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Leaders in parallel software development tools

Introducing Fully Enabled Debugging of CUDA 5 Applications with Allinea DDT

Challenges for Developers

Heterogeneity

Scale

Legacy

Diversity

The Allinea Environment

PERFORM
the
allinea
environment
FIX

allinea MAP

allinea DDT

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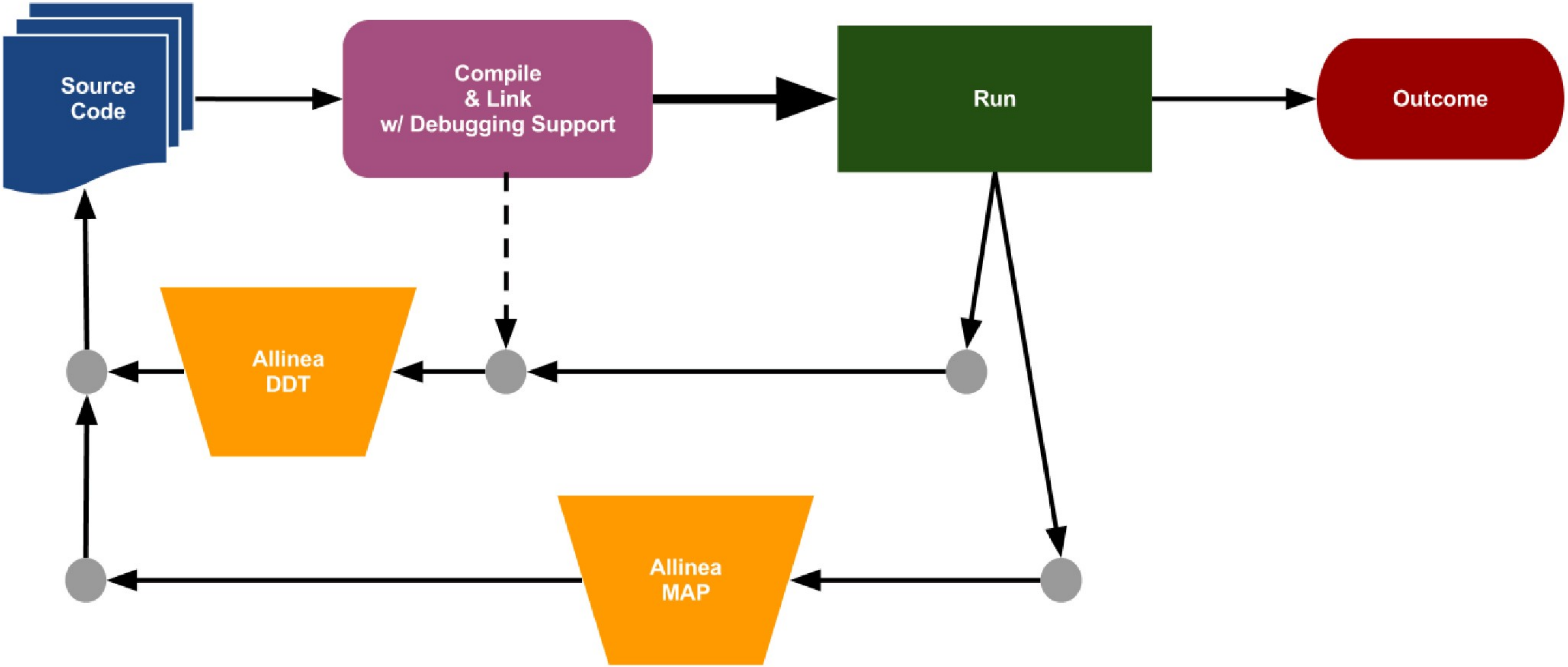
Source Code
Compile & Link w/ Debugging Support
Run
Outcome
Allinea DDT
Allinea MAP

The Allinea Environment: Benefits

- **At last:** a modern **integrated** environment for the HPC developer
- Supporting the lifecycle of application development and improvement
  - Productively debug code
  - Enhance application performance
- Designed for productivity
  - Consistent integrated easy to use tools
  - Enables effective HPC development
- Improve system usage
  - Fewer failed jobs
  - Higher application performance

PERFORM
the
allinea
environment
FIX

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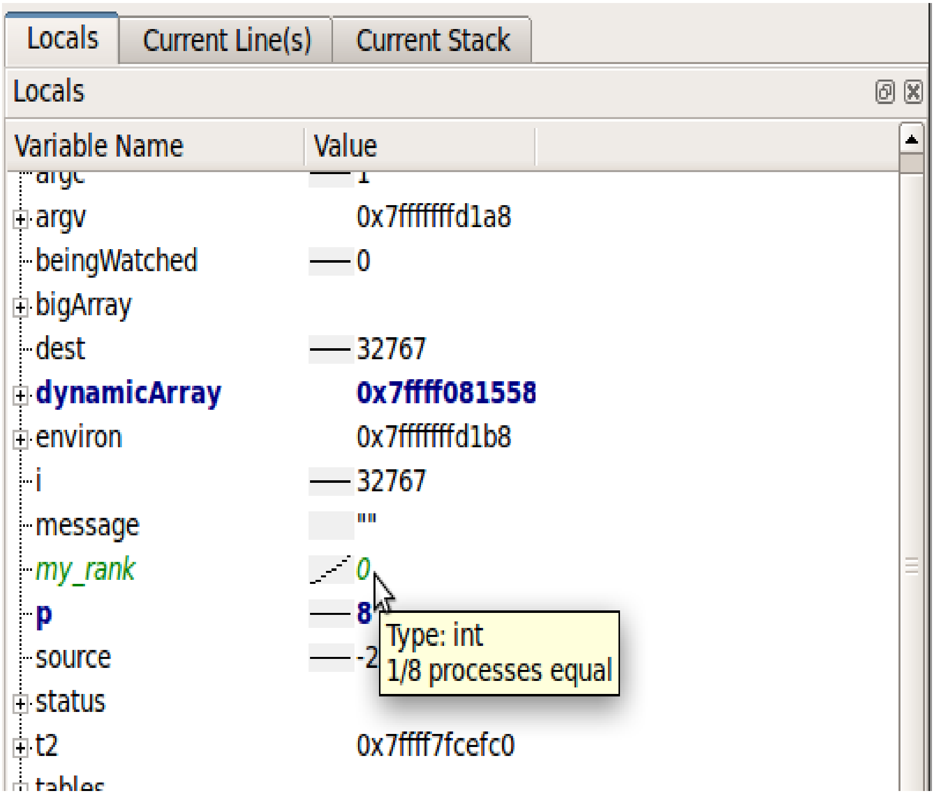
Allinea DDT: Fixing bugs made easy

- A tool that allows you to solve your problems faster
  - Control threads and processes en-masse
  - Syntax-highlighting source browser
  - Parallel stacks and variable views that highlight divergence
- Supports the latest in MPI, OpenMP, CUDA and more
  - CUDA 5.0 and Kepler K20
  - Intel Xeon Phi coprocessor

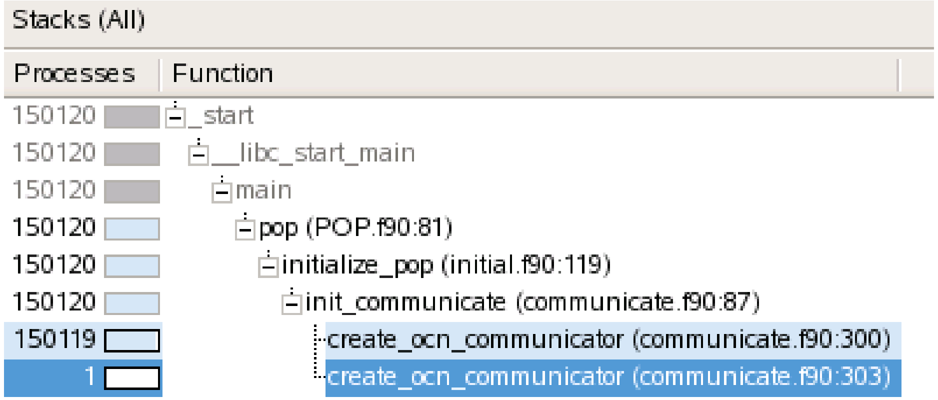


Variable Name	Value
argc	1
argv	0x7fffffffd1a8
beingWatched	0
bigArray	
dest	32767
dynamicArray	**0x7ffff081558**
environ	0x7fffffffd1b8
i	32767
message	""
my_rank	*0*
p	**8**
source	-2
status	
t2	0x7ffff7fcefc0
tables	

Type: int
1/8 processes equal

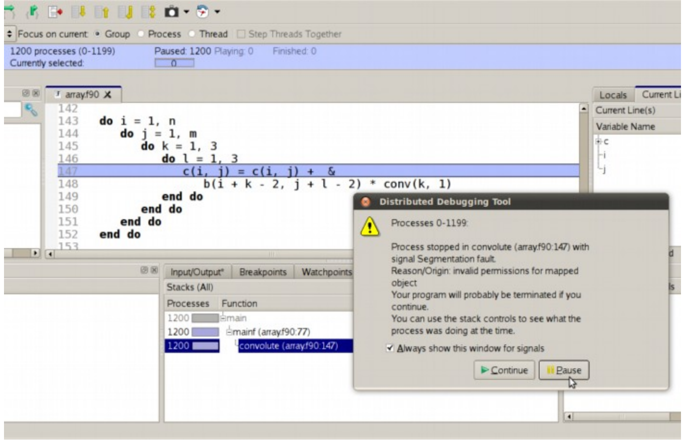
Allinea DDT: Proven to the extreme

- Scalability by design
  - User interface that scales
  - High performance tree architecture
- Proven performance at Petascale
  - Measured in milliseconds
  - Routine use at 100,000+ cores



Stacks (All)

Processes	Function
150120	_start
150120	__libc_start_main
150120	main
150120	pop (POP.f90:81)
150120	initialize_pop (initial.f90:119)
150120	init_communicate (communicate.f90:87)
150119	create_ocn_communicator (communicate.f90:300)
1	create_ocn_communicator (communicate.f90:303)



Focus on current ● Group ○ Process ○ Thread □ Step Threads Together
1200 processes (0-1199) Paused: 1200 Playing: 0 Finished: 0
Currently selected: 0
array.f90
Locals
Current Li
Current Line(s)
Variable Name
c
i
j
Input/Output*
Breakpoints
Watchpoints

```
do i = 1, n
   do j = 1, m
      do k = 1, 3
         do l = 1, 3
            c(i, j) = c(i, j) +  &
               b(i + k - 2, j + l - 2) * conv(k, 1)
         end do
      end do
   end do
end do
```

Stacks (All)

Processes	Function
1200	main
1200	mainf (array.f90:77)
1200	convolute (array.f90:147)

Distributed Debugging Tool

Processes 0-1199:

Process stopped in convolute (array.f90:147) with signal Segmentation fault.
Reason/Origin: invalid permissions for mapped object
Your program will probably be terminated if you continue.
You can use the stack controls to see what the process was doing at the time.

☑ Always show this window for signals

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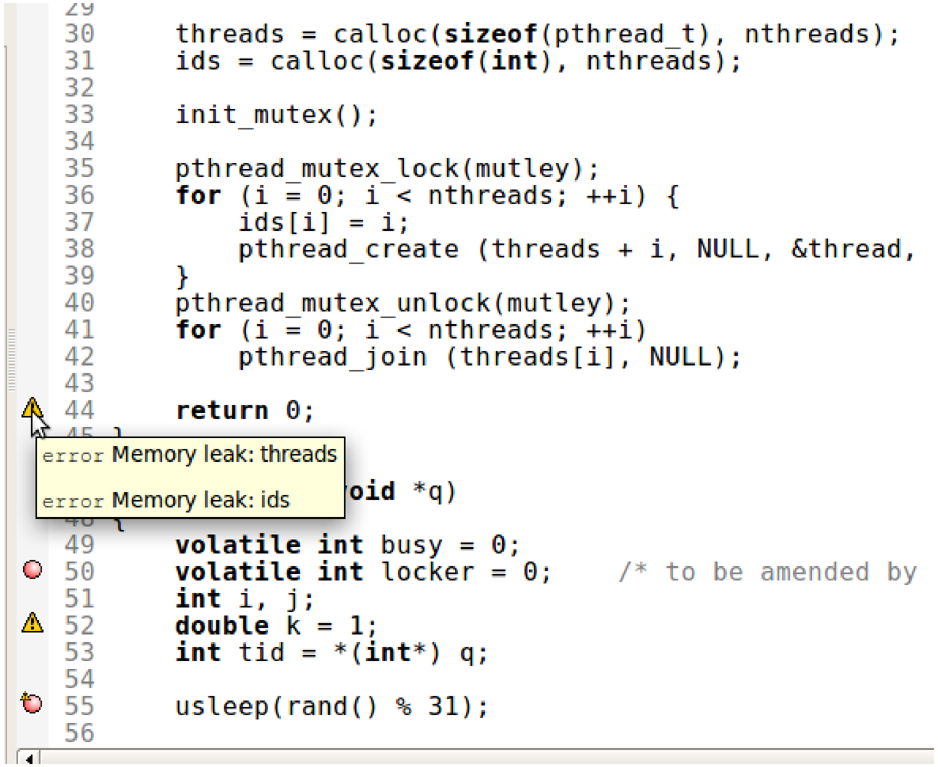
Allinea DDT: More than debugger

- Integrated automated detection of bugs
  - Static analysis
  - Memory leaks and errors
- Open plugin architecture
  - MPI checking tools
- Offline mode - debug in batch mode



```
    threads = calloc(sizeof(pthread_t), nthreads);
    ids = calloc(sizeof(int), nthreads);

    init_mutex();

    pthread_mutex_lock(mutley);
    for (i = 0; i < nthreads; ++i) {
        ids[i] = i;
        pthread_create (threads + i, NULL, &thread,
    }
    pthread_mutex_unlock(mutley);
    for (i = 0; i < nthreads; ++i)
        pthread_join (threads[i], NULL);

    return 0;
}

                   oid *q)
{
    volatile int busy = 0;
    volatile int locker = 0;     /* to be amended by
    int i, j;
    double k = 1;
    int tid = *(int*) q;

    usleep(rand() % 31);

```

error Memory leak: threads

error Memory leak: ids

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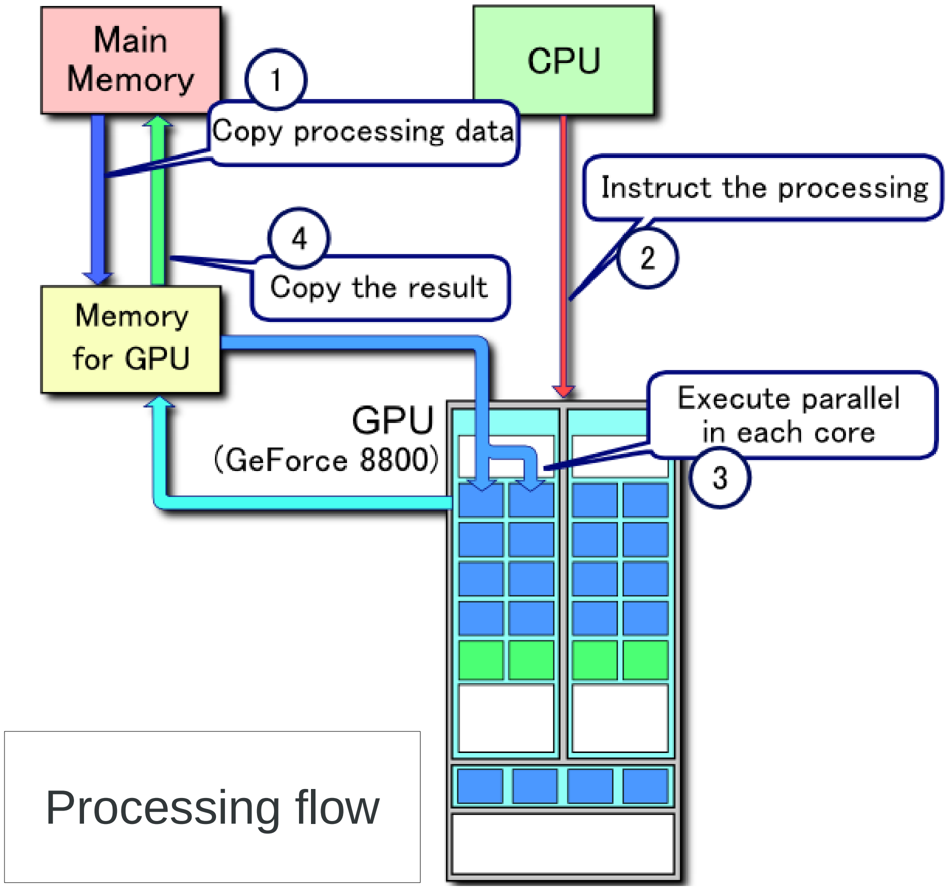
Embracing GPUs

- GPUs – a rival to traditional processors
  - Great price/performance ratios
- New languages, compilers, standards
  - CUDA, OpenACC, OpenCL, ...
- HPC developers need to consider
  - Data transfer
  - Multiple memory levels
  - Grid/block layout and thread scheduling
  - Synchronization
- Bugs are **inevitable**



Processing flow

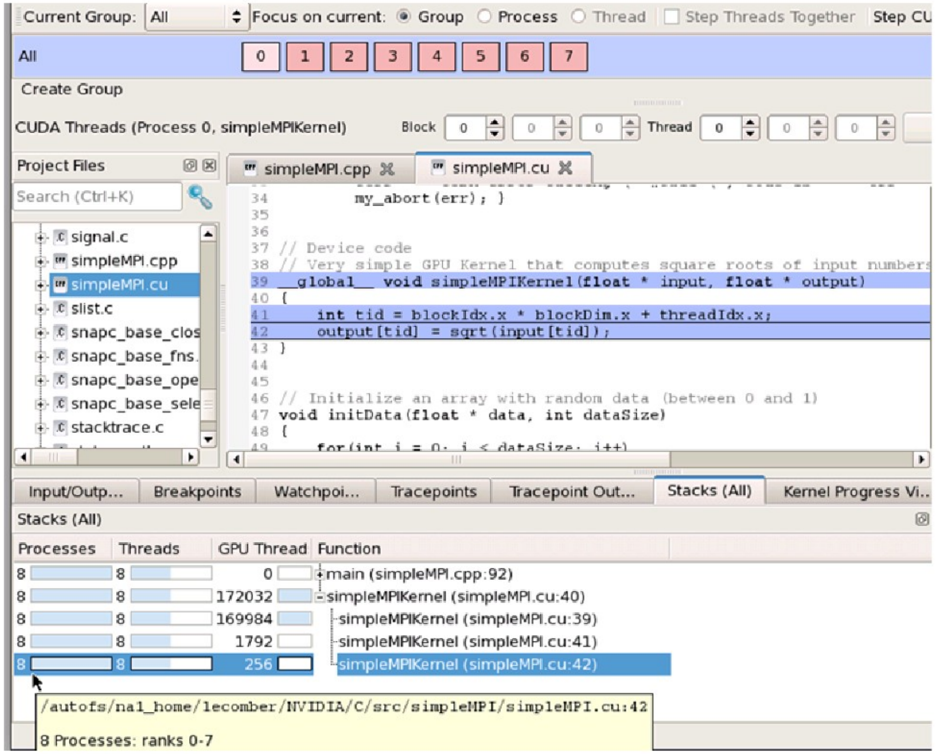
Allinea DDT and CUDA

- Supports
  - CUDA toolkits 3.1 -- 3.2 – 4.0 – 4.1 – 4.2 – **5**

- Makes use of
  - NVIDIA C/C++ compiler - nvcc
  - NVIDIA debugger - cuda-gdb

- Execution model is unusual
  - GUI work required to support 32-thread units (warps) in blocks and grids

- Mixed GPU/CPU in one interface
  - Interaction with CPUs
  - Easy to switch between contexts (stacks, threads, data...)
  - Support multiple nodes



CUDA Threads (Process 0, simpleMPIKernel) Block 0 0 0 Thread 0 0 0

```
        my_abort(err); }


// Device code
// Very simple GPU Kernel that computes square roots of input numbers
__global__ void simpleMPIKernel(float * input, float * output)
{
    int tid = blockIdx.x * blockDim.x + threadIdx.x;
    output[tid] = sqrt(input[tid]);
}


// Initialize an array with random data (between 0 and 1)
void initData(float * data, int dataSize)
{
    for(int i = 0; i < dataSize; i++)
```

Stacks (All)

Processes	Threads	GPU Thread	Function
8	8	0	+main (simpleMPI.cpp:92)
8	8	172032	-simpleMPIKernel (simpleMPI.cu:40)
8	8	169984	simpleMPIKernel (simpleMPI.cu:39)
8	8	1792	simpleMPIKernel (simpleMPI.cu:41)
8	8	256	simpleMPIKernel (simpleMPI.cu:42)

/autofs/na1_home/lecomber/NVIDIA/C/src/simpleMPI/simpleMPI.cu:42

8 Processes: ranks 0-7

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Demo

Allinea DDT – CUDA Debugging++

- Productively **debug** your parallel CUDA code
- Completely **understand** your parallel CUDA code
  - Interact with data, algorithms, codes, programs and applications in real time
- **Develop** your parallel CUDA code from scratch
- **Port** parallel algorithms, codes, programs and applications to CUDA
- **Scale** your CUDA algorithms, codes, programs and applications

Summary

- Allinea Environment in context
- Debugging via Allinea DDT
- Debugging Parallel CUDA Applications
  - Demo

- Call to Action
  - Evaluate Allinea DDT

http://www.allinea.com/products/ddt-trial

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