Modular Programming
2/16/01 Lecture #5 16.070

- Outline
  - Need for, and benefits of, modular programs
  - How to design modular programs
  - Using functions to build modular programs

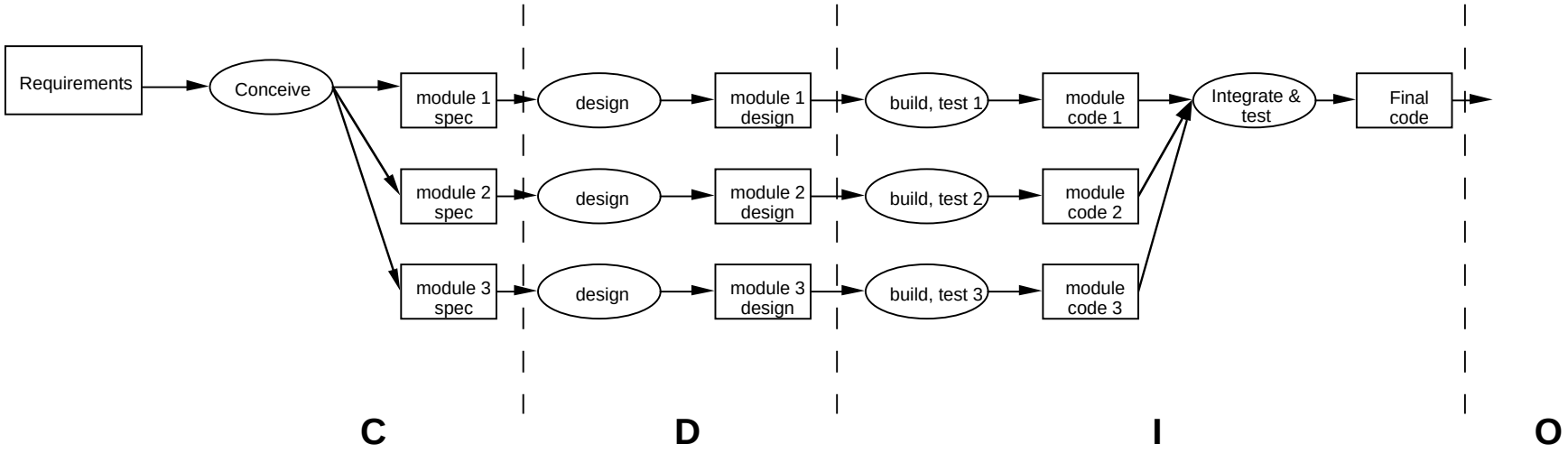
Modular Programming - Need and Approach

- Typical industry programming projects consist of thousands of lines of code or more
- One huge monolithic program would be unmanageable, incomprehensible, difficult to design, write, debug, test, etc.
- Modular Programming: Divide-and-Conquer approach to programming
  - Divide into sub-problems
  - Size of modules reduced to humanly comprehensible and manageable level
- Analogous approaches: manufacturing a spacecraft, or a car
  - Manufacture individual components, test separately
  - Assemble into larger components, integrate and test

Modular Programming - Process

- Late in the conceive phase, program is divided into small, independent modules that are separately named and individually invokeable program elements
  - ➢ Partitioning based on
    - – Intensity of information exchange among internal steps
    - – Likelihood that internal steps will change
    - – Hiding interfaces to hardware and humans
- Modules are designed, written, tested, debugged by individuals or small teams
  - ➢ Allows for multiple programmers to work in parallel
- Modules are integrated to become a software system that satisfies the problem requirements
  - ➢ To integrate successfully, original decision must be good and interfaces between modules must be correct

Modular Programming - Process



Modular Program Example

- Problem/Goal: Design and implement a program that moves Robbie the Robot based on user input from keyboard
- Requirements Specification: Develop a program that does the following:
  - Display a menu of choices for robot motion
  - Read keyboard input
    - Input can be any one of 4 arrows showing movement up, down, left, right
    - Input other than the arrows terminates the program.
  - Move Robbie based on keyboard input

Modular Program Example - cont.

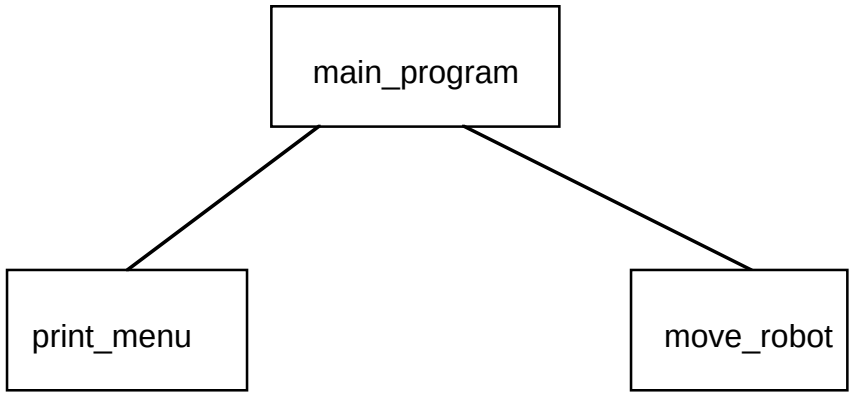
- Analysis: Input = A value for keyboard input; Output = Direction of robot movement
- Design: Pseudo-code algorithm

```
Print menu
Read request
If request is ⇑ move robot forward
Else if request is ⇐  move robot left
Else if request is ⇒  move robot right
Else if request is ⇓  move robot backward
Else print "Terminating program."
End if
```

Modular Program Example - cont.

- Algorithm contains two sub-problems
  - Print menu and read request -- based on interfacing with humans
  - Move Robot -- based in computation/interfacing with robot
- Perform top-down stepwise refinement
  - Define algorithms for sub-problems
  - Refine them - may need to be broken down into sub-sub-problems
  - At lowest level, assign name to each module and combine named modules into higher level sub-problem algorithm (e.g., Move Robot => move_robot)

Structure Chart for Top-Level Pseudo-code Algorithm



Pseudo-code for print-menu function

- Print_menu:

```
print "This program moves Robbie the Robot based on user input."
print "Enter ⇑ to move Robbie forward"
print "Enter ⇐  to move Robbie left"
print "Enter ⇒  to move Robbie right"
print "Enter ⇓  to move Robbie backward"
read request
```

Advantages of Modular Programming

- Manageable: Reduce problem to smaller, simpler, humanly comprehensible problems
- Divisible: Modules can be assigned to different teams/programmers
  - Enables parallel work, reducing program development time
  - Facilitates programming, debugging, testing, maintenance
- Portable: Individual modules can be modified to run on other platforms
- Re-usable: Modules can be re-used within a program and across programs

Using Functions to Build Modular Programs

- In C, modules are implemented as Functions
- A function is a block of code that performs a specific task
- The role of a Function is to
  - Accept input (optional)
  - Perform a task
  - Return output (optional)
- Functions are identified by unique, programmer-defined names

Function Elements

- Function Definition - used to define/implement a function
- Function Calls - used to invoke/run a function
  - Passing data between functions
- Function Declarations/Prototypes - used to identify a function to the compiler prior to calling the function

Function Definitions consist of

- Function type
  - Specified in the header, which is the first line of the Function
  - Identifies the type of value to be returned; e.g., integer
  - If no value is to be returned, type = *void*
- Function name - *main* or unique user-defined
- (Optional) List of parameters enclosed in parentheses (void if none)
- Function body - variable declarations/statements to express algorithm, in brackets

Example of a Function Definition

- Simple function that prints menu to screen

```
void print_menu(void)
    {
        printf ("This program …;
        printf ("Enter ⇑ to move …;
        …
    }
```

- Add in the read request

```
char print_menu(void)
    {
        char request;
        printf ("This program …;
        printf ("Enter ⇑ to move …;
        …
        scanf ("%c", &request);
        return request;
    }
```

Function Calls

- To run a function, it must be called by another function
- To call a function
  - List name of function e.g., *print_menu(), move_robot(user_input)*
  - List of actual parameters/arguments, if any, enclosed in parentheses
- When a function is called
  - Program control passes to called function
  - Code corresponding to called function is executed
  - Function code is kept in separate area of main memory during execution
  - After function body completes execution, program control returns to calling function

Parameter Passing

- Arguments can be used to supply input to a function
- Values of actual parameters are copied to memory locations of corresponding formal parameters in function's data area
  - Call function *move_robot(user_input)*
  - Value of *user_input* copied into *direction*
- After function completes, program control returned to calling function
  - If function was to return value, value is returned
  - Called function cannot access memory location of actual parameters

```
int main(void)
    {
        char user_input;
        …
        user_input = print_menu();
        move_robot(user_input);
        …
    }
```

```
void move_robot(char direction)
  {
      …
      …  /* move robot in direction */
      …  /* specified by passed     */
      …  /* argument                */
      …
  }
```

Passing Data Between Functions

- Data can be passed between functions in three ways
  - Input to a function: Parameters
    - Used to send values to function
    - Parameters are variables declared in formal parameter list of function header: *void move_robot(char direction);*
    - Calling function can send data (actual parameters/arguments) to called function: *move_robot(user_input);*
    - One-to-one correspondence between actual and formal parameters
  - Output from a function: return a value from a function
  - Global variables, declared in source file outside/before function defs

Function Declarations (also called Function Prototypes)

- A function must be declared before it can be called
- Notifies the compiler that you intend to define and use this function
  - Called function will have a definition consistent with prototype
  - List of parameters/arguments, if any, enclosed in parentheses
- Consists of
  - Function type e.g., *char print_menu(void);*
  - Function name
  - List of function parameter types enclosed in parentheses
  - Terminating semicolon e.g., *void move_robot(char direction);*

Scope of Functions

- Function Declaration/Prototype defines region in program in which function may be used by other functions
  - Global prototypes: Function prototype placed outside function definitions
    - Scope begins where prototype is placed and extends to end of source file
    - Any function in program may use it
    - Usually appear before definition of function *main*
  - Local prototypes: Function prototype placed in function definitions
    - Scope begins where prototype is placed and extends to end of function in which it appears
    - Must have calls to the declared function in the parent function

Style in Modular Programming

- Step-wise refinement until expressible in 1-2 short English sentences
- Optimize module size. Rule of thumb: 2-50 lines
- Restrict number of functions called by a function. Rule of thumb: ~7
- Assign descriptive names to functions that reflect purpose of function
- In comments before function definition header, clearly identify all I/O
- To pass data, use parameters instead of global variables
- Use function prototypes uniformly
- Design functions that can be used in other programs
- Use functions that have already been defined and tested

Summary

- Today we learned
  - What modular programming is
  - Why we want to design modular programs
  - How to implement modular programs using functions
- Readings:
  - Review chapter **C6** with this lecture
  - For Tuesday (Monday classes), read **C5.1-C5.8** on Variables and Operators.
  - For Wednesday, read **C4**
  - For Friday, read **C9**
- Note: Material for Weeks 3 and 4 have been swapped to provide you with more programming tools
- Errata: **16.070 TA office is 33-112**