

HTML5 Canvas

Drawing on a Web page



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Summary

- The canvas element
- Basic shapes
- Images
- Colors and gradients
- Pixel manipulation
- Animations
- Video and canvas

Drawing on a Web page

- Possible just very recently
- SVG and canvas
 - Provide native drawing functionality on the Web
 - Completely integrated into HTML5 documents (part of DOM)
 - Can be styled with CSS
 - Can be controlled with JavaScript

Canvas

- HTML5 element and plugin-free 2D drawing API that enables to dynamically generate and render graphics, charts, images, animation
- Scriptable bitmap canvas
 - Images that are drawn are final and cannot be resized
 - Can be manipulated with JavaScript and styled with CSS
 - 2D Context
 - 3D Context (Web GL)
- Canvas was originally introduced by Apple to be used in Mac OS

Canvas

- The HTML5 `<canvas>` element is used to draw graphics, on the fly, via scripting (usually JavaScript)
- A canvas is a rectangular area, where it is possible to control every pixel
- The canvas element has several methods for drawing paths, boxes, circles, characters, and adding images
- The `<canvas>` element is only a container for graphics
 - You must use a script to actually draw the graphics

```
<canvas id="myCanvas" width="200" height="100">  
</canvas>
```

Canvas features

- Canvas can draw text
 - Colorful text, with or without animation
- Canvas can draw graphics
 - Great features for graphical data presentation
- Canvas can be animated
 - Canvas objects can move: from simple bouncing balls to complex animations
- Canvas can be interactive
 - Canvas can respond to JavaScript events
 - Canvas can respond to any user action (key clicks, mouse clicks, button clicks, finger movement)
- HTML canvas can be used in games

Canvas

- The canvas is initially blank
- To display something a script needs to access the rendering context and draw on it
- The canvas element has a DOM method called `getContext`, used to obtain the rendering context and its drawing functions
 - `getContext()` takes one parameter: the type of context (2D or 3D)
 - `getContext()` is a built-in HTML object, with properties and methods for drawing (paths, boxes, circles, characters, images, and more)

```
var canvas = document.getElementById('example');  
var ctx = canvas.getContext('2d');
```

Canvas

- Skeleton template

```
<html>
  <head>
    <title>Canvas</title>
    <script type="application/javascript">
      function draw() {
        var canvas = document.getElementById('example');
        if (canvas.getContext) {
          var ctx = canvas.getContext('2d'); } }
    </script>
    <style type="text/css">
      canvas { border: 1px solid black; }
    </style>
  </head>
  <body onload="draw();" >
    <canvas id="example" width="150" height="150"></canvas>
  </body>
</html>
```

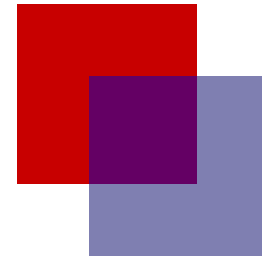

Example: basic shape



- All drawing must be done in JavaScript

```
<html>
  <head>
    <script type="application/javascript">
      function draw() {
        var canvas=document.getElementById("canvas");
        if (canvas.getContext) {
          var ctx = canvas.getContext("2d");
          ctx.fillStyle="#FF0000";
          ctx.fillRect(0,0,150,75); } }
    </script>
  </head>
  <body onload="draw();">
    <canvas id="canvas" width="200" height="100">
    </canvas>
  </body>
</html>
```

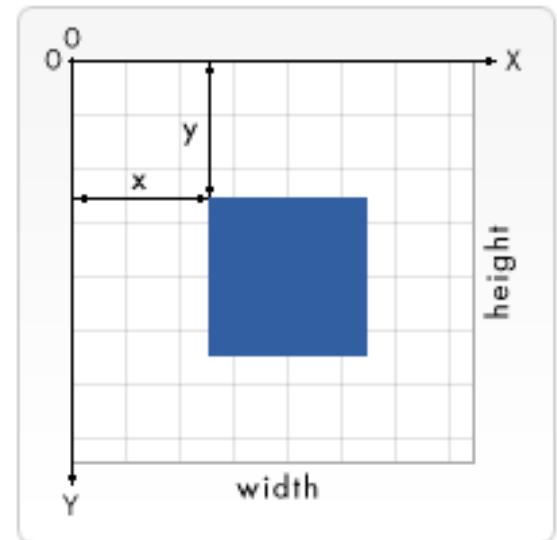
Example



```
<html>
  <head>
    <script type="application/javascript">
      function draw() {
        var canvas=document.getElementById("canvas");
        if (canvas.getContext) {
          var ctx = canvas.getContext("2d");
          ctx.fillStyle = "rgb(200,0,0)";
          ctx.fillRect (10, 10, 55, 50);
          ctx.fillStyle = "rgba(0, 0, 200, 0.5)";
          ctx.fillRect (30, 30, 55, 50); } }
    </script>
  </head>
  <body onload="draw();" >
    <canvas id="canvas" width="150" height="150">
    </canvas>
  </body>
</html>
```

Rectangles functions

- `fillRect(x,y,width,height)`
 - draws a filled rectangle
- `strokeRect(x,y,width,height)`
 - draws a rectangular outline
- `clearRect(x,y,width,height)`
 - clears the specified area and makes it fully transparent
- Canvas coordinate space



Path functions

- `beginPath()`:
 - creates a path (list of lines, arcs, ...)
- `closePath()`
 - closes the path by drawing a straight line from the current point to the start
- `stroke()`
 - draws an outlined shape
- `fill()`
 - paints a solid shape
- `moveTo(x,y)`
 - move the pencil to the x and y coordinates
- `lineTo(x,y)`
 - draws a straight line to the specified ending point
- `arc(x, y, radius, startAngle, endAngle, anticlockwise)`
 - draws an arc using a center point (x, y), a radius, a start and end angle (in radians), and a direction flag (false for clockwise, true for counter-clockwise)
 - to convert degrees to radians: `var radians = (Math.PI/180)*degrees`

Example: path



```
function drawShape() {
  var canvas = document.getElementById('tutorial');
  if (canvas.getContext){
    // use getContext to use the canvas for drawing
    var ctx = canvas.getContext('2d');
    // Draw shapes
    ctx.beginPath();
    ctx.arc(75,75,50,0,Math.PI*2,true);
    ctx.moveTo(110,75);
    ctx.arc(75,75,35,0,Math.PI,false);
    ctx.moveTo(65,65);
    ctx.arc(60,65,5,0,Math.PI*2,true);
    ctx.moveTo(95,65);
    ctx.arc(90,65,5,0,Math.PI*2,true);
    ctx.stroke(); }
  else { ... }
}
```

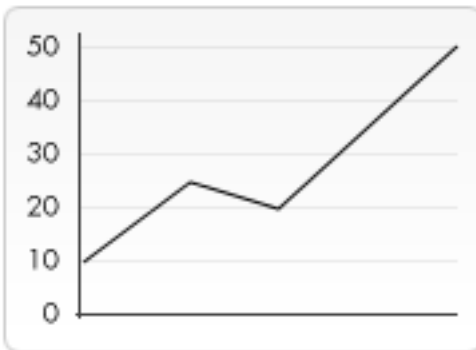
Examples: image

- `drawImage(image, x, y)`
 - renders an image



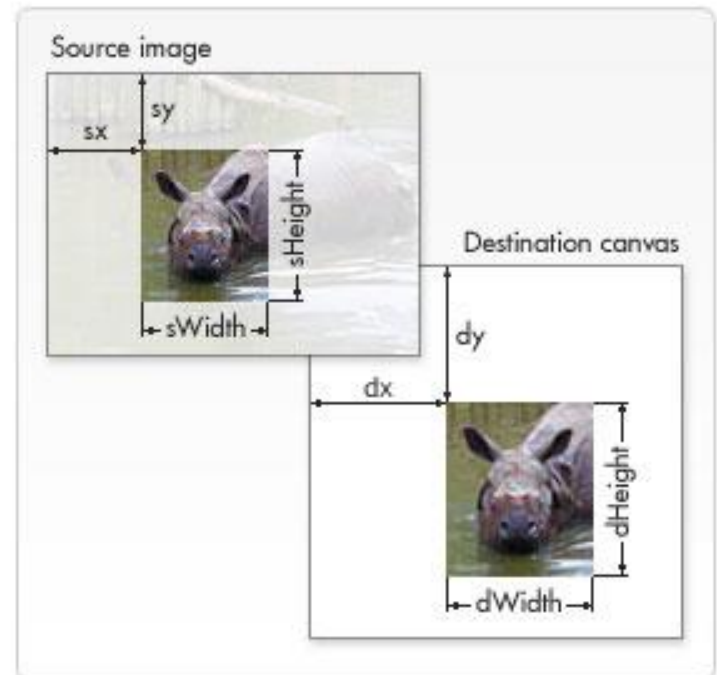
```
function draw() {  
  var ctx = document.getElementById('canvas').getContext('2d');  
  var img = new Image();  
  img.src = "img_flwr.png";  
  img.onload = function(){  
    ctx.drawImage(img,0,0);  
  }  
}
```

```
function draw() {  
  var ctx = document.getElementById('canvas').getContext('2d');  
  var img = new Image();  
  img.src = 'images/backdrop.png';  
  img.onload = function(){  
    ctx.drawImage(img,0,0);  
    ctx.beginPath();  
    ctx.moveTo(30,96);  
    ctx.lineTo(70,66);  
    ctx.lineTo(103,76);  
    ctx.lineTo(170,15);  
    ctx.stroke(); }  
}
```



Images

- Images can be scaled...
 - `drawImage(image, x, y, width, height)`
- ... and sliced
 - `drawImage(image, sx, sy, sWidth, sHeight, dx, dy, dWidth, dHeight)`



Example



```
function draw() {  
  var ctx = document.getElementById('canvas').getContext('2d');  
  var img = new Image();  
  img.src = 'images/rhino.jpg';  
  img.onload = function(){  
    for (i=0;i<4;i++) {  
      for (j=0;j<3;j++) {  
        ctx.drawImage(img,j*50,i*38,50,38);  
      }  
    }  
  }  
}
```



Example



```
function draw() {  
  var ctx = document.getElementById('canvas').getContext('2d');  
  ctx.drawImage(document.getElementById('source'),  
                33,71,104,124,21,20,87,104);  
  ctx.drawImage(document.getElementById('frame'),0,0);  
}
```



Example: colors and interaction



Click on the buttons below to change the color of the rectangle.



```
<body>
  <canvas id="drawing" style="" > </canvas>
  <p>Click on the buttons below to change the color of the
    rectangle. </p>

  <input type="button" value="Blue" id="blue" onclick="BlueRect()" />
  <input type="button" value="Green" id="green" onclick="GreenRect()" />
  <input type="button" value="Yellow" id="yellow" onclick="YellRect()" />
  <input type="button" value="Red" id="red" onclick="RedRect()" />
  <input type="button" value="Click to clear canvas" id="clear"
    onclick="ImgClr()" />
</body>
```

Example: colors and interaction

```
<script type="text/javascript">
var canvas=null; var context=null;
window.onload = function() {
    canvas=document.getElementById("drawing");
    context=canvas.getContext("2d");
    // Border
    context.beginPath(); //This initiates the border
    context.rect(100,60,175,70);
    context.fillStyle="#ffffff";
    context.fill();
    // Border width
    context.lineWidth=1; //This sets the width of the border
    // Border color
    context.strokeStyle="#000000";
    context.stroke(); }
function BlueRect () {
    context.fillStyle="#701be0"; // Changes the rectangle to blue
    context.fill();
    context.strokeStyle="#000000";
    context.stroke(); }
function GreenRect () { ... }
function ImgClr () {
    context.clearRect(0,0, canvas.width, canvas.height); }
</script>
```

Gradients

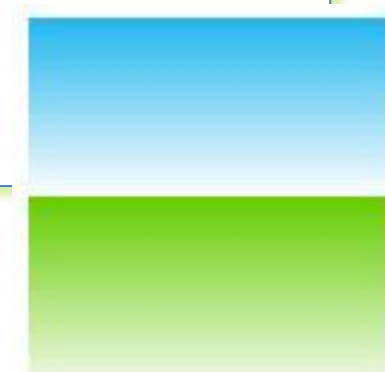
- `createLinearGradient(x1,y1,x2,y2)`
 - starting point (x1,y1) and end point (x2,y2) of the gradient
- `createRadialGradient(x1,y1,r1,x2,y2,r2)`
 - starting circle (x1,y1, r1) and end circle (x2,y2, r2)
- `addColorStop(position,color)`
 - position: a number between 0.0 and 1.0 that defines the relative position of the color in the gradient
 - color: string

```
var lineargradient = ctx.createLinearGradient(0,0,150,150);  
lineargradient.addColorStop(0,'red');  
lineargradient.addColorStop(1,'green');
```



Example: linear gradients

```
function draw() {  
  var ctx = document.getElementById('canvas').getContext('2d');  
  // Create gradient  
  var lingrad = ctx.createLinearGradient(0,0,0,150);  
  lingrad.addColorStop(0, '#00ABEB');  
  lingrad.addColorStop(0.5, '#fff');  
  lingrad.addColorStop(0.5, '#66CC00');  
  lingrad.addColorStop(1, '#fff');  
  // assign gradients to fill style  
  ctx.fillStyle = lingrad;  
  // draw shape  
  ctx.fillRect(10,10,130,130);  
}
```



Example 14

Radial gradients



```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');

  // Create gradients
  var radgrad = ctx.createRadialGradient(45,45,10,52,50,30);
  radgrad.addColorStop(0, '#A7D30C');
  radgrad.addColorStop(0.9, '#019F62');
  radgrad.addColorStop(1, 'rgba(1,159,98,0)');

  var radgrad2 = ctx.createRadialGradient(105,105,20,112,120,50);
  radgrad2.addColorStop(0, '#FF5F98');
  radgrad2.addColorStop(0.75, '#FF0188');
  radgrad2.addColorStop(1, 'rgba(255,1,136,0)');
  ...
}
```

Example: radial gradients



```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');
  // Create gradients
  var radgrad = ctx.createRadialGradient(45,45,10,52,50,30);
  radgrad.addColorStop(0, '#A7D30C');
  radgrad.addColorStop(0.9, '#019F62');
  radgrad.addColorStop(1, 'rgba(1,159,98,0)');
  var radgrad2 = ctx.createRadialGradient(105,105,20,112,120,50);
  radgrad2.addColorStop(0, '#FF5F98');
  radgrad2.addColorStop(0.75, '#FF0188');
  radgrad2.addColorStop(1, 'rgba(255,1,136,0)');
  var radgrad3 = ctx.createRadialGradient(95,15,15,102,20,40);
  radgrad3.addColorStop(0, '#00C9FF');
  radgrad3.addColorStop(0.8, '#00B5E2');
  radgrad3.addColorStop(1, 'rgba(0,201,255,0)');
  var radgrad4 = ctx.createRadialGradient(0,150,50,0,140,90);
  radgrad4.addColorStop(0, '#F4F201');
  radgrad4.addColorStop(0.8, '#E4C700');
  radgrad4.addColorStop(1, 'rgba(228,199,0,0)');
  // draw shapes
  ctx.fillStyle = radgrad4; ctx.fillRect(0,0,150,150);
  ctx.fillStyle = radgrad3; ctx.fillRect(0,0,150,150);
  ctx.fillStyle = radgrad2; ctx.fillRect(0,0,150,150);
  ctx.fillStyle = radgrad; ctx.fillRect(0,0,150,150);
}
```

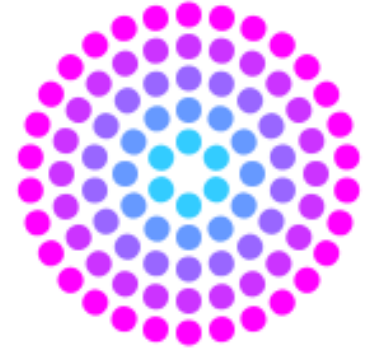
Example: save and restore



- Canvas states can be stored on a stack
- Methods `save()` and `restore()`

```
function draw() {  
  var ctx = document.getElementById('canvas').getContext('2d');  
  ctx.fillRect(0,0,150,150); // default settings  
  ctx.save(); // Save the default state  
  ctx.fillStyle = '#09F' // Make changes to the settings  
  ctx.fillRect(15,15,120,120); // Draw with new settings  
  ctx.save(); // Save the current state  
  ctx.fillStyle = '#FFF' // Make changes to the settings  
  ctx.globalAlpha = 0.5;  
  ctx.fillRect(30,30,90,90); // Draw with new settings  
  ctx.restore(); // Restore previous state  
  ctx.fillRect(45,45,60,60); // Draw with restored settings  
  ctx.restore(); // Restore original state  
  ctx.fillRect(60,60,30,30); // Draw with restored settings  
}
```


Example: trasformations



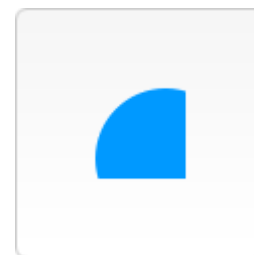
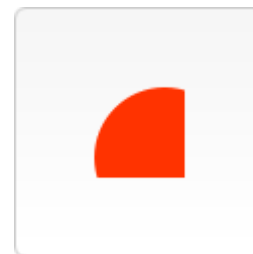
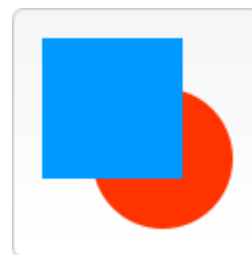
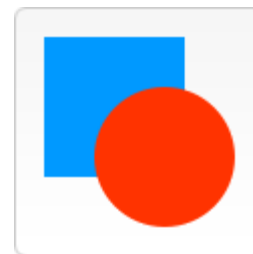
- translate(x,y)
- rotate(angle)
- scale(x,y)
- transform(m11,m12,m21,m22,dx,dy)

```
function draw() {  
    var ctx = document.getElementById('canvas').getContext('2d');  
    ctx.translate(75,75);  
    for (i=1;i<6;i++){  
        ctx.save();  
        ctx.fillStyle = 'rgb('+ (51*i) +',' + (255-51*i) +',255)';  
        for (j=0;j<i*6;j++){  
            ctx.rotate(Math.PI*2/(i*6));  
            ctx.beginPath();  
            ctx.arc(0,i*12.5,5,0,Math.PI*2,true);  
            ctx.fill(); }  
        ctx.restore(); }  
}
```

Compositing

```
globalCompositeOperation = type
```

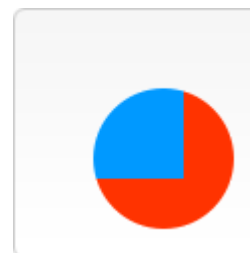
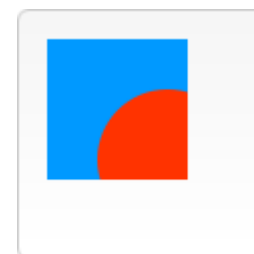
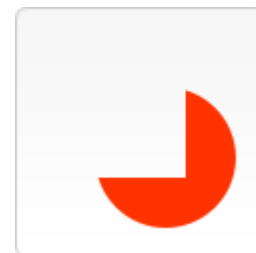
- **source-over (default)**
 - draws new shapes on top of the existing canvas content
- **destination-over**
 - new shapes are drawn behind the existing canvas content
- **source-in**
 - the new shape is drawn only where both the new shape and the destination canvas overlap; everything else is transparent
- **destination-in**
 - the existing canvas content is kept where both the new shape and existing canvas content overlap; everything else is transparent



Compositing

```
globalCompositeOperation = type
```

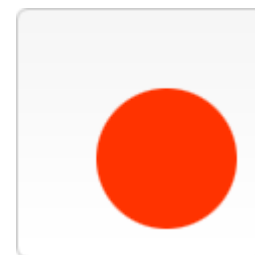
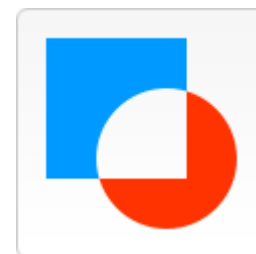
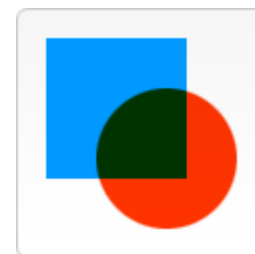
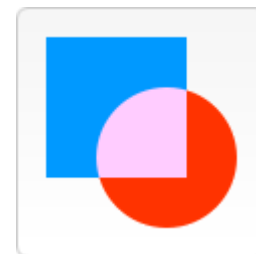
- **source-out**
 - the new shape is drawn where it doesn't overlap the existing canvas content
- **destination-out**
 - the existing content is kept where it doesn't overlap the new shape
- **source-atop**
 - the new shape is only drawn where it overlaps the existing canvas content
- **destination-atop**
 - the existing canvas is only kept where it overlaps the new shape; the new shape is drawn behind the canvas content



Compositing

```
globalCompositeOperation = type
```

- **lighter**
 - where both shapes overlap the color is determined by adding color values
- **darker (unimplemented)**
 - where both shapes overlap the color is determined by subtracting color values
- **xor**
 - shapes are made transparent where both overlap and drawn normal everywhere else
- **copy**
 - only draws the new shape and removes everything else



Example: clipping path



```
function draw() {  
  var ctx = document.getElementById('canvas').getContext('2d');  
  ...  
  
  // Create a circular clipping path  
  ctx.beginPath();  
  ctx.arc(0,0,60,0,Math.PI*2,true);  
  ctx.clip();  
  
  ...  
}
```

Canvas pixel manipulation

- It is possible to access the individual pixels of a canvas, by using the ImageData object
- The ImageData object has three properties: width, height and data
 - The width and height properties contain the width and height of the graphical data area
 - The data property is a byte array containing the pixel values
- The 2D context API provides three methods to draw pixel-by-pixel
 - `createImageData()`
 - `getImageData()`
 - `putImageData()`

Pixel manipulation

- Example: create a 100 x 100 pixels ImageData object

```
var canvas = document.getElementById("ex1");  
var context = canvas.getContext("2d");  
var width = 100;  
var height = 100;  
var imageData = context.createImageData(width, height);
```

- Each pixel in the data array consists of 4 bytes values: one value for the red color, green color and blue color, and a value for the alpha channel
 - Each of the red, green, blue and alpha values can take values between 0 and 255
- Example: sets the color and alpha values of the first pixel

```
var pixelIndex = 0;  
imageData.data[pixelIndex ] = 255;    // red color  
imageData.data[pixelIndex + 1] = 0;   // green color  
imageData.data[pixelIndex + 2] = 0;   // blue color  
imageData.data[pixelIndex + 3] = 255; // alpha
```

Pixel manipulation

- Once you have finished manipulating the pixels, you can copy them onto the canvas using the function `putImageData()`

```
var canvasX = 25;  
var canvasY = 25;  
context.putImageData(imageData, canvasX, canvasY);
```

- It is also possible to grab a rectangle of pixels from a canvas into an `ImageData` object, by using the `getImageData()` function
 - `x` and `y`: coordinates of the upper left corner of the rectangle to grab from the canvas
 - `width` and `height`: width and height of the rectangle to grab from the canvas

```
var x = 25;  
var y = 25;  
var width = 100;  
var height = 100;  
var imageData2 = context.getImageData(x, y, width, height);
```


Example: pixel manipulation



```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');
  var imgd = false;
  var w = 50, var h = 50, x = 0, y = 0;

  imgd = ctx.createImageData(w, h);
  var pix = imgd.data;

  // Loop over each pixel
  for (var i = 0, n = pix.length; i < n; i += 4) {
    pix[i] = 255; // the red channel
    pix[i+3] = 127; // the alpha channel
  }

  // Draw the ImageData object.
  ctx.putImageData(imgd, x, y);
}
```

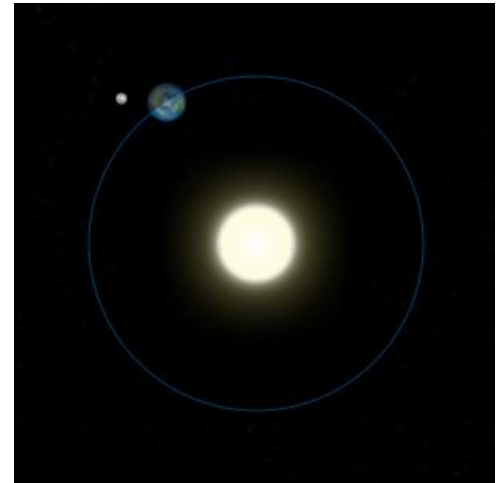
Example: pixel manipulation

```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');
  var x = 0, y = 0;
  // Create a new image
  var img = new Image();
  img.src = 'tree.jpg';
  // Draw the image on canvas
  img.onload = function(){
    ctx.drawImage(img,0,0);
    // Get the pixels
    var imgd = ctx.getImageData(x, y, this.width, this.height);
    var pix = imgd.data;
    // Loop over each pixel and invert the color.
    for (var i = 0, n = pix.length; i < n; i += 4) {
      pix[i ] = 255 - pix[i ]; // red
      pix[i+1] = 255 - pix[i+1]; // green
      pix[i+2] = 255 - pix[i+2]; // blue
      // i+3 is alpha (the fourth element)
    }
    // Draw the ImageData object
    ctx.putImageData(imgd, x, y);
  }
}
```



Animations

- Since scripts can control canvas elements, it's easy to make animations
- Unfortunately there are limitations: once a shape gets drawn it stays that way
 - To move it we have to redraw it and everything that was drawn before it
- It takes a lot of time to redraw complex frames and the performance depends highly on the speed of the computer it's running on



Basic animation steps

- Clear the canvas
 - Unless the shapes you'll be drawing fill the complete canvas (for instance a backdrop image), you need to clear any shapes that have been drawn previously
 - The easiest way to do this is using the clearRect method
- Save the canvas state
 - If you're changing any setting (styles, transformations, etc) which affect the canvas state and want to make sure the original state is used each time a frame is drawn, you need to save it
- Draw animated shapes
 - The step where you do the actual frame rendering
- Restore the canvas state
 - If you've saved the state, restore it before drawing a new frame

Controlling animations

- Two ways
 - Execute the drawing functions over a period of time

```
// execute every 500 milliseconds  
setInterval(animateShape,500);  
  
// execute once after 500 milliseconds  
setTimeout(animateShape,500);
```

- User input: by setting eventListeners to catch user interaction

- Examples



Example: video and canvas



Example: video timeline viewer

- Autoplay attribute: the video starts as soon as the page loads
- Two additional event handler functions, `oncanplay` (when the video is loaded and ready to begin play) and `onended` (when the video ends)

```
<video id="movies" autoplay oncanplay="startVideo()"
      onended="stopTimeline()" autobuffer="true"
      width="400px" height="300px">
  <source src="Intermission-Walk-in.ogv"
        type='video/ogg; codecs="theora, vorbis"'>
  <source src="Intermission-Walk-in_512kb.mp4"
        type='video/mp4; codecs="avc1.42E01E, mp4a.40.2"'>
</video>
```

- Canvas called `timeline` into which we will draw frames of video at regular intervals

```
<canvas id="timeline" width="400px" height="300px">
```

Example: video timeline viewer

- Variables declaration

```
// # of milliseconds between timeline frame updates (5sec)
var updateInterval = 5000;
// size of the timeline frames
var frameWidth = 100;
var frameHeight = 75;
// number of timeline frames
var frameRows = 4;
var frameColumns = 4;
var frameGrid = frameRows * frameColumns;
// current frame
var frameCount = 0;
// to cancel the timer at end of play
var intervalId;

var videoStarted = false;
```


Example: video timeline viewer

- Function `updateFrame`: grabs a video frame and draws it onto the canvas

```
// paints a representation of the video frame into canvas
function updateFrame() {
    var video = document.getElementById("movies");
    var timeline = document.getElementById("timeline");
    var ctx = timeline.getContext("2d");
    // calculate out the current position based on frame
    // count, then draw the image there using the video
    // as a source
    var framePosition = frameCount % frameGrid;
    var frameX = (framePosition % frameColumns) * frameWidth;
    var frameY = (Math.floor(framePosition / frameRows)) *
        frameHeight;
    ctx.drawImage(video, 0, 0, 400, 300, frameX, frameY,
        frameWidth, frameHeight);
    frameCount++;
}
```

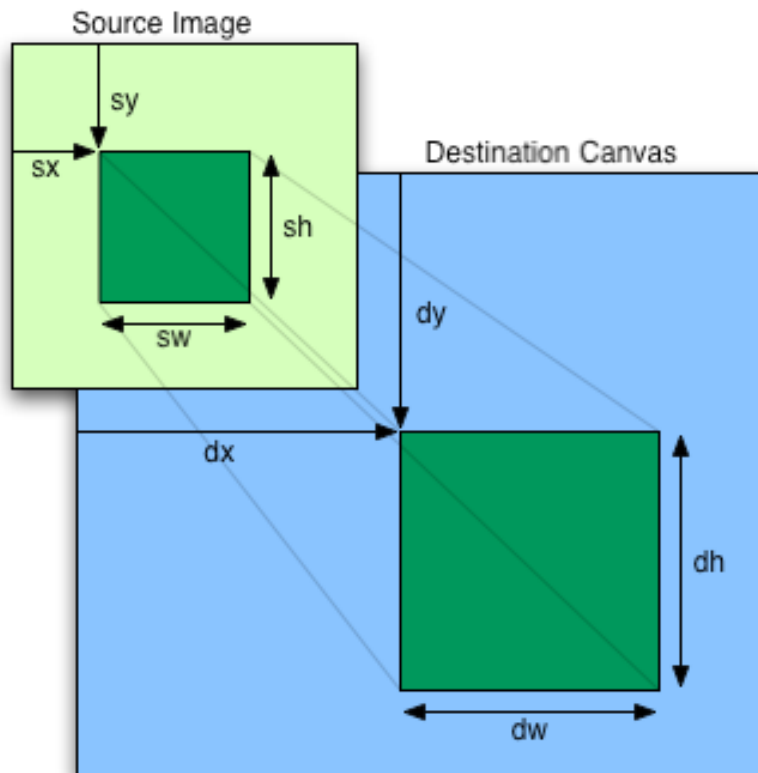
Example: video timeline viewer



```
frameCount = 25  
framePosition = 25 % 16 = 9  
frameX = (9 % 4) * 100 = 100  
frameY = (Math.floor(9 / 4)) * 75 = 150  
ctx.drawImage(video, 0, 0, 400, 300, 100, 150, 100, 75)
```

Canvas: drawImage

```
cxt.drawImage(image, dx, dy)
cxt.drawImage(image, dx, dy, dw, dh)
cxt.drawImage(image, sx, sy, sw, sh, dx, dy, dw, dh)
```



- The first argument can be an image, a canvas or a video element
- When a canvas uses a video as an input source, it draws only the currently displayed video frame
 - Canvas displays will not dynamically update as the video plays
 - If you want the canvas content to update, you must redraw your images as the video is playing

Example: video timeline viewer

- Function `startVideo`: updates the timeline frames regularly
 - The `startVideo()` function is triggered as soon as the video has loaded enough to begin playing

```
function startVideo() {  
    // only set up the timer the first time the video starts  
    if (videoStarted) return;  
    videoStarted = true;  
    // calculate an initial frame, then create  
    // additional frames on a regular timer  
    updateFrame();  
    intervalId = setInterval(updateFrame, updateInterval);  
    ...  
}
```

- `setInterval`: calls a function repeatedly, with a fixed time delay between each call to that function

```
var intervalID = window.setInterval(func, delay);
```

Example: video timeline viewer

- Function startVideo: handles user clicks on the individual timeline frames

```
// set up a handler to seek the video when a frame
// is clicked
var timeline = document.getElementById("timeline");
timeline.onclick = function(evt) {
    var offX = evt.layerX - timeline.offsetLeft;
    var offY = evt.layerY - timeline.offsetTop;
```

- offsetLeft: returns the number of pixels that the upper left corner of the current element is offset to the left within the parent node
- offsetTop: returns the distance of the current element relative to the top of the parent node
- layerX: returns the horizontal coordinate of the event relative to the current layer
- layerY: returns the vertical coordinate of the event relative to the current layer

Example: video timeline viewer

```
// calculate which frame in the grid was clicked
// from a zero-based index
var clickedFrame = Math.floor(offY/frameHeight) * frameRows;
clickedFrame += Math.floor(offX/frameWidth);
// find the actual frame since the video started
var seekedFrame = ((Math.floor(frameCount/frameGrid)) *
    frameGrid) + clickedFrame);
```

- The clicked frame should be only one of the most recent video frames, so seekedFrame determines the most recent frame that corresponds to that grid index

Example: video timeline viewer



```
offX= 120  
offY= 60  
clickedFrame = Math.floor(60/75) * 4 = 0  
clickedFrame += Math.floor(120/100) = 1  
seekedFrame = ((Math.floor(25/16)) * 16) + 1 = 17
```

Example: video timeline viewer

- Function startVideo: handles user clicks on the individual timeline frames

```
// if the user clicked ahead of the current frame
// then assume it was the last round of frames
if (clickedFrame > (frameCount%16))
    seekedFrame -= frameGrid;
// can't seek before the video
if (seekedFrame < 0) return;
// seek the video to that frame (in seconds)
var video = document.getElementById("movies");
video.currentTime = seekedFrame * updateInterval / 1000;
// then set the frame count to our destination
frameCount = seekedFrame;
}
}
```





Example: video timeline viewer

- Function `stopTimeline`: stops capturing frames when the video finishes playing
 - The `stopTimeline` handler is be called when the “onended” video handler is triggered, i.e. by the completion of video playback.

```
// stop gathering the timeline frames
function stopTimeline() {
    clearInterval(intervalId);
}
```

- `clearInterval`: cancels repeated action which was set up using `setInterval()`

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