PGI Tools Guide

Parallel Tools
for Scientists and Engineers

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PGI Tools Guide

Printed in the United States of America

Part Number: 2040-990-888-0603

Printing: Release 6.0, March 2005

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Preface

This guide describes how to use the *PGPROF* profiler and *PGDBG* debugger to tune and debug serial and parallel applications built with The Portland Group (PGI) Fortran, *C*, and *C++* for X86, AMD64 and EM64T processor-based systems. It contains information about how to use the tools, as well as detailed reference information on commands and graphical interfaces.

Intended Audience

This guide is intended for application programmers, scientists and engineers proficient in programming with the Fortran, *C*, and/or *C++* languages The PGI tools are available on a variety of operating systems for the X86, AMD64, and EM64T hardware platforms. This guide assumes familiarity with basic operating system usage.

Supplementary Documentation

See http://www.pgroup.com/docs.htm for the *PGDBG* documentation updates. Documentation delivered with PGDBG should be accessible on an installed system by accessing $PGI/docs/index.htm. See http://www.pgroup.com/faq/index.htm for frequently asked *PGDBG* questions and answers.

Compatibility and Conformance to Standards

The PGI compilers and tools run on a variety of systems. They produce and/or process code that conforms to the ANSI standards for FORTRAN 77, Fortran 95, *C*, and *C++* and includes extensions from MIL-STD-1753, VAX/VMS Fortran, IBM/VS Fortran, SGI Fortran, Cray Fortran, and K&R *C*. *PGF77*, *PGF90*, *PGCC* ANSI *C*, and *C++* support parallelization extensions based on the OpenMP defacto standard. *PGHPF* supports data parallel extensions based on the High Performance Fortran (HPF) defacto standard. The *PGI Fortran Reference Manual* describes Fortran statements and extensions as implemented in the PGI Fortran compilers. *PGDBG* permits debugging of serial and parallel (multi-threaded, OpenMP and/or MPI) programs compiled with PGI compilers. *PGPROF* permits profiling of serial and parallel (multi-threaded, OpenMP and/or MPI) programs compiled with PGI compilers.

For further information, refer to the following:

- *American National Standard Programming Language FORTRAN*, ANSI X3. -1978 (1978).
- *American National Standard Programming Language FORTRAN*, ANSI X3. -1991 (1991).
- *International Language Standard ISO Standard 1539-199 (E)*.
- *Fortran 90 Handbook*, Intertext-McGraw Hill, New York, NY, 1992.
- *High Performance Fortran Language Specification*, Revision 1.0, Rice University, Houston, Texas (1993), http://www.crpc.rice.edu/HPFF.
- *High Performance Fortran Language Specification*, Revision 2.0, Rice University, Houston, Texas (1997), http://www.crpc.rice.edu/HPFF.
- *OpenMP Fortran Application Program Interface*, Version 1.1, November 1999, http://www.openmp.org.
- *OpenMP C and C++ Application Program Interface*, Version 1.0, October 1998, http://www.openmp.org.
- *Programming in VAX Fortran*, Version 4.0, Digital Equipment Corporation (September, 1984).
- *IBM VS Fortran*, IBM Corporation, Rev. GC26-4119.
- Military Standard, Fortran, DOD Supplement to American National Standard Programming Language Fortran, ANSI x.3-1978, MIL-STD-1753 (November 9, 1978).
- *American National Standard Programming Language C*, ANSI X3.159-1989.
- HPDF Standard (High Performance Debugging Forum)

http://www.ptools.org/hpdf/draft/intro.html

Organization

This manual is divided into the following chapters:

Chapter 1 *The PGDBG Debugger*

This chapter describes *PGDBG*, a symbolic debugger for Fortran, *C*, *C++* and assembly language programs.

Sections 1.1 through 1.3 describe how to build a target application for debug and invoke *PGDBG*.

Section 1.4 describes how to use the *PGDBG* graphical user interface (GUI).

Sections 1.5 through 1.7 provide detailed information about the *PGDBG* command language, which can be used from the command-line user interface or from the command panel of the graphical user interface.

Sections 1.8 through 1.12 give some detail on how *PGDBG* interacts with signals, how to access registers, language-specific issues, and debugging with core files.

Sections 1.13 through 1.17 describe the parallel debugging capabilities of *PGDBG* and how to use them.

Chapter 2 The *PGPROF* Profiler section describes the *PGPROF* Profiler. This tool analyzes data generated during execution of specially compiled *C*, *C++*, F77, F95, and HPF programs.

Conventions

This guide uses the following conventions:

italic	is used for commands, filenames, directories, arguments, options and for emphasis.
`Constant Width`	is used in examples and for language statements in the text, including assembly language statements.
[*item1*]	in general, square brackets indicate optional items. In this case item1 is optional. In the context of p/t-sets, square brackets are required to specify a p/t-set.
{ *item2* | *item 3*}	braces indicate that a selection is required. In this case, you must select either *item2* or *item3*.
filename ...	ellipsis indicate a repetition. Zero or more of the preceding item may occur. In this example, multiple filenames are allowed.
FORTRAN	Fortran language statements are shown in the text of this guide using a reduced fixed point size.
C/C++	C/C++ language statements are shown in the test of this guide using a reduced fixed point size.

Related Publications

The following documents contain additional information related to the X86 architecture and the compilers and tools available from The Portland Group.

- *PGF77 Reference User Manual* describes the FORTRAN 77 statements, data types, input/output format specifiers, and additional reference material.
- *PGHPF Reference Manual* describes the HPF statements, data types, input/output format specifiers, and additional reference material.
- *System V Application Binary Interface Processor Supplement* by AT&T UNIX System Laboratories, Inc. (Prentice Hall, Inc.).
- *FORTRAN 90 HANDBOOK*, Complete ANSI/ISO Reference (McGraw-Hill, 1992).

- *Programming in VAX Fortran, Version 4.0*, Digital Equipment Corporation (September, 1984).
- *IBM VS Fortran*, IBM Corporation, Rev. GC26-4119.
- *The C Programming Language* by Kernighan and Ritchie (Prentice Hall).
- *C: A Reference Manual* by Samuel P. Harbison and Guy L. Steele Jr. (Prentice Hall, 1987).
- *The Annotated C++ Reference Manual* by Margaret Ellis and Bjarne Stroustrup, AT&T Bell Laboratories, Inc. (Addison-Wesley Publishing Co., 1990)
- *PGI User's Guide*, *PGI Tools Guide*, *PGI 5.2 Release Notes*, FAQ, Tutorials
  http://www.pgroup.com/docs.htm
- MPI-CH
  http://www.netlib.org/
- OpenMP
  http://www.openmp.org/
- Ptools (Parallel Tools Consortium)
  http://www.ptools.org/
- PAPI (Performance Application Program Interface)
  http://icl.cs.utk.edu/papi/
- HPDF (High Performance Debugging Forum) Standard
  http://www.ptools.org/hpdf/draft/intro.html

System Requirements

- PGI CDK 6.0, or WS 6.0
- Linux (See http://www.pgroup.com/faq/install.htm for supported releases)
- Intel X86 (and compatible), AMD Athlon, AMD64, or EM64T processors

Chapter 1

The *PGDBG* Debugger

PGDBG is a symbolic debugger for Fortran, *C*, *C++* and assembly language programs. It provides typical debugger features such as execution control using breakpoints and single-step as well as examination and modification of application variables, memory locations, and registers. In addition, *PGDBG* supports debugging of certain types of parallel applications, including:

- Multi-threaded and OpenMP Linux applications.
- MPI applications on Linux clusters.
- Hybrid applications, which use multiple threads or OpenMP as well as multiple MPI processes on Linux clusters.

Multi-threaded and OpenMP applications may be run using more threads than the available number of CPUs, and MPI applications may allocate more than one process to a cluster node. PGDBG supports debugging the listed types of applications regardless of how well the number of threads match the number of CPUs or how well the number of processes match the number of cluster nodes.

1.1 Definition of Terms

Host	The system on which *PGDBG* executes. This will generally be the system where source and executable files reside, and where compilation is performed.
Target	A program being debugged.
Target Machine	The system on which a target runs. This may or may not be the same system as the host.

For an introduction to terminology used to describe parallel debugging, see *Section 1.13.1 Summary of Parallel Debugging Features*.

1.2 Building Applications for Debug

To build an application for debug, compile with the *–g* option. With this option, the compiler will generate information about the symbols and source files in the program and include it in the executable file. The –g option also sets the compiler optimization to level zero (no optimization) unless you specify *–O, -fast, or -fastsse* on the command line. Programs built with –g and optimization levels higher than –O0 can be debugged, but due to transformations made to the program during optimization, source-level debugging may not be reliable. Machine-level debugging (e.g., accessing registers, viewing assembly code, etc.) will be reliable, even with optimized code. Programs built without *–g* can be debugged; however, information about types, local variables, arguments and source file line numbers will not be available.

1.3 PGDBG Invocation and Initialization

PGDBG includes both a command-line interface and a graphical user interface (GUI). Text commands are entered one line at a time through the command-line interface. The GUI interface supports command entry through a point-and-click interface, a view of source and assembly code, a full command-line interface sub-pane, and several other graphical elements and features. *Sections 1.5 through 1.7* describe in detail how to use the *PGDBG* command-line interface. *Section 1.4 PGDBG Graphical User Interface* describes how to use the *PGDBG* GUI.

1.3.1 Invoking PGDBG

PGDBG is invoked using the `pgdbg` command as follows:

```
% pgdbg arguments target arg1 arg2 ... argn
```

where *`arguments`* may be any of the command-line arguments described in the following section, *Command-line Arguments*. See *Section 1.13.4.1 Invoking PGDBG for MPI Debugging* for instructions on how to debug an MPI program.

The *`target`* parameter is the name of the program executable file being debugged. The arguments *`arg1 arg2 … argn`* are the command-line arguments to the target program. Invoking *PGDBG* as described will start the PGDBG Graphical User Interface (GUI) (*see section 1.4 PGDBG Graphical User Interface*). For users who prefer to use a command-line interface, PGDBG may be invoked with the `-text` parameter (see *Section 1.3 Command-Line Arguments* and *Section 1.5 PGDBG Command Language*).

Once PGDBG is started, it reads symbol information from the executable file, then loads the

application into memory. For large applications this process can take a few moments.

If an initialization file named `.pgdbgrc` exists in the current directory or in the home directory, it is opened and *PGDBG* executes the commands in the file. The initialization file is useful for defining common aliases, setting breakpoints and for other startup commands. If an initialization file is found in the current directory, then the initialization file in the home directory, if there is one, is ignored. However, a *script* command placed in the initialization file may execute the initialization file in the home directory, or execute *PGDBG* commands in any other file (for example in the file `.dbxinit` for users who have an existing *dbx* debugger initialization file).

After processing the initialization file, *PGDBG* is ready to process commands. Normally, a session begins by setting one or more breakpoints, using the *break, stop* or *trace* commands, and then issuing a *run* command followed by *cont, step, trace* or *next.*

1.3.2 PGDBG Command-Line Options

The `pgdbg` command accepts several command line arguments that must appear on the command line *before* the name of the program being debugged. The valid options are:

–dbx	Start the debugger in *dbx* mode.
––program_args	*PGDBG* passes all arguments following this command line option to the program being debugged if an executable is included on the command line. This command-line argument should appear after the name of the executable (e.g., `pgdbg a.out ––program_args 0 1 2 3`). This option is not required to pass target arguments on the *PGDBG* command line.
–s *startup*	The default initialization file is ~/.pgdbgrc. The *–s* option specifies an alternate initialization file *startup*.
–c "*command*"	Execute the debugger command *command* (*command* must be in double quotes) before executing the commands in the startup file.
–r	Run the debugger without first waiting for a command. If the program being debugged runs successfully, the debugger terminates. Otherwise, the debugger is invoked and stops when an exception occurs.
–text	Run the debugger using a command-line interface (CLI). The default is for the debugger to launch in graphical user interface (GUI) mode.

–tp px	
–tp k8-32	Debug a 32-bit program running on under a 64-bit operating system. This option is valid under the 64-bit version of *PGDBG* only.
–tp p7-64	
–tp k8-64	Debug a 64-bit program running under a 64-bit operating system. This option is valid under the 64-bit version of *PGDBG* only.
–help	Display a list of command-line arguments (this list).
–I <directory>	Adds <directory> to the list of directories that *PGDBG* uses to search for source files.

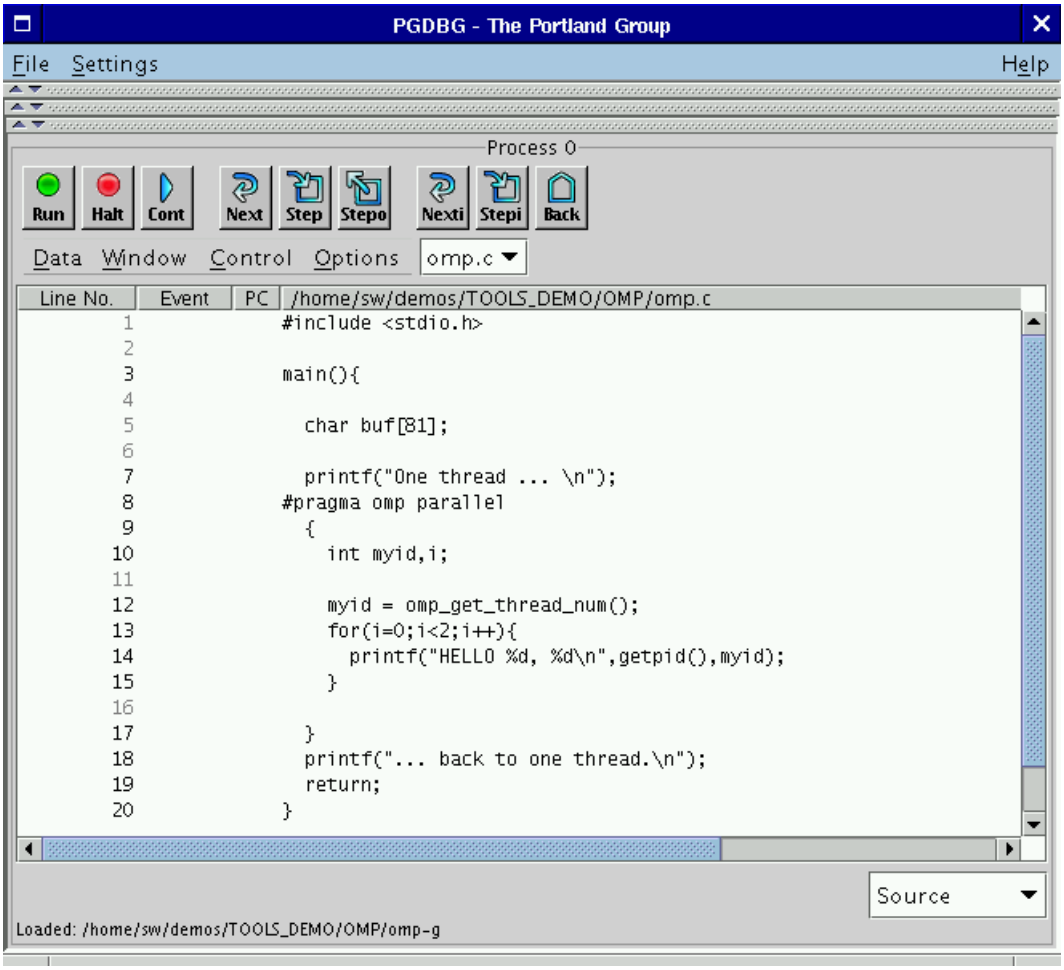
1.4 *PGDBG* Graphical User Interface

The default user interface used by *PGDBG* is a Graphical User Interface (GUI). There may be minor variations in the appearance of the *PGDBG* GUI from host to host, depending on the type of display hardware available, the settings for various defaults and the window manager used. Except for differences caused by those factors, the basic interface remains the same across all systems.

1.4.1 Main Window

Figure 1-1 shows the main window of *PGDBG* GUI when it is invoked for the first time. This window appears when *PGDBG* starts and remains throughout the debug session. The initial size of the main window is approximately `700 x 600`. It can be resized according to the conventions of the window manager. Changes in window size and other settings are saved and used in subsequent invocations of *PGDBG*. To prevent this, uncheck the *Save Settings on Exit* item under the *Settings* menu. See *Section 1.4.1.5 Main Window Menus* for information on the *Settings* menu.

Figure 1-1: Default Appearance of *PGDBG* GUI



There are three horizontal divider bars (controlled by small up and down arrow icons) at the top of the GUI in Figure 1-1. These dividers hide the following optional control panels: *Command Prompt, Focus Panel*, and the *Process/Thread Grid*. Figure 1-3 shows the main window with these controls visible. The GUI will remember which control panels are visible when you exit and will redisplay them when you reopen *PGDBG*. Below the dividers is the *Source Panel* described in *Section 1.4.1.4 Source Panel.*

A second window named the *Program I/*O window is displayed when *PGDBG* is started. Any input or output performed by the target program is entered and/or displayed in this window.

Figure 1-2: *PGDBG* Program I/O Window

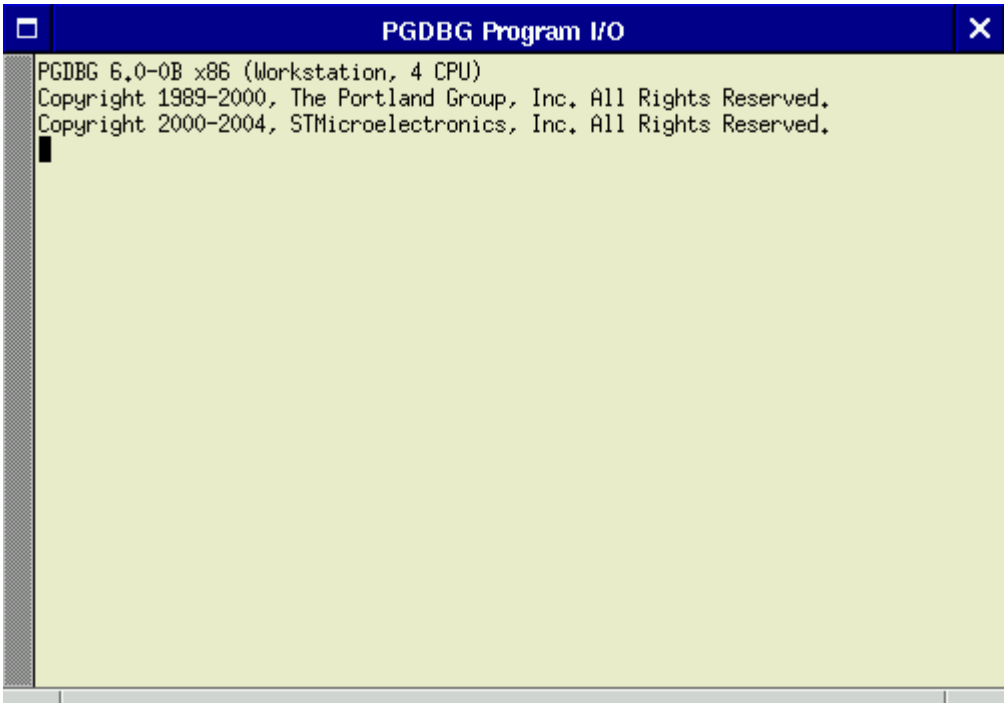
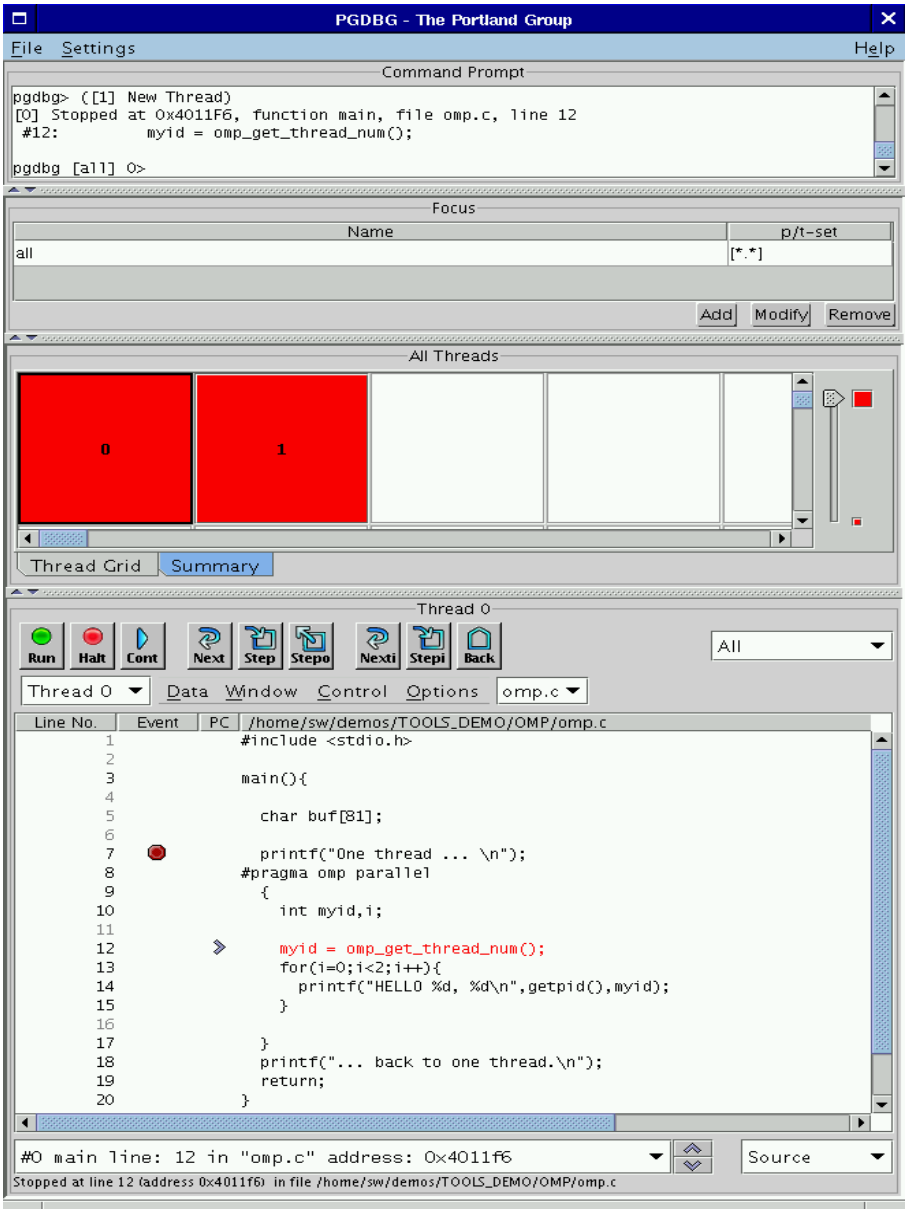


Figure 1-3: *PGDBG* GUI with All Control Panels Visible



The components of the main window (from top to bottom as seen in Figure 1-3) are:

- *Command Prompt*
- *Focus Panel*
- *Process/Thread Grid*
- *Source Panel*

1.4.1.1 Command Prompt Panel

The *Command Prompt Panel* provides an interface in which to use the PGDBG command language. Commands entered in this window are executed, and the results are displayed. See *Section 1.6 Commands Summary* for a list of commands that can be entered in the command prompt panel. The GUI also supports a "free floating" version of this window. To use the "free floating" command prompt window, select the *Command Window* check box under the *Window* menu (*Section 1.12.2.1 Source Panel Menus*). If you are going to only use GUI controls, then you can keep this panel hidden.

1.4.1.2 Focus Panel

The *Focus Panel* can be used in a parallel debugging session to specify subsets of processes and/or threads known as *p/t sets.* *P/t sets* allow application of debugger commands to a subset of threads and/or processes. *P/t sets* are displayed in the table labeled *Focus* (Figure 1-3). In Figure 1-3, the *Focus* table contains one group/t set called *All* that represents all processes/threads. *P/t sets* are covered in more detail in *Section 1.14.6 P/t-set Notation.* Within the *PGDBD* GUI, select a *group/t set* using a left mouse click on the desired group in the *Focus* table. The selected group is known as the *Current Focus.* By default, the *Current Focus* is set to all processes/threads. Note that this panel has no real use in serial debugging (debugging one single-threaded process).

1.4.1.3 Process/Thread Grid

The *Process/Thread Grid* is another component of the interface used for parallel debugging. All active target processes and threads are listed in the *Process/Thread Grid*. If the target application consists of multiple processes, the grid is labeled *Process Grid.* If the target application is a single multi-threaded process, the grid is labeled *Thread Grid.* The colors of each element in the grid represent the state of the corresponding component of the target application; for example, green means running and red means stopped. The colors and their meanings are defined in Table 1-1.

Table 1-1: Thread State is Described using Color

Option	Description
Stopped	Red
Signaled	Blue
Running	Green
Exited	Black
Killed	Black

In the *Process/Thread Grid*, each element is labeled with a numeric process identifier (see S*ection 1.14.3 Process-only debugging)* and represents a single process. Each element is a button that can be pushed to select the corresponding process as the *Current Process*. The *Current Process* is highlighted with a thick black border.

For single-process multi-threaded (e.g., OpenMP) targets, the grid is called the *Thread Grid*. Each element in the thread grid is labeled with a numeric thread identifier (see S*ection 1.14.2 Threads-only debugging).* As with the process grid, clicking on an element in the thread grid selects that element as the *Current Thread*, which is highlighted with a thick black border.

For multi-process/multi-threaded (hybrid) targets, the grid is labeled the *Process Grid*. Selecting a process in the grid will reveal an inner thread grid as shown in Figure 1-4. In Figure 1-4, process 0 has four threads labeled 0.0, 0.1, 0.2, and 0.3; where the integer to the left of the decimal is the process identifier and the integer to the right of the decimal is the thread identifier. See *Section 1.14.4 Multilevel debugging* for more information on processes/thread identifiers.

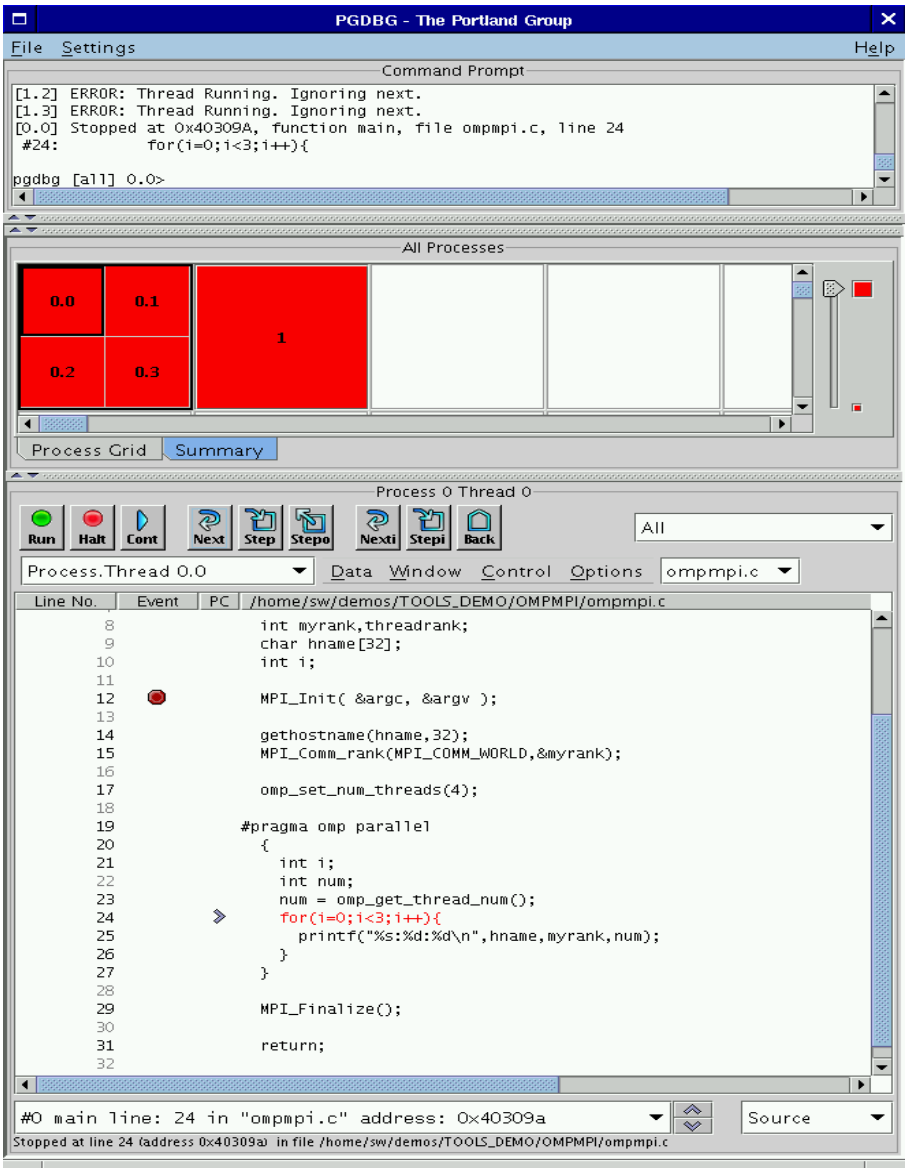
For a text representation of the *Process/Thread* grid, select the *Summary* tab under the grid. The text representation is essentially the output of the *threads* debugger command (see *Section 1.7.1.1 Process Control)*. When debugging a multi-process or multi-threaded application, the *Summary* panel will also include a *Context Selector* (as described in S*ection 1.4.3 Source Panel Pop-Up Menus*). Use the *Context Selector* to view a summary on a subset of processes/threads. By default, a summary of all the processes/threads displays.

Use the slider to the right of the grid to zoom in and out of the grid. Currently, the grid supports up to 1024 elements.

1.4.1.4 Source Panel

The *Source Panel* displays the source code for the current location. The current location is marked by an arrow icon under the *PC* column. Source line numbers are listed under the *Line No.* column. Figure 1-4 shows some of the line numbers grayed-out. A grayed-out line number indicates that its respective source line is *non-executable*. Some examples of non-executable source lines are comments, non-applicable preprocessed code, some routine prologs, and some variable declarations. A line number in a black font represent an *executable* source line. Breakpoints may be set at any executable source line by clicking the left mouse button under the *Event* column of the source line. The breakpoints are marked by stop sign icons. An existing breakpoint may be deleted by clicking the left mouse button on the stop sign icon. The source panel is described in greater detail in *Section 1.4.2 Source Panel.*

Figure 1-4: Process Grid with Inner Thread Grid



1.4.1.5 Main Window Menus

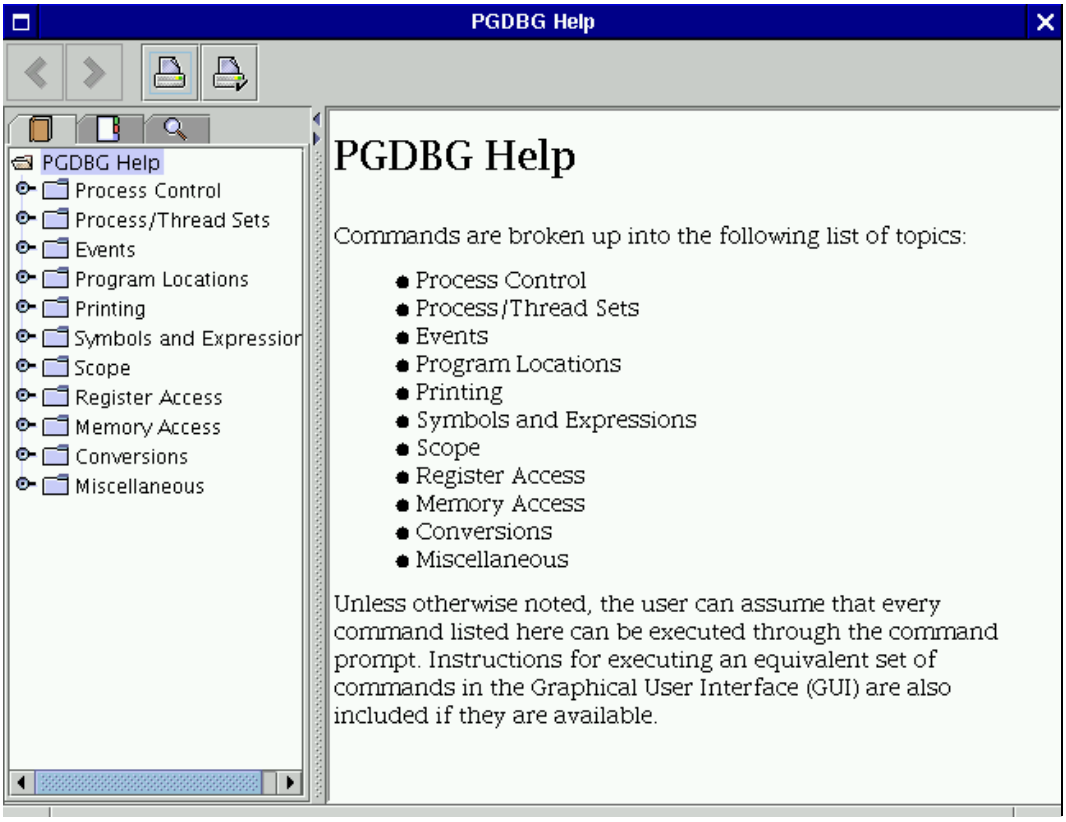
The main window includes three menus located at the top of the window: *File, Settings,* and *Help.* Below is a summary of each menu in the main window.

- **File Menu**
  - *Open Target…* – Select this option to begin a new debugging session. After selecting this option, select the program to debug (the *target*) from the file chooser dialog. The current target is closed and replaced with the target that you selected from the file chooser. Press the *Cancel* button in the file chooser to abort the operation. Also see the *debug* command in *Section 1.7.1.1 Process Control*.
  - *Attach to Target…* – Select this option to attach to a running process. You can attach to a target running on a local or a remote host. See also the *attach* command in *Section 1.7.1.1 Process Control.*
  - *Detach Target* – Select this option to end the current debug session. See also the *detach* command in *Section 1.7.1.1 Process Control*.
  - *Exit* – End the current debug session and close all the windows.
- **Settings Menu**
  - *Font…* – This option displays the font chooser dialog box. Use this dialog box to select the font and its size used in the *Command Prompt*, *Focus Panel*, and *Source Panel*. The default font is called *monospace* and the default size is 12.
  - *Show Tool Tips* – Select this check box to enable tool tips. Tool tips are small temporary messages that pop-up when you position the mouse pointer over a component in the GUI. They provide additional information on what a particular component does. Unselect this check box to turn them off.
  - *Restore Factory Settings* – Select this option to restore the GUI back to its initial state as shown in Figure 1-1.
  - *Restore Saved Settings* – Select this option to restore the GUI back to the state that it was in at the start of the debug session.
  - *Save Settings on Exit* – By default, the *PGDBG* will save the state (size and settings) of the GUI when you exit. Uncheck this option if you do not want the *PGDBG* to save the GUI state. You must uncheck this option every time you exit since PGDBG will always default to saving GUI state. When *PGDBG* saves state, it stores the size of the main window, the location of the main window on your desktop, the location of each control panel divider, your tool tips preference, the font and size used. The GUI state is not

shared across host machines.

- **Help Menu**
  - *PGDBG Help…* – This option starts up *PGDBG's* integrated help utility as shown in Figure 1-5. The help utility includes a summary of every *PGDBG* command. To find a command, use one of the following tabs in the left panel: The "book" tab presents a table of contents, the "index" tab presents an index of commands, and the "magnifying glass" tab presents a search engine. Each help page (displayed on the right) may contain hyperlinks (denoted in underlined blue) to terms referenced elsewhere in the help engine. Use the arrow buttons to navigate between visited pages. Use the printer buttons to print the current help page.
  - *About PGDBG…* – This option displays a dialog box with version and copyright information on *PGDBG*. It also contains sales and support points of contact.

Figure 1-5: *PGDBG* Help Utility



1.4.2 Source Panel

As described in S*ection 1.4.1.4 Source Panel,* the source panel is located at the bottom of the GUI; below the *Command Prompt, Focus Panel,* and *Process/Thread Grid*. Use the source panel to control the debug session, step through source files, set breakpoints, and browse source code. The source panel descriptions are divided into the following categories: *Menus, Buttons, Combo Boxes, Messages,* and *Events.*

1.4.2.1 Source Panel Menus

The source panel contains the following four menus: *Data, Window, Control, and Options*. In the descriptions below, keyboard shortcuts will be indicated by keystroke combinations (e.g., Control P) enclosed in parentheses.

- **Data Menu** – The items under this menu are enabled when a data item is selected in the source panel. Selecting and printing data in the source panel is explained in detail in S*ection 1.4.1.4 Source Panel*. See also *Section 1.7.1.5 Printing Variables.*
    - *Print* – Print the value of the selected item. (Control P).
    - *Print ** – Dereference and print the value of the selected item.
    - *String* – Treat the selected value as a string and print its value.
    - *Bin* – Print the binary value of the selected item.
    - *Oct* – Print the octal value of the selected item.
    - *Hex* – Print the hex value of the selected item.
    - *Dec* – Print the decimal value of the selected item.
    - *Ascii* – Print the ASCII value of the selected item.
    - *Addr* – Print the address of the selected item.
    - *Type Of* – Print data type information for the selected item.
- **Window Menu** – The items under this menu select various subwindows associated with the target application. Subwindows are explained in greater detail in *Section 1.4.3 Source Panel Pop-Up Menus.*
    - *Registers* – Display the registers subwindow. See also the *regs* command in *Section 1.7.1.8 Register Access.*
    - *Stack* – Display the stack subwindow. See also the *Stack* command in S*ection 1.7.1.4*

Program Locations.

- *Locals* – Display a list of local variables that are currently in scope. See also the *names* command in S*ection 1.7.1.7 Scope.*
- *Custom* – Bring up a custom subwindow.
- *Disassembler* – Bring up the *PGDBG* Disassembler subwindow.
- *Memory* – Bring up the memory dumper subwindow.
- *Messages* – Display the MPI message queues. See *Section* 1.16.3 MPI Message Queues for more information on MPI message queues.
- *Events* – Display a list of currently active break points, watch points, etc.
- *Command Window* – When this menu item's check box is selected, the GUI will display a "free floating" version of the command prompt window (*Section 1.12.1 Command Prompt*). See also *Section 1.6 Commands Summary* for a description of each command that can be entered in the command prompt.

- **Control Menu** – The items under this menu control the execution of the target application. Many of the items under this menu have a corresponding button associated with them (see *Section 1.4.2.2 Source Panel Buttons*).
  - *Arrive* – Return the source pane to the current PC location. See the *arrive* command in *Section 1.7.1.4 Program Locations* (Control A).
  - *Up* – Enter scope of routine up one level in the call stack. See the *up* command in *Section 1.9.1.7 Scope* (Control U).
  - *Down* – Enter scope of routine down one level in the call stack. See the *down* command in *Section 1.9.1.7 Scope* (Control D).
  - *Run* – Run or Rerun the target application. See the *run* and *rerun* commands in *Section 1.7.1.1 Process Control* (Control R).
  - *Run Arguments* - Opens a dialog box that allows you to add or modify the target's runtime arguments.
  - *Halt* – Halt the running processes or threads. See the *halt* command in *Section 1.7.1.1 Process Control* (Control H).
  - *Call…* – Open a dialog box to request a routine to call. See *Section 1.7.1.6 Symbols and Expressions* for more information on the *call* command.

- *Cont* – Continue execution from the current location. See the *cont* command in *Section 1.7.1.1 Process Control* (Control G).
- *Step* – Continue and stop after executing one source line, stepping into called routines. See the *step* command in *Section 1.7.1.1 Process Control* (Control S).
- *Next* – Continue and stop after executing one source line, stepping over called routines. See the *next* command in *Section 1.7.1.1 Process Control* (Control N).
- *Step Out* – Continue and stop after returning to the caller of the current routine. See the *stepout* command in *Section 1.7.1.1 Process Control* (Control O).
- *Stepi* – Continue and stop after executing one machine instruction, stepping into called routines. See the *stepi* command in *Section 1.7.1.1 Process Control* (Control I).
- *Nexti* – Continue and stop after executing one machine instruction, stepping over called routines. See the *nexti* command in *Section 1.7.1.1 Process Control* (Control T).

- ***Options Menu*** – This menu contains additional items that assist in the debug process.
  - *Search Forward…* – Select this option to perform a forward keyword search in the source panel (Control F).
  - *Search Backward…* – Select this option to perform a backward keyword search in the source panel (Control B).
  - *Search Again* – Select this option to repeat the last keyword search that was performed on the source panel (Control E).
  - *Locate Routine…* – When this option is selected, *PGDBG* will query for the name of the routine that you wish to find. If *PGDBG* has symbol and source information for that routine, it will display the routine in the source panel. See also *Section 1.4.3 Source Panel Pop-Up Menus.*
  - *Set Breakpoint…* – When this option is selected, *PGDBG* will query for the name of a routine for setting a breakpoint. The GUI will then set a breakpoint at the first executable source line in the specified routine.
  - *Disassemble* – Disassemble the data selected in the source panel. See also *Section 1.4.3 Source Panel Pop-Up Menus*.
  - *Cascade Windows* – If one or more subwindows are open, this option can be used to automatically stack subwindows in the upper left-hand corner of the desktop (Control W).
  - *Refresh* – Repaint the process/thread grid and source panels (Control L).

1.4.2.2 Source Panel Buttons

There are nine buttons located above the source panel's menus. Below is a summary of each button.

- *Run* – Same as the *Run* item under the *Control* menu.
- *Halt* – Same as the *Halt* item under the *Control* menu.
- *Cont* – Same as the *Cont* item under the *Control* menu.
- *Next* – Same as the *Next* item under the *Control* menu.
- *Step* – Same as the *Step* item under the *Control* menu.
- *Stepo* **–** Same as the *Step Out* item under the *Control* menu.
- *Nexti* – Same as the *Nexti* item under the *Control* menu.
- *Stepi* – Same as the *Stepi* item under the *Control* menu.
- *Back* - Reset the source panel view to the current PC location (denoted by the left arrow icon under the *PC* column).

1.4.2.3 Source Panel Combo Boxes

Depending on the state of the debug session, the source panel may contain one or more combo boxes. A combo box is a combination text field and list component. In its *closed* or default state, it presents a text field of information with a small down arrow icon to its right. When the down arrow icon is selected by a left mouse click, the box *opens* and presents a list of choices that can be selected.

The source panel, as shown in Figure 1-3, contains five combo boxes labeled *All, Thread 0, omp.c, #0 main line: 12 in "omp.c" address: 0x4011f6,* and *Source*. These combo boxes are called the *Apply Selector, Context Selector, Source File Selector, Scope Selector,* and *Display Mode Selector* respectively. Below is a description of each combo box.

- Use the *Apply Selector* to select the set of processes and/or threads on which to operate. Any command entered in the source panel will be applied to this set of processes/threads. These commands include setting break points, selecting items under the *Control* menu, pressing one of the nine buttons mentioned in *Section 1.12.2.2 Buttons*, and so on. Depending on whether you are debugging a multi-threaded, multi-process, or multi-process/multi-threaded (hybrid) target, the following options are available:
  - *All* – All processes/threads receive commands entered in the source panel (default).

- *Current Thread* – Commands are applied to the current thread ID only.
- *Current Process* – Commands are applied to all threads that are associated with the current process.
- *Current Process.Thread* – Commands are applied to the current thread on the current process only.
- *Focus* – Commands are applied to the focus group selected in the *Focus Panel* (described in *Section 1.12.1 Main Window).* Refer to *Section 1.14.5 Process/Thread Sets* for more information on this advanced feature.

This combo box is not displayed when debugging a serial program.

The function of the *Context Selector* is the same as for the *Process/Thread Grid*; it is used to change the current *Process*, *Thread*, or *Process.Thread* ID currently being debugged. This combo box is not displayed when debugging a serial program.

By default, the *Source File Selector* displays the source file that contains the current target location. It can be used to select another file for viewing in the *Source Panel*. When this combo box is closed, it displays the name of the source file displayed in the *Source Panel.* To select a different source file, open the combo box and select a file from the list. If the source file is available, the source file will appear in the *Source Panel.*

The *Scope Selector* displays the *scope* of the current Program Counter (PC). Open the combo box and select a different scope from the list or use the up and down buttons located on the right of the combo box. The *up* button is equivalent to the *up* debugger command and the *down* button is equivalent to the *down* debugger command. See *Section 1.9.1.7 Scope* for more information on the *up* and *down* commands.

The *Display Mode Selector* is used to select three different source display modes: *Source, Disassembly,* and *Mixed.* The *Source* mode shows the source code of the current source file indicated by the *File Selector*. This is the default display mode if the source file is available. The *Disassembly* mode shows the machine instructions of the current routine. This is the default display mode if the source file is not available. The *Mixed* mode shows machine instructions annotated with source code. This mode is available only if the source file is available.

1.4.2.4 Source Panel Messages

The source panel contains two message areas. The top center indicates the current process/thread ID (e.g., *Thread 0* in Figure 1-6) and the bottom left displays status messages (e.g., *Stopped at line 11…* in Figure 1-6).

1.4.2.5 Source Panel Events

Events, such as breakpoints, are displayed under the *Event* column in the source panel. The source panel only displays breakpoint events. The stop sign icon denotes a breakpoint. Breakpoints are added through the source panel by clicking the left mouse button on the desired source line under the *Event* column. click the left mouse button over a stop sign to delete the corresponding breakpoint. Select the *Events* item under the *Window* menu to view a global list of *Events* (e.g., breakpoints, watch points, etc.).

1.4.3 Source Panel Pop-Up Menus

The PGDBG source panel supports two pop-up menus to provide quick access to commonly used features. One pop-up menu is used to invoke subwindows. It is accessed using a right mouse-click in a blank or vacant area of the source panel. See *Section 1.4.4 Subwindows* for more information on invoking subwindows using a pop-up menu.

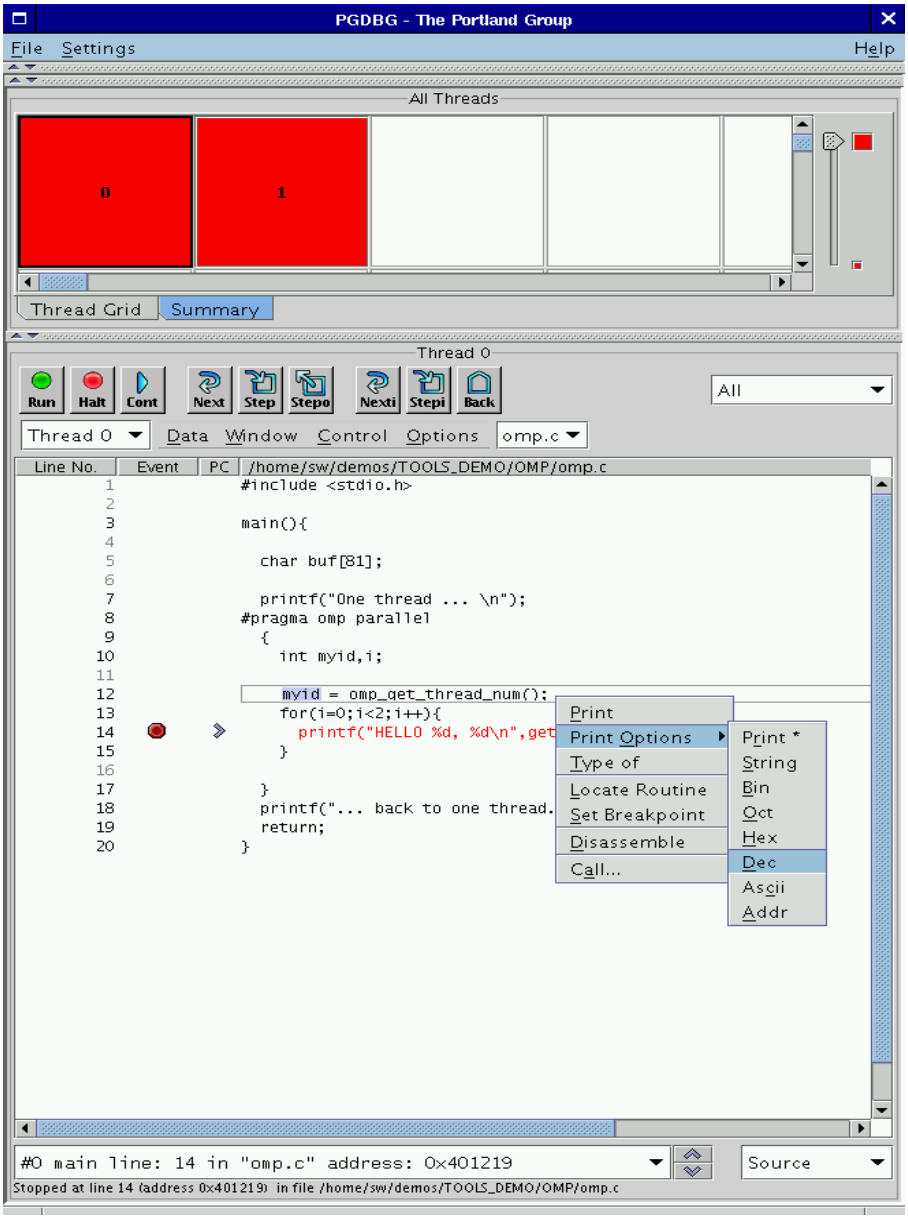
The other pop-up menu is accessed by first highlighting some text in the source panel, then using a right mouse click to bring up the menu. The selections offered by this pop-up menu take the selected text as input.

To select text in the source panel, first click on the line of source containing the text. This will result in the display of a box surrounding the source line. Next, hold down the left mouse button and drag the cursor, or mouse pointer, across the text to be selected. The text should then be highlighted.

Once the text is highlighted, menu selections from the Source Panel menus or from the Source Panel pop-up menu will use the highlighted text as input. In Figure 1-11, the variable `myid` has been highlighted and the pop-up menu is being used to print its value as a decimal integer. The data type of selected data items may also be displayed using the pop-up menu.

The pop-up menu provides the *Disassemble, Call,* and *Locate* selections, which use selected routine names as input. The *Disassemble* item opens a disassembler subwindow for the selected routine. The *Call* item can be used to manually call the selected routine. The *Locate* option displays the source code in which the selected routine is defined. Please see the description for each of these items in S*ection 1.4.2.1 Source Panel Menus* for more information.

Figure 1-11: Data Pop-up Menu

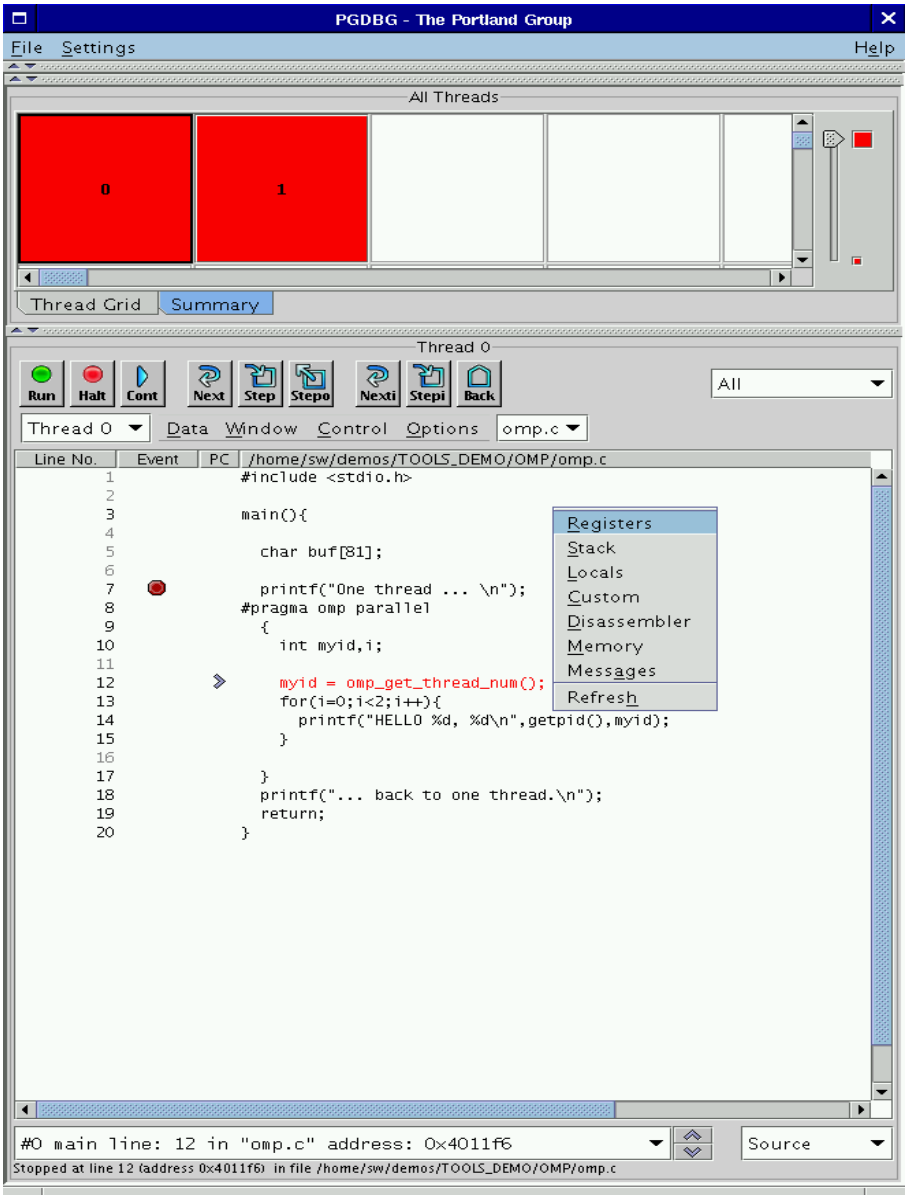


1.4.4 Subwindows

A subwindow is defined as any *PGDBG* GUI component that is not embedded in the main window described in *Section 1.12.1 Main Window*. One example of a subwindow is the *Program I/O* window introduced in Figure 1-2. Other examples of subwindows can be found under the source panel's *Window* menu. These include the *Registers, Stack, Locals, Custom, Disassembler, Memory, Messages, Events,* and *Command Window* subwindows. With the exception of the *Command Window*, all of these subwindows are controlled by similar mechanisms. The standard subwindow control mechanisms are described in *Section 1.4.4.1 Memory Subwindow*. Specific details of other subwindows are described in subsequent sections. See the description of the *Window* menu, S*ection 1.4.2.1 Source Panel Menus,* for more information on each subwindow.

The *Window* menu can be used to to bring up a subwindow. An alternative mechanism is to click the right mouse button over a blank spot in the source panel to invoke a pop-up menu (Figure 1-6), which can be used to select a subwindow. The subwindow that gets displayed is specific to the current process and/or thread. For example, in Figure 1-6, selecting *Registers* will display the registers for thread 0, which is the current thread.

Figure 1-6: Opening a Subwindow with a Pop-up Menu



1.4.4.1 Memory Subwindow

Figure 1-7 shows the memory subwindow. The memory subwindow displays a region of memory using a *printf*-like format descriptor. It is essentially a graphical interface to the debugger *dump* command (*Section 1.9.1.9 Memory Access).*

This subwindow shows all of the possible controls that are available in a subwindow. Not all subwindows will have all of the components shown in this figure. However, nearly all will have the following components: *File* menu, *Options* menu, *Reset* button, *Close* Button, *Update* button, and the *Lock/Unlock* toggle button.

The *File* menu contains the following items:

- *Save…* – Save the text in this subwindow to a file.
- *Close* – Close the subwindow.

The *Options* menu contains the following items:

- *Update* – Clear and regenerate the data displayed in the subwindow.
- *Stop* – Interrupt processing. This option comes in handy during long listings that can occur in the *Disassembler* and *Memory* subwindows. Control C is a hot key mapped to this menu item.
- *Reset* – Clear the subwindow.

The *Reset*, *Close*, and *Update* buttons are synonymous with their menu item counterparts mentioned above.

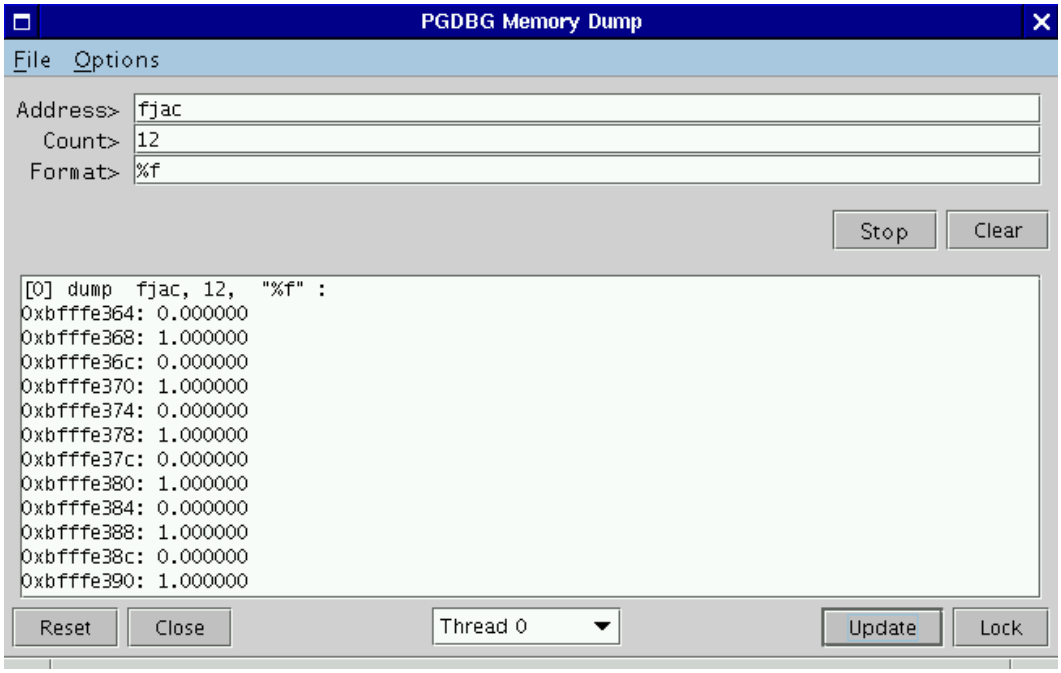
The *Lock/Unlock* button, located in the lower right hand corner of a subwindow, toggles between a lock and an unlock state. Figure 1-7 shows this button in an unlocked state with the button labeled *Lock.* Figure 1-8 shows this button in a locked state, with the button labeled *Unlock.* When the *Lock/Unlock* button is in its unlocked state, subwindows will update themselves whenever a process or thread halts. This can occur after a *step, next,* or *cont* command. To preserve the contents of a subwindow, click the left mouse button on the *Lock* button to lock the display in the subwindow. Figure 1-8 shows an example of a locked subwindow. Note that some of the controls in Figure 1-8 are disabled (grayed-out). After locking a subwindow, *PGDBG* will disable any controls that affect the display until the subwindow is unlocked. To unlock the subwindow, click the *Unlock* button. The toggle button will change to *Lock* and *PGDBG* will re-enable the other controls.

Besides the memory subwindow capabilities described above, subwindows may also have one to three input fields. In the *Memory* subwindow, enter the starting *address* in the *Address* field, the number of items in the *Count* field, and a *printf*-like format string in the *Format* field.

If the subwindow has one or more input fields, then they also contain *Stop* and *Clear* buttons. The *Stop* button is synonymous with the *Stop* item in the *Options* menu described above. The C*lear* button erases the input field(s).

For target applications with more than one process and/or thread, a *Context Selector* displays in the bottom center as shown in Figure 1-7. The *Context Selector* can be used to view data specific to a particular process/thread or a subset of process/threads when selecting *Focus.* Refer to *Section 1.15.5 Process/Thread Sets* for more information on *Focus*.

Figure 1-7: Memory Subwindow

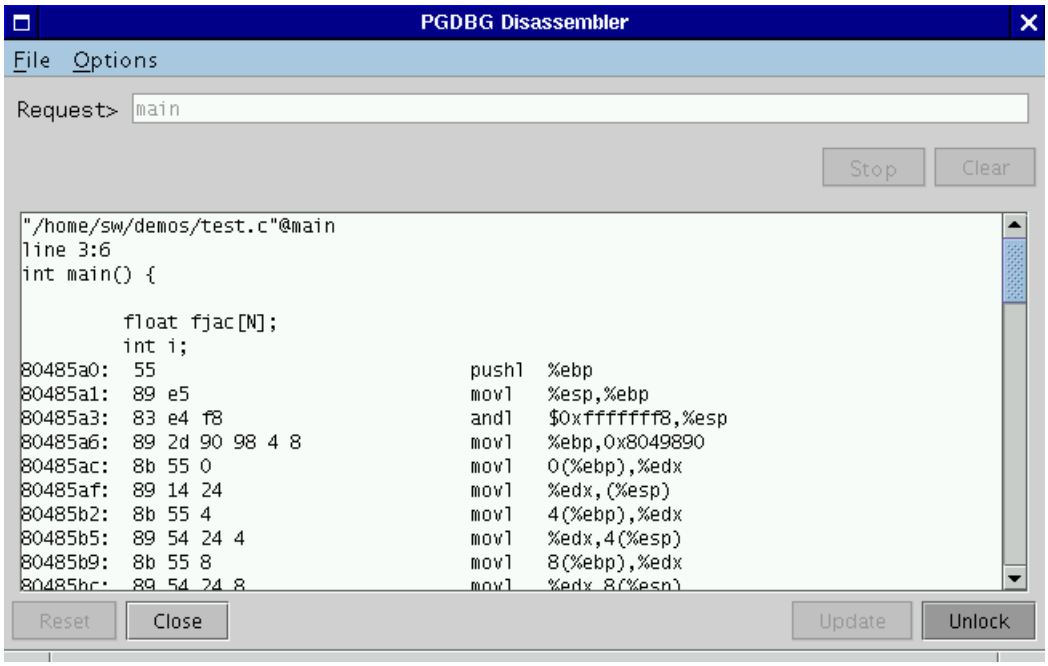


1.4.4.2 Disassembler Subwindow

Figure 1-8 shows the *Disassembler* subwindow. Use this subwindow to disassemble a routine (or a text address) specified in the *Request>* input field. *PGDBG* will default to the current routine if you specify nothing in the *Request>* input field. After a request is made to the *Disassembler*, the GUI will ask if you want to "Display Disassembly in the Source window". Choosing "yes" causes the *Disassembler* window to disappear and the disassembly to appear in the source panel. Viewing the disassembly in the source panel, allows setting breakpoints at the machine instruction level. Choosing "no" will dump the disassembly in the *Disassembler* subwindow as shown in Figure 1-8.

Specifying a text address (rather than a routine name) in the *Request>* field will cause *PGDBG* to disassemble address locations until it runs out of memory or hits an invalid op code. This may cause very large machine language listings. For that case, the subwindow provides a *Stop* button. Press the *Stop* button to interrupt long listings that may occur with the *Disassembler*. Specify a count after the text address to limit the number of instructions dumped to the subwindow. For example, entering 0xabcdef, 16 tells *PGDBG* to dump up to 16 locations following address 0xabcdef. The *Request>* field accepts the same arguments as the *disasm* command described in S*ection 1.9.1.4 Program Locations*.

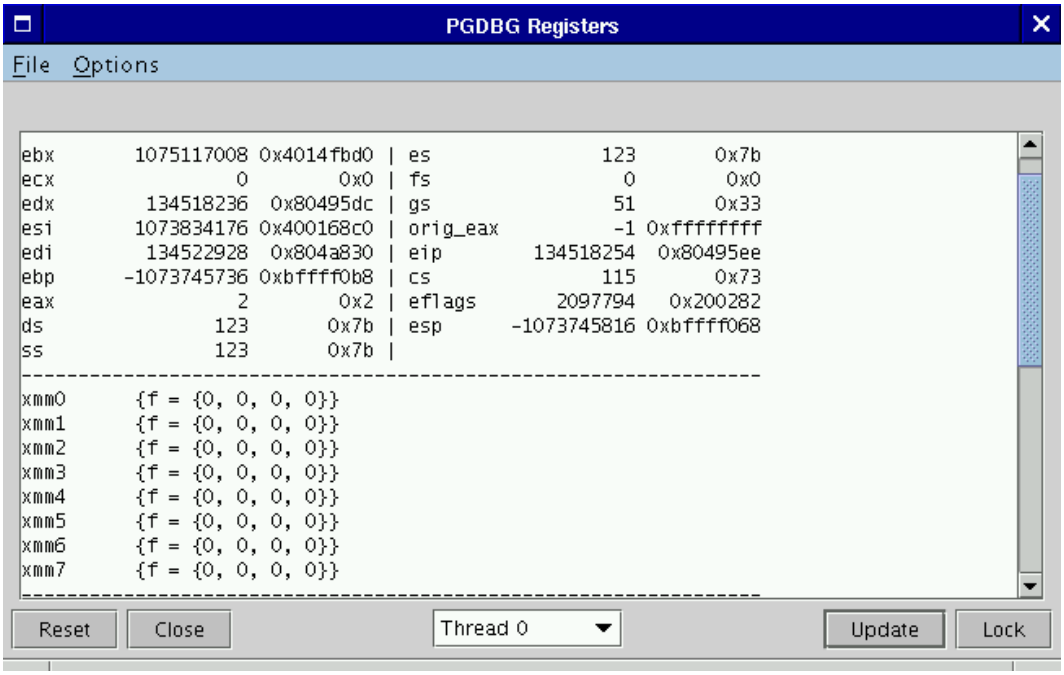
Figure 1-8: Disassembler Subwindow



1.4.4.3 Registers Subwindow

Figure 1-9 illustrates the *Registers* subwindow. As mentioned earlier, view the registers on one or more processes and threads using the *Context Selector*. The *Registers* subwindow is essentially a graphical representation of the *regs* debugger command (see *Section 1.7.1.8 Register Access*).

Figure 1-9: Registers Subwindow



1.4.4.4 Custom Subwindow

Figure 1-10 illustrates the *Custom* subwindow. The *Custom* subwindow is useful for repeatedly executing a sequence of debugger commands whenever a process/thread halts on a new location or when pressing the *Update* button. The commands, entered in the control panel, can be any debugger command mentioned in *Section 1.6 Commands Summary*.

Figure 1-10: Custom Subwindow

1.4.4.5 Messages Subwindow

Figure 1-14 (in *section 1.17.3*) illustrates the *Messages* subwindow. Refer to S*ection 1.17.3 MPI Message Queues* for more information on the content of this subwindow.

1.5 *PGDBG* Command Language

PGDBG supports a powerful command language, capable of evaluating complex expressions. The command language can be used by invoking the *PGDBG* command line interface with the –text option, or in the command panel of the *PGDBG* graphical user interface. The next three sections of this manual provide information about how to use this command language. See *Section 1.4 PGDBG Graphical User Interface* for instructions on using the *PGDBG* GUI.

Commands are entered one line at a time. Lines are delimited by a carriage return. Each line must consist of a command and its arguments, if any. The command language is composed of commands, constants, symbols, locations, expressions, and statements.

Commands are named operations, which take zero or more arguments and perform some action. Commands may also return values that may be used in expressions or as arguments to other commands.

There are two command modes: *pgi* and *dbx*. The *pgi* command mode maintains the original *PGDBG* command interface. In *dbx* mode, the debugger uses commands compatible with the familiar *dbx* debugger. *Pgi* and *dbx* commands are available in both command modes, but some command behavior may be slightly different depending on the mode. The mode can be set when PGDBG is invoked by using command line options, or while the debugger is running by using the *pgienv* command.

1.5.1 Constants

PGDBG supports *C* language style integer (hex, octal and decimal), floating point, character, and string constants.

1.5.2 Symbols

PGDBG uses the symbolic information contained in the executable object file to create a symbol table for the target program. The symbol table contains symbols to represent source files, subprograms (functions, and subroutines), types (including structure, union, pointer, array, and enumeration types), variables, and arguments. The *PGDBG* command line interface is case-sensitive with respect to symbol names; a symbol name on the command line must match the name as it appears in the object file.

1.5.3 Scope Rules

Since several symbols in a single application may have the same name, scope rules are used to

bind program identifiers to symbols in the symbol table. *PGDBG* uses the concept of a *search scope* for looking up identifiers. The *search scope* represents a routine, a source file, or global scope. When the user enters a name, *PGDBG* first tries to find the symbol in the search scope. If the symbol is not found, the containing scope, (source file, or global) is searched, and so forth, until either the symbol is located or the global scope is searched and the symbol is not found.

Normally, the search scope will be the same as the *current scope*, which is the routine where execution is currently stopped. The current scope and the search scope are both set to the current routine each time execution of the target program stops. However, the *enter* command can be used to change the search scope.

A scope qualifier operator `@` allows selection of out-of-scope identifiers. For example, if `f` is a routine with a local variable `i`, then:

```
f@i
```

represents the variable `i` local to `f`. Identifiers at file scope can be specified using the quoted file name with this operator, for example:

```
"xyz.c"@i
```

represents the variable `i` defined in file `xyz.c`.

1.5.4 Register Symbols

In order to provide access to the system registers, *PGDBG* maintains symbols for them. Register names generally begin with `$` to avoid conflicts with program identifiers. Each register symbol has a default type associated with it, and registers are treated like global variables of that type, except that their address may not be taken. See *Section 1.9 Register Symbols* for a complete list of the register symbols.

1.5.5 Source Code Locations

Some commands must refer to source code locations. Source file names must be enclosed in double quotes. Source lines are indicated by number, and may be qualified by a quoted filename using the scope qualifier operator.

Thus:

```
break 37
```

sets a breakpoint at line 37 of the current source file, and

```
break "xyz.c"@37
```

sets a breakpoint at line 37 of the source file `xyz.c`.

A range of lines is indicated using the range operator ":". Thus,

```
list 3:13
```

lists lines 3 through 13 of the current file, and

```
list "xyz.c"@3:13
```

lists lines 3 through 13 of the source file `xyz.c`.

Some commands accept both line numbers and addresses as arguments. In these commands, it is not always obvious whether a numeric constant should be interpreted as a line number or an address. The description for these commands says which interpretation is used. However, PGDBG provides commands to convert from source line to address and vice versa. The *line* command converts an address to a line, and the *addr* command converts a line number to an address. For example:

```
{line 37}
```

means "line 37",

```
{addr 0x1000}
```

means "address 0x1000" , and

```
{addr {line 37}}
```

means "the address associated with line 37" , and

```
{line {addr 0x1000}}
```

means "the line associated with address `0x1000`".

1.5.6 Lexical Blocks

Line numbers are used to name lexical blocks. The line number of the first instruction contained by a lexical block is used to indicate the start scope of the lexical block.

In the example below, there are two variables named ***var.*** One is declared in function main, and the other is declared in the lexical block starting at line 5. The lexical block has the unique name ***"lex.c"@main@5***. The variable ***var*** declared in ***"lex.c"@main@5*** has the unique name ***"lex.c"@main@5@var***. The output of the *whereis* command below shows how these identifiers can be distinguished.

```
lex.c:

1     main()
2     {
3         int var = 0;
4         {
5             int var = 1;
6             printf("var %d\n",var);
7         }
8         printf("var %d\n",var)
9     }
pgdbg> n
Stopped at 0x8048b10, function main, file
/home/demo/pgdbg/ctest/lex.c, line 6
#6:          printf("var %d\n",var);
pgdbg> print var
1
pgdbg> which var
"lex.c"@main@5@var
pgdbg> whereis var
variable:       "lex.c"@main@var
```

```
variable:       "lex.c"@main@5@var
pgdbg> names "lex.c"@main@5
var = 1
```

1.5.7 Statements

Although *PGDBG* command line input is processed one line at a time, *statement* constructs allow multiple commands per line, as well as conditional and iterative execution. The statement constructs roughly correspond to the analogous *C* language constructs. Statements may be of the following forms.

Simple Statement: A command and its arguments. For example:

```
print i
```

Block Statement: One or more statements separated by semicolons and enclosed in curly braces. ***Note:*** these may only be used as arguments to commands or as part of **if** or **while** statements. For example:

```
if(i>1) {print i; step }
```

If Statement: The keyword *if*, followed by a parenthesized expression, followed by a block statement, followed by zero or more *else if* clauses, and at most one *else* clause. For example:

```
if(i>j) {print i} else if(i<j) {print j} else {print "i==j"}
```

While Statement: The keyword **while,** followed by a parenthesized expression, followed by a block statement. For example:

```
while(i==0) {next}
```

Multiple statements may appear on a line separated by a semicolon. For example:

```
break main; break xyz; cont; where
```

sets breakpoints in routines *main* and *xyz*, continues, and prints the new current location. Any value returned by the last statement on a line is printed.

Statements can be parallelized across multiple threads of execution. See *Section 1.14.17 Parallel Statements* for details.

1.5.8 Events

Breakpoints, watchpoints and other mechanisms used to define the response to certain conditions, are collectively called *events*.

- An event is defined by the conditions under which the event occurs, and by the action taken when the event occurs.
- A breakpoint occurs when execution reaches a particular address. The default action for a breakpoint is simply to halt execution and prompt the user for commands.
- A watchpoint occurs when the value of an expression changes.
- A hardware watchpoint occurs when the specified memory location is accessed or modified.

The default action is to print the new value of the expression, and prompt the user for commands. By adding a location, or a condition, the event can be limited to a particular address or routine, or may occur only when the condition is true. The action to be taken when an event occurs can be defined by specifying a command list.

PGDBG supports five basic commands for defining events. Each command takes a required argument and may also take one or more optional arguments. The basic commands are *break*, *watch*, *hwatch*, *track* and *do*. The command *break* takes an argument specifying a breakpoint location. Execution stops when that location is reached. The *watch* command takes an expression argument. Execution stops and the new value is printed when the value of the expression changes. The *hwatch* command takes a data address argument (this can be an identifier or variable name). Execution stops when memory at that address is written.

The *track* command is like *watch* except that execution continues after the new value is printed. The *do* command takes a list of commands as an argument. The commands are executed whenever the event occurs.

The optional arguments bring flexibility to the event definition. They are:

`at` *`line`* Event occurs at indicated line.

`at` *`addr`* Event occurs at indicated address.

`in` *`routine`* Event occurs throughout indicated routine.

`if (`*`condition`*`)`
Event occurs only when condition is true.

`do {`*`commands`*`}`
When event occurs execute commands.

The optional arguments may appear in any order after the required argument and should not be delimited by commas.

For example:

```
watch i at 37 if(y>1)
```

This event definition says that whenever execution is at line 37, and the value of `i` has changed since the last time execution was at line 37, and `y` is greater than 1, stop and print the new value of `i`.

```
do {print xyz} in f
```

This event definition says that at each line in the routine `f` print the value of `xyz`.

```
break func1 if (i==37) do {print a[37]; stack}
```

This event definition says that each time the routine `func1` is entered and `i` is equal to 37, then the value of `a[37]` should be printed, and a stack trace should be performed.

Event commands that do not explicitly define a location will occur at each source line in the program. For example:

```
do {where}
```

prints the current location at the start of each source line, and

```
track a.b
```

prints the value of `a.b` at the start of each source line if the value has changed.

Events that occur at every line can be useful, but to perform them requires single-stepping the target program (this may slow execution considerably). Restricting an event to a particular address causes minimal impact on program execution speed, while restricting an event to a single routine causes execution to be slowed only when that routine is executed.

PGDBG supports instruction level versions of several commands (for example *breaki*, *watchi*, *tracki*, and *doi*). The basic difference in the instruction version is that these commands will interpret integers as addresses rather than line numbers, and events will occur at each instruction rather than at each line.

When multiple events occur at the same location, all event actions will be taken before the prompt for input. Defining event actions that resume execution is allowed but discouraged, since continuing execution may prevent or defer other event actions. For example:

```
break 37 do {continue}
```

```
break 37 do {print i}
```

This creates an ambiguous situation. It's not clear whether `i` should ever be printed.

Events only occur after the *continue* and *run* commands. They are ignored by *step*, *next*, *call*, and other commands.

Identifiers and line numbers in events are bound to the current scope when the event is defined.

For example:

```
break 37
```

sets a breakpoint at line 37 in the current file.

```
track i
```

will track the value of whatever variable `i` is currently in scope. If `i` is a local variable then it is wise to add a location modifier (*at* or *in*) to restrict the event to a scope where `i` is defined.

Scope qualifiers can also specify lines or variables that are not currently in scope. Events can be parallelized across multiple threads of execution. See *Section 1.14.16 Parallel Events* for details.

1.5.9 Expressions

The debugger supports evaluation of expressions composed of constants, identifiers, commands that return values, and operators. Table 1-2 shows the *C* language operators that are supported. The operator precedence is the same as in the *C* language.

To use a value returned by a command in an expression, the command and arguments must be enclosed in curly braces. For example:

```
break {pc}+8
```

invokes the pc command to compute the current address, adds 8 to it, and sets a breakpoint at that address. Similarly, the following command compares the start address of the current routine with the start address of routine `xyz`. It prints the value 1 if they are equal and 0 if they are not.

```
print {addr {func}}=={addr xyz}
```

The `@` operator, introduced previously, may be used as a scope qualifier. Its precedence is the same as the *C* language field selection operators "`.`", and "`->`" .

PGDBG recognizes a range operator ":" which indicates array sub-ranges or source line ranges.

For example,

```
print a[1:10]
```

prints elements 1 through 10 of the array `a`, and

```
list 5:10
```

lists source lines 5 through 10, and

```
list "xyz.c"@5:10
```

lists lines 5 through 10 in file `xyz.c`. The precedence of ':' is between '||' and '='.

The general format for the range operator is [*lo* : *hi* : *step*] where:

lo	is the array or range lower bound for this expression.
hi	is the array or range upper bound for this expression.
step	is the step size between elements.

An expression can be evaluated across many threads of execution by using a prefix p/t-set. See *Section 1.14.8 Current vs. Prefix P/t-set* for details.

Table 1-2: *PGDBG* Operators

Operator	Description	Operator	Description
*	indirection	<=	less than or equal
.	direct field selection	>=	greater than or equal
->	indirect field selection	!=	not equal
[ ]	``C'' array index	&&	logical and
()	routine call	||	logical or
&	address of	!	logical not
+	add	|	bitwise or
(type)	cast	&	bitwise and
-	subtract	~	bitwise not
/	divide	^	bitwise exclusive or

Operator	Description	Operator	Description
*	multiply	<<	left shift
=	assignment	>>	right shift
==	comparison	()	FORTRAN array index
<<	left shift	%	FORTRAN field selector
>>	right shift		

1.6 Commands Summary

This section contains a brief summary of the *PGDBG* debugger commands. For more detailed information on a command, see the section number associated with the command. If you are viewing an online version of this manual, select the hyperlink under the selection category to jump to that section in the manual.

Table 1-3: *PGDBG* Commands

Name	Arguments	Section
`arri[ve]`		1.7.1.4 Program Locations
`att[ach]`	<pid> [<exe>] | [<exe> <host>]	1.7.1.1 Process Control
`ad[dr]`	[*n* | *line* | *func* | *var* | *arg*]	1.7.1.10 Conversions
`al[ias]`	[*name* [*string*]]	1.7.1.11 Miscellaneous
`asc[ii]`	*exp* [,...*exp*]	1.7.1.5 Printing Variables
`as[sign]`	*var=exp*	1.7.1.6 Symbols and Expressions
`bin`	*exp* [,...*exp*]	1.7.1.5 Printing Variables
`b[reak]`	[*line* | *func*] [if (*condition*)] [do {*commands*}]	1.7.1.3 Events

Name	Arguments	Section
`breaki`	[*addr* | *func*] [if (*condition*)] [do {*commands*}]	1.7.1.3 Events
`breaks`		1.7.1.3 Events
`call`	*func* [(*exp*,...)]	1.7.1.6 Symbols and Expressions
`catch`	[*number* [,*number*...]]	1.7.1.3 Events
`cd`	[*dir*]	1.7.1.4 Program Locations
`clear`	[all | *func* | *line* | addr {*addr*}]	1.7.1.3 Events
`c[ont]`		1.7.1.1 Process Control
`cr[ead]`	*addr*	1.7.1.9 Memory Access
`de[bug ]`		1.7.1.1 Process Control
`dec`	*exp* [,...*exp*]	1.7.1.5 Printing Variables
`decl[aration]`	*name*	1.7.1.6 Symbols and Expressions
`decls`	[*func* | "*sourcefile*" | {global}]	1.7.1.7 Scope
`del[ete]`	*event-number* | all | 0 | *event-number* [,*.event-number*.]	1.7.1.3 Events
`det[ach`		1.7.1.1 Process Control
`dir[ectory]`	[*pathname*]	1.7.1.11 Miscellaneous
`dis[asm]`	[*count* | *lo*:*hi* | *func* | *addr*, *count*]	1.7.1.4 Program Locations
`disab[le]`	*event-number* | all	1.7.1.3 Events

Name	Arguments	Section
`display`	*exp* [,...*exp*]	1.7.1.5 Printing Variables
`do`	{*commands*} [at *line* | in *func*] [if (*condition*)]	1.7.1.3 Events
`doi`	{*commands*} [at *addr* | in *func*] [if (*condition*)]	1.7.1.3 Events
`down`		1.7.1.7 Scope
`defset`	*name* [p/t-set]	1.7.1.2 Process-Thread Sets
`dr[ead]`	*addr*	1.7.1.9 Memory Access
`du[mp]`	*address*, *count*, "format-string"	1.7.1.9 Memory Access
`edit`	[*filename* | *func*]	1.7.1.4 Program Locations
`enab[le]`	*event-number* | all	1.7.1.3 Events
`en[ter]`	*func* | "*sourcefile*" | {global}	1.7.1.7 Scope
`entr[y]`	*func*	1.7.1.6 Symbols and Expressions
`fil[e]`		1.7.1.4 Program Locations
`files`		1.7.1.7 Scope
`focus`	[p/t-set]	1.7.1.2 Process-Thread Sets
`fp`		1.7.1.8 Register Access
`fr[ead]`	*addr*	1.7.1.9 Memory Access

Name	Arguments	Section
`func[tion]`	[*addr* | *line*]	1.7.1.10 Conversions
`glob[al]`		1.14.10.3 Global Commands
`halt`	[*command*]	1.7.1.1 Process Control
`he[lp]`		1.7.1.11 Miscellaneous
`hex`	*exp* [,...*exp*]	1.7.1.5 Printing Variables
`hi[story]`	[*num*]	1.7.1.11 Miscellaneous
`hwatch`	*addr* [if (*condition*)] [do {*commands*}]	1.7.1.3 Events
`hwatchb[oth]`	*addr* [if (*condition*)] [do {*commands*}]	1.7.1.3 Events
`hwatchr[ead]`	*addr* [if (*condition*)] [do {*commands*}]	1.7.1.3 Events
`ignore`	[*number* [,*number*...]]	1.7.1.3 Events
`ir[ead]`	*addr*	1.7.1.9 Memory Access
`language`		1.7.1.11 Miscellaneous
`lin[e]`	[*n* | *func* | *addr*]	1.7.1.10 Conversions
`lines`	*routine*	1.7.1.4 Program Locations
`lis[t]`	[*count* | *line*,*count* | *lo*:*hi* | *routine*]	1.7.1.4 Program Locations
`log`	*filename*	1.7.1.11 Miscellaneous
`lv[al]`	*exp*	1.7.1.6 Symbols and Expressions
`mq[dump]`		1.7.1.9 Memory Access

Name	Arguments	Section
`names`	[*func* | "*sourcefile*" | {global}]	1.7.1.7 Scope
`n[ext]`	[*count*]	1.7.1.1 Process Control
`nexti`	[*count*]	1.7.1.1 Process Control
`nop[rint]`	*exp*	1.7.1.11 Miscellaneous
`oct`	*exp* [,...*exp*]	1.7.1.5 Printing Variables
`pc`		1.7.1.8 Register Access
`pgienv`	[*command*]	1.7.1.11 Miscellaneous
`p[rint]`	*exp1* [,...*expn*]	1.7.1.5 Printing Variables
`printf`	"*format_string*", *expr*,...*expr*	1.7.1.5 Printing Variables
`proc`	[*number*]	1.7.1.1 Process Control
`procs`		1.7.1.1 Process Control
`pwd`		1.7.1.4 Program Locations
`q[uit]`		1.7.1.1 Process Control
`regs`		1.7.1.8 Register Access
`rep[eat]`	[*first, last*] | [*first*: *last*:*n*] | [*num*] | [-*num*]	1.7.1.11 Miscellaneous
`rer[un]`	[*arg0 arg1 ... argn*] [< *inputfile*] [> *outputfile*]	1.7.1.1 Process Control
`ret[addr]`		1.7.1.8 Register Access
`ru[n]`	[*arg0 arg1 ... argn*] [< *inputfile*] [> *outputfile*]	1.7.1.1 Process Control

Name	Arguments	Section
`rv[al]`	*expr*	1.7.1.6 Symbols and Expressions
`sco[pe]`		1.7.1.7 Scope
`scr[ipt]`	*filename*	1.7.1.11 Miscellaneous
`set`	*var* = *ep*	1.7.1.6 Symbols and Expressions
`setenv`	*name* | *name value*	1.7.1.11 Miscellaneous
`sh[ell]`	*arg0* [... *argn*]	1.7.1.11 Miscellaneous
`siz[eof]`	*name*	1.7.1.6 Symbols and Expressions
`sle[ep]`	*time*	1.7.1.11 Miscellaneous
`source`	*filename*	1.7.1.11 Miscellaneous
`sp`		1.7.1.8 Register Access
`sr[ead]`	*addr*	1.7.1.9 Memory Access
`stackd[ump]`	[*count*]	1.7.1.4 Program Locations
`stack[trace]`	[*count*]	1.7.1.4 Program Locations
`stat[us]`		1.7.1.3 Events
`s[tep]`	[*count*] [up]	1.7.1.1 Process Control
`stepi`	[*count*] [up]	1.7.1.1 Process Control
`stepo[ut]`		1.7.1.1 Process Control

Name	Arguments	Section
`stop`	[at *line* | in *func*] [*var*] [if (*condition*)] [do {*commands*}]	1.7.1.3 Events
`stopi`	[at *addr* | in *func*] [*var*] [if (*condition*)] [do {*commands*}]	1.7.1.3 Events
`sync`	[*func* | *line*]	1.7.1.1 Process Control
`synci`	[*func* | *addr*]	1.7.1.1 Process Control
`str[ing]`	*exp* [,...*exp*]	1.7.1.5 Printing Variables
`thread`	*number*	1.7.1.1 Process Control
`threads`		1.7.1.1 Process Control
`track`	*expression* [at *line* | in *func*] [if (*condition*)] [do {*commands*}]	1.7.1.3 Events
`tracki`	*expression* [at *addr* | in *func*] [if (*condition*)] [do {*commands*}]	1.7.1.3 Events
`trace`	[at *line* | in *func*] [*var*| *func*] [if (*condition*)] do {*commands*}	1.7.1.3 Events
`tracei`	[at *addr* | in *func*] [*var*] [if (*condition*)] do {*commands*}	1.7.1.3 Events
`type`	*expr*	1.7.1.6 Symbols and Expressions
`unal[ias]`	*name*	1.7.1.11 Miscellaneous
`undefset`	[*name* | *-all*]	1.7.1.2 Process-Thread Sets
`undisplay`	[all | 0 | *exp*]	1.7.1.5 Printing Variables
`unb[reak]`	*line* | *func* | all	1.7.1.3 Events

Name	Arguments	Section
`unbreaki`	*addr* | *func* | all	1.7.1.3 Events
`up`		1.7.1.7 Scope
`use`	[*dir*]	1.7.1.11 Miscellaneous
`viewset`	*name*	1.7.1.2 Process-Thread Sets
`wait`	[any | all | none]	1.7.1.1 Process Control
`wa[tch]`	*expression* [at *line* | in *func*] [if (*condition*)] [do {*commands*}]	1.7.1.3 Events
`watchi`	*expression* [at *addr* | in *func*] [if(*condition*)] [do {*commands*}]	1.7.1.3 Events
`whatis`	[*name*]	1.7.1.6 Symbols and Expressions
`when`	[at *line* | in *func*] [if (*condition*)] do {*commands*}	1.7.1.3 Events
`wheni`	[at *addr* | in *func*] [if(*condition*)] do {*commands*}	1.7.1.3 Events
`w[here]`	[*count*]	1.7.1.4 Program Locations
`whereis`	*name*	1.7.1.7 Scope
`whichsets`	[p/t-set]	1.7.1.2 Process-Thread Sets
`which`	*name*	1.7.1.7 Scope
`/`	/ [*string*] /	1.7.1.4 Program Locations

Name	Arguments	Section
?	**?**[*string*] **?**	1.7.1.4 Program Locations
!	History modification	1.7.1.11 Miscellaneous
^	History modification	1.7.1.11 Miscellaneous

1.7 *PGDBG* Command Reference

This section describes the *PGDBG* command set in detail.

1.7.1 Notation Used in this Section

Command names may be abbreviated by omitting the portion of the command name enclosed in brackets ([]).. Some commands accept a variety of arguments. Arguments enclosed in brackets(`[]`) are optional. Two or more arguments separated by a vertical line (`|`) indicate that any one of the arguments is acceptable. An ellipsis (`. . .`) indicates an arbitrarily long list of arguments. Other punctuation (commas, quotes, etc.) should be entered as shown. Argument names appear in italics and are chosen to indicate what kind of argument is expected. For example:

```
lis[t] [count | lo:hi | routine | line,count]
```

indicates that the command *list* may be abbreviated to *lis*, and that it can be invoked without any arguments or with one of the following: an integer count, a line range, a routine name, or a line and a count.

1.7.1.1 Process Control

The following commands, together with the breakpoints described in the next section, control the execution of the target program. *PGDBG* lets you easily group and control multiple threads and processes. See *Section 1.14.11 Process and Thread Control* for more details.

```
att[ach] <pid>[ <exe>] | [ <exe> <host>]
```

Attach to a running process with process ID <pid>. If the process is not running on the local host, then specify the absolute path of the executable file (<exe>) and the host machine name (<host>). For example, *attach 1234* will attempt to attach to a running process whose process ID is 1234 on the local host. On a remote host, you may enter something like *attach 1234 /home/demo/a.out myhost.* In this example, *PGDBG* will try to attach to a process ID 1234 called /home/demo/a.out on a host named myhost.

PGDBG will attempt to infer the arguments of the attached target application. If PGDBG fails to infer the argument list, then the program behavior is undefined if the *run* or *rerun* command is executed on the attached process. This means that run and rerun should not be used for most attached MPI programs.

The stdio channel of the attached process remains at the terminal from which the program was originally invoked.

```
c[ont]
```

Continue execution from the current location.

```
de[bug]
de[bug] [target [ arg1 … argn]]
```

Print the name and arguments of the program being debugged, or load the specified target program with optional command line arguments.

```
det[ach]
```

Detach from the current running process.

```
halt
```

Halt the running process or thread.

`n[ext]` [*count*]

Stop after executing one source line in the current routine. This command steps over called routines. The *count* argument stops execution only after executing *count* source lines.

`nexti` [*count*]

Stop after executing one instruction in the current routine. This command steps over called routines. The *count* argument stops execution only after executing *count* instructions.

`proc` [*id*]

Set the current process to the process identified by *id*. When issued with no argument, proc lists the current program location of the current thread of the current process. See *Section 1.13.4 Multi-Process MPI Debugging* for information on how processes are numbered.

```
procs
```

Print the status of all active processes. Each process is listed by its logical process ID.

```
q[uit]
```

Terminate the debugging session.

```
rer[un]
rer[un] [arg0 arg1 ... argn] [< inputfile ] [ [ > | >& | >> | >>& ] outputfile ]
```

The *rerun* command is the same as *run* except if no *args* are specified, the previously used target arguments are not re-used.

```
ru[n]
ru[n] [arg0 arg1 ...argn] [< inputfile ] [ [ > | >& | >> | >>& ] outputfile ]
```

Execute program from the beginning. If arguments *arg0*, *arg1*,.. are specified, they are set up as the command line arguments of the program. Otherwise, the arguments for the previous *run* command are used. Standard input and standard output for the target program can be redirected using < or > and an input or output filename.

```
s[tep]
s[tep] count
s[tep]  up
```

Stop after executing one source line. This command steps into called routines. The *count* argument stops execution after executing *count* source lines. The up argument stops execution after stepping out of the current routine (see *stepout*). In a parallel region of code, *step* applies only to the currently active thread.

```
stepi
stepi count
stepi  up
```

Stop after executing one instruction. This command steps into called routines. The *count* argument stops execution after executing *count* instructions. The up argument stops the execution after stepping out of the current routine (see *stepout*). In a parallel region of code, *stepi* applies only to the currently active thread.

```
stepo[ut]
```

Stop after returning to the caller of the current routine. This command sets a breakpoint at the current return address, and does a *continue*. To work correctly, it must be possible to compute the value of the return address. Some routines, particularly terminal (or leaf) routines at higher optimization levels, may not set up a stack frame. Executing *stepout* from such a routine causes the breakpoint to be set in the caller of the most recent routine that set up a stack frame. This command halts execution immediately upon return to the calling routine.

`sync`
`synci`

Advance the current process/thread to a specific program location; ignoring any user defined events.

`thread` [*number*]

Set the current thread to the thread identified by number; where number is a logical thread id in the current process' active thread list. When issued with no argument, ***thread*** lists the current program location of the currently active thread.

`threads`

Print the status of all active threads. Threads are grouped by process. Each process is listed by its logical process id. Each thread is listed by its logical thread id.

`wait [any | all | none]`

Return the *PGDBG* prompt only after specific processes or threads stop.

1.7.1.2 Process-Thread Sets

The following commands deal with defining and managing process thread sets. See *Section 1.14.9 P/t-set Commands* for a detailed discussion of process-thread sets.

`defset`

Assign a name to a process/thread set. Define a named set. This set can later be referred to by name. A list of named sets is stored by *PGDBG*.

`focus`

Set the target process/thread set for commands. Subsequent commands will be applied to the members of this set by default.

`undefset`

Remove a previously defined process/thread set from the list of process/thread sets. The debugger-defined p/t-set `[all]` cannot be removed.

`viewset`

List the members of a process/thread set that currently exist as active threads.

```
whichsets
```

List all defined p/t-sets to which the members of a process/thread set belongs.

1.7.1.3 Events

The following commands deal with defining and managing events. See *Section 1.5.8 Events* for a general discussion of events, and the optional arguments.

```
b[reak]
b[reak] line [if (condition)] [do {commands}]
b[reak] routine [if (condition)] [do {commands}]
```

If no argument is specified, print the current breakpoints. Otherwise, set a breakpoint at the indicated line or routine. If a routine is specified, and the routine was compiled for debugging, then the breakpoint is set at the start of the first statement in the routine, that is, after the routine's prologue code. If the routine was not compiled for debugging, then the breakpoint is set at the first instruction of the routine, prior to any prologue code. This command interprets integer constants as line numbers. To set a breakpoint at an address, use the *addr* command to convert the constant to an address, or use the *breaki* command.

When a condition is specified with *if*, the breakpoint occurs only when the specified *condition* is true. If *do* is specified with a *command* or several *commands* as an argument, the command or commands are executed when the breakpoint occurs.

The following examples set breakpoints at line 37 in the current file, line 37 in file `xyz.c`, the first executable line of routine `main`, address `0xf0400608`, the current line, and the current address, respectively.

```
break 37
break "xyz.c"@37
break main
break {addr 0xf0400608}
break {line}
break {pc}
```

More sophisticated examples include:

```
break xyz if(xyz@n > 10)
```

This command stops when routine *xyz* is entered only if the argument *n* is greater than 10.

```
break 100 do {print n; stack}
```

This command prints the value of n and performs a stack trace every time line 100 in the current file is reached.

```
breaki
breaki routine [if (condition)] [do {commands}]
breaki addr [if (condition)] [do {commands}]
```

Set a breakpoint at the indicated address or routine. If a routine is specified, the breakpoint is set at the first address of the routine. This means that when the program stops at this breakpoint the prologue code which sets up the stack frame will not yet have been executed, and hence, values of stack arguments will not be correct. Integer constants are interpreted as addresses. To specify a line, use the *line* command to convert the constant to a line number, or use the *break* command.

The *if* and *do* arguments are interpreted in the same way as for the *break* command. The next set of examples set breakpoints at address 0xf0400608, line 37 in the current file, line 37 in file xyz.*c*, the first executable address of routine main, the current line, and the current address, respectively:

```
breaki 0xf0400608
breaki {line 37}
breaki "xyz.c"@37
breaki main
breaki {line}
breaki {pc}
```

Similarly,

```
breaki 0x6480 if(n>3) do {print "n=", n}
```

stops and prints the new value of n at address 0x6480 only if n is greater than 3.

```
breaks
```

Display all the existing breakpoints.

```
catch
catch [sig:sig]
catch [sig [, sig...]]
```

With no arguments, print the list of signals being caught. With the : argument, catch the specified range of signals. With a list, catch signals with the specified number. When signals are caught, PGDBG intercepts the signal and does not deliver it to the target application. The target runs as though the signal was never sent.

```
clear
clear all
clear routine
clear line
clear addr {addr}
```

Clear all breakpoints at current location. Clear all breakpoints. Clear all breakpoints from first statement in the specified routine named *routine.* Clear breakpoints from line number *line.* Clear breakpoints from the address *addr*.

```
del[ete] event-number
del[ete] 0
del[ete] all
del[ete] event-number [, event-number...]
```

Delete the event *event-number* or all events (delete 0 is the same as delete all). Multiple event numbers can be supplied if they are separated by commas.

```
disab[le] event-number
disab[le] all
```

Disable the event *event-numbe*r or all events. Disabling an event definition suppresses actions associated with the event, but leaves the event defined so that it can be used later.

```
do {commands} [if (condition)]
do {commands} at line [if (condition)]
do {commands} in routine [if (condition)]
```

Define a *do* event. This command is similar to *watch* except that instead of defining an expression, it defines a list of commands to be executed. Without the optional arguments *at* or *in*, the commands are executed at each line in the program The *at* argument with a *line* specifies the commands to be executed each time that line is reached. The *in* argument with a *routine* specifies the commands are executed at each line in the routine. The *if* option has the same meaning as in *watch*. If a condition is specified, the *do* commands are executed only when *condition* is true.

```
doi {commands} [if (condition)]
doi {commands} at addr [if (condition)]
doi {commands} in routine [if (condition)]
```

Define a *doi* event. This command is similar to *watchi* except that instead of defining an expression, it defines a list of commands to be executed. If an address (*addr*) is specified, then the commands are executed each time that the specified address is reached. If a routine (*routine*) is

specified, then the commands are executed at each instruction in the routine. If neither is specified, then the commands are executed at each instruction in the program. The *if* option has the same meaning as for the *do* command above.

`enab[le]` *event-number* | *all*

Enable the indicated event *event-number*, or all events.

`hwatch` *addr* | *var* `[if` (*condition*)] `[do` {*commands*}]

Define a hardware watchpoint. This command uses hardware support to create a watchpoint for a particular address or variable. The event is triggered by hardware when the byte at the given address is written. This command is only supported on systems that provide the necessary hardware and software support. Only one hardware watchpoint can be defined at a time.

When the *if* option is specified, the event action will only be triggered if the expression is true. When the *do* option is specified, then the commands will be executed when the event occurs.

`hwatchr[ead]` *addr* | *var* `[if` (*condition*)] `[do` {*commands*}]

Define a hardware read watchpoint. This event is triggered by hardware when the byte at the given address or variable is read. As with *hwatch*, system hardware and software support must exist for this command to be supported. The *if* and *do* options have the same meaning as for the *hwatch* command.

`hwatchb[oth]` *addr* | *var* `[if` (*condition*)] `[do` {*commands*}]

Define a hardware read/write watchpoint. This event is triggered by hardware when the byte at the given address or variable is either read or written. As with *hwatch*, system hardware and software support must exist for this command to be supported. The *if* and *do* options have the same meaning as for the *hwatch* command.

`ignore`
`ignore`[*sig:sig*]
`ignore` [*sig* [, *sig*...]]

With no arguments, print the list of signals being ignored. With the `:` argument, ignore the specified range of signals. With a list, ignore signals with the specified number. When a particular signal number is ignored, signals with that number sent to the target application are not intercepted by *PGDBG*. They are delivered to the target.

`stat[us]`

Display all the event definitions, including an event number by which the event can be identified.

`stop` *var*
`stop` at *line* [`if` (*condition*)][`do` {*commands*}]
`stop` in *routine* [`if` (*condition*)][`do` {*commands*}]
`stop` `if` (*condition*)

Set a breakpoint at the indicated routine or line. Break when the value of the indicated variable *var* changes. The *at* keyword and a number specifies a line number. The *in* keyword and a routine name specifies the first statement of the specified routine. With the *if* keyword, the debugger stops when the condition *condition* is true.

`stopi` *var*
`stopi at` *address* [`if` (*condition*)][`do` {*commands*}]
`stopi in` *routine* [`if` (*condition*)][`do` {*commands*}]
`stopi` `if` (*condition*)

Set a breakpoint at the indicated address or routine. Break when the value of the indicated variable var changes. The *at* keyword and a number specifies an address to stop at. The *in* keyword and a routine name specifies the first address of the specified routine to stop at. With the *if* keyword, the debugger stops when condition is true.

`track` *expression* [at *line* | in *func*] [`if` (*condition*)][`do` {*commands*}]

Define a track event. This command is equivalent to *watch* except that execution resumes after the new value of the expression is printed.

`tracki` *expression* [at *addr* | in *func*] [`if` (*condition*)][`do` {*commands*}]

Define an instruction level track event. This command is equivalent to *watchi* except that execution resumes after the new value of the expression is printed.

`trace` *var* [`if` (*condition*)][`do` {*commands*}]
`trace` *routine* [`if` (*condition*)][`do` {*commands*}]
`trace` at *line* [`if` (*condition*)][`do` {*commands*}]
`trace` in *routine* [`if` (*condition*)][`do` {*commands*}]

Activate source line tracing when var changes. Activate source line tracing and trace when in routine func. With *at*, activate source line tracing to display the specified line each time it is executed. With *in*, activate source line tracing to display the specified each source line when in the specified routine. If condition is specified, trace is on only if the condition evaluates to true. The *do* keyword defines a list of commands to execute at each trace point. Use the command *pgienv*

speed secs to set the time in seconds between trace points. Use the *clear* command to remove tracing for a line or routine.

`tracei` *var* [`if` (*condition*)][`do` {*commands*}]
`tracei` *routine* [`if` (*condition*)][`do` {*commands*}]
`tracei` at *line* [`if` (*condition*)][`do` {*commands*}]
`tracei` in *routine* [`if` (*condition*)][`do` {*commands*}]

Activate instruction tracing when var changes. Activate instruction tracing when in routine *routine*. With *at*, activate tracing to display the specified line each time it is executed. With the *in* keyword, display instructions while in the specified routine. Use the command *pgienv speed secs to* set the time in seconds between trace points. Use the *clear* command to remove tracing for a line or routine.

`unb[reak]` *line*
`unb[reak]` *routine*
`unb[reak] all`

Remove a breakpoint from the statement line. Remove a breakpoint from the routine *routine*. Remove all breakpoints.

`unbreaki` *addr*
`unbreaki` *routine*
`unbreaki all`

Remove a breakpoint from the address *addr*. Remove a breakpoint from the routine *routine*. Remove all breakpoints.

`wa[tch]` *expression*
`wa[tch]` *expression* [`if` (*condition*)][`do` {*commands*}]
`wa[tch]` *expression* at *line* [`if` (*condition*)][`do` {*commands*}]
`wa[tch]` *expression* in *routine* [`if` (*condition*)][`do` {*commands*}]

Define a watch event. The given expression is evaluated, and subsequently, each time the value of the expression changes, the program stops and the new value is printed. If a particular *line* is specified, the expression is only evaluated at that line. If a routine *routine* is specified, the expression is evaluated at each line in the routine. If no location is specified, the expression will be evaluated at each line in the program. If a *condition* is specified, the expression is evaluated only when the condition is true. If commands are specified, they are executed whenever the expression is evaluated and the value changes.

The watched expression may contain local variables, although this is not recommended unless a

routine or address is specified to ensure that the variable will only be evaluated when it is in the current scope.

Note: *Using watchpoints indiscriminately can dramatically slow program execution.*

Using the *at* and *in* options speeds up execution by reducing the amount of single-stepping and expression evaluation that must be performed to watch the expression. For example:

```
watch i at 40
```

will barely slow program execution at all, while

```
watch i
```

will slow execution considerably.

`watchi` *expression*
`watchi` *expression* [`if` (*condition*)][`do` {*commands*}]
`watchi` *expression* at *addr* [`if` (*condition*)][`do` {*commands*}]
`watchi` *expression* in *func* [`if` (*condition*)][`do` {*commands*}]

Define an instruction level watch event. This is just like the *watch* command except that the *at* option interprets integers as addresses rather than line numbers, and the expression is evaluated at every instruction instead of at every line.

This command is useful if line number information is limited. It causes programs to execute more slowly than *watch*.

`when do` {*commands*} [`if` (*condition*)]
`when` at *line* `do` {*commands*} [`if` (*condition*)]
`when` in *routine* do {*commands*} [`if` (*condition*)]

Execute command at every line in the program. Execute commands at specified line in the program. Execute command in the specified routine. If the optional *condition* is specified, commands are executed only when the expression evaluates to true.

`wheni do` {*commands*} [`if` (*condition*)]
`wheni` at *addr* `do` {*commands*} [`if` (*condition*)]
`wheni` in *routine* do {*commands*} [`if` (*condition*)]

Execute *commands* at each address in the program. If an *addr* is specified, the commands are executed each time the address is reached. If a routine *routine* is specified, the commands are executed at each line in the routine. If the optional *condition* is specified, commands are executed whenever the expression is evaluated true.

Events can be parallelized across multiple threads of execution. See *Section 1.14.16 Parallel Events* for details.

1.7.1.4 Program Locations

This section describes PGDBG program locations commands.

`arri[ve]`

Print location information for the current location.

`cd` [*dir*]

Change to the $HOME directory or to the specified directory *dir*.

`dis[asm]`
`dis[asm]` *count*
`dis[asm]` *lo*:*hi*
`dis[asm]` *routine*
`dis[asm]` *addr*, *count*

Disassemble memory. If no argument is given, disassemble four instructions starting at the current address. If an integer count is given, disassemble *count* instructions starting at the current address. If an address range is given, disassemble the memory in the range. If a routine name is given, disassemble the entire routine. If the routine was compiled for debug, and source code is available, the source code will be interleaved with the disassembly. If an address and a count are given, disassemble *count* instructions starting at address *addr*.

`edit`
`edit` *filename*
`edit` *routine*

If no argument is supplied, edit the current file starting at the current location. With a *filename* argument, edit the specified file *filename*. With the func argument, edit the file containing routine *routine*. This command uses the editor specified by the environment variable $EDITOR.

`file` [*filename*]

Change the source file to the file *filename* and change the scope accordingly. With no argument, print the current file.

`lines` *routine*

Print the lines table for the specified routine.

`lis[t]`
`lis[t]` *count*
`lis[t]` *line,num*
`lis[t]` *lo*:*hi*
`lis[t]` *routine*

With no argument, list 10 lines centered at the current source line. If a count is given, list *count* lines centered at the current source line. If a line and count are given, list *number* lines starting at line number *line*. In dbx mode, this option lists lines from *start* to *number*. If a line range is given, list the indicated source lines in the current source file (this option is not valid in the dbx environment). If a routine name is given, list the source code for the indicated routine.

`pwd`

Print the current working directory.

`stack[trace]` [*count*]

Print a stacktrace. For each active routine print the routine name, source file, line number, current address (if that information is available). This command also prints the names and values of the arguments, if available. If a count is specified, display a maximum of count stack frames.

`stackd[ump]` [*count*]

Print a formatted dump of the stack. This command displays a hex dump of the stack frame for each active routine. This command is a machine-level version of the *stacktrace* command. If a count is specified, display a maximum of count stack frames.

`w[here]` [*count*]

Print the address, routine, source file and line number for the current location. If *count* is specified, print a maximum of *count* live routines on the stack.

/
/ [*string*] /

Search forward for a string (*string*) of characters in the current source file. With just /, search for the next occurrence of *string* in the current source file.

?
?[*string*] ?

Search backward for a string (*string*) of characters in the current source file. With just ?, search for the previous occurrence of *string* in the current source file.

1.7.1.5 Printing Variables and Expressions

This section describes *PGDBG* commands used for printing and setting variables.

p[rint] *exp1* [,...*expn*]

Evaluate and print one or more expressions. This command is invoked to print the result of each line of command input. Values are printed in a format appropriate to their type. For values of structure type, each field name and value is printed. Character pointers are printed as a hex address followed by character string.

Character string constants print out literally. For example:

```
pgdbg> print "The value of i is ", i
       The value of i is 37
```

The array sub-range operator : prints a range of an array. The following examples print elements 0 through 9 of the array a:

C/C++ example:

```
pgdbg> print a[0:9]
a[0:4]:  0           1           2           3           4
a[5:9]:  5           6           7           8           9
```

FORTRAN example:

```
pgdbg> print a(0:9)

a(0:4):  0           1           2           3           4
a(5:9):  5           6           7           8           9
```

Note that the output is formatted and annotated with index information. *PGDBG* formats array output into columns. For each row, the first column prints an index expression which summarizes the elements printed in that row. Elements associated with each index expression are then printed in order. This is especially useful when printing slices of large multidimensional arrays.

PGDBG also supports strided array expressions. Below are examples for *C/C++* and FORTRAN.

C/*C*++ example:

```
pgdbg> print a[0:9:2]

a[0:8]  0           2           4           6           8
```

FORTRAN example:

```
pgdbg> print a(0:9:2)

a(0:8):  0           2           4           6           8
```

The *print* statement may be used to display members of derived types in FORTRAN or structures in *C/C++*. Below are examples.

C/*C*++ example:

```
typedef struct tt {
       int a[10];
}TT;

TT d = {0,1,2,3,4,5,6,7,8,9};
TT * p = &d;

pgdbg> print d.a[0:9:2]

d.a[0:8:2]:  0           2           4           6           8

pgdbg> print p->a[0:9:2]

p->a[0:7:2]:  0           2           4           6
p->a[8]:  8
```

FORTRAN example:

```
type tt
       integer, dimension(0:9) :: a
end type
type (tt) :: d
data d%a / 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 /

pgdbg> print d%a(0:9:2)

d%a(0:8:2):  0            2            4            6            8
```

`printf` "*format_string*", *expr*,*...expr*

Print expressions in the format indicated by the format string. Behaves like the *C* library function *printf*. For example:

```
pgdbg> printf "f[%d]=%G",i,f[i]
       f[3]=3.14
```

The *pgienv* command with the *stringlen* argument sets the maximum number of characters that will print with a *print* command. For example, the `char` declaration below:

```
char *c="a whole bunch of chars over 1000 chars long....";
```

By default, the `print c` command will only print the first 512 (or *stringlen*) bytes. Printing of C strings is usually terminated by the terminating null character. This limit is a safeguard against unterminated C strings.

`asc[ii]` *exp* [,*...exp*]

Evaluate and print as an ascii character. Control characters are prefixed with the '^' character; that is, 3 prints as ^c. Otherwise, values that can not be printed as characters are printed as integer values prefixed by `\'. For example, 250 prints as \250.

`bin` *exp* [,*...exp*]

Evaluate and print the expressions. Integer values are printed in binary.

`dec` *exp* [,*...exp*]

Evaluate and print the expressions. Integer values are printed in decimal.

`display`
`display` *exp* [,*...exp*]

Without arguments, list the expressions for PGDBG to automatically display at breakpoints. With

an argument or several arguments, print expression *exp* at every breakpoint. See the description for *undisplay* for a description of how to remove an expression from the display list.

`hex` *exp* [,*...exp*]

Evaluate and print expressions as hexadecimal integers.

`oct` *exp* [,*...exp*]

Evaluate and print expressions as octal integers.

`str[ing]` *exp* [,*...exp*]

Evaluate and print expressions as null-terminated character strings. This command will print a maximum of 70 characters.

`undisplay` 0
`undisplay` all
`undisplay` *exp* [,*...exp*]

Remove all expressions being printed at breakpoints. With an argument or several arguments, remove the expression *exp* from the list of display expressions.

1.7.1.6 Symbols and Expressions

This section describes the commands that deal with symbols and expressions.

`as[sign]` *var* = *exp*

Set variable *var* to the value of *expression*. The variable var can be any valid identifier accessed properly for the current scope. For example, given a C variable declared ‘int * i’, the command ‘set *i = 9999’ could be used to assign the value 9999 to it.

`call` *routine* [(*exp*,...)]

Call the named routine. *C* argument passing conventions are used. Breakpoints encountered during execution of the routine are ignored. Fortran functions and subroutines can be called, but the argument values will be passed according to *C* conventions. *PGDBG* may not always be able to access the return value of a Fortran function if the return value is an array. In the example below, *PGDBG* calls the routine `foo` with four arguments:

```
pgdbg> call foo(1,2,3,4)
```

If a signal is caught during execution of the called routine, *PGDBG* will stop the execution and ask if you want to cancel the call command. For example, suppose a command is issued to call `foo` as shown above, and for some reason a signal is sent to the process while it is executing the call to `foo`. In this case, *PGDBG* will print the following prompt:

```
PGDBG Message: Thread [0] was signalled while executing a function
reachable from the most recent PGDBG command line call to foo.  Would you
like to cancel this command line call?  Answering yes will revert the
register state of Thread [0] back to the state it had prior to the last
call to foo from the command line.  Answering no will leave Thread [0]
stopped in the call to foo from the command line

Please enter 'y' or 'n' > y

Command line call to foo cancelled
```

Answering yes to this question will return the register state of each thread back to the state they had before invoking the call command. Answering no to this question will leave each thread at the point they were at when the signal occurred.

Note: *Answering no to this question and continuing execution of the called routine may produce unpredictable results.*

`decl[aration]` *name*

Print the declaration for the symbol, based on the type of the symbol in the symbol table. The symbol must be a variable, argument, enumeration constant, routine, a structure, union, enum, or typedef tag.

For example, given declarations:

```
int i, iar[10];
struct abc {int a; char b[4]; struct abc *c;}val;
```

The commands,

```
decl I
decl iar
decl val
decl abc
```

will respectively print out as

```
int i
```

```
int iar[10]
```

```
struct abc val

struct abc {
       int a;
       char b[4];
       struct abc *c;
    };
```

`entr[y]`
`entr[y]` *routine*

Return the address of the first executable statement in the program or specified routine. This is the first address after the routine's prologue code.

`lv[al]` *expr*

Return the *lvalue* of the expression *expr*. The *lvalue* of an expression is the value it would have if it appeared on the left hand of an assignment statement. Roughly speaking, an *lvalue* is a location to which a value can be assigned. This may be an address, a stack offset, or a register.

`rv[al]` *expr*

Return the *rvalue* of the expression *expr*. The *rvalue* of an expression is the value it would have if it appeared on the right hand of an assignment statement. The type of the expression may be any scalar, pointer, structure, or function type.

`set` *var=expression*

Set variable *var* to the value of *expression*. The variable var can be any valid identifier accessed properly for the current scope. For example, given a C variable declared ‘int * i’, the command ‘set *i = 9999’ could be used to assign the value 9999 to it.

`siz[eof]` *name*

Return the size, in bytes, of the variable type *name*.

`type` *expr*

Return the type of the expression. The expression may contain structure reference operators (`.` , and ->), dereference (*), and array index ([ ]) expressions. For example, given declarations shown previously, the commands:

```
type I
type iar
type val
type val.a
type val.abc->b[2]
```

produce the following output:

```
int

int [10]

struct abc

int

char
```

`whatis`
`whatis` *name*

With no arguments, print the declaration for the current routine. With argument name, print the declaration for the symbol *name*.

1.7.1.7 Scope

The following commands deal with program scope. See *Section 1.5.3 Scope Rules* for a discussion of scope meaning and conventions.

`decls`
`decls` *routine*
`decls` "*sourcefile*"
`decls` {global}

Print the declarations of all identifiers defined in the indicated scope. If no scope is given, print the declarations for global scope.

`down` [*number*]

Enter scope of routine down one level or *number* levels on the call stack.

`en[ter]`
`en[ter]` *routine*
`en[ter]` "*sourcefile*"
`en[ter]` {global}

Set the search scope to be the indicated symbol, which may be a routine, source file or global. Using *enter* with no argument is the same as using *enter global*.

`files`

Return the list of the files that make up the object file.

`glob[al]`

Return a symbol representing global scope. This command is useful in combination with the scope operator @ to specify symbols with global scope.

`names`
`names` *routine*
`names` "*sourcefile*"
`names` {global}

Print the names of all identifiers defined in the indicated scope. If no scope is specified, use the search scope.

`sco[pe]`

Return a symbol for the search scope. The search scope is set to the current routine each time program execution stops. It may also be set using the *enter* command. The search scope is always searched first for symbols.

`up` [*number*]

Enter scope of routine up one level or *number* levels on the call stack.

`whereis` *name*

Print all declarations for *name*.

`which` *name*

Print full scope qualification of symbol *name*.

1.7.1.8 Register Access

System registers can be accessed by name. See *Section 1.5.4 Register Symbols* for the complete set of registers. A few commands exist for convenient access to common registers.

```
fp
```

Return the current value of the frame pointer.

```
pc
```

Return the current program address.

```
regs [format]
```

Print a formatted display of the names and values of the integer, float, and double registers. If the *format* parameter is omitted, then *PGDBG* will print all of the registers. Otherwise, *regs* accepts the following optional parameters:

- *f* – Print floats as single precision values (default)
- *d* – Print floats as double precision values
- *x* – Add hexadecimal representation of float values

```
ret[addr]
```

Return the current return address.

```
sp
```

Return the current value of the stack pointer.

1.7.1.9 Memory Access

The following commands display the contents of arbitrary memory locations. Note that for each of these commands, the *addr* argument may be a variable or identifier.

`cr[ead]`*addr*

Fetch and return an 8-bit signed integer (character) from the specified address.

`dr[ead]`*addr*

Fetch and return a 64 bit double from the specified address.

`du[mp]` *address*, *count*, "*format-string*"

This command dumps a region of memory according to a *printf*-like format descriptor. Starting at the indicated address, values are fetched from memory and displayed according to the format descriptor. This process is repeated *count* times.

Interpretation of the format descriptor is similar to *printf*. Format specifiers are preceded by `%`.

The meaning of the recognized format descriptors is as follows:

`%d, %D, %o, %O, %x, %X, %u, %U`

Fetch and print integral values as decimal, octal, hex, or unsigned. Default size is machine dependent. The size of the item read can be modified by either inserting 'h', or 'l' before the format character to indicate half bits or long bits. For example, if your machine's default size is 32-bit, then `%hd` represents a 16-bit quantity. Alternatively, a 1, 2, or 4 after the format character can be used to specify the number of bytes to read.

`%c`

Fetch and print a character.

`%f, %F, %e, %E, %g, %G`

Fetch and print a *float* (lower case) or double (upper case) value using *printf* `f`, `e`, or `g` format.

`%s`

Fetch and print a null terminated string.

`%p<format-chars>`

Interpret the next object as a pointer to an item specified by the following format characters. The pointed-to item is fetched and displayed. Examples:

`%px`

Pointer to int. Prints the value of the pointer, the pointed-to address, and the contents of the pointed-to address, which is printed using hexadecimal format.

`%i`

Fetch an instruction and disassemble it.

`%w, %W`

Display address about to be dumped.

`%z<`*n*`>, %Z<`*n*`>, %z<-`*n*`>, %Z<-`*n*`>`

Display nothing but advance or decrement current address by *n* bytes.

`%a<`*n*`>, %A<`*n*`>`

Display nothing but advance current address as needed to align modulo *n*.

`fr[ead]`*addr*

Fetch and print a 32-bit float from the specified address.

`ir[ead]` *addr*

Fetch and print a signed integer from the specified address.

`lr[ead]` *addr*

Fetch and print an address from the specified address.

`mq[dump]`

Dump message queue information for current process. Refer to *Section 1.16.3 MPI Message Queues* for more information on *mqdump*.

`sr[ead]`*addr*

Fetch and print a short signed integer from the specified address.

1.7.1.10 Conversions

The commands in this section are useful for converting between different kinds of values. These

commands accept a variety of arguments, and return a value of a particular kind.

```
ad[dr]
ad[dr] n
ad[dr] line
ad[dr] routine
ad[dr] var
ad[dr] arg
```

Create an address conversion under these conditions:

- If an integer is given return an address with the same value.
- If a line is given, return the address corresponding to the start of that line.
- If a routine is given, return the first address of the routine.
- If a variable or argument is given, return the address where that variable or argument is stored.

For example:

```
breaki {line {addr 0x22f0}}
```

```
func[tion]
func[tion] addr
func[tion] line
```

Return a routine symbol. If no argument is specified, return the current routine. If an address is given, return the routine containing that address. An integer argument is interpreted as an address. If a line is given, return the routine containing that line.

```
lin[e]
lin[e] n
lin[e] routine
lin[e] addr
```

Create a source line conversion. If no argument is given, return the current source line. If an integer *n* is given, return it as a line number. If a routine *routine* is given, return the first line of the routine. If an address *addr* is given, return the line containing that address.

For example, the following command returns the line number of the specified address:

```
line {addr 0x22f0}
```

1.7.1.11 Miscellaneous

The following commands provide shortcuts, mechanisms for querying, customizing and managing the PGDBG environment, and access to operating system features.

`al[ias]`
`al[ias]` *name*
`al[ias]` *name string*

Create or print aliases. If no arguments are given print all the currently defined aliases. If just a name is given, print the alias for that name. If a name and string are given, make *name* an alias for *string*. Subsequently, whenever *name* is encountered it will be replaced by *string*. Although *string* may be an arbitrary string, *name* must not contain any space characters.

For example:

```
alias xyz print "x= ",x,"y= ",y,"z= ",z; cont
```

creates an alias for `xyz`. Now whenever `xyz` is typed, *PGDBG* will respond as though the following command was typed:

```
print "x= ",x,"y= ",y,"z= ",z; cont
```

`dir[ectory]` [*pathname*]

Add the directory pathname to the search path for source files. If no argument is specified, the currently defined directories are printed. This command assists in finding source code that may have been moved or is otherwise not found by the default PGDBG search mechanisms.

For example:

```
dir morestuff
```

adds the directory *morestuff* to the list of directories to be searched. Now, source files stored in *morestuff* are accessible to *PGDBG*.

If the first character in pathname is ~, it will be substituted by $HOME.

`help` [*command*]

If no argument is specified, print a brief summary of all the commands. If a command name is specified, print more detailed information about the use of that command.

`history` [*num*]

List the most recently executed commands. With the *num* argument, resize the history list to hold *num* commands. History allows several characters for command substitution:

!! [modifier]	Execute the previous command
! num [modifier]	Execute command number num
!-num [modifier]	Execute command -num from the most current command
!string [modifier]	Execute the most recent command starting with string
!?string? [modifier]	Execute the most recent command containing string
^	Quick history command substitution ^old^new^<modifier> this is equivalent to !:s/old/new/

The history modifiers may be**:**

`:s/old/new/`	Substitute the value *new* for the value *old.*
`:p`	Print but do not execute the command.

The command `pgienv history off` tells the debugger not to display the history record number. The command `pgienv history on` tells the debugger to display the history record number.

`language`

Print the name of the language of the current file.

`log` *filename*

Keep a log of all commands entered by the user and store it in the named file. This command may be used in conjunction with the *script* command to record and replay debug sessions.

`nop[rint]` *exp*

Evaluate the expression but do not print the result.

`pgienv` [*command*]

Define the debugger environment. With no arguments, display the debugger settings.

help *pgienv*	Provide help on pgienv
pgienv	Display the debugger settings
pgienv dbx on	Set the debugger to use *dbx* style commands
pgienv dbx off	Set the debugger to use *pgi* style commands
pgienv history on	Display the `history' record number with prompt
pgienv history off	Do NOT display the `history' number with prompt

pgienv exe none	Ignore executable's symbolic debug information
pgienv exe symtab	Digest executable's native symbol table (typeless)
pgienv exe demand	Digest executable's symbolic debug information incrementally on command
pgienv exe force	Digest executable's symbolic debug information when executable is loaded
pgienv solibs none	Ignore symbolic debug information from shared libraries
pgienv solibs symtab	Digest native symbol table (typeless) from each shared library
pgienv solibs demand	Digest symbolic debug information from shared libraries incrementally on demand
pgienv solibs force	Digest symbolic debug information from each shared library at load time
pgienv mode serial	Single thread of execution (implicit use of p/t-sets)
pgienv mode thread	Debug multiple threads (condensed p/t-set syntax)
pgienv mode process	Debug multiple processes (condensed p/t-set syntax)
pgienv mode multilevel	Debug multiple processes and multiple threads
pgienv omp [on|off]	Enable/Disable the *PGDBG* OpenMP event handler. This option is disabled by default. The *PGDBG* OpenMP event handler, when enabled, sets breakpoints at the beginning and end of each parallel region. Breakpoints are also set at each thread synchronization point. The handler coordinates threads across parallel constructs to maintain source level debugging. This option, when enabled, may significantly slow down program performance. Enabling this option is recommended for localized debugging of a particular parallel region only.
pgienv prompt <*name*>	Set the command line prompt to <name>
pgienv promptlen <*num*>	Set maximum size of p/t-set portion of prompt
pgienv speed <*secs*>	Set the time in seconds <secs> between trace points
pgienv stringlen <*num*>	Set the maximum # of chars printed for `char *'s
pgienv termwidth <*num*>	Set the character width of the display terminal.
pgienv logfile <name>	Close logfile (if any) and open new logfile <name>
pgienv threadstop sync	When one thread stops, the rest are halted in place
pgienv threadstop async	Threads stop independently (asynchronously)
pgienv procstop sync	When one process stops, the rest are halted in place
pgienv procstop async	Processes stop independently (asynchronously)
pgienv threadstopconfig auto	For each process, debugger sets thread stopping mode to 'sync' in serial regions, and 'async' in parallel regions
pgienv threadstopconfig user	Thread stopping mode is user defined and remains unchanged by the debugger.
pgienv procstopconfig auto	Not currently used.
pgienv procstopconfig user	Process stop mode is user defined and remains unchanged by the debugger.
pgienv threadwait none	Prompt available immediately; no wait for running threads

pgienv threadwait any	Prompt available when at least a single thread stops
pgienv threadwait all	Prompt available only after all threads have stopped
pgienv procwait none	Prompt available immediately; no wait for running processes
pgienv procwait any	Prompt available when at least a single process stops
pgienv procwait all	Prompt available only after all processes have stopped
pgienv threadwaitconfig auto	For each process, the debugger will set the thread wait mode to ‘all’ in serial regions and ‘none’ in parallel regions. (default)
pgienv threadwaitconfig user	The thread wait mode is user defined and will remain unchanged by the debugger.
pgienv verbose <*bitmask*>	Choose which debug status messages to report. Accepts an integer valued bit mask of the following values: o 0x1 - Standard messaging (default). Report status information on current process/thread only. o 0x2 - Thread messaging. Report status information on all threads of (current) processes. o 0x4 - Process messaging. Report status information on all processes. o 0x8 - OpenMP messaging (default). Report OpenMP events. o 0x10 - Parallel messaging (default). Report parallel events. o 0x20 - Symbolic debug information. Report any errors encountered while processing symbolic debug information (e.g. STABS, DWARF). Pass 0x0 to disable all messages. o Pass 0x0 to disable all messages.

`rep[eat]` [*first, last*]
`rep[eat]` [*first,*:*last*:*n*]
`rep[eat]` [*num*]
`rep[eat]` [-*num*]

Repeat the execution of one or more previous history list commands. With the num argument, re-execute the command number *num*, or with -*num*, the last *num* commands. With the first and last arguments, re-execute commands number *first* to *last* (optionally *n* times).

`scr[ipt]` *filename*

Open the indicated file and execute the contents as though they were entered as commands. If you use ~ before the filename, it is expanded to the value of `$HOME`.

`setenv` *name*
`setenv` *name value*

Print value of environment variable *name*. With a specified *value*, set *name* to *value*.

`shell` [*arg0, arg1,... argn*]

Fork a shell (defined by `$SHELL`) and give it the indicated arguments (the default shell is `sh`). If no arguments are specified, an interactive shell is invoked, and executes until a "^D" is entered.

`sle[ep]` [*time*]

Pause for *time* seconds. If no time is specified, pause for one second.

`sou[rce]` *filename*

Open the indicated file and execute the contents as though they were entered as commands. If you use ~ before the filename, it is expanded to the value of `$HOME`.

`unal[ias]` *name*

Remove the alias definition for *name*, if one exists.

`use` [*dir*]

Print the current list of directories or add *dir* to the list of directories to search. If the first character in pathname is ~, it will be substituted with the value of $HOME.

1.8 Signals

PGDBG intercepts all signals sent to any of the threads in a multi-threaded program, and passes them on according to that signal's disposition as maintained by *PGDBG* (see the *catch* and *ignore* commands), except for signals that cannot be intercepted or signals used internally by *PGDBG*.

1.8.1 Control-C

If the target application is not running, control-C can be used to interrupt long-running PGDBG commands. For example, a command requesting disassembly of thousands of instructions might run for a long time, and it can be interrupted by control-C. In such cases the target application is

not affected.

If the target application is running, entering control-C at the *PGDBG* command prompt will halt execution of the target. This is useful in cases where the target “hangs” due to an infinite loop or deadlock,

Sending a SIGINT (control-C) to a program while it is in the middle of initializing its threads (calling *omp_set_num_threads()*, or entering a parallel region) may kill some of the threads if the signal is sent before each thread is fully initialized. Avoid sending SIGINT in these situations. Note that when the number of threads employed by a program is large, thread initialization may take a while.

Sending SIGINT (control-C) to a running MPI program is not recommended. See *Section* 1.16.5 MPI Listener Processes for details. Use the *PGDBG halt* command as an alternative to sending SIGINT to a running program. The *PGDBG* command prompt must be available in order to issue a *halt* command. The *PGDBG* command prompt is available while threads are running if *pgienv threadwait none* is set.

1.8.2 Signals Used Internally by *PGDBG*

SIGTRAP and SIGSTOP are used by Linux for communication of application events to *PGDBG*.. Management of these signals is internal to *PGDBG*. Changing the disposition of these signals in *PGDBG* will result in undefined behavior.

1.8.3 Signals Used by Linux Libraries

Some Linux thread libraries use SIGRT1 and SIGRT3 to communicate among threads internally. Other Linux thread libraries, on systems that do not have support for real-time signals in the kernel, use SIGUSR1 and SIGUSR2. Changing the disposition of these signals in *PGDBG* will result in undefined behavior.

Target applications built for sample-based profiling (compiled with ‘-pg’) generate numerous SIGPROF signals. Although SIGPROF can be handled by PGDBG, debugging of applications built for sample-based profiling is not recommended.

1.9 Register Symbols

This section describes the register symbols defined for X86 processors and EM64T/AMD64

processors operating in compatibility or legacy mode.

1.9.1 X86 Register Symbols

This section describes the X86 register symbols.

Table 1-4: General Registers

Name	Type	Description
`$edi`	`unsigned`	General purpose
`$esi`	`unsigned`	General purpose
`$eax`	`unsigned`	General purpose
`$ebx`	`unsigned`	General purpose
`$ecx`	`unsigned`	General purpose
`$edx`	`unsigned`	General purpose

Table 1-5: x87 Floating-Point Stack Registers

Name	Type	Description
`$d0 - $d7`	`80-bit IEEE`	Floating-point

Table 1-6: Segment Registers

Name	Type	Description
`$gs`	`16-bit unsigned`	Segment register
`$fs`	`16-bit unsigned`	Segment register
`$es`	`16-bit unsigned`	Segment register
`$ds`	`16-bit unsigned`	Segment register
`$ss`	`16-bit unsigned`	Segment register
`$cs`	`16-bit unsigned`	Segment register

Table 1-7: Special Purpose Registers

Name	Type	Description
`$ebp`	`32-bit unsigned`	Frame pointer
`$efl`	`32-bit unsigned`	Flags register
`$eip`	`32-bit unsigned`	Instruction pointer
`$esp`	`32-bit unsigned`	Privileged-mode stack pointer
`$uesp`	`32-bit unsigned`	User-mode stack pointer

1.9.2 AMD64/EM64T Register Symbols

This section describes the register symbols defined for AMD64/EM64T processors operating in 64-bit mode.

Table 1-8: General Registers

Name	Type	Description
`$r8 - $r15`	`64-bit unsigned`	General purpose
`$rdi`	`64-bit unsigned`	General purpose
`$rsi`	`64-bit unsigned`	General purpose
`$rax`	`64-bit unsigned`	General purpose
`$rbx`	`64-bit unsigned`	General purpose
`$rcx`	`64-bit unsigned`	General purpose
`$rdx`	`64-bit unsigned`	General purpose

Table 1-9: Floating-Point Registers

Name	Type	Description
`$d0 - $d7`	`80-bit IEEE`	Floating-point

Table 1-10: Segment Registers

Name	Type	Description
`$gs`	`16-bit unsigned`	Segment register
`$fs`	`16-bit unsigned`	Segment register
`$es`	`16-bit unsigned`	Segment register
`$ds`	`16-bit unsigned`	Segment register
`$ss`	`16-bit unsigned`	Segment register
`$cs`	`16-bit unsigned`	Segment register

Table 1-11: Special Purpose Registers

Name	Type	Description
`$ebp`	`64-bit unsigned`	Frame pointer
`$rip`	`64-bit unsigned`	Instruction pointer
`$rsp`	`64-bit unsigned`	Stack pointer
`$eflags`	`64-bit unsigned`	Flags register

Table 1-12: SSE Registers

Name	Type	Description
`$mxcsr`	`64-bit unsigned`	SIMD floating-point control
`$xmm0 - $xmm15`	`Packed 4x32-bit IEEE` `Packed 2x64-bit IEEE`	SSE floating-point registers

1.9.3 SSE Register Symbols

On AMD64/EM64T, Pentium III, and compatible processors, an additional set of SSE (streaming SIMD enhancements) registers and a SIMD floating-point control and status register are available.

Each SSE register contains four IEEE 754 compliant 32-bit single-precision floating-point values. The *PGDBG* `regs` command reports these values individually in both hexadecimal and floating-point format. *PGDBG* provides syntax to refer to these values individually, as members of a range,

or all together.

The component values of each SSE register can be accessed using the same syntax that is used for array subscripting. Pictorially, the SSE registers can be thought of as follows:

```
Bits:   127       96 95       65  63        32 31         0
```

`$xmm0(3)`	`$xmm0(2)`	`$xmm0(1)`	`$xmm0(0)`
`$xmm1(3)`	`$xmm1(2)`	`$xmm1(1)`	`$xmm1(0)`
`$xmm7(3)`	`$xmm7(2)`	`$xmm7(1)`	`$xmm7(0)`

To access a `$xmm0(3)`, the 32-bit single-precision floating point value that occupies bits 96 – 127 of SSE register 0, use the following *PGDBG* command:

```
pgdbg> print $xmm0(3)
```

To set `$xmm2(0)` to the value of `$xmm3(2)`, use the following *PGDBG* command:

```
pgdbg> set $xmm2(3) = $xmm3(2)
```

SSE registers can be subscripted with range expressions to specify runs of consecutive component values, and access an SSE register as a whole. For example, the following are legal *PGDBG* commands:

```
pgdbg> set $xmm0(0:1) = $xmm1(2:3)
pgdbg> set $xmm6 = 1.0/3.0
```

The first command above initializes elements 0 and 1 of `$xmm0` to the values in elements 2 and 3 respectively in `$xmm1`. The second command above initializes all four elements of `$xmm6` to the constant `1.0/3.0` evaluated as a 32-bit floating-point constant.

In most cases, *PGDBG* detects when the target environment supports the SSE registers. In the the event PGDBG does not allow access to SSE registers on a system that should have them, set the `PGDBG_SSE` environment variable to `` `on' `` to enable SSE support.

1.10 Debugging Fortran

1.10.1 Fortran Types

PGDBG displays Fortran type declarations using Fortran type names, not *C* type names. The only exception is Fortran character types, which are treated as arrays of the *C* type `char`.

1.10.1 Arrays

Fortran array subscripts and ranges are accessed using the Fortran language syntax convention, denoting subscripts with parentheses and ranges with colons.

PGI compilers for the linux86-64 platform (AMD64 or Intel EM64T) support large arrays (arrays with an aggregate size greater than 2GB). Large array support is enabled by compiling with '–mcmodel=medium –Mlarge_arrays'. *PGDBG* provides full support for large arrays and large subscripts.

PGDBG supports arrays with non-default lower bounds. Access to such arrays uses the same subscripts that are used in the target application.

PGDBG also supports adjustable arrays. Access to adjustable arrays may use the same subscripting that is used in the target application.

1.10.2 Operators

In general, PGDBG uses *C* language style operators in expressions. The Fortran array index selector "`()`" and the Fortran field selector "`%`" for derived types are supported. However, .eq., .ne., and so forth are not supported. The analogous *C* operators ==, !=, etc. must be used instead. Note that the precedence of operators matches the *C* language, which may in some cases be different than for Fortran. See *Table 1-2 PGDBG Operators* for a complete list of operators and their definition.

1.10.3 Name of Main Routine

If a `PROGRAM` statement is used, the name of the main routine is the name in the program statement. Otherwise, the name of the main routine is `__unnamed_`. A routine symbol named `_MAIN_` is defined with start address equal to the start of the main routine. As a result,

```
break MAIN
```

can always be used to set a breakpoint at the start of the main routine.

1.10.4 Fortran Common Blocks

Each subprogram that defines a common block will have a local static variable symbol to define the common. The address of the variable will be the address of the common block. The type of the variable will be a locally defined structure type with fields defined for each element of the common block. The name of the variable will be the common block name, if the common block has a name, or `_BLNK_` otherwise.

For each member of the common block, a local static variable is declared which represents the common block variable. Thus given declarations:

```
common /xyz/ integer a, real b
```

then the entire common block can be printed out using,

```
print xyz
```

Individual elements can be accessed by name. For example:,

```
print a, b
```

1.10.5 Nested Subroutines

To reference a nested subroutine qualify its name with the name of its enclosing routine using the scoping operator @.

For example:

```
subroutine subtest (ndim)
   integer(4), intent(in) :: ndim
   integer, dimension(ndim) :: ijk
   call subsubtest ()
   contains
       subroutine  subsubtest ()
       integer :: I
       i=9
       ijk(1) = 1
       end subroutine subsubtest
       subroutine  subsubtest2 ()
       ijk(1) = 1
       end subroutine subsubtest2
   end subroutine subtest
```

```
   program testscope
   integer(4), parameter :: ndim = 4
   call subtest (ndim)
   end program testscope
```

```
pgdbg> break subtest@subsubtest
breakpoint set at: subsubtest line: 8 in "ex.f90" address: 0x80494091
pgdbg> names subtest@subsubtest
i = 0
pgdbg> decls subtest@subsubtest
arguments:
variables:
integer*4 i;
pgdbg> whereis subsubtest
function:       "ex.f90"@subtest@subsubtest
```

1.10.6 Fortran 90 Modules

To access a member ***mm*** of a Fortran 90 module ***M,*** qualify ***mm*** with ***M*** using the scoping operator **@**. If the current scope is ***M,*** the qualification can be omitted.

For example:

```
module M
   implicit none
   real mm
   contains
   subroutine stub
   print *,mm
   end subroutine stub
   end module M
```

```
program test
   use M
   implicit none
   call stub()
   print *,mm
   end program test
```

```
pgdbg> Stopped at 0x80494e3, function MAIN, file M.f90, line 13
#13:       call stub()
pgdbg> which mm
"M.f90"@m@mm
pgdbg> print "M.f90"@m@mm
0
pgdbg> names m
```

```
mm = 0
stub = "M.f90"@m@stub
pgdbg> decls m
real*4 mm;
subroutine stub();
pgdbg> print m@mm
0
pgdbg> break stub
breakpoint set at: stub line:6 in "M.f90" address: 0x8049446      1
pgdbg> c
Stopped at 0x8049446, function stub, file M.f90, line 6
 #6:           print *,mm
pgdbg> print mm
0
pgdbg>
```

1.11 Debugging *C++*

1.11.1 Calling C++ Instance Methods

To use the `call` command to call a *C++* instance method, the object must be explicitly passed as the first parameter to the call. For example, given the following definition of `class Person` and the appropriate implementation of its methods:

```
class Person {
    public:
    char name[10];
    Person(char * name);

    void print();
};

main(){
     Person * pierre;
     pierre =  new Person("Pierre");
     pierre.print();
   }
```

To call the instance method `print` on object `pierre`, use the following syntax:

```
pgdbg> call Person::print(pierre)
```

Notice that `pierre` must be explicitly passed into the method, and the class name must also be specified.

1.12 Debugging with Core Files

PGDBG supports debugging of core files on the linux86 and linux86-64 platforms. To invoke *PGDBG* for core file debugging, use the following options:

```
$ pgdbg –core coreFileName programName
```

Core files are generated when a fatal exception occurs in an application. The shell environment in which the application runs must be set up to allow core file creation. On many systems, the default user *ulimit* does not allow core file creation. Check the *ulimit* as follows:

For sh/bash users:

```
$ ulimit –c
```

For csh/tcsh users:

```
$ limit coredumpsize
```

If the core file size limit is zero or something too small for the application, it can be set to *unlimited* as follows:

For sh/bash users:

```
$ ulimit –c unlimited
```

For csh/tcsh users:

```
% limit coredumpsize unlimited
```

See the Linux shell documentation for more details. Some versions of Linux provide system-wide limits on core file creation. If the environment is set correctly and a core file is not generated in the expected location, then check with your system administrator.

Core files (or core *dumps*) are generated when a program encounters an exception or *fault*. For example, one common exception is the *segmentation violation*, which can be caused by referencing an invalid memory address. The memory and register states of the program are written into a core file so that they can be examined by a debugger.

The core file is normally written into the current directory of the faulting application. It is usually named *core* or *core.pid* where *pid* is the process ID of the faulting thread.

Different versions of Linux handle core dumping slightly differently. The state of all process threads are written to the core file in most modern implementations of Linux. In some new versions of Linux, if more than one thread faults, then each thread's state is written to separate core files using the *core.pid* file naming convention mentioned above. In older versions of Linux, only one faulting thread is written to the core file.

If a program uses dynamically shared objects (i.e., shared libraries named *lib*.so*), as most programs on Linux do, then accurate core file debugging requires that the program be debugged on the system where the core file was created. Otherwise, slight differences in the version of a shared library or the dynamic linker can cause erroneous information to be presented by the debugger. Sometimes a core file can be debugged successfully on a different system, but this is definitely an *at your own risk* type of an activity.

PGDBG supports all non-control commands when debugging core files. It will perform any command that does not cause the program to run. Any command that causes the program to run will generate an error message in *PGDBG*. Depending on the type of core file created, PGDBG may provide the status of multiple threads. *PGDBG* does not support multi-process core file debugging.

1.13 Debugging Parallel Programs

This section gives an overview of how to use *PGDBG* to debugging parallel applications. It provides some important definitions and background information on how *PGDBG* represents processes and threads.

1.13.1 Summary of Parallel Debugging Features

PGDBG is a parallel application debugger capable of debugging multi-process MPI applications, multi-thread OpenMP and Linuxthreads/pthreads applications, and hybrid multi-thread/multi-process applications that use MPI to communicate between multi-threaded or OpenMP processes.

1.13.1.1 OpenMP and Multi-thread Support

PGDBG provides full control of threads in parallel regions. Commands can be applied to all threads, a single thread, or a group of threads. Thread identification in PGDBG uses the native thread numbering scheme for OpenMP applications; for other types of multi-threaded applications thread numbering is arbitrary. OpenMP PRIVATE data can be accessed accurately for each thread. PGDBG provides understandable status displays regarding per-thread state and location.

Advanced features provide for configurable thread stop modes and wait modes, allowing debugger operation that is concurrent with application execution.

1.13.1.2 MPI and Multi-Process Support

PGDBG supports debugging of multi-process MPI applications, whether running on a single system or distributed on multiple systems. MPI applications can be started under debugger control using the MPIRUN command, or PGDBG can attach to a running, distributed MPI application. In either case all processes are automatically brought under debugger control. Process identification uses the MPI rank within COMMWORLD.

1.13.1.3 Graphical Presentation of Threads and Processes

PGDBG graphical user interface components that provide support for parallelism are described in detail in *Section 1.4 PGDBG Graphical User Interface.*

1.13.2 Basic Process and Thread Naming

Because PGDBG can debug multi-threaded applications, multi-process applications, and hybrid multi-threaded/multi-process applications, it provides a convention for uniquely identifying each thread in each process. This section gives a brief overview of this naming convention and how it is used in order to provide adequate background for the subsequent sections. A more detailed discussion of this convention, including advanced techniques for applying it, is provided in *Section 1.14 Thread and Process Grouping and Naming.*

PGDBG identifies threads in an OpenMP application using the OpenMP thread IDs. Otherwise, *PGDBG* assigns arbitrary IDs to threads, starting at zero and incrementing in order of thread creation.

PGDBG identifies processes in an MPI application using MPI rank (in communicator COMMWORLD). Otherwise, *PGDBG* assigns arbitrary IDs to processes; starting at zero and incrementing in order of process creation. Process IDs are unique across all active processes.

In a multi-threaded/multi-process application, each thread can be uniquely identified across all processes by prefixing its thread ID with the process ID of its parent process. For example, thread 1.4 identifies the thread with ID 4 in the process with ID 1.

An OpenMP application (single-process) logically runs as a collection of threads with a single process, process 0, as the parent process. In this context, a thread is uniquely identified by its

thread ID. The process ID prefix is implicit and optional. See *Section 1.14.2 Threads-only debugging.*

An MPI program logically runs as a collection of processes, each made up of a single thread of execution. Thread 0 is implicit to each MPI process. A Process ID uniquely identifies a particular process, and thread ID is implicit and optional. See *Section 1.14.3 Process-only debugging.*

A hybrid, or *multilevel* MPI/OpenMP program, requires the use of both process and thread IDs to uniquely identify a particular thread. See *Section 1.14.4 Multilevel debugging.*

A serial program runs as a single thread of execution, thread 0, belonging to a single process, process 0. The use of thread IDs and process IDs is unnecessary but optional.

1.13.3 Multi-Thread and OpenMP Debugging

PGDBG automatically attaches to new threads as they are created during program execution. *PGDBG* reports when a new thread is created and the thread ID of the new thread is printed.

```
([1] New Thread)
```

The system ID of the freshly created thread is available through using the *threads* command. The *procs* command can be used to display information about the parent process.

The *PGDBG* maintains a conceptual *current thread*. The current thread is chosen by using the *thread* command when the debugger is operating in text mode (invoked with the *-text* option), or by clicking in the thread grid when the GUI interface is in use (the default). A subset of PGDBG commands known as “thread level commands”, when executed, apply only to the current thread. See *Section 1.14.10.2 Thread Level Commands* for more information.

The *threads* command lists all threads currently employed by an active program. The *threads* command displays each thread’s unique thread ID, system ID (Linux process ID), execution state (running, stopped, signaled, exited, or killed), signal information and reason for stopping, and the current location (if stopped or signaled). The arrow indicates the current thread. The process ID of the parent is printed in the top left corner. The *thread* command changes the current thread.

```
pgdbg [all] 2> thread 3

pgdbg [all] 3> threads

0   ID PID    STATE      SIGNAL      LOCATION

=> 3  18399  Stopped    SIGTRAP     main line: 31 in "omp.c" address:
   0x80490ab
```

```
2  18398  Stopped    SIGTRAP     main line: 32 in "omp.c" address:
0x80490cf
1  18397  Stopped    SIGTRAP     main line: 31 in "omp.c" address:
0x80490ab
0  18395  Stopped    SIGTRAP     f line: 5 in "omp.c" address:
0x8048fa0
```

1.13.4 Multi-Process MPI Debugging

1.13.4.1 Invoking *PGDBG* for MPI Debugging

In order to debug an MPI application, *PGDBG* is invoked via MPIRUN . MPIRUN sets a breakpoint at `main` and starts the program running under the control of *PGDBG*. When the initial process hits `main` no other MPI processes are active. The non-initial MPI processes are created when the process calls `MPI_Init`.

A Fortran MPI program stops at `main`, not the Fortran `MAIN program`.

PGDBG must be installed and the PGI environment variable set appropriately, and *PGDBG* must be found in the PATH.

GUI mode invocation:

```
%mpirun -np 4 -dbg=pgdbg <executable> <args>,...<args>
```

TEXT mode invocation:

```
%unsetenv DISPLAY   # unsetenv is for csh, for bash: unset DISPLAY
%mpirun -np 4 -dbg=pgdbg <executable> <args>,...<args>
```

An MPI debug session starts with the initial process stopped at `main`. Set a breakpoint at a program location after the return of `MPI_Init` to stop all processes there. If debugging Fortran, *step* into the `MAIN` program.

1.13.4.2 Using PGDBG for MPI Debugging

The initial MPI process is run locally; ‘local’ describes the host the on which *PGDBG* is running. *PGDBG* automatically attaches to new MPI processes as they are created by the running MPI application. *PGDBG* displays an informational message as it attaches to the freshly created processes.

```
([1] New Process)
```

The MPI global rank is printed with the message. The *procs* command can be used to list the host and the PID of each process by rank. The current process is marked with an arrow. The *proc* command can be used to change the current process by process ID.

```
pgdbg [all] 0.0> proc 1; procs
Process 1: Thread 0 Stopped at 0x804a0e2, function main, file mpi.c,
   line 30
 #30:       aft=time(&aft);
    ID   IPID   STATE      THREADS   HOST
    0    24765  Stopped    1          local
 => 1    17890  Stopped    1       red2.wil.st.com


pgdbg [all] 1.0>
```

The execution state of a process is described in terms of the execution state of its component threads. In the GUI, this state is represented by a color in the proess/thread grid.

Table 1-13: Process state is described using color

Process state	Description	Color
Stopped	If all threads are stopped at breakpoints, or where directed to stop by *PGDBG*	Red
Signaled	If at least one thread is stopped due to delivery of a signal	Blue
Running	If at least one thread is running	Green
Exited or Killed	If all threads have been killed or exited	Black

The prompt displays the current process and the current thread. The current process above has been changed to process 1, and the current thread of process 1 is 0. This is written as `1.0`. See *Section 1.14.11 Process and Thread Control* for a complete description of the prompt format.

The following rules apply during a *PGDBG* debug session:

- *PGDBG* maintains a conceptual current process and current thread.
- Each active process has a thread set of size >=1.
- The current thread is a member of the thread set of the current process.

Certain commands, when executed, apply only to the current process or the current thread. See *Sections 1.14.10.1 Process Level Commands* and *1.14.10.2 Thread Level Commands* for more information.

A license file distributed with *PGDBG* restricts *PGDBG* to debugging a total of 64 threads. *Workstation* and *CDK* license files may further restrict the number of threads that *PGDBG* is eligible to debug. *PGDBG* will use the *Workstation* or *CDK* license files to determine the number of threads it is allowed to debug.

With its 64 thread limit, *PGDBG* is capable of debugging a 16 node cluster with 4 CPUs on each node or a 32 node cluster with 2 CPUs on each node or any combination of threads that add up to 64.

1.13.4.3 MPI-CH Support

PGDBG supports redirecting `stdin`, `stdout`, and `stderr` with the following MPI-CH switches:

Table 1-14: MPI-CH Support

Command	Output
`-stdout <file>`	Redirect standard output to `<file>`
`-stdin <file>`	Redirect standard input from `<file>`
`-stederr <file>`	Redirect standard error to `<file>`

PGDBG also provides support for the following MPI-CH switches:

Command	Output
`-nolocal`	*PGDBG* runs locally, but no MPI processes run locally
`-all-local`	*PGDBG* runs locally, all MPI processes run locally

For information about how to configure an arbitrary installation of MPI-CH to use pgdbg, see the *PGDBG* online FAQ at http://www.pgroup.com/faq/index.htm.

When *PGDBG* is invoked via MPIRUN the following *PGDBG* command line arguments are not accessible. A workaround is listed for each.

Argument	Workaround
`-dbx`	Include `'pgienv dbx on'` in *.pgdbgrc* file
`-s startup`	Use *.pgdbgrc* default script file and the *script* command.
`-c "command"`	Use *.pgdbgrc* default script file and the *script* command.
`-text`	Clear your DISPLAY environment variable before invoking MPIRUN
`-t <target>`	Add to the beginning of the PATH environment variable a path to the appropriate *PGDBG*.

1.13.4.4 LAM-MPI Support

The Portland Group Cluster Development Kit (CDK) includes an implementation of MPI-CH. *PGDBG* is configured to automatically integrate with MPI-CH. *PGDBG* can also be used with LAM-MPI, but some configuration is required. For more information, see the online FAQ at http://www.pgroup.com/faq/index.htm.

1.14 Thread and Process Grouping and Naming

This section describes how to name a single thread, how to group threads and processes into sets, and how to apply *PGDBG* commands to groups of processes and threads.

1.14.1 *PGDBG* Debug Modes

PGDBG can operate in four debug modes. The mode determines a short form for uniquely naming threads and processes. The debug mode is set automatically or by the *pgienv* command.

Table 1-15: The *PGDBG* Debug Modes

Debug Mode	Program Characterization
Serial	A single thread of execution
Threads-only	A single process, multiple threads of execution
Process-only	Multiple processes, each process made up of a single thread of execution
Multilevel	Multiple processes, at least one process employing multiple threads of execution

PGDBG initially operates in serial mode reflecting a single thread of execution. Thread IDs can be ignored in serial debug mode since there is only a single thread of execution.

The *PGDBG* prompt displays the ID of the current thread according to the current debug mode. See *Section 1.14.15 The PGDBG Command Prompt* for a description of the *PGDBG* prompt.

The *pgienv* command is used to change debug modes manually.

```
pgienv mode [serial|thread|process|multilevel]
```

The debug mode can be changed at any time during a debug session.

1.14.2 Threads-only debugging

Enter threads-only mode to debug a program with a single multi-threaded process. As a convenience the process ID portion can be omitted. *PGDBG* automatically enters threads-only debug mode from serial debug mode when it detects and attaches to new threads.

Example 1-1: Thread IDs in threads-only debug mode

`1`	Thread 1 of all processes (*.1)
`*`	All threads of all processes (*. *)
`0.7`	Thread 7 of process 0 (Multilevel thread names valid in threads-only debug mode)

In threads-only debug mode, status and error messages are prefixed with thread IDs depending on context.

1.14.3 Process-only debugging

Enter process-only mode to debug an application consisting of single-threaded processes. As a convenience, the thread ID portion can be omitted. *PGDBG* automatically enters process-only debug mode from serial debug mode when the target program returns from `MPI_Init`.

Example 1-2: Process IDs in process-only debug mode

`0`	All threads of process 0 (0.*)
`*`	All threads of all processes (*.*)
`1.0`	Thread 0 of process 1 (Multilevel thread names are valid in this mode)

In process-only debug mode, status and error messages are prefixed with process IDs depending on context.

1.14.4 Multilevel debugging

The name of a thread in multilevel debug mode is the thread ID prefixed with its parent process ID. This forms a unique name for each thread across all processes. This naming scheme is valid in all debug modes. *PGDBG* changes automatically to multilevel debug mode from process-only debug mode or threads only-debug mode when at least one MPI process creates multiple threads.

Example 1-3: Thread IDs in multilevel debug mode

`0.1`	Thread 1 of process 0
`0.*`	All threads of process 0

In multilevel debug, mode status and error messages are prefixed with process/thread IDs depending on context.

1.14.5 Process/Thread Sets

A process/thread set (*p/t-set*) is used to restrict a debugger command to apply to just a particular set of threads. A p/t-set is a set of threads drawn from all threads of all processes in the target program. Use p/t-set notation (described below) to define a p/t-set.

The *current p/t-set* can be set using the *focus* command, which establishes the default p/t-set for cases where no p/t-set prefix is specified. This begins as the debugger-defined set `[all]`, which describes all threads of all processes.

P/t-set notation can be used to prefix a debugger command. This overrides the *current p/t-set* defining the target threads to be those threads described by the *prefix p/t-set.*

The *target p/t-set* is defined then to be the *prefix p/t-set* if present, it is the *current p/t-set* otherwise.

- Use *defset* to define a named or user-defined p/t-set.
- Use *viewset* and *whichsets* to inspect the active members described by a particular p/t-set.

The target p/t-set determines which threads are affected by a *PGDBG* command. If using the *PGDBG* Graphical User Interface (GUI) (*Section 1.4 PGDBG Graphical User Interface*), then you can define a *focus group* in the GUI's *Focus* panel as an alternative to the *defset* command (*Section 1.4.1.2 Focus Panel*). See *Section 1.14.9 P/t-set Commands* for more information on P/t-set commands.

1.14.6 P/t-set Notation

The following set of rules describes how to use and construct process/thread sets (*p/t-sets*).

```
simple command :
   [p/t-set-prefix] command parm0, parm1, ...

compound command :
   [p/t-set-prefix] simple-command [; simple-command ...]

p/t-id :
   {integer|*}.{integer|*}
```

Optional notation when processes-only debugging or threads-only debugging is in effect (see the *pgienv* command).

```
    {integer|*}

p/t-range :
    p/t-id:p/t-id

p/t-list :
    {p/t-id|p/t-range} [, {p/t-id|p/t-range} ...]

p/t set :
    [[!]{p/t-list|set-name}]
```

Example 1-4: P/t-sets in threads-only debug

`[0,4:6]`	Threads 0,4,5, and 6
`[*]`	All threads
`[*.1]`	Thread 1. Multilevel notation is valid in threads-only mode
`[*.*]`	All threads

Example 1-5: P/t-sets in process-only debug

`[0,2:3]`	Processes 0, 2, and 3 (equivalent to [0.*,2:3.*])
`[*]`	All processes (equivalent to [*.*])
`[0]`	Process 0 (equivalent to [0.*])
`[*.0]`	Process 0. Multilevel syntax is valid in process-only mode.
`[0:2.*]`	Processes 0, 1, and 2. Multilevel syntax is valid in process-only debug mode.

Example 1-6: P/t-sets in multilevel debug mode

`[0.1,0.3,0.5]`	Thread 1,3, and 5 of process 0
`[0.*]`	All threads of process 0
`[1.1:3]`	`Thread 1,2, and 3 of process 1`
`[1:2.1]`	`Thread 1 of processes 1 and 2`
`[clients]`	`All threads defined by named set clients`
`[1]`	`Incomplete; invalid in multilevel debug mode`

P/t-sets defined with *defset* are not mode dependent and are valid in any debug mode.

1.14.7 Dynamic vs. Static P/t-sets

The members of a *dynamic p/t-set* are those active threads described by the p/t-set at the time that p/t-set is used. A p/t-set is dynamic by default. Threads and processes are created and destroyed as the target program runs. Membership in a dynamic set varies as the target program runs.

Example 1-7: Defining a dynamic p/t-set

`defset clients [*.1:3]`	Defines a named set `clients` whose members are threads 1, 2, and 3 of all processes that are currently active when `clients` is used. Membership in `clients` changes as processes are created and destroyed.

The members of a *static p/t-set* are those threads described by the p/t-set at the time that p/t-set is defined. Use a `!` to specify a static set. Membership in a static set is fixed at definition time.

Example 1-8: Defining a Static p/t-set

`defset clients [!*.1:3]`	Defines a named set `clients` whose members are threads 1, 2, and 3 of those processes that are currently active at the time of the definition.

1.14.8 Current vs. Prefix P/t-set

The current p/t-set is set by the *focus* command. The current p/t-set is described by the debugger prompt (depending on debug mode). A p/t-set can be used to prefix a command to override the current p/t-set. The prefix p/t-set becomes the target p/t-set for the command. The target p/t-set defines the set of threads that will be affected by a command. See *Section 1.14.15 The PGDBG Command Prompt* for a description of the *PGDBG* prompt.

- The target p/t-set is the current p/t-set:

  ```
  pgdbg [all] 0.0> cont
  Continue all threads in all processes
  ```

- The target p/t-set is the prefix p/t-set:

  ```
  pgdbg [all] 0.0> [0.1:2] cont
  Continue threads 1 and 2 of process 0 only
  ```

Above, the current p/t-set is the debugger-defined set `[all]` in both cases. In the first case, `[all]` is the target p/t-set. In the second case, the prefix set overrides `[all]` as the target p/t-set. The *continue* command is applied to all active threads in the target p/t-set. Using a prefix p/t-set does not change the current p/t-set.

1.14.9 P/t-set Commands

The following commands can be used to collect threads into logical groups.

- *defset* and *undefset* can be used to manage a list of named p/t-sets.
- *focus* is used to set the current p/t-set.
- *viewset* is used to view the active members described by a particular p/t-set.
- *whichsets* is used to describe the p/t-sets to which a particular process/thread belongs.

Table 1-16: P/t-set commands

Command	Description
`focus`	Set the target process/thread set for commands. Subsequent commands will be applied to the members of this set by default.
`defset`	Assign a name to a process/thread set. Define a named set. This set can later be referred to by name. A list of named sets is stored by *PGDBG*.
`undefset`	'Undefine' a previously defined process/thread set. The set is removed from the list. The debugger-defined p/t-set `[all]` can not be removed.
`viewset`	List the members of a process/thread set that currently exist as active threads.
`whichsets`	List all defined p/t-sets to which the members of a process/thread set belongs.

```
pgdbg [all] 0> defset initial [0]
"initial"       [0] : [0]


pgdbg [all] 0> focus [initial]
[initial] : [0]
[0]
pgdbg [initial] 0> n
```

The p/t-set `initial` is defined to contain only thread 0. This example focuses on `initial` and advances the thread. *Focus* sets the current p/t-set. Because the code is not using a prefix p/t-set, the target p/t-set is the current p/t-set which is `initial`.

The *whichsets* command above shows us that thread 0 is a member of two defined p/t-sets. The *viewset* command displays all threads that are active and are members of defined p/t-sets. The `'pgienv verbose'` command can be used to turn on verbose messaging, displaying the stop location of each thread as it stops.

```
pgdbg [initial] 0> whichsets [initial]
Thread 0 belongs to:
```

```
all
initial

pgdbg [initial] 0> viewset
"all"   [*.*] : [0.0,0.1,0.2,0.3]
"initial"       [0] : [0]

pgdbg [initial] 0> focus [all]
[all] : [0.0,0.1,0.2,0.3]
[*.*]

pgdbg [all] 0> undefset initial
p/t-set name "initial" deleted.
```

The examples above illustrate how to manage named *p/t-sets* in the command-line interface. A similar capability is available in the *PGDBG GUI. Section 1.4.1.2 Focus Panel,* contains information about the *Focus Panel*. The *Focus Panel,* shown in Figure 1-3, contains a table labeled *Focus* with two columns: a *Name* column and a *p/t-set* column. The entries in this table are p/t sets exactly like the p/t sets used in the command line interface.

To create a *p/t set in the Focus Panel* , left-click the *Add* button. This opens a dialog box similar to the one in Figure 1-12. Enter the name of the *p/t set* in the *Focus Name* text field and the *p/t-set* in the *p/t-set* text field. Click the left mouse button on the *OK* button to add the *p/t set*. The new *p/t set will appear* in the *Focus Table.* Clicking the *Cancel* button or closing the dialog box will abort the operation. The *Clear* button will clear the *Focus Name* and *p/t-set* text fields

To select a *p/t set,* click the left mouse button on the desired *p/t set* in the table. The selected *p/t set* is also known as the *Current Focus*. *PGDBG* will apply all commands entered in the *Source Panel* to the *Current Focus* when you choose *Focus* in the *Apply Selector* (*Section 1.4.2.3 Source Panel Combo Boxes*). *Current Focus* can also be used in a GUI subwindow. Choose *Current Focus* in a subwindow's *Context Selector* (*Section 1.4.4 Subwindows*) to display data for the *Current Focus* only.

To modify an existing *p/t set,* select the desired group in the *Focus Table* and left-click the *Modify* button. A dialog box similar to that in Figure 1-12 will appear, except that the *Focus Name* and *p/t-set* text fields will contain the selected group's name and *p/t-set* respectively. You can edit the information in these text fields and click *OK* to save the changes.

To remove an existing *p/t set,* select the desired item in the *Focus Table* and left-click the *Remove* button. *PGDBG* will display a dialog box asking for confirmation of the request for removal of the

selected *p/t set.* Left-click the *Yes* button to confirm, or the *No* button to cancel the operation.

It should be noted that *p/t sets* defined in the Focus Panel of the *PGDBG* GUI are only used by the *Apply* and *Context Selectors* in the GUI. They do not affect *focus* in the Command Prompt Panel. Conversely, focus changes made in the Command Prompt Panel affect only the Command Prompt Panel and not the rest of the *PGDBG* GUI.

For example,in Figure 1-12 there is a *p/t set* named “process 0 odd numbered threads”. The *p/t-set* is `[ 0.1, 0.3 ]` which indicates threads 1 and 3 in process 0. Figure 1-13 shows this *p/t set* in the *Focus Table.* We also chose *Focus* in the *Apply Selector*. Any command issued in the *Source Panel* is applied to the *Current Focus,* or thread 1 and 3 on process 0 only. All other threads will remain idle until either the *All p/t set* is selected in the Focus Panel or *All* is select in the *Apply Selector*. But “process – odd numbered threads” is not available in the Command Prompt Panel.

Figure 1-12: Focus Group Dialog Box

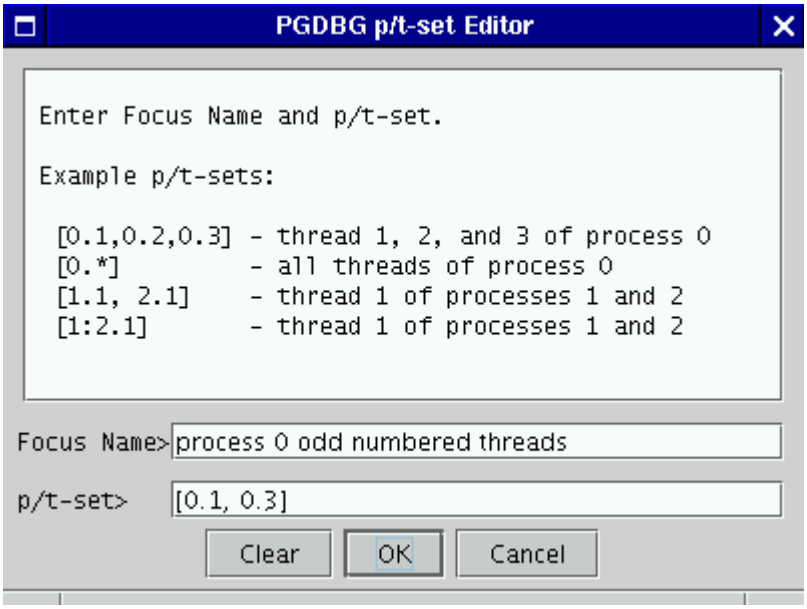
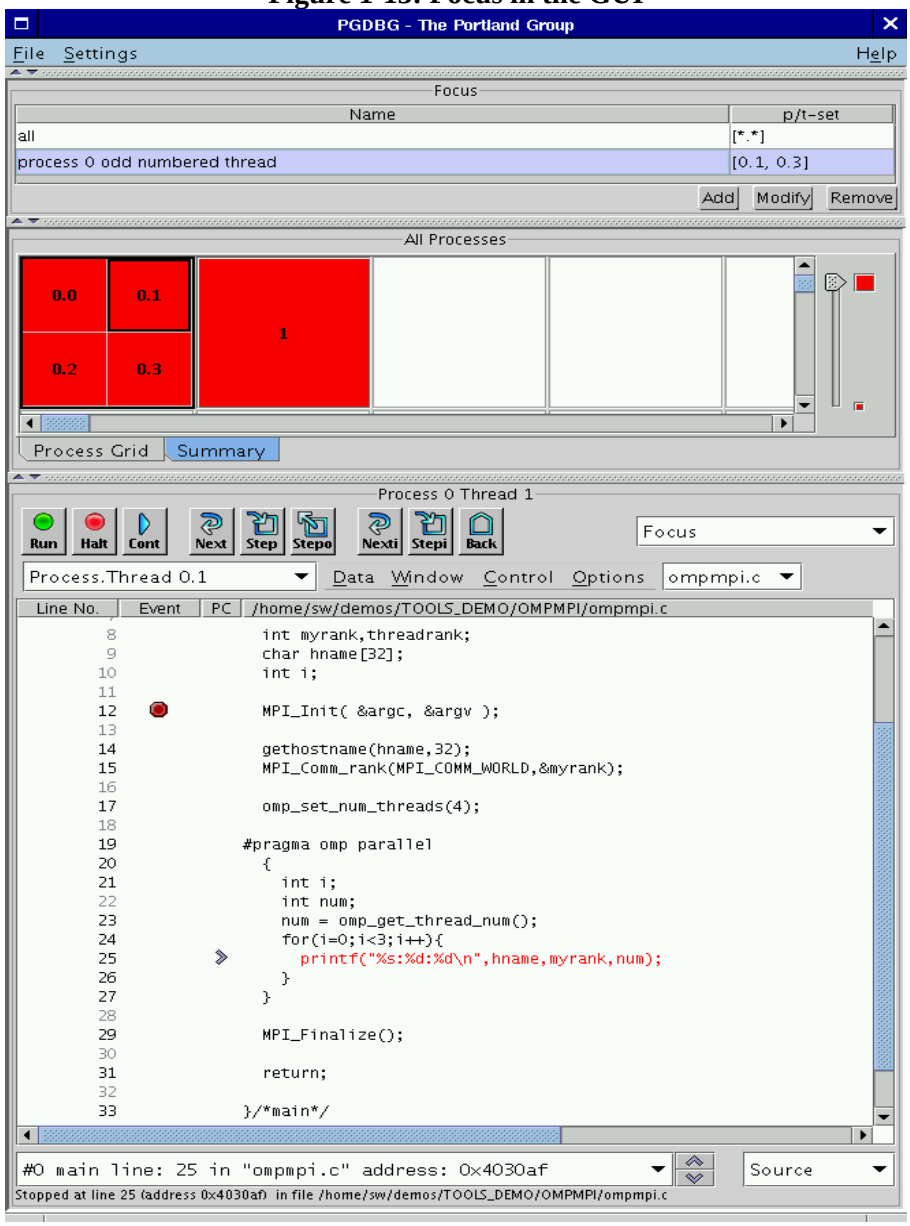


Figure 1-13: Focus in the GUI



1.14.10 Command Set

For the purpose of parallel debugging, the *PGDBG* command set is divided into three disjoint subsets according to how each command reacts to the current p/t-set. *Process level* and *thread level* commands can be parallelized. *Global* commands cannot be parallelized.

Table 1-17: *PGDBG* Parallel Commands

Commands	Action
Process Level Commands	Parallel by current p/t-set or prefix p/t-set
Thread Level Commands	Parallel by prefix p/t-set. Ignores current p/t-set
Global Commands	Non-parallel commands

1.14.10.1 Process Level Commands

The *process level commands* are the *PGDBG* control commands.

The *PGDBG* control commands apply to the active members of the current p/t-set by default. A prefix set can be used to override the current p/t-set. The target p/t-set is the prefix p/t-set if present. If a target p/t set does not exist, the current p/t-set is the prefix.

cont next nexti step stepi

stepout sync synci halt wait

Example:

```
pgdbg [all] 0.0> focus [0.1:2]
pgdbg [0.1:2] 0.0> next
```

The *next* command is applied to threads 1 and 2 of process 0.

Example:

```
pgdbg [clients] 0.0> [0.3] n
```

This demonstrates the use of a prefix p/t-set. The *next* command is applied to thread 3 of process 0 only.

1.14.10.2 Thread Level Commands

The following commands are not concerned with the current p/t-set. When no p/t-set prefix is used, these commands execute in the context of the current thread of the current process by default. That is, *thread level commands* ignore the current p/t-set. Thread level commands can be applied to multiple threads by using a prefix p/t-set. When a prefix p/t-set is used, the commands in this section are executed in the context of each active thread described by the prefix p/t-set. The target p/t-set is the prefix p/t-set if present, or the current thread if not prefix p/t set exists. The *thread level* commands are:

`set`	`assign`	`pc`	`sp`
`fp`	`retaddr`	`regs`	`line`
`func`	`lines`	`addr`	`entry`
`decl`	`whatis`	`rval`	`lval`
`sizeof`	`iread`	`cread`	`sread`
`fread`	`dread`	`print`	`hex`
`dec`	`oct`	`bin`	`ascii`
`string`	`disasm`	`dump`	`pf`
`noprint`	`where`	`stack`	`break*`
`stackdump`	`scope`	`watch`	`track`
`break`	`do`	`watchi`	`tracki`
`doi`	`hwatch`		

* breakpoints and variants: (stop, stopi, break, breaki) if no prefix p/t-set is specified, [all] is used (overriding current p/t-set).

The following occurs when a prefix p/t-set is used:

- the threads described by the prefix are sorted per process by thread ID in increasing order.
- the processes are sorted by process ID in increasing order, and duplicates are removed.
- the command is then applied to the threads in the resulting list in order.

```
pgdbg [all] 0.0> print myrank
0
```

Without a prefix p/t-set, the print command executes in the context of the current thread of the current process, thread 0.0, printing rank 0.

```
pgdbg [all] 0.0> [2:3.*,1:2.*] print myrank
[1.0] print  myrank:
1
[2.0] print  myrank:
2
[2.1] print  myrank:
2
[2.2] print  myrank:
2
[3.0] print  myrank:
3
[3.2] print  myrank:
3
[3.1] print  myrank:
3
```

The thread members of the prefix p/t-set are sorted and duplicates are removed. The *print* command iterates over the resulting list.

1.14.10.3 Global Commands

The rest of the *PGDBG* commands ignore threads and processes, or are defined globally for all threads across all processes. The current p/t-set and a prefix p/t-set are ignored.

The following is a list of commands that are defined globally.

debug	run	rerun	threads
procs	proc	thread	call
unbreak	delete	disable	enable
arrive	wait	breaks	status
help	script	log	shell
alias	unalias	directory	repeat
pgienv	files	funcs	source
use	cd	pwd	whereis
edit	/	?	history
catch	ignore	quit	focus
defset	undefset	viewset	whichsets
display			

1.14.11 Process and Thread Control

PGDBG supports thread and process control (e.g. *step*, *next*, *cont* ...) everywhere in the program. Threads and processes can be advanced in groups anywhere in the program.

The *PGDBG* control commands are:

```
cont,   step,  stepi,  next,  nexti,
stepout,  halt,  wait,   sync,  synci
```

To describe those threads to be advanced, set the current p/t-set or use a prefix p/t-set.

A thread inherits the control operation of the current thread when it is created. If the current thread '*next*'s over an `_mp_init` call (at the beginning of every OpenMP parallel region), then all threads created by `_mp_init` will '*nex*t' into the parallel region.

A process inherits the control operation of the current process when it is created. So if the current process is '*cont*inuing' out of a call to `MPI_Init`, the new process will do the same.

1.14.12 Configurable Stop Mode

PGDBG supports configuration of how threads and processes stop in relation to one another. *PGDBG* defines two new `pgienv` environment variables, `threadstop` and `procstop`, for this purpose. *PGDBG* defines two *stop modes*, synchronous (`sync`) and asynchronous (`async`).

Table 1-18: *PGDBG* Stop Modes

Command	Result
`sync`	Synchronous stop mode; when one thread stops at a breakpoint (event), all other threads are stopped soon after
`async`	Asynchronous stop mode; each thread runs independently of the other threads. One thread stopping does not affect the behavior of another

Thread stop mode is set using the `pgienv` command as follows:

```
pgienv threadstop [sync|async]
```

Process stop mode is set using the `pgienv` command as follows:

```
pgienv procstop [sync|async]
```

PGDBG defines the default to be asynchronous for both thread and process stop modes. When debugging an OpenMP program, *PGDBG* automatically enters synchronous thread stop mode in serial regions, and asynchronous thread stop mode in parallel regions.

The `pgienv` environment variable `threadstopconfig` and `procstopconfig` can be set to automatic `(auto)` or user defined `(user)` to enable or disable this behavior.

```
pgienv threadstopconfig [auto|user]
pgienv procstopconfig   [auto|user]
```

Selecting the user-defined stop mode prevents the debugger from changing stop modes automatically. Automatic stop configuration is the default for both threads and processes.

1.14.13 Configurable Wait mode

Wait mode describes when *PGDBG* will accept the next command. The wait mode is defined in terms of the execution state of the program. Wait mode describes to the debugger which threads/processes must be stopped before it will accept the next command. In certain situations, it is desirable to be able to enter commands while the program is running and not stopped. The *PGDBG* prompt will not appear until all processes/threads are stopped. However, a prompt may be available before all processes/threads have stopped. Pressing `<enter>` at the command line will bring up a prompt if it is available. The availability of the prompt is determined by the current wait mode and any pending wait commands (described below).

PGDBG accepts a compound statement at each prompt. Each compound statement is a bundle of commands, which are processed in order at once. The wait mode describes when to accept the next compound statement. *PGDBG* supports three wait modes:

Table 1-19: *PGDBG* Wait Modes

Command	Result
`any`	The prompt is available only after at least one thread has stopped since the last control command
`all`	The prompt is available only after all threads have stopped since the last control command
`none`	The prompt is available immediately after a control command is issued

- *Thread wait mode* describes which threads *PGDBG* waits for before accepting a next command.
- *Process wait mode* describes which processes *PGDBG* waits for before accepting a next command.

Thread wait mode is set using the `pgienv` command as follows:

```
pgienv threadwait [any|all|none]
```

Process wait mode is set using the `pgienv` command as follows:

```
pgienv procwait [any|all|none]
```

If process wait mode is set to `none`, then thread wait mode is ignored.

In TEXT mode, *PGDBG* defaults to:

```
threadwait  all
procwait    any
```

If the target program goes MPI parallel, then `procwait` is changed to `none` automatically by *PGDBG*.

If the target program goes thread parallel, then `threadwait` is changed to `none` automatically by *PGDBG*. The `pgienv` environment variable `threadwaitconfig` can be set to automatic (`auto`) or user defined (`user`) to enable or disable this behavior.

```
pgienv threadstopconfig [ auto | user ]
```

Selecting the user defined wait mode prevents the debugger from changing wait modes automatically. Automatic wait mode is the default thread wait mode.

PGDBG defaults to the following in GUI mode:

```
threadwait none
procwait   none
```

Setting the wait mode may be necessary when invoking the debugger using the **`-s`** (script file) option in GUI mode (to ensure that the necessary threads are stopped before the next command is processed if necessary).

PGDBG also provides a *wait* command that can be used to insert explicit wait points in a command stream. *`Wait`* uses the target p/t-set by default, which can be set to wait for any combination of processes/threads. The *`wait`* command can be used to insert wait points between the commands of a compound command.

The `threadwait` and `procwait` environment variables can be used to configure the behavior of `wait` (see *`pgienv`*).

The following table describes the behavior of *wait*. In the example in the table:

- S is the target p/t-set
- P is the set of all processes described by S and p is a process
- T is the set of all threads described by S and t is a thread

Table 1-20: *PGDBG* Wait Behavior

Command	threadwait	procwait	Wait set
`wait`	all	all	Wait for T
`wait`	all	none|any	Wait for all threads in at least one p in P
`wait`	none|any	all	Wait for T
`wait`	none|any	none|any	Wait for all t in T for at least one p in P
`wait any`	all	all	Wait for at least one thread for each process p in P
`wait any`	all	none|any	Wait for at least one t in T
`wait any`	none|any	all	Wait for at least one thread in T for each process p in P
`wait any`	none|any	none|any	Wait for at least one t in T
`wait all`	all	all	Wait for T
`wait all`	all	none|any	Wait for all threads of at least one p in P
`wait all`	none|any	all	Wait for T
`wait all`	none|any	none|any	Wait for all t in T for at least one p in P
`Wait none`	`all|none|any`	`all|none|any`	`Wait for no threads`

1.14.14 Status Messages

Use the `pgienv` command to enable/disable various status messages. This can be useful in text mode in the absence of the graphical aids provided by the GUI.

```
pgienv verbose <bitmask>
```

Choose the debug status messages that are reported by *PGDBG*. The tool accepts an integer valued bit mask of the values described in the following table.

Table 1-21: *PGDBG* Status Messages

Thread	Format	Information
0x1	Standard	Report status information on current process/thread only. A message is printed only when the current thread stops. Also report when threads and processes are created and destroyed. Standard messaging cannot be disabled. (default)
0x2	Thread	Report status information on all threads of (current) processes. A message is reported each time a thread stops. If Process messaging is also enabled, then a message is reported for each thread across all processes. Otherwise, messages are reported for threads of the current process only.
0x4	Process	Report status information on all processes. A message is reported each time a process stops. If Thread messaging is also enabled, then a message is reported for each thread across all processes. Otherwise messages are reported for the current thread only of each process.
0x8	SMP	Report SMP events. A message is printed when a process enters/exits a parallel region, or when the threads synchronize. The *PGDBG* OpenMP handler must be enabled.
0x16	Parallel	Report process-parallel events (default). Currently unused.
0x32	Symbolic debug information	Report any errors encountered while processing symbolic debug information (e.g. STABS, DWARF).

1.14.15 The PGDBG Command Prompt

The *PGDBG* command prompt reflects the current debug mode (See *Section 1.14.1 PGDBG*

Debug Modes).

In serial debug mode, the *PGDBG* prompt looks like this:

```
pgdbg>
```

In threads-only debug mode, *PGDBG* displays the current p/t-set followed by the ID of the current thread.

```
pgdbg [all] 0>
Current thread is 0
```

In process-only debug mode, *PGDBG* displays the current p/t-set followed by the ID of the current process.

```
pgdbg [all] 0>
Current process is 0
```

In multilevel debug mode, *PGDBG* displays the current p/t-set followed by the ID of the current thread prefixed by the id of its parent process.

```
pgdbg [all] 1.0>
Current thread 1.0
```

The *pgienv* `promptlen` variable can be set to control the number of characters devoted to printing the current p/t-set at the prompt. See *Section 1.14.1 PGDBG Debug Modes* for a description of the *PGDBG* debug modes.

1.14.16 Parallel Events

This section describes how to use a p/t-set to define an event across multiple threads and processes. Events, such as breakpoints and watchpoints, are user-defined events. User defined events are Thread Level commands (See *Section 1.14.10.2 Thread Level Commands* for details).

Breakpoints, by default, are set across all threads of all processes. A prefix p/t-set can be used to set breakpoints on specific processes and threads.

Example:

```
i)   pgdbg [all] 0> b 15
ii)  pgdbg [all] 0> [all] b 15
```

```
iii) pgdbg [all] 0> [0.1:3] b 15
```

(i) and (ii) are equivalent. (iii) sets a breakpoint only in threads 1,2,3 of process 0.

By default, all other user events are set for the current thread only. A prefix p/t-set can be used to set user events on specific processes and threads.

Example:

```
i)  pgdbg [all] 0> watch glob
ii) pgdbg [all] 0> [*] watch glob
```

(i) sets a data breakpoint for glob on thread 0 only. (ii) sets a watchpoint for glob on all threads that are currently active.

When a process or thread is created, it inherits all of the breakpoints defined for the parent process or thread. All other events must be defined explicitly after the process/thread is created. All processes must be stopped to add, enable, or disable a user event.

Events may contain ‘if’ and ‘do’ clauses.

Example:

```
pgdbg [all] 0> [*] break func if (glob!=0) do {set f = 0}
```

The breakpoint will fire only if `glob` is non-zero. The 'do' clause is executed if the breakpoint fires. The 'if' and 'do' clauses execute in the context of a single thread. The conditional in the 'if' and the body of the 'do' execute in the context of a single thread (the thread that triggered the event). The conditional definition as above can be restated as follows:

```
[0] if (glob!=0) {[0] set f = 0}
[1] if (glob!=0) {[1] set f = 0}
...
```

When thread 1 hits func, `glob` is evaluated in the context of thread 1. If `glob` evaluates to non-zero, f is bound in the context of thread 1 and its value is set to 0.

Control commands can be used in ‘do’ clauses, however they only apply to the current thread and are only well defined as the last command in the ‘do’ clause.

Example:

```
pgdbg [all] 0> [*] break func if (glob!=0) do {set f = 0; c}
```

If the *wait* command appears in a ‘do’ clause, the current thread is added to the wait set of the current process.

```
Pgdbg [all] 0> [*] break func if (glob!=0) do {set f = 0; c; wait}
```

‘if’ conditionals and ‘do’ bodies cannot be parallelized with prefix p/t-sets.

Example:

```
pgdbg [all] 0> break func if (glob!=0) do {[*] set f = 0} ILLEGAL
```

This is illegal. The body of a ‘do’ statement cannot be parallelized.

1.14.17 Parallel Statements

This section describes how to use a p/t-set to define a statement across multiple threads and processes.

1.14.17.1 Parallel Compound/Block Statements

Example:

```
i)pgdbg [all] 0>[*] break main;
cont; wait; print f@11@i
ii) pgdbg [all] 0>[*] break main;
[*]cont; [*]wait; [*]print f@11@i
```

(i) and (ii) are equivalent. Each command in a compound statement is executed in order. The target p/t-set is broadcast to all statements. Use the *wait* command if subsequent commands require threads to be stopped (the *print* command above). The commands in a compound statement are executed together in order.

The `threadwait` and `procwait` environment variables do not affect how commands within a compound statement are processed. These *pgienv* environment variables describe to *PGDBG* under what conditions (runstate of program) it should accept the next (compound) statement.

1.14.17.2 Parallel If, Else Statements

This section describes parallel 'if' and 'else' statements.

```
Example:
```

```
pgdbg [all] 0> [*] if (i==1) {break func; c; wait} else {sync func2}
```

A prefix p/t-set parallelizes an 'if' statement. An 'if' statement executes in the context of the current thread by default. The example above is equivalent to:

```
[*] if (i==1) ==> [s]
    [s]break func; [s]c; [s]wait;
else ==> [s']
    [s']sync func2
```

Where [s] is the subset of [*] for which (i==1), and [s'] is the subset of [*] for which (i!=1).

1.14.17.3 Parallel While Statements

This section describes parallel 'while' statements.

Example:

```
pgdbg [all] 0> [*] while (i<10) {n; wait; print i}
```

A prefix p/t-set parallelizes a 'while' statement. A 'while' statement executes in the context of the current thread by default. The above example is equivalent to:

```
[*] ==> [s]
while(|[s]|){
[s] if (i<10) ==> [s]
    [s]n; [s]wait; [s]print i;
}
```

Where [s] is the subset of [*] for which (i<10). The 'while' statement terminates when [s] is the empty set (or a 'return') statement is executed in the body of the 'while'.

1.14.17.4 Return Statements

The ‘return’ statement is defined only in serial context, since it cannot return multiple values. When 'return' is used in a parallel statement, it returns the last value evaluated.

1.15 OpenMP Debugging

An attempt is made by *PGDBG* to preserve line level debugging and to help make debugging OpenMP programs more intuitive. *PGDBG* preserves line level debugging across OpenMP threads in the following situations:

- Entrance to parallel region
- Exit parallel region
- Nested parallel regions synchronization points
- Critical and exclusive sections
- Parallel sections

This means that when directives or pragmas that imply complex parallel operations are encountered in the execution of an OpenMP application, PGDBG treats those directives as a single source line.

1.15.1 Serial vs. Parallel Regions

The initial thread is the thread with OpenMP ID 0. Conceptually, the initial thread is the only thread that can be effectively debugged in a serial region of code. All threads may be debugged in a parallel region of code. When the initial thread is in a serial region, the non-initial threads are waiting to be assigned to do some work in the next parallel region. All threads enter the (next) parallel region only when the first thread has entered the parallel region, (i.e., the initial thread is not in a serial region.)

PGDBG source level debugging operations (*next*, *step*,...) are not useful for debugging non-initial threads in serial regions, since these threads are idle, executing low-level code that is not compiled to include source line information. Non-initial threads in serial regions may be debugged using assembly-level debugging operations, but it is not recommended.

To ease debugging in serial and parallel regions of an OpenMP program, *PGDBG* automatically configures both the *thread wait mode* and the *thread stop mode* of the debug session.

Upon entering a serial region, *PGDBG* automatically changes the *thread stop mode* to *synchronous stop mode* and the *thread wait mode* to `all'. This allows easy control of all threads together in serial regions. For example, a *next* command, applied to all threads in a serial region, will complete successfully when the initial thread hits the next source line.

Upon entering a parallel region, *PGDBG* automatically changes the *thread stop mode* to

asynchronous stop mode and the *threadwait mode* to `none'. This allows control of each thread independently. For example, a *next* command, applied to all threads in a parallel region, will not complete successfully until all threads hit their next source line. With the *thread wait mode* set to `none', use the *halt* command on threads that hit barrier points.

To disable the automatic configuration of the *thread wait* and *thread stop* modes, see the *threadstopconfig* and *threadwaitconfig* options of the *pgienv* command (*Section 1.9.1.11 Miscellaneous).*

The configuration of the *thread wait* and *stop* modes, as described above, occurs automatically for OpenMP programs only. When debugging a Linuxthread program, the *threadstop* and *threadwait* configuration options should be set using the *pgienv* command (*Section 1.9.1.11 Miscellaneous).*

1.15.2 The PGDBG OpenMP Event Handler

PGDBG provides optional explicit support for OpenMP events. OpenMP events are points in a well-defined OpenMP program where the behavior of one thread depends on the location of another thread. For example, a thread may continue after another thread reaches a barrier point. The *PGDBG* OpenMP event handler is disabled by default. It can be enabled using the *omp pgienv* environment variable as shown below:

```
pgienv omp [ on | off ]
```

The *PGDBG* OpenMP event handler sets breakpoints before a parallel region, after a parallel region, and at each thread synchronization point. This causes a noticeable slowdown in performance of the program as it runs with the debugger.

The OpenMP event handler is deprecated as of *PGDBG* release 5.2.

1.15.3 Debugging Thread Private Data

PGDBG supports debugging of thread private data for all supported languages as of release 6.0. When an object is declared private in the context of an OpenMP parallel region, it essentially means that each thread team will have its own copy of the object. This capability is shown in the following example.

FORTRAN version of thread private example:

```
      program omp_private_data
            integer omp_get_thread_nu
            call omp_set_num_threads(2)
```

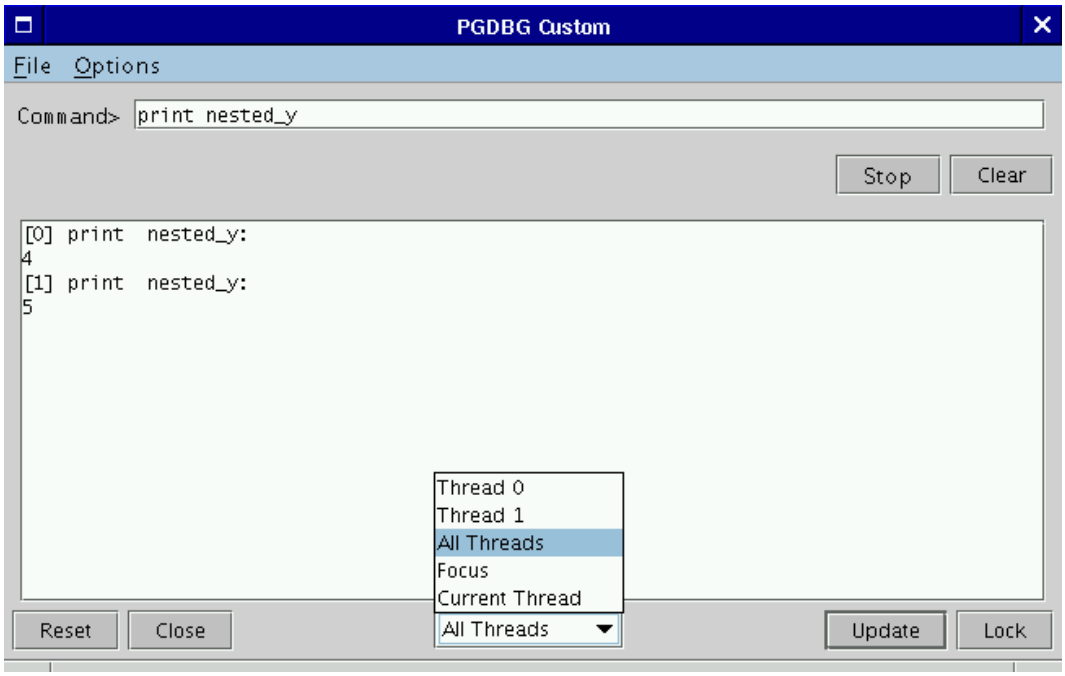
```
!$OMP PARALLEL PRIVATE(myid)
              myid = omp_get_thread_num()
              print *, 'myid = ',myid
!$OMP PARALLEL PRIVATE(nested_y)
              nested_y = 4 + myid
              print *, 'nested_y = ', nested_y
!$OMP END PARALLEL
!$OMP END PARALLEL
       end

C/C++ version of thread private example:

int main()
{
       int myid, nested_y;
       omp_set_num_threads(2);
#pragma omp parallel private(myid)
       {
              myid = omp_get_thread_num();
              printf("myid = %d\n",myid);
#pragma omp parallel private(nested_y)
              {
                     nested_y = 4 + myid;
                     printf("nested_y = %d\n",nested_y);
              }
       }
}
```

Display of thread private data when built with a PGI compiler (6.0 or higher) and displayed by PGDBG (6.0 or higher) is as follows:

```
pgdbg> [*] print myid

[0] print myid 0

[1] print myid 1

pgdbg> [*] print nested_y

[0] print nested_y 4

[1] print nested_y 5
```

The example specifies `[*]` for the p/t-set (defined in *Section 1.14.6 P/t-set Notation*) to execute the print command on all threads. Figure 1-14 shows the values for *nested_y* in the *PGDBG GUI* (*Section 1.12 PGDBG Graphical User Interface*) using a custom subwindow (*Section 1.12.3.4 Custom Subwindow*). Note that *All Threads* were selected in the *context selector* to display the value on both threads.

Figure 1-14: Thread Private Data in *PGDBG* GUI



1.16 MPI Debugging

1.16.1 Process Control

PGDBG is capable of debugging parallel-distributed MPI programs and hybrid distributed multi-threaded applications. *PGDBG* is invoked via *MPIRUN* and automatically attaches to each MPI process as it is created. See *Section 1.13.4 Multi-Process MPI Debugging* to get started.

Here are some things to consider when debugging an MPI program:

- Use p/t-sets to focus on a set of processes. Be mindful of process dependencies.
- In order for a process to receive a message, the sender must be allowed to run.

- Process synchronization points, such as `MPI_Barrier`, will not return until all processes have hit the sync point.
- `MPI_Finalize` will not return for Process 0 until Process 1..n-1 exit.

A control command (*cont*, *step*,...) can be applied to a stopped process while other processes are running. A control command applied to a running process is applied to the stopped threads of that process, and is ignored by its running threads. Those threads that are held by the OpenMP event handler will also ignore the control command in most situations.

PGDBG automatically switches to process wait mode `none` (`'pgienv procwait none'`) as soon as it attaches to its first MPI process. See the *pgienv* command and the *Section 1.14.13 Configurable Wait mode* for details.

Use the *run* command to rerun an MPI program. The *rerun* command is not useful for debugging MPI programs since MPIRUN passes arguments to the program that must be included. After MPI debugging is shut down, *PGDBG* will clean up all of its MPI processes.

1.16.2 Process Synchronization

Use the *PGDBG sync* command to synchronize a set of processes to a particular point in the program.

```
pgdbg [all] 0.0> sync MPI_Finalize
```

This command runs all processes to `MPI_Finalize`.

```
pgdbg [all] 0.0> [0:1.*] sync MPI_Finalize
```

This command runs process 0 and process 1 to `MPI_Finalize`.

A synchronize command will only successfully *sync* the target processes if the *sync* address is well defined for each member of the target process set, and all process dependencies are satisfied (otherwise the member could wait forever for a message for example). The debugger cannot predict if a text address is in the path of an executing process.

1.16.3 MPI Message Queues

PGDBG can dump the MPI message queues through the *mqdump* command (*Section Memory*

Access). In the *PGDBG* GUI, the message queues can be viewed by selecting the *Messages* item under the *Windows* menu. This command can also have a p/t-set prefix (*Section 1.14.6 P/t-set Notation)* to specify a subset of processes and/or threads. Figure 1-14 shows an example output of the *mqdump* command as seen in the GUI (the *PGDBG* text debugger produces the same output).

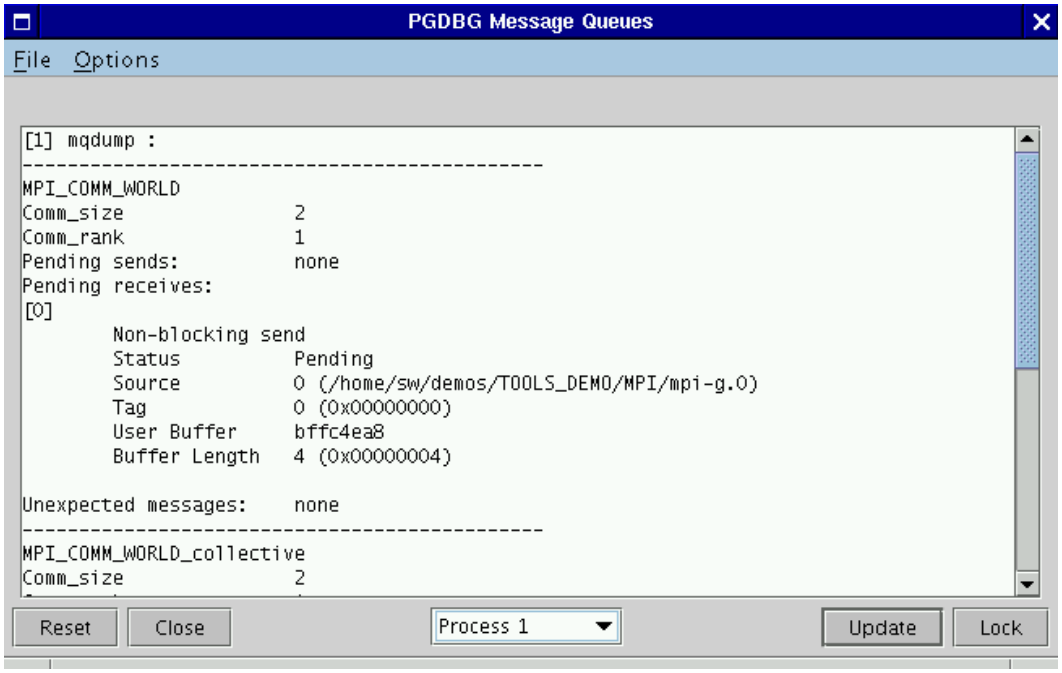
When using the GUI, a subwindow is displayed with the message queue output. Within the subwindow, you can select which process/threads to display with the *Context Selector* combo box located at the bottom of the subwindow (e.g., *Process 1* in Figure 1-15).

The message queue dump is only available for MPI application debugging on the *CDK* licensed version of *PGDBG*. The following error message may display if you invoke *mqdump:*

```
ERROR: MPI Message Queue library not found. Try setting
   'PGDBG_MQS_LIB_OVERRIDE' environment variable.
```

If this message is displayed by a *CDK* licensed version of *PGDBG*, then the `PGDBG_MQS_LIB_OVERRIDE` environment variable should be set to the absolute path of `libtvmpich.so` or compatible library (normally located in `$PGI/lib`).

Figure 1-15: Messages Subwindow



1.16.4 MPI Groups

PGDBG identifies each process by its COMMWORLD rank. In general, *PGDBG* currently ignores MPI groups.

1.16.5 MPI Listener Processes

Entering `Control-C` (^C) from the *PGDBG* command line can be used to halt all running processes. However, this is not the preferred method to use while debugging an MPI program. Entering ^C at the command line, sends a `SIGINT` signal to the debugger's children. This signal is never received by the MPI processes listed by the *procs* command (i.e., the initial and attached processes), `SIGINT` is intercepted in each case by *PGDBG*. *PGDBG* does not attach to the MPI listener processes paired with each MPI process. These processes handle IO requests among other things. As a result, a ^C from the command line will kill these processes resulting in undefined program behavior.

For this reason, *PGDBG* automatically switches to process wait mode `none ('pgienv procwait none')` as soon as it attaches to its first MPI process. This allows the use of the *halt* command to stop running processes, without the use of ^C. The setting of `'pgienv procwait none'` allows commands to be entered while there are running processes.

Note: *halt* cannot interrupt a *wait* command. ^C must be used for this. In MPI debugging, *wait* should be used with care.

1.16.6 SSH and RSH

By default, *PGDBG* uses *rsh* for communication between remote *PGDBG* components. *PGDBG* can also use *ssh* for secure environments. The environment variable **PGRSH**, should be set to *ssh* or *rsh*, to indicate the desired communication method.

Chapter 2

The *PGPROF* Profiler

This chapter describes the *PGPROF* profiler. The profiler is a tool that analyzes data generated during execution of specially compiled *C*, *C++*, F77, F95 and HPF programs. The *PGPROF* profiler displays which routines and lines were executed as well as how often they were executed and how much of the total time they consumed.

The *PGPROF* profiler can also be used to profile multi-process HPF or MPI programs, multi-threaded programs (e.g., OpenMP or programs compiled with *–Mconcur,* etc.), or hybrid multi-process programs employing multiple processes with multiple threads for each process. The multi-process information can be used to select combined minimum and maximum process data, or select process data on a process-by-process basis. Multi-threaded information can be queried in the same way as on a per-process basis. This information can be used to identify communications patterns, and identify the portions of a program that will benefit the most from performance tuning.

2.1 Introduction

Profiling is a three-step process:

Compilation — Compiler options cause special profiling calls to be inserted in the code and data collection libraries to be linked in.

Execution — The profiled program is invoked normally, but collects call counts and timing data during execution. When the program terminates, a profile data file is generated (e.g., *pgprof.out, gmon.out*, etc.).

Analysis — The *PGPROF* tool interprets the *pgprof.out* file to display the profile data and associated source files. The profiler supports routine level, line level and data collection modes. The next section provides definitions for these data collection modes.

2.1.1 Definition of Terms

Routine Level Profiling

Call counts and execution times are collected on a per-routine (e.g., subroutine, subprogram, function, etc.) basis.

Function Level Profiling

Synonymous with *Routine Level Profiling*.

Line Level Profiling

Execution counts and times are collected for source lines within a called routine.

Instruction Level Profiling

Execution counts and times are collected at the machine instruction level.

Hardware Counters

These are various performance monitors that allow the user to track specific hardware behavior in their program. Some examples of hardware counters include: *Instruction Counts, CPU Cycle Counts, Floating Point Operations, Cache Misses, Memory Reads,* and so on.

Hardware Events

Synonymous with *Hardware Counters.*

Elapsed Time

Total time to complete a task including disk accesses, memory accesses, input/output activities and operating system overhead.

Response Time

Synonymous with *Elapsed Time.*

Wall-Clock Time

Synonymous with *Elapsed Time.*

CPU Time

Measures the amount of time the CPU is computing; not waiting for input/output or running other programs.

Basic Block

At optimization levels above 0, code is broken into basic blocks, which are groups of sequential statements with only one entry and one exit.

Virtual Timer

A statistical method for collecting time information by directly reading a timer which is being incremented at a known rate on a processor by processor basis.

Data Set

A profile data file is considered to be a data set.

Host

The system on which the *PGPROF* tool executes. This will generally be the system where source and executable files reside, and where compilation is performed.

Target Machine

The system on which a profiled program runs. This may or may not be the same system as the host.

GUI

Stands for *Graphical User Interface*. A set of windows, and associated menus, buttons, scrollbars, etc., that can be used to control the profiler and display the profile data.

Combo Box

A combo box is a GUI component consisting of a text field and a list of text items. In its *closed* or default state, it presents a text field of information with a small down arrow icon to its right. When the down arrow icon is selected by a left mouse-click, the box opens and presents a list of choices.

Check Box

A check box is a GUI component consisting of a square or box icon that can be selected by left mouse clicking inside the square. The check box has a selected and an unselected state. In its selected state, a check mark will appear inside the box. The box is empty in its unselected state.

Radio Button

A radio button is a GUI component consisting of a circle icon that can be selected by left mouse clicking inside the circle. The radio button has a selected and an unselected state. In its selected state, the circle is filled in with a solid color, usually black. The circle is empty or unfilled when the button is in its unselected state.

Dialog Box

A dialog box is a GUI component that displays information in a graphical box. It may also request some input from the user. After reading and/or entering some information, the user can click on the *OK* button to acknowledge the message and/or accept their input.

2.1.2 Compilation

The following list shows compiler options that cause profile data collection calls to be inserted and libraries to be linked in the executable file:

-Mprof=dwarf	Add limited DWARF symbol information for third party profilers.
–Mprof=func	Insert calls to produce a *pgprof.out* file for routine level data (routine entry/exit profiling).
–qp	Same as *–Mprof=func*.
–Mprof=lines	Insert calls to produce a *pgprof.out* file which contains both routine and line level data.
–ql	Same as *–Mprof=lines.*
–pg	Enable gprof-style (sample-based) profiling. Running an executable compiled with this option will produce a *gmon.out* profile file which contains routine, line, and instruction level profiling data.
–qp	Same as *–pg*.
–Mprof=time	Same as *–pg* except a *pgprof.out* file is produced rather than a *gmon.out* file.
–Mprof=hwcts	Produce an instruction level profile using hardware counters. Compiling and linking with this option produces an executable that generates a *pgprof.out* file which contains function (routine), line, and instruction level profiling data. See *Section 2.1.3.3 Profiling Hardware Event Counters* for more information on profiling with hardware counters.

–Mprof=mpi	Link with an MPI profile library which intercepts MPI calls in order to record message sizes and to count message sends and receives. This switch can be used in addition to the other types of profiling available (e.g., *–Mprof=mpi,time; –Mprof=mpi,hwcts; –Mprof=mpi,func; –Mprof=mpi,lines).*
–Mprof=cost	Insert calls to produce a *pgprof.out* file for routine level cost profiling. See the definition of *COST* in *Section 2.1.6 Profile Data* for more information.

***Note**: Not all profiler options are available in every compiler. Please consult the appropriate compiler user guide for a complete list of profiling options. A list of available profiling options can also be generated with the compiler's –help option.*

PGI offers two methods for profiling: Sample based profiling and profiling through instrumentation of user code. The *–pg, –Mprof=time, and –Mprof=hwcts* switches generate profiles using a sample based profiling mechanism. Sample based profiling usually provides more accurate timings than instrumentation (e.g., *–Mprof=*[*lines*|*func*]) because it is less intrusive in the way it profiles user code. However, it may have some limitations on your system. Check the *PGPROF* release notes for more information. However, instrumentation of user code allows computing the path *coverage* of an application (see definition of *Coverage* in *Section 2.1.6 Profile Data*), while sample based profiling cannot. There are also differences in how instrumentation and sample based profiling measure time (see *Section 2.1.7 Measuring Time*).

When working with sample based profiles, it is important that *PGPROF* know the name of the executable. By default, *PGPROF* will assume that your executable is called *a.out*. To indicate a different executable, use the *–exe* command line argument or the *Set Executable…* option under the *File* menu in the GUI. See *Section 2.1.4 Profiler Invocation and Intitialization* for more information on changing the executable name.

2.1.3 Program Execution

Once a program is compiled for profiling, it needs to be executed. The profiled program is invoked normally, but while running, it collects call counts and/or time data. When the program terminates, a profile data file is generated. Depending on the profiling method used, this data file is called *pgprof.out* or *gmon.out*. Setting the following system environment variables changes the way profiling is performed:

- GMON_ARCS – Use this environment variable to set the maximum number of arcs

(caller/callee pairs). The default is 4096. This option only applies to gprof style profiling (e.g., programs compiled with the *–pg* option).

- PGPROF_DEPTH – Use this environment variable to change the maximum routine call depth for *PGPROF* profiled programs. The default is 4096 and is applied to programs compiled *–Mprof=func, –Mprof=lines, –Mprof=mpi, –Mprof=mpi,hwcts, or –Mprof=mpi,time.*

- PGPROF_EVENTS – Use this environment variable to specify hardware (event) counters to profile. This variable is applied to programs compiled with the *–Mprof=hwcts* or
–Mprof=hwcts,mpi options. Profiling hardware (event) counters are discussed in further detail in *Section 2.1.3.3 Profiling Hardware Event Counters*.

- PGPROF_NAME – Use this environment variable to change the name of the output file intended for *PGPROF*. The default is *pgprof.out.* This option is only applied to programs compiled with the *–Mprof=*[*func* | *hwcts* | *lines* | *mpi* | *time*] options. If a program is compiled with the *–pg* option, then the output file is always called *gmon.out.*

2.1.3.1 Profiling MPI Programs

To profile an MPI program, use *mpirun* to execute the program which was compiled and linked with the *–Mprof=mpi* switch. A separate data file is generated for each non-initial MPI process. The *pgprof.out* file acts as the "root" profile data file. It contains profile information on the initial MPI process and points to the separate data files for the rest of the processes involved in the profiling run.

2.1.3.2 Profiling Multi-threaded Programs

The way profiling of a multi-threaded program (e.g., OpenMP, programs compiled with –Mconcur, etc.) is performed depends on the profiling method used. If you compile your program with
–Mprof=hwcts, –Mprof=lines, –Mprof=func, or *–Mprof=mpi*,[*hwcts* | *lines* | *func*], then each thread gets profiled. If you compile your program with *–pg* or *–Mprof=time*, then only the master thread gets profiled.

The type of data presented by each profiling method varies. Profiles generated with *–Mprof=func, –Mprof=lines,* or *–Mprof=mpi*,[*func* | *lines*] measure elapsed or wall-clock time for each thread. Profiles generated with *–Mprof=hwcts* or *–Mprof=mpi,hwcts* collect hardware counter data for each thread. Profiles generated with *–pg* or *–Mprof=time* collect total CPU time for the master thread only. Elapsed time is not available for *–Mprof=hwcts, –Mprof=mpi,hwcts, – pg,* or

–Mprof=time.

2.1.3.3 Profiling Hardware Event Counters

Hardware event counter profiling is currently available on the Linux 64-bit version of the PGI compilers and tools. Other platforms may be supported in the future. Profiling of hardware counters on the 64-bit version of Linux requires the *Performance API* (PAPI). PAPI specifies a standard application program interface (API) for accessing hardware performance counters available on most modern microprocessors. PAPI is available for download from http://icl.cs.utk.edu/papi/.

PAPI must be installed on a system before hardware counter profiling can be performed. To profile using hardware counters, compile with the option *–Mprof=hwcts*. This option links with the PAPI and PGI profiling libraries. By default, this will use the PAPI_TOT_CYC counter to profile total CPU cycles executed by the application. *PGPROF* will also convert the cycle counts into CPU time (seconds). Use the *PGPROF_EVENTS* system environment variable to specify up to four counters to profile. Below is the format for the *PGPROF_EVENTS* variable:

```
event0[.over][:event1[.over]] …
```

The *event* field is the name of the event or hardware counter and the optional *over* field specifies the overflow value. The overflow value is the number of events to be counted before collecting profile information. Overflow provides some control on the sampling rate of the profiling mechanism. The default overflow is 1000000.

To determine what hardware counters are available on the system, compile and run the following simple program. This program uses the PAPI and PGI libraries to dump the available hardware counters to standard output.

```
int main(int argc, char *argv[]) {
   __pgevents();
   exit(0);
}
```

Type in the code in the previous example into a text editor and save it in a file called *pgevents.c*. Compile *pgevents.c* in the following manner:

```
pgcc pgeventc.c –o pgevents –lpgnod_prof_papi –lpapi
```

To display the available events, run the newly created program called *pgevents.* The *pgevents* utility shows the format of the *PGPROF_EVENTS* environment variable, the list of PAPI preset

events, and the list of native (or processor specific) events. Below is an example of specifying 4 events with the *PGPROF_EVENTS* environment variable (using *tcsh* or *csh* shells):

```
setenv PGPROF_EVENTS
   PAPI_TOT_CYC.1593262939:PAPI_FP_OPS:PAPI_L1_DCM:PAPI_L2_ICM
```

Specify the events above using the *sh* or *bash* shells in the following manner:

```
set PGPROF_EVENTS=PAPI_TOT_CYC.1593262939:PAPI_FP_OPS:PAPI_L1_DCM:PAPI_L2_ICM
export PGPROF_EVENTS
```

If *PGPROF_EVENTS* is not defined, then the profiling mechanism will count CPU cycles (PAPI_TOT_CYC event) by default.

The following example shows a partial output from *pgevents*:

```
Selecting Events


   setenv PGPROF_EVENTS event0[.over][:event1[.over]] …
```

The parameter *over* is the number of events counted before the counter overflows and increments a bucket, the default is 1000000.

```
Hardware Information


cpus/node - 4
nodes - 1
total cpus - 4
vendor - AuthenticAMD
model - AMD K8 Revision C
speed 1593.262939mhz
event counters 4


Preset Events
```

```
PAPI_L1_DCM - Level 1 data cache misses
PAPI_L1_ICM - Level 1 instruction cache misses
PAPI_L2_DCM - Level 2 data cache misses
PAPI_L2_ICM - Level 2 instruction cache misses
PAPI_L1_TCM - Level 1 cache misses
PAPI_L2_TCM - Level 2 cache misses
.
.
.
PAPI_TOT_CYC – Total Cycles
.
.
.
Native Events


FP_ADD_PIPE - Dispatched FPU ops - Revision B and later revisions -
   Add pipe ops excluding junk ops.
FP_MULT_PIPE - Dispatched FPU ops - Revision B and later revisions -
   Multiply pipe ops excluding junk ops.
.
.
.
CPU_CLK_UNHALTED - Cycles processor is running (not in HLT or STPCLK
   state)
```

2.1.4 Profiler Invocation and Initialization

The *PGPROF* profiler is used to analyze profile data produced during the execution phase as described in *Section 2.1 Introduction*.

The *PGPROF* profiler is invoked as follows:

```
% pgprof [options] [datafile]
```

If invoked without any options or arguments, the *PGPROF* profiler attempts to open a data file named *pgprof.out*, and assumes that application source files are in the current directory. The program executable name, as specified when the program was run, is usually stored in the profile data file. If all program-related activity occurs in a single directory, the *PGPROF* profiler needs no arguments.

If present, the arguments are interpreted as follows:

datafile — A single datafile name may be specified on the command line. For profiled MPI applications, the specified datafile should be that of the initial MPI process. Access to the profile data for all MPI processes is available in that case, and data may be filtered to allow inspection of the data from a subset of the processes.

–s — Use the *PGPROF* Command Line Interface (CLI).

–text — Same as –s.

–scale "files(s)" — Compare scalability of *datafile* with one or more files. A list of files may be specified by enclosing the list within quotes and separating each filename with a space. For example:

```
-scale "one.out two.out"
```

This example will compare the profiles *one.out* and *two.out* with *datafile* (or *pgprof.out* by default). If only one file is specified quotes are not required.

For sample based profiles (e.g., *gmon.out*) specified with this option, PGPROF assumes that all profile data was generated by the same executable. For information on how to specify multiple executables in a sample-based scalability comparison, see the *Scalability Comparison…* item in the description of the *File* menu (*Section 2.2.3.1 File Menu*).

–I srcdir — Specify the source file search path. The *PGPROF* profiler will always look for a program source file in the current directory first. If it does not find the source file in the current directory, it will consult the search path specified in *srcdir*. The *srcdir* argument is a string containing one or more directories separated by a *path separator*. The path separator is platform dependent; on Linux/Solaris it is a colon (:) and on Windows it is a semicolon (;). Directories in the path will then be searched in order from left-to-right. When a directory with a filename that matches a source file is found, that

directory is used. Below is an example for Linux/Solaris:

–I ../src:STEPS

In the example above, the profiler first looks for source files in the current directory, then in the *../src* directory, followed by the *STEPS* directory. The following is the same example for Windows:

–I ..\src;STEPS

See the *Set Source Directory…* item in the description of the *File* menu (*Section 2.2.3.1 File Menu*) for more information.

–exe filename — Set the executable to *filename* (default is *a.out*).

–o filename — Same as *–exe*.

–title string — Set the title of the application to *string* (GUI only).

–V — Print version information.

–help — Prints a list of available command line arguments.

–usage — Same as *–help.*

-dt (number) — Set the time multiply factor (default is 1.0). This is used to calibrate the times reported by *PGPROF*. The profiler will display a time multiplied by the specified number. This option works for all profiling mechanisms that measure time (e.g., *–Mprof=time, – pg, –Mprof=lines, –Mprof=func, –Mprof=mpi.*[*time* | *lines* | *func*]).

2.1.5 Measuring Time

The profiling mechanism will collect total CPU time for programs compiled with *–Mprof=time, –pg, and –Mprof=mpi,time* (see also *Section 2.1.3.2 Profiling Multithreaded Programs*). For programs compiled with *–Mprof=hwcts* or *–Mprof=mpi,hwcts,* no timings are collected. For programs compiled to count CPU cycles with *–Mprof=hwcts* or *–Mprof=mpi,hwcts, PGPROF* automatically converts CPU cycles into CPU time.

Programs compiled with *–Mprof=lines, –Mprof=func,* or *–Mprof=mpi,*[*time* | *lines* | *func*] employ a *virtual timer* for measuring the elapsed time of each running process/thread. This data collection method employs a single timer that starts at zero (0) and is incremented at a fixed rate while the active program is being profiled. For multiprocessor programs, there is a timer on each processor, and the profiler's summary data (minimum, maximum and per processor) is based on each

processor’s time executing in a function. How the timer is incremented and at what frequency depends on the target machine. The timer is read from within the data collection functions and is used to accumulate COST and TIME values for each line, function, and the total execution time. The line level data is based on source lines; however, in some cases, there may be multiple statements on a line and the profiler will show data for each statement.

***Note**: Due to the timing mechanism used by the profiler to gather data, information provided for longer running functions will be more accurate than for functions that only execute for a short percentage of the timer's granularity. Refer to Section” 2.1.7 Caveats” for more profiler limitations.*

2.1.6 Profile Data

The following statistics are collected and may be displayed by the *PGPROF* profiler.

BYTES — For HPF and MPI profiles only. This is the number of message bytes sent and received by the function or line.

BYTES RECEIVED — For HPF and MPI profiles only. This is the number of bytes received by the function or line in a data transfer.

BYTES SENT — For HPF and MPI profiles only. This is the number of bytes sent by the function or line.

CALLS — This is the number of times a function is called.

COST — This is the sum of the differences between the timer value entering and exiting a function. This includes time spent on behalf of the current function in all children whether profiled or not. *PGPROF* can provide cost information when you compile your program with the *–Mprof=cost* or *–Mprof=lines* options (see *Section 2.1.2 Compilation*).

COUNT — This is the number of times a line or function is executed.

COVERAGE — This is the percentage of lines in a function that were executed at least once.

LINE NUMBER — For line mode, this is the line number for that line. For function mode, this is the line number of the first line of the function.

MESSAGES For HPF and MPI profiles only. This is the number of messages sent and received by the function or line.

RECEIVES For HPF and MPI profiles only. This is the number of messages received by the function or line.

SENDS For HPF and MPI profiles only. This is the number of messages sent by the function or line.

STMT ON LINE For programs with multiple statements on a line, data is collected and displayed for each statement individually.

TIME This is only the time spent within the function or executing the line. The TIME does not include time spent in functions called from this function or line. TIME may be displayed in seconds or as a percent of the total time.

TIME PER CALL
This is the TIME for a function divided by the CALLS to that function. TIME PER CALL is displayed in milliseconds.

2.1.7 Caveats

Collecting performance data for programs running on high-speed processors and parallel processors is a complex task. There is no ideal solution. Since programs running on these processors tend to operate within large internal caches, external hardware cannot be used to monitor their behavior. The only other way to collect data is to alter the program itself, which is how this profiling process works. Unfortunately, it is impossible to do this without affecting the temporal behavior of the program. Every effort has been made to strike a balance between intrusion and utility, and to avoid generating misleading or incomprehensible data. It would, however, be unwise to assume the data is beyond question.

2.1.7.1 Clock Granularity

Many target machines provide a clock resolution of only 20 to 100 ticks per second. Under these circumstances, a function must consume at least a few seconds of CPU time to generate meaningful line level times.

2.1.7.2 Optimization

At higher optimization levels, and especially with highly vectorized code, significant code reorganization may have occurred within functions. Most line profilers deal with this problem by

disallowing profiling above optimization level 0. The *PGPROF* profiler allows line profiling at any optimization level, and significant effort was expended on associating the line level data with the source in a rational manner and avoiding unnecessary intrusion. Despite this effort, the correlation between source and data may at times appear inconsistent. Compiling at a lower optimization level or examining the assembly language source may be necessary to interpret the data in these cases.

2.2 Graphical User Interface

The *PGPROF* Graphical User Interface (GUI) is invoked using the command `pgprof`. This section describes how to use the profiler with the GUI on systems where it is supported. There may be minor variations in the GUI from host to host, depending on the type of monitor available, the settings for various defaults and the window manager used. Some monitors do not support the color features available with the *PGPROF* GUI. The basic interface across all systems remains the same, as described in this chapter, with the exception of the differences tied to the display characteristics and the window manager used.

There are two major advantages provided by the *PGPROF* GUI.

Source Interaction

The *PGPROF* GUI will display the program source of any routine for which the profiler has information, whether or not line level profile data is available. To display the source code of a routine, select the routine name. Since interpreting profile data usually involves correlating the program source and the data, the source interaction provided by the GUI greatly reduces the time spent interpreting data. The GUI allows you to easily compare data on a per processor/thread basis, and identify problem areas of code based on processor/thread execution time differences for routines or lines.

Graphical Display of Data

It is often difficult to visualize the relationships between the various percentages and execution counts. The GUI displays bar graphs that graphically represent these relationships. This makes it much easier to locate the 'hot spots' while scrolling through the data for a large program.

2.2.1 The *PGPROF* GUI Layout

On startup, *PGPROF*, the profiler attempts to load the profile datafile specified on the command line (or the default *pgprof.out*). If no file is found, a file chooser dialog box is displayed. Choose a profile datafile from the list or select *Cancel*.

When a profile datafile is opened, *PGPROF* populates the following areas in the GUI, shown from top to bottom in Figure 2-1:

- *Profile Summary* – Below the "File…Settings…Help" menu bar is the profile summary area. This information displays following the keyword *Profiled:* executable name, date last modified, the amount of time consumed by the executable and the number of processes if the application being profiling has more than one process.

- *Profile Entry Combo Box* – Below the *Profile Summary* is the *Profile Entry Combo Box*. The string of characters displayed in this box is known as the *current profile entry*. This entry corresponds to the data highlighted in the profile tables described below. The current entry can be changed by entering a new entry or selecting an entry from the combo box. Left-click on the down-arrow icon to show a list of previously viewed entries available for selection.

- *Navigation Buttons* – Use the left and right arrow buttons, located on the left of the *Profile Entry Combo Box*, to navigate between previously viewed profile entries.

- *Select Combo Box* – This combo box is located to the right of the *Profile Entry Combo Box*. Open the Select Combo Box to refine the criteria for displaying profile entries in the tables mentioned below. By default, the selection is set to *All* profile entries.

- *Top Left Table* – The Top Left Table, located below the *Navigation Buttons*, displays the static profile entry information. This includes filenames, routine names, and line numbers of the profile entries. When viewing line level information, this table will also show the source code if the source files are available. If this table has more than one entry in it, then a column labeled *View* displays. See the description on the *Bottom Table* for more information.

- *Top Right Table* – The Top Right Table displays profile summary information for each profile entry. To change what is displayed, select the *Processes* or *View* menus, discussed in *Sections 2.2.3.4 Processes Menu* and menu *2.2.3.5 View Menu* respectively. To view profile information at the line level, compiled with *–Mprof=lines* or *–pg*, then in the routine level view, double click the left mouse button to view its line level profile information.

- *Bottom Table* – The *Bottom Table* displays detailed profile information for the *current profile entry*. For a multi-process application, this table contains a profile entry for each application process. For a multi-threaded (or multi-process/multi-threaded) application, *PGPROF* offers the option to view either process or thread level profile information. A *Process/Thread Selector* (combo box) will appear in the lower right hand corner when profiling multi-threaded programs. Use this combo box to toggle between thread, process, or process/thread profile information. Figure 2-2 shows the Process/Thread Selector in its opened state. Three choices are available: Processes, Threads, Process.Threads.

  The heading in the leftmost column will read *Process(es)* by default. When profiling a multi-threaded application, the heading in the leftmost column will reflect whatever is selected in the *Process/Thread Selector*. When the leftmost column is displaying processes or threads, each entry will contain integers that represent process/thread IDs. When the leftmost heading is displaying processes and threads (denoted *Process(es).Threads* in the column heading), each entry is a floating-point number of the form *(Process_ID).(Thread_ID).* Following the process/thread ID, the *filename, routine name,* or *line number* display enclosed in parentheses. This provides additional ownership information of the process/thread. It also acts as a minor sort key. See the discussion on *Sort, Section 2.2.3.6 Sort Menu,* for more information.

  This table will display process/thread information for the *current profile entry* by default. To view other entries, use the *View* check boxes in the *Top Left Table* to select other entries. The *View* check boxes are shown in Figure 2-9 in *Section 2.2.3.5 View Menu*. These support easy comparison of more than one process/thread in the *Bottom Table*. When you *Print* the tables to a file or a printer, an entry with a checked *View* box gets printed with each profile entry. Again, this allows for easy comparison of more than one process/thread. See the *Print* option, under the *File* menu, in *Section 2.2.3.1 File Menu* for more information on printing.

- *Histogram* – Located at the bottom of the GUI is a tabbed pane with two tabs labeled *View* and *Histogram.* When the *Histogram* tab is selected, the GUI displays a histogram of one or more profiled data items. The data items that are displayed are the same data items selected in the *View* menu (see *Section 2.2.3.5 View Menu*). Each row is labeled

with the data in the histogram. Each column is a profile entry. The bars are sorted in the order specified in the *Sort* menu (see *Section 2.2.3.6 Sort Menu*). Left-clicking on a bar displays information for the corresponding profile item in the *Top Left* and *Right* tables. Double-clicking the left mouse button on a bar will *drill down* into the profile on that item (see *Section 2.2.2 Profile Navigation*). Selected bars are highlighted in blue. The histogram is illustrated in Figure 2-1-1.

- *Profile Name* – The Profile Name area is located in the lower left hand corner of the GUI. It is preceded with the keyword *Profile:* This area displays the profile filename.

2.2.1.1 GUI Customization

Figure 2-1 shows how the *PGPROF* GUI appears when launched for the first time. The default dimensions of the GUI are `800 x 600`. It can be resized according to the conventions of the window manager. The width of the *Top Left* and *Right* tables can be adjusted using the grey vertical divider located between the two tables. The height of the *Top Left*, *Right*, and *Bottom* tables can be adjusted using the grey horizontal divider. Both of these dividers can be dragged in the direction shown by arrow icons located on each divider. You can also left-click on these arrow icons to quickly "snap" the display in either direction.

After customizing of the display, PGPROF will save the size of the main window and the location of each divider for subsequent *PGPROF* sessions. To prevent saving these settings on exit from *PGPROF*, uncheck the *Save Settings on Exit* item under the *Settings* menu. The *Settings* menu is described in more detail in *Section 2.2.3.2 Settings Menu.*

Figure 2-1: Profiler Window

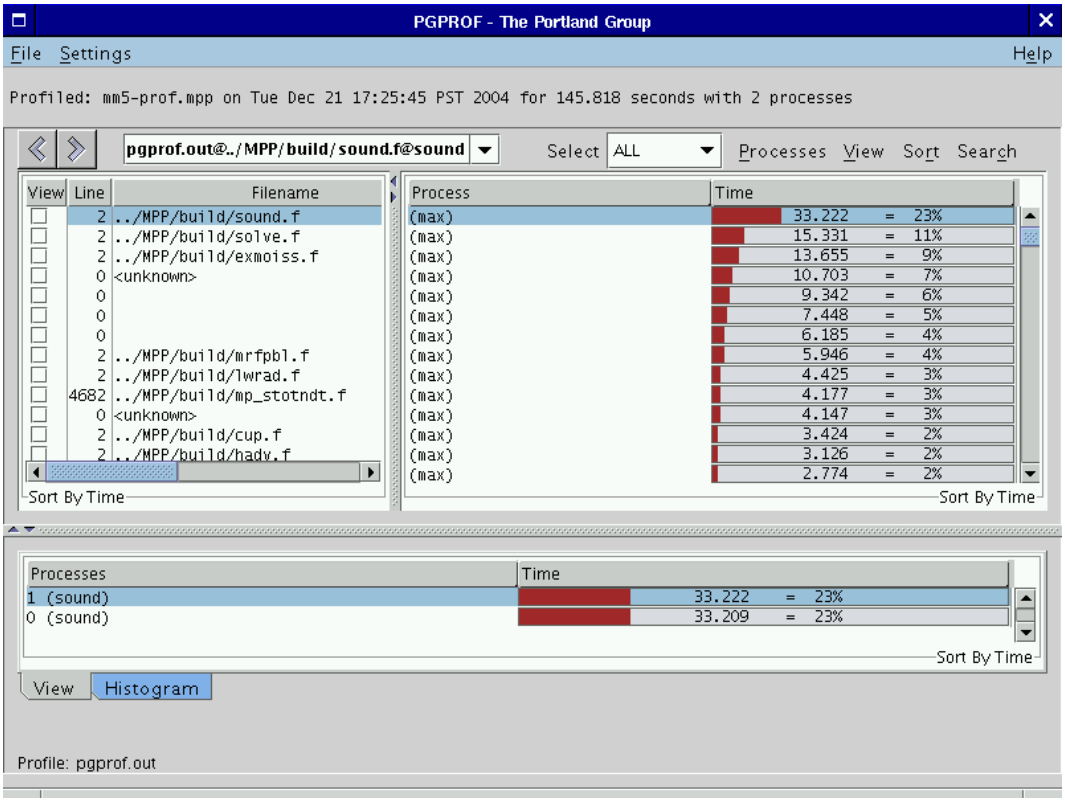


Figure 2-1-1: Profiler Window with Visible Histogram

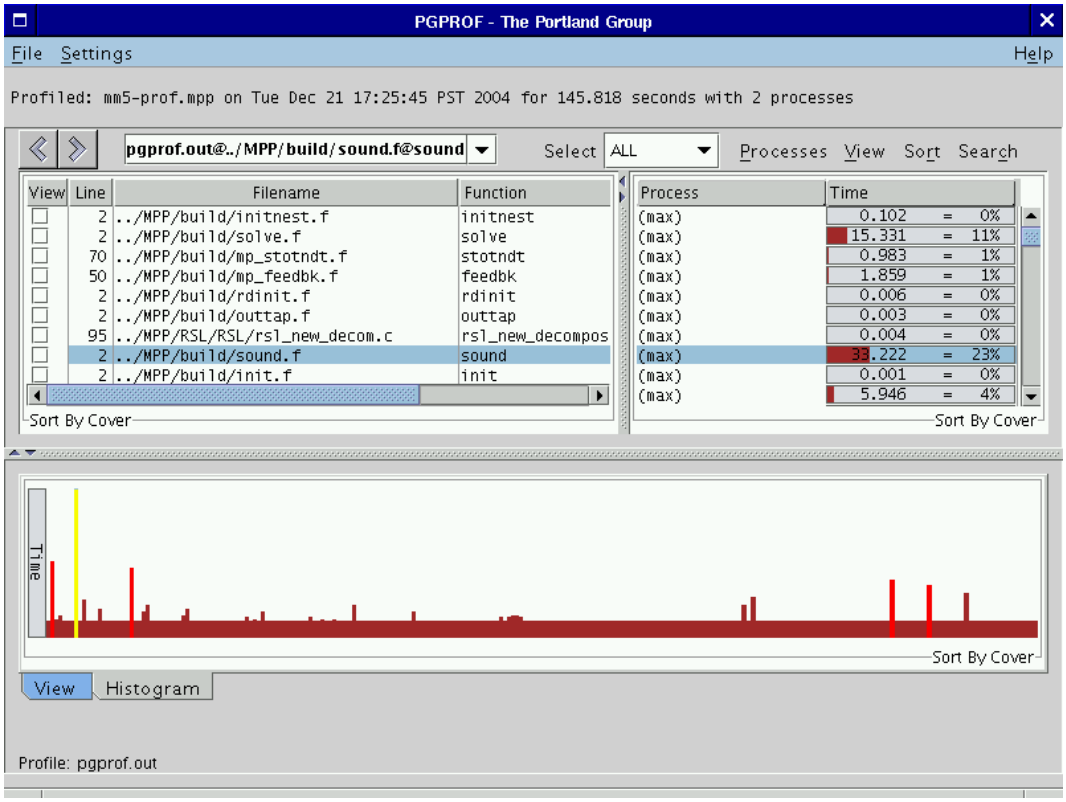
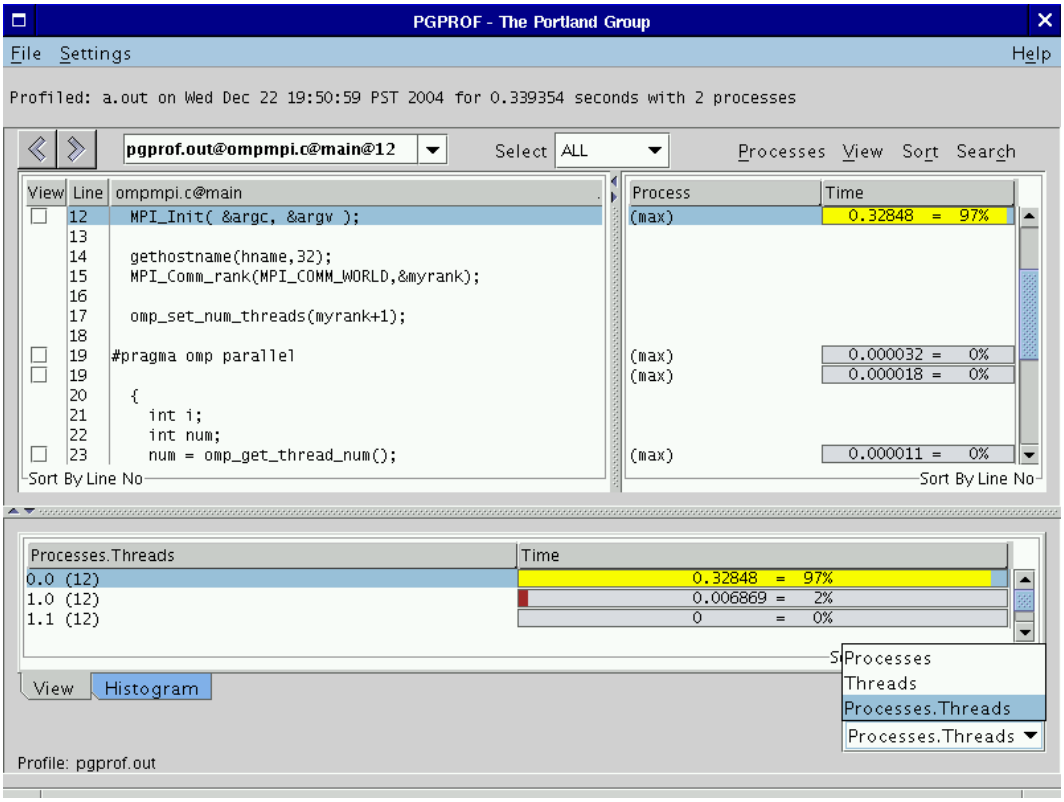


Figure 2-2: *PGPROF* with Visible Process/Thread Selector



2.2.2 Profile Navigation

The *PGPROF* GUI is modeled after a web browser. The *current profile entry* can be thought of as an address, similar to a web page address (or URL). This address is displayed in the *Profile Entry Combo Box;* introduced in *Section 2.2.1 The PGPROF GUI Layout*. The address format follows:

```
(profile)[@sourceFile[@routine[@lineNumber[@textAddress]]]]
```

The only required component of the address is the `profile` datafile (e.g., *pgprof.out*, *gmon.out*, etc.). Each additional component is separated by an '@'. For example, Figure 2-3 shows a profile of an application with a single routine called `main`. When a profile is initially displayed, the first entry in the *Top Left* and *Right* tables is selected (highlighted) by default. The Profile Entry Combo Box reflects the selected entry by displaying its address. In this case, the Profile Entry Combo Box contents are: `pgprof.out@regexec.c`@reg. This indicates that the *current profile entry* is a routine named `reg` located in file `regexec.c`.

A different address can be entered in the *Profile Entry Combo Box* using the above address format or by choosing a previously viewed profile entry in the combo box. Click on the *down arrow* in the combo box to choose from a list of previously viewed profile entries. As described in *Section 2.2.1 The PGPROF GUI Layout*, previously viewed profile entries can be selected with the *Profile Entry Combo Box* or with the *Navigation Buttons*.

The *current profile entry* is highlighted in the *Top Left, Right,* and *Histogram* tables. To change the *current profile entry*, left-click on a new entry in the *Right Table* or *Histogram.* This may also be done by clicking on an entry in the *Left Table*, but there must be a corresponding entry in the *Right Table.* Double clicking the left mouse button on a profile entry will *drill down* into the selected profile entry. The example in Figure 2-3 assumes that the program was compiled with *–Mprof=time* and the *current profile entry* is *`pgprof.out@regexec.c@reg`*. Double clicking on the highlighted entry in the *Right Table* causes *PGPROF* to display `reg`'s line level information. Figure 2-4 shows this example after double clicking on `main`. Double clicking on line 759 causes *PGPROF* to display the instruction level profile shown in Figure 2-4-1.

Drilling down works at higher levels of profiling too. For example, if the *current profile entry* is `pgprof.out,` then double clicking on `pgprof.out` displays a list of profiled files and their profile information. Double clicking on a file from this list moves to the *routine level profiling* information for that file, etc.

Figure 2-3: Example Routine Level Profile

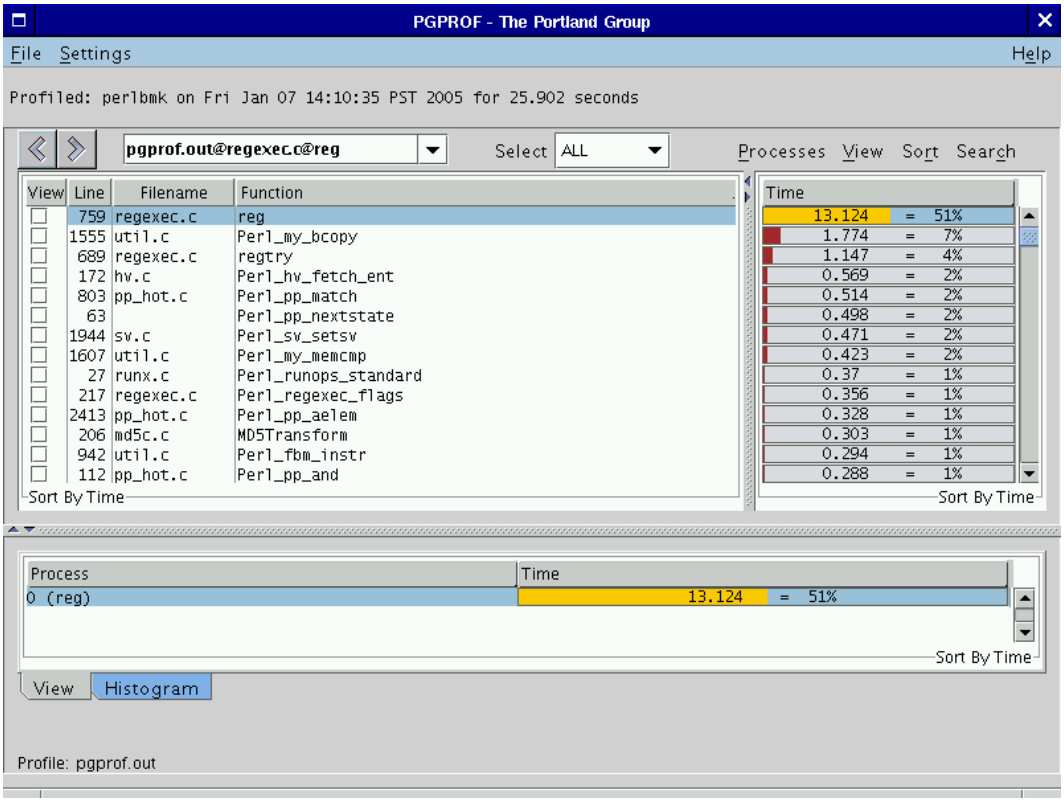


Figure 2-4: Example Line Level Profile

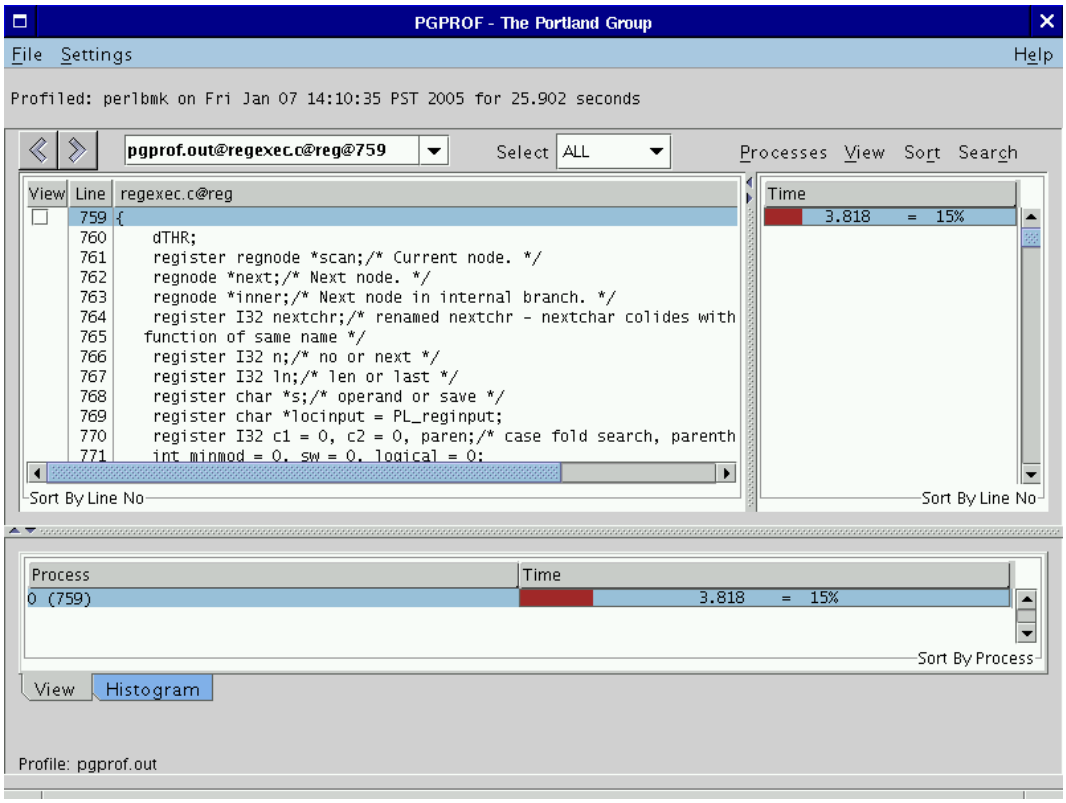
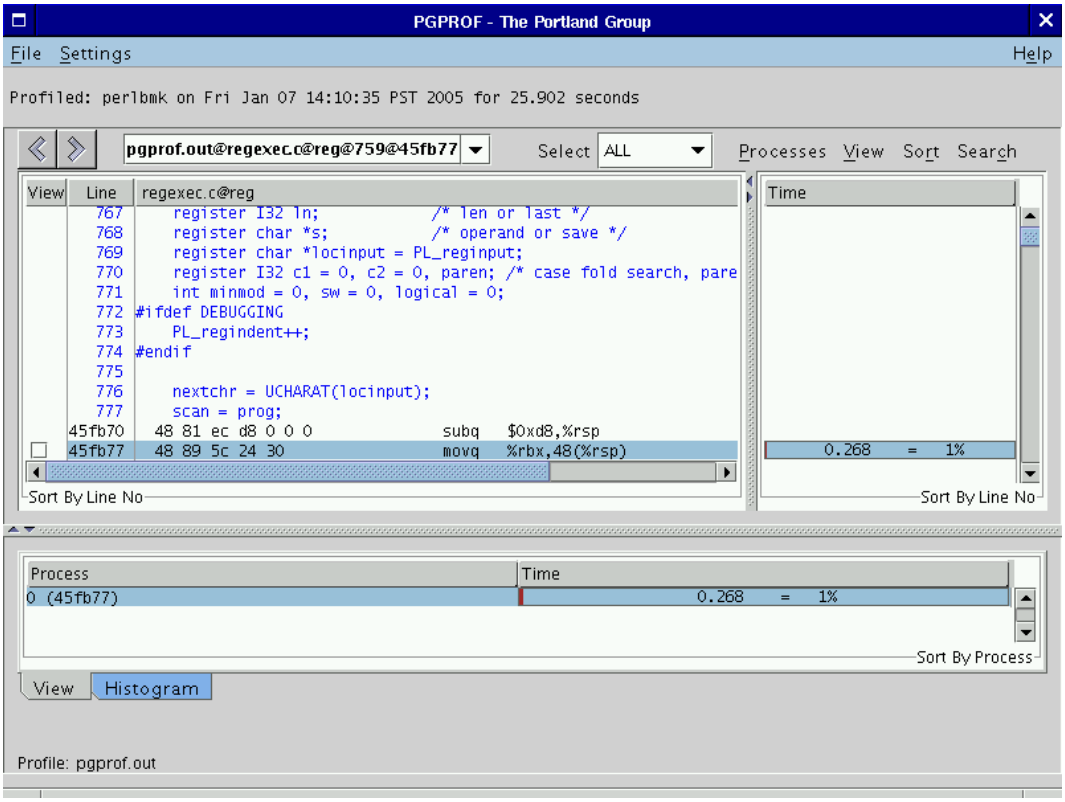


Figure 2-4-1: Example Instruction Level Profile



2.2.3 *PGPROF* Menus

As shown in Figures 2-1 through 2-4, there are five menus in the GUI: *File*, *Settings*, *Help*, *Processes*, *View*, and *Sort.* Sections *2.2.3.1 File Menu* through *2.2.3.6 Sort Menu* describe each menu in detail. Keyboard shortcuts, when available, are listed next to menu items.

2.2.3.1 File Menu

The *File* menu contains the following items:

- *New Window (control N)* – Select this option to create a copy of the current profiler window on your screen.

- *Open Profile…* – Select this option to open another profile. After selecting this menu item, locate a profile data file in a file chooser dialog box. Select the new file in the dialog by double clicking the left mouse button on it. A new profile window will appear with the selected profile. ***Note***: The name of the profile's executable must be set before opening a sample based profile (e.g., *gmon.out*). See the *Set Executable…* option below for more details.

- *Set Executable*… – Select this option to select the executable to be analyzed. Selection of this menu item gives a file chooser dialog in which to locate the profiled executable. Select the executable by double clicking the left mouse button on it. When working with sample based profiles (e.g., *gmon.out*), the executable chosen must match the executable that generated the profile. By default, the profiler assumes that the executable is called `a.out`.

- *Set Source Directory…* – Select this option to set the location of the profiled executable's source files. The profiler displays a text field in a dialog box. Enter one or more directories in this text field. Each directory is separated by a *path separator*. The path separator is platform dependent. On Linux/Solaris it is a colon (:), on Windows it is a semicolon (;). These directories act as a search path when the profiler cannot find a source file in the current directory. On Linux, for example:

  ../src:STEPS

  After entering the string above into the dialog box, the profiler will first search for source files in the current directory, then in the *../src* directory, and finally in the *STEPS* directory. The directory can also be set through the *–I* command line option described in *Section 2.1.4 Profiler Invocation and Initialization*. The same example for Windows follows:

  ..\src;STEPS

- *Scalability Comparison…* – Select this option to open another profile for scalability comparison. Follow the same directions for the *Open Profile…* option described above. The new profile will contain a *Scale* column in its *Top Right* table. You can also open one or more profiles for scalability comparison through the *–scale* command line option explained in *Section 2.1.4 Profiler Invocation and Initialization.* See also *Section 2.2.5 Scalability Comparison* for more information on scalability.

- *Print…* – The print option is used to make a hard copy of the current profile data. The profiler will combine the data in all three profile tables and send the output to a printer. A printer dialog box will appear. A printer may be selected from the *Print Service Name* combo box. Click on the *Print To File* check box to send the output to a file. Other print options may be available. However, they are dependent on the specific printer and the Java Runtime Environment (JRE).

- *Print to File…* – Same as *Print…* option except the output goes to a file. After selecting this menu item, a *save file* dialog box will appear. Enter or choose an output file in the dialog box. Click *Cancel* to abort the print operation.

2.2.3.2 Settings Menu

The *Settings* menu contains the following items:

- *Bar Chart Colors…* – This menu option will open a color chooser dialog box and a bar chart preview panel (Figure 2-5). There are four bar chart colors based on the percentage filled and three bar chart attributes. The *Filled Text Color* attribute represents the text color inside the filled portion of the bar chart. The *Unfilled Text Color* attribute represents the text color outside the filled portion of the bar chart. The *Background Color* attribute represents the color of the unfilled portion of the bar chart. Table 2-1 lists the default colors.

  To modify a bar chart or attribute color, click on its radio button. Next, choose a color from the *Swatches, HSB,* or *RGB* pane. Press the left mouse button on the *OK* button to accept the changes and close the dialog box. Click *Reset* to reset the selected bar chart or attribute to its previously selected color. Closing the window will also accept the changes. *PGPROF* will save color selections for subsequent runs unless the *Save Settings on Exit* box is unchecked (see discussion on this option below).

- *Font…* – This menu option opens the *Font Chooser* dialog box (Figure 2-6). A new font may be chohsen from a list of fonts in this dialog's top combo box. A new font size may also be chosen from a list of sizes in this dialog's bottom combo box. The font is previewed in the *Sample Text* pane to the left. The font does not change until the *OK* button is selected. Click *Cancel* or close the dialog box to abort any changes. The default font is *monospace* size *12*.

- *Show Tool Tips* – Select this check box to enable tool tips. Tool tips are small temporary messages that pop-up when the mouse pointer is positioned over a component in the GUI. They provide additional information on what a particular component does. Unselect this check box to turn tool tips off.

- *Restore Factory Settings…*– Use this option to restore the default look and feel of the GUI to the original settings. The *PGPROF* GUI will appear similar to the example in Figure 2-1 after selecting this option.

- *Restore Saved Settings…* – Use this option to restore the look and feel of the GUI to the previously saved settings. See the *Save Settings on Exit* option for more information.

- *Save Settings on Exit* – When this check box is enabled, *PGPROF* will save the current look and feel settings on exit. These settings include the size of the main window, position of the horizontal/vertical dividers, the bar chart colors, the selected font, the tools tips preference, and the options selected in the *View* menu. When the *PGPROF* GUI is started again on the same host machine, these saved settings are used. To prevent saving these settings on exit, uncheck this box. Unchecking this box disables the saving of settings only for the current session.

Table 2-1: Default Bar Chart Colors

Bar Chart Style/Attribute	Default Color
1-25%	Brown
51%-75%	Orange
76%-100%	Yellow
Filled Text Color	Black
Unfilled Text Color	Black
Background Color	Grey

Figure 2-5: Bar Chart Color Dialog Box

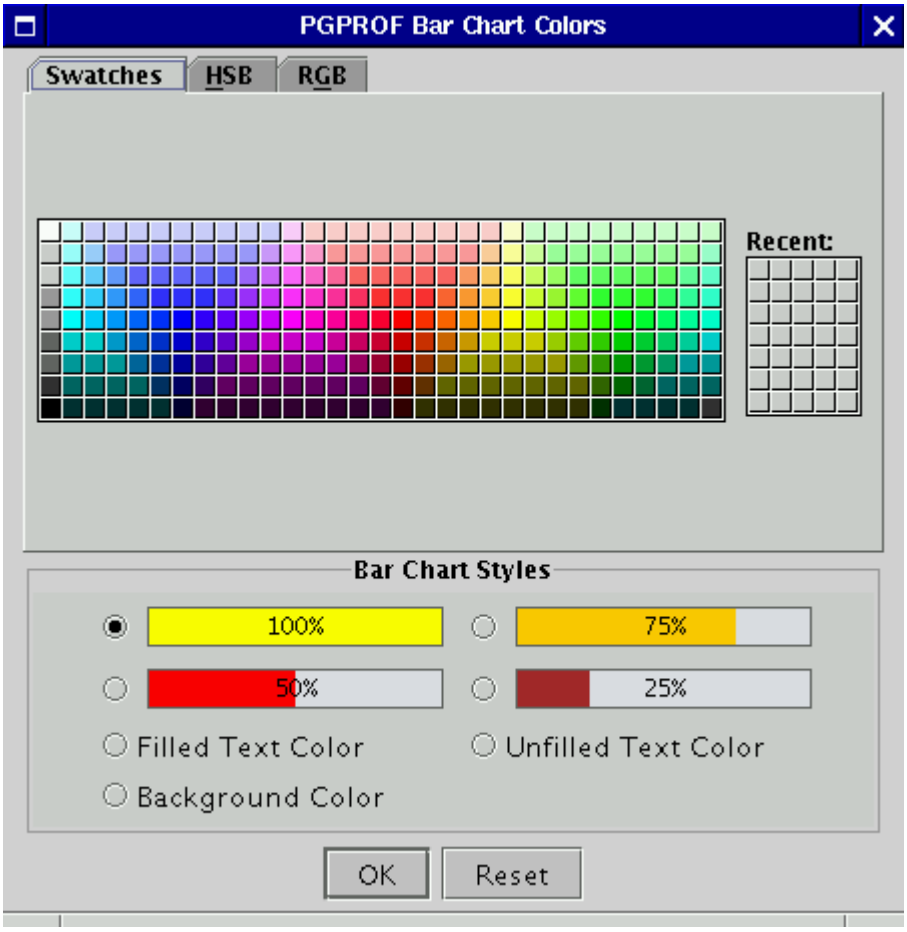
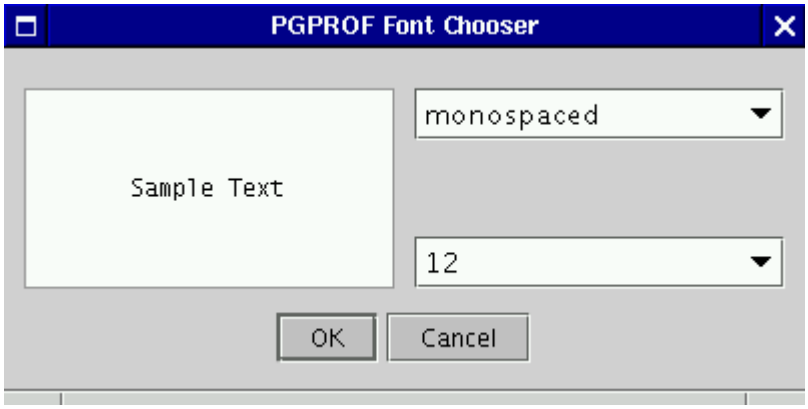


Figure 2-6: Font Chooser Dialog Box



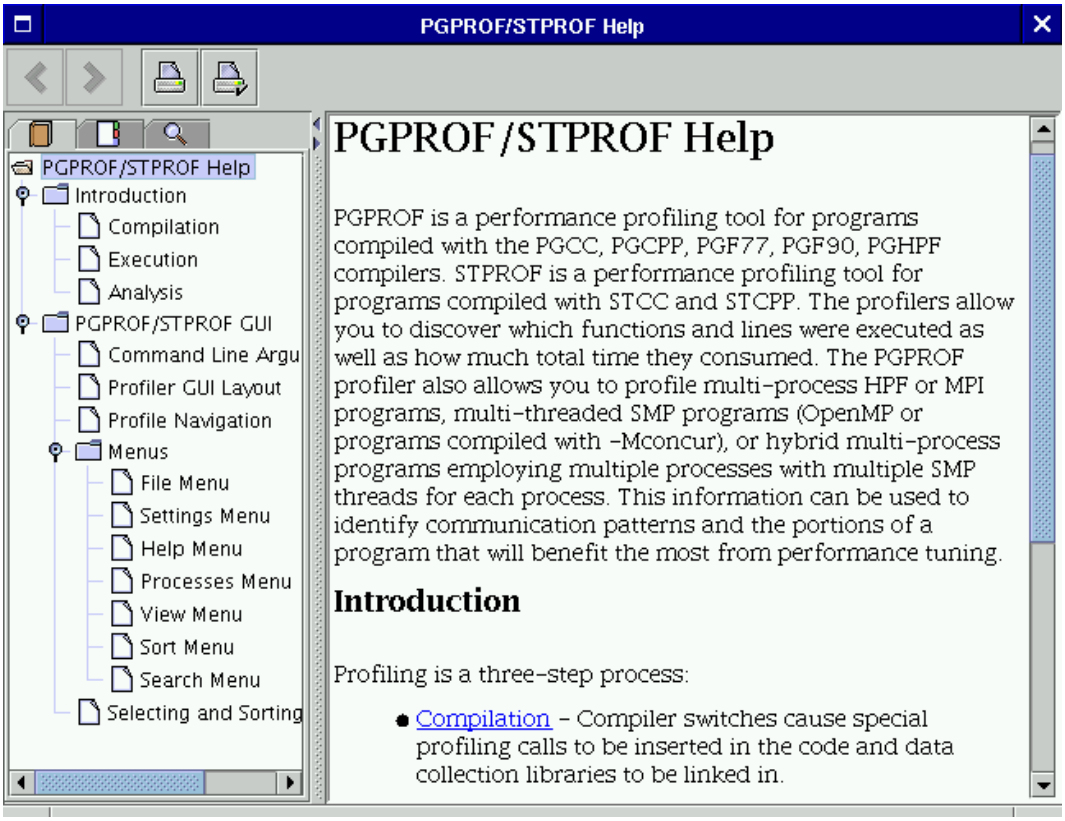
2.2.3.3 Help Menu

The *Help* menu contains the following items:

- *PGPROF Help…* – This option invokes *PGPROF's* integrated help utility as shown in Figure 2-7. The help utility includes an abridged version of this documentation. To find a help topic, use one of the follow tabs in the left panel: The "book" tab presents a table of contents, the "index" tab presents an index of commands, and the "magnifying glass" tab presents a search engine. Each help page (displayed on the right) may contain hyperlinks (denoted in underlined blue) to terms referenced elsewhere in the help engine. Use the arrow buttons to navigate between visited pages. Use the printer buttons to print the current help page.

- *About PGPROF…* – This option opens a dialog box with version and contact information for *PGPROF*.

Figure 2-7: *PGPROF* Help



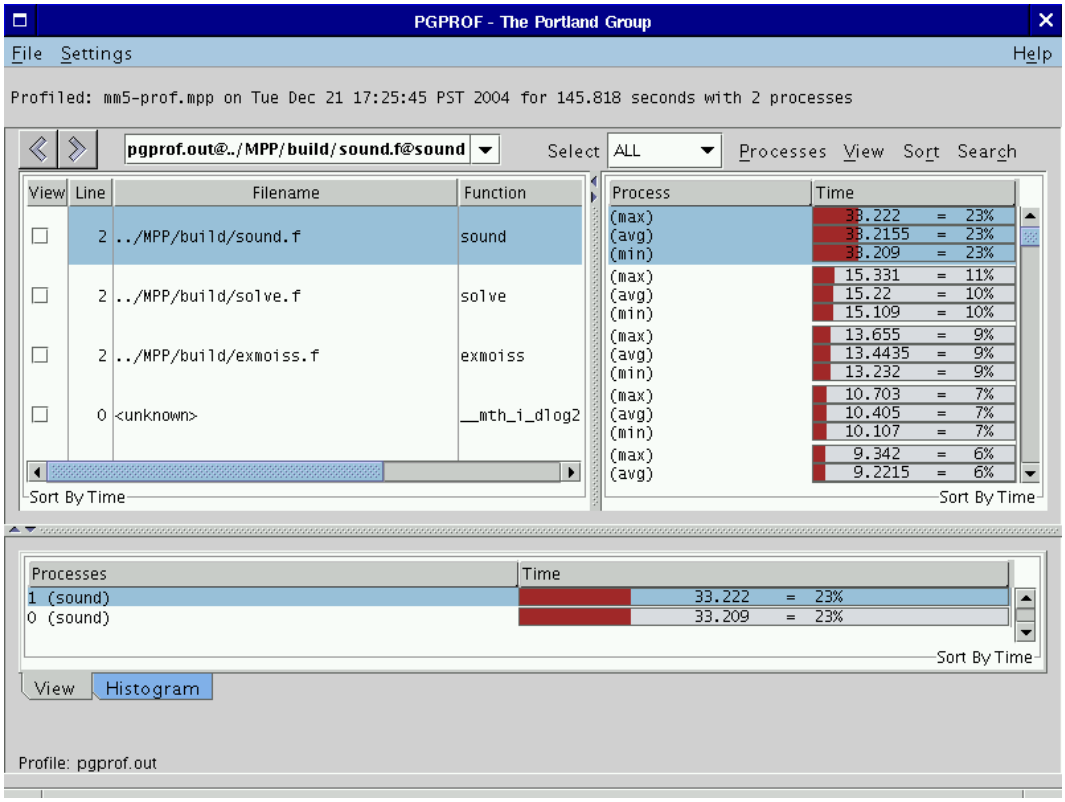
2.2.3.4 Processes Menu

The Processes menu is enabled for multi-process programs only. This menu contains three check boxes: *Min*, *Max*, and *Avg*. They represent the minimum process value, maximum process value, and average process value respectively. By default *Max*, is selected.

When *Max* is selected, the highest value for any profile data in the *Top Right Table* is reported. For example, when reporting *Time*, the longest time for each profile entry gets reported when *Max* is selected. When the *Min* process is selected, the lowest value for any profile data is reported in the *Right Table*. *AVG* reports the average value between all of the processes. Any, all, or none of these check boxes may be selected. When no check boxes are selected, the *Top*, *Left* and *Right Tables* are empty. If the *Process* check box under the *View* menu is selected, then each row of data in the *Right Table* is labeled *max*, *avg*, and *min* respectively.

Figure 2-8 illustrates *max*, *avg*, and *min* with the *Process* check box enabled.

Figure 2-8: *PGPROF* with *Max, Avg, Min* rows



2.2.3.5 View Menu

Use the *View* menu to select which columns of data to view in the *Top Left*, *Top Right*, and *Bottom* tables. This selection also affects the way that tables are printed to a file and a printer (see *Print* in *Section 2.2.3.1 File Menu*).

The following lists *View* menu items and their definition. Note that not all items may be available for a given profile.

- *Count* – Enables the *Count* column in the *Top Right* and *Bottom* tables. *Count* is associated with the number of times this profile entry has been visited during execution of the program. For function level profiling, *Count* is the number of times the routine was called. For line level profiling, *Count* is the number of times a profiled source line was executed.

- *Time* – Enables the *Time* column in the *Top Right* and *Bottom* tables. The time column displays the time spent in a routine (for function level profiling) or at a profiled source line (for line level profiling).

- *Cost* – Enables the *Cost* column in the *Top Right* and *Bottom* tables. Cost is defined as the execution time spent in this routine and all of the routines that it called. The column will contain all zeros if cost information is not available for a given profile.

- *Coverage* – Enables the *Cover* column in the *Top Right* and *Bottom* tables. Coverage is defined as the number of lines in a profile entry that were executed. By definition, a profiled source line will always have a coverage of 1. A routine's coverage is equal to the sum of all its source line coverages. Coverage is only available for line level profiling. The column will contain all zeros if coverage information is not available for a given profile.

- *Messages* – Enables the message count columns in the *Top Right* and *Bottom* tables. Use this menu item to display total MPI messages sent and received for each profile entry. This menu item contains *Message Sends* and *Message Receives* submenus for separately displaying the sends and receives in the *Top Right* and *Bottom* tables. The message count columns will contain all zeros if no messages were sent or received for a given profile.

- *Bytes* – Same as *Messages* except message byte totals are displayed instead of counts.

- *Scalability* – Enables the *Scale* column in the *Top Right* table. Scalability is used to measure the *linear speed-up* or *slow-down* of two profiles. This menu contains two check boxes: *Metric* and *Bar Chart.* When *Metric* is selected, the raw Scalability value is displayed. When *Bar Chart* is selected, a graphical representation of the metric is displayed. Scalability is discussed in *Section 2.2.5 Scalability Comparison.*

- *Processes…(control P)* – This menu item is enabled when profiling an application with more than one process. Use the *Processes* menu item to select individual processes for viewing in the *Bottom* table. When this item is selected, a dialog box will appear with a text field. Individual processes or a range of processes can be entered for viewing in this text field. Individual processes must be separated with a comma.

A range of processes must be entered in the form: `[start]-[end]`; where *start* represents the first process of the range and *end* represents the last process of the range. For example:

```
0,2-16,31
```

This tells the profiler to display information for process 0, process 2 through 16, and process 31. These changes remain active until they are changed again or the profiler session is terminated. Leave the text field blank to view all of the processes in the *Bottom* table.

- *Threads… (control T)* – Same as *Processes...* except it selects the threads rather than the processes viewed in the *Bottom* table.

- *Filename* – Enables the *Filename* column in the *Top Left* table.

- *Line Number* – Enables the *Line* column in the *Top Left* table.

- *Name* – Enables the *Function* (routine) name column in the *Top Left* table when viewing function level profiling.

- *Source* – Enables the *Source* column in the *Top Left* table when viewing line level profiles. If the source code is available, this column will display the source lines for the current routine. Otherwise, this column will be blank.

- *Statement Number* – Enables the *Stmt #* column in the *Top Right* table. Sometimes more than one statement is profiled for a given source line number. One example of this is a "C" *for* statement. The profiler will assign a separate row for each substatement in the *Top Left* and *Right* tables. In line level profiling, duplicate line numbers display in the *Line* column. Each substatement is assigned a statement number starting at 0. Any substatement numbered one or higher will have a '.' and their statement number tacked onto the end of their profile address. For example, in Figure 2-9, source lines 9 and 17 both have multiple profile entries. As shown in the *Profile Entry Combo Box*, the second entry for line 9 has the following address:

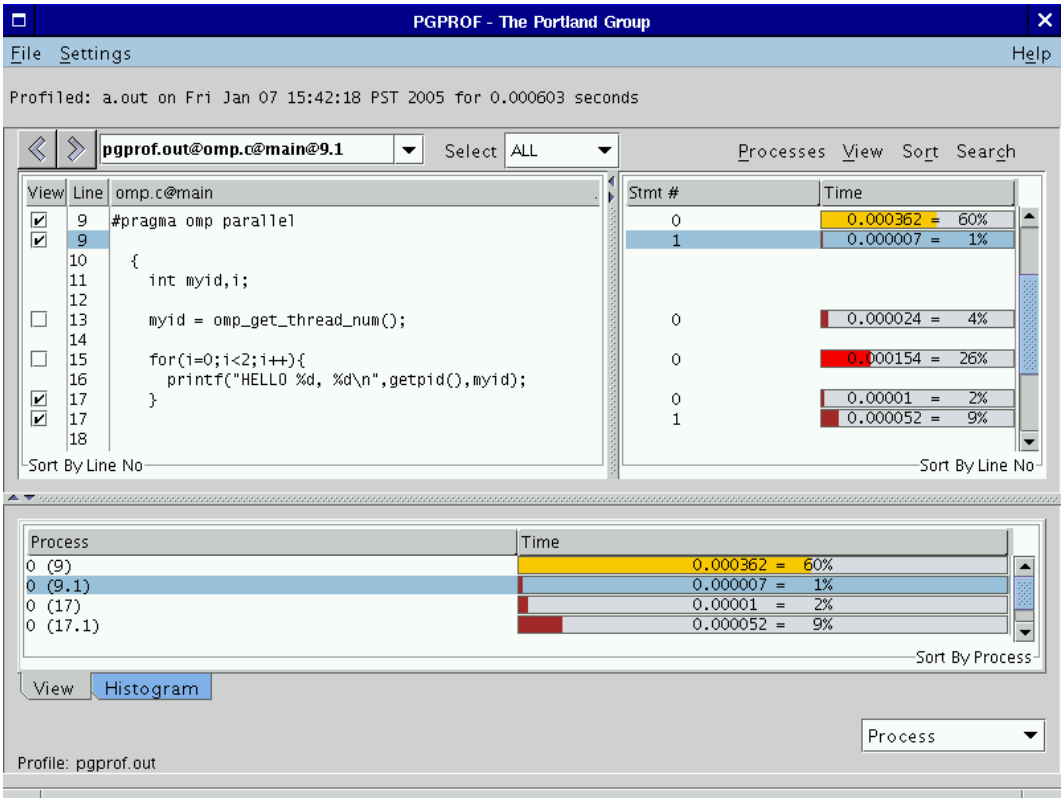
  ```
  pgprof.out@omp.c@main@9.1
  ```

  This line numbering convention is also reflected in the *Bottom* table of Figure 2-9 where the line number is enclosed in parentheses.

- *Process* – This menu option is enabled when more than one process was profiled for a given application. When this check box is selected, a column labeled *Process* is displayed in the *Top Right* table. The values for the *Process* column depend on whatever was enabled in the *Processes* menu discussed in *Section 2.2.3.4 Processes Menu*.

- *Event1 – Event4* – If hardware event counters are supported on the profiled system, then up to four unique events can be displayed in the *Top Right* and *Bottom* tables. In this case, menu items for each counter will be enabled, with names corresponding to each particular event. Each event can exist for some or all of the executing threads in the profiled application.

Figure 2-9: Source Lines with Multiple Profile Entries



The submenus *Count*, *Time*, *Cost*, *Coverage*, *Messages*, *Bytes*, and *Event1* through *Event4* contain three check boxes for selecting how the data is presented in each column. The first check box enables a raw number to be displayed. The second check box enables a percentage. The third check box is a bar chart.

When a percentage is selected, a percentage based on the global value of the selected statistic displays. For example, in Figure 2-9, line 13 consumed `0.000579` seconds, or `42%` of the total time of `0.001391` seconds.

When the bar chart is selected, a graphical representation of the percentage is displayed. The colors are based on this percentage. For a list of default colors and their respective percentages, see the *Bar Chart Colors* option under the *Settings* menu (*Section 2.2.3.2 Settings Menu*).

2.2.3.6 Sort Menu

The sort menu can be used to alter the order in which profile entries appear in the *Top Left, Top Right*, and *Bottom* tables. The current sort order is displayed at the bottom of each table. In Figure 2-9, the tables have a "Sort by" clause followed with "Line No" or "Process". This indicates the sort order is by source line number or by process number respectively. In *PGPROF*, the default sort order is by *Time* for function level profiling and by *Line No* (source line number) for line level profiling. The sort is performed in *descending order, from highest to lowest value, except when sorting by filename, function name, or* line number. Filename, function name, and line number sorting is performed in ascending order; lowest to highest value. Sorting is explained in greater detail in *Section 2.2.4.1 Selecting Profile Data*.

2.2.3.7 Search Menu

The search menu can be used to perform a text search within the *Top Left* table. The search menu contains the following items:

- *Forward Search… (control F)*
- *Backward Search… (control B)*
- *Search Again (control G)*
- *Clear Search (control Q)*

The *PGPROF* GUI displays a dialog box when you invoke the *Forward Search…* or *Backward Search…* menu items. The dialog box will prompt for the text to be located. Once the text is entered and the OK button selected, PGPROF will search for the text in the *Top Left* table. Select *Cancel* to abort the search. If *Forward Search* was selected, *PGPROF* will scroll forward to the next occurrence of the text entered in the dialog box. If *Backward Search* was selected, *PGPROF* will scroll backwards to the first previous occurrence of the text in the *Top Left* table. *Top Left* table columns that contain matching text are displayed in red. To repeat a search, select the *Search Again* menu item. To clear the search and turn the color of all matching text back to black, select the *Clear Search* menu item.

2.2.4 Selecting and Sorting Profile Data

Selecting and sorting affects what profile data is displayed and how it is displayed in *PGPROF*'s *Top Left, Top Right,* and *Bottom* tables. The *Sort* menu, explained in *Section 2.2.3.6 Sort Menu*, can be used to change the sort order. The sort order can also be changed by left-clicking a column heading in the *Top Left, Top Right,* and *Bottom* tables. The *Select Combo Box*, introduced in *Section 2.2.3.6 Sort Menu*, may be used to select which profile entries are displayed based on certain criteria.

2.2.4.1 Selecting Profile Data

By default, *PGPROF selects* all profile entries for display in the *Top Left* and *Right* tables. To change the selection criteria, left mouse click on the *Select Combo Box* next to the *Select* label.

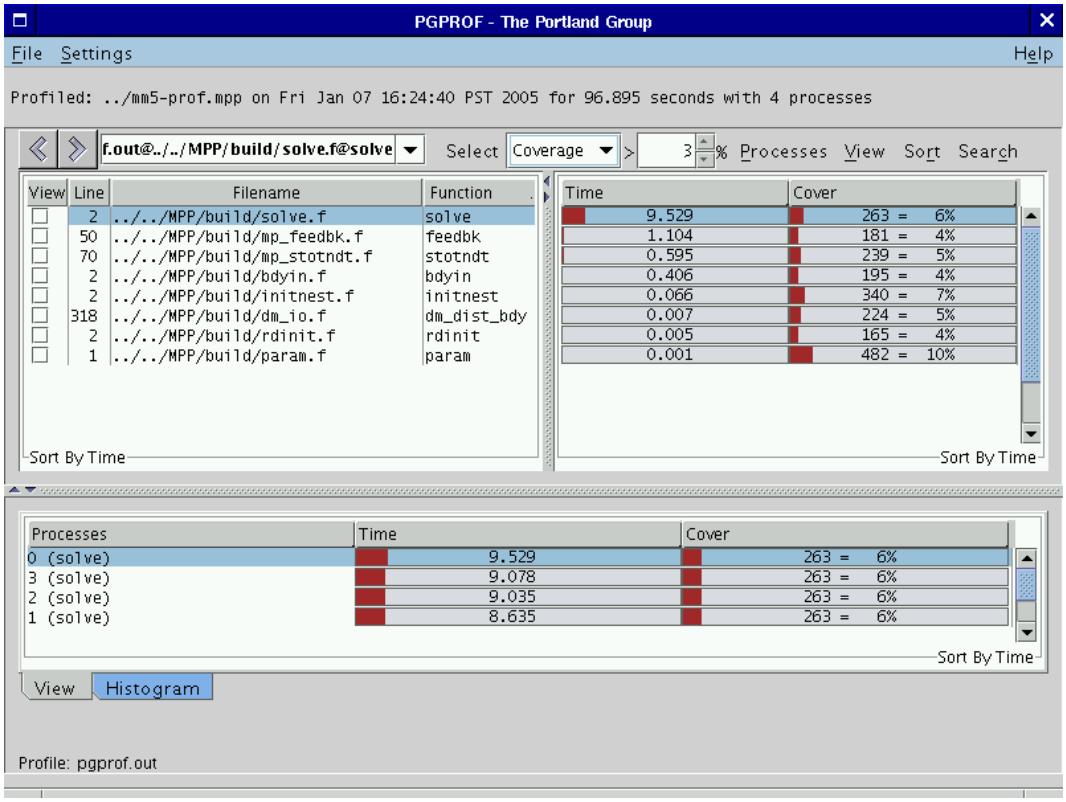
The following options are available:

- *All* – Default. Display all profile entries.
- *Coverage* – Select entries based on *Coverage*. When *Coverage* is selected, an additional text field will appear with up and down arrow keys. Use the up and down arrow keys to increase the minimum coverage a profile entry needs before *PGPROF* will display it. The desired minimum may be entered directly into the text field. The value in the text field represents a percentage. Profile entries with coverage that exceed the input percentage are displayed in the tables. In Figure 2-10, the example shows selecting all routines that have coverage greater than 3% of the coverage for the entire program.
- *Count* – Select entries based on a count criteria. This is the same as *Coverage* except this selects the minimum count required for each profile entry. Profile entries with counts greater than the entered count value are displayed in the tables.
- *Profiled* – Select all entries in the *Top Left* table that have a corresponding entry in the *Top Right* table. See the discussion below for more information.
- *Time* – Same as *Coverage* except the criteria is based on percent of Time a profile entry consumes rather than *Coverage.*
- *Unprofiled* – Select all entries in the *Top Left* table that do not have a corresponding entry in the *Top Right* table. See the discussion below for more information.

Note: *For applications compiled with –Mprof=hwcts or –Mprof=mpi,hwcts, a hardware event may be selected from the list above as well.*

When *Profiled* is selected , profile entries that have a corresponding entry in both the *Top Left* and *Right* tables are selected. A profile entry may be listed in the *Top Left* table but not in the *Top Right* table. In this case, the entry is an *Unprofiled* entry. A *Profiled* entry is a point in the program in which profile information was collected. Depending on the profiling method used, this could be at the end of a *basic block* (e.g., *–Mprof=*[*func* | *line*], *–Mprof=mpi*,[*func* | *lines*] instrumented profiles) or when the profiling mechanism saved its state (e.g., *–pg*, *–Mprof=time*, *–Mprof=hwcts*, *–Mprof=mpi*,[*time*, *hwcts*] sample based profiles).

Figure 2-10: Selecting Profile Entries with Coverage Greater Than 3%



2.2.4.2 Sorting Profile Data

The current sort order is displayed at the bottom of each table. For example, the message *Sort By Time* is present at the bottom of each table in Figure 2-10. The *Bottom* table will display one of the following messages when sorting by *Filename, Name,* or *Line Number*:

- *Sort By Process*
- *Sort By Processes*
- *Sort By Threads*
- *Sort By Process.Threads*
- *Sort By Processes.Threads*

If one of these messages appears in the *Bottom* table, then the profiler is treating the process/thread number as the major sort key and the *Filename, Name,* or *Line Number* as the minor sort key. This can be used to easily compare two different profile entries with the same process/thread number. Use the check boxes under the *View* column in the *Top Left* table to compare more than one profile entry in the *Bottom* table. This is demonstrated in Figure 2-9.

2.2.5 Scalability Comparison

PGPROF has a *Scalability Comparison* feature that can be used to measure *linear speed-up* or *slow-down* between multiple executions of an application. Scalability between executions can be measured with a varying number of processes or threads. To use scalability comparison, first generate two or more profiles for a given application. For best results, compare profiles from the same application using the same input data. Also, scalability comparison works best for serial or multi-process (MPI) programs. To measure scalability for a multi-threaded program, profiling with *–Mprof=func* or *–Mprof=lines* is recommended. See *Section 2.1.3.2 Profiling Multithreaded Programs* and *Section 2.1.5 Measuring Time* for more information on multi-threaded profiling.

The number of processes and/or threads used in each execution can be different. After generating two or more profiles, load one of them into *PGPROF*. Select the *Scalability Comparison* item under the *File* menu and choose another profile for comparison (*Section 2.2.3.1 File Menu*). A new profiler window will appear with a column called *Scale* in its *Top Right* table (*Section 2.2.3.5 View Menu*).

Figure 2-11 shows a profile of an application that was run with one process. Figure 2-12 shows a profile of the same application run with two processes. The profile in Figure 2-12 also has a *Scale* column in its *Top Right* table. Each profile entry that has timing information has a *Scale* value. The scale value measures the *linear speed-up* or *slow-down* for these entries across profiles. A scale value of zero (or one for serial/multi-threaded programs) indicates no change in the execution time between the two runs. A positive value means the time improved by that scaled factor. A negative value means that the time slowed down by that scaled factor.

Bar charts in the *Scale* column show positive values with bars extending from left to right and negative values with bars extending from right to left (Figure 2-12). If there is a question mark ('?') in the *Scale* column, then *PGPROF* is unable to perform the scalability comparison for this profile entry. This may happen if the two profiles do not share the same executable or input data.

Figure 2-11: Profile of an Application Run with 1 Process

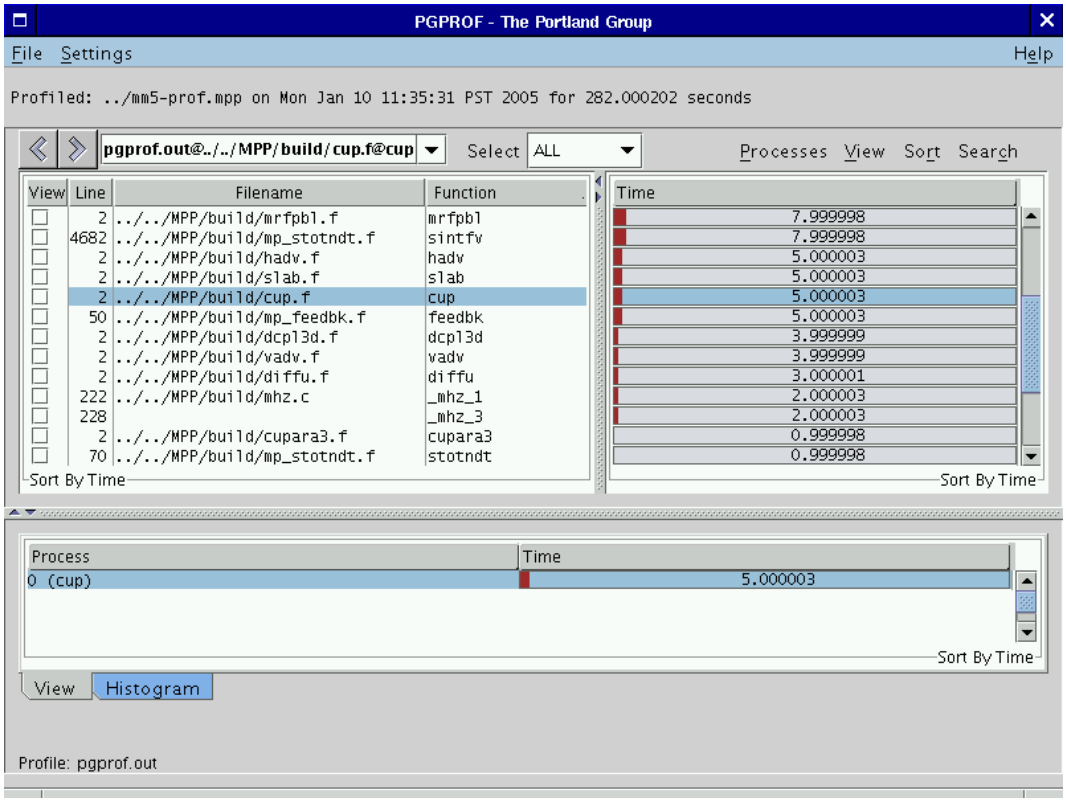
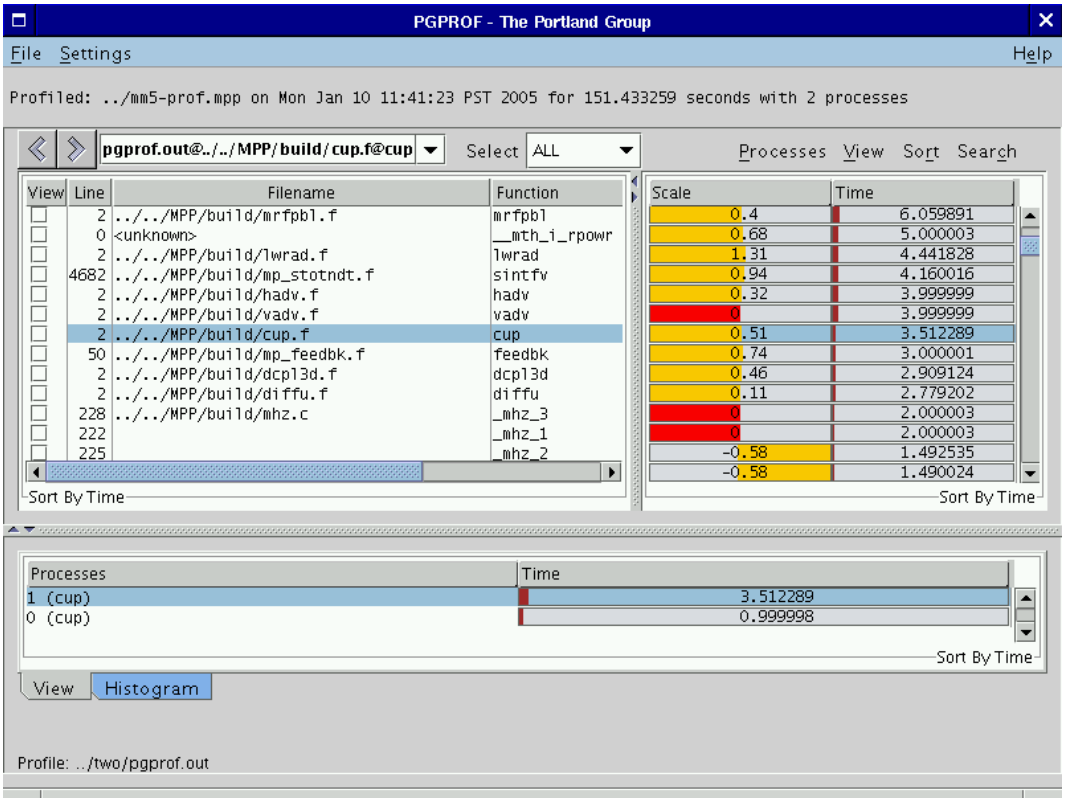


Figure 2-12: Profile with Visible Scale Column



PGPROF uses the two formulas shown below for computing scalability. Formula 2-1 computes scalability for multiprocess programs and Formula 2-2 computes scalability for serial and multi-threaded programs.

In Formula 2-1, a scalability value greater than zero indicates some degree of speed-up. A scalability value of one indicates *perfect linear speed-up*. Anything greater than one, indicates *super speed-up*. Similar negative values indicate *linear slow-down* and *super slow-down* respectively. A value of zero indicates that no change in execution time occurred between the two runs.

Formula 2-1: Scalability for Multiprocess Programs

P_1 = number of processes used in first run of application

P_2 = number of processes used in second run of application

where $P_2 > P_1$

$Time_1$ = Execution time using P_1 processes

$Time_2$ = Execution time using P_2 processes

$$Scalability = \log(Time_1 \div Time_2) \div \log(P_2 \div P_1)$$

In Formula 2-2, a scalability value greater than zero indicates some degree of speed-up. A scalability value equal to the ratio $(T_2 \div T_1)$ indicates *perfect linear speed-up*. Anything greater than one, indicates *super speed-up*. Similar negative values indicate *linear slow-down* and *super slow-down* respectively. A value of one indicates that no change in execution time occurred between the two runs.

Formula 2-2: Scalability for Serial and Multi-threaded Programs

T_1 = number of threads used in first run of application

T_2 = number of threads used in second run of application

where $T_2 \geq T_1$

$Time_1$ = Execution time using T_1 threads

$Time_2$ = Execution time using T_2 threads

$Scalability = Time_2 \div Time_1$

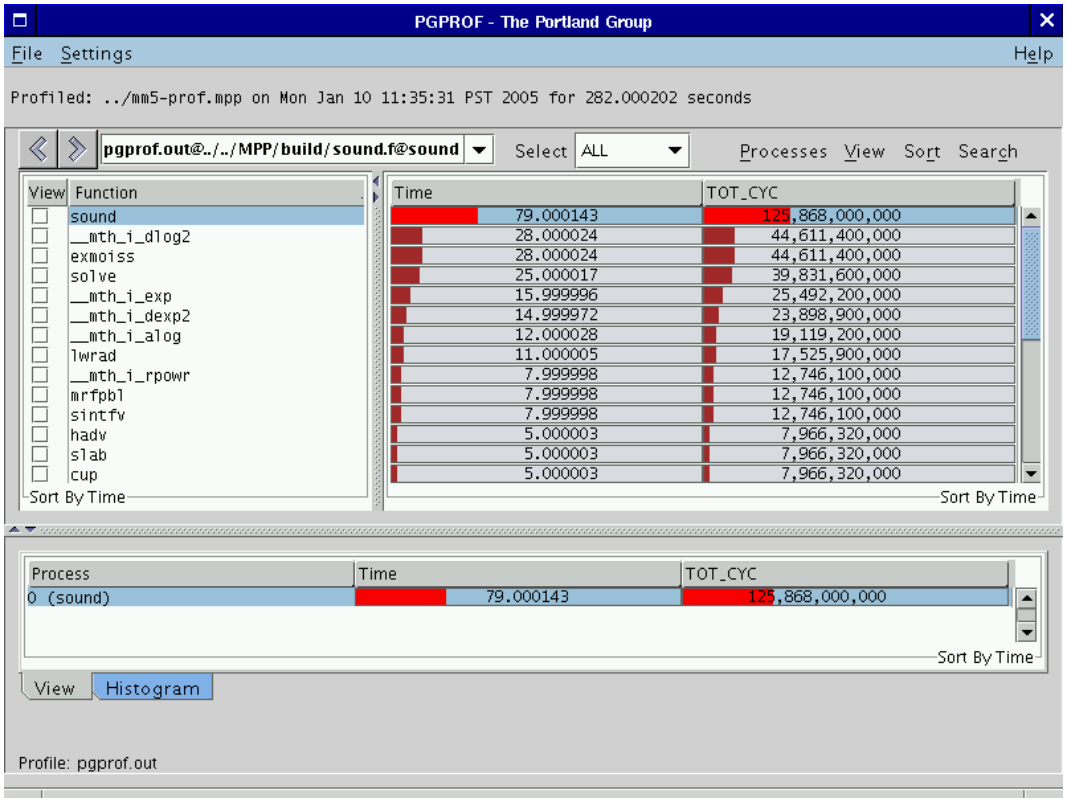
2.2.6 Viewing Profiles with Hardware Event Counters

If you compiled your program with the *–Mprof=hwcts* or the *–Mprof=mpi,hwcts* option, then you can profile up to four event counters and view them in *PGPROF*. See *Section 2.1.3.3 Profiling Hardware Event Counters* for more details.

Figure 2-13 shows a profile of one event counter called *TOT_CYC*, which counts the number of CPU cycles the program consumed. This event is enabled by default or by adding *PAPI_TOT_CYC* to your *PGPROF_EVENTS* environment variable (*Section 2.1.3.3 Profiling Hardware Event Counters*). Each entry under the *Time* column represents CPU time computed by its corresponding *TOT_CYC* entry. *PGPROF* will not report any time for hardware counter profiles unless one of the hardware events is *PAPI_TOT_CYC.*

Each event can be toggled for viewing and sorting under the *View* (*Section 2.2.3.5 View Menu*) and *Sort* (*Section 2.2.3.6 Sort Menu*) menus respectively. Hardware event criteria may also be selected under the *Select* combo box (*Section 2.2.4.1 Selecting Profile Data*).

Figure 2-13: Profile with Hardware Event Counter



2.3 Command Language

The user interface for non-GUI (Win32) versions of the *PGPROF* profiler is a simple command language. This command language is available in GUI versions of the profiler using the *–s* or –text option. The language is composed of commands and arguments separated by white space. A `pgprof>` prompt is issued unless input is being redirected.

2.3.1 Command Usage

This section describes the profiler's command set. Command names are printed in bold and may be abbreviated as indicated. Arguments enclosed by brackets ('[']') are optional. Separating two or more arguments by '|' indicates that any one is acceptable. Argument names in *italics* are

chosen to indicate what kind of argument is expected. Argument names that are not in italics are keywords and should be entered as they appear.

d[*isplay*] [*display options*] | all | none

Specify display information. This includes information on minimum values, maximum values, average values, or per processor/thread data. Below is a list of possible display options:

[no]calls [no]cover [no]time [no]timecall [no]cost [no]proc [no]thread [no]msgs [no]msgs_sent [no]msgs_recv [no]bytes [no]bytes_sent [no]name [no]file [no]line [no]lineno [no]visits [no]scale [no]stmtno

he[lp] [*command*]

Provide brief command synopsis. If the *command* argument is present only information for that command will be displayed. The character "?" may be used as an alias for *help*.

h[istory] [*size*]

Display the history list, which stores previous commands in a manner similar to that available with `csh` or `dbx`. The optional *size* argument specifies the number of lines to store in the history list.

l[ines] function [[>] *filename*]

Print (display) the line level data together with the source for the specified *function*. If the *filename* argument is present, the output will be placed in the named file. The '>' means redirect output, and is optional.

a[sm] routine [[>] *filename*]

Print (display) the instruction and line level data together with the source and assembly for the specified *routine*. If the *filename* argument is present, the output will be placed in the named file. The '>' means redirect output, and is optional. This command is only available on platforms that support instruction level profiling.

lo[ad] [*datafile*]

Load a new dataset. With no arguments reloads the current dataset. A single argument is interpreted as a new data file. With two arguments, the first is interpreted as the program and the second as the data file.

m[erge] datafile

Merge the profile data from the named *datafile* into the current loaded dataset. The *datafile* must be in standard *pgprof.out* format, and must have been generated by the same executable file as the original dataset (no

datafiles are modified.)

pro[cess] processor_num
: For multi-process profiles, specify the processor number of the data to display.

p[rint] [[>] *filename*]
: Print (display) the currently selected function data. If the *filename* argument is present, the output will be placed in the named file. The '>' means redirect output, and is optional.

q[uit]
: Exit the profiler.

sel[ect] `calls | timecall | time | cost | cover | all` [[>] *cutoff*]
: Display data for a selected subset of the functions. This command is used to set the selection key and establish a cutoff percentage or value. The cutoff value must be a positive integer, and for time related fields is interpreted as a percentage. The '>' means greater than, and is optional. The default is all.

so[rt] [by] [max | avg | min | proc | thread] `calls | cover | timecall | time | cost | name` | msgs | msgs_sent | msgs_recv | bytes | bytes_sent | bytes_recv | visits | file
: Function level data is displayed as a sorted list. This command establishes the basis for sorting. The default is *max* `time`.

src[dir] directory
: Set the source file search path.

s[tat] [no]min|[no]avg|[no]max|[no]proc|[no]thread|[no]all]
: Set which process fields to display (or not to display when using the arguments beginning with “no”).

th[read] thread_num.
: Specify a thread for a multi-threaded process profile.

t[imes] `raw | pct`
: Specify whether time-related values should be displayed as raw numbers or as percentages. The default is `pct`.

!!
: Repeat previous command.

! *num*	Repeat previous command numbered *num* in the history list.
!-*num*	Repeat the *num*-th previous command numbered *num* in the history list.
! *string*	Repeat the most recent previous command starting with *string* from the history list.

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