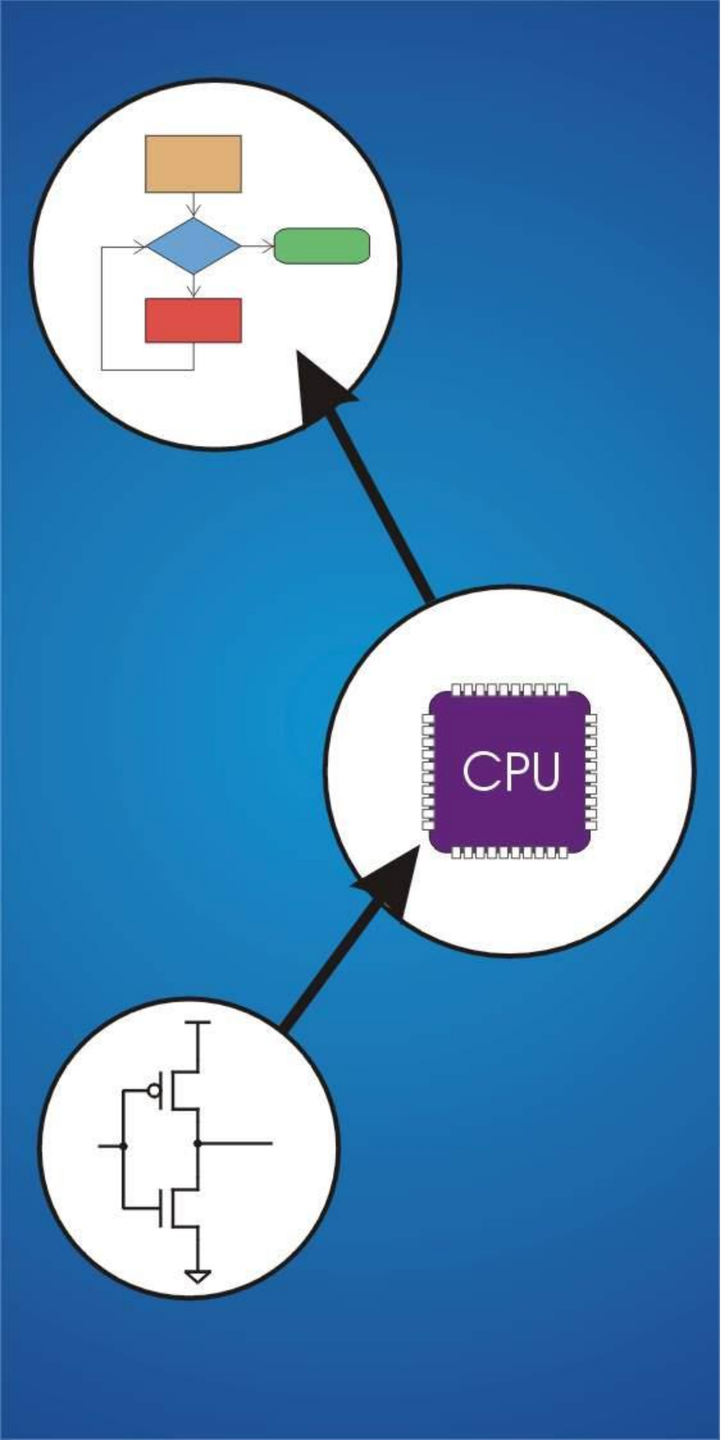


Chapter 15
Debugging

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

```
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 operator precedence, associativity
- Wrong limits on for-loop counter
- Uninitialized variables

h

```
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 many runs of program**

Maybe difficult to fix

- **Have to redesign, may have large impact on program code**

Classic example: Y2K bug

- **only allow 2 digits for year, assuming 19__**

Debugging Techniques

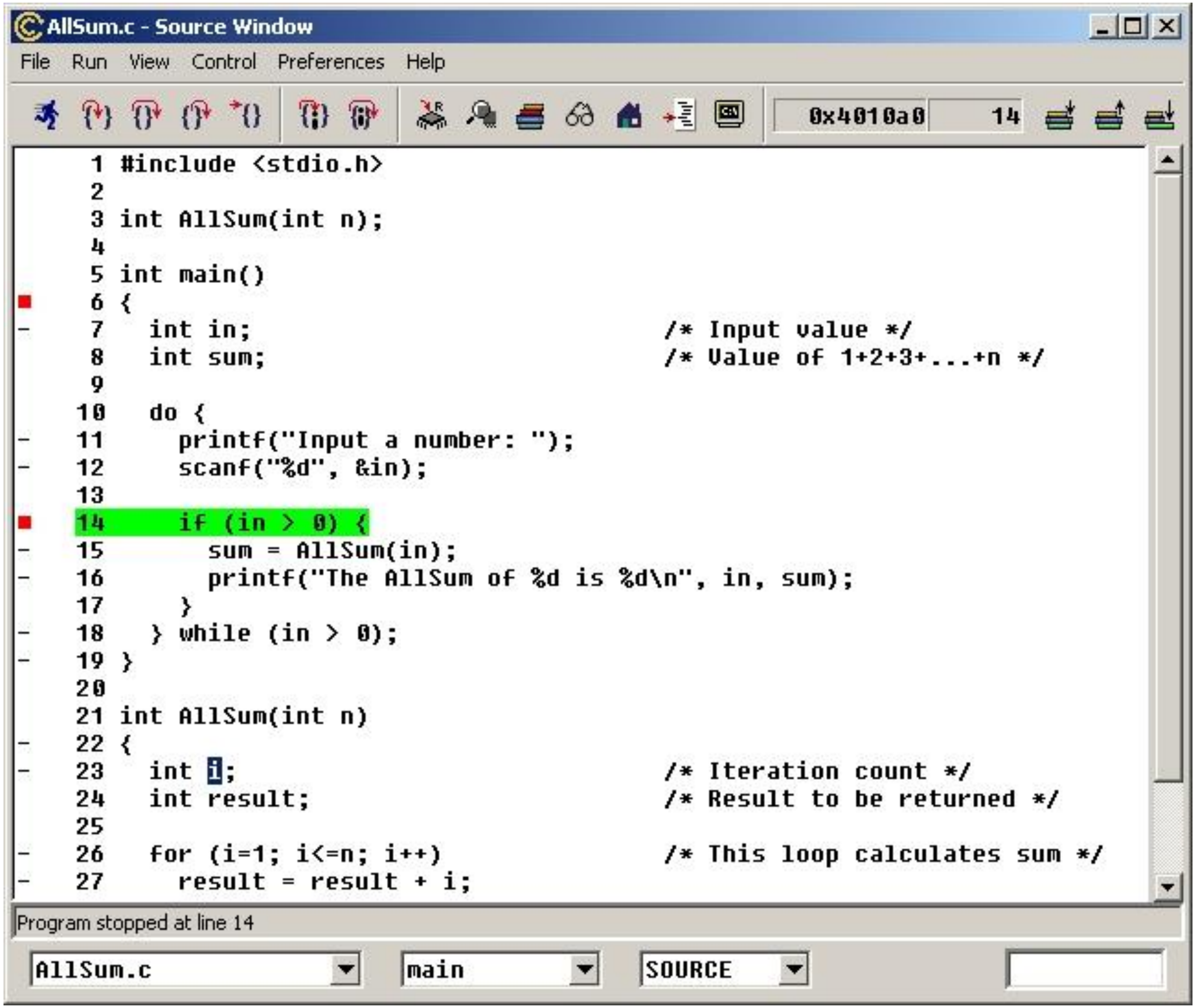
Ad-Hoc

- Insert printf statements to track control flow and values
- Code explicitly checks for values out of expected range, etc.
- Advantage:
  - No special debugging tools needed
- Disadvantages:
  - Requires intimate knowledge of code and expected values
  - Frequent re-compile and execute cycles
  - Inserted code can be buggy

Source-Level Debugger

- Examine and set variable values
- Tracing, breakpoints, single-stepping on source-code statements

Source-Level Debugger



0x4010a0 14

```
 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

AllSum.c | main | SOURCE

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 current function
    and stop on exit

LC-3 software also provides a similar capability