6 The Integrated Debugger

Your skill set for writing programs would not be complete without knowing how to use a debugger. While a debugger is traditionally associated with finding bugs, it can also be used as a general aid for understanding your program as you develop it. jGRASP provides a highly visual debugger for Java, which is tightly integrated with the CSD and UML windows, the Workbench, Viewers, and Interactions. The jGRASP debugger includes all of the traditional features expected in a debugger.

If the example program used in this section is not available to you, or if you do not understand it, simply substitute your own program in the discussion.

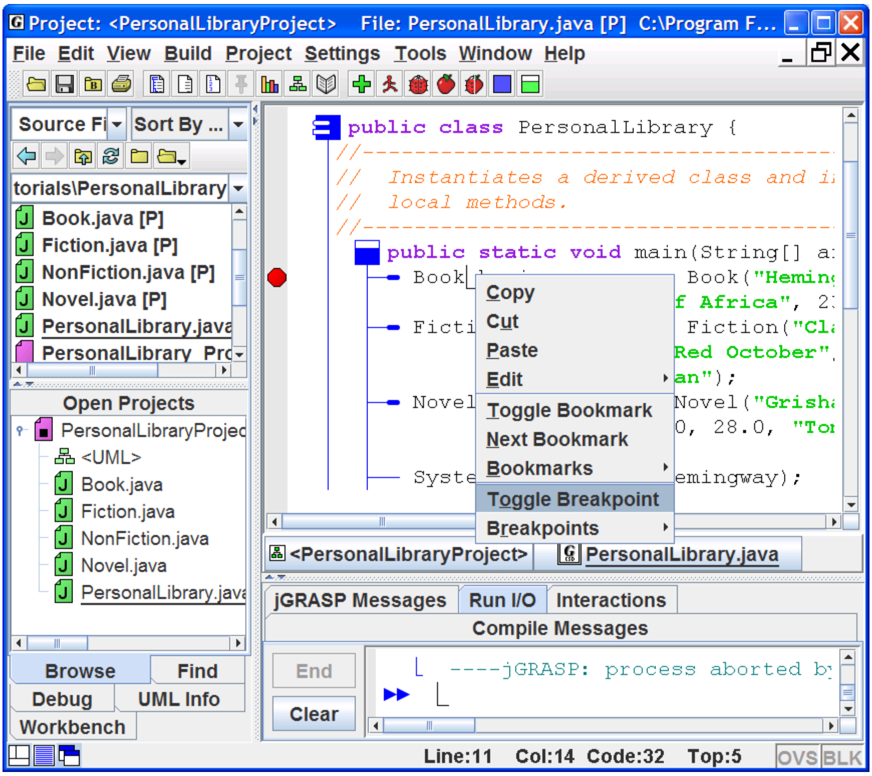
Objectives – When you have completed this tutorial, you should be able to set breakpoints and step through the program, either by single stepping or auto stepping. You should also be able to display the dynamic state of objects created by the program using the appropriate Object Viewer.

The details of these objectives are captured in the hyperlinked topics listed below.

6.1 Preparing to Run the Debugger
6.2 Setting a Breakpoint
6.3 Running a Program in Debug Mode
6.4 Stepping Through a Program – the Debug Buttons
6.5 Stepping Through a Program – without *Stepping In*
6.6 Stepping Through a Program – and *Stepping In*
6.7 Opening Object Viewers
6.8 Debugging a Program

6.1 Preparing to Run the Debugger

In preparation for using the debugger, we need to make sure that programs are being compiled in debug mode. This is the default, so this option is probably already turned on. With a CSD or UML window in focus, click **Build** on the menu and make sure **Debug Mode** is checked. If the box in front of Debug Mode is not checked, click on the box. When you click on Build again, you should see that Debug Mode is checked. When you compile your program in Debug Mode, information about the program is included in the .class file that would normally be omitted. This allows the debugger to display useful details as you execute the program. If your program has not been compiled with Debug Mode checked, you should recompile it before proceeding.



```
public class PersonalLibrary {
//-----------------------------------
//   Instantiates a derived class and i
//   local methods.
//-----------------------------------
   public static void main(String[] a
      Book                          Book("Heming
                                   f Africa", 2
      Ficti                         Fiction("Cla
                                   Red October",
                                   an");
      Novel                        Novel("Grisha
                                   0, 28.0,  "To
      Syste                        emingway);
```

```
----jGRASP: process aborted by
```

Figure 6-1. Setting a breakpoint

6.2 Setting a Breakpoint

In order to examine the state of your program at a particular statement, you need to set a breakpoint. The statement you select must be "executable" rather than a simple declaration. To set a breakpoint in a program, move the mouse to the line of code and left-click the mouse to move the cursor there. Now right-click on the line to display a set of options that includes **Toggle Breakpoint**. For example, in Figure 6-1 the cursor is on the first executable line in *main* (which declares Book hemingway …), and after Toggle Breakpoint is selected in the options popup menu, a small red stop sign symbol ● appears in the left margin of the line to indicate that a breakpoint has been set. To remove a breakpoint, you repeat the process since this is a toggle action. You may set as many breakpoints as needed.

You can also set a breakpoint by hovering the mouse over the leftmost column of the line where you want to set the breakpoint. When you see the red octagonal breakpoint symbol ●, you just left-click the mouse to set the breakpoint. You can remove a breakpoint by clicking on the red octagon. This second approach is the one most commonly used for setting and removing breakpoints.

6.3 Running a Program in Debug Mode

After compiling your program in Debug Mode and setting one or more breakpoints, you are ready to run your program with the debugger. You can start the debugger in one of two ways:

(1) Click **Build** – **Debug** on the CSD window menu, or

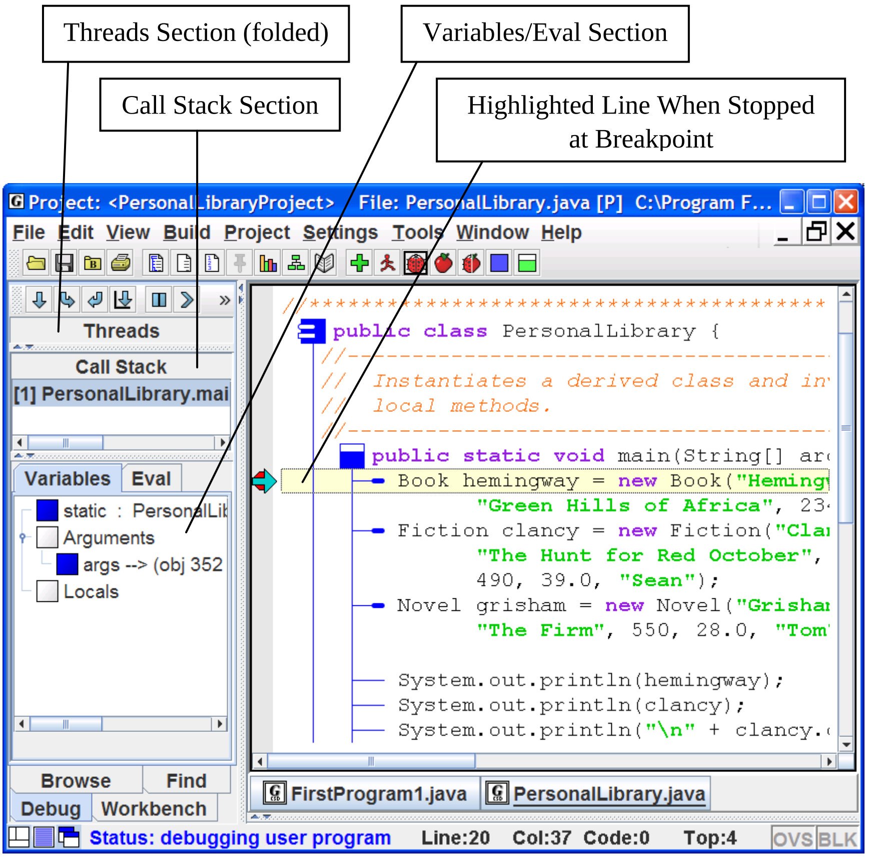
(2) Click the Debug button 🐞 on the toolbar.

After you start the debug session, several things happen. In the Run window near the bottom of the Desktop, you should see a message indicating that the debugger has been launched. In the CSD window, the line with the breakpoint set is eventually highlighted, indicating that the program will execute this statement next. On the left side of the jGRASP desktop, the Debug tab is popped to the top. Each of these can be seen in Figure 6-2. Notice the Debug tab pane is further divided into three sub-panes or sections labeled **Threads**, **Call Stack**, and **Variables/Eval**. Each of these sections can be resized by selecting and dragging one of the horizontal partitions.

The **Threads** section lists all of the active threads running in the program. In the example, the red thread symbol ▮ indicates the program is stopped in *main*, while the green symbols indicate that the other threads are running. Advanced users should find this feature useful for starting and stopping individual threads in their programs. However, since beginners and intermediate users rarely use multi-threading, the thread section is closed when the debugger is initially started. Once the Threads section is dragged open, it remains open for the duration of the jGRASP session or until it is closed.

The **Call Stack** section is useful to all levels of users since it shows the current call stack and allows the user to switch from one level to another in the call stack. When this occurs, the CSD window that contains the source code associated with a particular call is popped to the top of the desktop.

The **Variables/Eval** section shows the details of the current state of the program in the *Variables* tab and provides an easy way to evaluate expressions involving these variables in the *Eval* tab. Most of your attention will be focused on the *Variables* tab where you can monitor all current values in the program. From the *Variables* tab, you can also launch separate viewers on any primitives or objects as well as fields of objects.

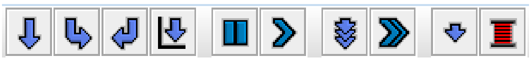


```
//*******************************************
public class PersonalLibrary {
   //-----------------------------------
   //  Instantiates a derived class and in
   //  local methods.
   //-----------------------------------
   public static void main(String[] ar
      Book hemingway = new Book("Heming
            "Green Hills of Africa", 23
      Fiction clancy = new Fiction("Cla
            "The Hunt for Red October",
            490, 39.0, "Sean");
      Novel grisham = new Novel("Grisha
            "The Firm", 550, 28.0, "Tom

      System.out.println(hemingway);
      System.out.println(clancy);
      System.out.println("\n" + clancy.
```

Status: debugging user program   Line:20   Col:37   Code:0   Top:4   OVS BLK

Figure 6-2. Desktop after debugger is started

6.4 Stepping Through a Program – the Debug Buttons



After the program stops at the breakpoint (Figure 6-2), you can use the buttons at the top of the Debug tab to *step*, *step into* a method call, *step out* of a method, *run to the cursor*, *pause* the current thread, *resume*, turn on/off *auto step* mode, turn on/off *auto resume* mode, and *suspend new threads*. The sequence of statements that is executed when you run your program is called the *control path* (or simply *path*). If your program includes statements with conditions (e.g., *if* or *while* statements), the control path will reflect the *true* or *false* state of the conditions in these statements.

Clicking the *Step* button will single step to the next statement. The highlighted line in the CSD window indicates the statement that's about to be executed. When the Step button is clicked, that statement is executed and the "highlighting" is moved to the next statement along the control path.

Clicking the *Step in* button for a statement with a method call that's part of the user's source code will open the new file, if it's not already open, and pop its CSD window to the top with the current statement highlighted. The top entry in the *Call Stack* indicates where you are in the program. Note that clicking the *Step in* button for a statement without a method call is equivalent to clicking *Step*.

Clicking the *Step out* button will take the debugger back to the point where the current method was called (i.e., it will step out of the current method). The *Call Stack* will be updated accordingly.

Clicking the *Run to Cursor* button will cause your program to step automatically until the statement with the cursor L is reached. If the cursor is not on a statement along the control path, the program will stop at the next breakpoint it encounters or at the end of the program. The *Run to Cursor* button is convenient since placing the cursor on a statement is like setting "temporary" breakpoint.

Clicking the *Pause* button will suspend the program running in debug mode. Note that if you didn't have a breakpoint set in your code, you may have to select the main thread in the *Threads* section before the *Pause* button is available. After the program has halted, refer to the *Call Stack* and select the last method in your source code that was invoked. This should open the CSD window containing the method with the current line highlighted. Click the *step* button to advance through the code.

Clicking the Resume button advances the program along the control path to the next breakpoint or to the end of the program. If you have set a breakpoint in a CSD window containing another file and this breakpoint is on the control path (i.e., in a method that gets called), then this CSD window will pop to the top when the breakpoint is reached.

The *Auto Step* button is used to toggle off and on a mode which allows you to step repeatedly after clicking the *step* button only once. This is an extremely useful feature in that it essentially let's you watch your program run. Notice that with this feature turned on, a *Delay* slider bar appears beneath the Debug controls. This allows you to set the delay between steps from 0 to 26 seconds (default is .5 seconds). While the program is auto stepping, you can stop the program by clicking the *Pause* button. Clicking the *Step* button again continues the auto stepping. Remember after turning on Auto Step, you always have to click the *step* button once to get things rolling.

The *Auto Resume* button is used to toggle off and on a mode which allows you to resume repeatedly after clicking the *Resume* button only once. The effect is that your program moves from breakpoint to breakpoint using the delay indicated on the *delay* slider bar. As with auto step above, you can click the *Pause* button to interrupt the auto resume; then click the *Resume* button again to continue the auto resume.

The *Use Byte Code Size Steps* button toggles on and off the mode that allows you to step through a program in the smallest increments possible. With this feature off, the step size is approximately one source code statement, which is what most users want to see. This feature is seldom needed by beginning and intermediate programmers.

The *Suspend New Threads* button toggles on and off the mode that will immediately suspend any new threads that start. With this feature on when the debugging process is started, all startup threads are suspended as soon as is possible. Unless you are writing programs with multiple threads, you should leave the feature turned off.

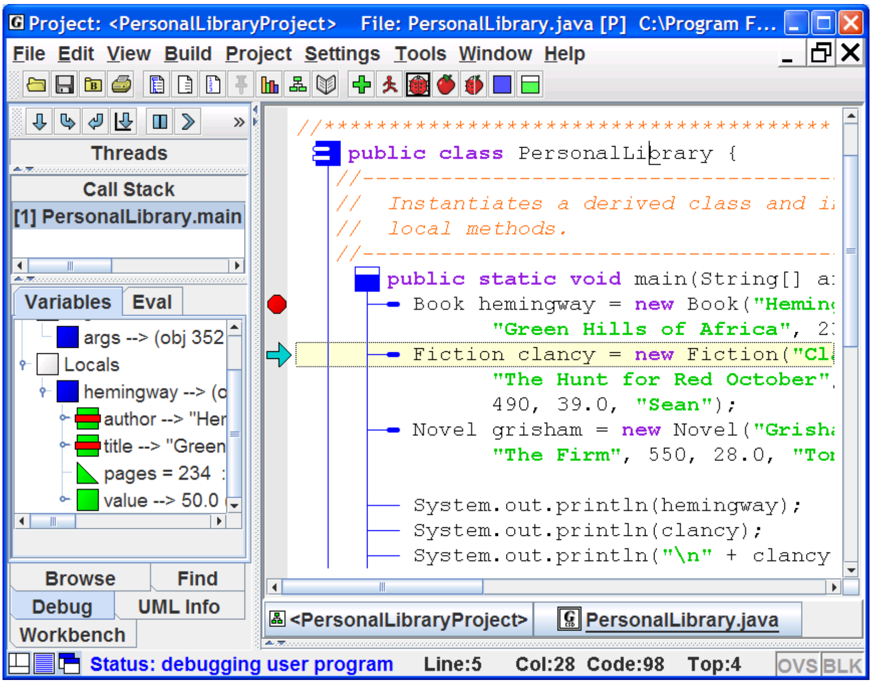
As you move through the program, you can watch the call stack and contents of variables change dynamically with each step. The integrated debugger is especially useful for watching the creation of objects as the user steps through various levels of constructors. The jGRASP debugger can be used very effectively to explain programs, since a major part of understanding a program is keeping track (mentally or otherwise) of the state of the program as one reads from line to line. We will make two passes through the example program as we explain it. During the first pass, we will "step" through the program without "stepping into" any of the method calls, so we can concentrate on the Variables section.

6.5 Stepping Through a Program – without *Stepping In*

After initially arriving at the breakpoint in Figure 6-2, the **Variables/ Settings** section indicates that no local variables exist. Figure 6-3 shows the results of clicking the *Step* ⬇ button to move to the next statement. Notice that under Locals in the **Variables/Eval** section, we now have an instance of Book called *hemingway*. Objects, represented by a colored square, can be opened and closed by clicking the "handle" in front of the square object. Primitives, like the integer *pages*, are represented by colored triangles. In Figure 6-3, *hemingway* has been opened to show the author, title, and pages fields. Each of the String instances (e.g., author) can be opened to show the details of a String object, including the character array that holds the actual value of the string.

Since *hemingway* is an instance of Book, the fields in *hemingway* are marked with green object or primitive symbols to indicate that they were declared in Book. Notice that the symbols for author and title have red borders since they were declared to be *private* in Book. This indicates that they are inaccessible from the current context of main in PersonalLibrary. The field *pages*, which was declared to be *protected* in Book, has a symbol without a red border. The reason for this is somewhat subtle. The *protected* field *pages* is accessible in all subclasses of Book as well as in any class contained in the Java package containing Book. Since the PersonalLibrary program is not in a package, it is considered to be in the "default package". Thus, since Book is also in the default package, the *protected* field *pages* is accessible to PersonalLibrary.

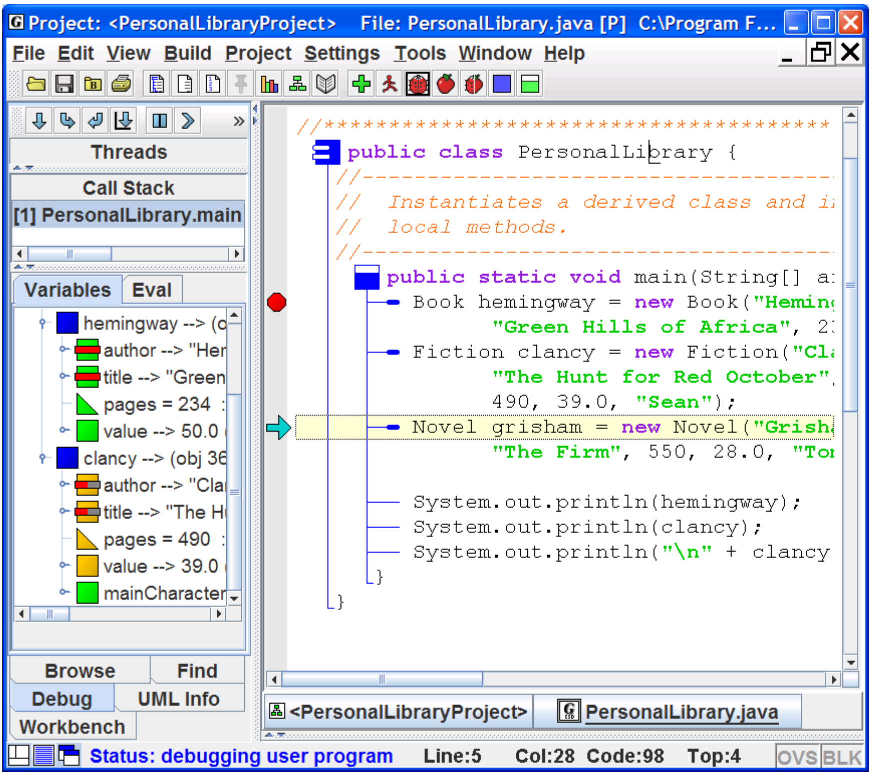
After executing the statement indicated in Figure 6-3, an instance of the Fiction class called clancy is created as shown in Figure 6-4. In the figure, clancy has been opened to reveal its fields. The field "mainCharacter" is green, indicating that it is defined in Fiction. The other fields (author, title, and pages) are orange, which indicates that these fields were inherited from Book.



```
//***********************************
public class PersonalLibrary {
   //-----------------------------------
   //  Instantiates a derived class and i
   //  local methods.
   //-----------------------------------
   public static void main(String[] a
      Book hemingway = new Book("Heming
               "Green Hills of Africa", 2
      Fiction clancy = new Fiction("Cl
               "The Hunt for Red October",
               490, 39.0, "Sean");
      Novel grisham = new Novel("Grisha
               "The Firm", 550, 28.0, "To

      System.out.println(hemingway);
      System.out.println(clancy);
      System.out.println("\n" + clancy
```

Figure 6-3. Desktop after hemingway (book) is created

As you continue to step though your program, you should see output of the program displayed in the Run I/O window in the lower half of the Desktop. Eventually, you should reach the end of the program and see it terminate. When this occurs, the Debug tab should become blank, indicating that the program is no longer running.


Project: <PersonalLibraryProject> File: PersonalLibrary.java [P] C:\Program F...
File Edit View Build Project Settings Tools Window Help
Threads
Call Stack
Variables
Eval
Browse
Find
Debug
UML Info
Workbench
<PersonalLibraryProject>
PersonalLibrary.java
OVS BLK

```
//*************************************
public class PersonalLibrary {
   //-----------------------------------
   //  Instantiates a derived class and i
   //  local methods.
   //-----------------------------------
   public static void main(String[] a
      Book hemingway = new Book("Heming
         "Green Hills of Africa", 2
      Fiction clancy = new Fiction("Cla
         "The Hunt for Red October",
         490, 39.0, "Sean");
      Novel grisham = new Novel("Grish
         "The Firm", 550, 28.0, "To

      System.out.println(hemingway);
      System.out.println(clancy);
      System.out.println("\n" + clancy
   }
}
```

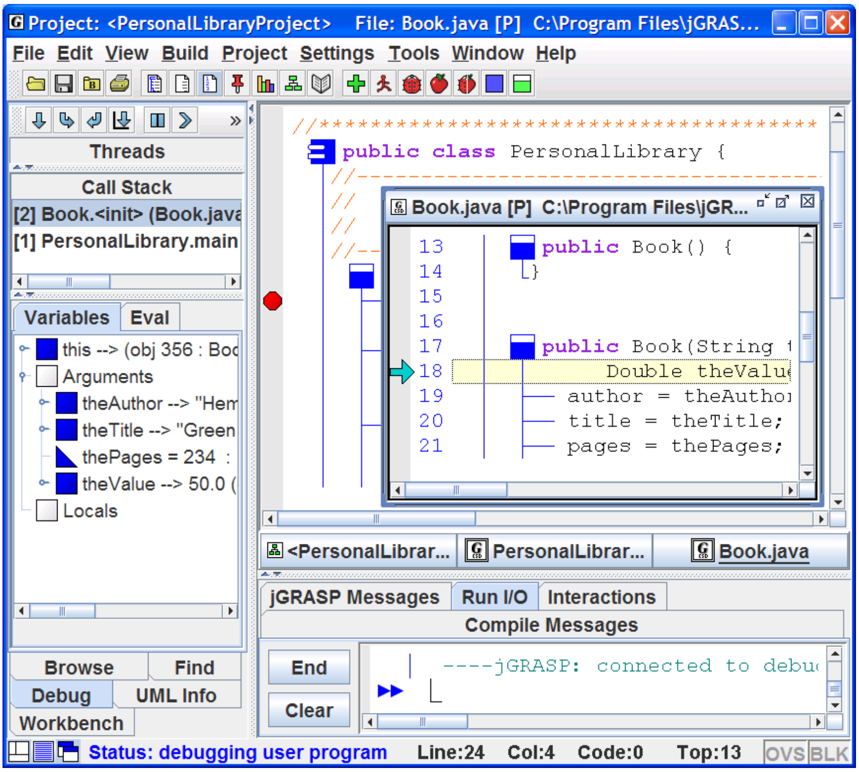
```
[1] PersonalLibrary.main

hemingway --> (o
   author --> "Her
   title --> "Green
   pages = 234
   value --> 50.0
clancy --> (obj 36
   author --> "Cla
   title --> "The H
   pages = 490
   value --> 39.0
   mainCharacter
```

```
Status: debugging user program    Line:5    Col:28  Code:98    Top:4
```

Figure 6-4. After next step and "clancy" created

6.6 Stepping Through a Program – and *Stepping In*

Now we are ready to make a second pass and “step in” to the methods called. Tracing through a program by following the calls to methods can be quite instructive in the obvious way. In the object-oriented paradigm, it is quite useful for illustrating the concept of constructors. As before, we need to run the example program in the debugger by clicking **Build – Debug** on the CSD window menu or by clicking the debug button on the toolbar. After arriving at the breakpoint, we click the *Step in* button and the constructor for class Book pops up in the CSD window (Figure 6-5). Notice that the C*all Stack* in the Debug tab indicates that you have moved into Book from PersonalLibrary (i.e., the entry for Book is listed above PersonalLibrary in the *call stack*). If you click on the PersonalLibrary entry in the call stack, the associated CSD window will pop to the top and you will see the variables associated with it. If you then click the Book entry, its CSD window will pop to the top and you will see the variables associated with the call to Book's constructor. In Figure 6-5, the entry for *this* has been expanded in the *Variables* section. The *this* object represents the object that is being constructed. Notice that none of the fields have a red border since we are inside the Book class. As you step through the constructor, you should see the fields in *this* get initialized to the values passed in as arguments. Also, note the *id* for *this* (it is 356 in our example debug session; it may be a different number in your session). You can then step through the constructor in the usual way, eventually returning to the statement in the main program that called the constructor. One more step should finally get you to the next statement, and you should see *hemingway* in the *Variables* section with the same *id* as you saw in the constructor as it was being built. If you expand *hemingway*, you should see that the red borders are back on *author* and *title* since we're no longer in the Book class.


Project: <PersonalLibraryProject> File: Book.java [P] C:\Program Files\jGRAS...
File Edit View Build Project Settings Tools Window Help
Threads
Call Stack
Variables
Eval
Book.java [P] C:\Program Files\jGR...
<PersonalLibrar...
PersonalLibrar...
Book.java
jGRASP Messages
Run I/O
Interactions
Compile Messages
End
Clear
Browse
Find
Debug
UML Info
Workbench
OVS BLK

```
[2] Book.<init> (Book.java
[1] PersonalLibrary.main
```

```
this --> (obj 356 : Boo
Arguments
  theAuthor --> "Hem
  theTitle --> "Green
  thePages = 234 :
  theValue --> 50.0 (
Locals
```

```
//*************************************
public class PersonalLibrary {
//-------------------------------------
//
//
//--
```

```
   public Book() {
   }


   public Book(String t
         Double theValue
      author = theAuthor
      title = theTitle;
      pages = thePages;
```

```
----jGRASP: connected to debu
```

```
Status: debugging user program    Line:24    Col:4    Code:0    Top:13
```

Figure 6-5. After next stepping into the Book constructor

There are many other scenarios where this approach of tracing through the process of object construction is useful and instructive. For example, consider the case where the Fiction constructor for “clancy” is called and it in turn calls the super constructor located in Book. By stepping into each call, you can see not only how the program proceeds through the constructor’s code, but also how fields are initialized.

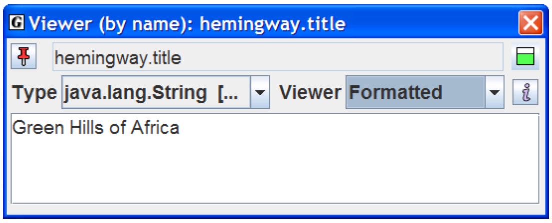
Another even more common example is when the *toString* method of an object is invoked indirectly in a print statement (System.out.println). The debugger actually takes the user to the object’s respective *toString* method.

6.7 Opening Object Viewers

A separate ***Viewer*** window can be opened for any primitive or object (or field of an object) displayed in *Variables* section of the Debug tab. All objects have a *basic* view which is similar to the view shown in the Debug tab. However, when a separate viewer window is opened for an entry, some objects will have additional views.

The easiest way to open a viewer is to left-click on an object and drag it from the workbench to the location where you want the viewer to open. This will open a “view by name” viewer. You can also open a viewer by right-clicking on the object and selecting either **View by Value** or **View by Name**.

Figure 6-6 shows an object viewer for the *title* field of *hemingway* in Figure 6-4, which is a String object in an instance of Book. *Formatted* is the default “view” for a String object which is especially useful when viewing a String object with a large value (e.g., a page of text). In Figure 6-7, the *Basic* view has been selected and expanded to show the details of the String object. Notice that the first field is value[21] which is a character array holding the actual value of the string. If we open a separate viewer on *value*, we have a *Presentation* view of the array as shown in Figure 6-8. Notice that the first element (‘G’) in the array has been selected and this opened a subview of type character. The subview displays the ‘G’ and its integral value of 71. If our example had been an array of strings (e.g., a list of words) then selecting an array element would have displayed the formatted view of a String object in the subview. Presentation view is the default for arrays. There is also a view called *Array Elements* which is quite useful for large arrays.

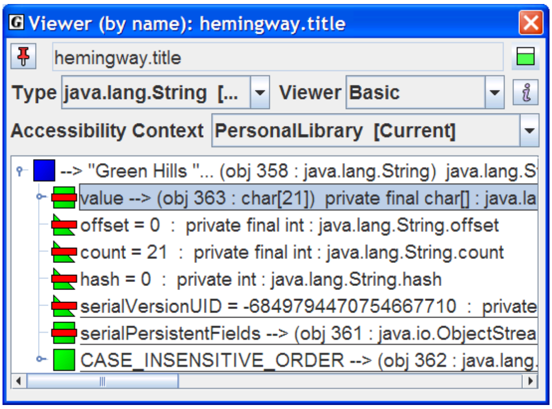

Viewer (by name): hemingway.title

hemingway.title

Type java.lang.String [... Viewer Formatted

Green Hills of Africa

Figure 6-6. Viewing a String Object



Viewer (by name): hemingway.title

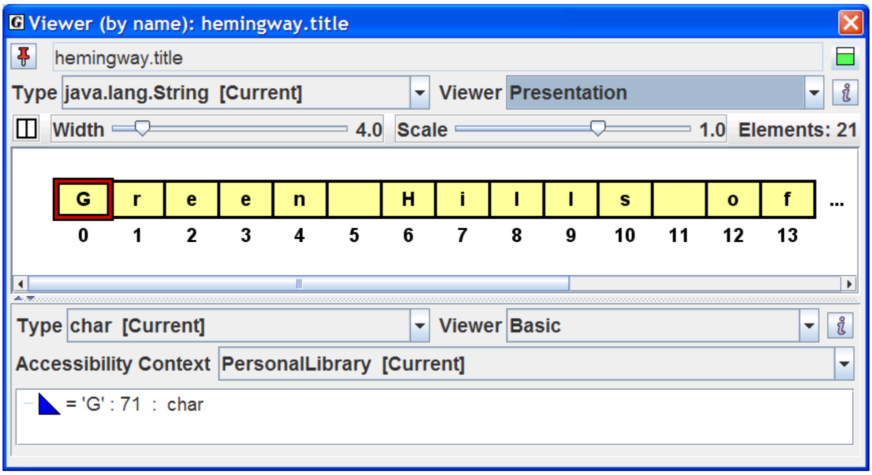
hemingway.title

Type java.lang.String [... Viewer Basic

Accessibility Context PersonalLibrary [Current]

```
--> "Green Hills "... (obj 358 : java.lang.String)  java.lang.S
   value --> (obj 363 : char[21])  private final char[] : java.la
   offset = 0  :  private final int : java.lang.String.offset
   count = 21  :  private final int : java.lang.String.count
   hash = 0  :  private int : java.lang.String.hash
   serialVersionUID = -6849794470754667710  :  private
   serialPersistentFields --> (obj 361 : java.io.ObjectStrea
   CASE_INSENSITIVE_ORDER --> (obj 362 : java.lang.
```

Figure 6-7. Basic view of a string (expanded to see fields)



Viewer (by name): hemingway.title

hemingway.title

Type java.lang.String [Current] Viewer Presentation

Width 4.0 Scale 1.0 Elements: 21

G	r	e	e	n		H	i	l	l	s		o	f	...
0	1	2	3	4	5	6	7	8	9	10	11	12	13	

Type char [Current] Viewer Basic

Accessibility Context PersonalLibrary [Current]

```
= 'G' : 71  :  char
```

Figure 6-8. Presentation View of hemingway.title.value

You are encouraged to open separate viewers for any of the primitives and objects in the Variables section of the Debug tab. In addition to providing multiple views of the object, each viewer includes an Invoke Method button 🟩 for the object being viewed.

In the tutorial *Viewers for Data Structures*, many other examples are presented along with a more detailed description of viewers in general. The "Structure Identifier" viewer is also introduced. This viewer attempts to automatically recognize and display linked lists, binary trees, and array wrappers (lists, stacks, queues, etc.) when opened on an object during debugging or workbench use.

6.8 Debugging a Program

You have, no doubt, noticed that the previous discussion was only indirectly related to the activity of finding and removing *bugs* from your program. It was intended to show you how to set and unset breakpoints and how to step through your program. Typically, to find a bug in your program, you need to have an idea where in the program things are going wrong. The strategy is to set a breakpoint on a line of code prior to the line where you think the problem occurs. When the program gets to the breakpoint, you can inspect the variables of interest to ensure that they have the correct values. Assuming the values are okay, you can begin stepping through the program, watching for the error to occur. Of course, if the value of one or more of the variables was wrong at the breakpoint, you will need to set the breakpoint earlier in the program.

You can also set several types of “watches” on a field of an object. In Figure 6-9, a *Watch for Access* has been set on the *title* in *hemingway* just after it was created. If you click the Resume button at this point, with no breakpoints set before the end of the program, the next place the program should stop is in the *toString* method of Book in conjunction with the *println* statement for *hemingway*. This is because the *title* field of *hemingway* is accessed in the statement:

```
      return("\nAuthor: " + author +
            "\nTitle: " + title +
            "\nPages: " + pages);
```

Note that setting *Watch All for Access* on the *title* field of *hemingway* sets the *watch* on all occurrences of the *title* field (i.e., in all instances of Book, Fiction, and Novel).

As your programs become more complex, the debugger can be an extremely useful for both understanding your program and isolating bugs. For additional details, see *Integrated Java Debugger* in jGRASP **Help**.

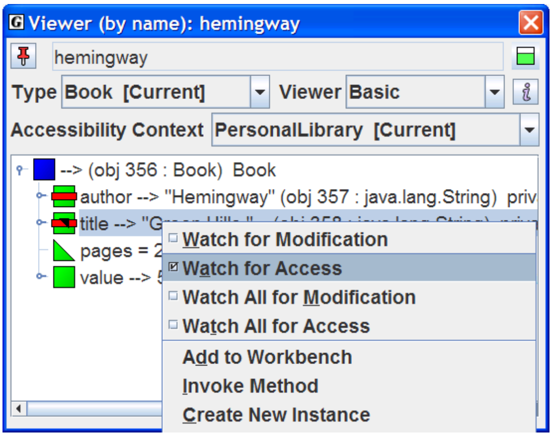
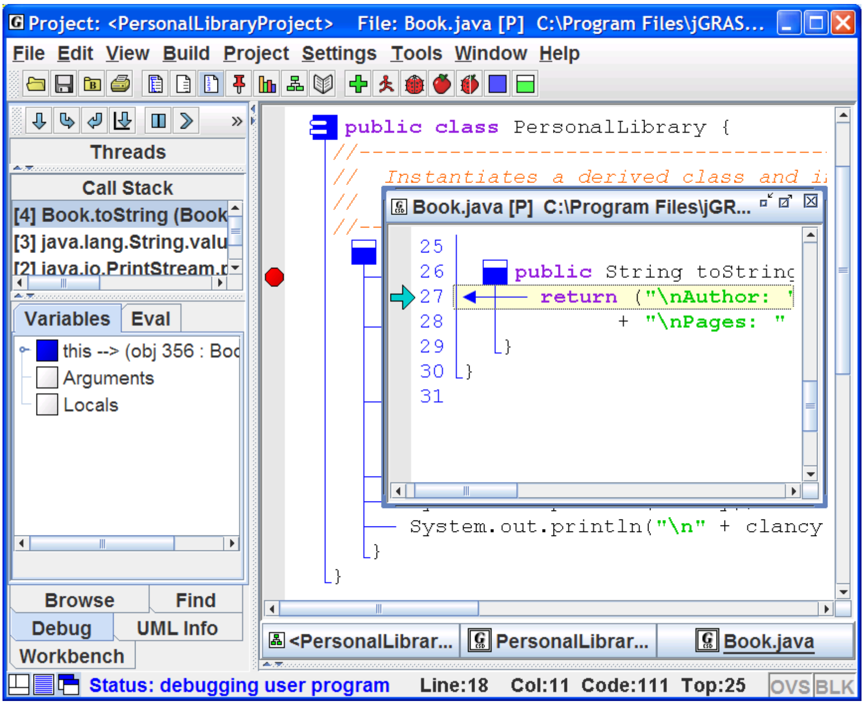

Viewer (by name): hemingway
hemingway
Type Book [Current]
Viewer Basic
Accessibility Context PersonalLibrary [Current]
--> (obj 356 : Book) Book
author --> "Hemingway" (obj 357 : java.lang.String) priv
title --> "G
pages = 2
value --> 5
Watch for Modification
Watch for Access
Watch All for Modification
Watch All for Access
Add to Workbench
Invoke Method
Create New Instance

Figure 6-9. Setting a Watch for Access


```
public class PersonalLibrary {
//-----------------------------------
//   Instantiates a derived class and i
//
//--
```

```
public String toString
   return ("\nAuthor: "
      + "\nPages: "
}
}
```

```
   System.out.println("\n" + clancy
}
}
```

Project: <PersonalLibraryProject> File: Book.java [P] C:\Program Files\jGRAS...
File Edit View Build Project Settings Tools Window Help
Threads
Call Stack
[4] Book.toString (Book
[3] java.lang.String.valu
[2] java.io.PrintStream.p
Variables Eval
this --> (obj 356 : Boo
Arguments
Locals
Book.java [P] C:\Program Files\jGR...
Browse Find
Debug UML Info
Workbench
<PersonalLibrar... PersonalLibrar... Book.java
Status: debugging user program Line:18 Col:11 Code:111 Top:25 OVS BLK

Figure 6-10. Stopping at a Watch for Access to hemingway.title