Lab 4 (10 points)
February 7 & 8, 2017

CS-2303, System Programming Concepts, C-term 2017

Laboratory Assignment #4 — More Debugging in Eclipse CDT

Due: at 11:59 pm on the day of your lab session

Objective

To learn additional techniques for the *Eclipse* *C/C++* debugger, particularly in *C++*.

Introduction

You should now have some basic skills surrounding the use of *Eclipse* and its debugger. Programming Assignment #4 requires to implement a linked list to support an event-driven simulation. This lab illustrates how you can examine the structure of a linked list.

In addition, we will learn how to examine the call stack, how to set conditional breakpoints, how to change a data value while debugging a running program, and how to watch an expression.

Getting Started

Sign the attendance sheet.

Create a directory to hold the files for Lab 4. Download and unzip the set of files at the following URL:–

http://web.cs.wpi.edu/~cs2303/c17/Resources_C17/Lab4_C++_example.zip

Your directory should now contain a **`makefile`**, a single header file **`SortedList.h`**, and two *C++* source code files, **`Lab4_example.cpp`** and **`SortedList.cpp`**. This program is a little bit like the **`Sample.c`** from Lab 3, but instead of putting its input arguments into an array, it puts them into a linked list in numerical order.[1] It also keeps a running total of the values in the list. There are no intentional bugs in this program.

Start *Eclipse* and create a new *C++* project containing copies of these files. Build the project, and set up the launch configuration with a sequence of random numbers, for example:–

```
123 456 789 -1001 2002 -3003 45 0 23 32767 -100000000
```

This program simply reads its arguments from the command line, inserts them one-at-a-time into a linked list, preserving numerical order, and prints them on the standard output.

Overview of the Code and its Classes

If you study the code, you will see that **`Lab4_example.cpp`** contains a the **`main()`** function and a global object **`S`** of class **`SortedList`**. The class itself is defined in **`SortedList.h`**, and its meth-

[1] This is called an *insertion sort.*

ods are implemented in **`SortedList.cpp`**. The body of the function **`main()`** is a **`for`**-loop that converts the command-line arguments to numeric values and calls **`S.InsertItem()`** to insert them into a linked list in numerical order. Then **`main()`**prints out the list in revere order, and it prints the sum of the items, which it obtains from the **`getSum()`** method of **`S`**.

In the *Project Explorer*, click on the small triangle next to **`SortedList.h`** to expand its contents. You will see something like the Figure 1 below.

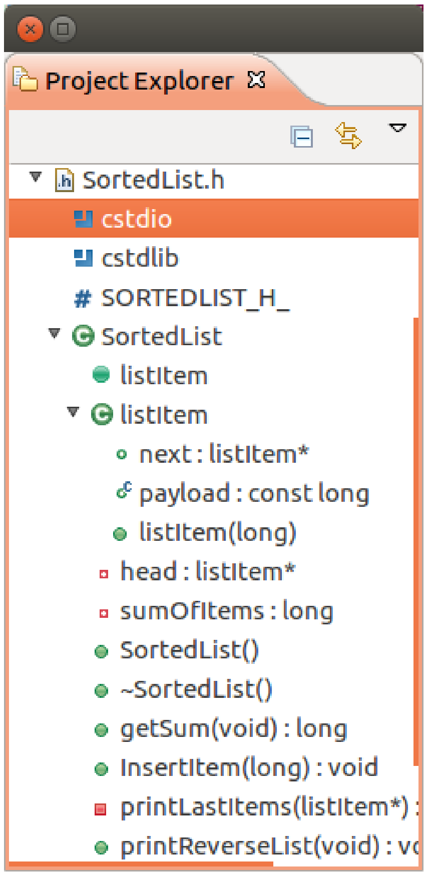


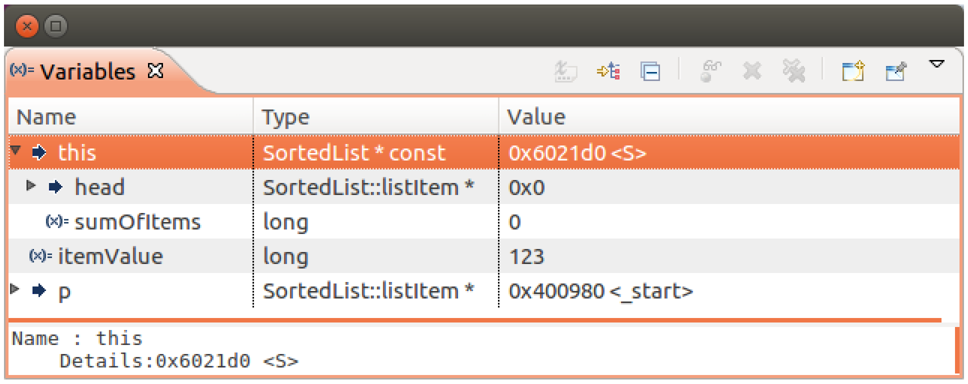
Figure 1

This shows a **`#define`** line (**`SORTEDLIST_H_`**), two included header files (**`<cstdio>`** and **`<cstdlib>`**), and the items declared in this file. The principal definition is a *C++* class named **`SortedList`**, indicated by a "C" in a green circle. This is the *Class View* of the project. Notice that this class contains a member class named **`listItem`**, indicated by another "C" in a green circle. The *Class View* is an important representation of any project in object-oriented languages such as *C++* and *Java*. In these languages, your thought processes are organized more around the classes, their members, and their relationships, rather than what the executing code does.

Linked List

Let us first watch the linked list being built up. Set a breakpoint at the beginning of **`InsertItem()`** (line 34) in **`SortedList.cpp`**, and invoke *Run > Debug* to start the program in the debugger with the argument list above. Click the *Resume* button to let it run to the breakpoint.

- Look at the *Variables* tab in the upper right. Notice that the values of the local variables of **`In-sertItem()`** are displayed, along with the virtual pointer **`this`**. Click on the tiny triangle to the left of the identifier **`this`**, and you will see the values of members of the class object. So far, both **`head`** and **`sumOfItems`** have values of zero (**`NULL`**).



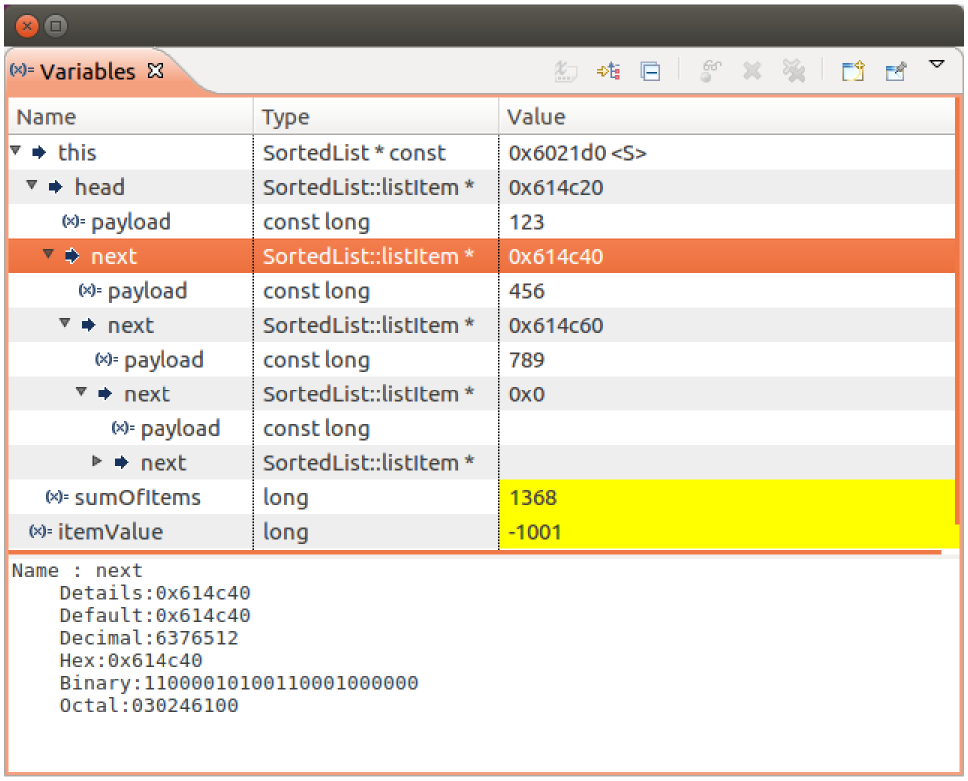
Variables

Name	Type	Value
▼ this	SortedList * const	0x6021d0 <S>
▶ head	SortedList::listItem *	0x0
sumOfItems	long	0
itemValue	long	123
▶ p	SortedList::listItem *	0x400980 <_start>

```
Name : this
    Details:0x6021d0 <S>
```

Figure 2

Resume the program by clicking the *Resume* button.[2] This takes you through the next iteration of the first **`for`**-loop of **`main()`** and to the next call to **`InsertItem()`**. Resume several more times until the list has accumulated several values. Now, look at the *Variables* tab and expand the value of **`head`**, the value of **`next`** in the **`listItem`** object pointed to by **`head`**, the value of **`next`** in the **`listItem`** object pointed to by the previous **`next`**, etc. You should see something resembling Figure 3:–



Variables

Name	Type	Value
▼ this	SortedList * const	0x6021d0 <S>
▼ head	SortedList::listItem *	0x614c20
payload	const long	123
▼ next	SortedList::listItem *	0x614c40
payload	const long	456
▼ next	SortedList::listItem *	0x614c60
payload	const long	789
▼ next	SortedList::listItem *	0x0
payload	const long	
▶ next	SortedList::listItem *	
sumOfItems	long	1368
itemValue	long	-1001

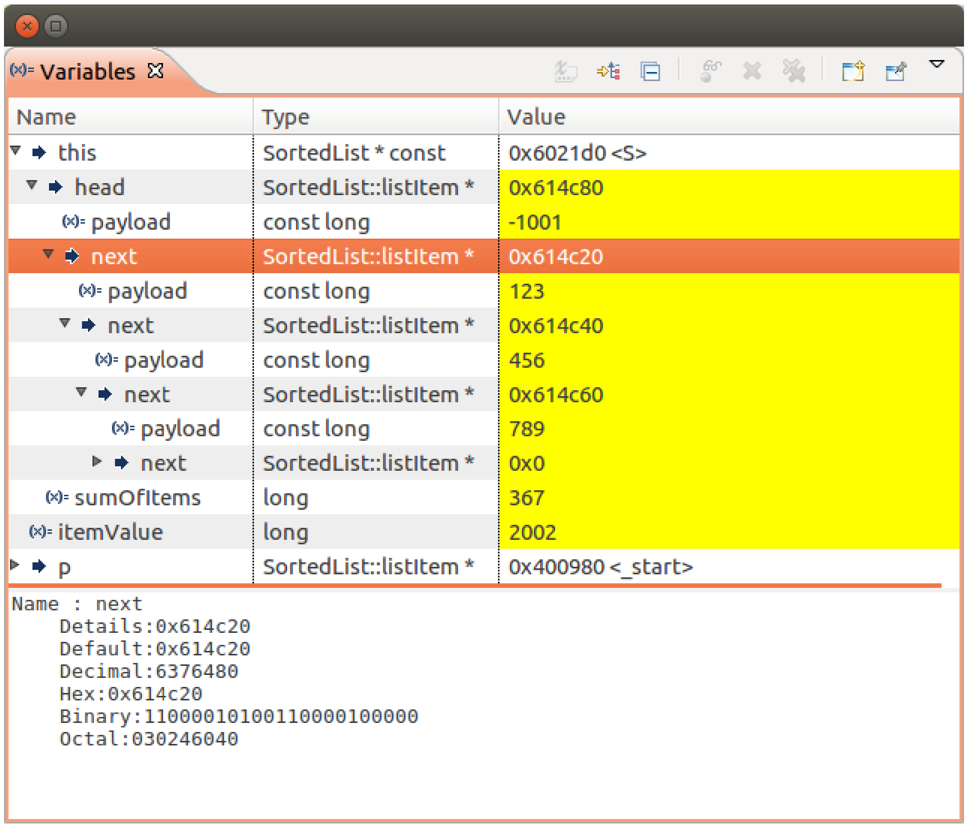
```
Name : next
    Details:0x614c40
    Default:0x614c40
    Decimal:6376512
    Hex:0x614c40
    Binary:11000010100110001000000
    Octal:030246100
```

Figure 3

Notice also at the bottom the information panel that tells you everything you need to know about the variable or member selected above (in this case, the **`next`** member of the first item in the list).

[2] I.e., the green arrow in the list of debug icons from last week's lab.

Finally, notice that in this example, the parameter **`itemValue`** of the next item to be inserted into the list has a value less than any previous member. Click *Resume* one more time, and you will get something resembling Figure 3, which shows the new sort order:–



Name	Type	Value
this	SortedList * const	0x6021d0 <S>
head	SortedList::listItem *	0x614c80
payload	const long	-1001
next	SortedList::listItem *	0x614c20
payload	const long	123
next	SortedList::listItem *	0x614c40
payload	const long	456
next	SortedList::listItem *	0x614c60
payload	const long	789
next	SortedList::listItem *	0x0
sumOfItems	long	367
itemValue	long	2002
p	SortedList::listItem *	0x400980 <_start>

```
Name : next
    Details:0x614c20
    Default:0x614c20
    Decimal:6376480
    Hex:0x614c20
    Binary:11000010100110000100000
    Octal:030246040
```

Figure 4

By this means, you have been able to inspect the contents of the linked list. If the list had been longer, you would have had to scroll the view vertically or horizontally or both.

You can also apply this technique to other kinds of data structures such as trees, queues, etc. For example, if you have an array of pointers in your program, you can follow any pointer of the array by clicking on the little arrow to the left. If, on the other hand, the pointer is really meant to be interpreted as the beginning of an array, you should use *Display as array…* from the previous laboratory session.

A little trick: If that you cannot remember where something was declared, select its identifier in an expression or statement, right click, and select *Declarations > project* from the popup menu. The *Search* tab of the *Console* group at the bottom will show you the file name and line number of the declaration. Double-clicking on that information will take you directly to the declaration. The search operation will also leave a small yellow arrow next to the declaration in both the **`.cpp`** file and the **`.h`** file.[3]

Other Debugging Techniques

To continue this lab, click *Reset Perspective…* in the *Window* menu. If the perspective no longer has all of the tabs that you wish to see, click *Show View* in the *Window* menu and select the *view* (i.e., the

[3] You can clear these little yellow arrows by right-clicking in the *Console* tab and selected *Remove Selected Matches* or *Remove All Matches*.

tab) that you wish to see. Also, terminate your debugging session by selecting the *Terminate* button (i.e., the red square) in the top row of the *Eclipse* window.

The following exercises will illustrate other debugging techniques.

Running to a specific line of code

You learned how to set breakpoints in Lab 3. A useful kind of breakpoint is the *temporary breakpoint* — i.e., a breakpoint that is to be used only once. In this case, you run the program, and when it reaches any breakpoint, the temporary breakpoint is deleted. In *Eclipse*, this is invoked by the menu command *Run to Line*.

Try this in **`Lab4_example.cpp`**. Start the debugger by invoking *Run > Debug*. Disable all breakpoints in the *Breakpoints* tab, and then select Line 26 — i.e., **`return EXIT_SUCCESS`**. Right-click to bring up the popup menu, and select *Run to Line* (about two-thirds of the way down the menu). The program will run to this line and take the temporary breakpoint. This is just like a normal breakpoint, and you can do all of the same things as a normal breakpoint. However, it is an unconditional breakpoint, and it evaporates as soon as you get there.

The temporary breakpoint also evaporates if you take another breakpoint on the way. To see this, re-enable other breakpoints — e.g., the one at **`SortedList.cpp`**, line 34. Start the debugger by invoking *Run > Debug*. Select Line 26 of again **`Lab4_example.cpp`** and invoke *Run To Line*. Note that it stops at your recently re-enabled breakpoint. Now disable your breakpoints and click the *Resume* button. Notice that the program goes all the way to completion. It does not stop at the temporary breakpoint you had previously requested.

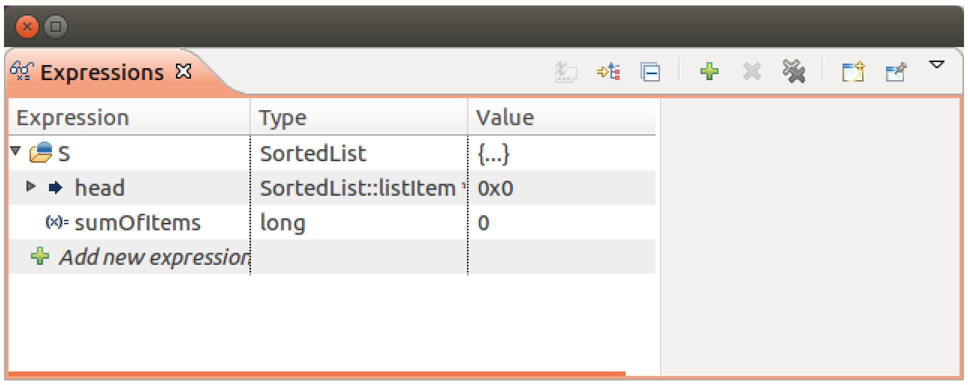
Displaying Global Variables

Last week, you learned how to view the values of the variables of a function in the *Variables* tab. However, you do not see the global variables there. Since these are not within the scope of any function, the display parser of the debugger does not find them whenever the debugger stops at a breakpoint.

To see the global variables, you need to use the *Expressions* tab. To expose the *Expressions* tab, select *Window > Show View > Expressions* starting in the top menu. Next, invoke *Run > Debug*. Before resuming the program, click the *Expressions* tab in the upper right tab group, and select *Add new expression*. Add the expression **`S`** — i.e., the name of the global *SortedList* item declared on Line 15 of **`Lab4_example.cpp`**. This is shown in Figure 5 below.

At this point during the execution of the program, **`S.head`** is **`NULL`** and the **`sumOfItems`** member has been initialized to zero. As the program executes and you stop at future breakpoints, you will see that **`S`** builds up the data structure of this program.[4]

[4] This is a minor inconvenience, because you need to switch between two tabs to both automatic and global variables. You can modify the perspective by dragging the *Expressions* tab to another part of the *Debug Perspective* in order to see both *Expressions* and *Variables* at the same time.

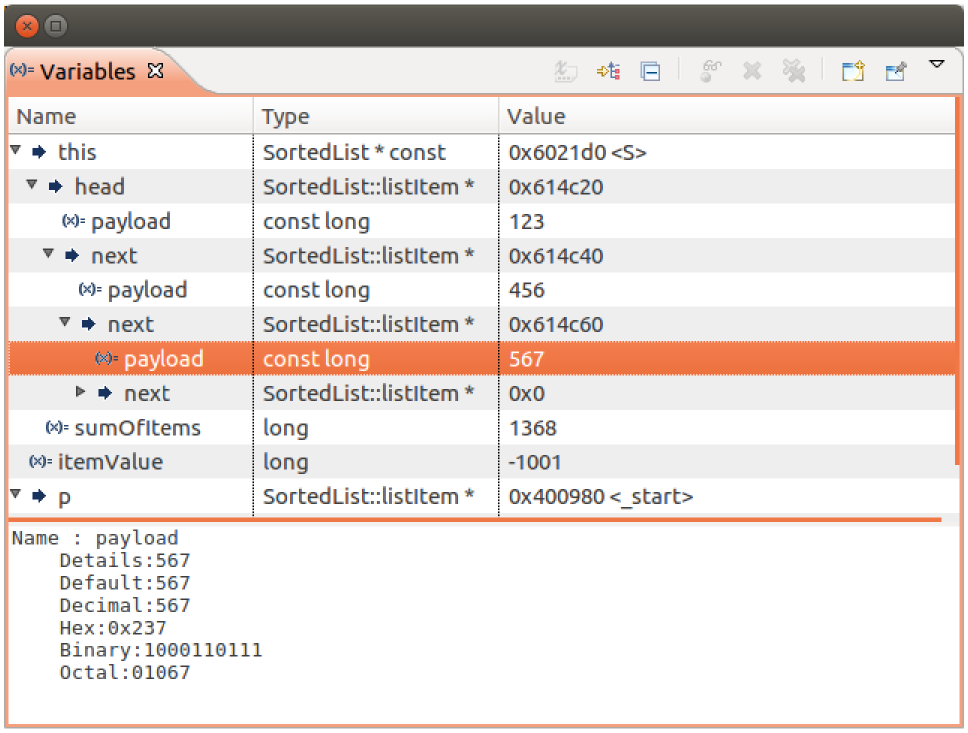


Expression	Type	Value
S	SortedList	{...}
head	SortedList::listItem *	0x0
sumOfItems	long	0
Add new expression		

Figure 5

Changing data values

Occasionally, you find that you are in the middle of a debugging session when you really wish that a certain variable had a different value in order that you can make progress without starting over. This is easy — you simply type the new values into the *Variables* view. To see how this is done, re-run you program in the debugger, stopping in **`SortedList::InsertItem()`** after receiving four inputs. In the *Expressions* view, edit the first few items by typing new values in the *Value* column for each payload. For example, Figure 6 shows the same items of Figure 4 edited to new values, right in the dialog box. Running the program to completion shows that the new values are printed as part of the output. Try this with your program.



Name	Type	Value
this	SortedList * const	0x6021d0 <S>
head	SortedList::listItem *	0x614c20
payload	const long	123
next	SortedList::listItem *	0x614c40
payload	const long	456
next	SortedList::listItem *	0x614c60
payload	const long	567
next	SortedList::listItem *	0x0
sumOfItems	long	1368
itemValue	long	-1001
p	SortedList::listItem *	0x400980 <_start>

```
Name : payload
    Details:567
    Default:567
    Decimal:567
    Hex:0x237
    Binary:1000110111
    Octal:01067
```

Figure 6

The program will run to completion and print out a list of the newly assigned values. However, it will end with an error, because the **`getSum()`** method of the **`SortedList`** class does a check that the running total maintained by the method is the actual sum of the element in the list.

Calling a function from the debugger

In serious debugging situations, you may find yourself needing to carry out a non-trivial computation on your data *while you are in the debugger*. This may necessitate writing some "support" functions in your program, just to help you debug. These support functions won't actually be called at run time, but you can get the debugger to execute them, simply by making them part of an expression in the *Expressions* view.

To try this, open the *Expressions* view and click *+Add new expression*. For the expression, type

```
S.getSum(head)
```

Now run the program in the Debugger, taking breakpoints as before at the **`InsertItem()`** method of the **`SortedList`** class (line 34). Watch the value of this expression in the *Expressions* view as you take each breakpoint. Notice that it adds up the current contents of the list, which changes with each input. This computation is carried out by the debugger, not by your program, but the debugger is calling the method in the context of the variables of your program.

Note about include files

In previous terms, several students had the problem that *Eclipse* could not find the *C++* include files. The environment variables were set up correctly, but it did not help. We stumbled on the solution of creating a whole new workspace. This seemed to solve it. Apparently, *Eclipse* left some toxic settings in the old workspace that were preventing it from telling **`gcc/g++`** where to find the include files.

Getting Credit for this Lab

This lab is designed to help you with Programming Assignment #4, the event-driven simulation. In that assignment, you need to implement a queuing module using a linked list. Spend the rest of your lab session using these techniques to debug that assignment.

To get credit for this Lab, set a conditional breakpoint to stop the PA4 program after it has run about half the number of time units specified in the command line arguments. Display the queue (i.e., either the array or the linked list) as you learned how to do in the Lab and last week's lab. Take a screenshot of that display and submit it to *Canvas* under the Assignment *Lab 4*.