A Balanced Introduction to Computer Science, 2/E

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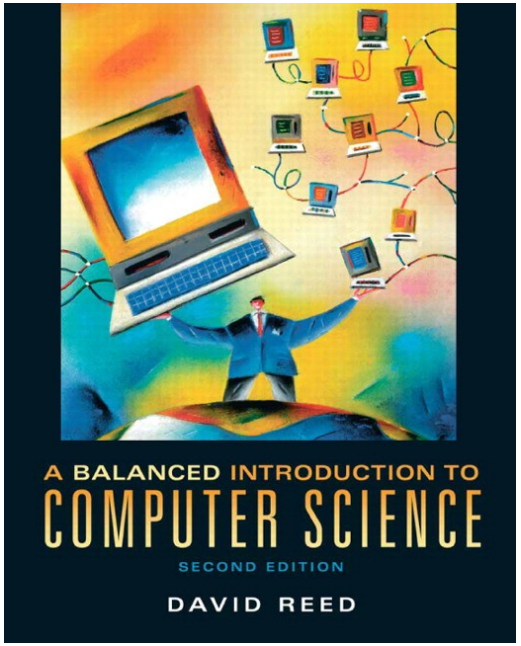
ISBN 978-0-13-601722-6



Chapter 9
Abstraction and User-Defined Functions

Abstraction

abstraction is the process of ignoring minutiae and focusing on the big picture

- in modern life, we are constantly confronted with complexity
- we don't necessarily know how it works, but we know how to use it

  e.g., how does a TV work? a car? a computer?

we survive in the face of complexity by abstracting away details

- to use a TV/car/computer, it's not important to understand the inner workings
- we ignore unimportant details and focus on those features relevant to using it

- e.g., TV has power switch, volume control, channel changer, …

JavaScript functions (like `Math.sqrt`) provide computational abstraction

- a function encapsulates some computation & hides the details from the user
- the user only needs to know how to call the function, not how it works

- Chapter 7 introduced simple user-defined functions
  - could encapsulate the statements associated with a button, call the function as needed

General Function Form

to write general-purpose functions, we can extend definitions to include:
1) parameters, 2) local variables, and 3) return statements

```
function FUNCTION_NAME(PARAMETER_1, PARAMETER_2, ..., PARAMETER_n)
// Assumes: DESCRIPTION OF ASSUMPTIONS MADE ABOUT PARAMETERS
// Returns: DESCRIPTION OF VALUE RETURNED BY FUNCTION
{
   var LOCAL_1, LOCAL_2, ..., LOCAL_n;            // optional

   STATEMENTS_TO_PERFORM_THE DESIRED_COMPUTATION;

   return OUTPUT_VALUE;                           // optional
}
```

- *parameters* are variables that correspond to the function's inputs (if any)
  - parameters appear in the parentheses, separated by commas
- *local variables* are temporary variables that are limited to that function only
  - if require some temporary storage in performing calculations, then declare local variables using the keyword `var`, separated by commas
  - a local variable exists only while the function executes, so no potential conflicts with other functions
- a *return statement* is a statement that specifies an output value
  - consists of the keyword `return` followed by a variable or expression

Functions with Inputs

most of the predefined function we have considered expect at least on input

e.g., `Math.sqrt` takes a number as input, and returns its square root as output

`Math.sqrt(9)` → `3`

e.g., `Math.max` takes two numbers as inputs, and returns the maximum as output

`Math.max(7, 3)` → `7`

in English, the word *parameter* refers to some aspect of a system that can be varied in order to control its behavior

- in JavaScript, a parameter is a variable (declared inside the function's parentheses) whose value is automatically initialized to the corresponding input value when the function is called
- parameters allow the same function to perform different (but related) tasks when called with different input values

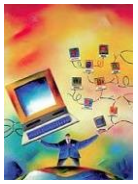
```
function ChangeImage(imgSource)
// Assumes: imgSource is a file containing an image
// Results: the source of faceImg is set to imgSource
{
  document.getElementById('faceImg').src = imgSource;
}
```

the call `ChangeImage("happy.gif")` will assign the input `"happy.gif"` to the parameter `imgSource`, resulting in the image being assigned to that file

---

the call `ChangeImage("sad.gif")` will assign the input `"sad.gif"` to the parameter `imgSource`, resulting in the image being assigned to that file

Newpics Page

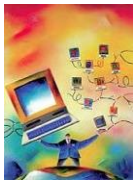


in newpics.html, each button performs a similar task - changing the image file

- the single `ChangeImage` function suffices for each (using different inputs)

```
 1. <html>
 2.   <!-- newpics.html                                          Dave Reed -->
 3.   <!-- This page allows the user to select from among two images. -->
 4.   <!-- ========================================================== -->
 5.
 6.   <head>
 7.     <title> Picture Fun </title>
 8.     <script type="text/javascript">
 9.       function ChangeImage(imgSource)
10.       // Assumes: imgSource is a file containing an image
11.       // Results: the source of faceImg is set to imgSource
12.       {
13.         document.getElementById('faceImg').src = imgSource;
14.       }
15.     </script>
16.   </head>
17.
18.   <body>
19.     <div style="text-align:center">
20.       <h2>How do you feel today?</h2>
21.       <img id="faceImg" src="happy.gif" alt="face image" />
22.       <br /><br />
23.       <input type="button" value="I feel happy" onclick="ChangeImage('happy.gif');" />
24.         
25.       <input type="button" value="I feel sad" onclick="ChangeImage('sad.gif');" />
26.     </div>
27.   </body>
28. </html>
```

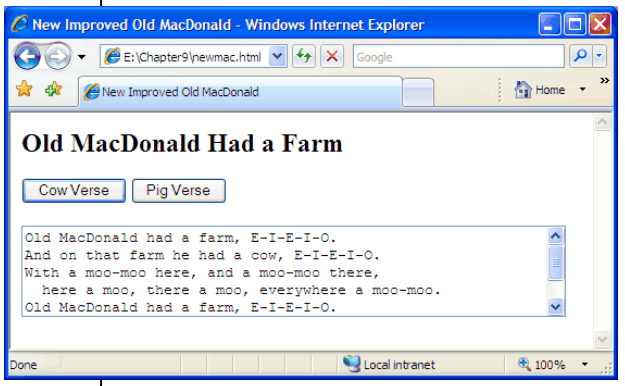
Newmac Page



```
 1. <html>
 2.   <!-- newmac.html                                          Dave Reed -->
 3.   <!-- This page uses a function to display verses from Old MacDonald. -->
 4.   <!-- ================================================================ -->
 5.
 6.   <head>
 7.     <title> New Improved Old MacDonald </title>
 8.     <script type="text/javascript">
 9.       function OldMacVerse(animal, sound)
10.       // Assumes: animal and sound are strings
11.       // Results: displays corresponding Old MacDonald verse in verseArea
12.       {
13.         document.getElementById('verseArea').value =
14.             "Old MacDonald had a farm, E-I-E-I-O.\n" +
15.             "And on that farm he had a " + animal + ", E-I-E-I-O.\n" +
16.             "With a " + sound + "-" + sound + " here, and a " +
17.             sound + "-" + sound + " there,\n" +
18.             " here a " + sound + ", there a " + sound +
19.             ", everywhere a " + sound + "-" + sound + ".\n" +
20.             "Old MacDonald had a farm, E-I-E-I-O.\n\n";
21.       }
22.     </script>
23.   </head>
24.
25.   <body>
26.     <h2>Old MacDonald Had a Farm</h2>
27.     <p>
28.     <input type="button" value="Cow Verse" onclick="OldMacVerse('cow', 'moo');" />
29.     <input type="button" value="Pig Verse" onclick="OldMacVerse('pig', 'oink');" />
30.     </p>
31.     <p>
32.     <textarea id="verseArea" rows="5" cols="60"></textarea>
33.     </p>
34.   </body>
35. </html>
```

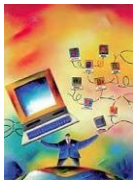
similarly, we could redefine oldmac.html from Chapter 5

- `OldMacVerse` has 2 inputs: the animal and sound for that verse



this function can be used to display any verse, given the animal and sound

Multiple Inputs



if a function has more than one input,

- parameters in the function definition are separated by commas
- input values in the function call are separated by commas

- values are matched to parameters by order

  1st input value in the function call is assigned to the 1st parameter in the function

  2nd input value in the function call is assigned to the 2nd parameter in the function

  . . .

```
function OldMacVerse(animal, sound)
// Assumes: animal and sound are strings
// Results: displays corresponding Old MacDonald verse
{
    . . .
}

-------------------------------------------------------------

OldMacVerse("cow", "moo");


OldMacVerse("moo", "cow");
```

Parameters and Locals

parameters play an important role in functions

- they facilitate the creation of generalized computations
- i.e., the function defines a formula, but certain values within the formula can differ each time the function is called

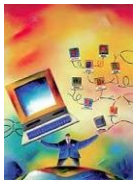
technically, a parameter is a *local variable,* meaning it exists only inside its particular function

- when the function is called, memory cells are allocated for the parameters and each input from the call is assigned to its corresponding parameter
- once a parameter has been assigned a value, you can refer to that parameter within the function just as you would any other variable
- when the function terminates, the parameters "go away," and their associated memory cells are freed

by default, variables other than parameters are considered *global,* meaning they exist and can be accessed by JavaScript code anywhere in the page

- note: it is possible to use the same name to refer to a local variable and a global variable
  - within the function, the local variable is accessible
  - outside that function, the global variable is accessible

Local vs. Global



```
 1. <html>
 2.   <!-- testmac.html                              Dave Reed -->
 3.   <!-- This page displays two verses of OldMacDonald. -->
 4.   <!------------------------------------------------------>
 5.
 6.   <head>
 7.     <title> Old MacDonald Test </title>
 8.     <script type="text/javascript">
 9.       function OldMacVerse(animal, sound)
10.       // Assumes: animal and sound are strings
11.       // Results: displays corresponding Old MacDonald verse
12.       {
13.         document.write("<p>Old MacDonald had a farm, E-I-E-I-O.<br />");
14.         document.write("And on that farm he had a " + animal +
15.                        ", E-I-E-I-O.<br />");
16.         document.write("With a " + sound + "-" + sound +
17.                        " here, and a " + sound + "-" + sound +
18.                        " there,<br />");
19.         document.write("   here a " + sound + ", there a " +
20.                        sound + ", everywhere a " + sound + "-" +
21.                        sound + ".<br />");
22.         document.write("Old MacDonald had a farm, E-I-E-I-O.</p>");
23.       }
24.     </script>
25.   </head>
26.
27.   <body>
28.     <script type="text/javascript">
29.       animal = prompt("Enter the name of an animal:", "");
30.       sound = prompt("What sound does it make?", "");
31.
32.       OldMacVerse(animal, sound);
33.       OldMacVerse("duck", "quack");
34.     </script>
35.   </body>
36. </html>
```

here, the variable names animal and sound are

- used for parameters in the function definition
  (local variables)
- used for variables in the BODY
  (global variables)

we can think of these as completely separate variables, identifiable via a subscript

- $\texttt{animal}_{\texttt{OldMacVerse}}$ and $\texttt{sound}_{\texttt{OldMacVerse}}$ are used in the function
- $\texttt{animal}_{\texttt{BODY}}$ and $\texttt{sound}_{\texttt{BODY}}$ are used in the BODY

Declaring Local Variables

we have seen that variables are useful for storing intermediate steps in a complex computation

- within a user-defined function, the programmer is free to create new variables and use them in specifying the function's computation
- however, by default, new variables used in a function are global
  - *but what if the same variable name is already used elsewhere?*

to avoid name conflicts, the programmer should *declare* temporary variables to be *local*

- a variable declaration is a statement that lists all local variables to be used in a function (usually the first statement in a function)
- general form: `var LOCAL_1, LOCAL_2, . . ., LOCAL_n;`

```
function IncomeTax(income, itemized)
// Assumes: income >= 0, itemized >= 0
// Results: displays flat tax (13%) due after deductions
{
    var deduction, taxableIncome, totalTax;

    deduction = Math.max(itemized, 4150);
    taxableIncome = Math.max(income - deduction, 0);
    totalTax = 0.13*taxableIncome

    alert("You owe $" + totalTax);
}
```

since these variables are declared as local, they will not affect (or be affected by) any variables with the same names elsewhere in the page

Functions with Return

displaying results using `document.write` or `alert` is OK for some functions

- for full generality, we need to be able to return an output value, which can then be used in other computations

e.g.,
```
number = Math.sqrt(9);

amountOwed = IncomeTax(38000, 6500);
```

a return statement can be added to a function to specify its output value

- when the return statement is reached, the variable or expression is evaluated and its value is returned as the function's output
- general form: `return OUTPUT_VALUE;`

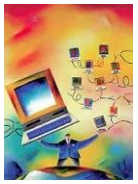
```
function IncomeTax(income, itemized)
// Assumes: income >= 0, itemized >= 0
// Returns: flat tax (13%) due after deductions
{
    var deduction, taxableIncome, totalTax;

    deduction = Math.max(itemized, 4150);
    taxableIncome = Math.max(income - deduction, 0);
    totalTax = 0.13*taxableIncome

    return totalTax;
}
```

since this function returns the value, it can be used in other computations, e.g., calculate amount owed in 4 payments:

```
payment =
  IncomeTax(38000, 6500)/4;
```

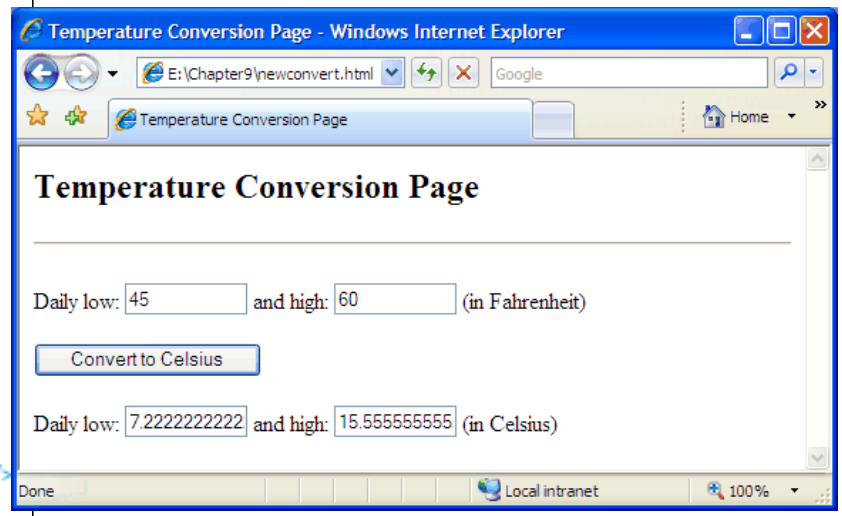


Newconvert Page

```
1.  <html>
2.   <!-- newconvert.html                                    Dave Reed -->
3.   <!-- This page converts temperatures from Fahrenheit to Celsius. -->
4.   <!-- ------------------------------------------------------------ -->
5.
6.   <head>
7.     <title>Temperature Conversion Page</title>
8.
9.     <script type="text/javascript">
10.      function FahrToCelsius(tempInFahr)
11.      // Assumes: tempInFahr is a temperature in Fahrenheit
12.      // Returns: the equivalent temperature in Celsius
13.      {
14.         var tempInCelsius;
15.         tempInCelsius = (5/9) * (tempInFahr - 32);
16.         return tempInCelsius;
17.      }
18.
19.      function ConvertFtoC()
20.      // Assumes: lowFahrBox and highFahrBox contain degrees Fahrenheit
21.      // Results: assigns lowCelsiusBox and highCelsiusBox the equivalent temperatures
22.      {
23.        var lowTempInF, highTempInF, lowTempInC, highTempInC;
24.
25.        lowTempInF = parseFloat(document.getElementById('lowFahrBox').value);
26.        lowTempInF = parseFloat(lowTempInF);
27.        highTempInF = parseFloat(document.getElementById('highFahrBox').value);
28.        highTempInF = parseFloat(highTempInF);
29.
30.        lowTempInC = FahrToCelsius(lowTempInF);
31.        highTempInC = FahrToCelsius(highTempInF);
32.
33.        document.getElementById('lowCelsiusBox').value = lowTempInC;
34.        document.getElementById('highCelsiusBox').value = highTempInC;
35.      }
36.    </script>
37.  </head>
38.
39.  <body>
40.    <h2>Temperature Conversion Page</h2>
41.    <hr />
42.    <p>
43.      Daily low: <input type="text" id="lowFahrBox" size="10" value="" />
44.      and high: <input type="text" id="highFahrBox" size="10" value="" />
45.      (in Fahrenheit)
46.    </p>
47.    <p>
48.      <input type="button" value="Convert to Celsius" onclick="ConvertFtoC();" />
49.    </p>
50.    <p>
51.      Daily low: <input type="text" id="lowCelsiusBox" size="10" value="" />
52.      and high: <input type="text" id="highCelsiusBox" size="10" value="" />
53.      (in Celsius)
54.    </p>
55.  </body>
56. </html>
```

if the same computation must be done repeatedly, a function can greatly simplify the page

- here, `FahrToCelsius` is called twice to convert two different temperatures



Designing Functions

functions do not add any computational power to the language

- a function definition simply encapsulates other statements

still, the capacity to define and use functions is key to solving complex problems, as well as to developing reusable code

- encapsulating repetitive tasks can shorten and simplify code
- functions provide units of computational abstraction – user can ignore details
- functions are self-contained, so can easily be reused in different applications

when is it worthwhile to define a function?

- if a particular computation is complex—meaning that it requires extra variables and/or multiple lines to define
- if you have to perform a particular computation repeatedly within a page

when defining a function, you must identify

- the inputs
- the computation to be performed using those inputs
- the output

Design Example

consider the task of designing an online Magic 8-ball® (Mattell, Inc.)

- must be able to ask a yes/no type question
- receive an answer (presumably, at random)

could use:

- a text area for entering the question (which could be several lines long)
- a text box for displaying the answer (which should be short)
- a button for initiating the action – which involves calling a function to process the question, select an answer, and display it in the text box

random.js

general-purpose functions can be grouped together in a *library*

- a library is a text file that contains one or more function definitions
- once the functions are defined in the library, that library can be loaded into pages as needed

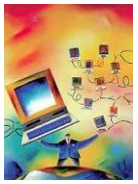
e.g., the `random.js` library contains useful functions for generating random values

Function	Inputs	Output
`RandomNum`	Two numbers (low and high limits of a range), e.g., `RandomNum(2, 4.5)`	A random number from the range low (inclusive) to high (exclusive)
`RandomInt`	Two integers (low and high limits of a range), e.g., `RandomInt(1, 10)`	A random integer from the range low to high (both inclusive)
`RandomChar`	A nonempty string, e.g., `RandomChar("abcd")`	A random character taken from the string
`RandomOneOf`	A list of options (in brackets separated by commas), e.g., `RandomOneOf(["yes", "no"])`	A random value taken from the list of options

to load a library of functions in a page, use a special pair of SCRIPT tags

```
<script type="text/javascript" src="URL_OR_LOCAL_FILENAME">
</script>
```

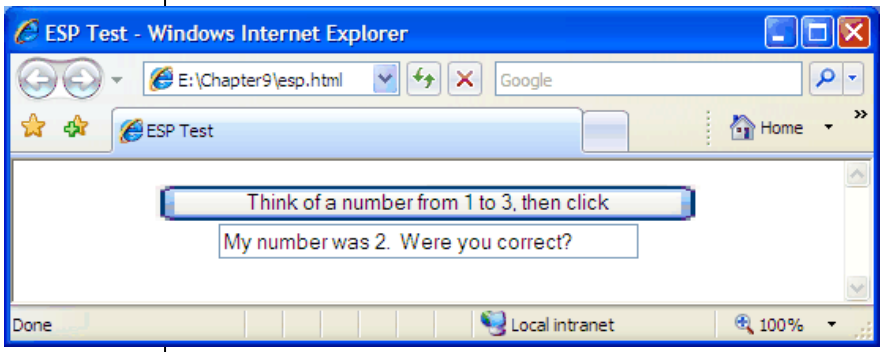
Using random.js



in the page below, the `random.js` library is accessed via the Web

- you can download the file and store it on your own machine
- then, simply specify the file name in the SRC attribute (the default is that the file is in the same folder as the Web page that includes it)

```
1.  <html>
2.    <!-- esp.html                                          Dave Reed -->
3.    <!-- This page uses RandomInt to pick and display a random number. -->
4.    <!-- ------------------------------------------------------------ -->
5.
6.    <head>
7.      <title> ESP Test </title>
8.      <script type="text/javascript"
9.              src="http://dave-reed.com/book/random.js">
10.     </script>
11.     <script type="text/javascript">
12.       function PickNumber()
13.       // Results: displays a random number in messageBox
14.       {
15.          var number;
16.
17.          number = RandomInt(1, 3);
18.
19.          document.getElementById('messageBox').value =
20.              "My number was " + number + ". Were you correct?";
21.       }
22.     </script>
23.   </head>
24.
25.   <body>
26.     <p style="text-align:center">
27.       <input type="button" value="Think of a number from 1 to 3, then click"
28.              onclick="PickNumber();" />
29.       <br />
30.       <input type="text" id="messageBox" size="40" />
31.     </p>
32.   </body>
33. </html>
```



note: the `RandomOneOf` function from `random.js` would similarly be useful for the Magic 8-ball page (in selecting possible answers at random)

Errors to Avoid

When beginning programmers attempt to load a JavaScript code library, errors of two types commonly occur:

1. if the SCRIPT tags are malformed or the name/address of the library is incorrect, the library will fail to load
   - this will not cause an error in itself, but any subsequent attempt to call a function from the library will produce

     "Error: Object Expected" (using Internet Explorer)
     or
     "Error: XXX is not a function" (using Firefox), where XXX is the entered name

1. when you use the SRC attribute in a pair of SCRIPT tags to load a code library, you cannot place additional JavaScript code between the tags
   - think of the SRC attribute as causing the contents of the library to be inserted between the tags, overwriting any other code that was erroneously placed there

```
<script type="text/javascript" src="FILENAME">
    ANYTHING PLACED IN HERE WILL BE IGNORED
</script>
```

   - if you want additional JavaScript code or another library, you must use another pair of SCRIPT tags