Compilers and Debuggers

Nikolaos Nikoloutsakos

Greek Research & Technology Network

Athens, 05-07 Nov. 2019

Contents

Environment

- Login Shell

/bin/bash

```
echo $SHELL
```

- Environment Variables

env

```
printenv GRNET_ROOT; echo $GRNET_ROOT
```

- Default variables
  - $GRNET_ROOT
  - $HOME
  - $WORKDIR

Environment Modules

- environment modules to manage user environment
- Access applications or versions on ARIS
- Dynamically set up environments for different applications PATH, LD_LIBRARY_PATH etc.
- One module for each software version
- Detects software dependencies and informs which modules must be loaded

What modules exist?

module avail

List available modules.

```
------------------------- /apps/modulefiles/applications ---
abinit/7.10.4(default)          namd/2.10/hybrid/normal
bigdft/1.7.6(default)           namd/2.10/purempi/memopt
cdo/1.7.0(default)              namd/2.10/purempi/normal
code_saturne/4.0.1/intel        ncarg/6.3.0(default)
```

What modules exist?

module avail <module>

List <module> available versions

```
/apps/modulefiles/compilers:
gnu/4.9.2(default)
gnu/4.9.3
gnu/5.1.0
gnu/5.2.0
```

Default version marked as (default)

- Default module version
  - Almost all ARIS software packages have multiple versions marked as (default) In these case the commands:

    ```
    module load MODULENAME
    ```

    and

    ```
    module load MODULENAME/DEFAULTVERSION
    ```

    are equivalent.
  - eg. current defaults

    ```
    module load intel
    ```

    and

    ```
    module load  intel/15.0.3
    ```

    are the same

- Sometimes, after proper notification, the system defaults may change.
- In that case if you are using the `defaults`, it's recommended to re-compile you code.
- If you need to use a specific software version, please use it's relevant module version.

Use Modules

module load/unload <module>

Load/Unload <module> into the shell environment

module switch <module1> <module2>

Switch loaded module1 with module2.

module list

List loaded modules.

```
Currently Loaded Modulefiles:
  1) gnu/4.9.2          2) intel/15.0.3      3) intelmpi/5.0.3
```

Examine a module

module show <module>

List all of the environment changes the <module> will make if loaded

```
-------------------------------------------------------------------
/apps/modulefiles/compilers/gnu/4.9.2:

module-whatis    Enable usage for the GNU Compiler Collection vers
setenv           COMPILER_GNUROOT /apps/compilers/gnu/4.9.2
prepend-path     PATH /apps/compilers/gnu/4.9.2/bin
prepend-path     INCLUDE /apps/compilers/gnu/4.9.2/include
prepend-path     LD_LIBRARY_PATH /apps/compilers/gnu/4.9.2/lib
prepend-path     LD_LIBRARY_PATH /apps/compilers/gnu/4.9.2/lib64
prepend-path     MANPATH /apps/compilers/gnu/4.9.2/share/man
-------------------------------------------------------------------
```

Examine a module

- setenv: Set environment variable
- prepend-path: Prepend value to environment variable.
- MODULENAMEROOT/include, MODULENAMEROOT/lib

module whatis <module>

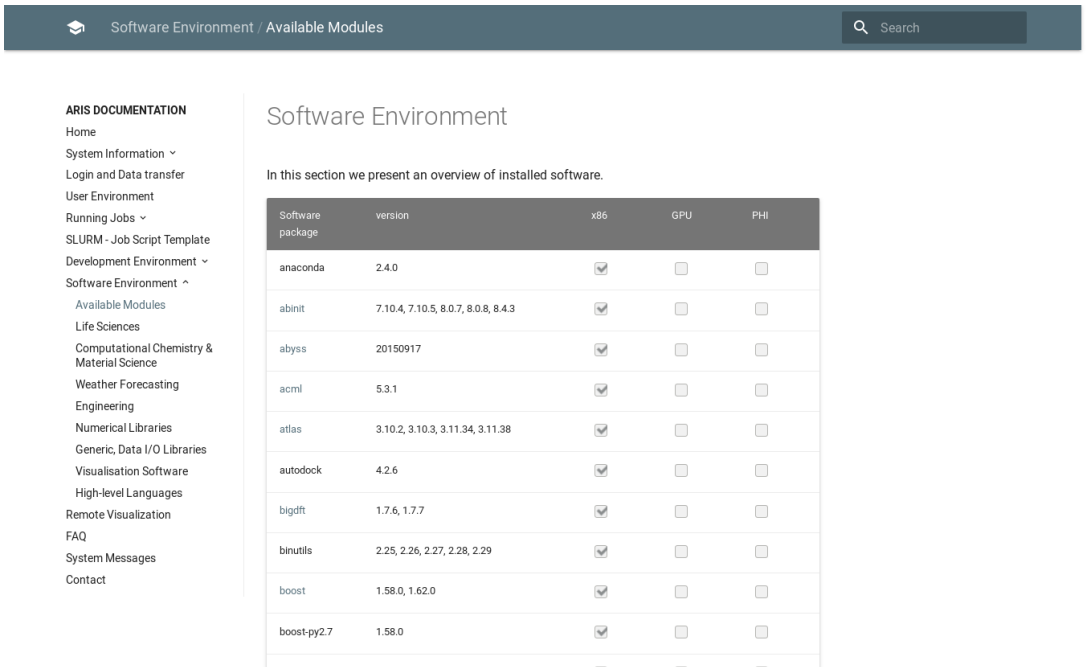
Display what is the module information

module help <module>

More specific help about <module>

Available Softwrare

http://doc.aris.grnet.gr/software/



Development Tools

- *Compilers:* GCC, INTEL, PGI
- *Parallel:* Intel MPI, OpenMPI
- *Debug:* gdb, gdb-ia , pgdbg, ddd
- *Profilers:* VTune, Scalasca, mpiP, gprof, pgprof

Table: Compilers

GNU	C	gcc
	C++	g++
	Fortran	gfortran
Intel	C	icc
	C++	icpc
	Fortran	ifort
PGI	C	pgcc
	C++	pgc++
	Fortran	pgfortran

Compilers

module avail

All available compilers check for ”compilers” section

```
------------------------- /apps/modulefiles/compilers --------------------------
binutils/2.25           gnu/5.1.0               intel/17.0.4
binutils/2.26           gnu/5.2.0               intel/17.0.5
binutils/2.27           gnu/5.3.0               intel/18.0.0
binutils/2.28           gnu/5.4.0               intel/18.0.1
binutils/2.29(default)  gnu/5.5.0               java/1.7.0
clang/5.0.0(default)    gnu/6.1.0               java/1.8.0(default)
cuda/6.5.14             gnu/6.2.0               pgi/15.5
cuda/7.0.28             gnu/6.3.0               pgi/16.10
cuda/7.5.18             gnu/6.4.0               pgi/16.4
cuda/8.0.27             gnu/7.1.0               pgi/16.5
cuda/8.0.44             gnu/7.2.0               pgi/16.7
cuda/8.0.61(default)    intel/15.0.3(default)   pgi/16.9
cuda/9.1.85             intel/15.0.6            pgi/17.1
gdb/7.11.1              intel/16.0.0            pgi/17.10(default)
```

MPI versions

module avail

Check for ”parallel” section

```
--------------------------- /apps/modulefiles/parallel ----------------------
intelmpi/2017.0           openmpi/1.10.0/gnu      openmpi/2.0.0/intel
intelmpi/2017.1           openmpi/1.10.0/intel    openmpi/2.0.1/gnu
intelmpi/2017.2           openmpi/1.10.1/gnu      openmpi/2.0.1/intel
intelmpi/2017.3           openmpi/1.10.1/intel    openmpi/2.0.2/gnu
intelmpi/2017.4           openmpi/1.10.2/gnu      openmpi/2.0.2/intel
intelmpi/2017.5           openmpi/1.10.2/intel    openmpi/2.0.3/gnu
intelmpi/2018.0           openmpi/1.10.3/gnu      openmpi/2.0.3/intel
intelmpi/2018.1           openmpi/1.10.3/intel    openmpi/2.1.0/gnu
intelmpi/5.0.3(default) openmpi/1.10.4/gnu      openmpi/2.1.0/intel
intelmpi/5.1.1            openmpi/1.10.4/intel    openmpi/2.1.1/gnu
intelmpi/5.1.2            openmpi/1.10.5/gnu      openmpi/2.1.1/intel
intelmpi/5.1.3            openmpi/1.10.5/intel    openmpi/2.1.2/gnu
intelmpi/5.1.3.258        openmpi/1.10.7/gnu      openmpi/2.1.2/intel
```

Intel MPI

Language	wrapper
C	mpiicc
C++	mpiicpc
Fortran	mpifort

Launcher

```
srun
```

module avail intelmpi

```
--------------------------- /apps/modulefiles/parallel --------------
intelmpi/2017.0          intelmpi/2017.5          intelmpi/5.1.2
intelmpi/2017.1          intelmpi/2018.0          intelmpi/5.1.3
intelmpi/2017.2          intelmpi/2018.1          intelmpi/5.1.3.258
intelmpi/2017.3          intelmpi/5.0.3(default)
intelmpi/2017.4          intelmpi/5.1.1
```

module list

```
Currently Loaded Modulefiles:
  1) gnu/4.9.2          2) intel/15.0.3      3) intelmpi/5.0.3
```

(gnu) mpicc -show

```
gcc -I/apps/compilers/intel/impi/5.0.3.048/intel64/include -L/apps/compilers/int
el/impi/5.0.3.048/intel64/lib/release_mt -L/apps/compilers/intel/impi/5.0.3.048/
intel64/lib -Xlinker --enable-new-dtags -Xlinker -rpath -Xlinker /apps/compilers
/intel/impi/5.0.3.048/intel64/lib/release_mt -Xlinker -rpath -Xlinker /apps/comp
ilers/intel/impi/5.0.3.048/intel64/lib -Xlinker -rpath -Xlinker /opt/intel/mpi-r
t/5.0/intel64/lib/release_mt -Xlinker -rpath -Xlinker /opt/intel/mpi-rt/5.0/inte
l64/lib -lmpifort -lmpi -lmpigi -ldl -lrt -lpthread
```

(intel) mpiicc -show

```
icc -I/apps/compilers/intel/impi/5.0.3.048/intel64/include -L/apps/compilers/int
el/impi/5.0.3.048/intel64/lib/release_mt -L/apps/compilers/intel/impi/5.0.3.048/
intel64/lib -Xlinker --enable-new-dtags -Xlinker -rpath -Xlinker /apps/compilers
/intel/impi/5.0.3.048/intel64/lib/release_mt -Xlinker -rpath -Xlinker /apps/comp
ilers/intel/impi/5.0.3.048/intel64/lib -Xlinker -rpath -Xlinker /opt/intel/mpi-r
t/5.0/intel64/lib/release_mt -Xlinker -rpath -Xlinker /opt/intel/mpi-rt/5.0/inte
l64/lib -lmpifort -lmpi -lmpigi -ldl -lrt -lpthread
```

OpenMPI

Language	wrapper
C	mpicc
C++	mpicxx
Fortran	mpifort, mpif90

Launcher

```
srun
```

module avail openmpi

```
---------------------------- /apps/modulefiles/parallel ---
openmpi/1.10.0/gnu(default)  openmpi/1.8.5/intel
openmpi/1.10.0/intel         openmpi/1.8.7/gnu
openmpi/1.8.5/gnu            openmpi/1.8.7/intel
```

module load openmpi/1.10.1/intel

```
Currently Loaded Modulefiles:
  1) gnu/4.9.2                      3) intelmpi/5.0.3
  2) intel/15.0.3                   4) openmpi/1.10.1/intel
```

mpicc -show

```
icc -I/apps/parallel/openmpi/1.10.1/intel/include -pthread -Wl,-rpath -Wl,/apps/
parallel/openmpi/1.10.1/intel/lib -Wl,--enable-new-dtags -L/apps/parallel/openmp
i/1.10.1/intel/lib -lmpi
```

module load openmpi/1.10.1/gnu

```
Currently Loaded Modulefiles:
  1) gnu/4.9.2                3) intelmpi/5.0.3
  2) intel/15.0.3             4) openmpi/1.10.1/gnu
```

mpicc -show

```
gcc -I/apps/parallel/openmpi/1.10.1/gnu/include -pthread -Wl,-rpath -Wl,/apps/pa
rallel/openmpi/1.10.1/gnu/lib -Wl,--enable-new-dtags -L/apps/parallel/openmpi/1.
10.1/gnu/lib -lmpi
```

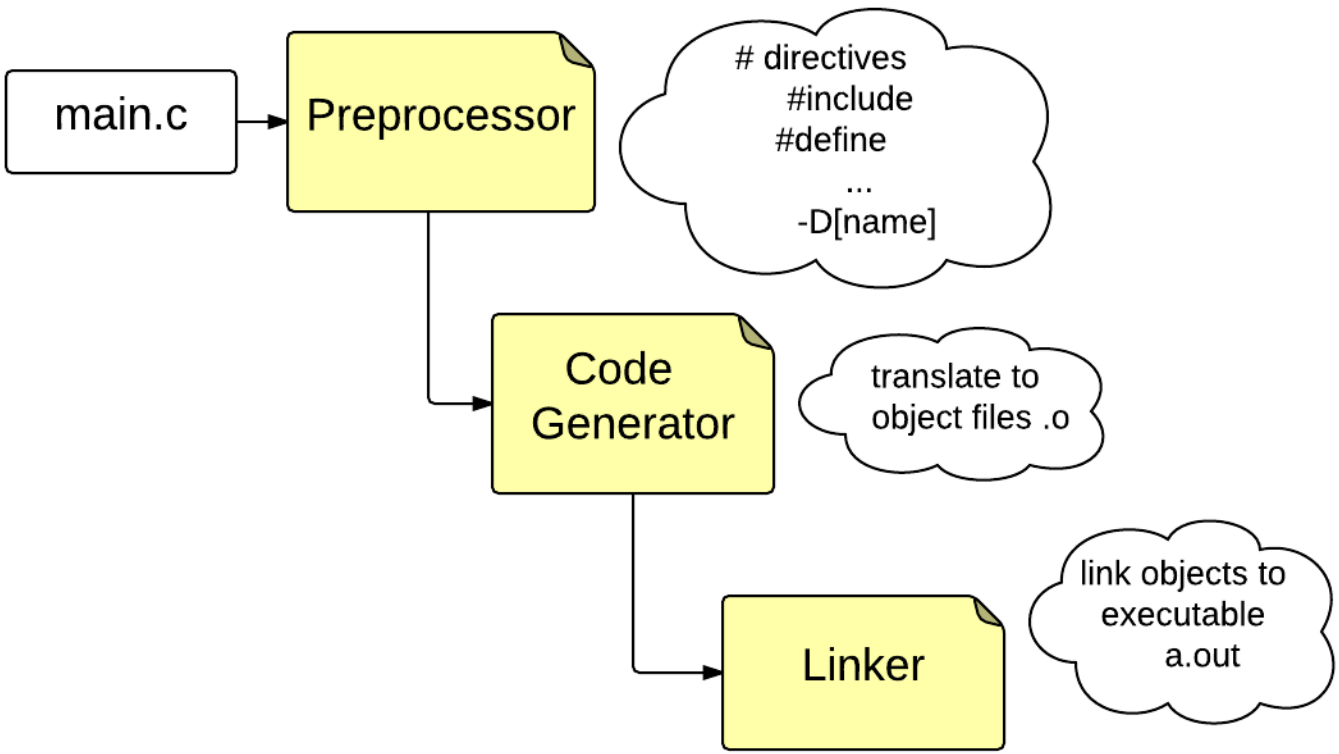
CUDA

module avail cuda

```
--------------------------- /apps/modulefiles/compilers ----------
cuda/6.5.14             cuda/8.0.27             cuda/9.1.85
cuda/7.0.28             cuda/8.0.44
cuda/7.5.18             cuda/8.0.61(default)
```

- TESLA K40: `nvcc -arch=compute_35 -code=sm_35 ...`
- OpenCL: -I $CUDAROOT/CL -lOpenCL

Compile


main.c
Preprocessor
directives
#include
#define
...
-D[name]
Code
Generator
translate to
object files .o
Linker
link objects to
executable
a.out

Compiling a program:

- check syntax errors, warn semantic problems, optimize the code.

1. **Pre-processing:** #define macros subtitution, #include code insertion, remove comments
2. **Compiling:** translate to object files. (machine code collection of symbols referring to variables and functions)
3. **Linking:** build the final executable, link the object files together with any external libraries.

`-c`	Compile or assemble the source files, but do not link.
`-o`	Name the outputfile filename.
`-g`	Produces symbolic debug information.
`-D[name]`	Predefine [name] as a macro for the prepro-cessor, with definition 1.
`-I[dir]`	Specifies an additional directory [dir] to search for include files.
`-l[lib]`	Search for library when linking.
`-static`	Force static linkage
`-L[dir]`	Search for libraries in a specified directory dir.
`-fpic`	Generate position-independent code.
`-version,-v`	Show version number.
`-help,-h`	Show help information, and list flags.
`-std=`	Conform to a specific language standard

```
main.c:2:17: fatal error: foo.h: No such file or directory
 #include "foo.h"
                 ^
compilation terminated.
```

Include dir

```
gcc -I/path/to/include main.c
gcc -I$MYPATH main.c
```

Find the paths

```
module show fftw/2.1.5
```

```
-------------------------------------------------------------------
/apps/modulefiles/libraries/fftw/2.1.5:

module-whatis     Enable usage for fftw version 2.1.5
setenv            FFTWROOT /apps/fftw/2.1.5
prepend-path      LD_LIBRARY_PATH /apps/fftw/2.1.5/lib
prepend-path      INFOPATH /apps/fftw/2.1.5/info
```

ls $FFTWROOT

```
gcc main.c -lfoo
```

```
/usr/bin/ld: cannot find -lfoo
collect2: error: ld returned 1 exit status
```

```
gcc -L/path/to/lib main.c -lfoo
```

```
./a.out: error while loading shared libraries: libfoo.so: cannot open shared obj
ect file: No such file or directory
```

```
echo $LD_LIBRARY_PATH
```

Runtime libraries

```
ldd a.out
```

Optimization Flags

- Without any optimization option, the compiler's goal is to reduce the cost of compilation and to make debugging produce the expected results
- Turning on optimization flags makes the compiler attempt to improve the performance and/or code size at the expense of compilation time and possibly the ability to debug the program.

Optimization levels common to aris compilers

`-O0`	No optimization (default), generates unoptimized code but has the fastest compilation time. Debugging support if using -g
`-O1`	Moderate optimization, optimize for size
`-O2`	Optimize even more, maximize speed
`-O3`	Full optimization, more aggressive loop and memory-access optimiz
`-Ofast`	Maximizes speed,more aggressive depending on hardware.

Intel Reference

The O3 (-O3) option is particularly recommended for applications that have loops that do many floating-point calculations or process large data sets. These aggressive optimizations may occasionally slow down other types of applications compared to /O2 (-O2).

Leave the compiler to optimize ?

- Example: Dense LU Factorization 1024x1024, gcc

-O0	1.768068 s
-O2	0.569985 s
-O3	0.459217 s
-Ofast	0.517295 s

```
gcc -help=optimizers
icc -help opt
pgcc -help=opt
```

```
The following options control optimizations:
  -O<number>                    Set optimization level to <number>
  -Ofast                        Optimize for speed disregarding exact standards
                                compliance
  -Og                           Optimize for debugging experience rather than
                                speed or size
  -Os                           Optimize for space rather than speed
  -faggressive-loop-optimizations Aggressively optimize loops using language
                                constraints
```

```
gcc -Q -O3 -help=optimizers
icc -help advanced
```

```
  -faggressive-loop-optimizations           [enabled]
  -falign-functions                         [enabled]
  -falign-jumps                             [enabled]
  -falign-labels                            [enabled]
  -falign-loops                             [enabled]
  -fasynchronous-unwind-tables              [enabled]
  -fbranch-count-reg                        [enabled]
  -fbranch-probabilities                    [disabled]
  -fbranch-target-load-optimize             [disabled]
  -fbranch-target-load-optimize2            [disabled]
  -fbtr-bb-exclusive                        [disabled]
```

GNU Option	Description
-O[0-3]	optimizer level
-Ofast	enables all -O3 optimizations plus -ffast-math, fno-protect-parens and -fstack-arrays
-Os	Optimize for size.
-ffast-math	it can result in incorrect output for programs that depend on an exact implementation of IEEE or ISO rules/specifications for math functions
march=[cputype]	GCC generate code for specific processor: native,ivybridge,core-avx-i,...
mtune=[cputype]	Optimize code for specific processor: native,ivybridge,core-avx-i,.. (march=native implies mtune=native)
-Q -march=native –help=target	Show details
-m[target]	Enable use of instructions sets, -mavx, ...
-fomit-frame-pointer	Don’t keep the frame pointer in a register for functions that don’t need one.
-fp-model[name]	May enhance the consistency of floating point results by restricting certain optimizations.
-fno-alias/-fno-fnalias	Assumes no aliasing(within functions) in the program
-finline-functions	Consider all functions for inlining
-funroll-loops	Unroll loops whose number of iterations can be determined at compile time

Intel Option	Description
-O[0-3]	Optimizer level
-fast	Maximize speed
-Os	Optimize for size
-opt-repot[n]	Generates an optimization report
-x[target]	Generates specialized code for any Intel® processor that supports the instruction set specified by target. AVX,…
-m[target]	Generates specialized code for any Intel processor or compatible, non-Intel processor that supports the instruction set specified by target. AVX,…
-xhost	Generates instruction sets up to the highest that is supported by the compilation host
-parallel	The auto-parallelizer detects simply structured loops that may be safely executed in parallel.
-ip, -ipo	Permits inlining and other interprocedural optimizations
-finline-functions	This option enables function inlining
-unroll, unroll-agressive	Unroll loops
-[no-]prec-div	Improves [reduces] precision of floating point divides. This may slightly degrade [improve] performance.

PGI Option	Description
-O[0-4]	Optimizer level
-fast	Overall maximize
-Minfo	Display compile time optimization listings.
-Munroll	Uroll loops
-Minline	Inline functions
-Mvect	Vectorization
-Mconcur	Auto-Parallelization
-Mipa=fast,inline	Interprocedural analysis (IPA)

GNU	INTEL	PGI	Descriptioin
-O[0-3]	-O[0-3]	-O[0-4]	Optimizer level
-Os	-Os	-	Optimize space
-Ofast	-fast	-fast	Maximizes speed across the entire program.
-mtune,-march=native	-xHost	-	Compiler generates instructions for the highest instruction set available on the host processor. (AVX)
-funroll-loops	-unroll/-unroll-agressive	-Munroll	Unroll loops
-	-opt-streaming-stores	-Mnontemporal	Specifies whether streaming stores are generated
-finline-functions	-ip	-Minline/-Mrecursvie	The compiler heuristically decides which functions are worth inlining.
-	-ipo	-Minline -Mextract	Permits inlining and other inter-procedural optimizations among multiple source files.

Suggested Flags

GNU

```
gcc -O3 -mavx -march=ivybridge
```

INTEL

```
icc -O3 -xCORE-AVX-I
```

PGI

```
pgcc -O4 -tp=sandybridge
```

Vectorization

- Modern CPUs multiple ops per cycle
- SIMD instructions for operating blocks of data
- SSE: 128 bit (intel core), 4FP single, 2FP double
- AVX: 256 bit (intel Sandy bridge), 8FP single, 4FP double
- AVX2: expansion of the AVX instruction set (intel haswell)
- MIC: 512 bit (intel knights corner), 16FP single, 8FP double

Vectorization Requirements

Requirements

- Vectorisable code,
- Countable loop, constant number of iterations
- only the inner loop is vectorized
- loop must not contain function calls (unless inlined)
- loo must have no dependencies between iterations
- aligned data, unit strid through memory.
- no branches, conditionals

Verify numerical results (FMA instructions)

Vectorization Flags

GNU	INTEL	PGI	Description
-O[2-3], -Ofast	-O[2-3], -fast	-O[2-4], -fast	Enable
-ftree-vectorize	-vec, -simd	-Mvect=simd	Specific enable
-fno-tree-vectorize	-no-vec	-Mnovect	Disable
-march=native	-xHost	-fast	Support AVX
-mavx	-xAVX	-	type of SIMD instruc

Debug I

“Debugging is the process of finding and resolving defects or problems within a computer program that prevent correct operation of computer software or a system.”

Programming Problems

- wrong results,
- run-time crashes (segmentation fault)
- pointer errors, array indexes
- memory allocation
- floating point exceptions
- infinite execution

Debug II

- initialization errors
- communication errors , synchronization issues

Debug by hand ?

- insert `printf` in the code
- needs to recompile, hard for complex programs, if parallel?
- debugger allows you to see what is going on `inside` another program while it executes - or what another program was doing at the moment it crashed.

Find the bug

1. Understand the whole application
2. Identify the test case(s) that cause the fault.
3. Run the program until crashes or on specified stop (breakpoint)
4. Examine what has happened
5. Change things and run again (one bug at a time)
6. Verify

Available Debuggers

Free

- GNU gdb
- `module load gdb`
- ddd (gui for debuggers)
- `module load ddd`

Commercial

- INTEL gdb-ia
- PGI pgdbg

`Valgrind` for memory specific inspection.
http://doc.aris.grnet.gr/development/debuggers/

```
gcc [flags] <source file> -o <output file>
```

- `-Wall, -Wextra`: Enables warnings for possible errors
- `-Werror`: Converts warnings to errors.
- `-Wfatal-errors`: Breaks compilation from the first warning.

Debug info

```
gcc [flags] -g <source file> -o <output file>
```

- `-g`: default debug information
- `-ggdb`: produces debugging information specifically intended for gdb.

Command "gdb <prog name>" or "gdb"

```
(gdb)
```

```
[nikoloutsa@login01 ~]$ gdb
GNU gdb (GDB) Red Hat Enterprise Linux (7.2-83.el6)
Copyright (C) 2010 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.  Type "show copying"
and "show warranty" for details.
This GDB was configured as "x86_64-redhat-linux-gnu".
For bug reporting instructions, please see:
<http://www.gnu.org/software/gdb/bugs/>.
(gdb)
```

```
(gdb) file <prog name>
```

(gdb) help <command>

```
(gdb) help
List of classes of commands:

aliases -- Aliases of other commands
breakpoints -- Making program stop at certain points
data -- Examining data
files -- Specifying and examining files
internals -- Maintenance commands
obscure -- Obscure features
running -- Running the program
stack -- Examining the stack
status -- Status inquiries
support -- Support facilities
tracepoints -- Tracing of program execution without stopping the program
user-defined -- User-defined commands

Type "help" followed by a class name for a list of commands in that class.
Type "help all" for the list of all commands.
Type "help" followed by command name for full documentation.
```

(gdb) help run

```
(gdb) help run
Start debugged program.  You may specify arguments to give it.
Args may include "*", or "[...]"; they are expanded using "sh".
Input and output redirection with ">", "<", or ">>" are also allowed.

With no arguments, uses arguments last specified (with "run" or "set args").
To cancel previous arguments and run with no arguments,
use "set args" without arguments.
```

start debugged program

```
(gdb) run
```

```
Program exited normally.
(gdb)
```

- Run the code until crash or breakpoint

```
Program received signal SIGSEGV, Segmentation fault.
_IO_getline_info (fp=0x33b5d8e6c0, buf=0x0, n=1023, delim=10, extract_delim=1,
of=0x0)
    at iogetline.c:91
91                  *ptr++ = c;
(gdb)
```

- Add breakpoints
- Inspect data

Basic Commands I

```
(gdb) attach
```

attach to a running process outside GDB

```
(gdb) break main.c:6
```

set breakpoint at specified line

```
(gdb) break my_function
```

Set breakpoint at specified function

Basic Commands II

`(gdb) clear , delete`

Remove a specified breakpoint

`(gdb) continue`

Continue execution after breakpoint

`(gdb) step`

Go to the next source line, will step into a function/subroutine

Basic Commands III

```
(gdb) next
```

Go to the next source line, function/subroutine calls are executed without stepping into them

```
(gdb) print <var>
```

Print value of expression (to print array *A@LEN)

```
(gdb) info locals
```

Local variables of current stack frame

Basic Commands IV

```
(gdb) watch <var>
```

Set a watchpoint for an expression. Stops execution whenever the value changes

```
(gdb) list
```

Display (default 10) lines of source surrounding the current lin

Basic Commands V

```
(gdb) backtrace
```

Displays a stack frame for each active subroutine Print backtrace of all stack frames. Use of the 'full' qualifier also prints the values of the local variables.

```
(gdb) core <core>
```

Core files can be examined specifying both an executable program and the core file

snapshot

Basic Commands VI

```
(gdb) generate-core-file
```

Produce a core file from within the GDB session to preserve a snapshot of a program's state

Valgrid: memory leaks

```
(gdb) quit
```

Quit the debugger

```c
#include <stdio.h>
#include <stdlib.h>
int myDiv(int, int);
int main(void)
{
int res, x = 5, y;
for(y = 1; y < 10; y++){
res = myDiv(x,y);
printf("%d,%d,%d\n",x,y,res);
}
return 0;
}
int myDiv(int x, int y){
return 1/( x – y);
}
```

```
PROGRAM main
INTEGER :: myDiv
INTEGER :: res, x = 5, y

DO y = 1, 10
 res = myDiv(x,y)
WRITE(*,*) x,y,res
END DO
END PROGRAM

FUNCTION myDiv(x,y)
INTEGER, INTENT(IN) :: x, y
 myDiv = 1/(x–y)
RETURN
END FUNCTION myDiv
```

```
gcc -g divcrash.c gdb ./a.out
```

```
gfortran -g divcras.f90 gdb ./a.out
```

```
(gdb) run
```

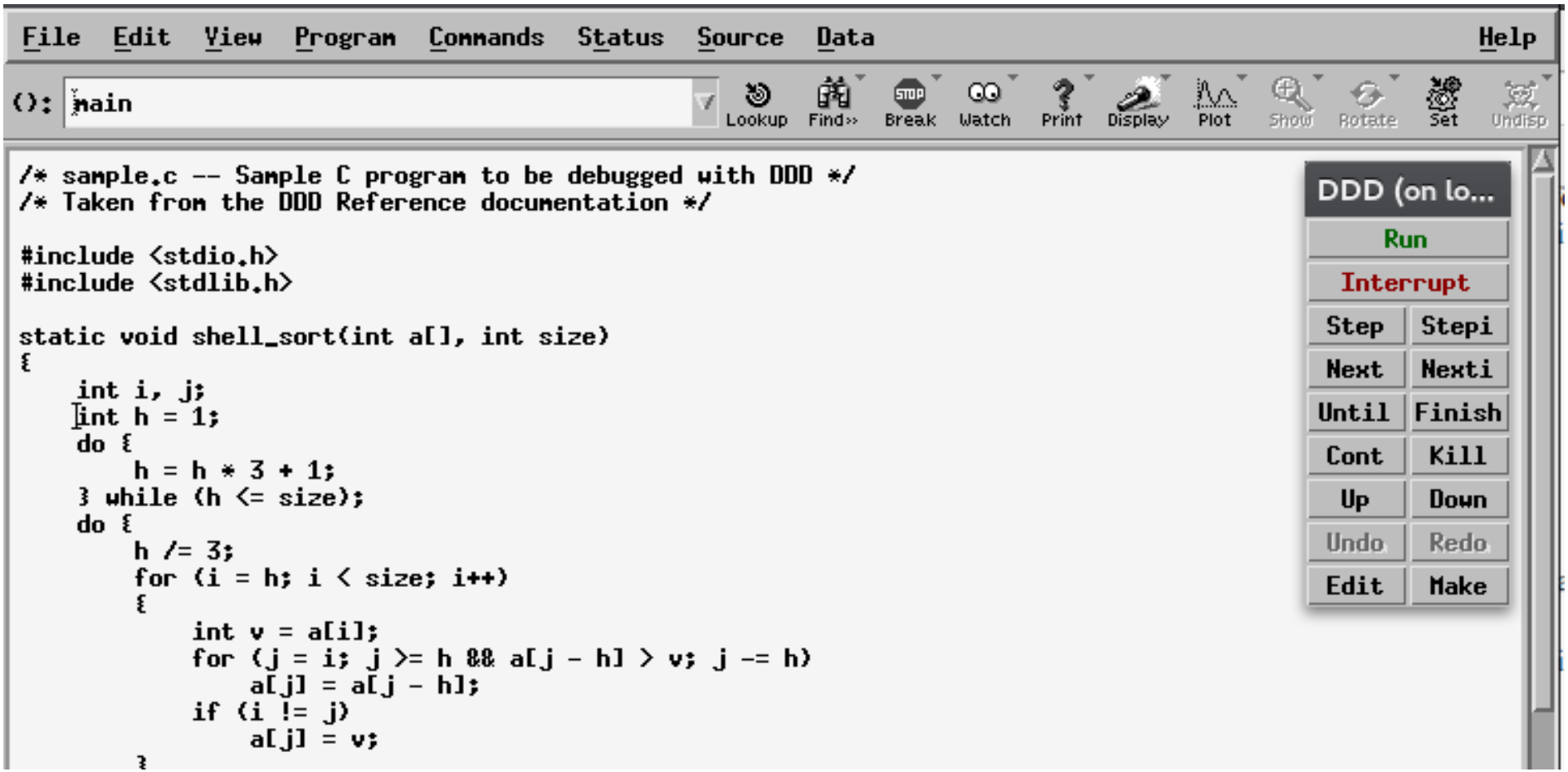
```
Program received signal SIGFPE, Arithmetic exception.
0x0000000000400595 in myDiv ()
```

Intel gdb-ia

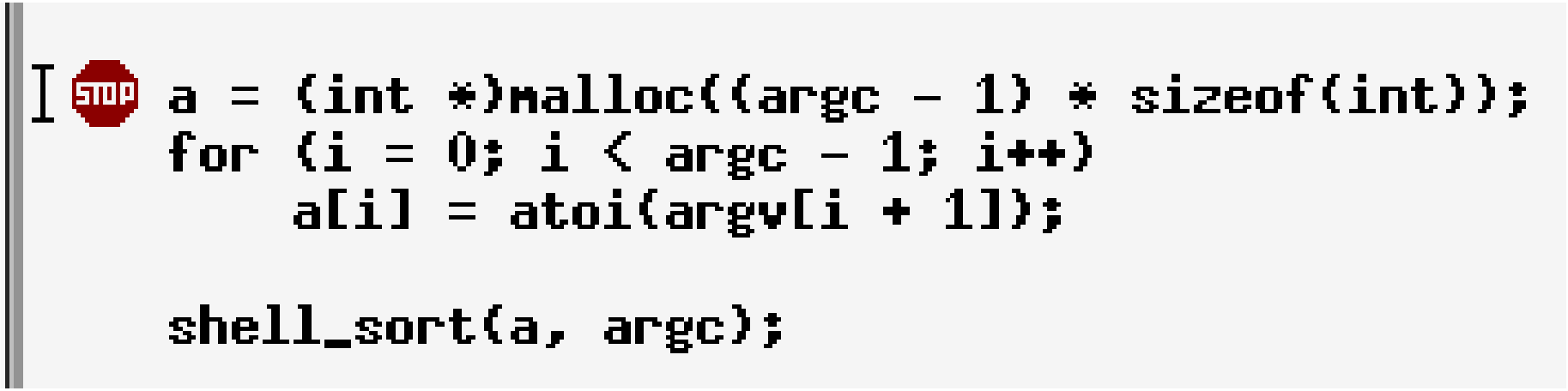
- `gdb-ia` Intel Debugger
- debugger, inspect errors: segmantation faults κλπ
- module intel

- `ddd` Data Display Debugger
- GUI environment
- debug, inspect errors: segmantation faults κλπ
- `http://www.gnu.org/software/ddd/`
- gui vs gdb –tui

ddd <prog name>



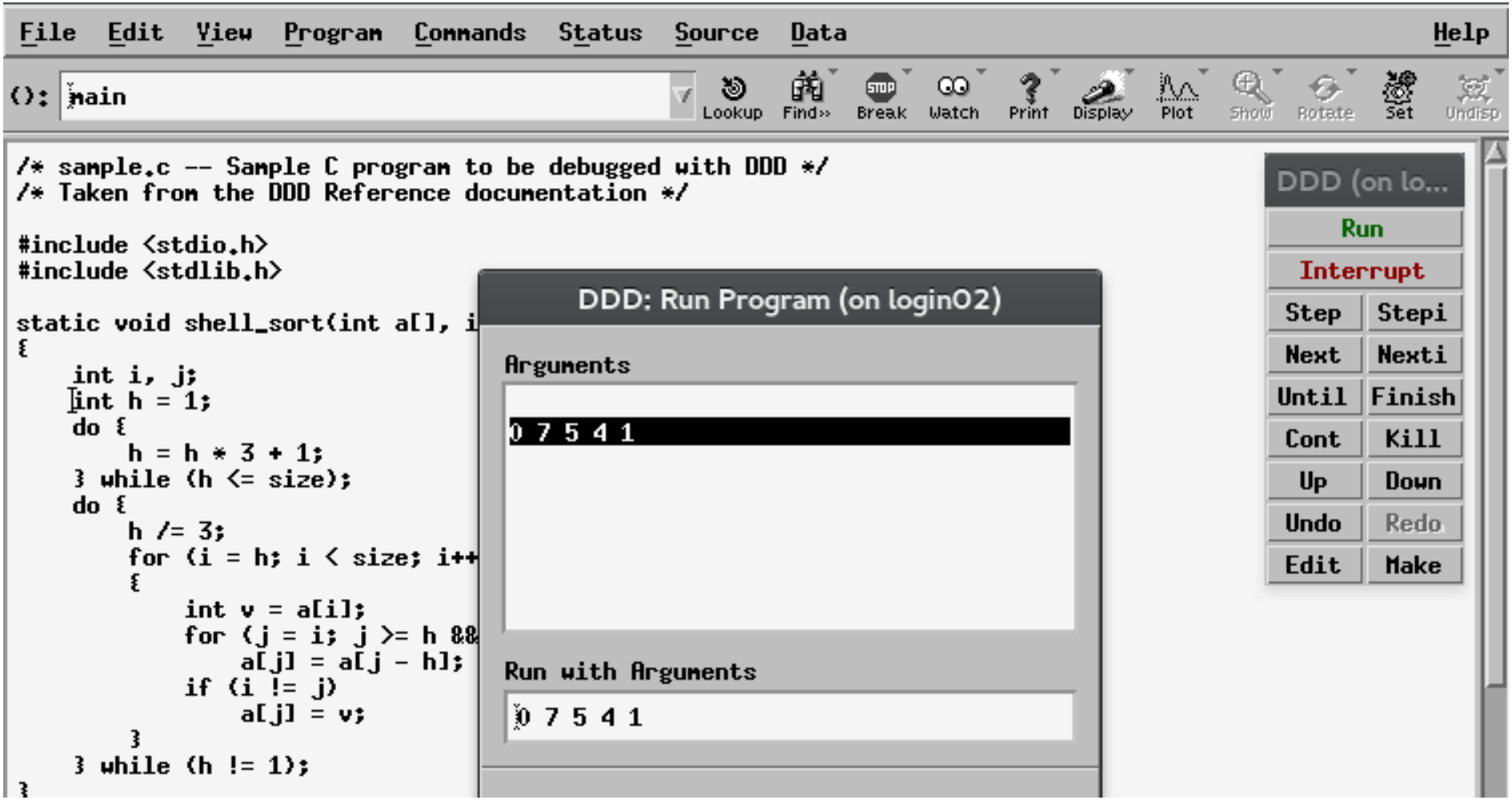
Line: ”Right Click”



```
a = (int *)malloc((argc - 1) * sizeof(int));
for (i = 0; i < argc - 1; i++)
    a[i] = atoi(argv[i + 1]);

shell_sort(a, argc);
```

Program -> Run


File Edit View Program Commands Status Source Data Help
(): main
Lookup Find>> Break Watch Print Display Plot Show Rotate Set Undisp
/* sample.c -- Sample C program to be debugged with DDD */
/* Taken from the DDD Reference documentation */
#include <stdio.h>
#include <stdlib.h>
static void shell_sort(int a[], i
{
int i, j;
int h = 1;
do {
h = h * 3 + 1;
} while (h <= size);
do {
h /= 3;
for (i = h; i < size; i++
{
int v = a[i];
for (j = i; j >= h &&
a[j] = a[j - h];
if (i != j)
a[j] = v;
}
} while (h != 1);
}
DDD: Run Program (on login02)
Arguments
0 7 5 4 1
Run with Arguments
0 7 5 4 1
DDD (on lo...
Run
Interrupt
Step Stepi
Next Nexti
Until Finish
Cont Kill
Up Down
Undo Redo
Edit Make

Debugging OpenMP Applications

- Parallel debug is complex, each process must be debugged simultaneously
- GDB provides basic functionality usually a dedicated debugger
- automatic notification of new threads
- `thread <thread-id>` a command to switch among threads
- `info threads` a command to inquire about existing threads
- thread specific breakpoints

- The GDB thread debugging facility allows you to observe all threads while your program runs—but whenever GDB takes control, one thread in particular is always the focus of debugging. This thread is called the current thread. Debugging commands show program information from the perspective of the current thread.
- When any thread stops (breakpoint) all other threads in the program are also stopped by GDB
- Cannot view values of private and shared variables in parallel regions
- `set scheduler-locking on` : full locking (no thread except the current thread may run). **else other threads may execute more than on statement on gdb step**

```
gcc -fopenmp -g parsec.c -o parsec
```

```
export OMP_NUM_NUMTHREADS=2 gdb parsec (gdb) run
```

```
[Thread debugging using libthread_db enabled]
Using host libthread_db library "/lib64/libthread_db.so.1
    ".
[New Thread 0x7ffff7dc8700 (LWP 6544)]
MASTER: This is thread 0 out of 2
MASTER: This is thread 1 out of 2
SECTION B: This is thread 1 out of 2
SECTION A: This is thread 0 out of 2
SECTION A: Done
SECTION B: Done
[Thread 0x7ffff7dc8700 (LWP 6544) exited]
[Inferior 1 (process 6540) exited normally]
```

(gdb) break 19

info threads

```
(gdb) info threads
Id   Target Id          Frame
* 1    Thread 0x7ffff7dc9760 (LWP 24135) ”parsec” main.
   _omp_fn.0 () at parsec.c:19
2    Thread 0x7ffff7dc8700 (LWP 24136) ”parsec” main.
   _omp_fn.0 () at parsec.c:19
```

(gdb) thread apply 1 b 25

(gdb) thread apply 2 b 35

```
(gdb) thread apply all cont
```

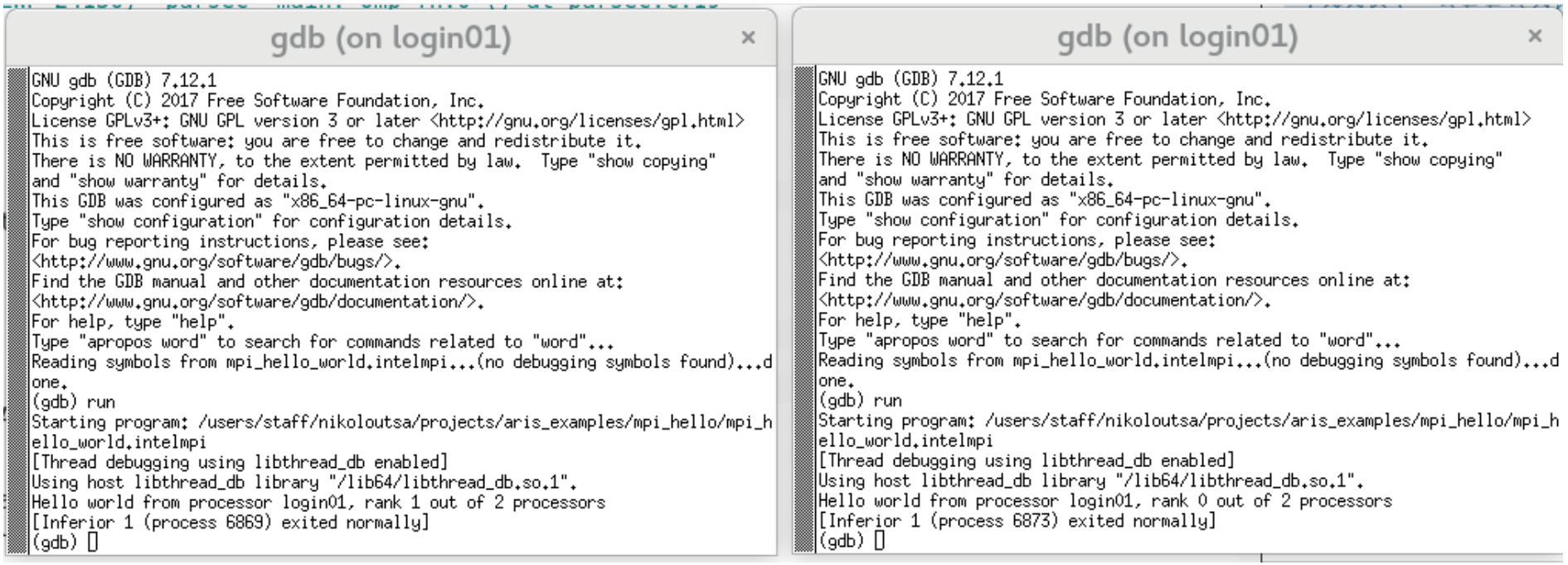
Debugging MPI Applications

- invalid arguments, race conditions, deadlocks, ...
- debugging communications ”MPIp profiler, Scalasca”
- run with the minimum number of tasks to get the unexpected behavior

Open a debug session for each MPI process

spawn GDB

```
mpiexec.hydra -n 2 xterm -e gdb a.out
```



Valgrind

- Valgrind is an instrumentation framework for building dynamic analysis tools. There are Valgrind tools that can automatically detect many memory management and threading bugs, and profile your programs in detail. You can also use Valgrind to build new tools.
- The most popular of these tools is called **Memcheck**. It can detect many memory-related errors that are common in C and C++ programs and that can lead to crashes and unpredictable behaviour.
- http://valgrind.org/

Prepare your program

```
gcc [flags] -g -O0 <source file> -o <output file>
```

Memory Leak

- Memcheck tool
- –leak-check option turns on the detailed memory leak detector.

```
#include <stdlib.h>

void f(void) {
int* x = malloc(10 * sizeof(int));
x[10] = 0; // problem 1: heap block overrun
}          // problem 2: memory leak -- x not freed

int main(void) {
f();
return 0; }
```

valgrind –tool=memcheck –leak-check=yes ./a.out

```
==18430== Invalid write of size 4
==18430==    at 0x400546: f (leak_check.c:6)
==18430==    by 0x400556: main (leak_check.c:11)
==18430==  Address 0x4c29068 is 0 bytes after a block
==18430==    at 0x4A06A2E: malloc (vg_replace_malloc.c
==18430==    by 0x400539: f (leak_check.c:5)
==18430==    by 0x400556: main (leak_check.c:11)
```

- **Invalid write:** the program wrote to some memory it should not have due to a heap block overrun.
- This one shows that the written memory is just past the end of a block allocated with `malloc()` on line 5 of `leak_check.c`.
- fix errors in the order they are reported, as later errors can be caused by earlier errors

Memory leak messages

```
==18430== 40 bytes in 1 blocks are definitely lost in
==18430==    at 0x4A06A2E: malloc (vg_replace_malloc.c
==18430==    by 0x400539: f (leak_check.c:5)
==18430==    by 0x400556: main (leak_check.c:11)
```

- **definitely lost:** your program is leaking memory – fix it!
- **probably lost:** your program is leaking memory, unless you're doing funny things with pointers (such as moving them to point to the middle of a heap block).

Uninitialized Variables

```
int var;
if(var == 0)
printf(”var = 0”);
```

```
==19964== Conditional jump or move depends on uninitia
==19964==    at 0x400534: main (uninit_var.c:6)
```

- difficult to determine the root cause of these errors. Try using the `--track-origins=yes`

```
==22801== Conditional jump or move depends on uninitia
==22801==    at 0x400534: main (uninit_var.c:6)
==22801==  Uninitialised value was created by a stack
==22801==    at 0x400528: main (uninit_var.c:4)\text{++
```

Thank you :)