 \$ 2.65++07 5.11 \$ 1.76++07 5.41 \$ 1.76++07 3.44 \$ 1.76++07 3.44 \$ 1.76++07 3.44 \$ 1.76++07 3.44 \$ 1.76++07 3.44 \$ 1.85++07 3.44 \$ 2.65++08 1.74 \$ 2.45++08 4.724 \$ 2.45++08 4.724 \$ 4.78++08 0.944	5.164+08 100 4 2.95e+07 5.74 2.95e+07 5.74 2.00e+07 3.94 2.00e+07 3.94 2.00e+07 3.94 2.00e+07 3.94 3.20e+07 3.94 4.2.00e+07 3.94 3.48e+06 1.84 1.71e+07 3.34 3.38e+08 65.55 1.47e+06 0.34	 S.16e+08 100 % Z.73e+07 5.3% Z.73e+07 5.3% L.85e+07 3.6% L.85e+07 3.6% L.85e+07 3.6% L.85e+07 3.6% L.69e+07 3.3% L.69e+08 47.6% L.47e+06 0.3% 	Percent Excess Work(b) 9.13e+00 2.62e+00 1.56e+00 1.56e+00 1.56e+00 1.67e+00 1.07e+00 1.58e+00 1.58e+00 6.58e-01
Experiment Aggregate Metrics viuti_spinandwaitcq w @ MPID_DeviceCheck @ @ MPID_SendComplete @ @ MPIP_Waitall # @ PMP_Sendrecv # @ pmpi_sendrecv_	MPI 0/32 (us) (1) 9.49e+08 100 8 3.24e+07 3.44 3.24e+07 3.44 2.40e+07 2.59 2.40e+07 2.59 2.40e+07 2.59 8.35e+06 0.99 1.66e+07 1.73 6.60e+08 69.59 3.00e+04 0.08	9.49++08 100 2.89++07 3.0 2.89++07 3.0 2.14++07 2.3 2.14++07 2.3 2.14++07 2.3 2.14++07 2.3 1.54++07 1.7 4.750++08 50.1 3.00++04 0.0 5.44++06 0.6	 5.204+08 100 1 2.870+07 5.51 2.870+07 5.51 1.910+07 3.71 1.910+07 3.71 1.910+07 3.74 1.910+07 3.74 1.910+07 3.74 3.580+06 1.91 3.380+08 63.01 4.780+07 63.51 4.780+06 0.91 7.960+06 1.51 	\$ 5.20+08 100 \$ 2.65e+07 5.11 \$ 2.65e+07 5.11 \$ 1.76e+07 5.11 \$ 1.76e+07 3.41 \$ 1.76e+07 3.44 \$ 1.76e+07 3.44 \$ 1.76e+07 3.44 \$ 1.68e+07 3.44 \$ 1.68e+07 3.44 \$ 2.65e+08 1.77 \$ 1.68e+07 3.24 \$ 2.45e+08 1.72 \$ 3.68e+07 3.24 \$ 3.68e+07 3.24 \$ 3.42e+08 0.91 \$ 4.78e+06 0.91 \$ 5.42e+06 1.00	 5.164+08 100 1 2.95e+07 5.74 2.95e+07 5.74 2.05e+07 5.74 2.00e+07 3.94 2.00e+07 3.94 2.00e+07 3.94 2.00e+07 3.94 3.48e+06 1.88 1.71e+07 3.34 3.38e+08 65.55 1.47e+06 0.334 	 5.16e+08 100 % 2.73e+07 5.3% 2.73e+07 5.3% 2.73e+07 5.3% 1.85e+07 3.6% 1.85e+07 3.6% 1.85e+07 3.6% 8.80e+06 1.7% 1.69e+07 3.3% 2.46e+08 47.6% 	Percent Excess Work(M) 9.13e+00 2.62e+00 1.56e+00 1.56e+00 1.56e+00 1.65e+00 1.65e+00 1.63e+00 1.63e+00 1.58e+00 6.56e-01 5.36e-01

Presentation - hpctraceview



Thank you for listening. Q&A

User's manual: http://hpctoolkit.org/manual/HPCToolkit-users-manual.pdf