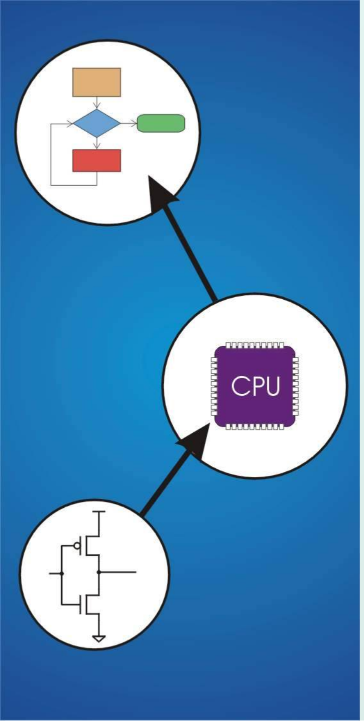


Chapter 15
Debugging

Original slides from Gregory Byrd, North Carolina State University

Modified slides by Chris Wilcox, Colorado State University

Debugging with High Level Languages

- Same goals as low-level debugging
  - Examine and set values in memory
  - Execute portions of program
  - Stop execution when (and where) desired
- Want debugging tools to operate on high-level language constructs
  - Examine and set variables, not memory locations
  - Trace and set breakpoints on statements and function calls, not instructions
  - … but also want access to low-level tools when needed

Types of Errors

- Syntactic Errors
  - Input code is not legal
  - Caught by compiler (or other translation mechanism)
- Semantic Errors
  - Legal code, but not what programmer intended
  - Not caught by compiler, because syntax is correct
- Algorithmic Errors
  - Problem with the logic of the program
  - Program does what programmer intended, but it doesn't solve the right problem

Syntactic Errors

- Common errors:
  - missing semicolon or brace
  - mis-spelled type in declaration
- One mistake can cause an avalanche of errors
  - because compiler can't recover and gets confused

```
int main () {
    int i
    int j;
    for (i = 0; i <= 10; i++) {
      j = i * 7;
      printf("%d x 7 = %d\n", i, j);
    }
  }
```

missing semicolon

Semantic Errors

- Common Errors
  - Missing braces to group statements together
  - Confusing assignment with equality
  - Wrong assumptions about precedence/associativity
  - Wrong limits on for-loop counter
  - Uninitialized variables

```
int main () {
    int i
    int j;
    for (i = 0; i <= 10; i++)
      j = i * 7;
      printf("%d x 7 = %d\n", i, j);
  }
```

missing braces,
so printf not part of if

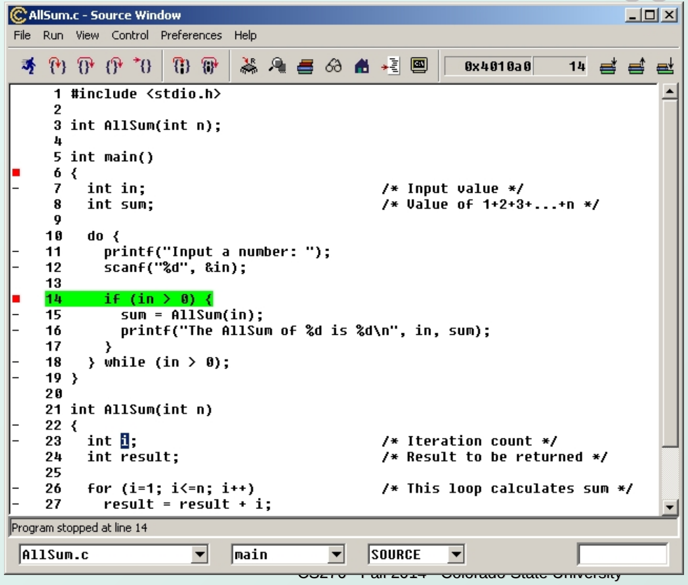
Algorithmic Errors

- Design is wrong, so program does not solve the correct problem
- Difficult to find
  - Program does what we intended
  - Problem might not show up until after many runs
- Maybe difficult to fix
  - May have to redesign
  - May have large impact on program code
- Classic example: Y2K bug
  - only allow 2 digits for year, assuming 19__

Debugging Techniques

- Ad-Hoc
  - Insert printf statements to track control flow and display values
  - Add code to explicitly check for values out of expected range, incorrect branches, etc.
  - Advantage:
    - No special debugging tools needed
  - Disadvantages:
    - Frequent recompile and execute cycles makes this method time-consuming
    - Requires intimate knowledge of code
    - Inserted code can be buggy
- Source-Level Debugger
  - Examine and set variable values
  - Tracing, breakpoints, single-stepping on source-code statements

Source-Level Debugger



```
 1 #include <stdio.h>
 2
 3 int AllSum(int n);
 4
 5 int main()
 6 {
 7   int in;                          /* Input value */
 8   int sum;                         /* Value of 1+2+3+...+n */
 9
10   do {
11     printf("Input a number: ");
12     scanf("%d", &in);
13
14     if (in > 0) {
15       sum = AllSum(in);
16       printf("The AllSum of %d is %d\n", in, sum);
17     }
18   } while (in > 0);
19 }
20
21 int AllSum(int n)
22 {
23   int i;                           /* Iteration count */
24   int result;                      /* Result to be returned */
25
26   for (i=1; i<=n; i++)             /* This loop calculates sum */
27     result = result + i;
```

Program stopped at line 14

main window of Cygwin version of gdb

Source-Level Debugging Techniques

- Breakpoints
  - Stop when a particular statement is reached
  - Stop at entry or exit of a function
  - Conditional breakpoints:
    Stop if a variable is equal to a specific value, etc.
  - Watchpoints:
    Stop when a variable is set to a specific value
- Single-Stepping
  - Execute one statement at a time
  - Step “into” or step “over” function calls
    - Step into: next statement is first inside function call
    - Step over: execute function without stopping
    - Step out: finish executing function, stop on exit

Source-Level Debugging Techniques

- Displaying Values
  - Show value consistent with declared type of variable
  - Dereference pointers (variables that hold addresses)
    - See Chapter 16
  - Inspect parts of a data structure
    - See Chapters 19