A Balanced Introduction to Computer Science, 3/E

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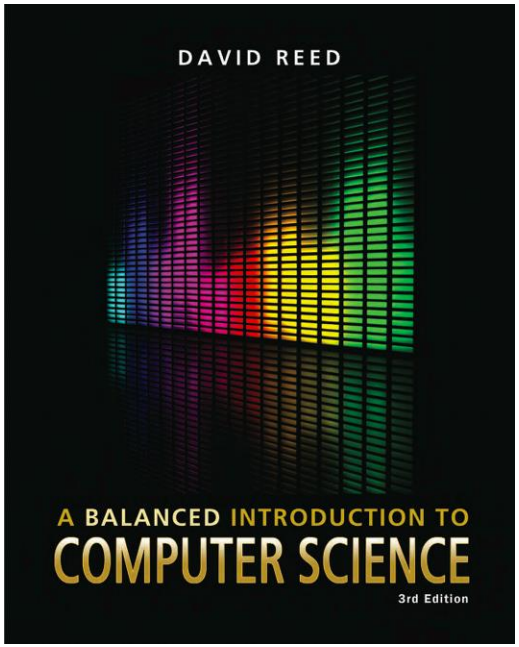


Chapter 9
Abstraction and Libraries

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(PARAMETER1, PARAMETER2, ..., PARAMETERn)
// Assumes: DESCRIPTION OF ASSUMPTIONS MADE ABOUT PARAMETERS
// Returns: DESCRIPTION OF VALUE RETURNED BY FUNCTION
{
   var LOCAL1, LOCAL2, ..., LOCALn;

   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

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* (i.e., exist and are accessible anywhere in the page)
  - *but what if the same variable name is already used elsewhere?*

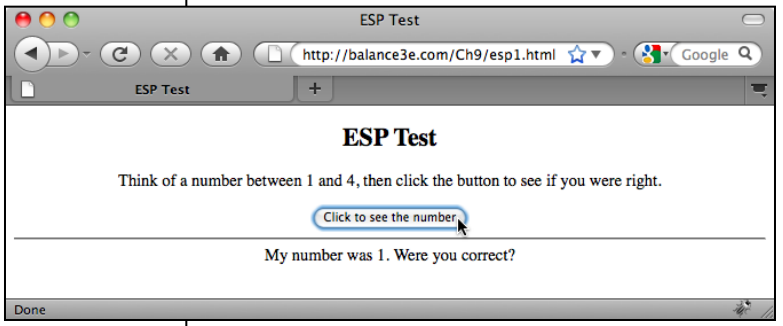
to avoid name conflicts, the programmer should declare temporary variables to be *local*

- 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;
```

ESP Test Page

```
 1. <!doctype html>
 2. <!-- esp1.html                                                Dave Reed  -->
 3. <!-- This page performs an ESP test by displaying a random number. -->
 4. <!-- ============================================================  -->
 5.
 6. <html>
 7.  <head>
 8.    <title> ESP Test </title>
 9.    <script type="text/javascript">
10.      function PickNumber()
11.      // Results: displays a random number between 1 and 4 in outputDiv
12.      {
13.        var number;
14.
15.        number = Math.floor(Math.random()*4) + 1;
16.        document.getElementById('outputDiv').innerHTML =
17.          'My number was ' + number + '. Were you correct?';
18.      }
19.    </script>
20.  </head>
21.
22.  <body>
23.    <div style="text-align:center">
24.      <h2>ESP Test</h2>
25.      <p>
26.        Think of a number between 1 and 4, then click the button to see
27.        if you were right.
28.      </p>
29.      <input type="button" value="Click to see the number"
30.             onclick="PickNumber();">
31.      <hr>
32.      <div id="outputDiv"></div>
33.    </div>
34.  </body>
35. </html>
```



consider a simple ESP test

1. user thinks of a number between 1-4
2. clicks on the button to see the computer's pick

`number` is declared local to `PickNumber`

- only exists while the function executes

Functions with Inputs

most of the predefined function we have considered expect at least one 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

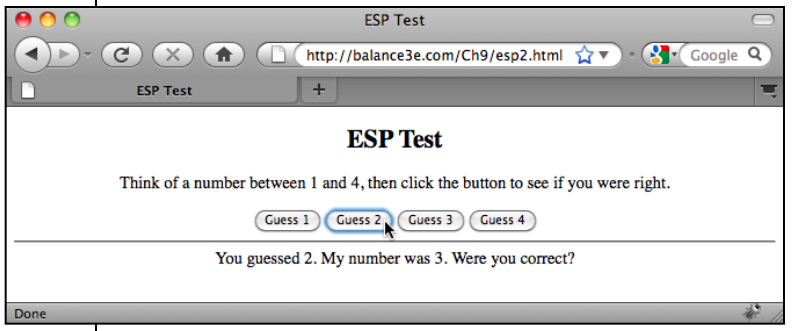
- in JavaScript, a parameter is a variable (declared inside the function's parentheses) whose value is automatically initialized to the corresponding input value when the function is called
- parameters allow the same function to perform different (but related) tasks when called with different input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

ESP Test Page Revisited

```
 1. <!doctype html>
 2. <!-- esp2.html                                                Dave Reed  -->
 3. <!-- This page performs an ESP test by displaying a random number. -->
 4. <!-- ================================================================  -->
 5.
 6. <html>
 7.   <head>
 8.     <title> ESP Test </title>
 9.     <script type="text/javascript">
10.       function PickNumber(guess)
11.       // Assumes: guess is the user's guess (between 1 and 4)
12.       // Results: displays a random number between 1 and 4 in outputDiv
13.       {
14.         var number;
15.
16.         number = Math.floor(Math.random()*4) + 1;
17.         document.getElementById('outputDiv').innerHTML =
18.           'You guessed ' + guess + '. My number was ' + number +
19.           '. Were you correct?';
20.       }
21.     </script>
22.   </head>
23.
24.   <body>
25.     <div style="text-align:center">
26.       <h2>ESP Test</h2>
27.       <p>
28.         Think of a number between 1 and 4, then click the button to see
29.         if you were right.
30.       </p>
31.       <input type="button" value="Guess 1" onclick="PickNumber(1);">
32.       <input type="button" value="Guess 2" onclick="PickNumber(2);">
33.       <input type="button" value="Guess 3" onclick="PickNumber(3);">
34.       <input type="button" value="Guess 4" onclick="PickNumber(4);">
35.       <hr>
36.       <div id="outputDiv"></div>
37.     </div>
38.   </body>
39. </html>
```

better design: have a button for each guess

- to guess 1, the user clicks the 'Guess 1' button
- instead of 4 different functions (that behave similarly), have 1 function with a parameter



- the number corresponding to the guess is passed in as an input, displayed as the guess

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 is the name of an animal, sound is the sound it makes
// Results: displays a verse of the song "Old MacDonald Had a Farm" in outputDiv
{
  document.getElementById('outputDiv').innerHTML =
       '<p>Old MacDonald had a farm, E-I-E-I-O.<br>' +
       'And on that farm he had a ' + animal + ', E-I-E-I-O.<br>' +
       'With a ' + sound + '-' + sound + ' here, and a ' + sound + '-' + sound +
       ' there,<br>' + ' here a ' + sound + ', there a ' + sound +
       ', everywhere a ' + sound + '-' + sound + '.<br>' +
       'Old MacDonald had a farm, E-I-E-I-O.</p>';
}
```

```
<input type="button" value="Cow Verse"
       onclick="OldMacVerse('cow', 'moo');">
```

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

parameters are special instances of local variables

- 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

parameters are declared and initialized automatically

- do not declare them as local variables

Functions with Return

displaying results using an INNERHTML assignment 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);`

`cm = InchesToCentimeters(in);`

```
function InchesToCentimeters(inches)
// Assumes: inches is a distance, measured in inches
// Returns: the corresponding distance in centimeters
{
    var cm;

    cm = inches * 2.54;
    return cm;
}

function CentimetersToInches(cm)
// Assumes: cm is a distance, measured in centimeters
// Returns: the corresponding distance in inches
{
    var inches;

    inches = cm / 2.54;
    return inches;
}
```

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 Libraries

functions such as `InchesToCentimeters` can be added to the HEAD of a page

- tedious if the function is to be used in many pages
- involves creating lots of copies that all must be maintained for consistency

the alternative for general purpose functions is to place them in a library file

- a *library file* is a separate text file that contains the definitions of one or more JavaScript functions
- it can be loaded into any page by adding an HTML element to the HEAD

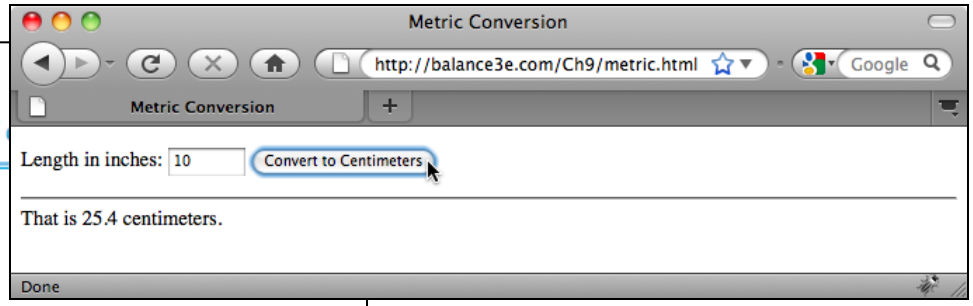
```
<script type="text/javascript" src="LIBRARY_FILENAME"><script>
```

advantages of library files:

- avoids duplication (only one copy of the function definition)
- makes it easy to reuse functions (simply load the library file into any page)
- makes it easy to modify functions (a single change to the library file automatically affects all pages that load the library

Conversion Page

```
 1. <!doctype html>
 2. <!-- metric.html
 3. <!-- This page converts between English and metri
 4. <!-- ==========================================
 5.
 6. <html>
 7.  <head>
 8.    <title>Metric Conversion</title>
 9.    <script type="text/javascript" src="convert.js"></script>
10.    <script type="text/javascript">
11.      function ConvertToCm()
12.      // Assumes: inchBox contains a distance in inches
13.      // Results: displays the distance in centimeters in outputDiv
14.      {
15.        var inches, cm;
16.
17.        inches = parseFloat(document.getElementById('inchBox').value);
18.        cm = InchesToCentimeters(inches);
19.        document.getElementById('outputDiv').innerHTML =
20.          'That is ' + cm + ' centimeters.';
21.      }
22.    </script>
23.  </head>
24.
25.  <body>
26.    <p>Length in inches:
27.      <input type="text" id="inchBox" size=6 value=1>
28.      <input type="button" value="Convert to Centimeters"
29.             onclick="ConvertToCm();">
30.    </p>
31.    <hr>
32.    <div id="outputDiv"></div>
33.  </body>
34. </html>
```



the `convert.js` library file is loaded into the page

- this makes the `InchesToCentimeters` function accessible within the page

- since `ConvertToCm` is specific to this page, it directly in the HEAD (as opposed to a library file)

random.js Library

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 square brackets, separated by commas; e.g., RandomOneOf(['yes', 'no'])	A random value taken from the list of options

any page can utilize the functions by first loading the random.js library

```
<script type="text/javascript" src="http://balance3e.com/random.js">
</script>
```

for example, could revise the ESP Test page to use RandomInt:

```
number = RandomInt(1, 4);
```

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

2. 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

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

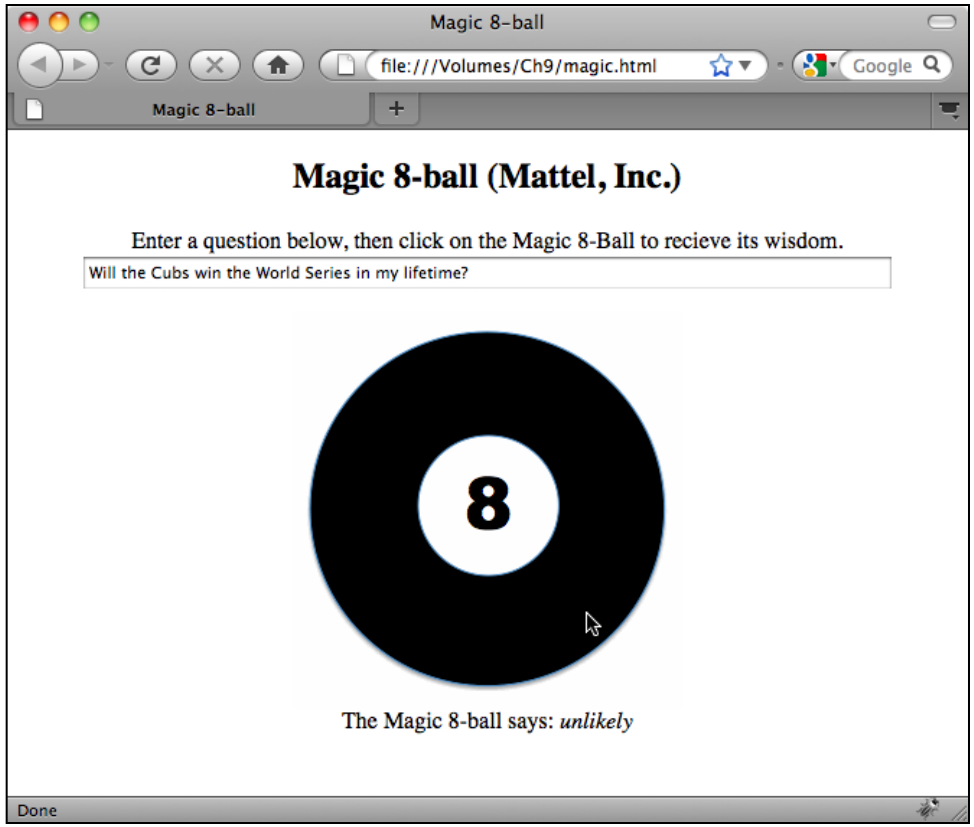
when defining a function, you must identify

- 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 box for entering the question
- a DIV element for displaying the answer
- a clickable image for initiating the action – which involves calling a function to process the question, select an answer, and display it in the DIV