



Debugging and Profiling

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Debugging

- **Debugging** is a methodical process of finding and reducing the number of bugs, or defects, in a computer program or a piece of electronic hardware thus making it behave as expected. Debugging tends to be harder when various subsystems are tightly coupled, as changes in one may cause bugs to emerge in another.
- A **debugger** is a computer program that is used to test and debug other programs.
- This can be hard enough with a single local process and but get's many times more complicated with many remote processes executing asynchronously. This is why **Parallel Debuggers** exist.



Debugging Requirements

- In general, while debugging you may need to:
 - Step through code
 - Set/Run to breakpoints
 - Examine variable values at different points during execution
 - Examine the memory profile/usage
 - Provide source-level information after a crash
- For MPI and OpenMP Code we have additional requirements
 - All of the above for remote processes
 - Examine MPI message status
 - Step individual processes independent of the rest



Profiling

- Software performance analysis
 - Profiling is examining where a given code is spending its time so that you can understand the performance characteristics of a program or set of functions.
 - There are several levels of profiling, but we will be talking about function level profiling which provides information on the frequency and duration of function calls.
 - A profile is a statistical summary of function calls, generally you get the number of times each function was called and the total amount of time spent in the function.
 - The goal of profiling is to identify “hot spots”, which are functions that occupy an inordinate amount of the total time of a program, which means that optimization of these functions will provide the greatest benefit.



Profiling

- The most basic form of profiling is finding out how long something runs for. On *nix platforms, we always have *time* and *date*.
- *Time* will give you the total wall time, user time, and system time of a process, which can help you understand how efficiently your process is running.
 - *\$ time sleep 5*
 - *real 0m5.003s*
 - *user 0m0.000s*
 - *sys 0m0.000s*
- Real is the walltime of the process. We slept for 5 seconds, so the total walltime is pretty close to 5 seconds. User is the time spent processing userland instructions. Sys is the time spent executing system calls.



Profiling

- Let's take a closer look at timing and understand those categories a bit better. There is a medium-sized zipped file in the lab bundle, let's unzip it and see what that takes.
 - Time `bunzip2 -kf wikipedia2text -extracted.txt.bz2`
 - real 0m2.983s
 - user 0m2.796s
 - sys 0m0.192s
- This looks better, we see that we actually did something here. The extraction work of the `bunzip2` command was recorded as user time (it was YOUR binary), but what is system time? That's time spent in the linux kernel itself, a good example of this are calls to things in the `std*` headers. A lot of this time is going to end up in the kernel.



Profiling

- I've included a couple of files to investigate what's going on here, the first is counts2words, this is just a little program that reads in one file and writes most of the contents out to another. So if File I/O is system time, this should show as almost all sys time, right?
 - `$ time counts2words arxiv_words.al words.out`
 - `real 0m0.128s`
 - `user 0m0.96s`
 - `sys 0m0.028s`
- Well, no not really. What's up? Let's actually do pure File I/O, first create a big 500GB file, then dump it into a new file
 - `$ time dd if=/dev/zero of=/tmp/test.bin bs=500000000 count=1`
 - `$ time cat /tmp/test.bin >> /tmp/test2.bin`



Profiling

- The output of `count2words` is used for `substring`, which searches for a word (or string of characters) in a file of words.
 - `$ time substring words.out zero`
real 1m31.317s
user 1m31.306s
sys 0m0.12s
- That looks a lot like `grep`, we can use `time` to see how long that takes.
 - `$ time grep -c zero words.out`
Real 0m0.008s
User 0m0.000s
Sys 0m0.004s



Profiling

- So our version of substring is appalling, we probably would like to know why this so slow.
- The first question might be, how much time is spent loading the file and how much is spent searching the file? Unfortunately, we can't seem to time File I/O (or at least very easily), so we need a finer-grained approach.
- This is easily done with timing in the code, using the built in time and clock functions (`#include <time.h>`) and getting wall clock times for arbitrary parts of our code.

```
t0 = time(NULL);  
    DO WORK  
t1 = time(NULL);  
printf( "elapsed wall clock: %ld\n", (long) (t1-t0))
```



Time and Clock

- Any Unix-ish system will have time and clock available, and they can get confused, but they're not the same thing.
- `time(NULL)` – pulls the current system time, basically asks the system to check the calendar and report the current time. The precision of this can vary, but the ANSI standard is seconds only.
- `Clock()` – this doesn't actually measure time, it measures cpu-ticks. This is why we have to divide by `CLOCKS_PER_SECOND` in order to convert this into a time. This implies that this is a sub-second timer, but it only measures actual cpu time. So anything that doesn't use the processor doesn't get included here (File I/O is the most common pitfall here).



Profiling

- Our timing told us that our guess was right, while the substring is slow, the appalling slowness is from how we are reading the file.
- Our next step is we really need to know which part of the file read is so painfully slow. Maybe that line terminator check is getting us? In order to figure this out, we really need an understanding of timing at a functional level. This is where a profiling tool comes in.
- Gprof – standard gnu tool for profiling code. Available everywhere gcc is available, can fail in interesting ways.
- Valgrind – standard developer tool for memory profiling and provides a good profiling tool as well. Available pretty much everywhere and very robust.
- Oprofile – newer tool which seems to be rapidly displacing gprof, very robust, but you'll probably need to install your own.



gprof

- Running gprof is relatively straight forward, we recompile with `-pg` and run the program as usual. This produces the `gmon.out` file which contains statistics about how many times things were called. We then call gprof to sort that out into a text file.
 - `$ make profile`
 - `$./substring words.out zero`
 - `$ gprof substring >> profile_results`
- `Profile_results` is a text file that will have a perplexing result in it.

%	cumulative	self	self	self	total	
time	seconds	seconds	calls	ms/call	ms/call	name
0.00	0.00	0.00	362559	0.00	0.00	trimNewLine
0.00	0.00	0.00	1	0.00	0.00	loadFile
0.00	0.00	0.00	1	0.00	0.00	substring



Profiling

- Flat profile – total time and number of calls of function

% time	cumulative seconds	self seconds	self calls	self ms/call	self ms/call	total name	
33.34	0.02	0.02	7208	0.00	0.00	open	
16.67	0.03	0.01	244	0.04	0.12	offtime	
16.67	0.04	0.01	8	1.25	1.25	memccpy	
16.67	0.05	0.01	7	1.43	1.43	write	

- Call graph – See how a function was called

index	% time	self	children	called	name	
[1]	100.	0 0.00	0.05	1/1	start [1]	
		0.00	0.05	1/1		main [2]
		0.00	0.00	1/2		on_exit [28]
		0.00	0.00	1/1		exit [59]

[2]	100.0	0.00	0.05	1/1	main [2]	start [1]
		0.00	0.05	1		report [3]
		0.00	0.05	1/1		



Gprof for profiling

- Gprof is used for monitoring the performance of a FUNCTIONAL program to help guide optimization efforts.
 - It's not a debugger, make sure you're program is working the way you want before you think about profiling.
 - Optimization often results in less readable, modular, and maintainable code, the best optimization strategy may be to not optimize.
- In order to get profiling output, compile with the `-pg` option.
 - Generally, you'll want to use all the other compile flags that you are using, otherwise you may be profiling code that performs differently than it does. However, in *most* cases, this is not a huge issue. Try it both ways if you are concerned.



Profiling – Lab 1

- Included in the lab section is `linpack.c` which is a traditional tool for measuring the performance of High Performance Computing systems, but is also useful for looking at any computing system.
- The goal of this lab is to generate `gprof` output for this function.
- You will need to
 - Compile this function with the appropriate options (standard build below)
`$ gcc -DDP -DROLL -lm linpack.c -o linpac`
 - Run the program to get `gmon.out` output
 - Run `gprof` to get the text-ified results
 - Examine the output and identify the function that should most likely be optimized to make `linpack` faster.
- **Advanced users can try and fix `substring` to make it less awful!**



Profiling

- Gprof will only give you valid counter information on functions that it was able to annotate. It can't annotate functions in system libraries, and so we get stuck with very little useful information from this because all of our work is in system calls. This isn't really a problem in non-toy problems, and if necessary you can get that information.
- Valgrind will give us a bit more without any work!
 - `$ valgrind --tool=callgrind ./substring words.out zero`



Profiling

- Time versus counts
 - Call counts as reported by `gprof` and `valgrind` are both completely accurate. This is your best information to understand what is being called.
 - Time can be less accurate. The example that we provide is a pathological case where all of the time is from system calls that we know don't get reported very well. You should expect better performance.
 - Don't be afraid to use `time` and `clock` to get timings on functions where profiling isn't working well. If you're going to spend 2 hours trying to get `gprof` to report the granularity that you need, just insert the timing statements and go!



Profiling

- The timing's we've mentioned just use the system time. MPI provides a nice high-resolution timer that can be used to generate timings in mpi code. Take a look at p2p_perf for examples.
- While valgrind is not installed on Ranger, it is easy to compile in your home directory. It will compile readily with any of the compilers you might use there. If you are writing C or C++ code, I highly recommend you become familiar with this tool suite.
- The longer your run is the more accurate things like gprof become. P2p_perf is a good example of this. That little test is used to identify latency and bandwidth characteristics of the interconnect. However, you need lots of iterations in order to develop reasonable timings. Your smallest dataset is likely a bad choice for doing profiling.



Profiling Caveats

- Basically, you're looking for functions that occupy a large amount of system time and/or are called a inordinate amount of times.
 - Functions that takes lots of time are candidates for optimization, particularly if they are called heavily. This will give you the best bang for the buck.
 - Functions that are called many times but don't occupy much system time are probably losers for optimization. You won't see much benefit from optimizing these even if you do!
- You should be careful about I/O!
 - I/O wait is not reported in profiling numbers, so examine timing information in I/O heavy functions carefully.
- Be cautious in interpretation of absolute time
- Don't shortchange the sample data when generating profile data



Lab 2 – Profiling (Optional)

- p2p_perf.c uses MPI_Wtime to get a accurate timer available in jobs.
 - The object of p2p_perf is to provide is to provide information about latency and bandwidth characteristics of an interconnect. You can learn something about latency by sending very small messages and you can learn something about bandwidth by sending very large messages.
- 1) Examine p2p_perf.c to see the use of MPI_Wtime use.
 - 2) Compile p2p_perf using your preferred compiler
 - 3) Write a batch script that will run p2p_perf to perform a ping-pong between two different nodes. From the results, estimate the maximum bandwidth that you are able to achieve on the Ranger interconnect.



Debugging Tools

- Debugging requires a debugger, of which many are available.
 - Your development environment may well have a built-in debugger available. Eclipse is a good a good example, which provides a nice interface to a debugger.
- GDB – The GNU Project Debugger
 - Universally available debugger that can debug C, C++, and Fortran code (if you can compile it with GCC, you should be able to debug it with gdb).
 - GDB has a command line interface to walking through code that takes a little getting used to.
 - Your code must be compiled in debug mode before you can use GDB, you can't just start debugging a binary.



Debugging with GDB

- Step 1 – build with debugging symbols.
 - `$ g++ -ggdb -Wall -o test main.cc`
- Step 2 – launch the application inside the debugger
 - `$ gdb test`
- Step 3 – Run the application
 - `$(gdb) run`
- Step 4 – Examine the backtrace
 - `$(gdb) backtrace`
- Step 5 – Examine the parameter values
 - `$(gdb) x 0x7ffa408c3d4`



Breakpoints and stepping

- Previously, we just used the debugger to examine what happened after the program exploded. It may be more useful to examine the program before it blows up, which can be done by setting breakpoints and stepping.
- A breakpoint halts execution of the program at a specific source line.
 - (gdb) break LinkedList<int>::remove
- This can be made conditional by using the “condition” statement, so that the breakpoint only occurs when a specific condition is meant.
 - (gdb) condition 1 item_to_remove==1
- Re start using run and execution will be halted at the breakpoint. Execute one line of code by using step.
 - (gdb) step



GDB commands summary

- run – execute the program from beginning.
- backtrace – produce the backtrace from the last fault
- break <line number> or break <function-name> - break at the line number or at the use of the function
- delete <breakpoint number> - remove a breakpoint
- step – step to next line of code (step into function if possible)
- next – step to next line of code (do not step into function)
- list – print source list (list <function> to print a specific function)
- print <variable name> - print the value stored by the variable
- continue – run until next break point
- quit – quit
- help – get help on any command



Lab 3 - Debugging

- Example3.c is a buggy print mangler, that you will likely be able to fix.
 - 1) Compile example3.c
 - 2) Execute example3 – it will segfault on you
 - 3) Compile example3.c with debugging turned on
 - 4) Start example3.c in the debugger so you can examine the backtrace information.
 - 5) Set a breakpoint at line 6, and step through the code until you can find what happens.
 - 6) Once you understand the problem, fix the offending line(s) and recompile

If you get hungup, look in example3.fixed for some solutions.



Instrumenting code for logging and Debugging



Debugging and Logging

- GDB is a debugger that you would use when you have identified a problem in your code and you're trying to isolate and identify the source of the problem.
- Printf() debugging is the debugging style where you add all sorts of printf(), cout, print, System.out.println(), etc to dump information to stdout or stderr to track what the problem is.
 - Learned folks often disapprove of such nonsense and suggest that practical use of a debugger is vastly more efficient.
 - Practical folks will admit to it's utility and point to the fact that it allows continuous monitoring of the code outside of a debugger
 - Both are right, and with some simple setup, you can add debugging/logging statements to your code that will be useful, informative, and unintrusive.



Printf Debugging

- First, let's take a look at what the much feared printf debugging looks like.

```
int main (int argc, char** argv) {  
    printf("Starting main...");  
    int iterations = 5;  
    int val = 0, val2=0;  
    printf("Initialized val to %d and val2 to %d", val, val2);  
    while (iterations --) {  
        val = sometime();  
        print("Sometime() returned %d\n", val);  
        val2 = moretime();  
        printf("moretime() returned %d\n", val);  
    }  
    printf("Exiting main, iterations ==%s%d", iterations);  
}
```



Printf Debugging

- With this example, we have pretty much covered the code with 5 printf statements. This results in several problems that can occur.
 - You have drastically increased the number of lines of code, and it's quite easy to make an error in one of these new lines (mess up a format string and you're debugging breaks your program). The number of lines required to get debugging level information is very high.
 - There is no easy way to remove these lines from your code without potentially breaking something. If you insert these lines in the middle of a debugging session, if they aren't manually removed this function will forever emit all of this stuff on stdout. I hope no meaningful data goes to stdout anywhere.
 - Writing to stdout slows down your program significantly, having a printf in the middle of a tight for loop will have a big impact on performance.



Advantages of Printf Debugging

- There are some cases where printf-style debugging is useful.
 - Long running applications where erroneous results are produced. Using a debugger is most useful when the identifying crashes or once the function/class/etc that has a bug is identified. Printf may help you identify the function or class where deviations occur.
 - It allows you to examine optimized code instead of code with debugging symbols added. It also let's you get output while running at full scale for parallel applications. This is occasionally useful.
 - Running multi-threaded or on remote machines. Connecting a debugger to a remote process can be difficult and tracking forks etc is non-trivial.
 - Help identify transient and/or timing related bugs.



What to do

- Printf debugging certainly has advantages, but it also creates ugliness in your code as well potentially the source of problems unrelated to the one you're trying to solve!
- These can be mitigated with a few easy steps
 - Don't ever use stdout, use stderr (unbuffered, seperation, etc)
 - Don't call printf directly, use a macro/function/class that handles the output safely.
 - Use "levels", which are the criticality of the problem and range from debug (the lines we showed earlier) to warning (possible erroneous values). You can then control when and where these various levels are printed.



Logging Libraries

- What we're actually talking about is "logging".
 - Logging is the process of computer systems logging state changes and informational content to a central location where they can be recorded and examined later.
 - Here's a chunk of an up2date log (stashed in /var/log/up2date)

```
[Mon May 18 09:53:49 2009] up2date logging into up2date server  
[Mon May 18 09:53:50 2009] up2date succesfully retrieved authentication token  
[Mon May 18 09:55:20 2009] up2date Updating pacakge profile  
[Mon May 18 09:57:25 2009] up2date Updating package profile
```

- There are libraries that we can use to get safe, readable logging added to your code very easily.



Log4Blah

- Log4J is an Apache Foundation project that provides logging utility for Java. The interface to this has now been copied to many different languages.
 - Log4Net – is for .NET and works with C++, C#, etc.
 - Log4CXX – is for C++ and works for most platforms.
 - Log4c – is for C
 - Log4py and log4p – is for python
 - Log4Ruby – you get the idea, yes?
- Other logging libraries exist, Log4J is the only one that crosses so many different languages, which makes it a little easier to use.
- As far as I know if you're using fortran, you'll need to implement the logging yourself (if someone knows differently, please let me know).



Log4J Features

- Automatic formatting of output with appending timestamps and who emitted the log.
- A library of “Appenders” which are objects that control *how* and *where* a log line is written.
 - RollingLogAppender – logs to a file which rolls when it reaches a certain size or date.
 - SocketAppender – logs over a socket to a log server
 - DatabaseAppenders – log information to a database
- It is a best-effort fail-stop system.
 - This means that it will not emit unexpected expectations causing your application to crash but will try really hard to actually log your info.
- It provides easy control of logging level at runtime



What does it look like

- Replacing printf lines with log lines doesn't significantly change the look of the program, some extra boilerplate and a logger object must be grabbed.

```
int main (int argc, char** argv) {  
    log4c_init();  
    mycat = log4c_category_get("sillyapp.main");  
    int iterations = 5;  
    log4c_category_log(mycat, LOG4C_PRIORITY_DEBUG, "Debugging app 1  
- loop %d", iterations);  
    int val = 0, val2=0;  
    log4c_category_log(mycat, LOG4C_PRIORITY_ERROR, "Some error"  
    printf("Initialized val to %d and val2 to %d", val, val2);  
    ...  
}
```



Configuration

```
<?xml version="1.0" encoding="utf-8" ?>
<configuration>
  <configSections>
    <section name="log4net" type="log4net.Config.Log4NetConfigurationSectionHandler,log4net" />
  </configSections>
  <log4net>
    <!--This is a rolling log file.  When the file exceeds 100Kb, it's rool to a new file, keeping at most 10 files.
    <appender name="RollingLogFileAppender" type="log4net.Appender.RollingFileAppender">
      <file value="c:\NateIsRolling.txt" />
      <appendToFile value="true" />
      <maxSizeRollBackups value="10" />
      <maximumFileSize value="100" />
      <rollingStyle value="Size" />
      <staticLogFileName value="true" />
      <layout type="log4net.Layout.PatternLayout">
        <header value="[Header] &#13;&#10;" />
        <footer value="[Footer] &#13;&#10;" />
        <conversionPattern value="%date [%thread] %-5level %logger [%ndc] - %message&newline" />
      </layout>
    </appender>
    <!--This is where we specify what loggers to use and at what level they should log.-->
    <!--This says that anything DEBUG should be logged!-->
    <root>
      <level value="DEBUG" />
      <appender-ref ref="RollingLogFileAppender" />
    </root>
  </log4net>
</configuration>
```



Results

- Log messages are then shunted to the appropriate location and formatted prior to putting them in the log.
- We can fancy things up and add headers and footers, as well as all sorts of other fanciness (log different levels to different files/appenders).

[Header]

```
2009-05-13 15:21:14,315 [11] WARN  Logger.Program Pretty sure I'm getting ready to die!  
2009-05-13 15:21:14,331 [11] ERROR Logger.Program uh-oh, no I wasn't!  
2009-05-13 15:21:14,331 [11] FATAL Logger.Program blech. Out
```

[Footer]

- There are many programs out there designed for “log file analysis”, aka handling large nicely formatted log files.



Conclusion

- Ad hoc printf debugging probably causes as many problems as it solves
- Nonetheless, it can be highly useful in some cases.
- A few easy steps can make this style of debugging much less problematic and the early inclusion of a logging library will save you a lot of time down the line.
- The log4J line of loggers are a nice suite of tools that serve many different languages with a common interface and actions.



DDT

Distributed Debugging Tool

Parallel Debugging on Ranger



DDT

- **DDT – Distributed Debugging Tool** (www.allinea.com)
- A graphical debugger for scalar, multi-threaded and parallel applications for C, C++ and Fortran
- DDT's provides graphical process grouping functionality. DDT makes it really easy to assign arbitrary processes into groups which can be acted on separately.
- Provides memory debugging features as well, things like checking pointers, array bounds, etc.
- Provides functionality to interact reasonable with STL components (ie you can see what a map actually contains) and create views for your own objects.
- Allows viewing of MPI message queues for running processes



DDT Demo

- By far the best way to show what DDT can do is to start it up and look at it and show some things with it. Once we do this, we'll have everybody log in and make sure they can DDT started.
- We'll talk about:
 - Creating and altering groups
 - Stepping groups and processes
 - Show Cross-group comparison
 - Show Memory Usage/Profiling
 - Show MPI Queues
 - Show multi-dimensional array viewer



Starting DDT

- Login to ranger with an X tunnel

```
$ ssh -X ranger.tacc.utexas.edu
```

- We need a binary compiled with debugging flags. If you don't have a binary already on ranger, you can get one from the train00 directory

```
login3% mkdir ~/ddt
```

```
login3$ cp ~/train00/ddt_debug/debug_code.f .
```

- Ensure you have your preferred compiler loaded

```
login3% module list
```

```
login3% module unload mvapich
```

```
login3% module swap pgi intel
```

```
login3% module load mvapich
```



Starting DDT

- Compile with debugging flags

```
login3% cd ~/ddt
```

```
login3% mpif90 -g -O0 debug_code.f -o ddt_app
```

- Load the DDT module

```
login3% module list
```

```
login3% module load ddt
```

```
login3% module list
```

```
login3% echo $DDTROOT
```

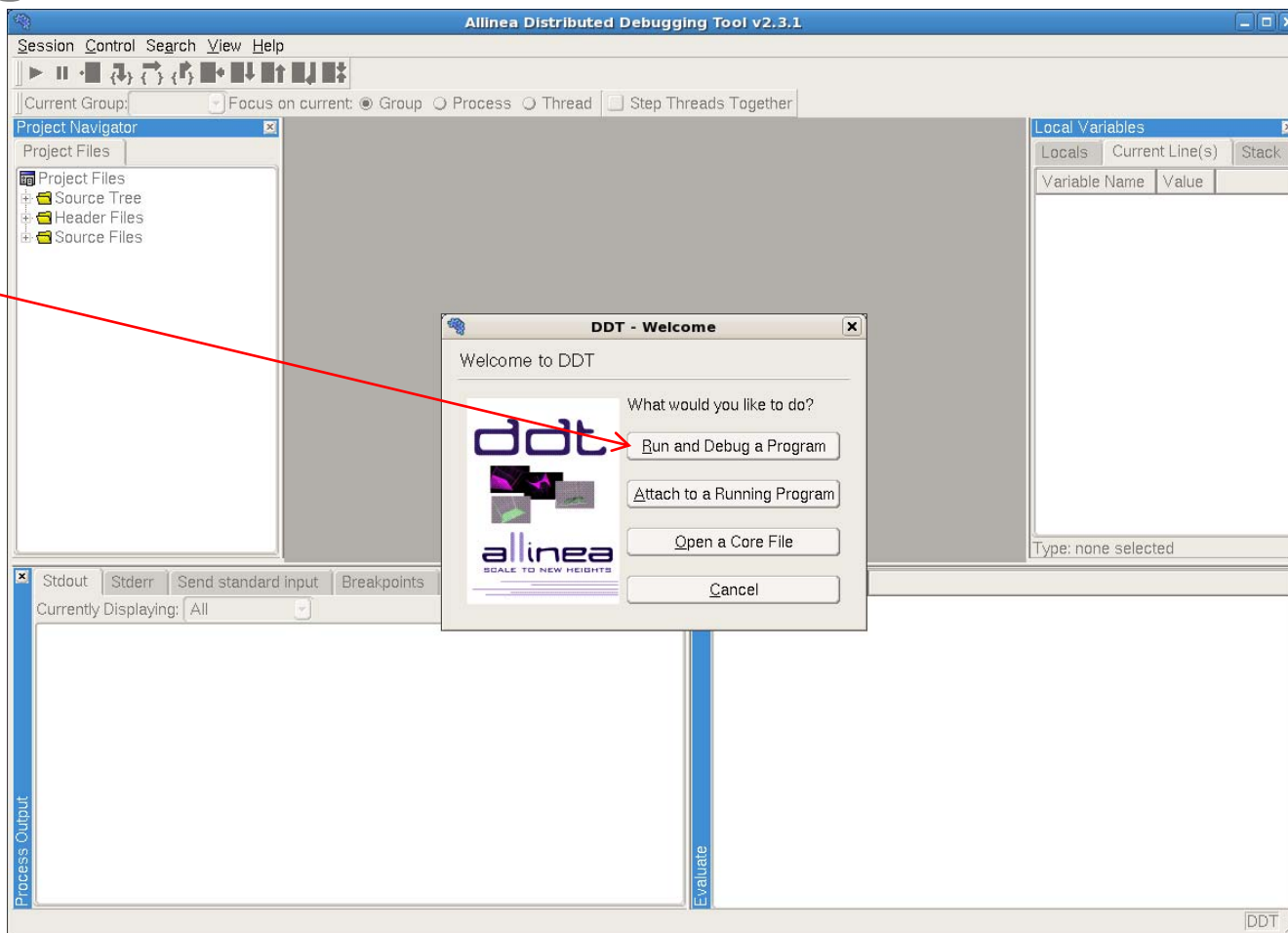
- Start DDT

```
login3% ddt ddt_app
```



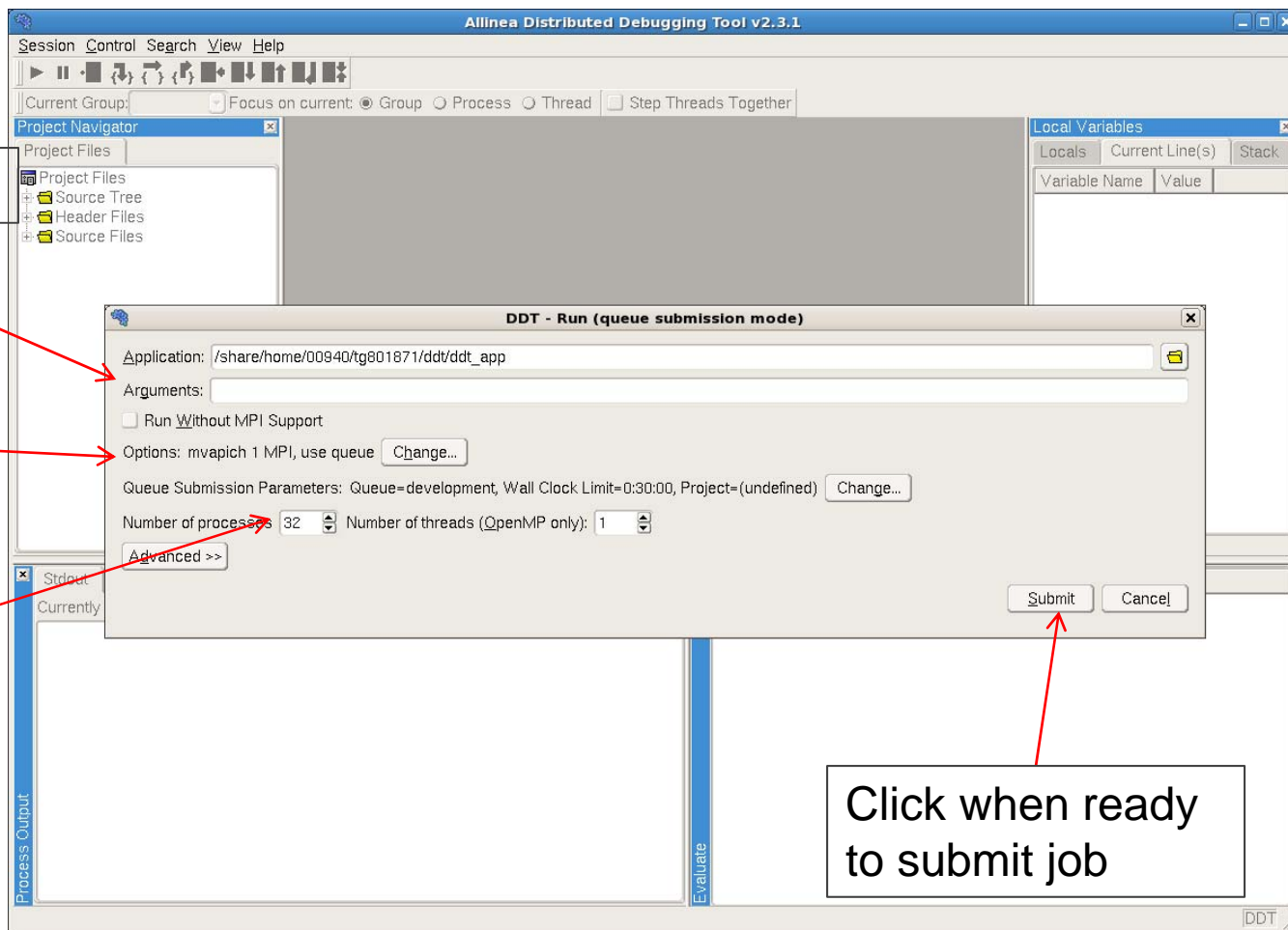
Starting DDT

Click!





Running a job



Add any arguments

Ranger default

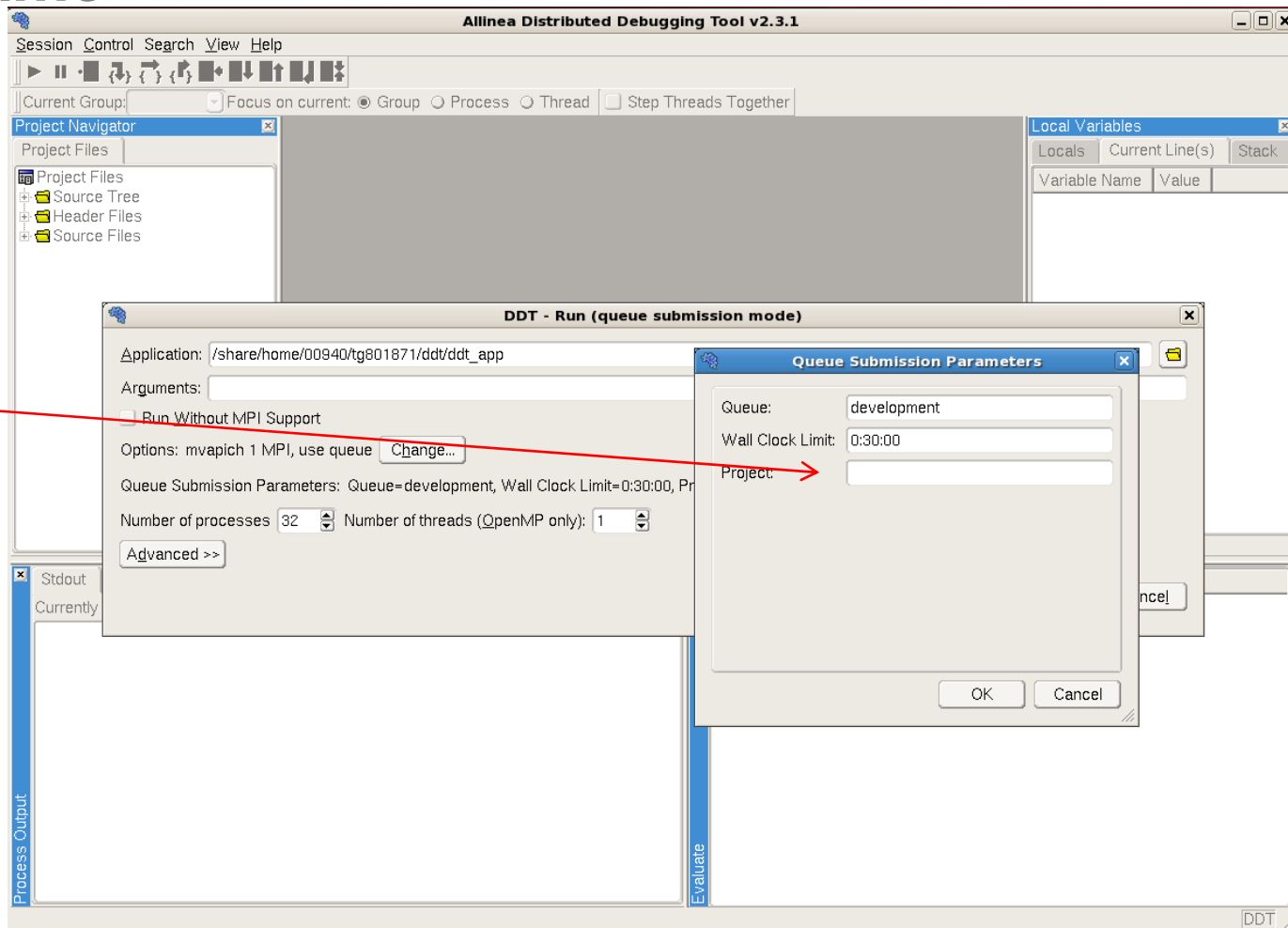
Sets number of nodes

Click when ready to submit job



Account Name

Provide
allocation id
(qsub -A value)
then click OK





Waiting for job to start

The screenshot shows the Alinea Distributed Debugging Tool (DDT) v2.3.1 interface. A dialog box titled "DDT - job Submitted" is open, displaying the following text:

Your debugging job has been submitted to the queue. DDT will continue automatically once the job has been started. You may cancel the job by closing DDT or clicking on the button below.

ACTIVE JOBS-----
JOBID JOBNAME USERNAME STATE CORE HOST QUEUE REMAINING STARTTIME
=====

0 active jobs : 0 of 3888 hosts (0.00 %)

WAITING JOBS-----
JOBID JOBNAME USERNAME STATE CORE HOST QUEUE WCLIMIT QUEUETIME
=====

JOBID	JOBNAME	USERNAME	STATE	CORE	HOST	QUEUE	WCLIMIT	QUEUETIME
571888	DDTJOB	tg801871	Waiting	32	2	development	00:30:00	Tue Mar 3 12:49:51

WAITING JOBS WITH JOB DEPENDENCIES-----
JOBID JOBNAME USERNAME STATE CORE HOST QUEUE WCLIMIT QUEUETIME
=====

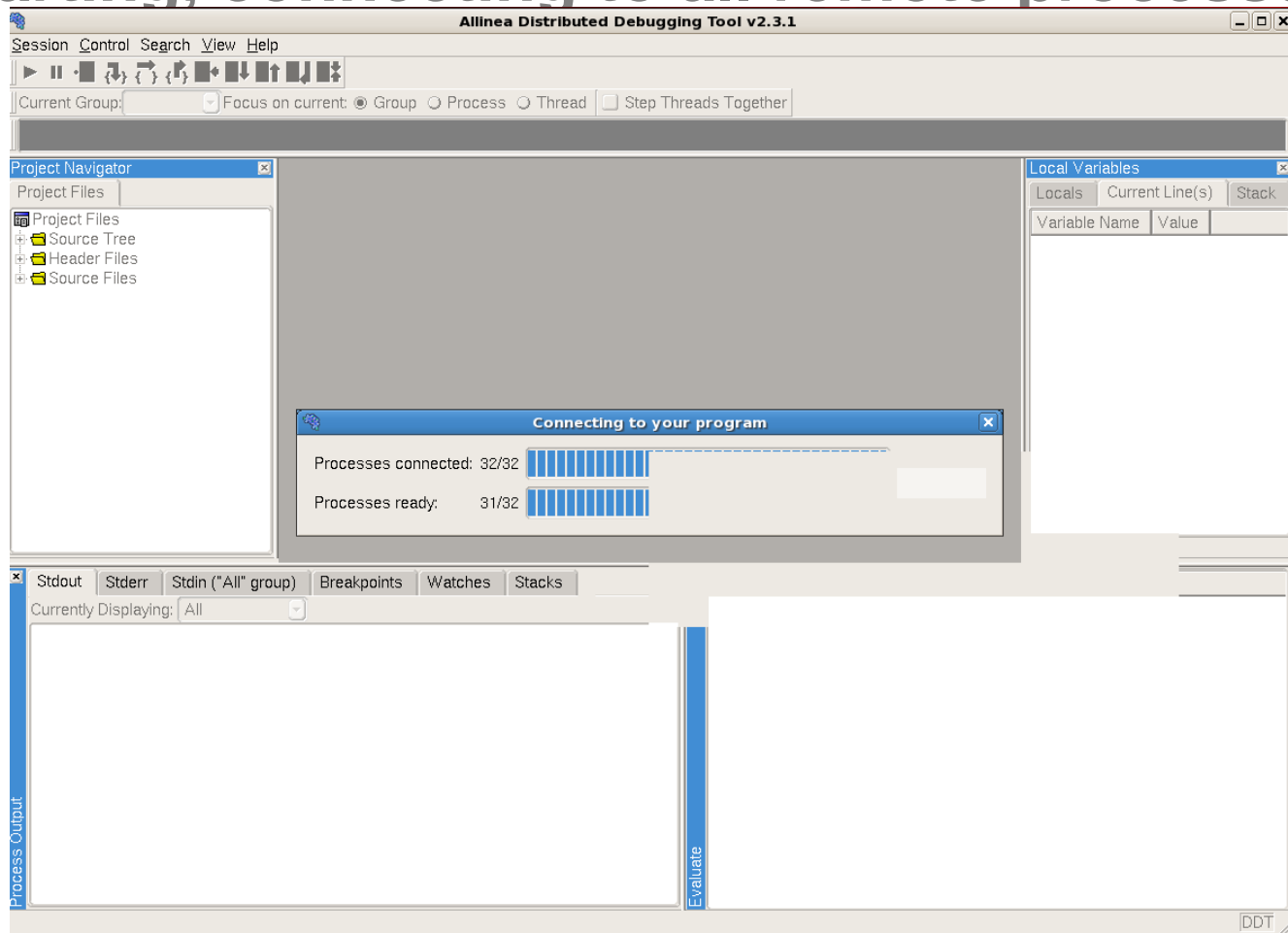
UNSCHEDULED JOBS-----
JOBID JOBNAME USERNAME STATE CORE HOST QUEUE WCLIMIT QUEUETIME
=====

Total jobs: 1 Active Jobs: 0 Waiting Jobs: 1 Dep/Unsched Jobs: 0

Cancel Job



Job starting, connecting to all remote processes





Session started!

The screenshot shows the Allinea Distributed Debugging Tool (DDT) v2.3.1 interface. At the top, the 'Session Control' menu is visible. Below it, the 'Current Group' is set to 'Root'. A process list at the top shows 'Root' (0) and 'Workers' (1-31). The 'Project Navigator' on the left shows the project structure. The main window displays the source code for 'debug_code.f'. The 'Local Variables' window on the right shows a variable 'i' with a value of 0. The 'Stdout' window at the bottom left is labeled 'STDOUT'. The 'Expression' window at the bottom right is labeled 'Watched Values, Expressions'.

Root process is selected

Source locations of processes

Local variables

STDOUT

Watched Values, Expressions



DDT

- At this point, DDT should be up and running for you and you only need to load the DDT module and any configuration changes you made (ie Account name) will be saved for the next time you use it.
- It should feel very much like an IDE debugger, just with the added capabilities of viewing remote processes and MPI information.
- It wasn't shown, but this can be used just as well to debug OpenMP programs, though you may need to be careful when stepping through non-threaded sections. Check out the User Guide for any questions you have or request help through the TeraGrid help desk.
- UserGuide: <http://www.allinea.com/downloads/userguide.pdf>
Or press F1 while running DDT to call up the help.



DDT Lab

- The DDT Lab is a free-form opportunity to get DDT running.
- Open an SSH session with an X-tunnel to `ranger.tacc.utexas.edu` and get the example code:

```
login3$ cp ~/train00/ddt_debug/debug_code.f .
```

- **Compile**

```
login3% mpif90 -g -O0 debug_code.f -o ddt_app
```

- **Load the DDT Module and run ddt**

```
login3% module load ddt
```

```
login3% ddt ddt_app
```