

HTML5: Introduction to canvas

14.1 Introduction

- ▶ The **canvas element**, which you'll learn to use in this chapter, provides a JavaScript application programming interface (API) with methods for drawing two-dimensional bitmapped graphics and animations, manipulating fonts and images, and inserting images and videos.
 - Due to the large number of examples in this chapter, most of the examples use embedded JavaScripts.
- ▶ A key benefit of canvas is that it's built into the browser, eliminating the need for plug-ins like Flash and Silverlight, thereby improving performance and convenience and reducing costs.

14.2 canvas Coordinate System

- ▶ To begin drawing, we first must understand canvas's **coordinate system** (Fig. 14.1), a scheme for identifying every point on a canvas.
- ▶ By default, the upper-left corner of a canvas has the coordinates $(0, 0)$.
- ▶ A coordinate pair has both an **x-coordinate** (the **horizontal coordinate**) and a **y-coordinate** (the **vertical coordinate**).
- ▶ The **x**-coordinate is the horizontal distance to the right from the left border of a canvas.
- ▶ The **y**-coordinate is the vertical distance downward from the top border of a canvas.
- ▶ The **x-axis** defines every horizontal coordinate, and the **y-axis** defines every vertical coordinate.
- ▶ You position text and shapes on a canvas by specifying their **x** and **y**-coordinates.
- ▶ Coordinate space units are measured in pixels ("picture elements"), which are the smallest units of resolution on a screen.

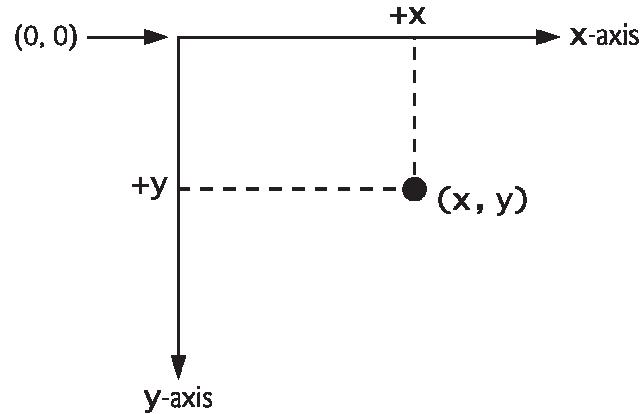


Fig. 14.1 | canvas coordinate system. Units are measured in pixels.

14.3 Rectangles

- ▶ Figure 14.2 demonstrates how to draw a rectangle with a border on a canvas.

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.2: drawrectangle.html -->
4 <!-- Drawing a rectangle on a canvas. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Drawing a Rectangle</title>
9   </head>
10  <body>
11    <canvas id = "drawRectangle" width = "300" height = "100"
12      style = "border: 1px solid black;">
13      Your browser does not support Canvas.
14    </canvas>
15    <script type>
16      var canvas = document.getElementById("drawRectangle");
17      var context = canvas.getContext("2d")
18      context.fillStyle = "yellow";
19      context.fillRect(5, 10, 200, 75);
20      context.strokeStyle = "royalblue";
21      context.lineWidth = 6;
22      context.strokeRect(4, 9, 201, 76);
23    </script>
24  </body>
25 </html>
```

Fig. 14.2 | Drawing a rectangle with a border on a canvas. (Part 1 of 2.)



Fig. 14.2 | Drawing a rectangle with a border on a canvas. (Part 2 of 2.)

14.3 Rectangles (cont.)

Creating a Canvas

- ▶ The canvas element has two attributes—width and height.
- ▶ The default width is 300 and the default height 150.
- ▶ We create a canvas starting with a `canvasID`—in this case, "drawRectangle".
- ▶ Assigning a unique ID to a canvas allows you to access it like any other element, and to use more than one canvas on a page.
- ▶ Next, we specify the canvas's width (300) and height (100), and a border of 1px solid black. You do not need to include a visible border.
- ▶ We include the *fallback text* Your browser does not support canvas. This will appear if the user runs the application in a browser that does not support canvas.

14.3 Rectangles (cont.)

Graphics Contexts and Graphics Objects

- ▶ We use the `getElementById` method to get the canvas element using the ID.
- ▶ Next we get the `context` object. A context represents a 2D rendering surface that provides methods for drawing on a canvas.
- ▶ The context contains attributes and methods for drawing, font manipulation, color manipulation and other graphics-related actions.

14.3 Rectangles (cont.)

Drawing the Rectangle

- ▶ To draw the rectangle, we specify its color by setting the **fillStyle** attribute to yellow.
- ▶ The **fillRect method** then draws the rectangle using the arguments *x*, *y*, *width* and *height*, where *x* and *y* are the coordinates for the top-left corner of the rectangle.
- ▶ The **strokeStyle** attribute specifies the stroke color or style (in this case, royalblue).
- ▶ The **lineWidth attribute** specifies the stroke width in coordinate space units.
- ▶ The **strokeRect method** specifies the coordinates of the stroke using the arguments *x*, *y*, *width* and *height*.

14.4 Using Paths to Draw Lines

- ▶ To draw lines and complex shapes in canvas, we use **paths**.
- ▶ A path can have zero or more **subpaths**, each having one or more points connected by lines or curves.
- ▶ If a subpath has fewer than two points, no path is drawn.
- ▶ Figure 14.3 uses paths to draw lines on a canvas.
- ▶ The **beginPath** method starts the line's path.
- ▶ The **moveTo** method sets the *x*- and *y*-coordinates of the path's origin.

14.4 Using Paths to Draw Lines

- ▶ From the point of origin, we use the `lineTo` method to specify the destinations for the path.
- ▶ The `lineWidth` attribute is used to change the thickness of the line.
- ▶ We then use the `lineJoin` attribute to specify the style of the corners where two lines meet—in this case, `bevel`.
- ▶ The `lineJoin` attribute has three possible values—`bevel`, `round`, and `miter`. The value `bevel` gives the path sloping corners.

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.3: lines.html -->
4 <!-- Drawing lines on a canvas. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Drawing Lines</title>
9   </head>
10  <body>
11    <canvas id = "drawLines" width = "400" height = "200"
12      style = "border: 1px solid black;">
13    </canvas>
14    <script>
15      var canvas = document.getElementById("drawLines");
16      var context = canvas.getContext("2d")
17
18      // red lines without a closed path
19      context.beginPath(); // begin a new path
20      context.moveTo(10, 10); // path origin
21      context.lineTo(390, 10);
22      context.lineTo(390, 30);
23      context.lineTo(10, 30);
24      context.lineWidth = 10; // line width
```

Fig. 14.3 | Drawing lines on a canvas. (Part 1 of 4.)

```
25    context.lineJoin = "bevel" // line join style
26    context.lineCap = "butt"; // line cap style
27    context.strokeStyle = "red" // line color
28    context.stroke(); //draw path
29
30    // orange lines without a closed path
31    context.beginPath(); //begin a new path
32    context.moveTo(40, 75); // path origin
33    context.lineTo(40, 55);
34    context.lineTo(360, 55);
35    context.lineTo(360, 75);
36    context.lineWidth = 20; // line width
37    context.lineJoin = "round" // line join style
38    context.lineCap = "round"; // line cap style
39    context.strokeStyle = "orange" //line color
40    context.stroke(); // draw path
41
42    // green lines with a closed path
43    context.beginPath(); // begin a new path
44    context.moveTo(10, 100); // path origin
45    context.lineTo(390, 100);
46    context.lineTo(390, 130);
47    context.closePath() // close path
48    context.lineWidth = 10; // line width
49    context.lineJoin = "miter" // line join style
```

Fig. 14.3 | Drawing lines on a canvas. (Part 2 of 4.)

```
50     context.strokeStyle = "green" // line color
51     context.stroke(); // draw path
52
53     // blue lines without a closed path
54     context.beginPath(); // begin a new path
55     context.moveTo(40, 140); // path origin
56     context.lineTo(360, 190);
57     context.lineTo(360, 140);
58     context.lineTo(40, 190);
59     context.lineWidth = 5; // line width
60     context.lineCap = "butt"; // line cap style
61     context.strokeStyle = "blue" // line color
62     context.stroke(); // draw path
63   </script>
64 </body>
65 </html>
```

Fig. 14.3 | Drawing lines on a canvas. (Part 3 of 4.)

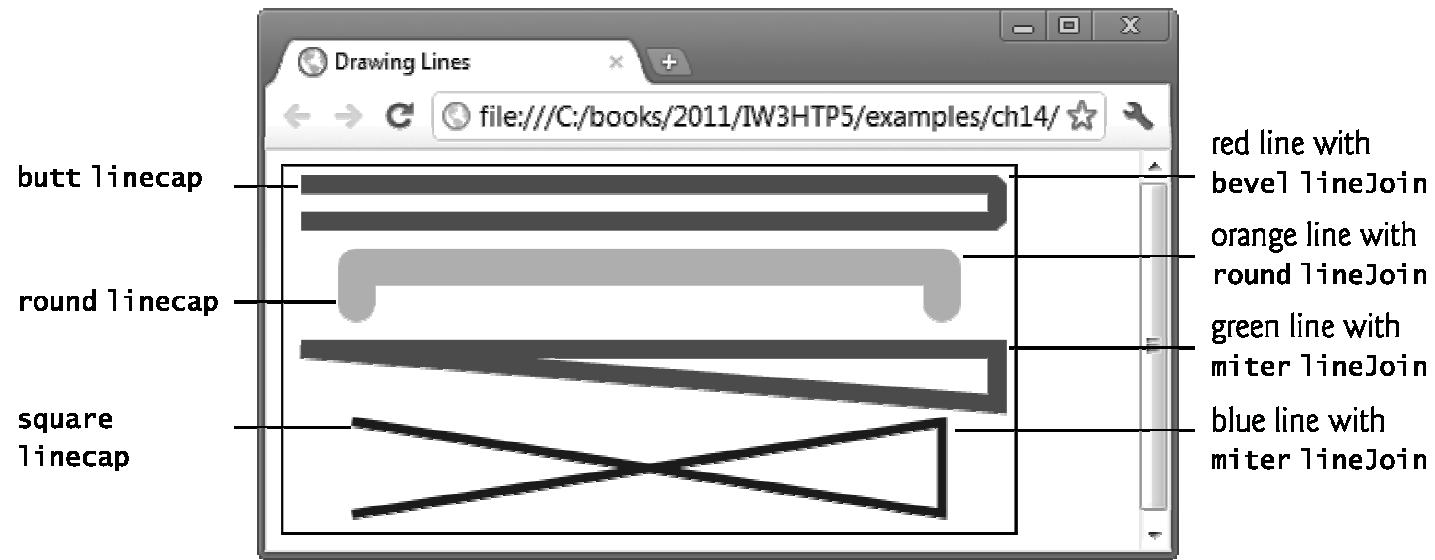


Fig. 14.3 | Drawing lines on a canvas. (Part 4 of 4.)

14.4 Using Paths to Draw Lines (cont.)

- ▶ The `lineCap` attribute specifies the style of the end of the lines.
- ▶ There are three possible values—`butt`, `round`, and `square`.
- ▶ A `butt` `lineCap` specifies that the line ends have edges perpendicular to the direction of the line and *no additional cap*.
- ▶ Next, the `strokeStyle` attribute specifies the line color—in this case, red.
- ▶ The `stroke` method draws the line on the canvas. The default stroke color is black.
- ▶ The `round` `lineJoin` creates rounded corners.

14.4 Using Paths to Draw Lines (cont.)

- ▶ The round `lineCap` adds a *semicircular* cap to the ends of the path—the cap's diameter is equal to the width of the line.
- ▶ The `closePath` method closes the path by drawing a straight line from the last specified destination back to the point of the path's origin.
- ▶ The miter `lineJoin` *bevels* the lines at an angle where they meet.

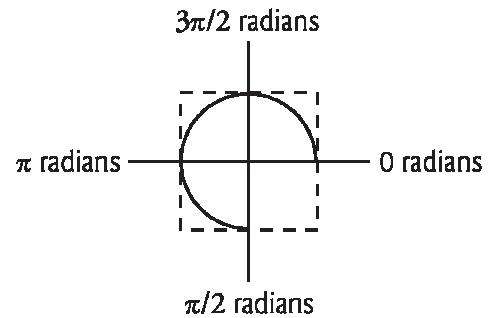
14.4 Using Paths to Draw Lines (cont.)

- ▶ The butt lineCap adds a rectangular cap to the line ends.
- ▶ The length of the cap is equal to the line width, and the width of the cap is equal to half the line width.
- ▶ The edge of the square lineCap is perpendicular to the direction of the line.

14.5 Drawing Arcs and Circles

- ▶ Arcs are portions of the circumference of a circle.
- ▶ To draw an arc, you specify the arc's **starting angle** and **ending angle** measured in *radians*—the ratio of the arc's length to its radius.
- ▶ The arc is said to sweep from its starting angle to its ending angle.
- ▶ Figure 14.4 depicts two arcs.
- ▶ The arc at the left of the figure sweeps *counterclockwise* from zero radians to $\pi/2$ radians, resulting in an arc that sweeps three quarters of the circumference a circle.
- ▶ The arc at the right of the figure sweeps *clockwise* from zero radians to $\pi/2$ radians.

Counterclockwise argument is true



Counterclockwise argument is false or omitted

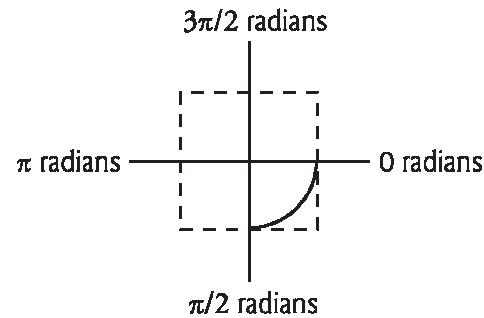


Fig. 14.4 | Positive and negative arc angles.

14.5 Drawing Arcs and Circles (cont.)

- ▶ Figure 14.5 shows how to draw arcs and circles using the `arc` method.
- ▶ The `beginPath` method starts the path.
- ▶ Next, the `arc` method draws the circle using five arguments.
- ▶ The first two arguments represent the x - and y -coordinates of the center of the circle—in this case, 35, 50.
- ▶ The third argument is the radius of the circle.
- ▶ The fourth and fifth arguments are the arc's starting and ending angles in radians. In this case, the ending angle is `Math.PI*2`.

14.5 Drawing Arcs and Circles (cont.)

- ▶ The constant `Math.PI` is the JavaScript representation of the mathematical constant π , the ratio of a circle's circumference to its diameter.
- ▶ 2π radians represents a 360-degree arc, π radians is 180 degrees and $\pi/2$ radians is 90 degrees.
- ▶ To draw the circle to the canvas, we specify a `fillStyle` of `mediumslateblue`, then draw the circle using the `fill` method.

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.5: drawingarcs.html -->
4 <!-- Drawing arcs and a circle on a canvas. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Arcs and Circles</title>
9   </head>
10  <body>
11    <canvas id = "drawArcs" width = "225" height = "100">
12    </canvas>
13    <script>
14      var canvas = document.getElementById("drawArcs");
15      var context = canvas.getContext("2d")
16
17      // draw a circle
18      context.beginPath();
19      context.arc(35, 50, 30, 0, Math.PI * 2);
20      context.fillStyle = "mediumslateblue";
21      context.fill();
22
```

Fig. 14.5 | Drawing arcs and circles on a canvas. (Part 1 of 3.)

```
23      // draw an arc counterclockwise
24      context.beginPath();
25      context.arc(110, 50, 30, 0, Math.PI, false);
26      context.stroke();
27
28      // draw a half-circle clockwise
29      context.beginPath();
30      context.arc(185, 50, 30, 0, Math.PI, true);
31      context.fillStyle = "red";
32      context.fill();
33
34      // draw an arc counterclockwise
35      context.beginPath();
36      context.arc(260, 50, 30, 0, 3 * Math.PI / 2);
37      context.strokeStyle = "darkorange";
38      context.stroke();
39    </script>
40  </body>
41 </html>
```

Fig. 14.5 | Drawing arcs and circles on a canvas. (Part 2 of 3.)

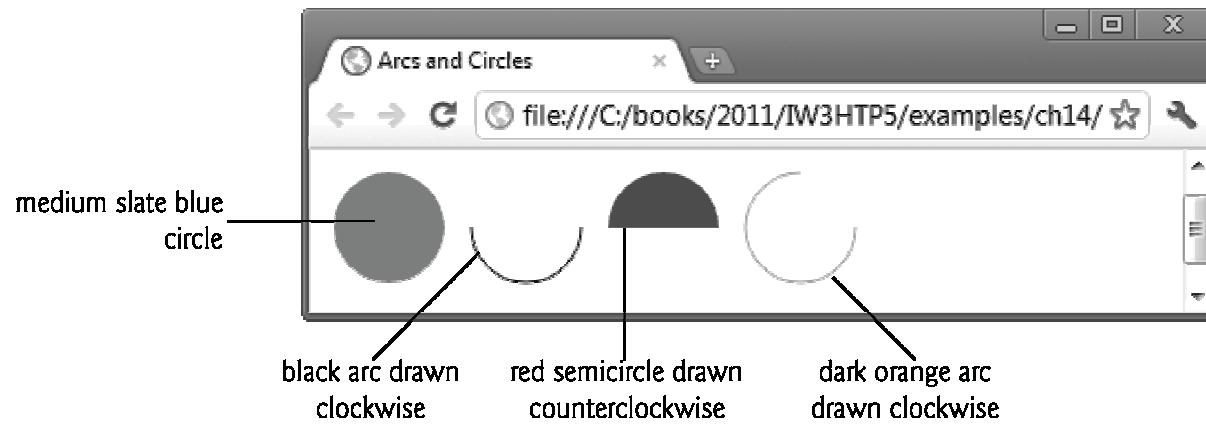


Fig. 14.5 | Drawing arcs and circles on a canvas. (Part 3 of 3.)

14.5 Drawing Arcs and Circles (cont.)

- ▶ We then draw a black arc that sweeps *clockwise*.
- ▶ Using the arc method, we draw an arc with a center at 110, 50, a radius of 30, a starting angle of 0 and an ending angle of Math.PI (180 degrees).
- ▶ The sixth argument is *optional* and specifies the direction in which the arc's path is drawn.
- ▶ By default, the sixth argument is false, indicating that the arc is drawn *clockwise*.
- ▶ If the argument is true, the arc is drawn *counterclockwise* (or *anticlockwise*).
- ▶ We draw the arc using the stroke method.

14.5 Drawing Arcs and Circles (cont.)

- ▶ Next, we draw a filled red semicircle counterclockwise so that it sweeps upward.
- ▶ To draw the arc counterclockwise, we use the sixth argument, true.
- ▶ Finally, we draw a darkorange 270-degree clockwise arc.
- ▶ Since we do not include the optional sixth argument, it defaults to false, drawing the arc *clockwise*.

14.6 Shadows

- ▶ In the next example, we add shadows to two filled rectangles (Fig. 14.6).
- ▶ We start by specifying the `shadowBlur` attribute, setting its value to 10. By default, the blur is 0 (no blur).
- ▶ The *higher* the value, the *more blurred* the edges of the shadow will appear.
- ▶ Next, we set the `shadowOffsetX` attribute to 15, which moves the shadow to the *right* of the rectangle.
- ▶ We then set the `shadowOffsetY` attribute to 15, which moves the shadow *down* from the rectangle.
- ▶ Finally, we specify the `shadowColor` attribute as blue.

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.6: shadows.html -->
4 <!-- Creating shadows on a canvas. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Shadows</title>
9   </head>
10  <body>
11    <canvas id = "shadow" width = "525" height = "250"
12      style = "border: 1px solid black;">
13    </canvas>
14    <script>
15
16      // shadow effect with positive offsets
17      var canvas = document.getElementById("shadow");
18      var context = canvas.getContext("2d")
19      context.shadowBlur = 10;
20      context.shadowOffsetX = 15;
21      context.shadowOffsetY = 15;
22      context.shadowColor = "blue";
23      context.fillStyle = "cyan";
24      context.fillRect(25, 25, 200, 200);
```

Fig. 14.6 | Creating shadows on a canvas. (Part 1 of 3.)

```
25
26    // shadow effect with negative offsets
27    context.shadowBlur = 20;
28    context.shadowOffsetX = -20;
29    context.shadowOffsetY = -20;
30    context.shadowColor = "gray";
31    context.fillStyle = "magenta";
32    context.fillRect(300, 25, 200, 200);
33  </script>
34 </body>
35 </html>
```

Fig. 14.6 | Creating shadows on a canvas. (Part 2 of 3.)



Fig. 14.6 | Creating shadows on a canvas. (Part 3 of 3.)

14.6 Shadows (cont.)

- ▶ For the second rectangle, we create a shadow that shifts *above* and to the *left* of the rectangle.
- ▶ Notice that the shadowBlur is 20. The effect is a shadow on which the edges appear more blurred than on the shadow of the first rectangle.
- ▶ Next, we specify the shadowOffsetX, setting its value to -20. Using a *negative* shadowOffsetX moves the shadow to the *left* of the rectangle.
- ▶ We then specify the shadowOffsetY attribute, setting its value to -20. Using a *negative* shadowOffsetY moves the shadow *up* from the rectangle.

14.7 Quadratic Curves

- ▶ Figure 14.7 demonstrates how to draw a rounded rectangle using lines to draw the straight sides and **quadratic curves** to draw the rounded corners.
- ▶ Quadratic curves have a starting point, an ending point and a *single* point of inflection.
- ▶ The **quadraticCurveTo** method uses four arguments.
 - The first two, *cpx* and *cpy*, are the coordinates of the *control point*—the point of the curve's inflection.
 - The third and fourth arguments, *x* and *y*, are the coordinates of the *ending point*.
 - The *starting point* is the last subpath destination, specified using the `moveTo` or `lineTo` methods.
- ▶ For example, if we write
 - `context.moveTo(5, 100);`
`context.quadraticCurveTo(25, 5, 95, 50);`
- ▶ the curve starts at (5, 100), curves at (25, 5) and ends at (95, 50).

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.7: roundedrectangle.html -->
4 <!-- Drawing a rounded rectangle on a canvas. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Quadratic Curves</title>
9   </head>
10  <body>
11    <canvas id = "drawRoundedRect" width = "130" height = "130"
12      style = "border: 1px solid black;">
13    </canvas>
14    <script>
15      var canvas = document.getElementById("drawRoundedRect");
16      var context = canvas.getContext("2d")
17      context.beginPath();
18      context.moveTo(15, 5);
19      context.lineTo(95, 5);
20      context.quadraticCurveTo(105, 5, 105, 15);
21      context.lineTo(105, 95);
22      context.quadraticCurveTo(105, 105, 95, 105);
23      context.lineTo(15, 105);
24      context.quadraticCurveTo(5, 105, 5, 95);
```

Fig. 14.7 | Drawing a rounded rectangle on a canvas. (Part 1 of 2.)

```
25     context.lineTo(5, 15);
26     context.quadraticCurveTo(5, 5, 15, 5);
27     context.closePath();
28     context.fillStyle = "yellow";
29     context.fill(); //fill with the fillStyle color
30     context.strokeStyle = "royalblue";
31     context.lineWidth = 6;
32     context.stroke(); //draw 6-pixel royalblue border
33 </script>
34 </body>
35 </html>
```

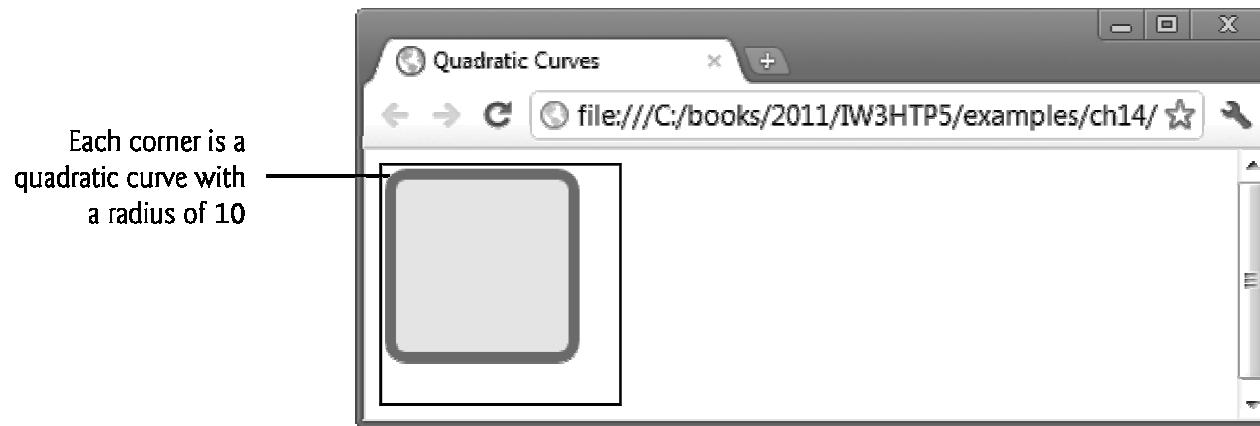


Fig. 14.7 | Drawing a rounded rectangle on a canvas. (Part 2 of 2.)

14.8 Bezier Curves

- ▶ Bezier curves have a starting point, an ending point and *two* control points through which the curve passes.
- ▶ These can be used to draw curves with one or two points of inflection, depending on the coordinates of the four points.
- ▶ For example, you might use a Bezier curve to draw complex shapes with *s*-shaped curves.
- ▶ The `bezierCurveTo` method uses six arguments.
 - The first two arguments, `cp1x` and `cp1y`, are the coordinates of the first control point.
 - The third and fourth arguments, `cp2x` and `cp2y`, are the coordinates for the second control point.
 - Finally, the fifth and sixth arguments, `x` and `y`, are the coordinates of the ending point.
- ▶ The starting point is the last subpath destination, specified using either the `moveTo` or `lineTo` method.
- ▶ Figure 14.8 demonstrates how to draw an *s*-shaped Bezier curve using the `bezierCurveTo` method.

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.8: beziercurves.html -->
4 <!-- Drawing a Bezier curve on a canvas. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Bezier Curves</title>
9   </head>
10  <body>
11    <canvas id = "drawBeziers" width = "150" height = "150"
12      style = "border: 1px solid black;">
13    </canvas>
14    <script>
15      var canvas = document.getElementById("drawBeziers");
16      var context = canvas.getContext("2d")
17      context.beginPath();
18      context.moveTo(115, 20);
19      context.bezierCurveTo(12, 37, 176, 77, 32, 133);
20      context.lineWidth = 10;
21      context.strokeStyle = "red";
22      context.stroke();
23    </script>
24  </body>
25 </html>
```

Fig. 14.8 | Drawing a Bezier curve on a canvas. (Part 1 of 2.)

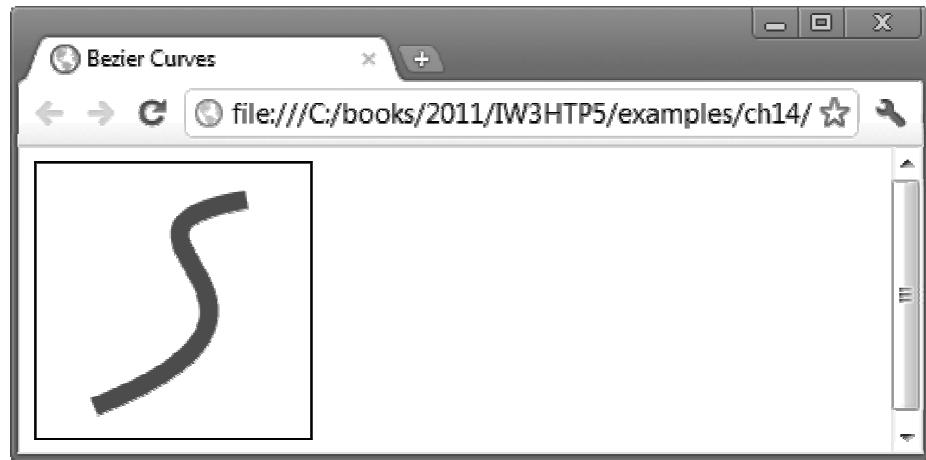


Fig. 14.8 | Drawing a Bezier curve on a canvas. (Part 2 of 2.)

14.9 Linear Gradients

- ▶ Figure 14.9 fills three separate canvases with linear gradients—vertical, horizontal and diagonal.
- ▶ On the first canvas, we draw a *vertical* gradient. We use the `createLinearGradient` method
 - the first two arguments are the x - and y -coordinates of the gradient's start, and the last two are the x - and y -coordinates of the end.
 - The start and end have the *same* x -coordinates but *different* y -coordinates, so the start of the gradient is a point at the top of the canvas directly above the point at the end of the gradient at the bottom.
- ▶ This creates a vertical linear gradient that starts at the top and changes as the gradient moves to the bottom of the canvas.

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.9: lineargradient.html -->
4 <!-- Drawing linear gradients on a canvas. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Linear Gradients</title>
9   </head>
10  <body>
11
12    <!-- vertical linear gradient -->
13    <canvas id = "linearGradient" width = "200" height = "200"
14      style = "border: 1px solid black;">
15    </canvas>
16    <script>
17      var canvas = document.getElementById("linearGradient");
18      var context = canvas.getContext("2d");
19      var gradient = context.createLinearGradient(0, 0, 0, 200);
20      gradient.addColorStop(0, "white");
21      gradient.addColorStop(0.5, "lightsteelblue");
22      gradient.addColorStop(1, "navy");
23      context.fillStyle = gradient;
24      context.fillRect(0, 0, 200, 200);
25    </script>
```

Fig. 14.9 | Drawing linear gradients on a canvas. (Part 1 of 4.)

```
26
27    <!-- horizontal linear gradient -->
28    <canvas id = "linearGradient2" width = "200" height = "200"
29        style = "border: 2px solid orange;">
30    </canvas>
31    <script>
32        var canvas = document.getElementById("linearGradient2");
33        var context = canvas.getContext("2d");
34        var gradient = context.createLinearGradient(0, 0, 200, 0);
35        gradient.addColorStop(0, "white");
36        gradient.addColorStop(0.5, "yellow");
37        gradient.addColorStop(1, "orange");
38        context.fillStyle = gradient;
39        context.fillRect(0, 0, 200, 200);
40    </script>
41
42    <!-- diagonal linear gradient -->
43    <canvas id = "linearGradient3" width = "200" height = "200"
44        style = "border: 2px solid purple;">
45    </canvas>
46    <script>
47        var canvas = document.getElementById("linearGradient3");
48        var context = canvas.getContext("2d");
49        var gradient = context.createLinearGradient(0, 0, 45, 200);
50        gradient.addColorStop(0, "white");
```

Fig. 14.9 | Drawing linear gradients on a canvas. (Part 2 of 4.)

```
51         gradient.addColorStop(0.5, "plum");
52         gradient.addColorStop(1, "purple");
53         context.fillStyle = gradient;
54         context.fillRect(0, 0, 200, 200);
55     </script>
56 </body>
57 </html>
```

Fig. 14.9 | Drawing linear gradients on a canvas. (Part 3 of 4.)



Gradient changes vertically
from white to light steel blue
to navy

Gradient changes
horizontally from white to
yellow to orange

Gradient changes diagonally
from white to plum to purple

Fig. 14.9 | Drawing linear gradients on a canvas. (Part 4 of 4.)

14.9 Linear Gradients (cont.)

- ▶ We use the `addColorStop` method to add three *color stops*.
 - Each color stop has a positive value between 0 (the start of the gradient) and 1 (the end of the gradient).
 - For each color stop, we specify a color.
- ▶ The `fillStyle` method specifies a gradient and then the `fillRect` method draws the gradient on the canvas.

14.9 Linear Gradients (cont.)

- ▶ On the second canvas, we draw a *horizontal* gradient.
- ▶ We use the `createLinearGradient` method where the first two arguments are $(0, 0)$ for the start of the gradient and $(200, 0)$ for the end.
- ▶ In this case, the start and end have *different x-coordinates* but the *same y-coordinates*, horizontally aligning the start and end. This creates a horizontal linear gradient.

14.9 Linear Gradients (cont.)

- ▶ On the third canvas, we draw a *diagonal* gradient.
- ▶ Using the `createLinearGradient` method, the first two arguments are $(0, 0)$ —the coordinates of the starting position of the gradient in the top left of the canvas.
- ▶ The last two arguments are $(135, 200)$ —the ending position of the gradient.
- ▶ This creates a diagonal linear gradient that starts at the top left and changes at an angle as the gradient moves to the right edge of the canvas.

14.10 Radial Gradients

- ▶ Fig. 14.10 shows how to create *radial* gradients on a canvas.
- ▶ A radial gradient is comprised of two circles—an *inner circle* where the gradient starts and an *outer circle* where it ends.
- ▶ We use the `createRadialGradient` method whose first three arguments are the *x*- and *y*-coordinates and the radius of the gradient's start circle, respectively, and whose last three arguments are the *x*- and *y*-coordinates and the radius of the end circle.
- ▶ The first radial gradient has *concentric* circles—they have the *same* *x*- and *y*-coordinates but each has a *different* radius, creating a radial gradient that starts in a common center and changes as it moves outward.

14.10 Radial Gradients

- ▶ On the second canvas, the start and end circles have *different* x - and y -coordinates, altering the effect.
- ▶ These are *not* concentric circles. The start circle of the gradient is near the bottom left of the canvas and the end circle is centered on the canvas.
- ▶ This creates a radial gradient that starts near the bottom left of the canvas and changes as it moves to the right.

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.10: radialgradient.html -->
4 <!-- Drawing radial gradients on a canvas. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Radial Gradients</title>
9   </head>
10  <body>
11    <!-- radial gradient with concentric circles -->
12    <canvas id = "radialGradient" width = "200" height = "200"
13      style = "border: 1px solid black;">
14    </canvas>
15    <script>
16      var canvas = document.getElementById("radialGradient");
17      var context = canvas.getContext("2d")
18      var gradient = context.createRadialGradient(
19        100, 100, 10, 100, 100, 125);
20      gradient.addColorStop(0, "white");
21      gradient.addColorStop(0.5, "yellow");
22      gradient.addColorStop(0.75, "orange");
23      gradient.addColorStop(1, "red");
```

Fig. 14.10 | Drawing radial gradients on a canvas. (Part 1 of 3.)

```
24         context.fillStyle = gradient;
25         context.fillRect(0, 0, 200, 200);
26     </script>
27
28     <!-- radial gradient with nonconcentric circles -->
29     <canvas id = "radialGradient2" width = "200" height = "200"
30         style = "border: 1px solid black;">
31     </canvas>
32     <script>
33         var canvas = document.getElementById("radialGradient2");
34         var context = canvas.getContext("2d")
35         var gradient = context.createRadialGradient(
36             20, 150, 10, 100, 100, 125);
37         gradient.addColorStop(0, "red");
38         gradient.addColorStop(0.5, "orange");
39         gradient.addColorStop(0.75, "yellow");
40         gradient.addColorStop(1, "white");
41         context.fillStyle = gradient;
42         context.fillRect(0, 0, 200, 200);
43     </script>
44     </body>
45 </html>
```

Fig. 14.10 | Drawing radial gradients on a canvas. (Part 2 of 3.)



Fig. 14.10 | Drawing radial gradients on a canvas. (Part 3 of 3.)

14.11 Images

- ▶ Figure 14.11 uses the `drawImage` method to draw an image to a canvas.
- ▶ We create a new `Image` object and store it in the variable `image`.
- ▶ Function `draw` is called to draw the image after the document and all of its resources load.
- ▶ The `drawImage` method draws the image to the canvas using five arguments.
 - The first argument can be an `image`, `canvas` or `video` element.
 - The second and third arguments are the destination *x*- and destination *y*-coordinates—these indicate the position of the top-left corner of the image on the canvas.
 - The fourth and fifth arguments are the *destination width* and *destination height*.
- ▶ If the values do not match the size of the image, it will be *stretched* to fit.

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.11: image.html -->
4 <!-- Drawing an image to a canvas. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Images</title>
9     <script>
10       var image = new Image();
11       image.src = "yellowflowers.png";
12
13       function draw()
14     {
15         var canvas = document.getElementById("myimage");
16         var context = canvas.getContext("2d")
17         context.drawImage(image, 0, 0, 175, 175);
18     } // end function draw
19
20     window.addEventListener( "load", draw, false );
21   </script>
22 </head>
```

Fig. 14.11 | Drawing an image to a canvas. (Part 1 of 2.)

```
23    <body>
24        <canvas id = "myimage" width = "200" height = "200"
25            style = "border: 1px solid Black;">
26        </canvas>
27    </body>
28 </html>
```

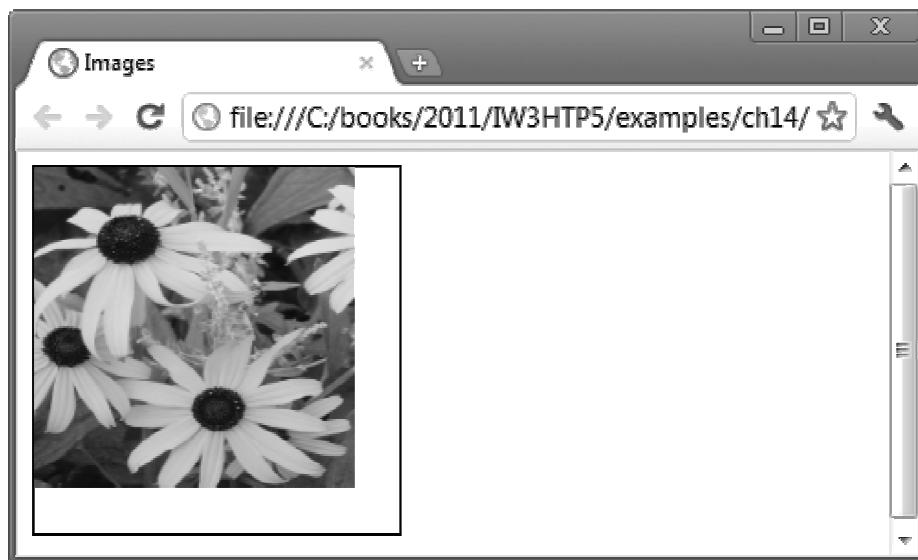


Fig. 14.11 | Drawing an image to a canvas. (Part 2 of 2.)

14.11 Images (cont.)

- ▶ Note that you can call `drawImage` in three ways. In its simplest form, you can use
 - `context.drawImage(image, dx, dy)`
- ▶ where *dx* and *dy* represent the position of the top-left corner of the image on the destination canvas.
- ▶ The default width and height are the source image's width and height.
- ▶ Or, as we did in this example, you can use
 - `context.drawImage(image, dx, dy, dw, dh)`
- ▶ where *dw* is the specified width of the image on the destination canvas and *dh* is the specified height of the image on the destination canvas.
- ▶ Finally, you can use
 - `context.drawImage(image, sx, sy, sw, sh, dx, dy, dw, dh)`
- ▶ where *sx* and *sy* are the coordinates of the top-left corner of the source image, *sw* is the source image's width and *sh* its height.

14.12 Image Manipulation: Processing the Individual Pixels of a canvas

- ▶ Figure 14.12 shows how to obtain a canvas's pixels and manipulate their red, green, blue and alpha (RGBA) values.
- ▶ For security reasons, some browsers allow a script to get an image's pixels only if the document is requested from a web server.
- ▶ For this reason, you can test this example at
 - http://test.deitel.com/iw3htp5/ch14/fig14_12/imagemanipulation.html
- ▶ You can change the RGBA values with the input elements of type range defined in the body.
- ▶ You can adjust the amount of red, green or blue from 0 to 500% of its original value—on a pixel-by-pixel basis, we calculate the new amount of red, green or blue accordingly.
- ▶ For the alpha, you can adjust the value from 0 (completely transparent) to 255 (completely opaque).
- ▶ The script begins when the window's load event calls function start.

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.12: imagemanipulation.html -->
4 <!-- Manipulating an image's pixels to change colors and transparency. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Manipulating an Image</title>
9     <style>
10       label { display: inline-block; width: 3em; }
11       canvas { border: 1px solid black; }
12       input[type="range"] { width: 600px; }
13     </style>
14     <script>
15       var context; // context for drawing on canvas
16       var redRange; // % of original red pixel value
17       var greenRange; // % of original green pixel value
18       var blueRange; // % of original blue pixel value
19       var alphaRange; // alpha amount value
20
21       var image = new Image(); // image object to store loaded image
22       image.src = "redflowers.png"; // set the image source
23
```

Fig. 14.12 | Manipulating an image's pixels to change colors and transparency. (Part 1 of 8.)

```
24     function start()
25     {
26         var canvas = document.getElementById( "thecanvas" );
27         context = canvas.getContext("2d")
28         context.drawImage(image, 0, 0); // original image
29         context.drawImage(image, 250, 0); // image for user change
30         processGrayscale(); // display grayscale of original image
31
32         // configure GUI events
33         redRange = document.getElementById( "redRange" );
34         redRange.addEventListener( "change",
35             function() { processImage( this.value, greenRange.value,
36                 blueRange.value ); }, false );
37         greenRange = document.getElementById( "greenRange" );
38         greenRange.addEventListener( "change",
39             function() { processImage( redRange.value, this.value,
40                 blueRange.value ); }, false )
41         blueRange = document.getElementById( "blueRange" );
42         blueRange.addEventListener( "change",
43             function() { processImage( redRange.value,
44                 greenRange.value, this.value ); }, false )
```

Fig. 14.12 | Manipulating an image's pixels to change colors and transparency. (Part 2 of 8.)

```
45     alphaRange = document.getElementById( "alphaRange" );
46     alphaRange.addEventListener( "change",
47         function() { processAlpha( this.value ); }, false )
48     document.getElementById( "resetButton" ).addEventListener(
49         "click", resetImage, false );
50 } // end function start
51
52 // sets the alpha value for every pixel
53 function processAlpha( newValue )
{
54     // get the ImageData object representing canvas's content
55     var imageData = context.getImageData(0, 0, 250, 250);
56     var pixels = imageData.data; // pixel info from ImageData
57
58     // convert every pixel to grayscale
59     for ( var i = 3; i < pixels.length; i += 4 )
60     {
61         pixels[ i ] = newValue;
62     } // end for
63
64     context.putImageData( imageData, 250, 0 ); // show grayscale
65 } // end function processImage
66
67
```

Fig. 14.12 | Manipulating an image's pixels to change colors and transparency. (Part 3 of 8.)

```
68     // sets the RGB values for every pixel
69     function processImage( redPercent, greenPercent, bluePercent )
70     {
71         // get the ImageData object representing canvas's content
72         context.drawImage(image, 250, 0);
73         var imageData = context.getImageData(0, 0, 250, 250);
74         var pixels = imageData.data; // pixel info from ImageData
75
76         //set percentages of red, green and blue in each pixel
77         for ( var i = 0; i < pixels.length; i += 4 )
78         {
79             pixels[ i ] *= redPercent / 100;
80             pixels[ i + 1 ] *= greenPercent / 100;
81             pixels[ i + 2 ] *= bluePercent / 100;
82         } // end for
83
84         context.putImageData( imageData, 250, 0 ); // show grayscale
85     } // end function processImage
86
```

Fig. 14.12 | Manipulating an image's pixels to change colors and transparency. (Part 4 of 8.)

```
87      // creates grayscale version of original image
88      function processGrayscale()
89      {
90          // get the ImageData object representing canvas's content
91          context.drawImage(image, 500, 0);
92          var imageData = context.getImageData(0, 0, 250, 250);
93          var pixels = imageData.data; // pixel info from ImageData
94
95          // convert every pixel to grayscale
96          for ( var i = 0; i < pixels.length; i += 4 )
97          {
98              var average =
99                  (pixels[ i ] * 0.30 + pixels[ i + 1 ] * 0.59 +
100                     pixels[ i + 2 ] * 0.11).toFixed(0);
101
102              pixels[ i ] = average;
103              pixels[ i + 1 ] = average;
104              pixels[ i + 2 ] = average;
105          } // end for
106
107          context.putImageData( imageData, 500, 0 ); // show grayscale
108      } // end function processGrayscale
109
```

Fig. 14.12 | Manipulating an image's pixels to change colors and transparency. (Part 5 of 8.)

```

110     // resets the user manipulated image and the sliders
111     function resetImage()
112     {
113         context.drawImage(image, 250, 0);
114         redRange.value = 100;
115         greenRange.value = 100;
116         blueRange.value = 100;
117         alphaRange.value = 255;
118     } // end function resetImage
119
120     window.addEventListener( "load", start, false );
121 </script>
122 </head>
123 <body>
124     <canvas id = "thecanvas" width = "750" height = "250" ></canvas>
125     <p><label>Red:</label> 0 <input id = "redRange"
126         type = "range" max = "500" value = "100"> 500%</p>
127     <p><label>Green:</label> 0 <input id = "greenRange"
128         type = "range" max = "500" value = "100"> 500%</p>
129     <p><label>Blue:</label> 0 <input id = "blueRange"
130         type = "range" max = "500" value = "100"> 500%</p>
131     <p><label>Alpha:</label> 0 <input id = "alphaRange"
132         type = "range" max = "255" value = "255"> 255</p>

```

Fig. 14.12 | Manipulating an image's pixels to change colors and transparency. (Part 6 of 8.)

```
I33      <p><input id = "resetButton" type = "button"  
I34          value = "Reset Image">  
I35      </body>  
I36  </html>
```

Fig. 14.12 | Manipulating an image's pixels to change colors and transparency. (Part 7 of 8.)

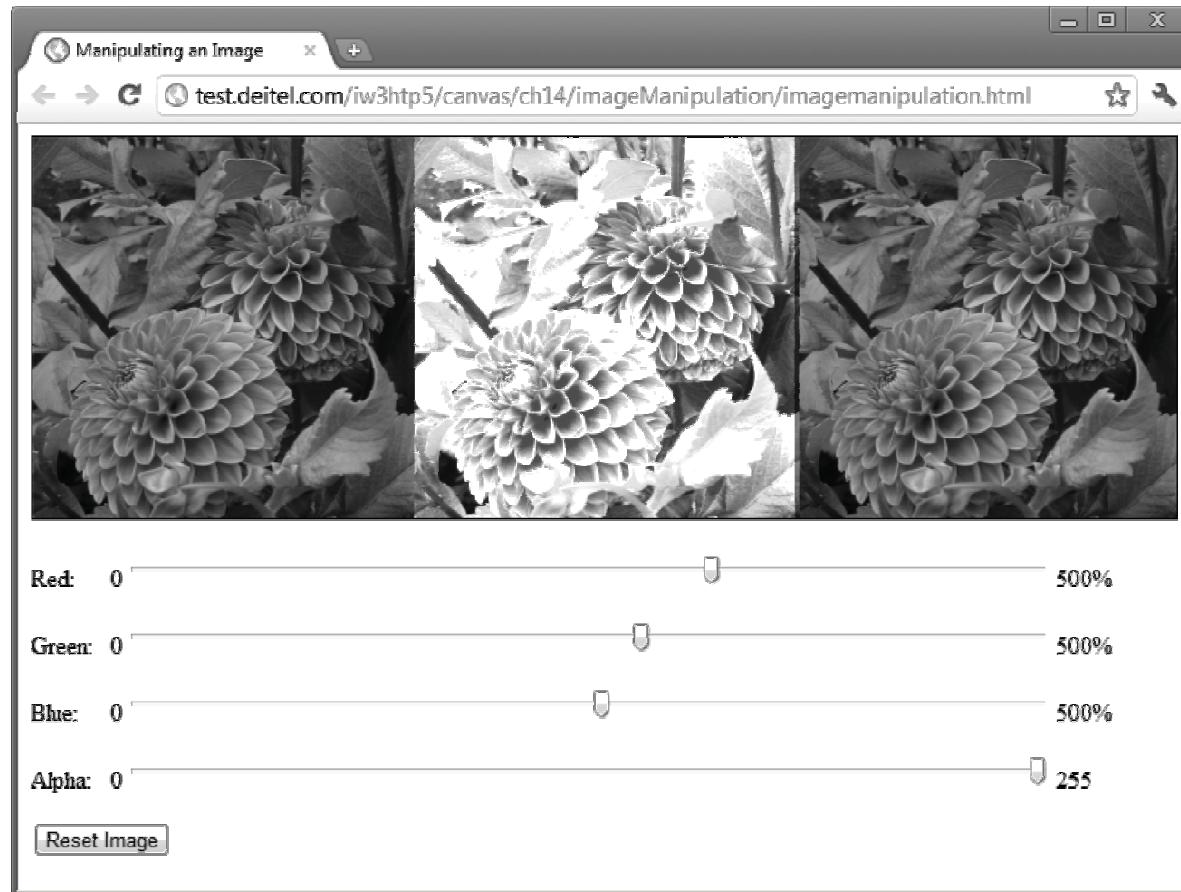


Fig. 14.12 | Manipulating an image's pixels to change colors and transparency. (Part 8 of 8.)

14.12 Image Manipulation: Processing the Individual Pixels of a canvas (cont.)

Script-Level Variables and Loading the Original Image

- ▶ Variables redRange, greenRange, blueRange and alphaRange will refer to the four range inputs so that we can easily access their values in the script's other functions.
- ▶ Variable image represents the original image to draw.
- ▶ Next, create an Image object and use it to load the image redflower.png, which is provided with the example.

14.12 Image Manipulation: Processing the Individual Pixels of a canvas (cont.)

Function start

- ▶ Draw the original image twice—once in the upper-left corner of the canvas and once 250 pixels to the right.
- ▶ Call function `processGrayscale` to create the grayscale version of the image which will appear at x -coordinate 500.
- ▶ Get the range `input` elements and register their event handlers.
- ▶ For the `redRange`, `greenRange` and `blueRange` elements, we register for the `change` event and call `processImage` with the values of these three range inputs.
- ▶ For the `alphaRange` elements we register for the `change` event and call `processAlpha` with the value of that range input.

14.12 Image Manipulation: Processing the Individual Pixels of a canvas (cont.)

Function processAlpha

- ▶ Function `processAlpha` applies the new alpha value to every pixel in the image.
- ▶ Call canvas method `getImageData` to obtain an object that contains the pixels we wish to manipulate.
- ▶ The method receives a bounding rectangle representing the portion of the canvas to get—in this case, a 250-pixel square from the upper-left corner.
- ▶ The returned object contains an array named `data` which stores every pixel in the selected rectangular area as four elements in the array.
- ▶ Each pixel's data is stored in the order red value, green value, blue value, alpha value.

14.12 Image Manipulation: Processing the Individual Pixels of a canvas (cont.)

- ▶ So, the first four elements in the array represent the RGBA values of the pixel in row 0 and column 0, the next four elements represent the pixel in row 0 and column 1, etc.
- ▶ We then iterate through the array processing every fourth element, which represents the alpha value in each pixel, and assigning it the new alpha value.
- ▶ canvas method `putImageData` places the updated pixels on the canvas with the upper-left corner of the processed image at location 250, 0.

14.12 Image Manipulation: Processing the Individual Pixels of a canvas (cont.)

Function processImage

- ▶ Function `processImage` is similar to function `processAlpha` except that its loop processes the first three of every four elements—that is, the ones that represent a pixel's RGB values.

Function processGrayscale

- ▶ Function `processGrayscale` is similar to function `processImage` except that its loop performs a weighted-average calculation to determine the new value assigned to the red, green and blue components of a given pixel.
- ▶ We used the formula for converting from RGB to grayscale provided at <http://en.wikipedia.org/wiki/Grayscale>.

Function resetImage

- ▶ Function `resetImage` resets the on-screen images and the range input elements to their original values.

14.13 Patterns

- ▶ Figure 14.13 demonstrates how to draw a *pattern* on a canvas.
- ▶ Create and load the image we'll use for our pattern.
- ▶ Function `start` is called in response to the window's `load` event.
- ▶ The [createPattern method](#) creates the pattern.
- ▶ The first argument is the image we're using for the pattern, which can be an `image` element, a `canvas` element or a `video` element.
- ▶ The second argument specifies how the image will repeat to create the pattern and can be one of four values—`repeat` (repeats horizontally and vertically), `repeat-x` (repeats horizontally), `repeat-y` (repeats vertically) or `no-repeat`.
- ▶ Specify the coordinates for the pattern on the canvas.
- ▶ Then specify the `fillStyle` attribute (`pattern`) and use the `fill` method to draw the pattern to the canvas.

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.13: pattern.html -->
4 <!-- Creating a pattern using an image on a canvas. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Patterns</title>
9     <script>
10       var image = new Image();
11       image.src = "yellowflowers.png";
12
13       function start()
14     {
15         var canvas = document.getElementById("pattern");
16         var context = canvas.getContext("2d");
17         var pattern = context.createPattern(image, "repeat");
18         context.rect(5, 5, 385, 200);
19         context.fillStyle = pattern;
20         context.fill();
21     } // end function start
22
23     window.addEventListener( "load", start, false );
24   </script>
25 </head>
```

Fig. 14.13 | Creating a pattern using an image on a canvas. (Part 1 of 2.)

```
26    <body>
27        <canvas id = "pattern" width = "400" height = "200"
28            style = "border: 1px solid black;">
29        </canvas>
30    </body>
31 </html>
```



Fig. 14.13 | Creating a pattern using an image on a canvas. (Part 2 of 2.)

14.14 Transformations

- ▶ The next several examples show you how to use canvas transformation methods including translate, scale, rotate and transform.

14.14.1 `scale` and `translate` Methods: Drawing Ellipses

- ▶ Figure 14.14 demonstrates how to draw ellipses.
- ▶ We change the *transformation matrix* (the coordinates) on the canvas using the `translate method` so that the *center* of the canvas becomes the origin (0, 0).
- ▶ To do this, we use half the canvas width as the *x*-coordinate and half the canvas height as the *y*-coordinate.
- ▶ This will enable us to center the ellipse on the canvas.
- ▶ We then use the `scale method` to *stretch* a circle to create an ellipse.
 - The *x* value represents the *horizontal scale factor*, the *y* value represents the *vertical scale factor*—in this case, our scale factor indicates that the ratio of the width to the height is 1:3, which will create a tall, thin ellipse.
- ▶ Next, we draw the circle that we want to stretch using the `beginPath` method to start the path, then the `arc` method to draw the circle.
- ▶ The *x*- and *y*-coordinates for the center of the circle are (0, 0), which is now the *center* of the canvas (*not* the top-left corner).

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.14: ellipse.html -->
4 <!-- Drawing an ellipse on a canvas. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Ellipse</title>
9   </head>
10  <body>
11    <!-- vertical ellipse -->
12    <canvas id = "drawEllipse" width = "200" height = "200"
13      style = "border: 1px solid black;">
14    </canvas>
15    <script>
16      var canvas = document.getElementById("drawEllipse");
17      var context = canvas.getContext("2d")
18      context.translate(canvas.width / 2, canvas.height / 2);
19      context.scale(1, 3);
20      context.beginPath();
21      context.arc(0, 0, 30, 0, 2 * Math.PI, true);
22      context.fillStyle = "orange";
23      context.fill();
24    </script>
```

Fig. 14.14 | Drawing an ellipse on a canvas. (Part 1 of 3.)

```
25
26    <!-- horizontal ellipse -->
27    <canvas id = "drawEllipse2" width = "200" height = "200"
28        style = "border: 1px solid black;">
29    </canvas>
30    <script>
31        var canvas = document.getElementById("drawEllipse2");
32        var context = canvas.getContext("2d")
33        context.translate(canvas.width / 2, canvas.height / 2);
34        context.scale(3, 2);
35        context.beginPath();
36        context.arc(0, 0, 30, 0, 2 * Math.PI, true);
37        context.fillStyle = "indigo";
38        context.fill();
39    </script>
40    </body>
41 </html>
```

Fig. 14.14 | Drawing an ellipse on a canvas. (Part 2 of 3.)

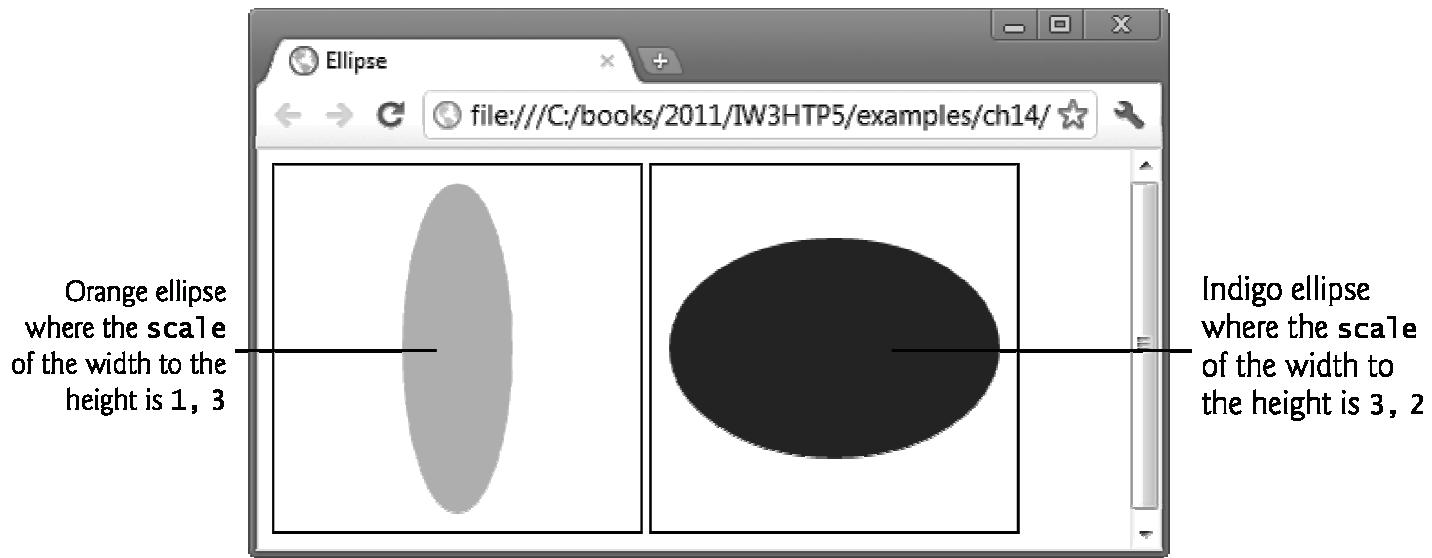


Fig. 14.14 | Drawing an ellipse on a canvas. (Part 3 of 3.)

14.14.1 `scale` and `translate` Methods: Drawing Ellipses (cont.)

- ▶ Next, we create a horizontal purple ellipse on a separate canvas.
- ▶ We use a scale of 3, 2, indicating that the ratio of the width to the height is 3:2.

14.14.2 `rotate` Method: Creating an Animation

- ▶ Figure 14.15 uses the `rotate` method to create an animation of a rotating rectangle on a canvas.
- ▶ First, we create the JavaScript function `startRotating`.
- ▶ We change the transformation matrix on the canvas using the `translate` method, making the center of the canvas the origin with the x, y values $(0, 0)$. This allows us to rotate the rectangle (which is centered on the canvas) around its center.

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.15: rotate.html -->
4 <!-- Using the rotate method to rotate a rectangle on a canvas. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Rotate</title>
9   </head>
10  <body>
11    <canvas id = "rotateRectangle" width = "200" height = "200"
12      style = "border: 1px solid black;">
13    </canvas>
14    <script>
15      var canvas = document.getElementById("rotateRectangle");
16      var context = canvas.getContext("2d")
17
18      function startRotating()
19      {
20          context.translate(canvas.width / 2, canvas.height / 2);
21          setInterval(rotate, 10);
22      }
23
```

Fig. 14.15 | Using the `rotate` method to rotate a rectangle on a canvas. (Part 1 of 3.)

```
24         function rotate()
25     {
26         context.clearRect(-100, -100, 200, 200);
27         context.rotate(Math.PI / 360);
28         context.fillStyle = "lime";
29         context.fillRect(-50, -50, 100, 100);
30     }
31
32     window.addEventListener( "load", startRotating, false );
33 </script>
34 </body>
35 </html>
```

Fig. 14.15 | Using the `rotate` method to rotate a rectangle on a canvas. (Part 2 of 3.)

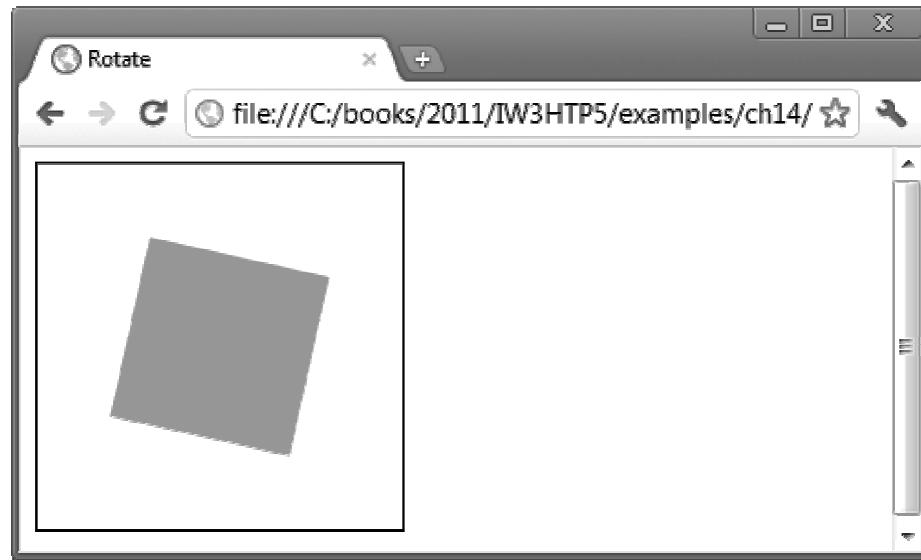


Fig. 14.15 | Using the rotate method to rotate a rectangle on a canvas. (Part 3 of 3.)

14.14.2 rotate Method: Creating an Animation (cont.)

- ▶ We use the `setInterval` method of the `window` object. The first argument is the name of the function to call (`rotate`) and the second is the number of milliseconds between calls.
- ▶ Next, we create the JavaScript function `rotate`.
- ▶ We use the **clearRect method** to clear the rectangle's pixels from the canvas, converting them back to transparent as the rectangle rotates. This method takes four arguments—`x`, `y`, `width` and `height`.
- ▶ Next, the `rotate` method takes one argument—the angle of the clockwise rotation, expressed in radians.

14.14.3 transform Method: Drawing Skewed Rectangles

- ▶ The **transform method** allows you to skew, scale, rotate and translate elements without using the separate transformation methods discussed earlier in this section.
- ▶ The transform method takes six arguments in the format (a, b, c, d, e, f).
- ▶ The first argument, a , is the x -scale—the factor by which to scale the element horizontally.
- ▶ The second argument, b , is the y -skew.
- ▶ The third argument, c , is the x -skew.
- ▶ The fourth argument, d , is the y -scale—the factor by which to scale the element vertically.
- ▶ The fifth argument, e , is the x -translation and the sixth argument, f , is the y -translation.
- ▶ The default x - and y -scale values are 1. The default values of the x - and y -skew and the x - and y -translation are 0, meaning there is no skew or translation.

14.14.3 transform Method: Drawing Skewed Rectangles (cont.)

- ▶ Figure 14.16 uses the transform method to *skew*, *scale* and *translate* two rectangles.
- ▶ On the first canvas (lines 12–32), we declare the variable rectangleWidth and assign it the value 120, and declare the variable rectangleHeight and assign it the value 60 (lines 18–19).

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.16: skew.html -->
4 <!-- Using the translate and transform methods to skew rectangles. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Skew</title>
9   </head>
10  <body>
11    <!-- skew left -->
12    <canvas id = "transform" width = "320" height = "150"
13      style = "border: 1px solid Black;">
14    </canvas>
15    <script>
16      var canvas = document.getElementById("transform");
17      var context = canvas.getContext("2d");
18      var rectangleWidth = 120;
19      var rectangleHeight = 60;
20      var scaleX = 2;
21      var skewY = 0;
22      var skewX = 1;
23      var scaleY = 1;
```

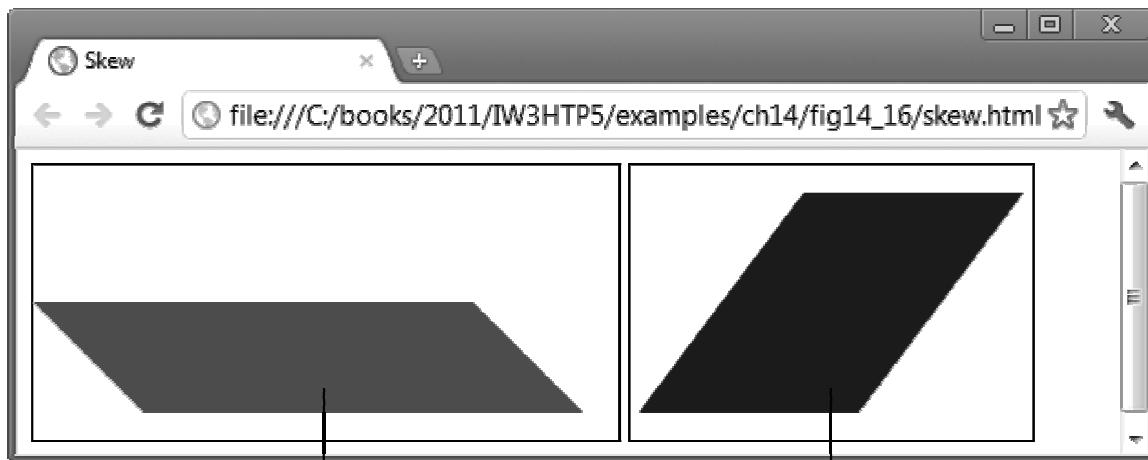
Fig. 14.16 | Using the translate and transform methods to skew rectangles. (Part 1 of 4.)

```
24     var translationX = -10;
25     var translationY = 30;
26     context.translate(canvas.width / 2, canvas.height / 2);
27     context.transform(scaleX, skewY, skewX, scaleY,
28         translationX, translationY);
29     context.fillStyle = "red";
30     context.fillRect(-rectangleWidth / 2, -rectangleHeight / 2,
31         rectangleWidth, rectangleHeight);
32 </script>
33
34 <!-- skew right -->
35 <canvas id = "transform2" width = "220" height = "150"
36     style = "border: 1px solid Black;">
37 <script>
38     var canvas = document.getElementById("transform2");
39     var context = canvas.getContext("2d");
40     var rectangleWidth = 120;
41     var rectangleHeight = 60;
42     var scaleX = 1;
43     var skewY = 0;
44     var skewX = -1.5;
45     var scaleY = 2;
46     var translationX = 0;
```

Fig. 14.16 | Using the `translate` and `transform` methods to skew rectangles. (Part 2 of 4.)

```
47     var translationY = 0;
48     context.translate(canvas.width / 2, canvas.height / 2);
49     context.transform(scaleX, skewY, skewX, scaleY,
50         translationX, translationY);
51     context.fillStyle = "blue";
52     context.fillRect(-rectangleWidth / 2, -rectangleHeight / 2,
53         rectangleWidth, rectangleHeight);
54   </script>
55 </body>
56 </html>
```

Fig. 14.16 | Using the `translate` and `transform` methods to skew rectangles. (Part 3 of 4.)



Red rectangle skewed left, scaled horizontally and translated to the left and down from the canvas's point of origin

Blue rectangle skewed right and scaled vertically

Fig. 14.16 | Using the translate and transform methods to skew rectangles. (Part 4 of 4.)

14.15 Text

- ▶ Figure 14.17 shows you how to draw text on a canvas.
- ▶ We use the **font attribute** to specify the style, size and font of the text.

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.17: text.html -->
4 <!-- Drawing text on a canvas. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Text</title>
9   </head>
10  <body>
11    <canvas id = "text" width = "230" height = "100"
12      style = "border: 1px solid black;">
13    </canvas>
14    <script>
15      var canvas = document.getElementById("text");
16      var context = canvas.getContext("2d")
17
18      // draw the first line of text
19      context.fillStyle = "red";
20      context.font = "italic 24px serif";
21      context.textBaseline = "top";
22      context.fillText ("HTML5 Canvas", 0, 0);
23
```

Fig. 14.17 | Drawing text on a canvas. (Part 1 of 2.)

```
24      // draw the second line of text
25      context.font = "bold 30px sans-serif";
26      context.textAlign = "center";
27      context.lineWidth = 2;
28      context.strokeStyle = "navy";
29      context.strokeText("HTML5 Canvas", 115, 50);
30  </script>
31  </body>
32 </html>
```

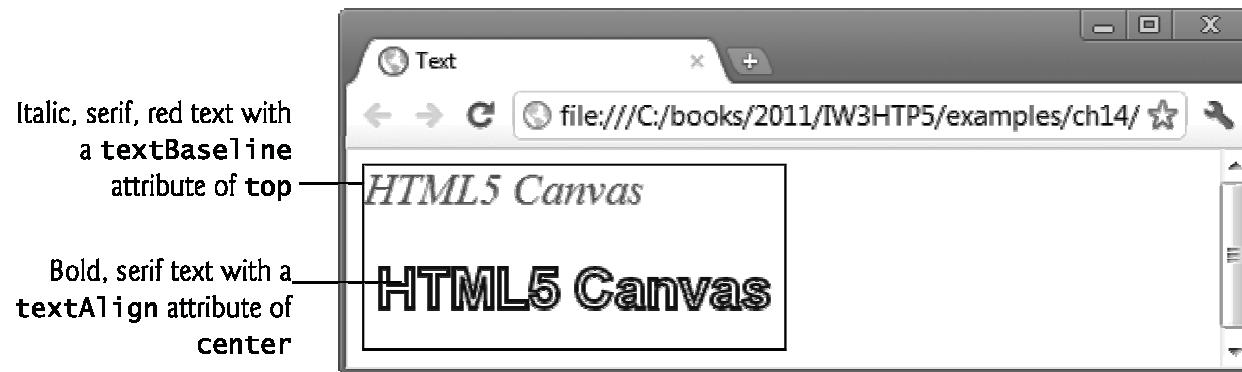


Fig. 14.17 | Drawing text on a canvas. (Part 2 of 2.)

14.15 Text (cont.)

- ▶ Next, we use **textBaseline** attribute to specify the alignment points of the text.
- ▶ There are six different **textBaseline** attribute values (Fig. 14.18).
- ▶ To see how each value aligns the font, see the graphic in the HTML5 canvas specification at
 - <http://www.whatwg.org/specs/web-apps/current-work/multipage/the-canvas-element.html#text-0>
- ▶

Value	Description
top	Top of the em square
hanging	Hanging baseline
middle	Middle of the em square
alphabetic	Alphabetic baseline (the default value)
ideographic	Ideographic baseline
bottom	Bottom of the em square

Fig. 14.18 | textBaseline values.

14.15 Text (cont.)

- ▶ The `fillText` method draws the text to the canvas. This method takes three arguments.
 - The first is the text being drawn to the canvas.
 - The second and third arguments are the x - and y -coordinates.
 - You may include the optional fourth argument, `maxWidth`, to limit the width of the text.
- ▶ We center the second line of text on the canvas using the `textAlign` attribute which specifies the horizontal alignment of the text relative to the x -coordinate of the text.
- ▶ Fig. 14.19 describes the `textAlign` attribute values.

Value	Description
left	Text is left aligned.
right	Text is right aligned.
center	Text is centered.
start (the default value)	Text is left aligned if the start of the line is left-to-right; text is right aligned if the start of the text is right-to-left.
end	Text is right aligned if the end of the line is left-to-right; text is left aligned if the end of the text is right-to-left.

Fig. 14.19 | textAlign attribute values.

14.15 Text (cont.)

- ▶ The `strokeStyle` specifies the color of the text.
- ▶ Finally, we use `strokeText` to specify the text being drawn to the canvas and its *x*- and *y*-coordinates .
- ▶ By using `strokeText` instead of `fillText`, we draw outlined text instead of filled text.
- ▶ Keep in mind that once text is on a canvas it's just bits—it can no longer be manipulated as text.

14.16 Resizing the canvas to Fill the Browser Window

- ▶ Figure 14.20 demonstrates how to dynamically resize a canvas to fill the window.

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.20: fillingwindow.html -->
4 <!-- Resizing a canvas to fill the window. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Filling the Window</title>
9     <style type = "text/css">
10       canvas { position: absolute; left: 0px; top: 0px;
11           width: 100%; height: 100%; }
12     </style>
13   </head>
14   <body>
15     <canvas id = "resize"></canvas>
```

Fig. 14.20 | Dynamically resizing a canvas to fill the window. (Part 1 of 3.)

```
16 <script>
17     function draw()
18     {
19         var canvas = document.getElementById( "resize" );
20         var context = canvas.getContext( "2d" );
21         context.fillStyle = "yellow";
22         context.fillRect(
23             0, 0, context.canvas.width, context.canvas.height );
24     } // end function draw
25
26     window.addEventListener( "load", draw, false );
27 </script>
28 </body>
29 </html>
```

Fig. 14.20 | Dynamically resizing a canvas to fill the window. (Part 2 of 3.)

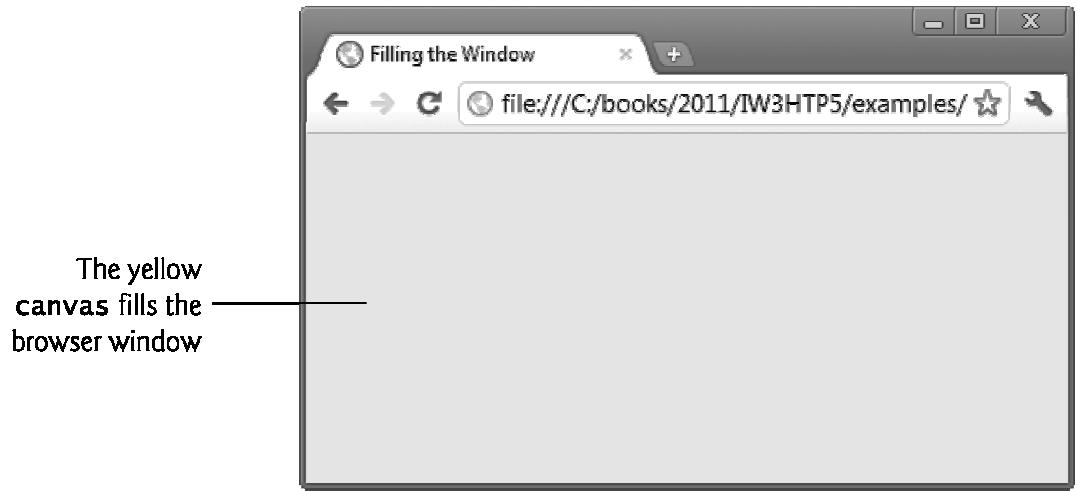


Fig. 14.20 | Dynamically resizing a canvas to fill the window. (Part 3 of 3.)

14.16 Resizing the canvas to Fill the Browser Window (cont.)

- ▶ Use a CSS style sheet to set the position of the canvas to absolute and set both its width and height to 100%, rather than using fixed coordinates.
- ▶ This places the canvas at the top left of the screen and allows the canvas width and height to be resized to 100% of those of the window.
- ▶ Do not include a border on the canvas.
- ▶ We use JavaScript function draw to draw the canvas when the application is rendered.

14.16 Resizing the canvas to Fill the Browser Window (cont.)

- ▶ `fillRect` draws the color to the canvas. Recall that in previous examples, the four coordinates we used for method `fillRect` were x , y , $x1$, $y1$, where $x1$ and $y1$ represent the coordinates of the bottom-right corner of the rectangle.
- ▶ In this example, the x - and y -coordinates are $(0, 0)$ —the top left of the canvas.

14.16 Resizing the canvas to Fill the Browser Window (cont.)

- ▶ The the x1 value is context.canvas.width and the y1 value is context.value.height, so no matter the size of the window, the x1 value will always be the width of the canvas and the y1 value will always be the height of the canvas.

14.17 Alpha Transparency

- ▶ In Fig. 14.21, the `globalAlpha` attribute is used to demonstrate three different alpha transparencies.
- ▶ The `globalAlpha` value can be any number between 0 (fully transparent) and 1 (the default value, which is fully opaque).
 - The first canvas has a `globalAlpha` attribute value of 0.9 to create a circle that's *mostly opaque*.
 - The second canvas has a `globalAlpha` attribute value of 0.5 to create a circle that's *semitransparent*.
 - The third canvas has a `globalAlpha` attribute value of 0.15 to create a circle that's *almost entirely transparent*.

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.21: alpha.html -->
4 <!-- Using the globalAlpha attribute on a canvas. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Alpha Transparency</title>
9   </head>
10  <body>
11
12    <!-- 0.75 alpha value -->
13    <canvas id = "alpha" width = "200" height = "200"
14      style = "border: 1px solid black;">
15    </canvas>
16    <script>
17      var canvas = document.getElementById("alpha");
18      var context = canvas.getContext("2d")
19      context.beginPath();
20      context.rect(10, 10, 120, 120);
21      context.fillStyle = "purple";
22      context.fill();
23      context.globalAlpha = 0.9;
```

Fig. 14.21 | Using the `globalAlpha` attribute on a canvas. (Part 1 of 4.)

```
24      context.beginPath();
25      context.arc(120, 120, 65, 0, 2 * Math.PI, false);
26      context.fillStyle = "lime";
27      context.fill();
28  </script>
29
30  <!-- 0.5 alpha value -->
31  <canvas id = "alpha2" width = "200" height = "200"
32    style = "border: 1px solid black;">
33  </canvas>
34  <script>
35    var canvas = document.getElementById("alpha2");
36    var context = canvas.getContext("2d")
37    context.beginPath();
38    context.rect(10, 10, 120, 120);
39    context.fillStyle = "purple";
40    context.fill();
41    context.globalAlpha = 0.5;
42    context.beginPath();
43    context.arc(120, 120, 65, 0, 2 * Math.PI, false);
44    context.fillStyle = "lime";
45    context.fill();
46  </script>
```

Fig. 14.21 | Using the globalAlpha attribute on a canvas. (Part 2 of 4.)

```
47      <!-- 0.15 alpha value -->
48      <canvas id = "alpha3" width = "200" height = "200"
49          style = "border: 1px solid black;">
50      </canvas>
51      <script>
52          var canvas = document.getElementById("alpha3");
53          var context = canvas.getContext("2d")
54          context.beginPath();
55          context.rect(10, 10, 120, 120);
56          context.fillStyle = "purple";
57          context.fill();
58          context.globalAlpha = 0.15;
59          context.beginPath();
60          context.arc(120, 120, 65, 0, 2 * Math.PI, false);
61          context.fillStyle = "lime";
62          context.fill();
63      </script>
64  </body>
65 </html>
```

Fig. 14.21 | Using the `globalAlpha` attribute on a canvas. (Part 3 of 4.)



a) `globalAlpha` value of
0.9 makes the circle only
slightly transparent

b) `globalAlpha` value of
0.5 makes the circle semi-
transparent

c) `globalAlpha` value of
0.15 makes the circle
almost entirely transparent

**Fig. 14.21 | Using the `globalAlpha` attribute on a canvas. (Part 4
of 4.)**

14.18 Compositing

- ▶ Compositing allows you to control the layering of shapes and images on a canvas using two attributes—the `globalAlpha` attribute described in the previous example, and the `globalCompositeOperation` attribute.
- ▶ There are 11 `globalCompositeOperation` attribute values (Fig. 14.22).
- ▶ The *source* is the image being drawn to a canvas.
- ▶ The *destination* is the current bitmap on a canvas.
- ▶ In Fig. 14.23, we demonstrate six of the compositing effects.

Value	Description
source-atop	The source is placed on top of the destination image. If both images are opaque, the source is displayed where the images overlap. If the source is transparent but the destination image is opaque, the destination image is displayed where the images overlap. The destination image is transparent where there is no overlap.
source-in	The source image is displayed where the images overlap and both are opaque. Both images are transparent where there is no overlap.
source-out	If the source image is opaque and the destination image is transparent, the source image is displayed where the images overlap. Both images are transparent where there is no overlap.
(default) source-over	The source image is placed over the destination image. The source image is displayed where it's opaque and the images overlap. The destination image is displayed where there is no overlap.

Fig. 14.22 | `globalCompositeOperation` values. (Part 1 of 3.)

Value	Description
<code>destination-atop</code>	The destination image is placed on top of the source image. If both images are opaque, the destination image is displayed where the images overlap. If the destination image is transparent but the source image is opaque, the source image is displayed where the images overlap. The source image is transparent where there is no overlap.
<code>destination-in</code>	The destination image is displayed where the images overlap and both are opaque. Both images are transparent where there is no overlap.
<code>destination-out</code>	If the destination image is opaque and the source image is transparent, the destination image is displayed where the images overlap. Both images are transparent where there is no overlap.
<code>destination-over</code>	The destination image is placed over the source image. The destination image is displayed where it's opaque and the images overlap. The source image is displayed where there is no overlap.
<code>lighter</code>	Displays the sum of the source-image color and destination-image color—up to the maximum RGB color value (255)—where the images overlap. Both images are normal elsewhere.

Fig. 14.22 | `globalCompositeOperation` values. (Part 2 of 3.)

Value	Description
copy	If the images overlap, only the source image is displayed (the destination is ignored).
xor	Source-image xor (exclusive-or) destination. The images are transparent where they overlap and normal elsewhere.

Fig. 14.22 | globalCompositeOperation values. (Part 3 of 3.)

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.23: image.html -->
4 <!-- Compositing on a canvas. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Compositing</title>
9   </head>
10  <body>
11    <canvas id = "composite" width = "220" height = "200">
12    </canvas>
13    <script>
14      function draw()
15      {
16        var canvas = document.getElementById("composite");
17        var context = canvas.getContext("2d")
18        context.fillStyle = "red";
19        context.fillRect(5, 50, 210, 100);
20
21        // source-atop
22        context.globalCompositeOperation = "source-atop";
23        context.fillStyle = "lime";
24        context.fillRect(10, 20, 60, 60);
25    
```

Fig. 14.23 | Demonstrating compositing on a canvas. (Part 1 of 4.)

```
26      // source-over
27      context.globalCompositeOperation = "source-over";
28      context.fillStyle = "lime";
29      context.fillRect(10, 120, 60, 60);
30
31      // destination-over
32      context.globalCompositeOperation = "destination-over";
33      context.fillStyle = "lime";
34      context.fillRect(80, 20, 60, 60);
35
36      // destination-out
37      context.globalCompositeOperation = "destination-out";
38      context.fillStyle = "lime";
39      context.fillRect(80, 120, 60, 60);
40
41      // lighter
42      context.globalCompositeOperation = "lighter";
43      context.fillStyle = "lime";
44      context.fillRect(150, 20, 60, 60);
45
46      // xor
47      context.globalCompositeOperation = "xor";
48      context.fillStyle = "lime";
49      context.fillRect(150, 120, 60, 60);
50  } // end function draw
```

Fig. 14.23 | Demonstrating compositing on a canvas. (Part 2 of 4.)

```
51         window.addEventListener( "load", draw, false );
52     </script>
53 </body>
54 </html>
```

Fig. 14.23 | Demonstrating compositing on a canvas. (Part 3 of 4.)

destination-over
shows the **red** destination
where the images overlap,
and the **lime** source
where there's no overlap.

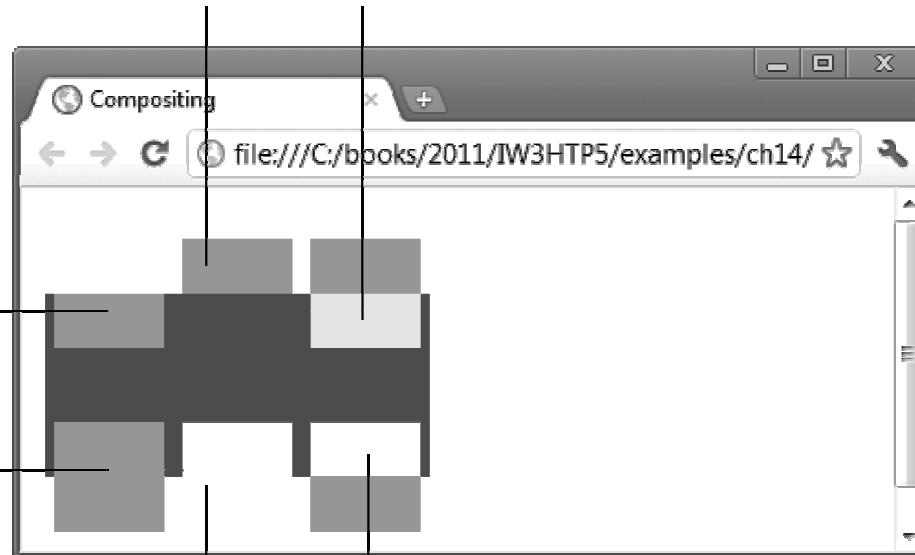
lighter displays the
overlapping area in yellow
(the sum of the red and
lime values). Both images
are normal elsewhere.

source-atop shows the
lime source where the
shapes overlap and
transparency elsewhere.

source-over shows the
lime source where the
shapes overlap and where
there's no overlap.

destination-out
shows transparency
where the shapes
overlap and where
there's no overlap.

xor displays
transparency where
the images overlap.
Both images are
normal elsewhere.



14.19 Cannon Game

- ▶ The Cannon Game app challenges you to destroy a seven-piece moving target before a ten-second time limit expires (Fig. 14.24).
 - The Cannon Game currently works in Chrome, Internet Explorer 9 and Safari. It does not work properly in Opera, Firefox, iPhone and Android.

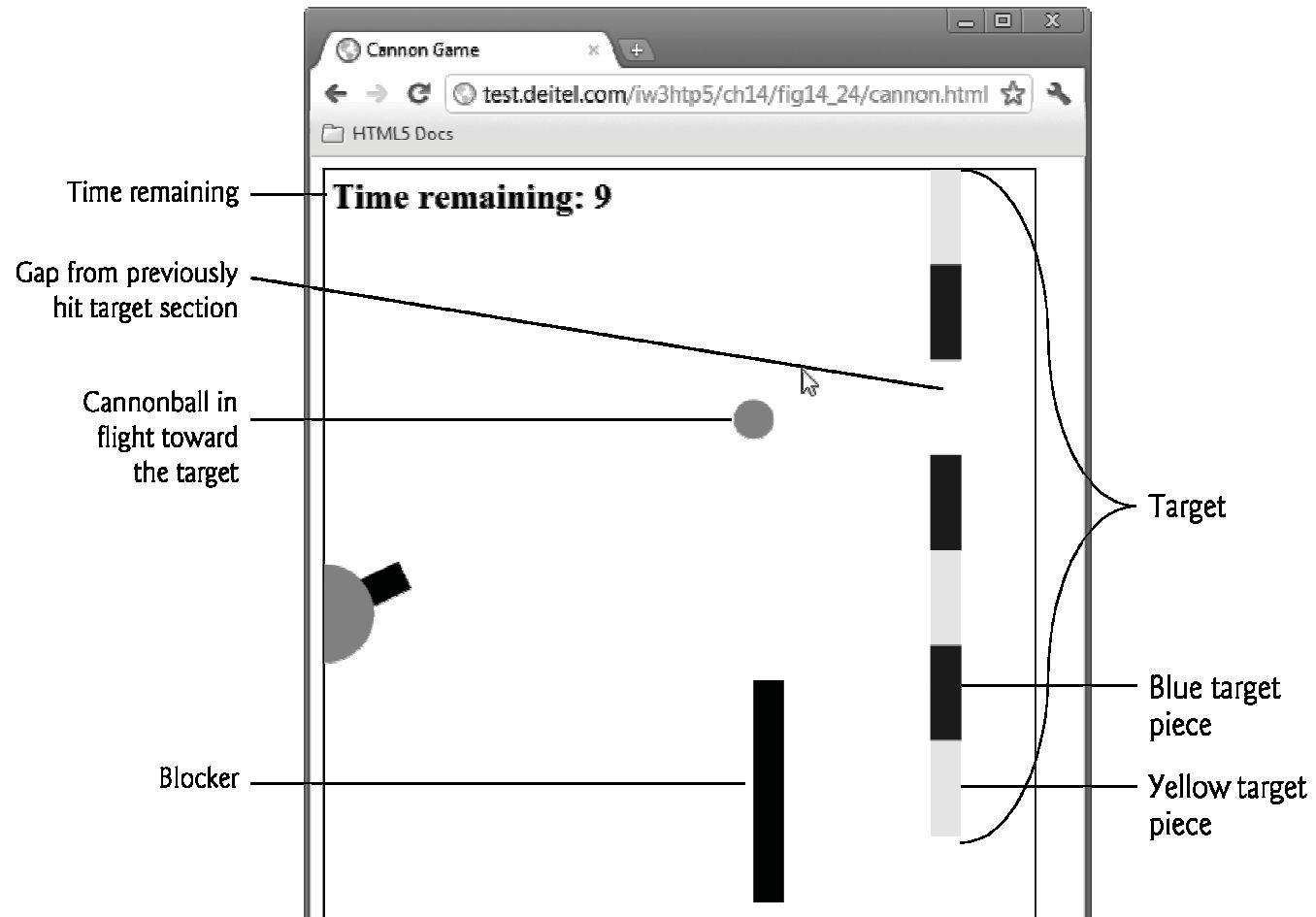


Fig. 14.24 | Completed Cannon Game app.

14.19 Cannon Game (cont.)

- ▶ The game consists of four visual components—a *cannon* that you control, a *cannonball* fired by the cannon, the *seven-piece target* and a moving *blocker* that defends the target to make the game more challenging.
- ▶ You aim the cannon by clicking the screen—the cannon then aims where you clicked and fires a cannonball. You can fire a cannonball only if there is *not* another one on the screen.

14.19 Cannon Game (cont.)

- ▶ The game begins with a *10-second time limit*. Each time you hit a target section, you are *rewarded* with three seconds being *added* to the time limit; each time you hit the blocker, you are *penalized* with two seconds being *subtracted* from the time limit.
- ▶ You win by destroying all seven target sections before time runs out. If the timer reaches zero, you lose.
- ▶ When the game ends, it displays an alert dialog indicating whether you won or lost, and shows the number of shots fired and the elapsed time (Fig. 14.25).
- ▶

a) alert dialog displayed after user destroys all seven target sections



b) alert dialog displayed when game ends before user destroys all seven targets



Fig. 14.25 | Cannon Game app alerts showing a win and a loss.

14.19 Cannon Game (cont.)

- ▶ When the cannon fires, the game plays a *firing sound*.
- ▶ The target consists of seven pieces. When a cannonball hits a piece of the target, a *glass-breaking sound* plays and that piece disappears from the screen.
- ▶ When the cannonball hits the blocker, a *hit sound* plays and the cannonball bounces back.
- ▶ The blocker cannot be destroyed.
- ▶ Figure 14.26 shows the HTML5 document for the Cannon Game.
- ▶

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.26: cannon.html -->
4 <!-- Cannon Game HTML5 document. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Cannon Game</title>
9     <style type = "text/css">
10       canvas { border: 1px solid black; }
11     </style>
12     <script src = "cannon.js"></script>
13   </head>
14   <body>
15     <audio id = "blockerSound" preload = "auto">
16       <source src = "blocker_hit.mp3" type = "audio/mpeg"></audio>
17     <audio id = "targetSound" preload = "auto">
18       <source src = "target_hit.mp3" type = "audio/mpeg"></audio>
19     <audio id = "cannonSound" preload = "auto">
20       <source src = "cannon_fire.mp3" type = "audio/mpeg"></audio>
21     <canvas id = "theCanvas" width = "480" height = "600"></canvas>
22     <p><input id = "startButton" type = "button" value = "Start Game">
23     </p>
24   </body>
25 </html>
```

Fig. 14.26 | Cannon Game HTML5 document.

14.19.1 Instance Variables and Constants

- ▶ Figure 14.27 lists the Cannon Game's numerous constants and instance variables.
- ▶

```
1 // Fig. 14.27 cannon.js
2 // Logic of the Cannon Game
3 var canvas; // the canvas
4 var context; // used for drawing on the canvas
5
6 // constants for game play
7 var TARGET_PIECES = 7; // sections in the target
8 var MISS_PENALTY = 2; // seconds deducted on a miss
9 var HIT_REWARD = 3; // seconds added on a hit
10 var TIME_INTERVAL = 25; // screen refresh interval in milliseconds
11
12 // variables for the game loop and tracking statistics
13 var intervalTimer; // holds interval timer
14 var timerCount; // times the timer fired since the last second
15 var timeLeft; // the amount of time left in seconds
16 var shotsFired; // the number of shots the user has fired
17 var timeElapsed; // the number of seconds elapsed
18
```

Fig. 14.27 | Cannon Game variable declarations. (Part 1 of 3.)

```
19 // variables for the blocker and target
20 var blocker; // start and end points of the blocker
21 var blockerDistance; // blocker distance from left
22 var blockerBeginning; // blocker distance from top
23 var blockerEnd; // blocker bottom edge distance from top
24 var initialBlockerVelocity; // initial blocker speed multiplier
25 var blockerVelocity; // blocker speed multiplier during game
26
27 var target; // start and end points of the target
28 var targetDistance; // target distance from left
29 var targetBeginning; // target distance from top
30 var targetEnd; // target bottom's distance from top
31 var pieceLength; // length of a target piece
32 var initialTargetVelocity; // initial target speed multiplier
33 var targetVelocity; // target speed multiplier during game
34
35 var lineWidth; // width of the target and blocker
36 var hitStates; // is each target piece hit?
37 var targetPiecesHit; // number of target pieces hit (out of 7)
38
```

Fig. 14.27 | Cannon Game variable declarations. (Part 2 of 3.)

```
39 // variables for the cannon and cannonball
40 var cannonball; // cannonball image's upper-left corner
41 var cannonballVelocity; // cannonball's velocity
42 var cannonballOnScreen; // is the cannonball on the screen
43 var cannonballRadius; // cannonball radius
44 var cannonballSpeed; // cannonball speed
45 var cannonBaseRadius; // cannon base radius
46 var cannonLength; // cannon barrel length
47 var barrelEnd; // the end point of the cannon's barrel
48 var canvasWidth; // width of the canvas
49 var canvasHeight; // height of the canvas
50
51 // variables for sounds
52 var targetSound;
53 var cannonSound;
54 var blockerSound;
55
```

Fig. 14.27 | Cannon Game variable declarations. (Part 3 of 3.)

14.19.2 Function setupGame

- ▶ Figure 14.28 shows function setupGame.

S

```
56 // called when the app first launches
57 function setupGame()
58 {
59     // stop timer if document unload event occurs
60     document.addEventListener( "unload", stopTimer, false );
61
62     // get the canvas, its context and setup its click event handler
63     canvas = document.getElementById( "theCanvas" );
64     context = canvas.getContext("2d");
65
66     // start a new game when user clicks Start Game button
67     document.getElementById( "startButton" ).addEventListener(
68         "click", newGame, false );
69
70     // JavaScript Object representing game items
71     blocker = new Object(); // object representing blocker line
72     blocker.start = new Object(); // will hold x-y coords of line start
73     blocker.end = new Object(); // will hold x-y coords of line end
74     target = new Object(); // object representing target line
75     target.start = new Object(); // will hold x-y coords of line start
76     target.end = new Object(); // will hold x-y coords of line end
77     cannonball = new Object(); // object representing cannonball point
78     barrelEnd = new Object(); // object representing end of cannon barrel
79
```

Fig. 14.28 | Cannon Game function setupGame. (Part I of 2.)

```
80    // initialize hitStates as an array
81    hitStates = new Array(TARGET_PIECES);
82
83    // get sounds
84    targetSound = document.getElementById( "targetSound" );
85    cannonSound = document.getElementById( "cannonSound" );
86    blockerSound = document.getElementById( "blockerSound" );
87 } // end function setupGame
88
```

Fig. 14.28 | Cannon Game function `setupGame`. (Part 2 of 2.)

14.19.3 Functions startTimer and stopTimer

- ▶ Figure 14.29 presents functions startTimer and stopTimer which manage the click event handler and the interval timer.

```
89 // set up interval timer to update game
90 function startTimer()
91 {
92     canvas.addEventListener( "click", fireCannonball, false );
93     intervalTimer = window.setInterval( updatePositions, TIME_INTERVAL );
94 } // end function startTimer
95
96 // terminate interval timer
97 function stopTimer()
98 {
99     canvas.removeEventListener( "click", fireCannonball, false );
100    window.clearInterval( intervalTimer );
101 } // end function stopTimer
102
```

Fig. 14.29 | Cannon Game functions startTimer and stopTimer.

14.19.4 Function resetElements

- ▶ Function `resetElements` (Fig. 14.30) is called by function `newGame` to position and scale the size of the game elements relative to the size of the canvas.
- ▶ The calculations performed here *scale* the game's on-screen elements based on the canvas's pixel width and height—we arrived at our scaling factors via trial and error until the game surface looked good.
- ▶

```
103 // called by function newGame to scale the size of the game elements
104 // relative to the size of the canvas before the game begins
105 function resetElements()
106 {
107     var w = canvas.width;
108     var h = canvas.height;
109     canvasWidth = w; // store the width
110     canvasHeight = h; // store the height
111     cannonBaseRadius = h / 18; // cannon base radius 1/18 canvas height
112     cannonLength = w / 8; // cannon length 1/8 canvas width
113
114     cannonballRadius = w / 36; // cannonball radius 1/36 canvas width
115     cannonballSpeed = w * 3 / 2; // cannonball speed multiplier
116
117     lineWidth = w / 24; // target and blocker 1/24 canvas width
118 }
```

Fig. 14.30 | Cannon Game function resetElements. (Part 1 of 2.)

```

I19    // configure instance variables related to the blocker
I20    blockerDistance = w * 5 / 8; // blocker 5/8 canvas width from left
I21    blockerBeginning = h / 8; // distance from top 1/8 canvas height
I22    blockerEnd = h * 3 / 8; // distance from top 3/8 canvas height
I23    initialBlockerVelocity = h / 2; // initial blocker speed multiplier
I24    blocker.start.x = blockerDistance;
I25    blocker.start.y = blockerBeginning;
I26    blocker.end.x = blockerDistance;
I27    blocker.end.y = blockerEnd;
I28
I29    // configure instance variables related to the target
I30    targetDistance = w * 7 / 8; // target 7/8 canvas width from left
I31    targetBeginning = h / 8; // distance from top 1/8 canvas height
I32    targetEnd = h * 7 / 8; // distance from top 7/8 canvas height
I33    pieceLength = (targetEnd - targetBeginning) / TARGET_PIECES;
I34    initialTargetVelocity = -h / 4; // initial target speed multiplier
I35    target.start.x = targetDistance;
I36    target.start.y = targetBeginning;
I37    target.end.x = targetDistance;
I38    target.end.y = targetEnd;
I39
I40    // end point of the cannon's barrel initially points horizontally
I41    barrelEnd.x = cannonLength;
I42    barrelEnd.y = h / 2;
I43 } // end function resetElements
I44

```

Fig. 14.30 | Cannon Game function resetElements. (Part 2 of 2.)

14.19.5 Function newGame

- ▶ Function newGame (Fig. 14.31) is called when the user clicks the Start Game button; the function initializes the game's instance variables.
- ▶

```
145 // reset all the screen elements and start a new game
146 function newGame()
147 {
148     resetElements(); // reinitialize all the game elements
149     stopTimer(); // terminate previous interval timer
150
151     // set every element of hitStates to false--restores target pieces
152     for (var i = 0; i < TARGET_PIECES; ++i)
153         hitStates[i] = false; // target piece not destroyed
154
155     targetPiecesHit = 0; // no target pieces have been hit
156     blockerVelocity = initialBlockerVelocity; // set initial velocity
157     targetVelocity = initialTargetVelocity; // set initial velocity
158     timeLeft = 10; // start the countdown at 10 seconds
159     timerCount = 0; // the timer has fired 0 times so far
160     cannonballOnScreen = false; // the cannonball is not on the screen
161     shotsFired = 0; // set the initial number of shots fired
162     timeElapsed = 0; // set the time elapsed to zero
163
164     startTimer(); // starts the game loop
165 } // end function newGame
166
```

Fig. 14.31 | Cannon Game function newGame.

14.19.6 Function updatePositions: Manual Frame-by-Frame Animation and Simple Collision Detection

- ▶ This app performs its animations *manually* by updating the positions of all the game elements at fixed time intervals.
- ▶ The interval timer (Fig. 14.29) in function startTimer calls function updatePositions (Fig. 14.32) to update the game every 25 milliseconds (i.e., 40 times per second).

```
167 // called every TIME_INTERVAL milliseconds
168 function updatePositions()
169 {
170     // update the blocker's position
171     var blockerUpdate = TIME_INTERVAL / 1000.0 * blockerVelocity;
172     blocker.start.y += blockerUpdate;
173     blocker.end.y += blockerUpdate;
174
175     // update the target's position
176     var targetUpdate = TIME_INTERVAL / 1000.0 * targetVelocity;
177     target.start.y += targetUpdate;
178     target.end.y += targetUpdate;
179
180     // if the blocker hit the top or bottom, reverse direction
181     if (blocker.start.y < 0 || blocker.end.y > canvasHeight)
182         blockerVelocity *= -1;
183
184     // if the target hit the top or bottom, reverse direction
185     if (target.start.y < 0 || target.end.y > canvasHeight)
186         targetVelocity *= -1;
187 }
```

Fig. 14.32 | Cannon Game function updatePositions. (Part I of 5.)

```
188 if (cannonballOnScreen) // if there is currently a shot fired
189 {
190     // update cannonball position
191     var interval = TIME_INTERVAL / 1000.0;
192
193     cannonball.x += interval * cannonballVelocityX;
194     cannonball.y += interval * cannonballVelocityY;
195
196     // check for collision with blocker
197     if (cannonballVelocityX > 0 &&
198         cannonball.x + cannonballRadius >= blockerDistance &&
199         cannonball.x + cannonballRadius <= blockerDistance + LineWidth &&
200         cannonball.y - cannonballRadius > blocker.start.y &&
201         cannonball.y + cannonballRadius < blocker.end.y)
202     {
203         blockerSound.play(); // play blocker hit sound
204         cannonballVelocityX *= -1; // reverse cannonball's direction
205         timeLeft -= MISS_PENALTY; // penalize the user
206     } // end if
207 }
```

Fig. 14.32 | Cannon Game function updatePositions. (Part 2 of 5.)

```
208     // check for collisions with left and right walls
209     else if (cannonball.x + cannonballRadius > canvasWidth ||
210               cannonball.x - cannonballRadius < 0)
211     {
212         cannonballOnScreen = false; // remove cannonball from screen
213     } // end else if
214
215     // check for collisions with top and bottom walls
216     else if (cannonball.y + cannonballRadius > canvasHeight ||
217               cannonball.y - cannonballRadius < 0)
218     {
219         cannonballOnScreen = false; // make the cannonball disappear
220     } // end else if
221
222     // check for cannonball collision with target
223     else if (cannonballVelocityX > 0 &&
224               cannonball.x + cannonballRadius >= targetDistance &&
225               cannonball.x + cannonballRadius <= targetDistance + lineWidth &&
226               cannonball.y - cannonballRadius > target.start.y &&
227               cannonball.y + cannonballRadius < target.end.y)
228     {
```

Fig. 14.32 | Cannon Game function updatePositions. (Part 3 of 5.)

```
229     // determine target section number (0 is the top)
230     var section =
231         Math.floor((cannonball.y - target.start.y) / pieceLength);
232
233     // check whether the piece hasn't been hit yet
234     if ((section >= 0 && section < TARGET_PIECES) &&
235         !hitStates[section])
236     {
237         targetSound.play(); // play target hit sound
238         hitStates[section] = true; // section was hit
239         cannonballOnScreen = false; // remove cannonball
240         timeLeft += HIT_REWARD; // add reward to remaining time
241
242         // if all pieces have been hit
243         if (++targetPiecesHit == TARGET_PIECES)
244         {
245             stopTimer(); // game over so stop the interval timer
246             draw(); // draw the game pieces one final time
247             showGameOverDialog("You won!"); // show winning dialog
248         } // end if
249     } // end if
250 } // end else if
251 } // end if
```

Fig. 14.32 | Cannon Game function updatePositions. (Part 4 of 5.)

```
252
253     ++timerCount; // increment the timer event counter
254
255     // if one second has passed
256     if (TIME_INTERVAL * timerCount >= 1000)
257     {
258         --timeLeft; // decrement the timer
259         ++timeElapsed; // increment the time elapsed
260         timerCount = 0; // reset the count
261     } // end if
262
263     draw(); // draw all elements at updated positions
264
265     // if the timer reached zero
266     if (timeLeft <= 0)
267     {
268         stopTimer();
269         showGameOverDialog("You lost"); // show the losing dialog
270     } // end if
271 } // end function updatePositions
272
```

Fig. 14.32 | Cannon Game function updatePositions. (Part 5 of 5.)

14.19.6 Function updatePositions: Manual Frame-by-Frame Animation and Simple Collision Detection (cont.)

- ▶ This function also performs simple *collision detection* to determine whether the cannonball has collided with any of the canvas's edges, with the blocker or with a section of the target.
- ▶ Game-development frameworks generally provide more sophisticated, built-in collision-detection capabilities.

14.19.6 Function updatePositions: Manual Frame-by-Frame Animation and Simple Collision Detection (cont.)

- ▶ The function begins by updating the positions of the blocker and the target.
- ▶ Lines 171–173 change the blocker's position by multiplying blockerVelocity by the amount of time that has passed since the last update and adding that value to the current x - and y -coordinates.
- ▶ Lines 176–178 do the same for the target.

14.19.6 Function updatePositions: Manual Frame-by-Frame Animation and Simple Collision Detection (cont.)

- ▶ If the blocker has collided with the top or bottom wall, its direction is *reversed* by multiplying its velocity by -1 (lines 181–182).
- ▶ Lines 185–186 perform the same check and adjustment for the full length of the target, including any sections that have already been hit.
- ▶ Line 188 checks whether the cannonball is on the screen. If it is, we update its position by adding the distance it should have traveled since the last timer event. This is calculated by multiplying its velocity by the amount of time that passed.

14.19.6 Function updatePositions: Manual Frame-by-Frame Animation and Simple Collision Detection (cont.)

- ▶ We perform simple *collision detection*, based on the rectangular boundary of the cannonball. Four conditions must be met if the cannonball is in contact with the blocker:
 - The cannonball has reached the blocker's distance from the left edge of the screen.
 - The cannonball has not yet passed the blocker.
 - Part of the cannonball must be lower than the top of the blocker.
 - Part of the cannonball must be higher than the bottom of the blocker.

14.19.6 Function updatePositions: Manual Frame-by-Frame Animation and Simple Collision Detection (cont.)

- ▶ If all these conditions are met, we play blocker hit sound, *reverse* the cannonball's direction on the screen and *penalize* the user by *subtracting* MISS_PENALTY from timeLeft.
- ▶ We remove the cannonball if it reaches any of the screen's edges.
- ▶ We then check whether the cannonball has hit the target.

14.19.6 Function updatePositions: Manual Frame-by-Frame Animation and Simple Collision Detection (cont.)

- ▶ If the cannonball hit the target, we determine which *section* of the target was hit by dividing the distance between the cannonball and the bottom of the target by the length of a piece.
- ▶ This expression evaluates to 0 for the topmost section and 6 for the bottommost.

14.19.7 Function fireCannonball

- ▶ When the user clicks the mouse on the canvas, the click event handler calls function `fireCannonball` (Fig. 14.33) to fire a cannonball.

```
273 // fires a cannonball
274 function fireCannonball(event)
275 {
276     if (cannonballOnScreen) // if a cannonball is already on the screen
277         return; // do nothing
278
279     var angle = alignCannon(event); // get the cannon barrel's angle
280
281     // move the cannonball to be inside the cannon
282     cannonball.x = cannonballRadius; // align x-coordinate with cannon
283     cannonball.y = canvasHeight / 2; // centers ball vertically
284
285     // get the x component of the total velocity
286     cannonballVelocityX = (cannonballSpeed * Math.sin(angle)).toFixed(0);
287
288     // get the y component of the total velocity
289     cannonballVelocityY = (-cannonballSpeed * Math.cos(angle)).toFixed(0);
290     cannonballOnScreen = true; // the cannonball is on the screen
291     ++shotsFired; // increment shotsFired
292
293     // play cannon fired sound
294     cannonSound.play();
295 } // end function fireCannonball
296
```

Fig. 14.33 | Cannon Game function fireCannonball.

14.19.8 Function alignCannon

- ▶ Function alignCannon (Fig. 14.34) aims the cannon at the point where the user clicked the mouse on the screen.
- ▶ We compute the vertical distance of the mouse click from the center of the screen.
- ▶ If this is not zero, we calculate the cannon barrel's angle from the horizontal.

```
297 // aligns the cannon in response to a mouse click
298 function alignCannon(event)
299 {
300     // get the location of the click
301     var clickPoint = new Object();
302     clickPoint.x = event.x;
303     clickPoint.y = event.y;
304
305     // compute the click's distance from center of the screen
306     // on the y-axis
307     var centerMinusY = (canvasHeight / 2 - clickPoint.y);
308
309     var angle = 0; // initialize angle to 0
310
311     // calculate the angle the barrel makes with the horizontal
312     if (centerMinusY !== 0) // prevent division by 0
313         angle = Math.atan(clickPoint.x / centerMinusY);
314
315     // if the click is on the lower half of the screen
316     if (clickPoint.y > canvasHeight / 2)
317         angle += Math.PI; // adjust the angle
318
```

Fig. 14.34 | Cannon Game function alignCannon. (Part 1 of 2.)

```
319     // calculate the end point of the cannon's barrel  
320     barrelEnd.x = (cannonLength * Math.sin(angle)).toFixed(0);  
321     barrelEnd.y =  
322         (-cannonLength * Math.cos(angle) + canvasHeight / 2).toFixed(0);  
323  
324     return angle; // return the computed angle  
325 } // end function alignCannon  
326
```

Fig. 14.34 | Cannon Game function alignCannon. (Part 2 of 2.)

14.19.8 Function alignCannon

- ▶ If the click is on the lower half of the screen we adjust the angle by Math.PI.
- ▶ We then use the cannonLength and the angle to determine the x - and y -coordinates for the end point of the cannon's barrel—this is used in function draw (Fig. 14.35) to draw a line from the cannon base's center at the left edge of the screen to the cannon barrel's end point.

14.19.9 Function draw

- ▶ When the screen needs to be *redrawn*, the draw function (Fig. 14.35) renders the game's on-screen elements—the cannon, the cannonball, the blocker and the seven-piece target.
- ▶

```
327 // draws the game elements to the given Canvas
328 function draw()
329 {
330     canvas.width = canvas.width; // clears the canvas (from W3C docs)
331
332     // display time remaining
333     context.fillStyle = "black";
334     context.font = "bold 24px serif";
335     context.textBaseline = "top";
336     context.fillText("Time remaining: " + timeLeft, 5, 5);
337
338     // if a cannonball is currently on the screen, draw it
339     if (cannonballOnScreen)
340     {
341         context.fillStyle = "gray";
342         context.beginPath();
343         context.arc(cannonball.x, cannonball.y, cannonballRadius,
344                     0, Math.PI * 2);
345         context.closePath();
346         context.fill();
347     } // end if
348 }
```

Fig. 14.35 | Cannon Game function draw. (Part 1 of 4.)

```
349 // draw the cannon barrel
350 context.beginPath(); // begin a new path
351 context.strokeStyle = "black";
352 context.moveTo(0, canvasHeight / 2); // path origin
353 context.lineTo(barrelEnd.x, barrelEnd.y);
354 context.lineWidth = lineWidth; // line width
355 context.stroke(); // draw path
356
357 // draw the cannon base
358 context.beginPath();
359 context.fillStyle = "gray";
360 context.arc(0, canvasHeight / 2, cannonBaseRadius, 0, Math.PI*2);
361 context.closePath();
362 context.fill();
363
364 // draw the blocker
365 context.beginPath(); // begin a new path
366 context.moveTo(blocker.start.x, blocker.start.y); // path origin
367 context.lineTo(blocker.end.x, blocker.end.y);
368 context.lineWidth = lineWidth; // line width
369 context.stroke(); //draw path
370
```

Fig. 14.35 | Cannon Game function draw. (Part 2 of 4.)

```
371 // initialize currentPoint to the starting point of the target
372 var currentPoint = new Object();
373 currentPoint.x = target.start.x;
374 currentPoint.y = target.start.y;
375
376 // draw the target
377 for (var i = 0; i < TARGET_PIECES; ++i)
378 {
379     // if this target piece is not hit, draw it
380     if (!hitStates[i])
381     {
382         context.beginPath(); // begin a new path for target
383
384         // alternate coloring the pieces yellow and blue
385         if (i % 2 === 0)
386             context.strokeStyle = "yellow";
387         else
388             context.strokeStyle = "blue";
389
390         context.moveTo(currentPoint.x, currentPoint.y); // path origin
391         context.lineTo(currentPoint.x, currentPoint.y + pieceLength);
392         context.lineWidth = lineWidth; // line width
393         context.stroke(); // draw path
394     } // end if
395 }
```

Fig. 14.35 | Cannon Game function draw. (Part 3 of 4.)

```
396      // move currentPoint to the start of the next piece
397      currentPoint.y += pieceLength;
398  } // end for
399 } // end function draw
400
```

Fig. 14.35 | Cannon Game function draw. (Part 4 of 4.)

14.19.10 Function showGameOverDialog

- ▶ When the game ends, the showGameOverDialog function (Fig. 14.36) displays an alert indicating whether the player won or lost, the number of shots fired and the total time elapsed.

```
401 // display an alert when the game ends
402 function showGameOverDialog(message)
403 {
404     alert(message + "\nShots fired: " + shotsFired +
405         "\nTotal time: " + timeElapsed + " seconds");
406 } // end function showGameOverDialog
407
408 window.addEventListener("load", setupGame, false);
```

Fig. 14.36 | Cannon Game function showGameOverDialog.

14.20 save and restore Methods

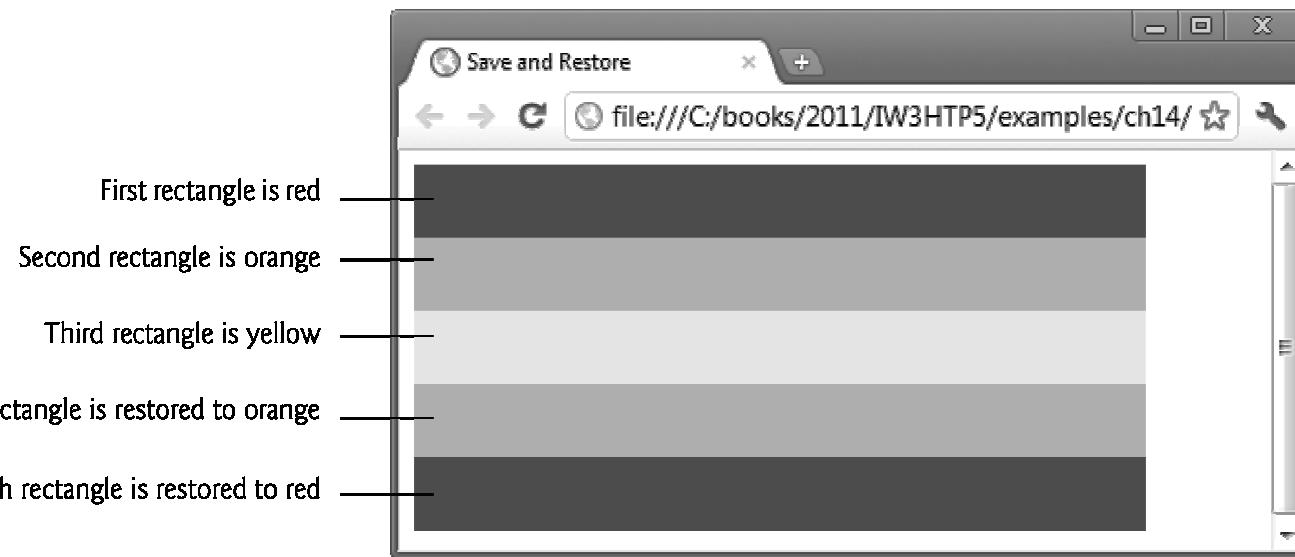
- ▶ The canvas's **state** includes its current style and transformations, which are maintained in a stack.
- ▶ The **save method** is used to save the context's current state.
- ▶ The **restore method** restores the context to its previous state.
- ▶ Figure 14.37 demonstrates using the `save` method to change a rectangle's `fillStyle` and the `restore` method to restore the `fillStyle` to the previous settings in the stack.

```
1 <!DOCTYPE html>
2
3 <!-- Fig. 14.37: saveandrestore.html -->
4 <!-- Saving the current state and restoring the previous state. -->
5 <html>
6   <head>
7     <meta charset = "utf-8">
8     <title>Save and Restore</title>
9   </head>
10  <body>
11    <canvas id = "save" width = "400" height = "200">
12    </canvas>
13    <script>
14      function draw()
15      {
16        var canvas = document.getElementById("save");
17        var context = canvas.getContext("2d")
18
19        // draw rectangle and save the settings
20        context.fillStyle = "red"
21        context.fillRect(0, 0, 400, 200);
22        context.save();
23
```

Fig. 14.37 | Saving the current state and restoring the previous state.
(Part 1 of 3.)

```
24      // change the settings and save again
25      context.fillStyle = "orange"
26      context.fillRect(0, 40, 400, 160);
27      context.save();
28
29      // change the settings again
30      context.fillStyle = "yellow"
31      context.fillRect(0, 80, 400, 120);
32
33      // restore to previous settings and draw new rectangle
34      context.restore();
35      context.fillRect(0, 120, 400, 80);
36
37      // restore to original settings and draw new rectangle
38      context.restore();
39      context.fillRect(0, 160, 400, 40);
40  }
41  window.addEventListener( "load", draw, false );
42 </script>
43 </body>
44 </html>
```

Fig. 14.37 | Saving the current state and restoring the previous state.
(Part 2 of 3.)



**Fig. 14.37 | Saving the current state and restoring the previous state.
(Part 3 of 3.)**

14.21 A Note on SVG

- ▶ Most current browsers also support **SVG (Scalable Vector Graphics)**, which offers a different approach to developing 2D graphics.
- ▶ *Vector graphics* are made of scalable geometric primitives such as line segments and arcs.
- ▶ SVG is XML-based, so it uses a *declarative* approach—you say *what* you want and SVG builds it for you.

14.21 A Note on SVG

- ▶ With SVG, each separate part of your graphic becomes an *object* that can be manipulated through the DOM.
- ▶ The DOM manipulation in SVG can degrade performance, particularly for more complex graphics.
- ▶ SVG graphics easily and accurately scale to larger or smaller drawing surfaces.

14.21 A Note on SVG (cont.)

- ▶ SVG is more appropriate for accessibility applications for people with disabilities. It's easier, for example, for people with low vision or vision impairments to work with the XML text in an SVG document than with the pixels in a canvas.
- ▶ SVG has better animation capabilities, so game developers often use a *mix* of both the canvas and SVG approaches.

14.21 A Note on SVG (cont.)

- ▶ SVG is more convenient for cross-platform graphics, which is becoming especially important with the proliferation of “form factors,” such as desktops, notebooks, smartphones, tablets and various special-purpose devices such as car navigation systems.

14.22 A Note on canvas 3D

- ▶ Figure 14.38 lists several websites with fun and interesting 3D examples.

URL	Description
http://www.kevs3d.co.uk/dev/html5logo/	Spinning 3D HTML5 logo.
http://sebleedelisle.com/demos/GravityParticles/ParticlesForces3D2.html	A basic 3D particle distribution system.
http://www.kevs3d.co.uk/dev/canvask3dk3d_test.html	Includes several 3D shapes that rotate when clicked.
http://alteredqualia.com/canvasmol/#DNA	Spinning 3D molecules.
http://deanm.github.com/pre3d/monster.html	A cube that morphs into other 3D shapes.
http://html5canvastutorials.com/demos/webgl/html5_canvas_webgl_3d_world/	Click and drag the mouse to smoothly change perspective in a 3D room.
http://onepixelahead.com/2010/09/24/10-awesome-html5-canvas-3d-examples/	Ten HTML5 canvas 3D examples including games and animations.
http://sixrevisions.com/web-development/how-to-create-an-html5-3d-engine/	The tutorial, “How to Create an HTML5 3D Engine.”
http://sebleedelisle.com/2011/02/html5-canvas-3d-particles-uniform-distribution/	The short tutorial, “HTML5 Canvas 3D Particles Uniform Distribution.”

Fig. 14.38 | HTML5 canvas 3D demos and tutorials. (Part 1 of 2.)

URL	Description
http://www.script-tutorials.com/how-to-create-3d-canvas-object-in-html5/	The tutorial, “How to Create Animated 3D Canvas Objects in HTML5.”
http://blogs.msdn.com/b/davrous/archive/2011/05/27/how-to-add-the-3d-animated-html5-logo-into-your-webpages-thanks-to-lt-canvas-gt.aspx	The tutorial, “How to Add the 3D Animated HTML5 Logo to Your Webpages.”
http://www.bitstorm.it/blog/en/2011/05/3d-sphere-html5-canvas/	The tutorial, “Draw Old School 3D Sphere with HTML5.”

Fig. 14.38 | HTML5 canvas 3D demos and tutorials. (Part 2 of 2.)