Chapter 9

Functions

Introduction

- A function is a series of statements that have been grouped together and given a name.
- Each function is essentially a small program, with its own declarations and statements.
- Advantages of functions:
  - A program can be divided into small pieces that are easier to understand and modify.
  - We can avoid duplicating code that's used more than once.
  - A function that was originally part of one program can be reused in other programs.

Program: Computing Averages

- A function named `average` that computes the average of two `double` values:

```
double average(double a, double b)
{
  return (a + b) / 2;
}
```

- The word `double` at the beginning is the ***return type*** of `average`.
- The identifiers `a` and `b` (the function's ***parameters***) represent the numbers that will be supplied when `average` is called.

Program: Computing Averages

- Every function has an executable part, called the ***body,*** which is enclosed in braces.
- The body of `average` consists of a single `return` statement.
- Executing this statement causes the function to "return" to the place from which it was called; the value of `(a + b) / 2` will be the value returned by the function.

Program: Computing Averages

- A function call consists of a function name followed by a list of ***arguments.***
  - `average(x, y)` is a call of the `average` function.
- Arguments are used to supply information to a function.
  - The call `average(x, y)` causes the values of `x` and `y` to be copied into the parameters `a` and `b`.
- An argument doesn't have to be a variable; any expression of a compatible type will do.
  - `average(5.1, 8.9)` and `average(x/2, y/3)` are **legal**.

Program: Computing Averages

- We'll put the call of `average` in the place where we need to use the return value.
- A statement that prints the average of `x` and `y`:

```
printf("Average: %g\n", average(x, y));
```

  The return value of `average` isn't saved; the program prints it and then discards it.
- If we had needed the return value later in the program, we could have captured it in a variable:

```
avg = average(x, y);
```

Program: Computing Averages

- The `average.c` program reads three numbers and uses the `average` function to compute their averages, one pair at a time:

```
Enter three numbers: 3.5 9.6 10.2
Average of 3.5 and 9.6: 6.55
Average of 9.6 and 10.2: 9.9
Average of 3.5 and 10.2: 6.85
```

average.c

```
/* Computes pairwise averages of three numbers */

#include <stdio.h>

double average(double a, double b)
{
  return (a + b) / 2;
}

int main(void)
{
  double x, y, z;

  printf("Enter three numbers: ");
  scanf("%lf%lf%lf", &x, &y, &z);
  printf("Average of %g and %g: %g\n", x, y, average(x, y));
  printf("Average of %g and %g: %g\n", y, z, average(y, z));
  printf("Average of %g and %g: %g\n", x, z, average(x, z));

  return 0;
}
```

Function Definitions

- General form of a ***function definition:***

  return-type function-name (*parameters*)
  {
      declarations
      statements
  }

Function Definitions

- The return type of a function is the type of value that the function returns.
- Rules governing the return type:
  - Functions may not return arrays.
  - Specifying that the return type is `void` indicates that the function doesn't return a value.
- If the return type is omitted in C89, the function is presumed to return a value of type `int`.

Function Definitions

- After the function name comes a list of parameters.
- Each parameter is preceded by a specification of its type; parameters are separated by commas.
- If the function has no parameters, the word `void` should appear between the parentheses.

Function Definitions

- The body of a function may include both declarations and statements.
- An alternative version of the `average` function:

```
double average(double a, double b)
{
  double sum;          /* declaration */

  sum = a + b;         /* statement */
  return sum / 2;      /* statement */
}
```

Function Calls

- A function call consists of a function name followed by a list of arguments, enclosed in parentheses:

```
average(x, y)
```

Function Declarations

- A ***function declaration*** provides the compiler with a brief glimpse at a function whose full definition will appear later.
- General form of a function declaration:

  return-type function-name (*parameters*) ;
- The declaration of a function must be consistent with the function's definition.
- Here's the `average.c` program with a declaration of `average` added.

Function Declarations

```
#include <stdio.h>

double average(double a, double b);   /* DECLARATION */

int main(void)
{
  double x, y, z;

  printf("Enter three numbers: ");
  scanf("%lf%lf%lf", &x, &y, &z);
  printf("Average of %g and %g: %g\n", x, y, average(x, y));
  printf("Average of %g and %g: %g\n", y, z, average(y, z));
  printf("Average of %g and %g: %g\n", x, z, average(x, z));

  return 0;
}

double average(double a, double b)    /* DEFINITION */
{
  return (a + b) / 2;
}
```

Function Declarations

- Function declarations of the kind we're discussing are known as ***function prototypes.***
- C also has an older style of function declaration in which the parentheses are left empty.
- A function prototype doesn't have to specify the names of the function's parameters, as long as their types are present:

```
double average(double, double);
```

- It's usually best not to omit parameter names.

Arguments

- In C, arguments are ***passed by value:*** when a function is called, each argument is evaluated and its value assigned to the corresponding parameter.
- Since the parameter contains a copy of the argument's value, any changes made to the parameter during the execution of the function don't affect the argument.

Arguments

- The fact that arguments are passed by value has both advantages and disadvantages.
- Since a parameter can be modified without affecting the corresponding argument, we can use parameters as variables within the function, reducing the number of genuine variables needed.

Arguments

- Consider the following function, which raises a number `x` to a power `n`:

```
int power(int x, int n)
{
  int i, result = 1;

  for (i = 1; i <= n; i++)
    result = result * x;

  return result;
}
```

Arguments

- Since `n` is a *copy* of the original exponent, the function can safely modify it, removing the need for `i`:

```
int power(int x, int n)
{
  int result = 1;

  while (n-- > 0)
    result = result * x;

  return result;
}
```

Arguments

- C's requirement that arguments be passed by value makes it difficult to write certain kinds of functions.
- Suppose that we need a function that will decompose a `double` value into an integer part and a fractional part.
- Since a function can't *return* two numbers, we might try passing a pair of variables to the function and having it modify them:

```
void decompose(double x, long int_part,
               double frac_part)
{
  int_part = (long) x;
  frac_part = x - int_part;
}
```

Arguments

- A call of the function:

```
decompose(3.14159, i, d);
```

- Unfortunately, `i` and `d` won't be affected by the assignments to `int_part` and `frac_part`.
- **Chapter 11** shows how to make `decompose` work correctly.

Argument Conversions

- C allows function calls in which the types of the arguments don't match the types of the parameters.
- The rules governing how the arguments are converted depend on whether or not the compiler has seen a prototype for the function (or the function's full definition) prior to the call.

Array Arguments

- When a function parameter is a one-dimensional array, the length of the array can be left unspecified:

```
int f(int a[])  /* no length specified */
{
  ...
}
```

- C doesn't provide any easy way for a function to determine the length of an array passed to it.
- Instead, we'll have to supply the length—if the function needs it—as an additional argument.

Array Arguments

- Example:

```
int sum_array(int a[], int n)
{
  int i, sum = 0;

  for (i = 0; i < n; i++)
    sum += a[i];

  return sum;
}
```

- Since `sum_array` needs to know the length of `a`, we must supply it as a second argument.

Array Arguments

- The prototype for `sum_array` has the following appearance:

```
int sum_array(int a[], int n);
```

- As usual, we can omit the parameter names if we wish:

```
int sum_array(int [], int);
```

Array Arguments

- When `sum_array` is called, the first argument will be the name of an array, and the second will be its length:

```
#define LEN 100

int main(void)
{
  int b[LEN], total;
  …
  total = sum_array(b, LEN);
  …
}
```

- Notice that we don't put brackets after an array name when passing it to a function:

```
total = sum_array(b[], LEN);    /*** WRONG ***/
```

Array Arguments

- A function has no way to check that we've passed it the correct array length.
- We can exploit this fact by telling the function that the array is smaller than it really is.
- Suppose that we've only stored 50 numbers in the `b` array, even though it can hold 100.
- We can sum just the first 50 elements by writing

```
total = sum_array(b, 50);
```

Array Arguments

- Be careful not to tell a function that an array argument is *larger* than it really is:

```
total = sum_array(b, 150);   /*** WRONG ***/
```

`sum_array` will go past the end of the array, causing undefined behavior.

Array Arguments

- A function is allowed to change the elements of an array parameter, and the change is reflected in the corresponding argument.
- A function that modifies an array by storing zero into each of its elements:

```
void store_zeros(int a[], int n)
{
  int i;

  for (i = 0; i < n; i++)
    a[i] = 0;
}
```

Array Arguments

- A call of `store_zeros`:

```
store_zeros(b, 100);
```

- The ability to modify the elements of an array argument may seem to contradict the fact that C passes arguments by value.
- **Chapter 12** explains why there's actually no contradiction.

Array Arguments

- If a parameter is a multidimensional array, only the length of the first dimension may be omitted.
- If we revise `sum_array` so that `a` is a two-dimensional array, we must specify the number of columns in `a`:

```
#define LEN 10

int sum_two_dimensional_array(int a[][LEN], int n)
{
  int i, j, sum = 0;

  for (i = 0; i < n; i++)
    for (j = 0; j < LEN; j++)
      sum += a[i][j];

  return sum;
}
```

The `return` Statement

- A non-`void` function **must** use the `return` statement to specify what value it will return.
- The `return` statement has the form

  `return` *expression* `;`
- The expression is often just a constant or variable:

```
return 0;
return status;
```

- More complex expressions are possible:

```
return n >= 0 ? n : 0;
```

The `return` Statement

- If the type of the expression in a `return` statement doesn't match the function's return type, the expression will be implicitly converted to the return type.
  - If a function returns an `int`, but the `return` statement contains a `double` expression, the value of the expression is converted to `int`.

The `return` Statement

- `return` statements may appear in functions whose return type is `void`, provided that no expression is given:

```
return;  /* return in a void function */
```

- Example:

```
void print_int(int i)
{
  if (i < 0)
    return;
  printf("%d", i);
}
```

The `return` Statement

- A `return` statement may appear at the end of a `void` function:

```
void print_pun(void)
{
  printf("To C, or not to C: that is the question.\n");
  return;   /* OK, but not needed */
}
```

  Using `return` here is unnecessary.

- If a non-`void` function fails to execute a `return` statement, the behavior of the program is undefined if it attempts to use the function's return value.