Chapter 3: Browser based programming

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Content

Webpages

3 elements of a webpage:

- HTML: structure and contents of the page
- CSS: appearance of the page
- Javascript: dynamics of the page

This course:

- just a tiny bit of HTML
- no CSS
- lots of Javascript

HTML: Tags

HTML is a structure based on *tags*.
Syntax:

```
<tagname>Text or more tags</tagname>
```

- An opening tag <**tagname**> *must* be accompanied by a closing tag </**tagname**>
- HTML standard: only certain tags are allowed, e.g. <**h1**>, <**p**>, <**img**>, <**div**>, etc.
  (more general: XML).
- Comments:

```
<!-- <p>commented out</p> -->
```

- Tags can be nested in a tree structure:

```
<div>
<p>Some text</p>
</div>
```

HTML: Attributes

- Opening tags can have attributes:

```
<tagname attr="abc"> ... </tagname>
```

- Most common attributes:
  - `class`
  - `id`

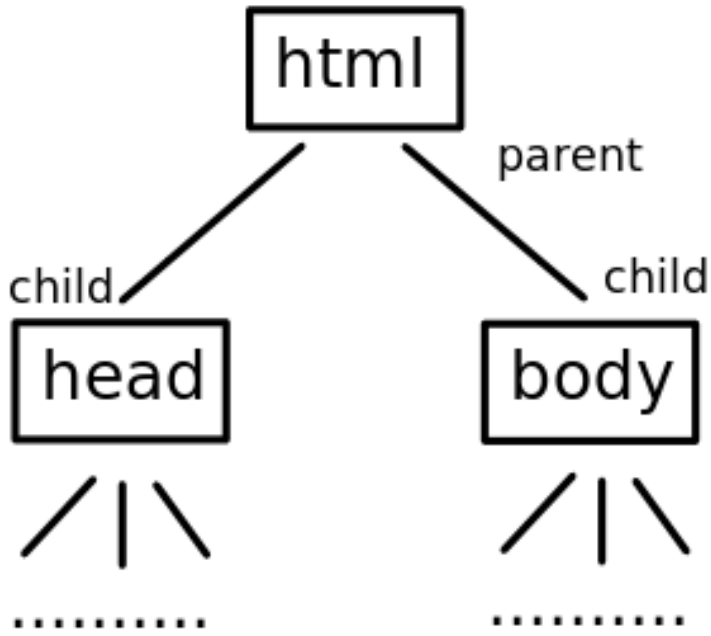
  used by CSS and Javascript to identify tags.

HTML: DOM

Mandatory structure of an html document: *DOM-tree*

(DOM: document object model)

```
<html>
<head>
...
</head>
<body>
...
</body>
</html>
```



- The DOM-tree can be accessed and manipulated using Javascript.

HTML: Loading scripts

Loading of Javascript code: the <**script**> tag

- Option 1: Inline (code *inside* html document)

```
<script type="text/javascript">
  javascript goes here
</script>
```

- Option 2: Code in separate file

```
<script type="text/javascript" src="filename.js">
</script>
```

  Javascript file names either relative to html document or absolut.

- Option 3: *Modules*
  - important recent Javascript feature
  - see material below

Javascript

Main features:

- C-like syntax:
  - control structures `for`, `while`, `if`, `else`, etc.
  - curly braces define scopes
- Scripting language (like Matlab):
  - No compilation and binary files
  - Access through command prompt (e.g. inside browser)
- Dynamic typing:
  - No type declaration of variables
  - Types are assigned by Javascript engine

Javascript: A little history

- Invented around 1995 by Brendan Eich for use in the Netscape browser.
- Considered to be a nice little language with some quirks.
- Standardized under the Name of *ECMAScript (ES)*
- **Major** revision in 2015: ES6 -> Most features now supported by modern browsers.
- Huge amount of pre-ES6 code still out there!

Web applications

HTML content can be manipulated with Javascript:

- DOM-API: standardized method to do this
- provided by `document` object

Example:

```
<script type="text/javascript">
  const myItem = document.getElementById('myItem');
  myItem.innerText = "Hallo";
</script>
```

- Real world web apps use frameworks wrapping the DOM-API.
- This is *not* a course about web apps.

Defining variables

- No type declaration required!
- Variable definition indicated by keyword: **`const`** or **`let`**
  - Use **`const`** as default method to declare variables:

```
const x = 2;
```

  `const` variables cannot be reassigned:

```
const x = 2;
x = 3;          // error
```

  - Use **`let`** to declare variables that are later reassigned:

```
let x = 2;
x = 3;          // works
```

Defining variables

- The *"use strict"* directive:
  - Turn on strict mode by inserting the string

```
use strict";
```

    at beginning of file or function.
  - non-strict mode is very tolerant to crappy code!
  - strict mode helps to catch errors!
  - Danger: file based strict mode applies strict mode to all files loaded later.
- Obsolete variable definition:

```
var x = 3;    // works, but don't do this!
```

  var is old and has confusing scoping rules!
- Omitting **let** or **const** creates a global variable!

```
x = 3;    // works, but don't do this!
```

Types

Javascript assignes one of the 7 types to each variable:

- **`number`**
- **`string`**
- **`boolean`**
- **`undefined`**
- **`null`** (similar to **`undefined`**)
- **`Symbol`** (we don't need this)
- **`Object`**

Remarks:

- Identification with the **`typeof`** operator:

```
typeof "Hallo"  // => string
typeof 12  // => number
```

- The first 6 types are *primitve*
  - Primitve types live on the stack and are passed by value!

Types

Objects:

- similar to C structs:
  - field access with dot-notation: **`object.field`**
  - creation with `{}` brackets
  - Popular syntax: *JSON* (Javascript object notation) is common data exchange format
- Particulary important objects: **`Array`** objects
  - similar to C arrays
  - creation and element access with `[]` brackets
  - can store elements of different types
- Objects are reference types!
- All objects derived from **`Object`**

Strings

- can be defined like `'this'` or like `"this"`
- String concatenation with **+**, e.g.

```
const s = 'abc' + 'def';    // s = 'abcdef'
```

- The function `console.log` prints strings to the console, e.g.

```
console.log('s='+s);
```

- Numbers can be turned to strings with `parseFloat` or `parseInt` (global functions)
- Strings have many methods, e.g.

```
'abc'.charAt(1)   // => 'b'
```

See String type documentation

The Math object

One use case for objects: define a *name space*, e.g. the `Math` name space.

Some of the Math functions and constants:

- `Math.PI`
- `Math.E`
- `Math.sin`
- `Math.cos`
- `Math.sqrt`
- `Math.pow`

Logical operators

Same as in C except for logical comparison. There are two comparison operators:

- == takes type conversion into account.
- === ignores type conversion.

Almost always === is what you want.

Example

```
2 == '2';       // true
2 === '2';      // false
```

Control flow

Very similar to C:

- `for` - loop:

```
for(let k=0; k<5; k++) {
  console.log(k);
}
```

- `while` - loop:

```
let x = 0;
while(x<5) {
  console.log(x);
  x;
}
```

- **`break`** and **`continue`** work just as in C

Control flow

- `if` - conditions:

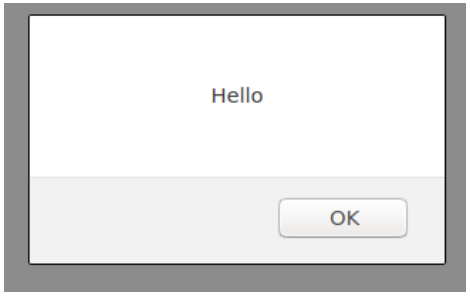
```
if (x>8) {
   // executed if x > 8
} else {
   // executed if x not > 8
}
```

- `switch` - statement:

```
switch(s) {
  case 'case 1':
  // some code for case 1
  break;
  case 'case 2':
  // some other code for case 2
  break;
  default:
  // ...
}
```

Simple user interaction

- `alert(msg)`: shows string *msg* in a popup window.



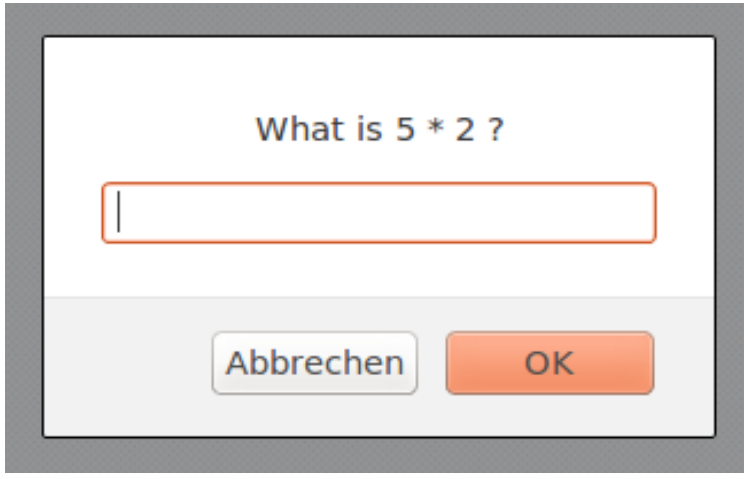
- `prompt(msg)`: shows string *msg* in a popup window and lets the user enter some text. Returns the text after pressing *OK*.

Exercise 1

Write a web page that asks

What is n * m?

with ’n’ and ’m’ random integers between 1 and 10 until the answer is correct.



Hints:

- `Math.random()` creates a random number.
- `Math.floor`, `Math.ceil`, `Math.round` are the usual rounding functions.

Functions

- There are several types of function definition:
  - Function declaration with `function` keyword
  - Function expression with `function` keyword
  - Arrow functions
- The concepts of function parameters, return value and local variables are like in C.
- Functions can be passed around (e.g. as arguments to other functions) like function pointers in C.

Functions

Function declaration example:

```
function mysum(a,b,c=0) {
  const s = a + b + c;
  return s;
}
```

- no semicolon at end of statement.
- optional argument c has default value 0.

Exercise: what is wrong with this?

```
function mysum(a,b,c=0) {
  s = a + b + c;
  return s;
}
```

Functions

Function definition as variable assignment:

```
const mysum = function(a,b,c=0) {
  const s = a + b + c;
  return s;
};
```

- Semicolon at end of expression!

Functions can be passed as parameters, e.g.

```
function mysum(a,b,printFunc) {
  const s = a + b;
  if(printFunc !== undefined) printFunc('s='+s);
    return s;
  }
let x = mysum(1,2,console.log);
```

Exercise 2

- Write a function

  `mysqrt(a, tol)`

  calculating $\sqrt{a}$ with Newtons iteration:

$$x_{k+1} = \frac{1}{2}\left(x_k + \frac{a}{x_k}\right), \qquad k = 1, 2, \ldots$$

  Start the iteration with $x_0 = a$ and stop if

$$|x_k^2 - a| < \texttt{tol}.$$

- Use the function to calculate $\sqrt{2}$ with $\texttt{tol} = 10^{-8}$.

Objects

Example of an object definition:

```
let obj = {
  x: 3,
  y: "Hello"
};
```

- Field access with dot-notation:

```
console.log("obj.x=", obj.x);
```

- Fields can be added *after* object creation:

```
obj.z = {a:1, b:2};
```

Objects

Objects can have function fields: methods!

```
let obj = {
  x: 3,
  f() {console.log("Hello");}
};
obj.f();    // => prints "Hello"
```

The keyword **this** has to be used to refer to fields from within methods:

```
let obj = {
  x: 3,
  f() {console.log("x="+this.x);}
};
obj.f();    // => prints 3
```

Exercise 3

1. Create an object representing a bank account, which
   - has a number
   - keeps track of depositing and withdrawing money
   - can print its state
2. Model an account with number '1234' where
   - 300 Euros are deposited,
   - 200 Euros are withdrawn,
   - the final state of the account is printed.

   The output could look like this:

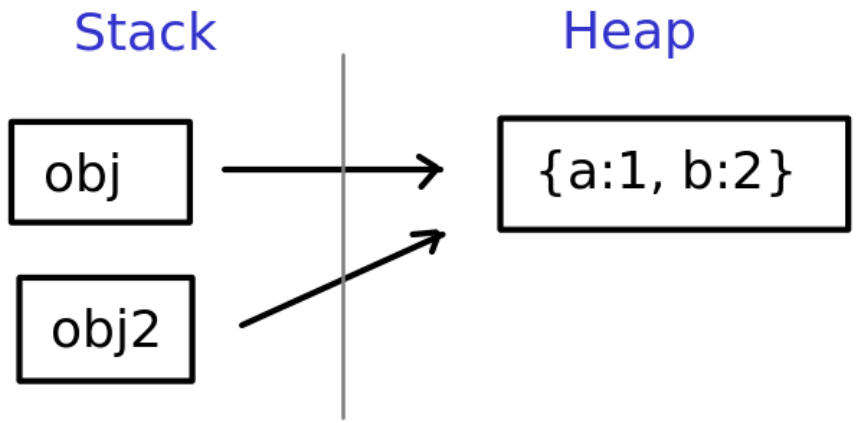
```
Account 1234 contains 100 Euros
```

Objects

Questions: Does line 3 create an error? What is printed to the console?

```
1   const obj = {a:1, b:2};
2   const obj2 = obj;
3   obj2.a = 12;
4   console.log(obj.a);
```

- Objects are reference types:
  - the object itself lives on the *heap*.
  - `obj` and `obj2` referring to the object live on the *stack*.
  - line 2 does *not* create a new object, just a new reference.



Objects

Objects can also be created with constructor functions:

```
function Obj(a,b) {
  this.a = a;
  this.b = b;
}
```

- Convention: constructors start with capital letter.
- New objects created with `new` operator

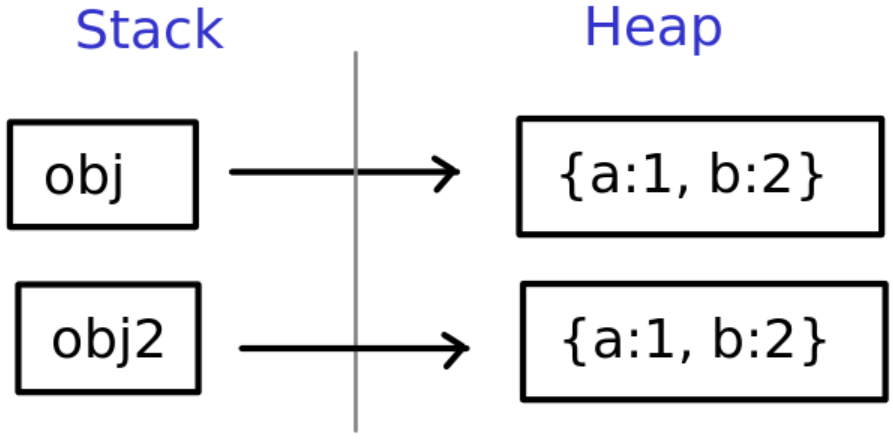
```
const obj = new Obj(1,2);
const obj2 = new Obj(1,2);
```

Question: What is printed to the console?

```
obj2.a = 12;
console.log(obj.a);
```

Objects

- Each call to **`new`** creates a new object:



- Pitfall: forgetting **`new`** works but is a bug!!

```
const obj = Obj(1,2);
```

  - this adds fields `a` and `b` to global object!
  - Catch this by adding `"use strict";` as first line of constructor

Exercise 4

Rewrite the Bank Account application using constructor functions.

Arrays

Arrays are objects with special features.

- array creation:

```
let a1 = [1,2,3,4];
let a2 = [];  // empty array
let a3 = new Array(3);  // 3 x 'undefined'
```

- length of an array:

```
let len = a1.length;   // len=4
```

- element access identical to C:

```
console.log(a1[0]);   // prints 1
console.log(a1[3]);   // prints 4
```

Arrays

- Looping over an array:

```
for(let k=0; k<a1.length; ++k) {
  console.log(a1[k]);
}
```

- Slightly shorter special looping syntax:

```
for(let elem of a1) {
  console.log(elem);
}
```

- Useful array methods:

```
a1.push(5);   // adds new element to end of array
a1.pop();   // returns and removes last element
```

Exercise 5

- Write a Javascript version

  `colon(start, end, incr)`

  of Matlabs colon operator `:`.

- Write a Javascript version

  `linspace(start, end, N)`

  of Matlabs `linspace` function.

Vectorization in Javascript

Most functions in Javascript don't operate naturally on arrays (unlike Matlab)!!

The Javascript way of vectorization:

- Use Array-methods like (among many)
  - `Array.forEach`: just for side effect
  - `Array.map`: returns values
- Pass in a function operating on elements
  - arrow functions useful here

Example:

```
const sq = function(x) {return x*x;}
const square = [1,2,3,4].map(sq);
square.forEach(function(x) { console.log(x);});
```

Vectorization with arrow functions

There is yet another way to define functions: *arrow* functions

```
f1 = x => x*x;          // single argument
f2 = (a,b) => a+b;      // two arguments
f3 = (x) => {x+=5;      // multiple statements as block
   return x*x;}         // return necessary in blocks
f4 = () => 5;           // no argument
```

Features:

- implicit return statement.
- doesn't rebind **`this`** $\Longrightarrow$ don't use arrow functions as constructor function.

Vectorization example:

```
const square = [1,2,3,4].map(x => x*x);
square.forEach((x) => console.log(x));
```

Loading of libraries

Two options:

1. The *old* way: load `js`-files as text files
   - Easy to use
   - Order of script tags in html file matters
   - Can lead to names clashes
   - Not suitable for serious projects
2. The *new* way: use Javascripts module system
   - Systematic way to handle names
   - Requires running a web server

Loading of libraries as text files

Option 1 (the old way): use script tags with text type

```
<script type="text/javascript" src="filename1.js"/>
<script type="text/javascript" src="filename2.js"/>
        ...
```

- loads one file for each script tag, in the order of the script tags.
- Usual file format for libraries: *minified* Javascript
  - comments, whitespace and new lines stripped
  - plain Javascript
  - Extension: `.min.js`, e.g. `three.min.js`.
- File name: path *relative* to html file
  `..` denotes the parent directory

Loading of libraries as modules

Option 2 (the new way): libraries as modules

- by now: supported by all major browsers
- html loads just main js file with module type script tag
- libraries loaded from Javascript files with `import` statements
- Only works if files are provided by web server

Loading of libraries as modules

Example: loading `three.js` and working with some `Vector3` objects

1. In html file:

```
<script type="module" src="chap3/vec3Example.js"/>
```

   - no need to load `three.js` module from html!

2. In `vec3Example.js` file: load `three.js` module:

```
import * as THREE from "three";

const v1 = new THREE.Vector3(1, 2, 3);
console.log("v1.x = ", v1.x);
```

Loading of libraries as modules

3. Also in html file: tell the browser where to find the library with import maps:

```
<script type="importmap">
  {"imports": {
     "three": "./lib/three.module.min.js",
  }}
</script>
```

Loading of libraries as modules

Problem: Loading the previous example will create a *Cross-Origin* error!

Solution: Run a webserver in a directory which contains all required files

- Python: `python3 -m http.server`
- Node.js: `http-server . -p 8000`

Then open the page `http://localhost:8000/`

- see *Installation* section in `three.js` documentation.

Exercise 6

1. Find and scroll through the `Vector3` documentation.
2. Calculate the sum `v1 + v2` of the vectors defined in `vec3Example.js` *without* changing `v1` or `v2`.
3. Calculate their scalar product.
4. Write the following function:

```
/**
* calculate specular reflection
* @param {Vector3} incoming vector
* @param {Vector3} normal vector
* @returns {Vector3} outgoing vector
*/
function specRef(vin, n) {
```

- Test with the example from slide 18 of chapter 2.
- Make sure arguments `vin` and `n` are not changed by `specRef`.