Canvas 2D Graphics

Web Based Programming - CMP4011A

Dr. David Greenwood

david.greenwood@uea.ac.uk

SCI 2.16a University of East Anglia

October 28, 2021

Contents

- The `canvas` element
- The rendering *context*
- Drawing shapes
- Sprites
- Animation with `requestAnimationFrame`
- Responding to events

Documentation

- W3Schools
- Mozilla
- Canvas API

Further reading

Eloquent JavaScript has a chapter on the canvas element.

- https://eloquentjavascript.net

```
<canvas>
```

Canvas element

A canvas is a single DOM element that contains a image.

Unlike an SVG image, the canvas does not preserve shapes such that they can be moved or resized.

The only way to move a shape is to *clear* the canvas and *redraw* it.

Canvas element

```
<canvas width="150" height="150"></canvas>
```

- Two attributes: width and height.
- Both optional
- Can be set using DOM properties.
- Default values are 300 wide 150 high.

Canvas element

- A new canvas is transparent and shows as an empty space in the document.
- The element can be sized by CSS, but during rendering is scaled to fit its layout size.
- If the CSS sizing doesn't respect the ratio of the initial canvas, it will appear distorted.

Canvas element

```
<canvas width="150" height="150">
  display this text if the browser
  does not support HTML5 canvas
</canvas>
```

- Fallback content is placed between the open and closing tags.
- The closing tag is **required**. . .
  - . . . else all subsequent content is ignored.

Canvas element

```
<!DOCTYPE html>
<html lang="en">
<head>
    <meta charset="UTF-8">
    <link rel="stylesheet" href="style.css">
    <script src="script.js" defer></script>
    <title>HTML Canvas</title>
</head>
<body>
    <canvas id="canvas"></canvas>
</body>
</html>
```

Canvas API

The Canvas *API* provides a means for drawing graphics using JavaScript and the `<canvas>` DOM element.

Canvas API

We can use the canvas for:

- animation
- game graphics
- data visualization
- image manipulation
- real-time video

The rendering context

The `<canvas>` element creates a fixed-size drawing surface that exposes a rendering *context*.

The rendering context

We will use the `2d` rendering context.

The rendering context

There is also a 3D rendering context: **WebGL**

This has many powerful features, including access to the graphics hardware, and openGL like shaders.

We will not cover the 3D context in this lecture.

The rendering context

```
const canvas = document.getElementById("canvas");
const ctx = canvas.getContext("2d");
```

You create a context with the getContext method on the `<canvas>` DOM element.

The rendering context

Access the Canvas API via the `ctx` object.

You should inspect the context object in the console.

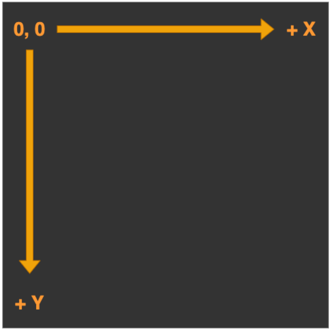
```
console.log(ctx)
```

The rendering context

```
console.log(ctx)
```

You will see current values for all the attributes, and if you expand the `CanvasRenderingContext2D` field you will see the many methods available.

Drawing



The rendering context has a coordinate system which, by default, places the *origin* at the top left corner of the canvas. Each unit of length is 1 pixel.

Drawing

Canvas supports two primitive shapes: rectangles and paths.

A shape can be *filled*, meaning its area is given a certain colour or pattern, or it can be *stroked*, which means a line is drawn along its edge.

Drawing

There are three functions that draw rectangles on the canvas:

```
fillRect(x, y, width, height)
strokeRect(x, y, width, height)
clearRect(x, y, width, height)
```

Drawing

```
fillRect(x, y, width, height)
strokeRect(x, y, width, height)
clearRect(x, y, width, height)
```

The parameters are the same for all three functions:

- `x, y` define the top left corner
- then we have width and height

Drawing

The colour of the fill, thickness of the stroke, and so on, are not determined by an argument to the drawing method, but by properties of the context object.

Drawing

```
ctx.fillStyle = "red";
```

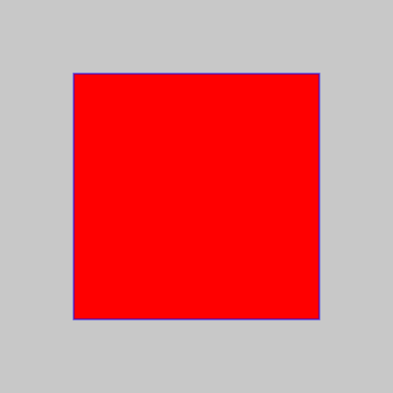
- `fillStyle` defines the fill appearance.
- Set to a string that specifies a colour.
- Uses the same colour notation as CSS.

Drawing

```
ctx.strokeStyle = "blue";
ctx.lineWidth = 5;
```

- `strokeStyle` specifies the colour of a stroked line.
- Width is set by the `lineWidth` property.
- `lineWidth` may be any positive number.

Drawing



```
const x = y = 75
const w = h = 250
ctx.fillStyle = "red"
ctx.strokeStyle = "blue"
ctx.fillRect(x, y, w, h)
ctx.strokeRect(x, y, w, h)
```

Paths

A path is a sequence of points, connected by segments of lines that can be of different shapes, of different width and of different colour.

Paths

It is possible to build any complex shape using a combination of the path tools.

Paths

- Paths are not values that can be stored and passed around.
- You must make a sequence of method calls to describe its shape.

Paths

- Each segment created with `lineTo` starts at the path's current position.
- The current position is usually the end of the last segment.
- Or, it is the position passed to `moveTo`.

Paths

When filling a path:

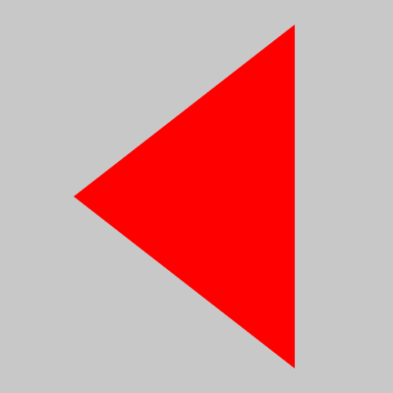
- Each shape is filled separately.
- A path can have multiple shapes.
- The path needs to be closed.

Paths

If the path is not already closed, a line is added from its end to its start.

The shape enclosed by the now completed path is filled.

Paths



```
ctx.fillStyle = "red"
ctx.beginPath()
ctx.moveTo(75, 200)
ctx.lineTo(300, 375)
ctx.lineTo(300, 25)
ctx.fill()
```

Curves

A path may also contain curved lines.

These are a bit more involved to draw.

Curves

Complex curves and shapes can be drawn using *Bezier* and *quadratic* curves. We wont cover these functions for now.

- `quadraticCurveTo()`
- `bezierCurveTo()`

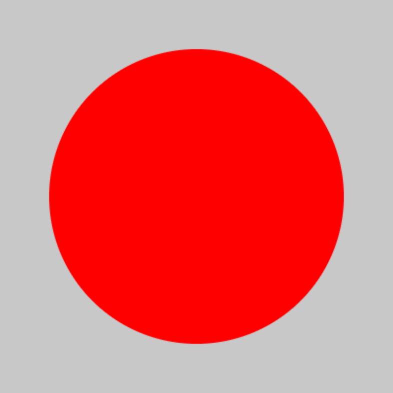
But it is useful to know that they are available.

Curves

To draw circle segments we use the arc functions.

- `arc(x, y, radius, startAngle, endAngle, counterclockwise)`
- `arcTo(x1, y1, x2, y2, radius)`

Curves



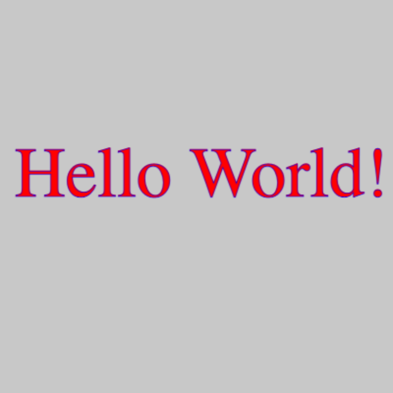
```
ctx.fillStyle = "red"
ctx.arc(200, 200, 150, 0, Math.P
ctx.fill()
```

Text

The canvas rendering context provides two methods to render *text*:

- `fillText(text, x, y [, maxWidth])`
- `strokeText(text, x, y [, maxWidth])`

Text



Hello World!

```
const text = "Hello World!"
const x = 15, y = 200
ctx.fillStyle = "red"
ctx.strokeStyle = "blue"
ctx.font = '72px serif'
ctx.fillText(text, x, y)
ctx.strokeText(text, x, y)
```

Bitmap graphics

Images for computer graphics are usually in one of two categories:

- Vector graphics
- Bitmap graphics

So far we have been working with vector graphics - where we have specified shapes with lines and curves.

Bitmap graphics

Bitmap graphics don't specify shapes but work with **pixel** data.

Pixel data defines values on a regular 2D grid.

Bitmap graphics

The `drawImage()` method allows us to draw pixel data onto a canvas.

This pixel data can originate from an element or from another canvas.

```
let img = document.createElement("img")
img.src = "img.png"
```

Bitmap graphics

However, if we just call `drawImage()`, it is unlikely to display the image as we expect.

```
let img = document.createElement("img")
img.src = "img.png"
ctx.drawImage(img, 0, 0)
```

Why is this?

Bitmap graphics

It is **essential** to ensure the image resource is loaded *before* drawing.

Bitmap graphics

```
const canvas = document.getElementById("canvas")
const ctx = canvas.getContext("2d")

let img = document.createElement("img")
img.src = "img.png"

img.addEventListener("load", () => {
  ctx.drawImage(img, 0, 0)
});
```

Bitmap graphics

In addition to the previous example, the `drawImage()` method can take two further arguments:

- `drawImage(image, dx, dy, dWidth, dHeight)`
- this lets us scale the image.

Bitmap graphics

The `drawImage()` method also has a nine argument version which lets us specify the source rectangle:

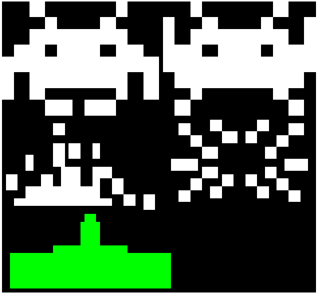
- `drawImage(image, sx, sy, sWidth, sHeight, dx, dy, dWidth, dHeight)`
- `sx, sy, sWidth, sHeight` define the source rectangle.
- `dx, dy, dWidth, dHeight` define the destination rectangle.

Sprites

Sprites are two-dimensional images included in a larger scene.

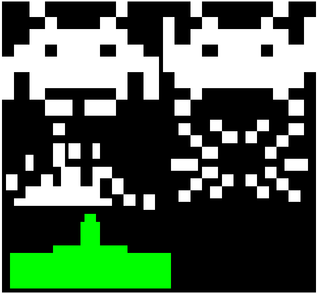
- Often used for animation.
- Multiple poses can be stored in one image - a **sprite sheet**.

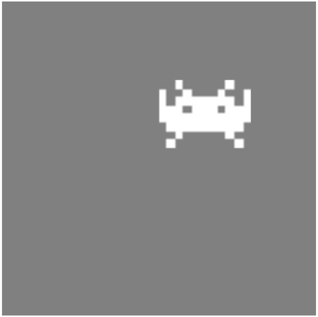
Sprites



Storing all the image frames in a single file is often preferred for compression efficiency.

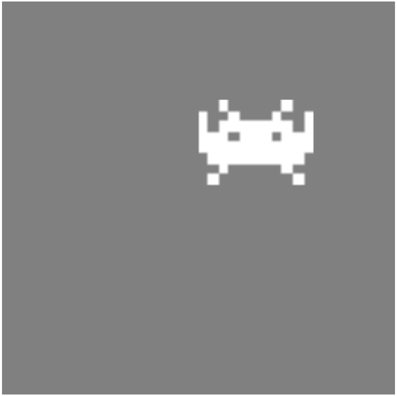
Sprites





The ability to select a source rectangle allows us to render a section of the entire sheet.

Sprites



- Source rectangle is `41,0,40,29`
- Destination is `200,100,120,87`
- We have “cut out” a region of the sprite sheet and placed it on the canvas.
- The canvas respects the alpha value of the source image.

Sprites

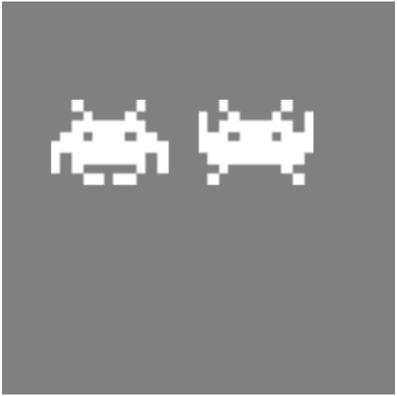
consider this source code:

```
const sw = 40, sh = 29
const dw = 120, dh = 87

sprite.addEventListener('load', () => {
  ctx.drawImage(sprite, 0, 0, sw, sh, 50, 100, dw, dh)
  ctx.drawImage(sprite, 41, 0, sw, sh, 200, 100, dw, dh)
})
```

what does this code do?

Sprites



We have cut out **two** regions of the sprite sheet and placed them on the canvas.

Sprites

Here is the Idea. . .

Draw one image, then draw another image *in the same place*.

Animation

`requestAnimationFrame()`

- Tells the browser that you wish to perform an animation.
- Requests that the browser calls a **callback** function.
- The callback *updates* an animation before the next **repaint**.

Animation

`requestAnimationFrame()`

A **callback** is a function passed as an argument to another function.

- The callback function is always passed a *timestamp*.
- The timestamp gives the *milliseconds* since the page was loaded.

Using a callback function

You will write the callback function:

```
function myCallBack(timestamp) {
  console.log(timestamp)
}

requestAnimationFrame(myCallBack)
```

Using a callback function

You will notice that we get only one value printed to console.

- We need to call `requestAnimationFrame()` again to get the next value.

Recursion

We do this using **recursion**

```
function myCallBack(timestamp) {
  console.log(timestamp)
  requestAnimationFrame(myCallBack)
}

myCallBack()
```

- we moved `requestAnimationFrame()` into our callback

Recursion

We make a call to our function, to start the recursion.

```
function myCallBack(timestamp) {
  console.log(timestamp)
  requestAnimationFrame(myCallBack)
}

myCallBack()
```

Recursion

How often does the callback function get called?

```
1396.32
1412.986
1429.652
1446.318
1462.984
1479.65
1496.316
```

Using a callback function

Often we want to do something after a period of time has passed.

- Store the previous time globally and compare it to the current time.
- Check if the enough time has passed in our callback.

Using a callback function

```javascript
let prevTime = 0

function myCallBack(timestamp) {
  if (timestamp - prevTime > 500) {
    prevTime = timestamp
    console.log(timestamp)
  }
  requestAnimationFrame(myCallBack)
}

myCallBack()
```

Using a callback function

Now we get this sort of output:

```
514.689
1031.335
1547.981
2064.627
2581.273
3097.919
3598.031
```

Animation

Instead of logging to console, we could draw our image on the canvas.

Animation

Store some global variables.

```
let prevTime = 0
let frame = 0
```

Animation

Write a draw function.

```
function draw(frame, x, y) {
  let sx = 41
  if (frame === 0) sx = 0
  ctx.clearRect(0, 0, canvas.width, canvas.height)
  ctx.drawImage(sprite, sx, 0, 40, 29, x, y, 120, 87)
}
```

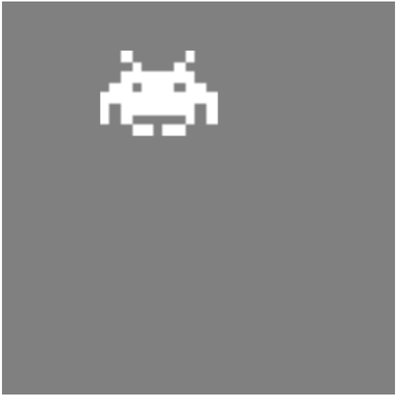
Animation

Finally, we call our animate function.

```
function animate(timestamp) {
  if (timestamp - prevTime > 500) {
    prevTime = timestamp
    frame = (frame + 1) % 2
  }
  draw(frame, 100, 50)
  requestAnimationFrame(animate)
}

animate()
```

Animation



We now have our sprites frames drawn alternately.

Events

Formally, an event is a message sent from the browser to a JavaScript function, for example:

- mouse clicks
- key presses
- window resizes

Events

Informally, we can describe events in our animation that require some sort of response, such as collision detection in a game.

Keyboard Events

```
const KEYS = {}

document.addEventListener("keydown", (event) => {
    KEYS[event.code] = event.type === "keydown"
})

document.addEventListener("keyup", (event) => {
    KEYS[event.code] = event.type === "keydown"
})
```

Keyboard Events

To check if a key is pressed, we can read the KEYS object.

```
if (KEYS['ArrowLeft']) x -= 1
if (KEYS['ArrowRight']) x += 1
```

Collision Detection

Often we want to know if two objects are touching, or overlapping.

- game characters
- frame boundaries
- UI elements

AABB Collision Detection

What is an Axis Aligned Bounding Box (AABB)?

AABB Collision Detection

An AABB is the smallest rectangle that encloses an object and is *aligned* with the *axes* of the coordinate system.

- the left and right edges of the AABB are parallel to the x-axis
- the top and bottom edges of the AABB are parallel to the y-axis

AABB Collision Detection

compare two objects with x, y, width and height properties

```
function AABB(a, b) {
  if (a.x > b.x + b.w) return false
  if (a.x + a.w < b.x) return false
  if (a.y > b.y + b.h) return false
  if (a.y + a.h < b.y) return false
  return true
}
```

AABB Collision Detection

You could consider a variation of this method to check if an object is within the bounds of the canvas.

Radial Collision Detection

Radial collision detection uses Pythagoras' theorem to determine if two objects are touching.

If the squared sum of the radii is greater than the squared distance between the centres, then the objects are colliding.

Radial Collision Detection

compare two objects with x, y and radius properties

```
function radial(a, b) {
  let radii = a.radius + b.radius
  let dx = a.x - b.x
  let dy = a.y - b.y
  return radii * radii > dx * dx + dy * dy
}
```

Collision Detection

Once we have detected a collision, we can respond. . .

Summary

- The `canvas` element
- Drawing shapes
- Sprites
- Animation with `requestAnimationFrame`
- Events
- Collisions

See you in the labs!